Wheat and Barley Seed Systems in Ethiopia and Syria

Promotor: Prof. dr. ir. P.C. Struik
Hoogleraar in de Gewasfysiologie

Co-promotor: Dr. ir. A.J.G. van Gastel
Seed Unit, ICARDA, Aleppo, Syria

Promotiecommissie:
Prof. dr. P. Richards (Wageningen Universiteit)
Dr. ir. R.W. van den Bulk (Plant Research International)
Dr. ir. E.T. Lammerts van Bueren (Louis Bolk Instituut)
Ir. N.P. Louwaars (Plant Research International)

Dit onderzoek is uitgevoerd binnen de onderzoekschool: Production Ecology and Resource Conservation

Wheat and Barley Seed Systems in Ethiopia and Syria

Zewdie Bishaw

Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
prof. dr. ir. L. Speelman
in het openbaar te verdedigen
op maandag 26 april 2004
des namiddags te half twee in de Aula

Zewdie Bishaw (2004)

Wheat and Barley Seed Systems in Ethiopia and Syria
Bishaw, Z. –[S.l.:s.n.]. Ill.
PhD thesis Wageningen University. –With ref.–
With summaries in English and Dutch
ISBN: 90-8504-035-3

Dedicated to my immediate elder sister Bogaletch Bishaw

Abstract

Bishaw, Z., 2004. Wheat and Barley Seed Systems in Ethiopia and Syria. PhD Thesis, Wageningen University, The Netherlands, 383 pp., with English and Dutch summaries.

In Ethiopia and Syria, wheat and barley are the two most important principal cereal crops grown since ancient times. Many generations of natural and human selection led into highly adapted and diverse populations of local landraces. For most of the history of agriculture, plant improvement and seed selection were farmer-based activities carried out as an integral part of crop production. With the development of commercial agriculture, plant breeding and seed production evolved into different disciplines. The wheat and barley seed systems were studied in Ethiopia and Syria to obtain an insight into the functioning of formal and informal seed systems with emphasis on understanding: the flow of information on new agricultural technologies; farmers' perception, criteria and adoption of modern varieties; farmers' seed sources and indigenous knowledge in seed management practices; quality of seed planted by farmers and its constraints; and on-farm wheat and barley diversity.

Farmers use multiple sources of information such as the formal (extension services, development agencies, research institutions, media broadcast) or the informal (own experience, relatives, neighbours, other farmers, local traders) sources to acquire knowledge on varieties and/or agronomic packages for crop production. Most wheat growers (over 90%) are aware of and have information on modern varieties, agrochemical inputs (fertilizers, herbicides, etc.) and agronomic packages. In Ethiopia, the formal extension service was the main source of information for new technologies generated by research through its recently introduced agricultural package programme, comparatively more so than in Syria where fellow farmers (relatives, neighbours and other farmers) were the major source of information. Neighbours and other farmers were the second most important informal sources of information particularly for modern varieties partly due to the lateral varietal diffusion through traditional seed exchanges.

Farmers grew three broad categories of wheat varieties, i.e. recommended, 'obsolete' or landraces. An extensive use of modern wheat varieties and production packages was found among wheat growers in both countries. In Ethiopia, the majority of farmers grew modern bread wheat varieties (76% recommended and 10% obsolete varieties), and applied fertilizers (97%) and herbicides (64%) to their wheat crop. Similarly, wheat farmers in Syria used modern varieties from the recommended list (97%), fertilizers (100%), herbicides (93%), storage pesticides (41%), and seed treatment chemicals (90%). However, the use of modern varieties and associated technologies was negligible for barley growers in Syria except for the use of fertilizers (56%). Although seven modern barley varieties were released none of them were widely adopted because of farmers' preferences or lack of varietal adaptability. The entire barley area (99%) was planted with a local landrace Arabi Aswad in north-eastern Syria. Developing crop varieties with high yield and yield stability for agro-ecologically diverse durum wheat growing environments in Ethiopia or agro-climatically variable marginal environments typical to barley production areas in north-eastern Syria still remains a challenging task.

About 26 technological and socio-economic criteria were identified by farmers for adopting new modern wheat and barley varieties or for evaluating those currently grown on their farm. Grain yield, grain colour, grain size, marketability and food quality (feed quality for barley), appeared most important in both crops and transcended all regions. Ethiopian farmers also consider tolerance to pests very important given their awareness of the susceptibility of the existing wheat varieties to major rust diseases. In Syria, non-lodging, frost tolerance or drought tolerance were additional agronomic characteristics farmers were seeking from new wheat varieties. Some wheat local landraces were highly preferred by farmers because of their unique adaptation to diverse agro-ecological zones, stable yield, grain quality, marketability and for traditional food preparation. Most farmers in Syria had

positive perceptions of the barley local landrace where one third saw no disadvantage in growing it.

Farmers' seed acquisition from external sources was dynamic reflecting their response to specific technical and socio-economic factors associated with farming. Farmers used four main sources of seed for planting: (a) own saved seed from the previous years' harvest; (b) seed obtained from relatives, neighbours or other farmers; (c) seed purchased through local markets or grain traders; and (d) seed purchased from the formal sector. The informal farmer-to-farmer seed exchange was the major initial source of wheat and barley varieties as well as for seed used for planting each year. In Ethiopia, the informal sector accounted as an initial source of modern varieties for 58% of the wheat farmers and as a source of seed for planting for 92% of farmers in the 1997/98 crop season. In Syria the formal sector was the main initial seed source of modern wheat varieties where it accounted for nearly 60%, but provided wheat seed for only 24% among sample farmers in the 1998/99 crop season. Almost all barley farmers (87%) as expected initially sourced their current seed stock from informal sources (relatives, other farmers, neighbours or local markets). Farmers had a positive perception of seed both from formal and informal sources and were generally satisfied with the quality of seed obtained from different sources. Farmers purchased seed from the formal sector because of likely perception of high physical purity, chemical treatment, or as a strategy to acquire new varieties. Moreover, most farmers were also satisfied with the quality of own saved seed or that obtained from other informal sources due to its timely availability, less or no transaction costs or lack of credit facilities, adaptable varieties and certified seed.

Farmers' perception of seed influenced them to practise different on-farm seed management approaches to maintain the quality of their wheat and barley seed through selection (46-67%), cleaning (83-90%), treatment (4-90%), separate storage (64-76%) or informal assessment of physiological quality (3-34%). Almost all wheat and barley growers recognized the difference between grain and seed and attributed these to physical purity, absence of weeds, big kernel size, good germination, free of insect damage. The responsibility for on-farm seed management was shared between men and women, who had a distinctive role to play.

In Ethiopia, the mean physical purity and germination of wheat seed was 99 and 96%, respectively and the majority of samples reached the minimum purity and germination standards. In Syria, mean physical purity and germination for wheat was 98% and 86%, respectively whereas for barley the average analytical purity was 95% and germination was 86%. However, the quality of wheat seed samples was higher than that of barley seed samples where most of the samples (90 and 28% for purity and germination, respectively) failed to meet the minimum official seed standards. Highly significant differences in seed quality were observed for seed samples collected from different regions and districts for wheat and barley crops in both countries. However, there was limited significant difference in physiological quality of seed samples obtained from different sources, but not in physical quality.

Several seed-borne fungi such as *Drechslera sativum, Septoria nodorum* and *Fusarium graminearum, F. poae, F. avenaceum,* and *F. nivale* including storage fungi were recorded across samples from different wheat growing region of Ethiopia. Among fungal pathogens isolated from wheat seed, 83.6% of samples were infected with *D. sativum* (average infection rate of 1.9%) and 74% of the samples with *Fusarium graminearum* (average infection rate of 1.5%). Infection with loose smut (*Ustilago tritici*), common bunt (*Tilletia* spp.) and seed gall nematode (*Anguina tritici*) was low where only 11.2, 2.3 and 8.6% of the samples were infected, respectively. In Syria, 68 and 14% of wheat seed samples were infected with common bunt and loose smut, respectively. The average loose smut infection was 0.8%. The majority of barley seed samples were also infected with covered smut (*Ustilago hordei*=85%) and loose smut (83%) in varying proportion. The average loose smut infection for barley was 18%. Seed health quality of wheat was better than of barley in terms of the frequency (number of samples) and intensity of infection (% infection).

On-farm varietal diversity in terms of the number of varieties/landraces grown and area coverage were quite low both for wheat and barley. Farm level surveys showed low spatial diversity where a

few dominant wheat varieties occupied a large proportion of area. These few wheat varieties were also grown by the majority of farmers threatening the diversity of local landraces. In Ethiopia, the five top wheat varieties were grown by 56% of the sample farmers and these varieties were planted on 80% of the total wheat area whereas for Syria it was 78 and 81%, respectively in the same order. In case of barley one single local landrace was grown in the entire survey area. The weighted average age of wheat varieties was 13.8 years for bread wheat in Ethiopia and 10.8 years for wheat in Syria showing low varietal replacement by farmers, an indicator of low temporal diversity. The coefficient of parentage analysis showed that the average and weighted diversity for bread wheat was 0.76 and 0.66, respectively in Ethiopia and for bread wheat (0.73/0.42) and durum wheat (0.85/0.73) in Syria. The field experiments showed significant variations for desirable agronomic and phenotypic traits diversity such as plant height, grain yield, and yield components (spike length, spikelets spike^{-1}, kernels per spike^{-1}, seed weight) among wheat and barley varieties and/or local landraces. This study combined farmer surveys, laboratory analysis and field experiments to better understand farmer’s perception and adoption of modern varieties (and associated technologies) and to investigate on-farm genetic diversity and seed quality suggesting alternative ways for improving and strengthening the national seed system. Moreover, the study used extensive secondary data to draw a synthesis on the future direction of the national seed sector in developing countries in general and of the Ethiopian and Syrian seed industry in particular.

Key words: Wheat, *Triticum* spp., Barley, *Hordeum vulgare* L., Seed Systems, Formal Seed Sector, Informal Seed Sector, National Seed Programme, Seed Source, Seed Selection, Seed Management, Seed Quality, Genetic Diversity, Ethiopia, Syria.

Acknowledgements

This is a thesis on the performance of wheat and barley seed systems in Ethiopia and Syria. It describes the functioning of the formal and informal seed sectors with particular reference to farmers' adoption and perception of modern varieties and associated agricultural technologies, on-farm varietal diversity, farmers' seed sources and acquisition strategies, on-farm seed management practices and quality of seed produced. It recommends the formulation of alternative ways of strengthening the national seed delivery mechanisms that are responsive to the needs of farming communities, particularly smallholder farmers, contributing towards increasing agricultural production and ensuring food security.

The preparation of this thesis passed through several stages from its inception to its completion in the present format. Many people and institutions have rendered their support in different ways during the entire period of my study.

First and foremost I would like to express my sincere gratitude and deepest appreciation to Professor Dr Ir Paul Struik, my supervisor and promotor who first, without any reservation, accepted me for enrollment as a PhD student. He arranged my study as a 'sandwich' student at Wageningen University. Without his keen interest in the subject, invaluable academic guidance, professional advice, and continuous encouragement it would have been difficult to bring this study to its successful completion.

My deep gratitude also goes to Dr Anthonius J.G. van Gastel, Head of Seed Unit and my co-promotor who from the beginning made the initial contacts with Wageningen University and arranged for my study. He is a motivator –near or afar– who put all his energy behind the success of this study always reminding me of the significance of my work. His constant encouragement and regular reminder was an inspiration. Ir Kees Hellingman from the International Agricultural Centre, The Netherlands, made the initial contacts and the arrangements for my first visit to Wageningen University. He remained a friend and a colleague for which I am very grateful.

My special thanks go to Dr Mohan Saxena, Assistant Director General (At Large) at ICARDA who gave me a go ahead with the initial arrangements of my study and eventually the formal approval from the ICARDA. He keenly followed my progress and always provided me with words of encouragement during the course of my study.

I am highly indebted to Ms Gon van Laar for editing and designing the layout of the thesis. Without her able handed support it would not have been possible to print the thesis on time in its current format.

I am greatly indebted to the farmers in Ethiopia and Syria who shared with us their wisdom and experience and received us with unparalleled generosity and warm hospitality during the field work. They gave us everything free and without any reservation. My thanks also goes to the members of the field survey team in Ethiopia, particularly the late Dr Abebe Belachew, and other members Hussein Abi, Olkaba Bote, Tasew Gobezie and Woldeleul Ayalew. The Syrian survey team, Bashar Bakar, Faisal Jawesh, Najaeh Hallak, Daniel Ashkanian and Majid Issa, is also gratefully acknowledged.

My special appreciation and thanks goes to Wageningen University and the International Center for Agriculture Research in the Dry Areas (ICARDA) for providing me with the funding and the facilities to conduct my PhD research. For this the management of Wageningen University and ICARDA are gratefully acknowledged.

Many persons and institutions in Ethiopia and Syria provided support during the entire course of my study. I would like to thank the management and staff of the Ethiopian Seed Enterprise, Addis Ababa, Ethiopia and the General Organization for Seed Multiplication, Aleppo, Syria for their kind support during the field survey, laboratory analysis and field experiments and on providing secondary data on the national seed sector. Aberu Dagne, Getahun Alemu, Yonas Sahlu, Kasahun Shawel, Abebe Tedla, Mustafa Sultan, Ali Adem and Mrs Mebrak Gebretinsae from ESE; Awgechew Kidane from EARO; and Abebe Getamessay from APPRC in Ethiopia; and Mohamed Karim, Mahmoud Ahmed, Ms Hayam Alawi from Seed Unit, ICARDA; Dr Ahmed El-Ahmed and Dr Siham Asa’ad, Seed Health Laboratory, ICARDA; and Abdulwahab Madarati formerly from GOSM in Syria deserve special thanks.

I also wish to extend many thanks to all my colleagues (past or present) in the Seed Unit: Dr M.R. Turner formerly Head of Seed Unit, Dr Sam Kugbei, Abdoul Aziz Niane, Mohamed Makkawi, Ms Omaya Jabri and Ms Lamis Makhoul for their sincere support and encouragement in one way or another. A.A. Niane assisted in field work at ICARDA and participated in the field survey in Syria. Mohammed Makkawi participated in the field survey in Syria and Omaya Jabri assisted in data entry.

Finally all my heartfelt appreciation goes to my wife Fikerte Gebretsadik Gebresellassie, my daughter Kalkidan and son Hizkeal whose staunch support and unreserved love was a source of inspiration to complete my PhD study. To my immediate elder sister Bogaletch Bishaw who died at a young age, this thesis is dedicated.

Contents

CHAPTER 1

General Introduction

Chapter 1

General Introduction

1.1. Introduction

Seeds play a key role in human history and agriculture. First, seeds are instrumental in the domestication of wild species into cultivated plants. Prehistoric humans (probably women) were the first to recognize the value of seeds as planting material (Dominguez *et al*., 2001). Since then seeds played a central role in agricultural development.

Second, seeds are reproductive organs representing both continuity and change of the species. Seeds are a means for spatial and temporal dispersion for plant populations. They embody the genetic combinations that determine the inherent characteristics of plants, and thus their adaptation to the agro-ecosystems in which they grow. For example, the inherent seed characteristic such as dormancy optimizes germination over an extended period of time and helps the geographic spread of plants and survival of species.

Third, seeds have certain unique quality characteristics. Apart from the genetic quality, the physical quality (freedom from weeds), physiological quality (germination capacity and vigour) and health quality (freedom from seed-borne pests) standard are key features of seed quality. Farmers have refined over time the techniques of maintaining these quality attributes as part of crop selection and seed retention under the environment in which they operate.

Fourth, seeds provide the bulk of food for mankind. Each year about 60% of all agricultural food crops are grown from seed producing over 2.3 billion tonnes of grain excluding horticultural crops. At present we depend on 30 crops, many of these are cereals grown for their grains, where the three most important food crops, i.e., wheat, rice and maize account for 75% of global cereal consumptions (SAM, 1984).

Therefore, from both a biological and a technological viewpoint, seeds are the pillars of our livelihood and food security. Any policy and regulatory measures or technological advances that affect seeds will have a profound effect on the livelihood of mankind worldwide.

1.2. Seeds as Agricultural Resource Base

Seeds played a critical role in agricultural development since prehistoric man domesticated the first crops 10,000 years ago. The domestication of wild species into crop plants probably started with the collection, storage and utilization of seeds not only for food, but also for planting, a major step in the evolution of settled agriculture. The domestication of plants was a gradual transformation from hunting and gathering to sedentary agriculture rather than a sudden revolution. During this process conscious and unconscious selection occurred, leading to significant modification of many of our crop plants from their wild ancestors into highly adapted and diverse population of local landraces.

According to Buddenhagen and Richards (1988) domestication of wild species into cultivated crops has probably altered natural adaptation very little in the centres of origin. The migration of human populations and/or diffusion of crops from the centres of crop domestication exposed crops to new biophysical environments. The landraces, by disseminating into different agro-ecosystems, have acquired new genes or gene combinations and frequencies to fit into their new environments (Buddenhagen and Richards, 1988). Thus, farmers' selection coupled with natural selection conditioned the adaptation of landraces to their agro-ecosystems.

According to Tripp (2001), the European exploration and 'imperial germplasm flow' since the 16th century (1500 to 1900) greatly accelerated the movements of crops across the old and new world and contributed to the transformation of agriculture. For example, the worldwide dispersal of wheat germplasm and its contribution to wheat genetic diversity is described in Smale *et al*. (1996). This crop diffusion has generated many local landraces well adapted to specific environments and agricultural practices giving rise to greater genetic variability and diversity of crops which serve as a germplasm pool for modern plant breeding and seed industry.

1.3. Genesis of Modern Seed Industry

For most of the history of agriculture, crop genetic improvement and seed selection were farmer-based activities carried out as an integral part of crop production and without any functional specialization (Turner and Bishaw, in press). Empirical evidence shows that for millennia farmers selected plants from their local landraces and saved their own seeds for planting. They harvested seed from crops grown on fertile or new land, collected seed from vigorous plants or of larger grain size and discarded seed from unwanted plants. These are still the seed selection criteria in traditional farming systems. Within the community there were also reputable and knowledgeable farmers who managed their crops better and served as source of seed both in good and bad harvest years. Moreover, farmers exchanged seeds not only with relatives, neighbours and other farmers in adjacent villages, but also across large valleys and geographic regions. Sometimes seeds moved over long distances and were introduced into new civilizations, regions and continents as part of human migrations, conquests and explorations (Tripp, 2001).

The history of seed trade is as old as agriculture itself. Farmers exchanged seed in various traditional forms such as gifts, barter, labour exchange or social obligations. However, information on when, where and how organized seed production and trade started, is limited. It is believed that the introduction of new crops and knowledge-based agriculture including scientific plant breeding, mechanization, intensification and commercialization at various stages of agricultural development might have played a key role. Tripp (2001) described the progress of vegetable seed trade in England from the 13th century in response to a growing demand for seed and the diversification of the agricultural economy. Thomson (1979) indicated that the introduction of feed crops to European agriculture (300 years ago) was a stimulus for seed trade in forage crops. In crops such as vegetables and forages, production of food/feed and seed are different and requires special knowledge and experience. This is in contrast to crops such as cereals where grain and seed production are essentially the same and the grain can also be used for seed and easily produced and saved by farmers. These technical differences might have created demand for seed and led to specialization in seed production.

The most dramatic impetus for the development of the seed industry was the beginning of the systematic improvement of crops which began about 100 years ago stimulated by the new science of genetics. The rediscovery of Mendelian genetics at the beginning of the 20th century, and the steady development of scientific plant breeding based on these principles have been crucial in improving crop varieties. In the 1880s, the first attempts in scientific plant breeding began and the first plant breeding stations were established (Kahre, 1990). In Europe, governmental institutions or ‘entrepreneurial’ farmer breeders became involved in crop improvement and made available seed of these new varieties for sale to others by themselves or through local traders encouraging the nascent commercial seed trade. The advent of modern agriculture which itself is based on the knowledge of plant breeding and fertilizer use and technology (Plucknett, 1991) further accelerated the development of the seed industry. In the United States of America, the development of maize hybrids in the 1930s transformed commercial plant breeding and seed supply in the country. It created the foundation for a highly profitable commercial plant breeding industry capable of investing in crop improvement. The continued specialization in the seed trade brought significant changes in the seed supply systems giving birth to an organized seed industry in developed countries (Groosman, 1987). Traditionally seed firms started as independent, small family enterprises with a division of labour between grain and seed production. The degree of sophistication and specialization in the seed industry increased over time owing to advances in agricultural science and technology. The development of modern seed industry took almost three centuries to reach the current level of progress even in countries with advanced seed programmes – an evolutionary rather than a revolutionary process.

In many developing countries information on the history of agricultural research and organized seed production prior to 1950s is rather scanty. Early research might have focused on plantation and cash crops with little attention to food crops. Traditional farming practices and use of local landraces dominated subsistence agriculture. The introduction of highly productive semi-dwarf wheat and rice cultivars in the late 1960s and 1970s, which is referred to as the green revolution, probably served as a first launching ground for organized seed production in developing countries. Thus, seed of modern varieties coupled with external inputs like irrigation water, fertilizers, pesticides and better agronomic management, not only acted as a catalyst in increasing agricultural production (Byerlee and Heisey, 1992), but also brought significant technological changes in agriculture of developing countries. This stimulated interest in agricultural research and the establishment of organized seed sector.

Douglas (1980) and Pray and Ramasawmi (1991) proposed a four-stage linear model to classify and analyse the progress of seed industry development. In Stage 1, subsistence agriculture dominates without effective variety development where farmers solely use local varieties and own saved seed. In Stage 2, the development of modern varieties is progressing and they are replacing farmers' varieties. Commercial seed production and increase in use of inputs is evident although the quantity of seed available is a major constraint due to increased demand for seed. Stage 3 is characterized by a well-established variety development, adequate availability of seed and wider use of inputs, but inefficient distribution and little private sector participation. In Stage 4, agriculture is technologically advanced and a national seed industry is fully integrated and operated largely by the private sector with international links and supported by effective regulations. The model, however, is based on the experiences of seed industry development in industrialized countries and failed to recognize the diversity of farming systems in developing countries. Whether, the progress of seed industry in developing countries also follows the same course of evolution remains to be seen.

1.4. Seed System Definitions

The entire seed supply of a country comes from different sources, including on-farm saved by the farmer or off-farm from commercial sources or local trading depending on the degree of sophistication in agricultural production, the crop and the environment. Most of the early literature on seed systems focused on the commercial sector and several attempts have been made to define the national seed system from this perspective (Feistritzer and Kelly, 1978; Cromwell, 1990; Jaffee and Srivastava, 1992). Feistritzer and Kelly (1978) described a seed programme as a complex and integrated organizational concept which can be defined as '*an outline of measures to be implemented and activities to be carried out to secure the timely production and supply of* *seeds of prescribed quality in the required quantity*'. This and other definitions emphasize the quantity and quality of improved seed supplied and the proper timing and proper place of delivery at a reasonable cost (Venkatsean, 1994) and are biased towards the organized seed sector. In recent times, the concept of seed systems has been developed and expanded to include the role of the 'informal' sector in seed provisions. Van Amstel *et al.* (1996) defined the seed system as '*the sum of physical, organizational and institutional components, their actions and interactions that determine seed supply and use, in quantitative and qualitative terms*'. Thus, two distinctive, but interacting seed delivery systems are now recognized: the formal and informal sectors. The borderline between the formal and informal sector, however, is imprecise (Turner, 1996; Cromwell, 1997). For example a farmer may have adopted a modern variety that is the product of the formal sector, but decided to save seed from his own harvest for next year planting which is produced informally.

1.4.1. Formal Seed Systems

The formal seed system is composed of institutional and organizational arrangements consisting of all enterprises and organizations that are involved in the flow of modern varieties from agricultural research to the farming communities. These include several interrelated components which are described briefly as follows:

Variety development, release and registration Modern plant breeding is a two-step process, creating genetic variability and selecting from the resulting populations to identify new varieties that show promising performance under given agro-ecological conditions. These varieties are evaluated through multi-location trials for yield and other agronomic characteristics and are officially sanctioned for release, sometimes by an independent agency, to be used in crop production. The varieties must be distinct, uniform and stable according to certain set of standards.

Seed multiplication and processing The small quantity of genetically pure parental material obtained from plant breeding institutions called the 'breeder seed' is multiplied through a 'generation' system often on contracts to produce enough certified seed to supply it to farmers. In each stage of seed multiplication, the seed is cleaned to remove contaminants and sometimes treated with chemicals against pests to ensure quality.

Seed marketing and distribution The production of seed is not an end in itself. Seed that has been produced and processed, should be marketed and distributed to make seed available at the right time and place for farmers to use it. In addition to physical handling of seeds at various stages of production, marketing also includes promotional efforts to create awareness and financial provisions to ensure access to seed.

Seed quality control and certification At each stage of operation, i.e., multiplication, processing, marketing and distribution, a series of measures are taken to ensure that the varietal identity and genetic purity as well as other seed quality attributes are maintained. A set of field and seed standards are prescribed and enforced through field inspection and laboratory testing; sometimes these standards are backed by regulations.

The formal seed system is a distinct, but highly interdependent chain of operations of which the overall performance can be measured by the efficiency of the different links in the chain (Pray and Ramasawmi, 1991). Advances in plant breeding research influence varieties that are developed by agricultural research, but the efficiency in identifying varieties acceptable by farmers and effective seed production and delivery systems coupled with appropriate agricultural extension and rural development policies help in adopting and diffusing modern varieties and seeds.

The formal system comprises of public and/or private plant breeding institutions; parastastal, private or multinational seed companies; seed certification agencies; and agricultural input distribution agencies operating within a specified national seed policy and regulatory framework. In general, it is a vertically organized large-scale operation, mostly with commercial interests.

Several authors discussed the framework for performance analysis of a formal seed sector (Pray and Ramasawmi, 1991; Cromwell *et al.*, 1992; Friis-Hansen, 1992). In reference to developing countries, there are serious concerns on the appropriateness and choice of varieties available, quantity and quality of seed delivered, seed production costs and prices and timeliness of supply (Cromwell *et al.*, 1992; Sperling *et al.*, 1993b). In many developing countries several policy, regulatory, institutional, technical and infrastructural constraints contribute to the under-performance of the formal seed sector (Bishaw and Kugbei, 1997).

1.4.2. Informal Seed Systems

More than 80% of the crops in developing countries are sown from seed stocks selected and saved by farmers who manage their crops (Delouche, 1982; Osborn and Faye, 1991; Jaffe and Srivastava, 1992; Almekinders *et al.*, 1994; Venkatesan, 1994; Alemkinders and Louwaars, 1999). The system has been variously called a farmer managed seed system (Bal and Douglas, 1992), informal seed system (Cromwell *et al.*, 1992), traditional system (Linnemann and de Bruijn, 1987), local seed system (Almekinders *et al.*, 1994) or farmers' seed system (Almekinders and Louwaars, 1999). The informal seed system deals with small quantities of seed, is semi-structured, operates at the individual farmer or community level (Cromwell *et al*., 1992), and may depend on indigenous knowledge of plant and seed selection, sourcing, retaining and management, as well as local diffusion mechanisms. The informal sector is more flexible and adaptable to changing local conditions and less dependent on or less influenced by other external factors.

The informal system comprises a multitude of individual private farmers who select and save their own seed or exchange seed with others through traditional means such as gift, barter, labour exchange, cash transactions or social obligations as well as a diversity of local level seed production initiatives organized by farmers' groups and/or NGOs working under no legal norms and certification schemes of the organized seed sector.

In parallel to the recognition of the informal sector in seed supply (Cromwell *et al*., 1993, Almekinders *et al*., 1994) there is also growing interest in farmer participatory approaches in genetic resource conservation (Worede, 1992), plant breeding (Sperling *et al*., 1993a; Ceccarelli *et al*., 2000; Almekinders and Elings, 2001) and germplasm or variety evaluation (Abidin *et al*., 2002). The informal seed system can also be linked to local germplasm conservation, crop improvement and use (Worede, 1992; Tesemma and Bechere, 1998), and plays an important role in seed security of local landraces at the household and community levels. Turner and Bishaw (in press) discussed the potential linkages between participatory plant breeding and seed supply system to exploit farmers' knowledge in crop improvement and rapid diffusion of varieties. They advocated national policies recognize the role of participatory plant breeding and support the establishment of small seed enterprises for production and marketing of varieties developed through these approaches.

1.5. Changing Seed Industry

1.5.1. Perspectives of Seed Industry in Developed Countries

Until the 1960s and 1970s, the seed industry in developed countries consisted of mainly independent small- and medium-scale private enterprises or agricultural co-operatives producing seed for limited national and international markets (Groosman *et al*., 1991; McMullen, 1987). Most public plant breeding organizations conduct basic and applied research including development of new crop varieties whereas the public and private seed companies are responsible for commercialization of these varieties. Some larger seed companies are involved both in adaptive research and are dealing with hybrid seeds whereas smaller companies dominate non-hybrid seed markets.

Emergence of Multinational Seed Companies (MNCs) The picture started to change where the seed industry has been gradually transformed from family-operated small to medium enterprises and consolidated into multinational seed companies through mergers and acquisitions. In the 1970s and 1980s consolidation of independent seed firms into transnational corporations went with greater speed. The last two decades have seen the mergers of seeds, agrochemical and biotechnology companies. The main attraction was the diversification of the product portfolio and the opportunities recognized in the complimentary roles of seed trade and agrochemical business such as pesticides (Groosman *et al.*, 1991; Tripp, 1997a).

According to recent estimates the world wide market for agricultural seed is worth US$45 to US$50 billion a year (www.worldseed.org) of which about one-third is commercial proprietary seed (private sector), one-third is produced by governments or publicly funded institutions (public sector) and one-third is the value of seed saved by farmers which appears to be an even distribution among the three sources. However, nearly 40% of the commercial business is accounted for by hybrid seed sales in various crops which are dominated by large multinational seed companies (MNCs).

Emergence of Agricultural Biotechnology Advances in molecular biology already opened new frontiers, opportunities and challenges in plant breeding and seed supply systems. For example, MNCs and private biotechnology companies entered the USA seed industry in the early 1960s (Groosman *et al.*, 1991). The last two decades have seen massive investment in genetic engineering and lately a substantial increase in area planted to genetically modified crops. Such mergers have been prompted by the potentials offered by genetic engineering and increased globalization of the seed industry. According to the International Seed Federation estimates, the area cultivated with transgenic crops (mostly herbicide tolerant, insect tolerant, etc.) jumped from 2.8 million in 1996 (www.worldseed.org) to 58.7 million ha in 2002 (www.isaa.org) in a matter of half a decade and will continue to increase in the coming years. The 21st century will probably see an expansion of genetically modified crops throughout the world to meet the demands of increased food production. Although not yet commercially exploited the potential benefits to be accrued from application of new Genetic Use Restriction Technologies (GURTs) such as Variety-GURTs and Gene-GURTs need further analysis (Louwaars, 2002).

In developed countries, the enactment of plant variety protection, decline in public plant breeding programmes, emerging plant biotechnology and globalization of the seed industry are the key factors with great impact on the structural changes of the seed sector (McMullen, 1987; Groosman *et al.*, 1991). However, most of the attention is principally focused on crops with hybrid seed technology and a few important cash crops. In case of many self-pollinated or non-commercial crops farmers are still the main source of seed even in developed countries (Jaffee and Srivastava, 1994; Ghijsen, 1996).

1.5.2. Perspectives of Seed Industry in Developing Countries

In parallel to the evolution of the seed system in the industrialized world, organized seed programmes in developing countries have a relatively short history. International Agricultural Research Centres (IARCs) are instrumental in the establishment of national plant breeding programmes, thus laying the foundations of the seed industry in many developing countries. The birth of organized seed supply is linked to the success of the *green revolution* stimulated by the availability of short stature, input efficient and management responsive wheat and rice varieties emerged from the IARCs. These successes motivated many governments to establish public research organizations to develop new varieties and parastatal corporations to deliver improved seeds to the farmers.

Establishment of the Public Seed Sector Since the 1960s many seed projects have been supported and/or executed by external donors such as the Seed Improvement and Development Program (of the Food and Agriculture Organization of the United Nations), the International Bank for Reconstruction and Development (World Bank), the United States Agency for International Development and other regional and international organizations (Douglas, 1984; Cromwell, 1990; Venkatesan, 1994) which were designed to introduce the same model based on seed sector development in industrialized countries (Groosman *et al*., 1991). These projects were implemented with government participation primarily with social and developmental objectives, fully subsidized and less market-oriented. They are above all successful in putting in place the key physical and institutional infrastructure of the national seed industry.

The formal sector made significant contributions through variety development and provision of seeds, at least for a few crops and in most favourable environments of developing countries. There is a steady progress in adoption of modern varieties across different environments and farmer groups. It is estimated that about 80% of the wheat (Heisey *et al*., 2003), 70% of the rice (Tripp, 2001) and 60% of the maize (Morris *et al*., 2003) area in developing countries is planted with modern varieties. However, despite huge investments through bilateral and multilateral donor assisted projects and massive government subsidies the performance of the majority of the public seed companies did not meet the expectations of many governments and donor agencies. These directly imported seed industry development models partly failed because they were based on large-scale, mechanized and commercial agriculture of industrialized countries. They often overlooked the diversity of agriculture and farming systems

(Groosman *et al*., 1991), farmer's indigenous knowledge and local seed systems (Bishaw and Kugbei, 1997), poor infrastructure and the vagaries of climate.

Emergence of the Private Seed Sector In most developing countries the seed industry lacks the participation of private sector and strong market orientation, the key features for successful seed enterprise development elsewhere. Seed production and distribution is quite often handled by state enterprises, extension services, rural development programmes or farmers' cooperatives (Tripp *et al*., 1997) which are often bureaucratic, inefficient and less market-oriented.

In the 1980s, in response to new economic realities and demands from the international financial institutions and donor agencies, many governments implemented structural adjustment programmes as a step towards a market economy. Such deregulation and decentralization of public sector activities affected the agriculture sector in general and the seed sector in particular. In some countries governments introduced reforms for state seed enterprises to operate with financial and management autonomy to remain efficient, competitive and profitable whereas in other countries the government encouraged the outright privatization of the seed sector (Turner *et al*., 2000).

Some governments undertook policy and regulatory reforms and provided investment opportunities and financial incentives to stimulate the private sector and to attract both foreign and domestic investment in the seed sector. As a result domestic and foreign companies started operating in the seed sector through direct investment or joint ventures in some countries of West Asia and North Africa region (e.g., Egypt, Morocco, Pakistan and Turkey).

Local Seed Systems and NGOs Small-scale farmers occupy a larger proportion of cultivated land and farming population and the environment of production in developing countries (Byerlee and Heisey, 1992). Ceccarelli *et al.* (1996) cited that about 1.4 billion people are still dependent on agriculture in stress environments; and that resource-poor farmers practise approximately 60% of global agriculture and produce only 15 to 20% of the world's food. For the majority of small-scale farmers depending on minor crops, living in less favourable environments and remote areas, provision of modern varieties and seeds remains a challenge for agricultural development. At present there is a growing recognition of alternative seed delivery systems that exist at a community level. Such initiatives complement the formal programme in supplying seed to small-scale farmers in less favourable environments and less accessible remote areas through a decentralized system of seed production and marketing (Kugbei and Bishaw, 2002). Such local seed supply systems can also be linked to participatory plant breeding initiatives as well (Turner and Bishaw, in press).

Both natural and man-made disasters can have devastating effects on agriculture and seed supply systems. Man-made disasters such as internal strife and conflict displace the population and disrupt agricultural production. Natural disasters such as recurrent drought deplete seed stocks making farmers vulnerable to food insecurity. The history of Non-Governmental Organizations (NGOs) in the seed sector started owing to the recurrence of man-made and/or natural disasters particularly in developing countries. Since the 1970s, several NGOs are active in relief operations and emergency seed supply in these countries. As part of a rural development programme some NGOs are also involved in informal approaches to encourage local seed supply by the farming communities (Cromwell *et al.*, 1993). Some NGOs encourage conservation of local germplasm while others promote the diffusion of modern varieties especially to small-scale farmers. Most of the activities, however, are uncoordinated and haphazard with serious problems of long-term sustainability in the absence of external support.

1.6. Evolution of a Seed Regulatory Framework

The emergence of the seed regulations was a response to evolution of technical and economic changes in the seed industry usually prompted by the desire of the society for government intervention (Tripp, 1997b). The structural changes to traditional agriculture brought by new crop improvement techniques and the arrangements for seed production and marketing required new institutions to regulate the industry. These changes entailed setting of standards against which quality had to be determined, establishing the agency to monitor that procedures were followed to reach desired standards and enforcing the standards to make sure that they were observed. The regulations of particular relevance to seed systems are: (a) variety regulation for testing, release and registration; (b) seed regulation prescribing field and seed standards for certification; (c) plant variety protection to protect breeders of new varieties; (d) seed trade regulation setting specifications for seed import or export; and (e) quarantine regulation for exclusion of exotic pests (insects, diseases and weeds).

1.6.1. Seed Quality Concepts

Seed quality is a multiple concept made up of different attributes (Thomson, 1979). In technical terms, seed quality can be broadly categorized into four main components: (a) genetic seed quality, (b) physical seed quality, (c) physiological seed quality, and (d) seed health quality. Plant breeders through selection, introduction and/or hybridization using conventional or modern biotechnological tools develop new crop varieties for use by farmers. The genes and combinations of genes constituted in the variety define the genetic seed quality and therefore its potential attributes such as grain yield and other agronomic traits. The physical, physiological and health quality of seed contributes towards realizing these potentials of the variety. The recognition of these quality parameters led to the establishment of field and seed standards and different test methods and procedures to verify whether the seed for sale meets these standards. Therefore, seed quality control and certification is a series of procedures designed to maintain and make available high quality seed of improved crop varieties, so as to ensure desirable standards of varietal identity and genetic purity and other quality attributes. The control can be achieved through strict supervision of seed production and processing operations and checking them against minimum field and seed standards. Through time these procedures and methods have been refined, standardized and updated in response to changing circumstances and usually backed by legislation.

1.6.2. Variety Regulation and Seed Certification

The beginning of scientific crop improvement enabled breeders or farmers to develop new crop varieties and make available the seed by themselves or through local traders. However, maintaining the identity and purity of these new varieties became a great challenge. According to Parsons (1985) and Hackleman and Scott (1990), for example, ‘Fultz’ wheat distributed first in 1871 was reported under 24 names and ‘Silvermine’ oats introduced in 1895 was grown under 18 different names. The emergence of systematic plant breeding brought two important developments in the seed industry. The first development was the immediate need of maintaining the varietal identity and purity of the new varieties for seed production and distribution to farmers: varietal certification. The second aspect was the need for developing a systematic procedure and criteria for introducing new varieties to commercial seed production: varietal evaluation and recommendation. In recognition of these problems, initially voluntary associations of breeders, merchants and farmers were established to organize and control seed multiplication of new varieties (Thomson, 1979), which gradually evolved into what is now commonly called seed certification. However, these schemes were often developed independently without any knowledge from what happened in other countries (Svensson *et al.*, 1975) and later improved and expanded to meet the challenges in plant breeding, seed production and farmers' interests (Parsons, 1985; Hackleman and Scott, 1990). The development of seed certification in Western Europe and elsewhere was described by ISTA (ISTA, 1967) and in 1990 edition of Plant Varieties and Seeds.

In Germany, listing varieties in terms of morphological characteristics and performance was started as early as 1905, whereas in Sweden seed certification was started in 1888 (Tripp, 2001). Field inspection started in Canada in 1905 and in some states of the USA by 1913 (Hackleman and Scott, 1990). The establishment of the

International Crop Improvement Association (later Association of Official Seed Certifying Agencies, AOSCA) in 1919 (Parsons, 1985) was the first attempt to standardize varietal certification schemes in North America. Since 1958 the Organization for Economic Cooperation and Development (OECD) seed schemes have been operational (Thomson, 1979) with a membership now of over 50 countries (http://www.oecd.org). These organizations standardized certification schemes and put in place variety evaluation, release and registration procedures for accepting and listing varieties and strict generation control to maintain the identity and purity of the variety.

Similarly, advances in botanical science also led to the recognition of physical and physiological quality of seeds when in 1869 the first seed testing station was established in Germany (Thomson, 1979). Later on the practice spread to other European countries and elsewhere. Subsequently, the need for standardization of definitions, methods, materials and equipment for quality tests culminated into the establishment of international or regional organizations such as the International Seed Testing Association (ISTA; http://www.seedtest.org) and the Association of Official Seed Analysts (AOSA; http://www.aosa.org) in 1924 and 1908, respectively. The test procedures are refined and updated regularly with further advances in knowledge of seed science and technology.

To date the AOSCA and OECD seed certification schemes to maintain varietal identity and genetic purity, and the rules, procedures and methods for evaluation of seed quality attributes of the ISTA and AOSA are universally accepted and widely used in seed programmes of many countries. These certification schemes and seed associations established standards for seed quality attributes and developed procedures to achieve uniformity in seed quality assessment both in the field and laboratory. The EU variety and seed regulation is a good example of regionally harmonized seed certification scheme for member countries.

Likewise, the governments enacted national seed regulations to support the implementation of these schemes. The ‘Adulteration of Seeds Act’ of the United Kingdom in 1869 could probably be the first seed act to put quality control on legal footing. However, compared to the long history of organized seed production many developed countries enacted comprehensive seed regulations fairly recently. In some countries the governments established public certification agencies whereas in others private industry associations were formed to implement and enforce these regulations.

However, as the seed industry advanced the need for quality assurance programmes also changed which is based on the concepts of International Standards Organizations (ISO 9000) where product excellence can be ascertained by setting rigorous guidelines and requirements for processes and facilities and these are validated by auditing the processes. To date the new concepts of quality assurance and accreditation programmes have emerged as guiding principles for the seed industry (Svajgr, 1997). In recent years many larger seed companies with well established research and quality control programmes are establishing own self-monitoring quality assurance programmes and use brand names instead of traditional seed certification. The International Seed Testing Association is now offering an accreditation programme for governmental or private company seed testing laboratories wishing to issue ISTA certificates. Similarly, the OECD seed scheme is also experimenting an accreditation programme for field inspection and seed sampling.

It should be noted that the compulsory and voluntary seed certification schemes which exist today and are followed by different countries have emerged owing to the regional variations in approaches in the early development of variety release and registration and seed quality control systems.

1.6.3. Plant Variety Protection

Intellectual property rights (IPR) are considered a useful tool to promote private investment in research and development. The interest in IPR of plants emerged in the 19th century linked to the remuneration for breeders who developed new varieties and later consolidated into various laws in Europe in the 1920s and the USA in the 1930s to protect new plant varieties. Some of the early examples are use of patents in USA (Tripp, 2001) and plant variety acts in the Netherlands (Ghijsen, 1996). In 1961, the Union Internationale pour la Protection des Obtentions Végétales (UPOV) was established to protect breeders of new plant varieties by providing an exclusive property right on the basis of a set of uniform and clearly defined principles (http://www.upov.org). The 1991 UPOV Convention is a latest in a series providing a legal framework for plant variety protection. At the beginning of 2003 UPOV membership has reached 52 countries with potential for further expansion, as more countries are obliged to put in place an internationally acceptable mechanism for plant variety protection under the TRIPs agreements of the World Trade Organization.

1.6.4. International Seed Trade

From the outset, the drive for standardization arises from the movement of seed in international trade, but tariff and non-tariff barriers remain an impediment. In 1924, the Fédération Internationale du Commerce des Semences (FIS) was initially established to represent the private sector interest and to facilitate global seed trade. It promotes uniform trade rules and arbitration procedures for international seed trade. It also represents the interests of private plant breeders by encouraging plant variety protection. In 2002, the seed federation and plant breeders association were merged to form the International Seed Federation (ISF) representing the seed trade and plant breeders in 68 countries worldwide (http://www.worldseed.org).

Tripp *et al*. (1997) and Louwaars (1996) described the key features and limitations of variety and seed regulations and their introductions to developing countries. Most of these regulations are influenced by past historical relationships and donor supports of the seed programme development. They are excessively strict and inflexible limiting the range of varieties, the quality of seed available and movement of the seed within or across national boundaries, thus severely limiting opportunities for national and/or international seed trade. Tripp (1995) argues that regulatory reforms must be seen as a continuous process, and sufficiently flexible to respond to and promote the evolution and diversification of the national seed sector in developing countries.

1.7. Summary

Since the 1960s, the national seed industry in developing countries has made significant progress particularly in more favourable environments and for few major food crops. To summarize, today it is common to find a mix of multinational companies, parastatal corporations, domestic private companies, small enterprises, cooperatives or farmers associations, NGOs, individual producers operating side by side in seed supply in many developing countries (López-Pereira and Filippello, 1995). The public sector has a major role in crop research, seed production and quality control, promotion and provision of credits and capacity building for the balanced development of the national seed system. The private sector, which includes a range from individual seed producer-sellers to small, medium, and large seed enterprises, continues to produce and market seed for their niche markets (Bishaw and Kugbei, 1997). More and more countries are developing strategies to stimulate pluralistic seed industries. Therefore, national governments are expected to develop and adopt flexible policy, regulatory, institutional and technical options to optimize this diversity at national, regional and global levels.

Given the historical development of the seed industry described above, the national agricultural research systems and national seed programmes in Ethiopia and Syria are of relatively young history. The advent of modern agriculture in both countries started with the establishment of national agricultural research systems in the mid 1960s (ICARDA *et al*., 1999) and the establishment of the national seed programmes in the mid to late 1970s (Gurmu *et al*., 1998; Radwan, 1997). The national governments have made huge investments in crop improvement and seed supply in view of national policy for achieving food self sufficiency and food security in the country. However, there is limited information on the functioning of the formal and informal sectors of wheat and barley in both countries.

1.8. Statement of the Problem

Bread and durum wheats are the two most important wheat species widely grown worldwide. According to CIMMYT's world wheat survey the West Asia North Africa (WANA) region is the second major rain-fed wheat production zone in the developing world next to South Asia (Byerlee and Moya, 1993). In the year 1990 the wheat area in WANA covered 25.2 million ha accounting for 36% of the total area of the wheat crop in developing countries. The area planted to modern varieties in WANA was only 42% compared to 88% in south Asia and 82% in Latin America. In 1997, the area covered by modern varieties has increased to 66% in WANA, 86% in Asia and 90% in Latin America (Heisey *et al*., 2003). Many countries do not differentiate between bread and durum wheats in reporting area planted and harvested, yields, and production. However, about 10% of the world's wheat area is covered by durum wheat of which 90% or approximately 11 million ha is cultivated in the drier areas of the Mediterranean (Nachit, 1998) which also includes most of the WANA region. Syria is the third most important durum wheat producing country in the WANA region next to Turkey and Morocco (Belaid, 2000). Ethiopia is the largest producer of wheat in Sub-Saharan Africa with a potential expansion of the area to 1.3 million ha (Geleta *et al.*, 1994).

Barley was domesticated in the fertile crescent of the Near East over 10,000 years ago. Today the area is still home to a tremendous variety of plant types and their wild relatives. In the Central and West Asia and North Africa region barley plays an important role as feed and forage crop in the crop-livestock production system. However, in many developing countries the crop still remains an important food crop (e.g., Ethiopia and some North African countries). From 19 million ha of barley grown by developing countries, 72, 19 and 6% is grown in WANA, Central Asia and Latin America, respectively (Aw-Hassan *et al*., 2003) with an average yield of about 1 tonne ha^{-1} (Tahir *et al.*, 1997). Syria is one of the major producers of barley in the CWANA region. Although high adoption levels of up to 50% have been reported for some countries, the major producers registered less than 5% (including Syria) with an overall average of 14% in selected WANA countries (Aw-Hassan *et al*., 2003).

Syria is located in the Fertile Crescent, one of the centres of origin and diversity of both tetraploid and hexaploid wheats and barley. The Ethiopian highlands exhibit one of the unique centres of genetic variability and diversity of tetraploid wheat and barley as well. In the past much of the wheat area was planted with landraces selected and maintained by farmers over millennia. But this landscape is changing fast and modern varieties developed by scientific plant breeding are replacing the genetic diversity and variability that existed in the field. Most traditional local landraces of wheat are being replaced and losing ground to isolated marginal areas particularly in Syria because of low productivity and competition from productive modern varieties to meet surplus production for the market.

In the West Asia North Africa region, including Ethiopia and Syria, agriculture plays an important role in the national economy employing a large workforce, contributing to the gross domestic product, providing raw input for the industry and valuable foreign exchange earnings. Most governments have invested significant resources into strengthening their agricultural research systems and national seed programmes to increase production and productivity in the agricultural sector of the economy. It is believed that the availability of high quality seed of a wide range of adaptable crop varieties to farmers is one of the key elements for achieving food security and reducing rural poverty.

The national seed industries comprise of formal an informal seed sectors. The status of the formal seed supply system varies from country to country, but it is largely dominated by the public sector and relies heavily on subsidies with very limited or no participation of the private sector except in few countries and with few crops. Despite more than three decades of investment in agricultural research and formal seed supply systems by bilateral and multilateral organizations, the formal sector is currently unable to meet more than 10% of seed needs of farmers in the region. The adoption of improved varieties varies across countries, crops, farming systems and production environments and is generally very low except for a few cereal crops (Bishaw and Kugbei, 1997).

The analysis of national seed industries in 22 countries of the Near East and North Africa revealed substantial variation in their seed programme development and only few countries could claim a well-functioning formal seed supply system (FAO, 1999). In all countries seed production and supply of most cereals, legumes, vegetables and forage species is invariably underdeveloped and currently far from meeting the seed needs of farmers. The organization of the national seed industry is suffering from policy, regulatory, institutional and technical constraints as described by Bishaw and Kugbei (1997).

The informal seed supply system, an indigenous knowledge based farmer managed seed production, remains one of the main sources of seed for farmers in the WANA region. This system has been largely ignored by the earlier investments in the seed sector and its vast potentials are untapped. A great amount of literature and information is available on variety development, seed production and quality control in the formal seed sector (Cromwell *et al.*, 1992). On the other hand there is little information on the informal seed sector; farmers' indigenous knowledge in plant and seed selection and maintenance; farmers' seed sources, seed quality and seed management practices; farmers' perception of new varieties, adoption behaviour and diffusion of new varieties and seed.

The main objectives of this study are therefore to understand the functioning of the national seed sector with particular reference to wheat and barley crops in Ethiopia and Syria focusing on the informal seed sector. The study combines field surveys, laboratory tests, field experiments and secondary data in analysing the seed system in both countries. The specific objectives of the study are to:

- Study wheat and barley seed systems in Ethiopia and Syria to understand the functioning of the national seed sector with particular reference to the informal sector;
- Study and characterize farmer's perception and adoption of existing varieties and associated technologies and criteria for adoption of new varieties to assist breeders to focus on farmers' preferences;
- Study and document farmers' indigenous knowledge of on-farm plant and seed selection and seed management practices as a means to strengthen and develop responsive seed delivery systems;
- Study the physical and physiological quality of wheat and barley seed used by farmers and its relation to source of seed and seed management practices of farmers;
- Study the occurrence and distribution of major wheat and barley seed-borne diseases and assist in developing an on-farm seed treatment strategy and technology; and
- Understand the on-farm genetic diversity of both modern varieties and local landraces used by farmers in terms of agronomic and morphological characteristics and associate with farmers' preference for these varieties.

1.9. Thesis Outline

The thesis is organized into seven main chapters. Chapter 1 gives an overview of the evolution of the seed industry both in industrialized and developing countries highlighting current perspectives and future trends in seed sector development. Chapter 2 describes the wheat seed system in Ethiopia based on the survey conducted among farmers focusing on the adoption of wheat varieties and associated technologies. It highlights the organization of the Ethiopian wheat seed system and farmers' perception and use of modern varieties, farmers' seed source and management practices and any constraints perceived by farmers. Chapter 3 describes the wheat and barley seed system in Syria based on the survey conducted among farmers focusing on the adoption of wheat and barley varieties and associated technologies. It highlights the organization of the Syrian seed system and farmers' perception and use of modern varieties, farmers' seed source and management practices and any constraints perceived by farmers. Chapter 4 discusses the seed quality of wheat and barley seed samples focusing on physical and physiological parameters whereas Chapter 5 will provide an insight into the seed health quality of wheat and barley seed with particular reference to the occurrence and distribution of major seed-borne diseases on samples collected from farmers in respective countries. In Chapter 6 the diversity of wheat and barley varieties collected from farmers will be presented based on spatial and temporal diversity, coefficient of parentage analysis and on morphological and agronomic characteristics measured in field experiments. Chapter 7 will provide a synthesis and conclusions of the study in both countries.

CHAPTER 2

Farmers' Wheat (*Triticum* spp.) Seed Sources and Seed Management in Ethiopia

Chapter 2

Farmers' Wheat (*Triticum* spp.) Seed Sources and Seed Management in Ethiopia

2.1 Abstract

Ethiopia is the largest producer of wheat in Sub-Saharan Africa with a potential expansion to 1.3 million ha. A substantial investment has been made in agricultural research to improve wheat production and productivity to attain national food self-sufficiency. Farm level data on farmers' perception and adoption of modern wheat varieties, source of information on new agricultural technology, wheat seed sources and on-farm seed management practices were collected from farmers in four major wheat growing areas of the country. A total of 304 farmers growing wheat during the 1997/98 crop season were interviewed in Arsi, West Shoa, North Shoa and East Gojam zones. Most wheat growers were aware of and had information on modern wheat varieties, agronomic packages and agrochemical inputs where over 90% state having knowledge of these agricultural technologies, the formal extension system being the major source of information. There is an extensive adoption of new technologies where the majority of farmers grow modern wheat varieties (76% on recommended list and 10% 'obsolete' varieties), apply fertilizers (97%) and herbicides (64%) to their wheat crop. Although a wide range of modern wheat varieties were adopted, ET 13 (West Shoa, North Shoa and East Gojam) and Pavon 76 (Arsi) were found predominant and each was grown by 20% of the farmers replacing previously popular varieties such as Dashen and Enkoy, presently grown by less than 10% of the farmers. Farmers have identified as many as 26 technological and socio-economic criteria for adopting and continuously growing a particular wheat variety on their farm. However, grain yield, food quality, marketability, grain colour and grain size appeared to be the most important criteria and transcended all zones. The traditional farmer-to-farmer seed exchange played a significant role for lateral diffusion of modern varieties and as a major source of seed for planting wheat crop in any given year. The informal sector was an initial source of modern wheat varieties for 58% of the farmers, through neighbours/other farmers (36%), relatives (7%) or local trading (15%). Moreover, the majority of farmers sourced their wheat seed informally whereby 79% used retained seed or sourced off-farm from neighbours (9%) and local traders/markets (3%) for planting wheat during the survey year. In contrast, the formal sector was the initial source of wheat varieties for 40% of farmers, but only 8% of farmers purchased certified seed in the 1997/98 crop season. Farmers' positive perception of seed influenced them to practise different management approaches to maintain the quality of their wheat seed through on-farm selection (67%), cleaning (83%), chemical

treatment (4%), separate storage (65%) or informal assessment of seed quality (34%) whereas the responsibility was shared between men and women with each playing a distinctive role. The adoption and diffusion of modern bread wheat varieties and associated technologies appeared to be higher than for other crops, although largely remained informal. However, given the diversity and complexity of agro-ecological zones and farming systems overlaid by socio-economic conditions of the farmers, agricultural research is lagging behind in solving the major production constraints of Ethiopian agriculture. It is imperative, however, for the government to put in place a sound national policy for addressing and strengthening agricultural research, transfer of technology, input delivery, and grain pricing and marketing responsive to the needs of the farmers. Within this context, it is important to recognize the role of the national seed system, both formal and informal, to create a competitive, efficient and sustainable seed industry.

Key words: Ethiopia, wheat, *Triticum* spp., formal seed system, informal seed system, seed source, seed selection, seed management, seed storage.

2.2. Introduction

Ethiopia is located in the horn of Africa between longitudes 33° W and 48° E and between latitudes 3.4° S and 15.4° N. It is one of the largest countries in Sub-Saharan Africa with an area of 112 million ha where 65% of the land is suitable for arable agriculture, but at present only 15% is cultivated. In 2003, the population reached an estimated 70 million with an annual growth rate of 3%.

Three major climatic zones are recognized in relation to altitude and temperature: *Dega* (cool highlands) above 2400 m asl where temperatures range from near freezing to 16 °C; *Woina dega* (temperate medium highlands) from 1500-2400 m asl and temperatures from 16-30 °C; and *Kola* (hot tropical and arid lowlands) below 1500 m asl and daytime temperatures ranging from 27 °C to 50 °C. The main rainy season (*meher*) is from June to September preceded by short rains (*belg*) from February to April in some highland areas. The mean annual rainfall varies from 100 mm in the northeast to more than 2400 mm in the southwest showing large spatial and temporal variability.

The country has 18 major and 49 sub-agro-ecological zones where crops and cropping patterns evolved over millennia giving rise to an array of unique germplasm adapted to local conditions. According to Vavilov the region is an important primary and secondary centre of domestication for some 38 crop species (Worede, 1992) where early introductions of Mediterranean crops such as wheat, barley and chickpea acquired tremendous genetic variability and diversity (Demissie and Habtemariam, 1991).

Agriculture is the oldest industry and means of subsistence contributing to over 85% of employment, 50% of gross domestic product and 90% of export. The most productive agriculture is carried out in the mid- to high-altitudes above 1500 m asl where over 95% of the cropped lands are found and over 80% of the country's population resides. During 1999/00 main (*meher*) crop season cereals, legumes and other crops including oilseeds occupy 82, 13 and 5% of the total area of 8.2 million ha under crop production (CSA, 2000). Smallholder farmers cover 96% of cultivated land and dominate the agricultural sector.

2.3. Government Agricultural Policy

Agriculture is the foundation of the national economy and plays a major role in the socio-economic development of the country. In 1991, the Government launched the agriculture-led industrialization development strategy (ICARDA *et al*., 1999) where emphasis is put on linking research with development through well focused and targeted transfer of appropriate technology to farmers. The agricultural development strategy is aimed at promoting growth, reducing poverty and attaining food self-sufficiency while protecting the environment through safe use of improved technologies. The agricultural package programme is spearheaded through demonstration and provision of modern varieties and required inputs such as improved seeds, fertilizers and pesticides as well as better access to credit facilities.

2.4. Wheat Production Trends

Wheat is one of the major cereal crops in the Ethiopian highlands, between 6° and 16° N and 35° and 42° E, at altitudes ranging from 1500 to 2800 m asl (Gebremariam, 1991a) and predominantly grown in the southeastern, central and northwestern regions of the country. From seven wheat (*Triticum*) species grown in Ethiopia, bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum durum* Desf.) are the dominant species (Demissie and Habtemariam, 1991; Gebremariam, 1991b; Tesemma and Belay, 1991).

Ethiopia is the largest producer of wheat in Sub-Saharan Africa with a potential expansion of the area to 1.3 million ha (Geleta *et al.,* 1994) and wheat ranks fourth in terms of area and production and second in terms of productivity among food crops (Table 2.1). The area of wheat increased from 769,000 ha in 1995 (CSA, 1998) to 1,025,000 ha in 2000 (CSA, 2000) an impressive increase of 33% whereas grain production showed a modest increase of 18% compared to the expansion of an area devoted to wheat production. This could be attributed to rather stagnant productivity with an average yield of 1.26 t ha^{-1} during the same period, 24% and 48% below

Table 2.1. Area, production and yield of major crops in Ethiopia from 1994/95 to 1999/00 crop season.

	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	Average
Area in ha ('000)							
All crops	6960.2	7948.5	8072.4	6852.7	8016.3	8216.7	7677.8
Cereals	5746.0	6652.6	6688.6	5601.9	6744.7	6747.5	6363.5
Legumes	878.5	904.4	905.4	837.6	875.4	1044.9	907.7
Oil seeds	322.9	377.7	461.2	383.5	374.8	408	388.0
Others	12.8	13.9	17.3	29.7	6.2	16.3	16.0
Wheat	769.3	882.1	772.2	787.7	987.1	1025.3	870.6
% all crops	11.1	11.1	9.6	11.5	12.3	12.5	11.33
% cereals	13.4	13.3	11.5	14.1	14.6	15.2	13.68
Production in tonnes ('000)							
All crops	7044.5	9279.1	9645.2	7359.7	8583.9	8890.9	8467.2
Cereals	6154.2	8269.7	8629.3	6498.8	7683	7741.3	6205.9
Legumes	774.9	814.2	802.6	680.2	931.9	959.5	667.3
Oil seeds	109.1	187.9	203.3	164.5	156.8	179.5	166.8
Others	6.2	7.4	10.0	16.2	12.1	10.8	10.5
Wheat	1023.9	1076.3	1001.6	1106.8	1113.8	1212.6	1089.2
% all crops	14.5	11.6	10.4	15.0	13.0	13.6	13.03
% cereals	16.6	13.0	11.6	17.0	14.5	15.7	14.74
Yield in tonnes ha^{-1}							
All crops	1.01	1.17	1.19	1.07	1.07	1.08	1.10
Cereals	1.07	1.24	1.29	1.16	1.14	1.15	1.18
Legumes	0.88	0.9	0.89	0.81	0.84	0.92	0.87
Oil seeds	0.34	0.5	0.45	0.45	0.45	0.44	0.44
Others	0.48	0.53	0.58	0.55	0.57	0.67	0.56
Wheat	1.33	1.22	1.3	1.41	1.13	1.18	1.26
% all crops	131.7	104.3	109.2	131.8	105.6	109.3	114.5
% cereals	124.3	98.4	100.8	121.6	99.1	102.6	106.8

Source: Central Statistical Authority, Statistical Bulletin Numbers 171, 189, 200 and 227 reporting years 1997, 1998, 1999 and 2000, respectively.

African and world averages, respectively.

Wheat is exclusively grown under rainfed conditions both by small-scale peasant farmers and large-scale state farms. Earlier reports indicated that durum wheat occupies 60% whereas the remaining 40% is occupied by bread wheat (Geberemariam, 1991a). These figures are rapidly changing as local durum wheat landraces are rapidly replaced by more productive, improved bread wheat varieties (Negatu *et al*., 1992). It is still difficult to get precise estimates of bread and durum wheat production as statistical abstracts put the two species together, and farmers largely fail to distinguish the difference between the two species in terms of use (Negatu *et al*., 1992).

2.5. Wheat Consumption Trends

Wheat is a staple crop in the highlands of Ethiopia. In the 1980s, most of the wheat grain produced by small-scale farmers was consumed or retained as seed on the farm and little surplus (19.4%) went to the market (Adissu, 1991). During the same period, 43% of domestic (mostly from state farms) and imported grain market was comprised of wheat grain. Almost 90% of the grain was sold to the Ethiopian Food Corporation and Urban Dwellers Association and 81% was processed to flour. The calorie and protein contribution of wheat relative to other common cereals varied from 11 to 16% for energy and 15 to 20% for protein requirement (Bekele, 1991). A recent statistics shows that wheat consumption in Ethiopia is 34 kg caput^{-1} (Curtis, 2002).

Wheat is used for preparation of traditional foods such as *injera* (pancake like bread), *dabo* (fermented bread), *hambasha/kitta* (non-fermented bread), *nifro* (boiled grain), *kolo* (roasted grain), *dabokolo* (snacks made from bread flour), *kinche* (craked and boiled grain) and *genfo* (porridge). Some of these food items are prepared for daily consumption whereas some are used for specific purposes during special occasions. Moreover, wheat is also used for brewing local drinks such as *tela* (fermented local beer) and *areke* (distilled local spirit).

Wheat straw is primarily used as livestock feed during dry season and stubble grazing in integrated crop-livestock farming systems. It is also used as a fuel at times of scarcity and as a component of plaster for the construction of local houses and grain storage facilities.

2.6. Structure of National Seed Industry

In Ethiopia, the national seed system is composed of formal and informal sectors. In Chapter 1, we have defined the formal and informal sectors and what constitutes each element in the national seed industry. In this section, we look into those components within the Ethiopian context and describe briefly the beginning of formal agricultural research, crop improvement, extension service, seed production and supply in the country.

2.6.1. Formal Seed Sector

In the highlands of Ethiopia, farmers have practised agriculture based on crop production for millennia. Despite the long history of agriculture in the highlands of Ethiopia, modern crop improvement and technology have been introduced very recently. The establishment of Jimma and Ambo Agricultural Technical Schools (1942 and 1947) and Alemaya College of Agriculture and Mechanical Arts (1953), was the beginning of formal agricultural research in Ethiopia (ICARDA *et al*., 1999). Later on the Institute of Agricultural Research (1966), the Chilalo Agricultural Development Unit (1967) and the Wolaita Agricultural Development Unit (1970) became operational.

Agricultural Research The Institute of Agricultural Research (IAR) was formally established as a semi-autonomous public institution with a mandate to conduct and co-ordinate agricultural research at the national level. Agricultural technology generation and transfer originally adopted a departmental approach, but was later reorganized in 1987/88 and included commodity-oriented research and zonal/regional oriented research using both high and low external input technologies (Mekuria, 1995).

In 1997, the agriculture research sector was restructured and renamed the Ethiopian Agricultural Research Organization (EARO) absorbing different research centres and institutions previously affiliated to the Ministry of Agriculture and the institutes of higher education. Agricultural research centres are now based at federal and state levels representing major agro-ecological zones, although arid and semiarid zones are least addressed. EARO has five main departments with major allocation of financial and human resources to crop related research because of the government strategy emphasizing food self-sufficiency. EARO has strong collaborative research with international agricultural research centres (CIAT, CIMMYT, ICARDA, ICRISAT, IITA) for introducing and developing new crop varieties. Apart from EARO, the institutes of higher education such as the Alemaya University, the Debub University and the Mekele University are also involved in agricultural research.

Wheat Research The historical development of bread and durum wheat research was reviewed by Gebremariam (1991b) and Tesemma and Belay (1991), respectively including breeding objectives, progresses and constraints. A concerted effort in wheat improvement started in 1966 with the establishment of the IAR and by 1976 it has been reorganized into bread and durum wheat and coordinated by Holetta and Debre Zeit agricultural research centres, respectively. The wheat breeding strategy is two fold: improving local materials through selection and incorporating specific characters from exotic materials. From the outset, the main objectives of wheat breeding are to develop high-yielding stable varieties with resistance to major diseases and insects and strong straw whereas at times tolerance to abiotic stresses such as drought and waterlogging and grain quality such as virtuousness, grain colour and size are considered (Gebremariam, 1991b; Tesemma and Belay, 1991). In durum wheat, the emphasis shifted towards the use of landraces in breeding programmes and focused on specific rather than wide adaptation.

The wheat variety development and release procedures pass through several stages, a minimum of six to seven years from initial identification of promising lines to eventual release of the variety for seed multiplication (Tesemma and Belay 1991; Gebremariam, 1991b).

Agricultural Extension Haile *et al.* (1991) reviewed the historical development of agricultural technology transfer in Ethiopia since its early inception in 1908. Formal extension was started in 1953 with the establishment of the Alemaya College of Agriculture and Mechanical Arts combining research, training and extension. In 1963, the agricultural extension was formally transferred to the Ministry of Agriculture (MoA) and went through different phases of reorganizations: comprehensive integrated package projects (1967, CADU; 1970, WADU), Minimum Package Program I (1975, EPID), Minimum Package Program II (1980); Training and Visit (1986, World Bank) and modified Training and Visit (1988, PADEP). At present, the agricultural package programme through the Extension Management Training Plots aims at demonstrating and popularizing modern crop varieties with associated technologies. The District (*Woreda*) Agricultural Development Department has a mandate to disseminate the package programme and introduces new varieties and agronomic practices through development agents who have direct contacts with farmers and peasant associations (Gebeyehu *et al.*, 2002).

In 1974, the IAR/EPID joint research and extension programme was established with a focus on adaptive research to develop technology recommendations for different agro-ecological zones. In 1985, Research and Extension Linkage Committees (RELCs) were established at national and regional levels. RELCs were responsible for providing overall guidelines for reviewing/prioritizing problems to be addressed by researchers, reviewing/approving research findings and recommendations, and monitoring the operation of research-extension linkages. The responsibilities included verification, demonstration, popularization and training of new technologies.

Despite several efforts in reorganizing the extension service, there has been a weak linkage between extension and agricultural research. Lack of appropriate education including in-service training, lack of proper information and communication between research and extension, lack of participation in IAR’s on-farm research and inadequate infrastructure were some of the drawbacks of the extension service in Ethiopia (Stroud and Mekuria, 1992; Mekuria, 1995).

Wheat Technology Transfer Since 1958, the Ministry of Agriculture, Alemaya University of Agriculture and IAR conducted several demonstrations through which many wheat technologies have been transferred to farmers including modern varieties. The demonstrations have shown that, under normal environmental conditions, modern bread and durum wheat varieties with an improved package of cultural practices can yield up to 2.5 and 1.8 t ha^{-1}, respectively. The demonstrations (0.25 ha each) consisted of improved recommended package (variety, seed rate, fertilizer rate/type and weeding) versus farmer's method comprised of the traditional wheat production practices at each site.

Agricultural Input Supply The Ministry of Agriculture was not only responsible for conducting adaptive research and transfer of technology, but also played a key role in provision of inputs, particularly fertilizers and pesticides. The Agricultural Input Supply Enterprise (former AISCO, now AISE) has the primary responsibility of input supply (fertilizers, pesticides, seeds and credit) for the peasant sector. AISE operates under the Ministry of Agriculture and collates demands, arranges the importation and distribution of inputs with strong emphasis on fertilizers and pesticides. AISCO managed over 600 distribution centres throughout the country although little has been achieved in certified seed marketing and distribution.

National Seed Policy In 1993, a national seed industry policy and strategy was formulated and the National Seed Industry Council (NSIC) was established under Proclamation No 56/1993 (amended by Proclamation No 122/98) as an advisory body to the Government. The key policy objectives were to build a sustainable national seed industry by establishing efficient and effective seed production and supply systems through the participation of public and private sectors, improved institutional linkages and appropriate regulatory oversight.

In 1993, the National Seed Industry Agency (NSIA) was established as an executing arm of the Council and served as a focal point for policy and regulatory functions of the seed sector. Moreover, the agency played a pivotal role in developing protocols for variety release and registration and seed quality control and certification. Since 2002 NSIA was reorganized into a National Agricultural Inputs Authority entrusted with the responsibility to implement and control the enforcement laws for production and trade of agricultural inputs such as seeds, fertilizers and agricultural pesticides. However, such policy reforms did not bring tangible changes where a single public seed enterprise continues to dominate the national seed sector.

Seed Laws and Regulations A Ministerial Regulation Number16/1997 was enacted to cover registration of new crop varieties; seed producers, processors and distributors; seed quality control; and seed trade. The Seed Proclamation No. 206/2000 is comprehensive and provides a strong legal framework for the quality assurance and protection of the interests of all stakeholders. Moreover, field and seed standards prepared for 74 crops were officially issued for implementation. NSIA (now NAIA) is building the necessary technical and institutional capacity to implement and enforce the standards.

Variety Development Systematic crop improvement and variety development for major crops began in 1966 with the establishment of IAR (now EARO), a semi-autonomous public organization. It is a principal plant breeding institution, undertaking responsibilities for cereals, legumes, oilseeds, fibres, horticultural and forage crops. Prior to 1997, bread and durum wheat improvement were under the jurisdiction of IAR and Alemaya University of Agriculture, respectively. At present, Debre Zeit and Kulumsa Agricultural Research Centres, the principal research centres located in major wheat production regions of the country coordinate bread and durum wheat improvement, respectively.

Variety Release The variety release system evolved over a long period since the establishment of the National Crop Improvement Conference in 1967. From 1984, variety release became the responsibility of the National Variety Release Committee (NVRC). In 1992, the NVRC was legally affiliated to the National Seed Industry Agency. The NVRC proposed a reform of its current structure and functions and elaborated procedures for variety release and registration not only of agricultural crops, but also of horticultural, fruit and tree crops.

Plant breeders carry out a minimum of two to three years regional or national trials in at least three to five different agro-ecological zones before submitting an application to NVRC for variety release. The variety should be tested for yield and important agronomic characters compared with standard varieties or local checks. A complete data set of the promising variety proposed for release must be submitted to NVRC for review and approval to enter verification trials. The varieties will be evaluated for one more season under farmers' management practices along with established local or modern cultivar(s) in relatively large plots (100 m^2 at two to three sites), the so-called on-station and on-farm verification trials.

A sub-committee composed of NVRC members and other specialists examines the submitted data and makes field visits to assess the performance. Based on these evaluations it prepares the recommendations for the NVRC. The NVRC may release a variety not only on superior yield, but also on the basis of other important characters such as grain colour, early maturity, etc., compared to existing standard commercial varieties or local checks. Apart from agronomic performance acceptable level of distinctness, uniformity and stability are required to grant a release. Upon the release of the variety breeders will provide a small quantity of seed to the Institute of Biodiversity Conservation and Research for long-term storage and to the Ethiopian Seed Enterprise to initiate seed multiplication. The national wheat programme is expected to maintain an appropriate quantity of breeder seed for replenishing commercial seed of the variety.

The Seed Quality Control and Certification Department of NAIA serves as a Secretariat of the NVRC and maintains the crop variety register. Although it has established a legal framework of its operation, the committee lacks the expertise, resources and facilities to implement an impartial and independent variety release system.

Seed Production In 1956, the Debre Zeit Agricultural Research Center initiated the earliest seed multiplication scheme where 350 tonnes of wheat seed was distributed to farmers in Ada (Shoa) and other wheat growing regions of the country through the Ministry of Agriculture (Haile *et al*., 1991). Initially the Extension and Project Implementation Department (MoA) in collaboration with CADU (Chilalo Agricultural Development Unit) also produced wheat seed at Asasa and Kulumsa in Arsi region and distributed it to other areas. Prior to the 1970s the formal seed sector was very much *ad hoc* and uncoordinated.

In 1976, the National Seed Council (NSC) was set up to formulate recommendations for organized seed production and supply of modern varieties released from the national programmes. The Ethiopian Seed Enterprise (ESE) was established in 1979 formalizing seed production, processing, distribution and quality control of major food crops. ESE's direct sale of seed to farmers has been insignificant throughout its existence as there were no formally established linkages. In 1990, the Ethiopian Pioneer Hi-bred Seed Inc. was established dealing with hybrid seed maize and it is still the only private sector company operating in the country.

EARO and agricultural universities are responsible for maintenance of released varieties and production of early generation materials, breeder seed and provide ESE with pre-basic seed. They also produce basic seed on contracts for ESE. ESE operates seed farms for multiplication of pre-basic and basic seed and produces certified seed on contract with large-scale state and private farms and small-scale farmers. In addition, seed was produced and distributed through special on-farm based seed production and marketing projects launched in 1997 through the financial assistance of IFAD and SIDA. The former was implemented at the national level whereas the latter was at the regional level.

Wheat and maize seeds dominate the formal sector comprising 70 and 22%, respectively of seed distributed (Table 2.2). Further analysis reveals that few modern varieties such as Enkoy in the 1980s and K6295, Pavon and ET 13 in the early 1990s dominated the production accounting for up to 70% of commercial wheat seed distribution. From 1996 to 1999, the formal sector commercial seed distribution was 60.8% (wheat), 82.4% (maize), 16.2% (*tef*) and 1.9% (barley) certified seed request from the main distributors and users such as the Ministry of Agriculture, NGOs and state farms. At a national level the formal sector covers a very small amount of seed supply (4.49% for all crops) compared to the total national seed requirement. For major cereal crops, the commercial seed supply from 1994/95 to 1998/99 covered 0.43, 1.29, 7.00, 12.09 and 1.72% for *tef*, barley, wheat, maize and sorghum, respectively, a very tiny segment of the seed industry.

2.6.2. Informal Seed Sector

In the highlands of Ethiopia, farmers have practised agriculture based on crop production for millennia. Subsistence agriculture predominates throughout the country and little has changed in terms of farming practices and farm implements, although some efforts are underway to modernize it. Farmers are accustomed to selecting and

Table 2.2. Amount of seed distributed (tonnes) by Ethiopian Seed Enterprise from 1994 to 1999 crop season.

Crop	1994	1995	1996	1997	1998	1999	Average	%
Wheat	12062	10135	9375	8283	11084	8445	9897	69.67
Barley	169	153	273	371	139	67	195	1.37
Tef	2424	434	357	280	52	244	632	4.45
Maize	3610	2632	1889	1668	4253	4550	3100	21.83
Sorghum	294	588	163	7	20	-	179	1.26
Haricot	151	52	113	38	9	3	61	0.43
Chickpea	417	120	-	-	-	0	90	0.63
Soya bean		14	-	-	-	0	2	0.02
Lentil	78	-	-	1	-	-	13	0.09
Field pea	112	-	-	1	2	34	25	0.17
Faba bean	-	-	-	23	6	-	5	0.03
Oilseeds[1]	3	4	3	7	9	6	5	0.04
Total	19320	14131	12174	10680	15575	13349	14205	100

Source: ESE; [1] Oilseed crops include *noug*, linseed and rapeseed.

saving seed of their local landraces using indigenous knowledge and traditional practices. This practice still provides the bulk of seed required, up to over 90 to 100% for some crops. In 1997, a national farmer-based seed production and marketing project was launched by NSIA in collaboration with Regional Agricultural Bureaus through financial assistance from IFAD. Likewise, a regional *woreda* (district)-based seed multiplication and supply project was also started at the same time through the assistance of the Swedish International Development Agency in northern Ethiopia. The main objectives of both projects were to strengthen the informal sector whereby farmers produce seed for local markets and eventually develop into self-sustainable rural small seed enterprises.

In the Ethiopian context, the informal sector comprises millions of individual small-scale farmers, medium-scale estate farmers, small to medium-scale local grain traders, development-oriented and/or relief operating NGOs, community seed banks and other local level seed production and distribution. Although over 120 NGOs are operating in the country, their activities are uncoordinated and little is documented about their seed operations. In general there is little information on the role of informal sector in the national seed industry.

2.7. Objectives of the Study

Wheat is a principal staple crop in the highlands of Ethiopia. The crop has been designated as one of the high priority commodity crops and substantial resources have been allocated to improve the crop through research. Variety development and seed production programmes are strong in the country. Since the 1950s several modern bread and durum wheat varieties have been released along with recommended production packages (Geberemariam, 1991b; Tesemma and Belay, 1991). The main wheat breeding objectives are to develop new varieties performing better than varieties currently grown by farmers, assuming that farmers desire varieties which are high yielding and tolerant to environmental stresses. Although the diffusion of modern wheat varieties is believed to be higher than that of other cereal crops, there is still concern that the substantial gap between yields on research stations and on farmers' fields will persist (Geleta *et al.*, 1994; Mekuria, 1995). Several technical and socio-economic constraints for wheat production have been identified. Important ones are lack of seed of modern varieties, lack of credit and low producer prices (Beyene *et al.*, 1991).

There is little study on the adoption of technology prior to the 1990s (Haile *et al.*, 1991). Most farm-level studies are purely technical and there is little information available on farmers' perception of new varieties and associated technologies (Negatu *et al.*, 1992; Negatu and Parikh, 1999). Moreover, information on farmers' seed acquisition and management and informal exchange mechanisms are not explored properly. The main general objectives of the current study are:

- to investigate the extent of adoption and diffusion of modern wheat varieties released by the national agricultural research systems,
- to review farmers' knowledge and perception of released modern varieties, and
- to understand farmers wheat seed sources and management practices.

Therefore, the main specific goals of the current research were:

- to study wheat seed systems in Ethiopia to understand the functioning of the national seed sector with particular reference to informal sector,
- to study and characterize farmers' perception and adoption of modern varieties and associated technologies and criteria for adoption of new varieties to assist breeders to focus on farmers' preferences,
- to study and document farmers' indigenous knowledge of on-farm plant and seed selection, farmer's seed sources and seed management practices as a means to strengthen and develop responsive seed delivery systems.

2.8. Methodology and Data Collection

A questionnaire was designed to gather information on:

- farmers' knowledge and source of information of new agricultural technologies,
- farmers' perception and adoption of varieties and diffusion of modern varieties,
- farmers' seed source, seed selection and seed management practices, and
- technical (varietal acceptability, seed quality) and socio-economic factors limiting adoption.

2.8.1. Study Areas

The Amhara and Oromoia Regional States were selected purposively based on the informal assessment and secondary data available from the Central Statistic Authority. The two regional states together accounted for over 83% of the wheat area and production in the country (CSA, 1997). The Arsi and West Shoa zones from Oromia Regional State and North Shewa and East Gojam zones from Amhara Regional State were selected for the survey (Fig. 2.1). These zones are representing the major wheat growing zones and also provide contrasting situations in terms of agro-ecological diversity (climate, wheat types), exposure to and use of modern agricultural technology, and institutional factors such as proximity to research centres and agricultural input providers (ESE) and output markets.

The Arsi zone represents the major wheat growing areas in the southeastern part of the country and is located where the first comprehensive package programme was

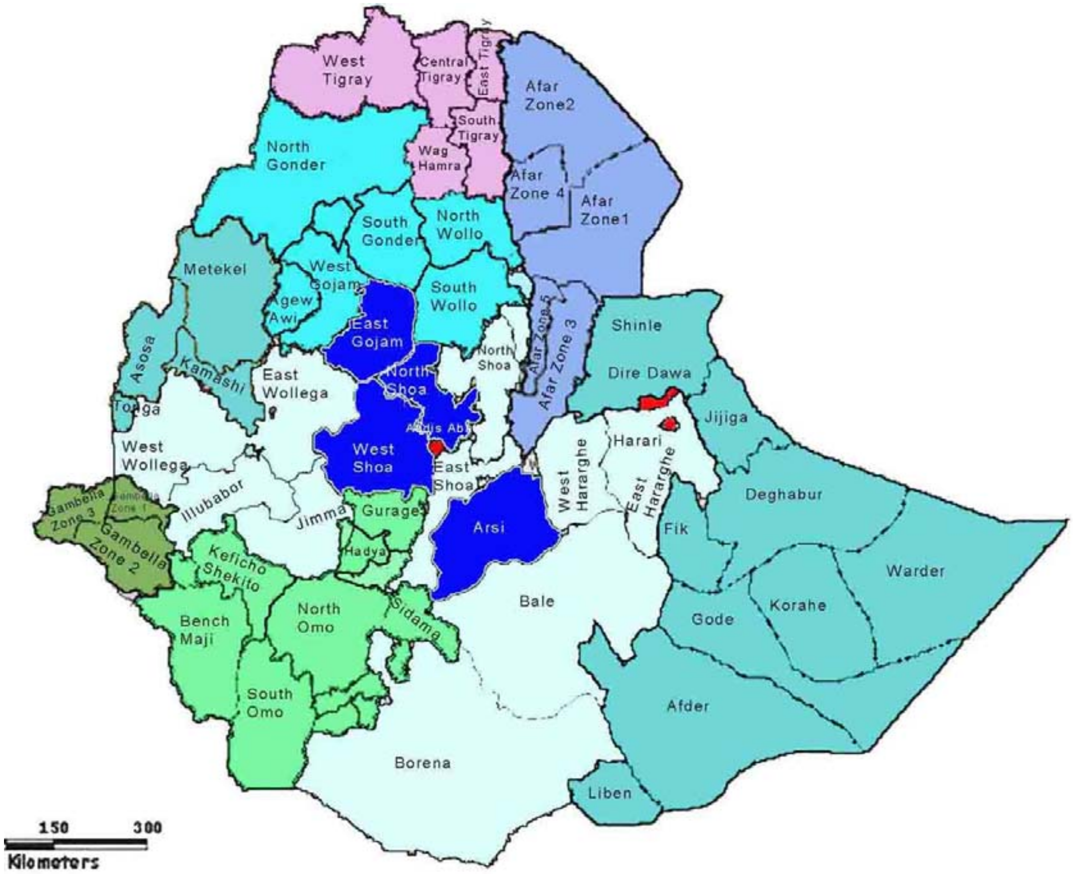

Fig. 2.1. Wheat seed system study areas (in black) in Amhara and Oromoia administrative regions of Ethiopia.

initiated in 1967 and the main bread wheat research station is located. Since the 1970s large state farms are involved in commercial wheat production. It is also the major wheat seed production area where the regional office and basic seed farm of the Ethiopian Seed Enterprise are located. Therefore, farmers are expected to be aware of and have better access to wheat varieties and associated technology.

The West Shoa zone represents one of the most important wheat growing areas in the central highlands. The Holleta Agricultural Research Center is located in this area and has been involved in wheat research and demonstrating the technology to farmers for a long time. However, there is no formal seed sector operation and commercial seed has to be transported over long distances and the availability could be a major constraint.

The North Shoa and East Gojam zones represent the major wheat production areas of the country in the central and northwestern parts of the country, respectively. Moreover, both regions are far from the main agricultural research stations, large-scale state farms or major operation centres of the Ethiopian Seed Enterprise. These areas are expected to be relatively new to the introduction of modern agricultural technologies including wheat varieties. Commercial seed has to be transported over long distances and the availability could be a major constraint.

2.8.2. Sampling Procedures

A multi-stage purposive random sampling procedure was followed from higher to lower administrative levels, with farmers being sampling units. A five-stage sampling procedure has been adopted involving the selection of administrative regions, zones, districts, villages and wheat farmers.

First stage: Two major wheat growing regions were purposively selected from all wheat growing regions in the country, with each region's probability of selection made proportional to the area cropped to wheat in the region.

Second stage: Four major wheat growing zones were randomly selected from all wheat growing zones in the two regions selected, with each zone's probability of selection made proportional to the area cropped to wheat in the zones. This self-weighing sampling procedure resulted in the selection of two zones each located in the two regions selected.

Third stage: Within each of the four selected zones, at least two adjacent major wheat producing districts were selected at random from among all districts considered as main wheat production districts based on the proportional area planted to wheat in the districts.

Fourth Stage: Within each of the selected districts, two enumeration areas were randomly selected once again in proportion to the area of wheat grown in the enumeration areas.

Fifth Stage: Within the enumeration areas, villages and wheat growing farmers were randomly selected based on the list of farmers from peasant associations. In each village a minimum of two farmers were selected and interviewed.

2.8.3. Data Collection

A team of four enumerators and two supervisors conducted the survey including the author. A two-day training course was organized for the enumerators and the supervisors, which included discussion of the survey objectives, a detailed question-by-question review of the survey tool, instructional sessions on interviewing techniques and practice interviews with farmers. After the training, the questionnaire was pre-tested during the first day of the survey and further discussed with the enumerators. At the end of each day all questionnaires were checked with the enumerators and clarifications were made.

During the survey the enumerators were organized into two teams; each team consisting of one supervisor and two enumerators. The survey was carried out during June and July of the 1997/98 main crop season, which coincides with the main wheat planting time in the country. A total of 304 farmers were surveyed distributed over four administrative zones, nine districts and 81 villages located in different regions of the country. About 141 farmers from Arsi (46%), 69 farmers from West Shoa (23%), 38 from North Shoa (13%) and 69 from East Gojam (18%) were interviewed based on the proportion of wheat area in respective selected zones. Each farmer was interviewed using a structured and open-ended questionnaire. Moreover, a sample of 1000 g seed was drawn from the farmers' seed intended for planting for seed quality analysis (Chapters 4 and 5) and to study the diversity of wheat varieties (Chapter 6).

2.9. Results and Discussion

2.9.1. Demographic and Socio-Economic Factors

The descriptive analysis of the demographic socio-economic factors revealed interesting results. The average age of household head was 41.4 years (SD=14.6; n=304) with a range from 18 to over 70 years. More than half of the farmers were below the average age indicating the involvement of younger generation in farming. A mere 7% were over 65 years of age and seldom assisted by children. About 93% of the farmers were married with an average number of children of 5.2 and a female to male ratio of almost 1:1. Children were contributing to farm labour significantly and considered insurance for the welfare of the family at old age. Farmers who were illiterate constituted 49%; and 36% of the farmers could read and write. Farmers with formal education (elementary to high school) constituted 15%, a proportion that may continue to rise, as the rural population with access to formal education would probably stay on farm because of limited opportunities in urban employment. Ensermu *et al*. (1998) also reported that about 20% of the sample farmers in Chilalo *awraja* had some formal education. The increase in education level can play a positive role through well-targeted extension programmes supporting adoption of new agricultural technology generated by research. Ferede *et al*. (2000) reported that farmer education level influences adoption of new agricultural technologies. These demographic and socio-economic indicators are in agreement with most diagnostic or technology adoption studies conducted in recent years in various parts of the country (Gemeda *et al*., 2001; Ensermu *et al*., 1998; Beyene *et al*., 1998; Hailye *et al*., 1998; Tiruneh *et al*., 1999; Ferede *et al*., 2000).

Agriculture was the main source of income for all farmers and there were limited opportunities for off-farm income generation as the farm sites investigated were far away from urban centres and large-scale state farms, except in the Arsi zone where farmers had limited opportunities as casual labourers during planting, weeding and harvesting time. In Ethiopia, off-farm work and income generations by head of the household are low compared to other African countries (Stroud and Mekuria, 1992).

About 93% of farmers had holding rights over the land they cultivated whereas the rest were landless and worked with their parents as partners providing labour. In the Land Reform Declaration of 1975, all land became public property and farmers had no legal ownership, but holding rights that could be transferred to children or temporarily rented for contract farming. For example about 45% of the farmers had previous experience having hired additional land from other farmers for wheat production. Land redistribution is occasionally carried out by the state where farmers with relatively larger areas relinquished their rights for the younger generations who enter farming. This practice not only led to land fragmentation, but also to transfer of rights outside kinship which was disincentive for any long-term development and investment in natural resource management and conservation.

Wheat production was practically subsistence; and the majority of farmers neither hired tractors (77%) for land preparation/planting nor combines (67%) for harvesting. However, in the Arsi Zone 21.7 or 31.6% of the farmers hired tractors or combine harvesters, respectively. Hassena *et al.* (2000) reported that the contribution of tractor for land preparation is minimal even among farmers in the Arsi region. Moreover, proximity to a hiring station, topography (accessibility), education level, and wheat area significantly affected farmers' decisions to adopt combine harvesting with negative consequence of increasing income gaps between farmers living in accessible and less accessible areas (Hassena *et al.*, 2000). An exceptionally low number of farmers owned tractors (1%) or combine harvesters (1%), indicating the low level of mechanization of agriculture in general and wheat production technology in particular. Individual farmers lacked cash outlay and property to invest in large-scale agricultural machinery for crop production.

2.9.2. Gender Differentiation in Wheat Production

Wheat production includes sequential operations such as land preparation, planting, weeding, harvesting, transporting, threshing, winnowing, grain storage and marketing. The family was the major source of farm labour (mostly from members between 15 to 65 years of age) and there appeared to be labour differentials by age and sex. Farming was considered predominantly the occupation of men, but in a predominantly rural economy that tells only part of the full story. The role of both men and women in wheat production is high. During the survey it was found that the relative participation of women in land preparation was minimal (0.7%) whereas their involvement in weeding was as high as 85.5%. Women contributed labour in decreasing order to weeding (85.5%), threshing (48.7%), harvesting (29.3%), planting (28.6%), and land preparation (0.7%). Likewise, children between 8 and 14 years old usually provided labour for the family in land preparation (45.7%), planting (36.8%), weeding (63.2%), harvesting (45.4%) or threshing (50.7%). In many African countries, studies have confirmed that the contribution of female labour in traditional agriculture is significant (>50%). In Ethiopia, earlier studies also showed that generally men are responsible for farming whereas women and children contribute to weeding, harvesting, threshing and transporting grain (Asamenew *et al.,* 1993). Although men have an overall responsibility and contribute to all farm operations and decision-making women can usually give their opinion (Stroud and Mekuria, 1992). Tiruneh *et al.* (1999) found that the decision to grow improved wheat varieties is a joint decision by over half of male-headed households in central Ethiopia.

Apart from family members, farmers also hired additional labour for wheat production, particularly for harvesting and weeding. Moreover, the traditional informal community labour exchange still existed in the form of *wonfel* and *debo* where individual or group arrangements are made to work together particularly at planting, weeding or harvesting time. *Wonfel* is in kind labour exchange as part of one's obligation and usually arranged between two individuals. The *debo* is organized on a group basis particularly during peak planting or harvesting time and a voluntary labour contribution from individuals to the host who organized the event. The *debo* can also function as part of a social gathering where informal exchange of information takes place. Zegeye *et al*. (2001) also reported *debo* and *wonfel* as two most important community labour arrangements contributing 24 and 14 work-days among adopters and non-adopters of modern wheat varieties, respectively.

2.9.3. Cropping Pattern and Land Allocation

Farmers (n=304) in the survey area grew different crops up to a maximum of six field crops such as cereals, legumes, oilseeds and forage oats (Table 2.3), excluding vegetables grown by some around homesteads. There is variation in diversity of crops grown in different regions. In addition to wheat, the two major cereal crops, barley and *tef* (*Eragrostis tef*), were grown by 66.8 and 66.4% of the farmers in the survey areas, respectively. Maize was grown by 20.4% of the farmers, mostly in the Arsi zone (Hetosa and Dodota), and in the West Shoa and East Gojam zones. Smaller proportion of the farmers grew legumes (less than 20%). Faba bean was planted by 16.1% and predominated in the Arsi Zone, whereas chickpea, lentil and grass pea were mostly grown in the West Shoa, North Shoa and East Gojam zones. Among oil crops, flax was most common in the Arsi zone and *noug* (*Guzotia abysinica*) in the West Shoa and East Gojam zones.

About 280 farmers (92.1%) grew bread wheat varieties compared to 51 (16.8%) for durum wheat (Table 2.3). Most strikingly, the majority of the farmers grew either bread (83.2%) or durum wheat (7.9%) which together constituted 91.1% compared to a mere 8.9% who grew both crops. From the 27 farmers who grew both wheat species, 22 were from the North Shoa region. Durum wheat was grown mostly in the West and North Shoa regions and no farmer was encountered growing durum wheat in the Arsi region.

The mean crop/farm area was 2.78 ha (Table 2.3). Almost 40% of farmers had a total crop area of less than 2 ha; and two-thirds of the farmers (64%) had land below the average (data not shown). The mean area allocated for crop production varied from the lowest value of 0.31 ha for lentil and maize (SD=0.11) to the highest value of 1.21 ha (SD=1.06) allocated for bread wheat followed by 0.89 ha for *tef* (SD=0.68 ha).

The number of crops grown indicated the level of species diversity on the farm where small-scale farmers were producing 'multiple' crops to minimize risk and maintain household food security (Fig. 2.2). The majority of farmers grew two (24%), three (27%) or four (28%) crops which together constituted 79% whereas those who grew one crop only (wheat) accounted for less than 4%. There was a tendency for farmers in the Arsi zone to specialize on a few crops compared to those in other regions who grew relatively more crops. The allocation of resources and management of different crop enterprises by farmers in situations of imperfect market information (varieties, seed availability, etc.) seems remarkable. However, small-scale farmers by producing many different crops face severe resource and labour constraints to apply optimum management practice for maximum return from a single crop enterprise (Mekuria *et al*., 1992). For example, *tef* production directly competes for resources and labour with wheat (Tessema *et al*., 1999) and farmers face serious constraints to carry out timely farm operations such as planting, weeding, etc, which substantially reduces the benefits of any improved packages adopted. Moreover, they give priority to *tef* instead of wheat for input allocation such as fertilizers, herbicides and hand weeding.

2.9.4. Wheat Production Technology Packages

The generation and transfer of new technology are prerequisites for agricultural development particularly for an agrarian based economy such as Ethiopia. There are many factors that influence the technology development including the perception of the scientist, appropriateness to the farming conditions, economic benefits to the farmers and then the means for transferring the technology itself. The need for agricultural technology promotion has been long recognized and formal extension was started in the 1950s (Haile *et al*., 1991). Apart from technical constraints, the role of the extension agent in grain quota system (1980 to 1990) and the villagization

Table 2.3. Major food crops grown and land allocation by sample farmers (n=304) in Ethiopia.

	Number of farmers growing						Land allocation	
Crops	Arsi	W. Shoa	N. Shoa	E. Gojam	Total	%	Area (ha)	SD
Bread wheat	141	54	31	54	280	92	1.21	1.06
Durum wheat	-	17	29	5	51	17	0.59	0.36
Barley	119	34	3	47	203	67	0.69	0.58
Tef	51	61	36	54	202	66	0.89	0.68
Forage oats	-[1]	-	1	1	2	1	0.50	0.00
Maize	23	4	-	35	62	20	0.31	0.11
Sorghum	2	3	-	10	15	5	0.34	0.19
Faba bean	19	16	13	1	49	16	0.37	0.26
Field pea	14	3	2	-	19	6	0.48	0.25
Chickpea	-	6	16	1	23	8	0.38	0.20
Lentil	1	2	10	-	13	4	0.31	0.11
Lathyrus	-	6	25	10	41	14	0.41	0.26
Linseed	11	12	1	4	28	9	0.58	0.36
Noug	-	15	1	18	34	11	0.61	0.46
Total	141	69	38	56	304	100	2.78	1.83

[1] - indicates farmers not growing the crop.

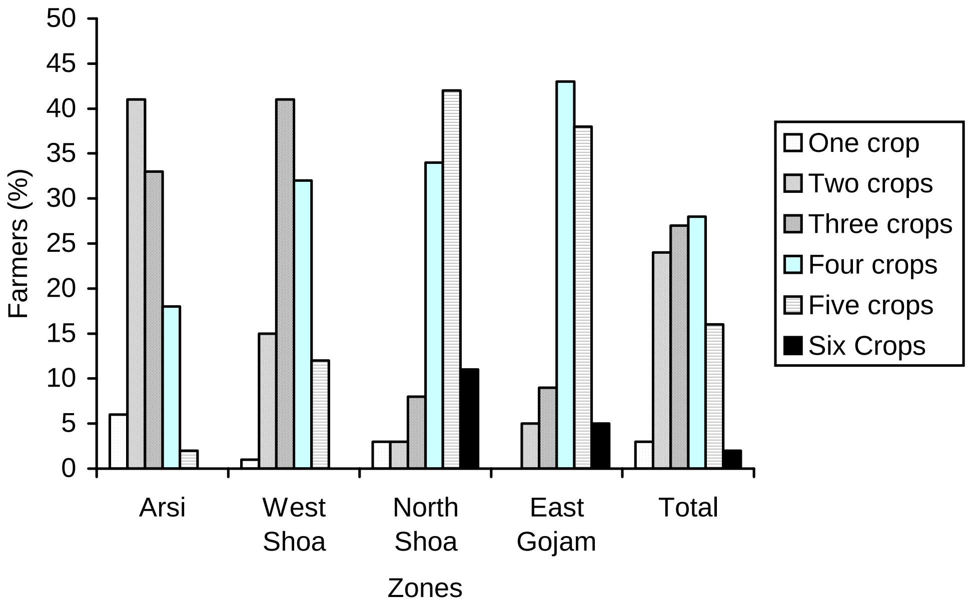

Fig. 2.2. On-farm diversity of crops grown by surveyed farmers in Ethiopia (n=304).

programme (1986) make them unpopular with the farmers (Mekuria, 1995). The agricultural package programme has restored farmers' confidence in the extension agents, but there are still some underlying fundamental problems.

Sources of Information Most wheat growers were aware of and had information on modern wheat varieties, agrochemical inputs and agronomic packages. Over 90% of farmers have knowledge of these agricultural technologies (Table 2.4). In comparison, the awareness on pesticides and grain storage practices was relatively low and only 43.8% and 65.8% of farmers had information, respectively. The formal agricultural extension service was the main source of information for new technologies generated by research such as modern varieties, wheat agronomy, fertilizers and herbicides. Zegeye *et al.* (2001) also reported that 98% of the farmers in the study areas knew about improved wheat varieties and the agricultural extension as the major source of information followed by neighbours in northwestern Ethiopia. Similar results were reported for maize varieties in Ethiopia (Gemeda *et al.*, 2001) and other agricultural packages (Gebeyehu *et al*., 2002). The majority of farmers grew modern varieties from the recommended list (86.2%), applied fertilizers (96.7) and herbicides (63.5%) to their wheat crop. Similarly, extensive diffusion and widespread use of improved wheat production packages was reported in central Ethiopia (Ferede *et al*., 2000; Yirga *et al*., 1996; Beyene and Yirga, 1992b).

However, the data also show that farmers used multiple sources of information. Neighbours and other farmers appeared to be the second most important informal source of information particularly for modern varieties and grain storage. The lateral farmer-to-farmer diffusion of varieties may play a significant role in this exchange of knowledge and information. Ensermu *et al*. (1998) also reported farmers as major source of information followed by the extension service for wheat varieties in southeastern Ethiopia. The informal sources such as relatives and neighbours were more important for grain storage where limited information was available from formal sources. Pesticide use for field insect pests was insignificant although aphids pose a major threat in certain years. Kotu *et al*. (2000) found that only 9% of the farmers try to control plant diseases and insect pests mainly due to lack of knowledge of appropriate control measures and unavailability of pesticides. The agricultural package programme recently in operation has played a very commendable positive role in promoting the new wheat production technologies. Similar observations were also made for northwestern Ethiopia (Zegeye *et al*., 2001).

Agronomic Practices The agronomic practices for wheat production such as sowing date, planting method, seed rate and fertilizer application are given in Table 2.5.

Table 2.4. Farmers' source of information and awareness of wheat production technology packages (n=304).

	Modern variety	Agro-nomy	Ferti-lizers	Herbi-cides	Pesti-cides	Grain storage
Have information						
Farmers	301	287	301	278	133	200
%[1]	99	94	99	91	44	66
Source of information			%			
Media (TV & Radio)	1	0	1	1	0	0
Research	3	3	2	2	1	1
Extension	74	68	83	71	37	21
Relatives	3	4	3	2	2	26
Neighbours	39	6	6	8	3	4
Other farmers	34	6	6	5	2	4
Traders	0	0	0	0	0	1
Others (SF, Global 2000)	3	8	3	2	1	11

[1] Figures will not add up to 100% because of multiple sources of information.

Traditional land preparation method was used in all zones where the soil was worked by four to five passes each perpendicular to the first with a local plough called *maresha* drawn by a pair of oxen. Despite relatively wide spread uses of tractors for land preparation in the Arsi region (21.7%) almost all sowing was carried out by hand broadcast.

Farmers generally plant their crop following the first showers to make use of soil moisture. Planting date has a significant influence on biomass, grain yield and yield components and is affected by the variety and the environment. Survey data showed that wheat planting started with the onset of rains from early June to end of August and was equally distributed over the specified period of time (Table 2.5). Farmers in Arsi and East Gojam tended to plant earlier than farmers in central highlands in West and North Shoa who planted wheat later in the season particularly where waterlogging is a major constraint. It was also reported earlier that the time of sowing wheat ranges across the regions from mid June to August depending on soil type, rainfall and the varieties and late sowing would reduce grain yields by up to 34% (Beyene *et al.*, 1991). Tarekegne (1996b) suggested early planting (third week of June) in south-eastern and late (mid July) in the central highlands which coincides with farmers wheat planting practices. Geleto *et al.* (1990) found that the optimum sowing dates in

Table 2.5. Agronomic practices used for wheat production by sample farmers (n=304) in Ethiopia.

	Arsi		West Shoa		North Shoa		East Gojam		Total	
Agronomic practices	Farmers	%	Farmers	%	Farmers	%	Farmers	%	Farmers	%
Planting date										
Early June to first week of July	58	41	9	13	4	11	31	55	102	34
Second week of July to August	77	55	22	32	10	26	24	44	133	44
Beginning of August	6	4	38	55	24	63	1	2	69	23
Total	141	100	69	100	38	100	56	101	304	101
Seed rate in kg ha^{-1}										
Less or equal 100	1	1	28	41	15	40	15	27	59	20
101 - 150	50	36	34	49	23	61	29	52	136	45
151 - 200	83	59	7	10	-	0.0	12	21	102	34
201 - 300	6	4		0	-	0.0	-	0	6	2
Total	140	100	69	100	38	101	56	100	303	101
Fertilizer use										
No	0	0	8	12	2	6	0	0	10	3
Yes	141	100	61	88	36	94	56	100	294	97
Total	141	100	69	100	38	100	56	100	304	100
Herbicide use										
No	24	17	13	19	35	92	39	70	111	37
Yes	117	83	56	81	3	8	17	30	193	64
Total	141	100	69	100	38	100	56	100	304	101

northwestern Ethiopia ranged between May 31 and June 15 for two modern varieties. Given varietal responses to planting dates and seed rates, it would be rather difficult to ascertain whether farmers observe the actual optimum planting dates. It is important that farmers are aware of varietal differences and apply the appropriate recommendations to maximize production.

Usually, wheat is broadcasted by hand and covered by oxen ploughing at a variable depth of 5-15 cm to facilitate crop establishment. The recommended seed rate is 150 kg ha^{-1} for hand broadcasting (125 kg ha^{-1} for drilling) both for bread and durum wheat (IAR, 1990). There are also location and varietal specific recommendations but these are not widely popularized or used by farmers. The mean seed rate according to the survey data was 154.7 kg ha^{-1} (SD=43.4; n=302), and 39.1% of the farmers used the recommended rate (data not shown). There was an interesting variation among regions in seed rate: almost all farmers who planted less than the recommended rate (25.2%) were from West Shoa, North Shoa and East Gojam, whereas almost all farmers who used more than the recommended rates (35.8%) were from the Arsi zones (data not shown). Such regional variation in seed rate has also been observed for barley (Woldeselassie, 1999) and for faba bean (Bishaw *et al.,* 1994).

Lower seed rates than the normal recommended packages were also reported for the central highlands (Beyene and Yirga, 1992a) and this could be attributed to the land preparation methods that require less seed. Some attribute low seed rate use to limited fertilizer application and less problems with weeds. Increased seed rate is used as a weed control strategy or may be associated with the farmers' lack of prior knowledge on germination potential of seed planted. Moreover, poor emergence due to short coleoptiles or poor tillering capacity of modern varieties and traditional hand broadcasting which requires more seed rate (20-30%) than drilling may contribute to high seed rates (Tanner *et al*., 1991). Although farmers claim that certified seed is expensive some of them plant as much as 1.3-1.6 times the recommended rate of uncertified seed, a quantity which is almost equivalent to the price of the normal amount of certified seed.

Perception of Soil Fertility Farmers' perception of soil fertility (Table 2.6) did not vary significantly among different zones. About 57% of the farmers considered their land suitable for wheat production and fertile in terms of productivity, whereas 39% considered it of intermediate fertility. The remaining 5% of farmers considered their land of low soil fertility. In general, wheat is produced in relatively favourable environments in the highlands with adequate rainfall for the whole growing period. Moreover, bread wheat is grown on well-drained soils compared to durum wheat which is planted predominantly on poorly drained soils (Tarkegene *et al.,* 1999).

Table 2.6. Farmers' perception of soil fertility in different wheat production regions in Ethiopia.

Soil fertility	Arsi		West Shoa		North Shoa		East Gojam		Total	
status	Farmers	%	Farmers	%	Farmers	%	Farmers	%	Farmers	%
Good	84	60	51	74	18	47	19	34	172	57
Medium	50	36	16	23	19	50	32	57	117	39
Poor	7	5	2	3	1	3	5	9	15	5
Total	141	101	69	100	38	100	56	100	304	100

Fertilizer Use and Application The use of manure (organic fertilizer) has decreased with the introduction of inorganic fertilizers and declining livestock population (Asamenew *et al*., 1993). Inorganic fertilizers are popular with farmers and shown to be profitable in wheat production both with modern and farmers varieties (Yalew, 1997b). Despite high adoption rates, there are major technical constraints such as conflicting recommendation rates arising from the national agricultural research system and the Ministry of Agriculture (Extension Project Implementation Department, National Fertilizer Input Unit). The two most commonly used inorganic fertilizers were DAP (18-48% N-P_2O_5) and Urea (46% N) as source of nitrogen and phosphorus throughout the country. The 'blanket' fertilizer recommendations of EPID is 100 kg ha^{-1} DAP and 50 kg ha^{-1} Urea, i.e., 41 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} all applied at planting time for all agro-ecological zones, soils and crops. The National Fertilizer Input Unit made region-based general recommendations without due consideration to differences in agro-climates and soil types. The IAR recommendations differentiate fertilizer rates between wheat and soil types, but based on colour rather than the nutrient status of the soil (IAR, 1990).

A total of 294 farmers (96.7%; n=304) applied fertilizer to their wheat crops using DAP (95.5%) and/or Urea (66.1%) in various combinations including as a single dose at planting or split application (Table 2.7). One hundred eighty eight farmers applied DAP and Urea together (61.8%) usually as mixtures of which nine applied additional urea as split and 13 applied Urea as a split only (not use Urea at planting). The remaining 106 farmers either applied DAP (102) or Urea (4) only at planting time. In general, there was no significant difference among the regions in the trend and rate of fertilizer usage. In contrast, Ferede *et al*. (2000) found that 92% of sample farmers applied DAP but substantially lower percentages (26%) applied Urea in southeastern Ethiopia. Moreover, 32% of farmers who adopted Urea practised split application, slightly higher than our findings.

Fertilizer is applied by hand broadcasting at planting time usually mixed with seed, broadcasted and then incorporated into the soil using a local plough called *maresha*. Almost 91.7% of DAP (n=290) and 99.5% (n=179) of Urea was applied using this method. However, about 22 farmers applied Urea as split by hand broadcasting during the vegetative stage of the wheat crop.

In recent years inorganic fertilizer import and use show a progressive increase, but further analysis of the application rates showed a serious gap between the recommended rate and the actual amount used by the farmers. The mean fertilizer application rates for DAP and Urea were 82.4 (SD=24.9) and 75.1 (SD=29.2) kg ha^{-1}, respectively showing large variation in the amount of fertilizer used. The blanket recommendation of EPID appeared to be the most widely adopted practice used by farmers. From all farmers who used fertilizer only 122 (40%) reached the minimum EPID blanket recommendation of 100 kg DAP and 50 kg Urea (41 N; 48 P_2O_5) per ha (Table 2.7). The percentage of sample farmers applying fertilizers below the recommended rate would increase substantially if the current blanket fertilizer recommendation from EARO is considered. Under such circumstances, it is difficult to ascertain if potential yield of modern variety reaches the desired level of production and productivity. The chronic shortage of fertilizer, higher prices due to removal of subsidies and falling output prices in reasonable harvest years are the main problems associated with low rates of application. Moreover, farmers may revert to use of local landraces in the absence of fertilizers or when they anticipate the problem of waterlogging due to high rainfall (Beyene and Yirga, 1992a). In previous surveys almost all farmers in Arsi region applied fertilizer with the average rate of 60 kg ha^{-1} DAP with the range of 33 to 125 kg ha^{-1} (Yirga *et al*., 1992). Beyene *et al*. (1991) reported that DAP is the most common fertilizer used by the farmers. In central Ethiopia, results of on-farm trials showed that application of 64 and 20.9 kg ha^{-1} nitrogen and phosphorus, respectively, is economically profitable compared to lower fertilizer rates applied by farmers (Negatu and Mwangi, 1994) and advocated favourable policy environment for provision of fertilizers and other inputs to increase durum wheat production. Moreover, differences in fertilizer application based on agro-ecological zones were also reported where 90% of farmers in the highlands and mid

Table 2.7. Farmers' use of fertilizers and rates of application for wheat production (n=304).

Fertilizer type	Arsi		West Shoa		North Shoa		East Gojam		Total	
and rate (kg ha^{-1})	Farmers	%	Farmers	%	Farmers	%	Farmers	%	Farmers	%
DAP										
Less or equal 50	48	15.8	25	8.2	15	4.9	11	3.6	99	32.6
51 - 75	3	1.0	0	0.0	3	1.0	1	0.3	7	2.3
76 - 100	85	28.0	36	11.8	17	5.6	43	14.1	181	59.5
More or equal 101	2	0.7	0	0.0	0	0.0	1	0.3	3	1.0
Total	138	45.4	61	20.1	35	11.5	56	18.4	290	95.4
Urea										
Less or equal 50	41	13.5	17	5.6	14	4.6	27	8.9	99	32.6
51 - 75	0	0.0	0	0.0	4	1.3	2	0.7	6	2.0
76 - 100	29	9.5	23	7.6	11	3.6	26	8.6	89	29.3
More or equal 101	2	0.7	0	0.0	5	1.6	0	0.0	7	2.3
Total	72	23.7	40	13.2	34	11.2	55	18.1	201	66.1

highlands and 50% in the lowlands apply fertilizer for crop production (Gebeyehu *et al.*, 2002).

In recent years, a series of zone-specific on-farm fertilizer response trials have been conducted for wheat varieties to derive optimum N and P recommendations in major growing regions (Gorfu *et al.*, 1991) and differences in variety response have been reported for yield and nutrient uptake, efficiency and recovery (Geleto *et al.*, 1995, 1996), including economic benefits of fertilizer use (Tanner *et al.*, 1999). In light of available information on changes of farming systems and new spectrum of wheat varieties it is obvious that previous fertilizer recommendations need to be verified or modified (Tanner *et al.*, 1999; Tarekegne *et al.*, 1999). There is also concern that farmers using DAP as sole fertilizer, deplete N and reduce soil fertility. From 1998 onwards, an increase in fertilizer demand of 16% for DAP and 11% for Urea year^{-1} was projected (Tanner *et al.*, 1999). However, socio-economic constraints such as availability, access and prices are still limiting optimum rate of application for wheat production (Beyene and Yirga, 1992b; Gebeyehu *et al.,* 2002). The price of fertilizer was more than doubled from 90 and 81 Eth. Birr for DAP and Urea, respectively to over 200 Eth. Birr per 100 kg for both types of fertilizers by late 1990s. Therefore, it is essential to develop robust fertilizer recommendations for wheat farmers in Ethiopia (Tanner *et al*., 1999).

Herbicide Use and Application Farmers considered weeds as important wheat production constraints and named several broadleaf and grass weed species (see Chapter 4). Weeds cause severe adverse effects on wheat including reduced grain yield and quality. Yield losses from weeds could reach up to 36% in bread wheat (Beyene *et al*., 1991). Application of herbicides or hand weeding are the two most commonly recommended weed control measures. For wheat single hand weeding or use of 2,4-D (U46), a selective herbicide against broadleaf weeds, is recommended at the rate of 1 l ha^{-1} about 30 to 35 days after emergence. Farmers are aware of 2,4 D and it is widely used (63.5%; n=304) for weed control in wheat because of its relatively low cost and availability. From those farmers who use herbicides, only 37.3% apply the recommended rate and 50.8% apply half the recommended rate. Beyene *et al.* (1991) reported that 2,4 D is the most widely used herbicide by farmers. Girma *et al.* (2000) found that from farmers who applied herbicide, about 71% applied less than the recommended rate (48% half or less than half). Ferede *et al.* (2000) also found that 63% of farmers adopted chemical weed control (2,4-D), but on average applied a sub-optimal rate of 0.46 l ha^{-1} for wheat production. Moreover variation at district level was also reported where farmers in Asasa on average applied a rate close to the recommended rate (1 l ha^{-1}) compared to farmers in the Ethaya district who applied less than half the recommended rate (0.45 l ha^{-1}) in the Arsi zone (Hassena *et al.*, 2000).

Moreover, 35.7, 59.1 and 5.2%, respectively, applied the herbicide 30-35, 40-50 and 50 days after emergence. There was significant regional variation in the use of herbicides. Among farmers (n=193) who applied herbicide 60.1% and 29% were from Arsi and West Shoa, respectively. In case all sample farmers across the four regions are considered (n=304) the number of farmers who applied herbicides would drop to 38.5 and 19% in the Arsi and West Shoa regions. Beyene and Yirga (1992b) reported that over 40% of farmers apply herbicides in central highlands of Ethiopia. Negatu and Mwangi (1992) also found that application of herbicides is economic on wheat under government controlled price levels in central Ethiopia. Gebeyehu *et al.* (2002) also found variation among agro-ecological zones where 75% and 15% of farmers in highland and lowland areas, respectively, apply herbicide for wheat production. Hassena *et al.* (2000) also reported regional differences in the Arsi zone where herbicides were applied to only 34% of wheat plots in Asasa compared to 66% in Ethaya.

Sahile and Workiye (1997) found that monocropping of wheat (or rotation with other cereals) coupled with continuous use of phenoxy type herbicides caused a shift in weed population from easy to control annual broadleaf weed species towards problematic annual grasses and resistant broadleaf weed species. Moreover, lack of adequate knowledge in proper application techniques and lack of equipment (sprayers) may result in inaccurate dosage, which is un-economic, reduces the efficacy and may lead to herbicide tolerance of weeds (Tessema *et al.*, 1999; Girma *et al.*, 2000). In some parts of Ethiopia, farmers do not practise weeding and weed species such as *Phalaris* are left in the field until crop maturity where they can be used as livestock feed. Moreover, any late coming weeds are used for stubble grazing following the crop harvests. Both practices have substantial influence on the yield of wheat crops. Beyene and Yirga (1992a) made a similar observation in the central highlands of Ethiopia.

Development of appropriate crop production technologies requires a thorough understanding of site-specific problems. Agricultural researchers must know farmers' production constraints. Such a client-driven approach is rather new in many developing countries. Sometimes it remains questionable if at all the new technology is relevant to the need of farmers. Does the technology meet the technical, biophysical and socio-economic expectations of farmers? If so, why are farmers not adopting the new technology? If that is purely lack of awareness, then farmers should be made aware by popularizing and demonstrating the new technology. McMullen (1987) suggested that the extension system should create a linkage between plant breeders and farmers through seed producer demonstration plots.

Wheat production is affected by the interplay of wide range of biophysical (climatic, soil, etc.) and socio-economic factors and therefore site-specific recommendations are necessary. Apart from use of modern varieties, the main technological packages recommended for wheat production include application of fertilizers (rate, type, time), pesticides (herbicide, insecticides), and agronomic practices (seed rate, planting date, etc.). However, the wheat production guidelines are general and mostly lack variety and site specific recommendation (IAR, 1990) and are based on altitude and rainfall patterns. In recent years, more detailed advice is emerging on varietal adaptation (Gebeyehu, 1988; Geleta *et al*., 1992), agronomic management practices (Tarekegne *et al*., 1999), use of chemical inputs and their economic benefits (Tessema and Tanner, 1999; Tanner *et al*., 1999) for bread wheat production.

2.9.5. Farmers' Adoption and Perception of Wheat Varieties

Wheat Varieties Grown by Farmers Since the 1950s several modern varieties of bread (49) and durum (16) wheat were recommended or released for use by farmers in the highly diverse agro-ecological regions of the country (Gebremaraim, 1991b; Tesemma and Belay, 1991; Gurmu *et al*., 1998; NSIA, 2000). Eleven bread and three durum wheat varieties were released during or after the survey years. Most of the old and new released varieties are introductions from CIMMYT and Kenya with very few selections from Ethiopian local landraces.

During the 1997/98 cropping season, 31 modern and farmer varieties of bread and durum wheat were grown across the region by sampled farmers (Table 2.8). Most farmers grew bread wheat (86%) whereas the remaining planted durum wheat varieties (14%). Farmers grew three broad categories of wheat varieties, i.e., recommended, 'obsolete' or local landraces. The recommended varieties are those developed by agricultural research, officially released and currently under commercial production. In theory, the seed is available from formal sources where it is multiplied and distributed by the national seed programmes. 'Obsolete' varieties are those introduced from elsewhere or released in the recent past, but no longer on the recommended list. These varieties are considered having low yield or agronomic potential and are therefore removed from recommended list and certified seed is no more marketed by the formal sector. They can be considered as farmers' varieties and generally remain as mixtures of modern and/or local landraces. Local landraces are long established farmers' varieties or those varieties of which precise origin or any history of formal crop improvement are not clearly known.

In 1997/98 crop season farmers grew eight recommended, three 'obsolete' and four local landraces of bread wheat (Table 2.8). The eight recommended bread wheat

Table 2.8. Patterns of bread and durum wheat varieties and landraces grown by farmers in different regions of Ethiopia.

Wheat types	Variety (Origin)	Year released	Arsi	West Shoa	North Shoa	East Gojam	Number of respondents	% responses
Bread wheat								
Recommended	Dashen (CIYMMT)	1984	11	15	1	1	28	6.4
	Enkoy (Ken/Eth)	1974	-	5	-	3	8	1.8
	ET 13 (Ethiopia)	1981	-	27	30	31	88	20.1
	HAR 1685	1995	48	1	-	-	49	11.2
	HAR 1709	1994	-	-	-	21	21	4.8
	HAR 710	1995	34	2	-	1	37	8.4
	K6295 (Kenya)	1980	2	5	-	2	9	2.1
	Pavon (CIYMMT)	1982	90	-	-	-	90	20.5
	HAR 416 (CIYMMT)	1987	1	-	-	-	1	0.2
Obsolete	Batu (CIYMMT)	1984	27	-	-	-	27	6.2
	Kenya (Kenya)	1954	-	7	-	-	7	1.6
Local	Goli		-	3	-	-	3	0.7
	Israel		5	-	-	-	5	1.1
	Menze		-	-	1	-	1	0.2
	Zombolel		-	-	-	3	3	0.7
	Subtotal		218	65	32	62	377	86
Durum wheat								
Recommended	Boohai (CIYMMT)	1982	-	3	-	-	3	0.7
Local	Guande		-	-	1	-	1	0.2
	Baghade		-	7	-	-	7	1.6
	Baherseded		-	8	-	-	8	1.8
	Enat sende		-	-	8	-	8	1.8
	Enat zer		-	-	1	-	1	0.2
	Gojam gura		-	-	5	-	5	1.1
	Gotoro		-	2	-	-	2	0.5
	Key sende		-	2	-	-	2	0.5
	Legedadi		-	1	-	-	1	0.2
	Local		-	-	8	5	13	3.0
	Nech shemet		-	-	2	-	2	0.5
	Rash (Ruso?)		-	1	-	-	1	0.2
	Shemame		-	-	2	-	2	0.5
	Shemet		-	-	4	-	4	0.9
	Tikur shemet		-	-	1	-	1	0.2
	Subtotal		-	24	32	5	61	13.9
	Total[1]		218	89	64	67	438	100

[1] 186, 102 and 16 farmers grew, respectively, one, two and three bread and durum wheat varieties.

varieties, namely: Dashen, Enkoy, ET 13, HAR 416, HAR 710, HAR 1685, HAR 1709, K6295 and Pavon altogether were planted by 75.5% of farmers. However, the two older varieties released in the early 1980s, ET 13 and Pavon, almost occupied the highest proportion and were planted by 40.6% of these farmers. Pavon, originally released for irrigated lowlands, was predominantly planted across all surveyed districts in Arsi whereas ET 13 was planted across the other three regions. Increasing trends in proportion of farmers growing and area cropped to Pavon in the Arsi region (Ensermu *et al*., 1998) and ET 13 in northwestern Ethiopia (Hailye *et al*., 1998) have been reported. Hassena *et al*. (2000) also reported that most commonly grown varieties were Pavon (38.3%) followed by Batu (25.11%) and Dashen (23%) in Asasa and Etheya districts of the Arsi region.

The new HAR bread wheat varieties were released in the mid 1990s, and fairly widely grown in Arsi (HAR 1685, HAR 710) and East Gojam regions (HAR 1709) by one quarter (25%) of farmers surveyed. HAR 1685 (Qubsa) and HAR 1709 (Mitikie) were released on a national scale because of wider adaptation and better grain yield and stability (Tanner *et al*., 1999). Kotu *et al.* (2000) observed high adoption of HAR 1685 and HAR 710 (Wabe) by farmers in the Aadaba and Dodola districts of the Bale region in southeastern Ethiopia. Similar results were also reported in the Arsi region in southeastern Ethiopia (Ferede *et al*., 2000). Pavon and HAR1685 were widely adopted and appeared to be important in suitability scoring by farmers in south central Ethiopia (Gebeyehu *et al*., 2002). HAR 1709 shows less response to fertilizer and is, therefore, popular with farmers in northwestern Ethiopia where fertilizer use is minimal (Tarekegne *et al*., 1999).

There was a remarkable shift in the proportion of bread wheat varieties grown by farmers in the Arsi region. In a previous survey it was reported that about 33.8 and 25.5% farmers, respectively, grew Dashen and Enkoy (Bishaw *et al*., 1994). Similar results were also found by (Ensermu *et al*., 1998; Alemayehu *et al*., 1999a) and elsewhere in the country (Beyene *et al*., 1998). Dashen and ET 13 were also found to be better performing in northwestern Ethiopia (Geleto *et al*., 1990) compared to local varieties such as Israel. However, Dashen became susceptible to yellow (stripe) rust and Enkoy to stem rust and both lost their popularity with farmers. Meanwhile, in some areas farmers grew Dashen at lower altitudes and Enkoy at higher altitudes outside their optimum recommendation domain to overcome the disease problem. In the absence of new varieties, many farmers reverted to less popular older varieties with moderate tolerance to important rust diseases such as Pavon and ET 13. Later surveys also showed wider adoption of these varieties (Ferede *et al*., 2000). Farmers in Arsi were quicker to change and adopt newer varieties compared to their counterparts elsewhere in other parts of the country. The persistence of older varieties, however, reflected the lack of a new generation of wheat varieties with durable resistance, better and stable yield across different regions. This illustrates not only the weakness of the formal sector seed production and distribution but also of the national agricultural research system.

The 'obsolete' bread wheat varieties were grown by 8% of farmers, mostly occupied by Batu and grown in Arsi region. Some bread wheat varieties introduced in the early 1950s such as Kenya are still grown in small pockets and used by small-scale farmers. Israel is of unknown origin and was planted by 21.5% of farmers (Bishaw *et al*., 1994), but now grown by a small proportion of farmers in Arsi. Israel and durum wheat landraces such as Tikur sende were previously grown by farmers because of their preferred food quality, grain colour and performance in poor soil (Ensermu *et al*., 1998). Menze (Beyene and Yirga, 1992a) and Zombolel (Hailye *et al*., 1998) are local landraces grown in central and northwestern parts of the country.

The number of modern durum wheat varieties released from formal research is limited owing to difficulties of developing varieties with wider adaptation and high yield compared to bread wheat (Tesemma and Belay, 1991). Although some varieties are on the recommended list, commercial seed production and marketing by the formal sector remains insignificant. Most farmers in traditional durum wheat growing areas of central and northwestern Ethiopia are shifting to bread wheat because of high yield and better agronomic performance including grain colour, grain size and tolerance to pests. About 0.7% of surveyed farmers planted Boohai whereas the remaining 13.3% of farmers grew a wide range of local landraces, mostly in West Shoa, North Shoa and East Gojam regions where the penetration of bread wheat is taking place at a very rapid pace. Baherseded, Baghede, Enat sende, Gojam gura, Shemet, Tikur sende were some of the local durum landraces grown by farmers (Hailye *et al*., 1998; Beyene and Yirga, 1992a; Negatu *et al*., 1992; Tanner *et al*., 1991). However, farmers who grew local landraces only (n=23) all had information about the new varieties, but could not grow it either because of poor adaptation or lack of seed.

The proportion of farmers who grew obsolete and/or local wheat varieties only was 13.9% (n=42 out of 304), i.e., 23 (7.6%) for bread wheat and 19 (6.3%) for durum wheat. The remaining 29 farmers who grew local landraces of durum wheat also planted modern wheat varieties as a second crop. It is assumed that the durum wheat area is still larger than the bread wheat area whereas recent studies suggested otherwise: that more farmers were adopting and expanding the bread wheat area. Zegeye *et al.* (2001) made similar observations in northwestern Ethiopia. A more detailed study would be required to assess the actual pattern of modern varieties used for wheat production on a national scale.

Some recent studies have shown high adoption rates of modern varieties of bread wheat across different wheat growing regions (Yirga *et al.*, 1996; Ensermu *et al.*, 1998; Beyene *et al.*, 1998; Hailye *et al.*, 1998). Negatu *et al.* (1992) also found that 94% of sampled farmers in predominantly durum wheat producing areas in the central highlands grew five modern wheat varieties. About 63% of these farmers were formerly used to grow as many as 27 durum local landraces, but abandoned them primarily due to lack of seed or resistance to diseases and pests. Similarly, Ensermu *et al.* (1998) also indicated that farmers could name nearly 50 wheat varieties and local landraces previously grown, but that those were no longer in production except a few landraces and currently recommended modern varieties. Zegeye *et al.* (2001) reported a dramatic increase in the rate of adoption of modern wheat varieties from less than 1% in 1981 to 72% in 1998 in northwestern Ethiopia particularly following the new extension package programme started in the 1990s.

The area allocated to wheat production is given in Table 2.9. The mean area allocated to wheat is 2.8 ha. Almost 60% of farmers allocated less than 0.50 ha on their farm to wheat. The average area of 1.33 ha allocated to modern varieties was higher than that of farmers' varieties (0.56 ha).

In case of local landraces about 76.4% (n=55) of farmers allocated less than 0.50 ha whereas for modern varieties 42.7% (n=281) allocated less than one ha. This shift in farmers practice is due to the perception of better return owing to the expected higher productivity of modern varieties as compared to local landraces, which are generally low yielding.

Table 2.9. Area allocation for bread and durum wheat crop production in different regions of Ethiopia.

Area in ha	All wheat varieties (n=438)		Modern varieties (n=281)		Farmers' varieties (n=60)	
	Farmers	%	Farmers	%	Farmers	%
< 0.50 ha	259	59	120	43	47	78
0.51 - 1.00 ha	99	23	62	22	8	13
1.01 - 1.50 ha	28	6	24	9	3	5
1.51 - 2.00 ha	30	7	36	13	2	3
> 2.01 ha	22	5	39	14	-	-
Total	438	100	281	100	60	99
%			92.4		19.7	
Mean	2.8		1.21		0.56	
SD	1.8		1.06		0.36	

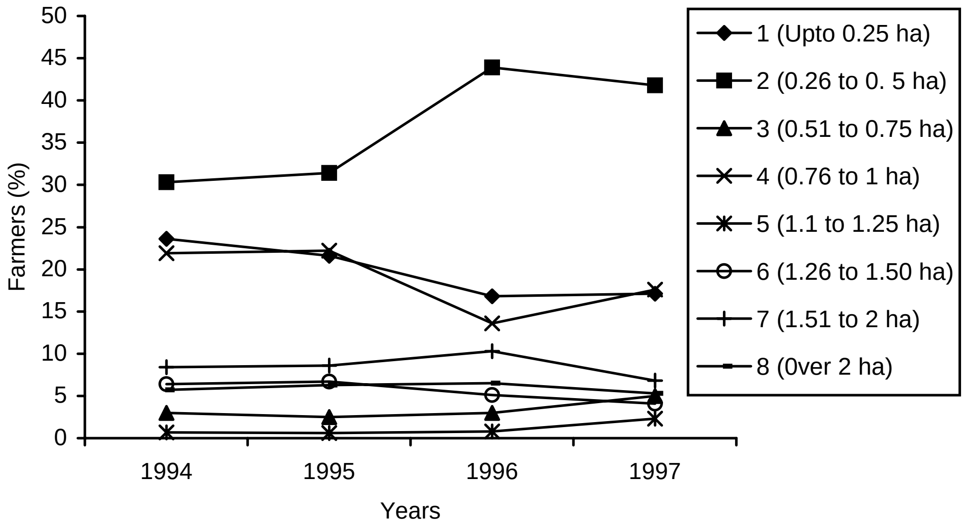

Fig. 2.3. Patterns of area allocation for wheat production in Ethiopia.

The land allocation for wheat production showed a decline in smaller plots of less than 0.25 ha and use of plots of 0.51 to 0.75 ha (Fig. 2.3). There appears to be a trend to allocate more area for wheat production. This could possibly be explained by the fact that more farmers are shifting from local landraces of durum wheat for which they allocate small plots towards adopting modern varieties and expanding their areas. In the 1997/98 crop season 49% of farmers allocated 50% of their farm land to wheat (data not shown). According to Kotu *et al.* (2000), 28 and 15% of adopters and non-adopters of modern wheat varieties indicated decreasing their total area under local wheat varieties over time. If the trend continues it may threaten not only wheat landraces, but also the diversity of other crops on the farm as more land is being allocated to few bread wheat varieties. However, the observations made are of limited duration and inconclusive and require monitoring over a longer period.

In Ethiopia, growing crops in mixtures such as wheat and barley (Woldeselassie, 1999); faba bean and field pea (Beyene *et al*., 1998); intercropping *tef* with safflower, sunflower and rapeseed (Ketema, 1997); intercropping faba bean with linseed (Beyene and Yirga, 1992a) and beans with maize or sorghum (Mekbib, 1997) is a common practice in some parts of the country. These are farmers' strategies of crop diversification, resource use maximization, disease control and/or maintenance of household food security. Naturally farmers' local landraces can be considered as blends or mixtures of different lines. There is credible evidence to suggest that farmers use variety mixtures of modern varieties with local landraces. About 27 (8.9%; n=304) farmers reported using variety mixtures of modern varieties and/or local landraces in different proportions and combinations. From the total, five farmers used variety mixtures of modern varieties, 20 farmers used mixtures of local landraces and two farmers used mixtures of modern and local landraces. In most cases two-way mixtures in equal or more proportions were used except in one case where three local landraces were mixed for use. Hailye *et al*. (1998) reported that most wheat varieties grown by farmers are found in mixtures of a modern variety (Enkoy) and a local landrace (Zombolel) in northwestern Ethiopia. Geberemariam (1991b) reported some studies with wheat variety mixtures and found that mixtures on average gave 5% more yield and the mixtures of disease susceptible varieties had 6-10% heavier kernel weight than in pure stands.

Perception of Wheat Varieties Farmers were interviewed in an open-ended questionnaire and specifically encouraged to identify wheat varieties they grew during the season and to provide as much information as possible and to rank them according to their perceptions (Table 2.10). Every effort has been made to avoid a 'yes' or 'no' answer on farmers' preferences by using an array of questions in predetermined format asking them to rate a particular character of the variety over another. Farmers identified as many as 26 technological and socio-economic factors for growing a particular modern wheat variety or a local landrace on their farm. Data are recorded only for those characteristics farmers perceived as important and on which they provided qualitative assessments.

Although farmers identified many varietal characteristics, grain yield, food quality, marketability, grain colour and grain size appeared to be most important in both crops and all regions (Table 2.10). These results are in agreements with other findings in central (Negatu *et al.,* 1992; Negatu and Parikh, 1999), southeastern (Alemayehu *et al.,* 1999a) and northwestern (Agidie *et al*., 2000) major wheat growing regions of Ethiopia and elsewhere (Mwanga *et al.,* 1999). This is not surprising as the final destination of the product has a strong influence on the choice of the varieties to grow. About 98.7% and 91.8% of farmers surveyed used the grain for home consumption and producing surplus for marketing, respectively. Wheat is the second most important cash crop for small farmers after *tef* (Tarekegne *et al*., 1999). In the Ethiopian grain market, there is a strong price difference based on grain colour for cereals including wheat (Adissu, 1991; Agidie *et al*., 2000) where the prices can go up to one-third depending on the crop and location. White kernel seeded wheat varieties fetch better price than brown/red or mixed colour types because of consumer preferences for food preparation (Addisu, 1991) whereas for making local drinks the choices are less pronounced and the coloured once are more preferred (Belay *et al*., 1995).

Wheat varieties were rated fairly for agronomic characters such as straw yield and quality because of its wider use as feed for livestock, fuel for household or for house

Table 2.10. Farmer's perception of selected wheat varieties currently grown in different regions of Ethiopia (n=436; Frs=number of farmers).

Farmers'	HAR 1685		HAR 710		Pavon		Dashen		Batu		ET 13		Baherseed		Enat sende		Total[1]	
Perception	Frs	%	Frs	%	Frs	%	Frs	%	Frs	%	Frs	%	Frs	%	Frs	%	Frs	%
Grain yield	30	61	23	62	75	83	24	86	25	93	69	79	5	63	0	0	317	73
Grain size	7	14	10	27	23	26	5	18	2	7	21	24	3	38	0	0	87	20
Grain colour	12	24	15	41	35	39	8	29	6	22	26	30	7	88	1	13	134	31
Food quality	25	51	19	51	71	79	23	82	25	93	72	83	7	88	6	75	336	77
Marketability	20	41	23	62	69	77	20	71	25	93	65	75	6	75	2	25	303	69
Straw yield	4	8	3	8	4	4	1	4	0	0	22	25	1	13	2	25	48	11
Straw quality	6	12	2	5	6	7	2	7	0	0	19	22	2	25	3	38	59	14
Lodging tolerance	6	12	6	16	3	3	4	14	0	0	11	13	0	0	1	13	35	8
Shattering tolerance	3	6	0	0	3	3	0	0	1	4	2	2	0	0	0	0	10	2
Frost tolerance	3	6	1	3	2	2	1	4	2	7	7	8	0	0	0	0	21	5
Drought tolerance	1	2	0	0	1	1	0	0	0	0	5	6	1	13	0	0	9	2
Disease tolerance	9	18	6	16	10	11	2	7	4	15	29	33	1	13	0	0	75	17
Pest tolerance	4	8	1	3	4	4	1	4	1	4	8	9	1	13	0	0	29	7
Less fertilizers	0	0	0	0	1	1	0	0	0	0	1	1	1	13	2	25	14	3
Less need for water	0	0	1	3	2	2	0	0	0	0	2	2	1	13	0	0	9	2
Low soil fertility	0	0	2	5	4	4	1	4	2	7	5	6	1	13	1	13	17	4
Others	12	24	7	19	17	19	2	7	8	30	6	7	0	0	0	0	64	15
Total	49	100	37	100	90	100	28	100	27	100	87	100	8	100	8	100	436	100

[1] Figures include all varieties grown by farmers.

construction, although less considered in the breeding programmes. Despite the emphasis of breeders on agronomic characteristics such as tolerance to insect pests, lodging, shattering, frost, etc., farmers have a limited appreciation of these criteria and the varieties were rated as poor or very poor.

ET 13 was favoured by farmers because of its high yield (79%; n=87), marketability (75%) and food quality (83%), but less so for grain size and colour. It was also rated high for its straw yield and quality (>33%) and tolerance to diseases (33%) compared to other bread wheat varieties. Agidie *et al*. (2000) also reported that farmers rated ET 13 high for its resistance against foliar diseases in northwestern Ethiopia. Moreover, most farmers liked Dashen, Batu and the newly released 'HAR' varieties for their yield, marketability and food quality. It was reported that ET 13 has better competition with weeds, ease of harvesting and bundling, greater height and white grain colour and is most preferred by farmers, in contrast to Dashen which is poor in weed competition, difficult in harvesting and bundling and susceptible to stripe rust (Tanner *et al.*, 1991). K6295 was less favoured because of low yield, red grain colour and poor food quality. Enkoy was superior to Dashen, especially under conditions of low soil fertility and high weed competition, where it gave 49% better yield (Gebre *et al.*, 1988). Pavon was rated for its high yield (75%; n=90), marketability (77%) and food quality (79%), but less so for grain size and colour. Pavon was previously found resistant to leaf and stripe rust. Pavon and HAR1865 were widely adopted and appeared to be important in suitability scoring by farmers elsewhere in south central Ethiopia (Gebeyehu *et al.*, 2002). Farmers identified high yield, resistance to sprouting and lodging, seed colour and size, and baking quality as important agronomic characters and their perceptions about some of these characteristics positively influenced their adoption of modern wheat varieties (Kotu *et al.*, 2000).

Some bread and durum local landraces are highly preferred by farmers because of their unique adaptation to varied agro-ecological zones, more stable yield and grain quality characteristics, marketability and traditional food preparation. Baherseed is a local durum wheat variety and was rated highly for yield, grain colour, food quality, marketability, but less so for straw yield and quality. However, farmers prefer Enat sende for food quality, straw quality and yield, marketability, but not for yield, grain size and colour. Israel is a local bread wheat variety uniquely appreciated by farmers across regions because of yield, grain colour, good bread quality, strong and long straw, disease resistance, performance in light soil, frost tolerance and marketability (Negatu *et al.*, 1992). The variety appeared to be widely grown and popular throughout major wheat growing area of the country, although its exact origin is not known. According to Beyene and Yirga (1992a) Gounde is a local durum wheat preferred by farmers for its tolerance to waterlogging, high straw quality for livestock feed, good taste, performance under unfertilized condition and its vigorous growth and better competition with weeds.

A similar questionnaire was also administered to farmers to find out what their 'ideal' wheat variety for adoption. The results indicated that grain yield (91.7%), food quality (50.7%), marketability (42.8%) and grain colour (23.4%) were rated as very important for farmers to adopt new variety (Table 2.11). Moreover, tolerance to pests was considered very important to important by 50% of the farmers showing farmers' awareness of the susceptibility of the existing wheat varieties. The major wheat production regions of southeastern Ethiopia had experienced major stripe rust (*Puccinia striformis*) epidemics in 1977, 1980-83 and 1986 and yield losses of up to 40% were registered on some commercial varieties (Badebo and Bayu, 1992). Moreover, according to the survey results about 78.6% (n=304) of sample farmers

Table 2.11. Farmers' perception and criteria for adoption of new wheat variety in Ethiopia.

Varietal characteristics	Very important	Important	Less important
	%[1] (n = 304)		
Grain yield	91	2	0
Grain size	20	3	0
Grain colour	23	8	1
Food quality	51	17	1
Marketability	43	16	1
Storability	4	2	0
Straw yield	8	7	0
Straw quality	7	13	0
Strong straw	0	1	0
Lodging resistance	6	1	0
Shattering resistance	1	3	0
Frost resistance	8	6	1
Drought tolerance	4	4	1
Disease resistance	36	15	2
Pest resistance	3	1	0
Yield with less fertilizers	5	2	1
Yield with less rainfall	0	1	0
Performance in poor soil	8	2	0
Adaptation (plant height)	15	0	0
Weed competition	7	0	0
Early maturity	1	0	0
Waterlogging	3	0	0

[1] Figures do not add to 100% because of multiple responses.

considered rusts as important wheat production constraints. As a result farmers showed their concern on less durability of the modern varieties released from the research programme (Yirga *et al.*, 1992). Dashen, one of the most productive wheat varieties released in the country, became susceptible after its second year of entering commercial production and dramatic high adoption rates in Arsi region. HAR 1685 and HAR 604 were broadly adapted and clearly superior, in terms of grain yield potential, yield stability and seed characteristics (Yalew *et al.*, 1997a). Farmers also recognized the shortcomings of modern varieties which were found to give higher yields under favourable soil fertility through use of chemical fertilizers and favourable rainfall conditions. Seed colour and end-use quality (bread and *injera*) reported to be important post-harvest criteria by farmers in selecting new bread wheat varieties in northwestern Ethiopia (Agidie *et al*., 2000). They also reported that ease of grinding, flour volume per unit of grain, water absorption of the flour, elasticity and extensibility of the dough as well as bread and *injera* (‘eye’ size, product colour and elasticity) quality as important criteria.

Most farmers (90.1%; n=304) considered the varieties they grew adapted to their agroclimatic zones whereas 3.2% doubted the suitability to their local condition. However, 6.7% of farmers grew the varieties for the first time and had reservation if the new variety will meet their expectations. The actual yield obtained during the previous three years and the expected yield potential during the survey year are given in Fig. 2.4. The number of farmers expecting less than 2 t ha^{-1} is falling continuously. In contrast the number of farmers expecting higher productivity (i.e., > 3 t ha^{-1}) is increasing particularly in Arsi and East Gojam as a result of adopting new and better yielding varieties. During the 1997/98 crop season 46.9% of farmers were expecting a yield of 3 t ha^{-1} or more. Alemayehu *et al.* (1999a) also found similar results where farmers obtained higher yields (3.47 t ha^{-1}) compared to the actual average yields registered nationwide (1.2 t ha^{-1}). Gavian and Degefa (1996) also observed that 4% of the wheat farmers surveyed produced equal or higher grain yields ha^{-1} compared to the demonstration plots with equivalent or greater profits. Under improved management conditions the yield of modern durum varieties can reach as high as 2.5 to 4 t ha^{-1} in farmers’ fields (Tesemma and Belay, 1991). Other scientists indicated that wheat grain

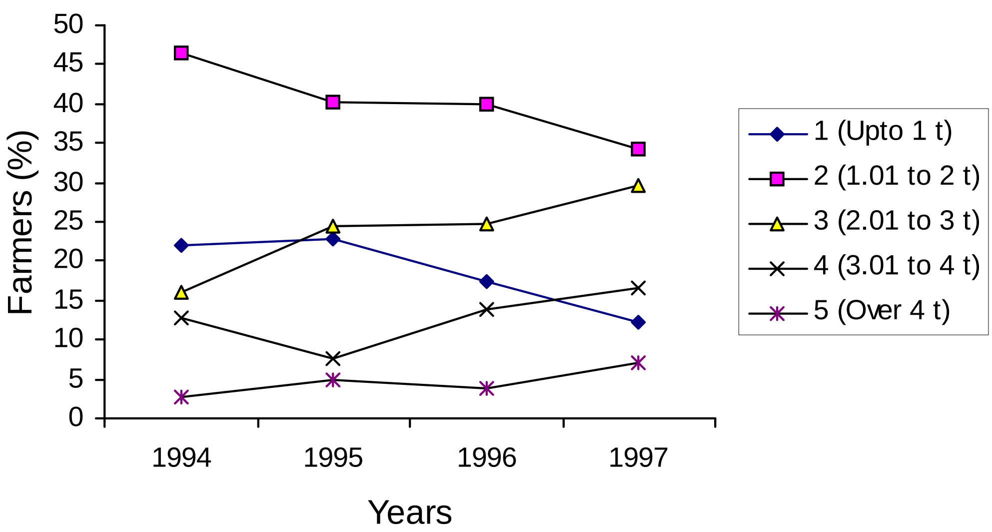

Fig. 2.4. Farmers’ perception of productivity of wheat varieties grown in Ethiopia.

yields ranged from 3-6 t ha^{-1} on the farmers' field and 5-7 t ha^{-1} at research centres (Tarekegne, 1996a). Studies of previously released modern varieties showed that there is a steady increase in yield over time for bread wheat (Tarekegne *et al*., 1995) and durum wheat (Tarekegne *et al*., 1997). Yield increases of 68 (1.5%) and 50-77 (1.77 to 2.21%) kg ha^{-1} each release year, respectively have been observed for durum and bread wheat varieties released since 1950s. The perception of the technology would influence farmers' decision to adopt or not to adopt the new agricultural technology. Negatu and Parikh (1999) reported the positive effect of farmer's perception of modern variety on adoption; and found that grain yield and marketability as most important varietal characteristics preferred among wheat growers in central Ethiopia.

Patterns of Seed Prices The price of grain changes from year to year depending on the production level and the weather conditions. In dry years the price increases because of decrease in grain production whereas in wet years the reverse is true. Since 1991, the Ethiopian grain market has been deregulated and this by itself is viewed as an incentive to produce surplus for market. Although farmers are aware of the price differential between harvesting time and at planting time, most of them sell their produce at harvest time to pay off debts for inputs purchased on credits from formal sector or to meet other social obligations. They have limited resources to keep the produce towards the end of the year to benefit from these price differences. Analysis of grain price for wheat at planting and harvesting time showed that the price at harvesting showed less difference than at planting time which coincides with depletion of reserve grain (Gebeyehu *et al*., 2002). Fig. 2.5 presents the price of the grain at harvesting time from 1994 to 1997. The figure showed a declining trend of wheat grain price at harvest time (a decrease from higher prices of over 100 Eth. Birr to lower prices of less than 100 Eth. Birr 100 kg^{-1}). The declining grain prices are of concern in a situation where input prices are increasing and output prices are decreasing. On the contrary the grain price of new variety is higher than the grain price of the already existing varieties by at least 1½ times. Ensermu *et al*. (1998) also made similar observations in southeastern Ethiopia.

2.9.6. Farmers' Seed Sources and Seed Management

Farmers' Seed Sources A clear distinction should be made between demand for variety and demand for seed as well as a difference between regular and transient demand for seed. The decision by farmers to change varieties already adopted is termed variety replacement, whereas the decision to obtain fresh seed stocks of the same variety is termed seed renewal (Bishaw and Kugbei, 1997). In both cases, the decision to

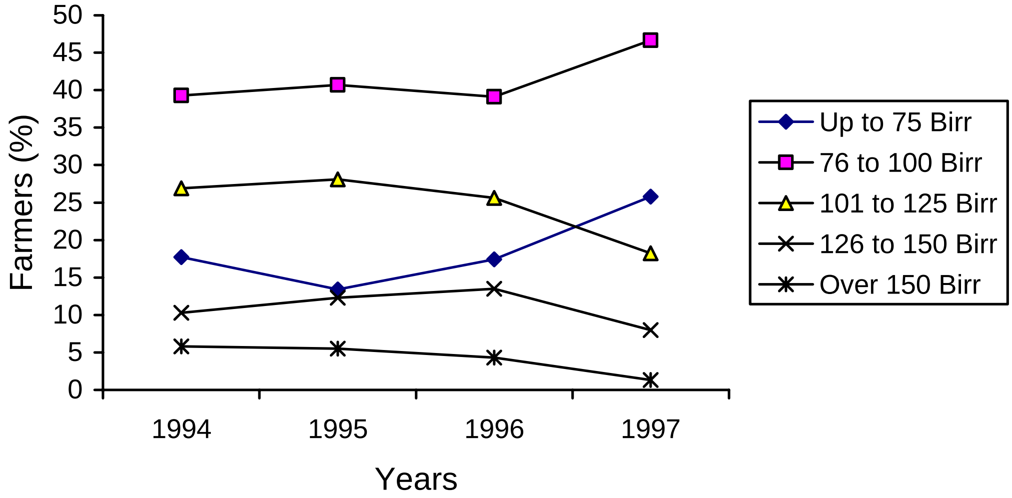

Fig. 2.5. Patterns of wheat grain prices at harvesting time during 1994/95-1997/98 crop seasons.

replace seed may be due to perceived reduction in productivity arising probably from genetic change and/or deterioration in quality through continuous use of the same seed.

Small-scale farmers grow as many diverse crops as possible dictated by their domestic circumstances including the provision of household food security. The alternatives to source seed for a mix of crops grown are challenging and complex decision-making processes. Some studies confirmed that farmers are not short of seed even in case of extreme and recurrent disasters (Rohrbach, 1997), although the extent of disruption varies between crops, seed sources, farming systems and farmers seed management practices (Sperling, 1998). Is seed acquisition a simple one step decision associated with lack of seed on-farm and static as we think or dynamic reflecting farmers' response to address specific farming problems? While farm saved seed is the most attractive alternative there are ample reasons for any off-farm demand for seed which may include:

- last minute change in cropping pattern due to delay in onset of rain;
- need for replanting because of poor crop establishment or failure;
- introducing new/existing crops on the farm as part of diversification and profit maximization plan;
- introducing new/better variety of the crop already grown on the farm;
- changing seed because of perceived weaknesses in existing stock such as declining yield or product quality;

- seed shortage where not enough quantity is available on hand to plant a crop;
- emergency situation because of manmade and/or natural disasters; and
- out of choice/necessity because sourcing seed off-farm is more convenient/essential.

In some countries subsidized seed price could be the main reason for artificially high seed demand from the formal sector rather than the actual demand for seed. In general farmers have four major sources of seed for planting:

- own saved seed from the previous years,
- seed obtained from other farmers (relatives, neighbours),
- seed purchased through local trading (markets, grain traders), and
- seed purchased from the formal sector.

There is an interplay of many technical and socio-economic factors to source seed from a particular client and how this affects the anticipated benefits and household food security; availability of reliable information on source, quantity and quality of the product; proximity and timely availability; price and risks associated with it. Zeven (1999) gave a historical account of traditional seed replacement practices by farmers in different countries.

Farmers' Initial Seed Sources for New Wheat Varieties Farmers' seed source and acquisition for all wheat varieties grown is presented in Table 2.12. Here we can distinguish between two aspects: (a) the initial seed source for all wheat varieties currently grown by farmers; and (b) farmers' seed source for wheat planting during the survey year. The formal sector, either through the extension service of Regional Agricultural Bureau (through its demonstration and popularization programme) or the Ethiopian Seed Enterprise (a public seed production and marketing organization), accounts for about 40% of the initial source of seed of the modern wheat varieties grown by farmers. Some of the varieties released a few years prior to the survey year particularly the three HARs were at the initial stage of diffusion and the formal sector was the main source of seed compared to the older varieties. Seed marketing to the peasant sector was previously handled by the Agricultural Inputs Supply Enterprise. In recent years, however, the Regional Agricultural Bureau became a major supplier of seed to farmers and customer of the ESE as part of the agricultural extension package programme. Moreover, few private companies are also involved in purchasing seed from ESE and distributed seed to limited number of farmers. The agricultural research stations played a limited role in dissemination of modern varieties despite their long-term involvement in on-farm demonstration of technology to farmers.

Likewise the informal farmer-to-farmer seed exchange was the major initial source of wheat seed particularly for the relatively 'older' modern varieties and farmers'

Table 2.12. Farmers' initial wheat seed sources and during 1997/98 crop season.

Initial wheat seed source for all varieties (n=436)			Wheat seed sources in 1997/98 crop season (n=438)[1]		
Seed source	Nr of farmers	% of responses	Seed source	Nr of farmers	% of responses
ESE	8	1.8	ESE	3	0.7
RAB	170	39.0	RAB	33	7.5
Research	5	1.2			
Neighbours/ Farmers	155	35.5	Neighbours/ Farmers	41	9.4
Traders/Market	67	15.4	Traders/Market	15	3.4
Relatives	30	6.9	Own seed	346	79.0
State farm	1	0.2			
Total	436	100	Total	438	100

[1] Two farmers obtained seed of the same variety from two different sources.

varieties. The informal sector was an initial source of modern wheat varieties for 57.8% of the farmers where seed was obtained from neighbours/other farmers (35.5%), relatives (6.9%) or local trading (15.4%). Ensermu *et al.* (1998) also found the local market and other farmers as the main initial source of seed for wheat in southeastern Ethiopia. Although seed was purchased on the local markets or from traders, farmers always checked the source of the seed through their acquaintances or word of mouth (informal). Similar results have been observed for wheat in Pakistan (Tetlay *et al.*, 1991) and in the central (Beyene *et al.*, 1998) and northwestern (Hailye *et al.*, 1998) highlands of Ethiopia. In both cases, on average over 70% of Ethiopian wheat farmers get their initial seed of modern varieties from the informal sector, although the percentages from each source is slightly different. It was also found that relatively more small-scale farmers (79.2%) obtained seed of new wheat varieties from other farmers compared to large-scale farmers (69.8%) in Kenya (Gamba *et al.*, 1999).

Farmers' Wheat Seed Sources During the survey year in 1997/98 crop season, the majority of farmers used seed from the informal sector for planting wheat crop (Table 2.12). About 79% of respondents used retained seed whereas the remaining sourced their seed off-farm from neighbours (9.4%) and traders (3.4%). The formal sector accounted for only 8.2%, which is the reflection of its actual performance for typically self-pollinated crops such as wheat where retained seed is a major source for planting. Similar results are reported from both developed and developing countries. In Europe, for example, the number of farmers using farm saved seed varies from as low as 5% in Denmark to 50% in Germany and France to as high as 90% in Greece and Spain for self-pollinating crops such as wheat (Ghijsen, 1996). Similarly, about 80% of farmers in USA also use wheat seed from informal sources (Stanelle *et al*., 1984). In a wheat seed survey in Pakistan, the most common seed source for planting was retained seed (55-62%), followed by seed from other farmers (21-27%) (Tetlay *et al*., 1991). Similar results were also found for wheat in Ethiopia (Bishaw *et al*., 1994).

Patterns of Wheat Seed Sources The patterns of wheat seed sources over time showed some changes following significant varietal turnover observed during the mid 1990s (Fig. 2.6). Acquisition of seed from the formal sector showed some increase as farmers in Arsi were looking for newly released bread wheat varieties and those in East Gojam and West Shoa were being exposed to seed from the formal sector. The acquisition of seed from neighbours, other farmers, traders or markets was consistent and provided collectively about 20% of the seed each year.

Further analysis of the pattern of seed source showed that about 81% (n=304) used only one seed source for planting wheat crop whereas 18.4% obtained seed from two sources during 1997/98 crop season (Table 2.13). Moreover, almost all farmers who did source seed off-farm from neighbours, traders or formal sector had their own seed for planting at least one wheat variety. This shows that there is no acute shortage of seed for farmers to purchase seed from outside sources, but rather reflects their interest for changing the variety or seed.

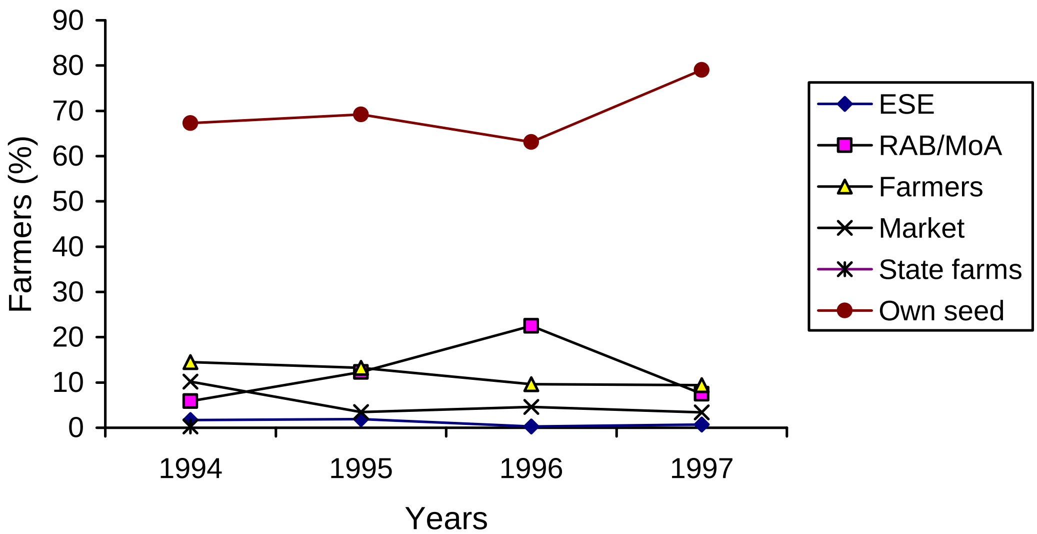

Fig. 2.6. Patterns of wheat seed sources by the sample farmers in Ethiopia.

The results in Table 2.12 and Fig. 2.6 may indicate the nature and functioning of the formal and informal sector in wheat seed supply. First, it implies the critical role of the formal sector in the initial diffusion of modern varieties. The new variety created a surge in seed demand and thereby a potential market for the formal sector being the only source for the seed. Second, once the variety entered production local farmers had several options to acquire seed from different sources. For the formal sector to remain competitive with the informal sector it should provide newer varieties and 'inject' the seed to the market, instead of trying to sell seed of the same variety to the same group of farmers who have many alternatives. In developing countries such a radical approach would enable the formal sector to effectively contribute towards accelerated adoption and diffusion of new varieties and play a complementary role to the informal sector. Grisely (1993) advocated similar approaches to ensure rapid diffusion of modern bean varieties (in Africa).

Farmers' Perception of Different Seed Sources Farmers may use various seed sources for different crops or even for a single crop or variety they grow on the farm. The analysis of wheat seed sources for the 1997/98 crop season showed that of the 304 farmers surveyed 36, 41, 15 and 346 seed lots were sourced from the formal sector, neighbours/other farmers, traders/markets or own seed, respectively (Table 2.12). Farmers were asked why they acquired seed from a particular source and how they managed this seed.

Formal Sector Seed Source It was reported elsewhere that farmers buy 10% of their wheat seed for planting every year from the formal sector and multiply that to meet their total wheat seed requirement for the next planting season as a strategy to reduce cost. This ingenious approach is rather an exception than a norm, and most farmers buy certified seed less frequently from the formal sector particularly in less developed seed programmes where availability of seed and access to credits is a limiting factor.

Table 2.13. Patterns of seed sources for planting wheat during 1997/98 crop season.

Province	Seed Sources (n=304)							
	1		2		3		Total	
	Farmers	%	Farmers	%	Farmers	%	Farmers	%
Arsi	101	71.6	38	27.0	2	1.4	141	46.4
West Shoa	65	94.2	4	5.8	-	-	69	22.7
North Shoa	29	76.3	9	23.7	-	-	38	12.5
East Gojam	52	92.9	4	7.1			56	18.4
Total	247	81.3	55	18.0	2	0.7	304	100

About 171 farmers (56.1%; n=304) previously acquired seed from the formal sector at one point in time, but only 36 (8.2%; n=438) respondents purchased seed from the formal sector in the 1997/98 crop season. The reasons for obtaining seed from the formal sector and the anticipated frequency of purchase are given in Table 2.14. Sourcing seed from the formal sector appeared to be a strategy for acquiring a new variety (varietal replacement) or for the renewal of old seed (seed replacement). There is also a general belief that certified seed gives better yield, although no distinction is made whether this is from the variety or is simply due to better seed quality. Ensermu *et al.* (1998) quoted that use of certified seed would increase wheat yield by 0.2 to 0.5 t ha^{-1} although this estimate is difficult to realize.

The distance travelled to buy certified seed was in the range of 0 to 15 km (13.8% over 10 km) and most transactions were based on credit from the government. This indicates farmers' interest in investing their time to obtain wheat seed in situations where rural infrastructure is very poor. In western Ethiopia, some maize farmers at least travelled more than 10 km to obtain improved seed although there are differences between districts (Gemeda *et al*., 2001). Gamba *et al.* (1999) reported that 21% of small-scale and 63% of large-scale farmers travelled over a distance of 10 km to purchase seed. In general farmers appreciated the quality of seed received and were satisfied with the price. However, against this background regular purchase of certified seed was not common in Ethiopia, although quite a significant percentage of farmers obtained seed from formal sector in recent years.

Table 2.14. Farmers' perception of formal seed source and frequency of purchasing certified seed (n=36).

Why farmers purchase certified seed			*Frequency of certified seed purchase*		
	Farmers	%		Farmers	%
Replace old variety	10	27.7	Every year	1	2.7
Replace old seed	9	25.0	Every two years	2	5.5
Better seed quality	11	30.5	Every three years	4	11.1
Better grain yield	32	88.9	After 5 years	2	5.5
No own seed	1	2.7	Less regularly	21	58.3
Others	1	2.7	First time	7	19.9
Why farmers not regularly buy certified seed			*Distance travelled to buy certified seed (km)*		
Own seed good	14	38.9	0	2	5.5
Certified seed not available	5	13.8	1 to 4	19	52.7
Certified seed expensive	7	19.9	5 to 10	10	27.7
Others	10	27.7	11 to 15	5	13.8

High seed price and lack of seed were the two major constraints for farmers not to use seed from the formal sector. Gamba *et al* (1999) also reported that 66.7% of small-scale farmers and 68.4% of large-scale farmers did not adopt new varieties because of high seed price and lack of seed availability, respectively.

Local Off-farm Seed Sources Farmer-to-farmer seed exchange or local seed trading is as old as agriculture itself. The practice contributed to the wider global distribution of major food crops before the advent of the commercial seed industry. It continues to be the main source of seed for the majority of farmers especially for self-pollinated crops such as wheat. During the 1997/98 cropping season 41 respondents had sourced seed from immediate relatives, neighbours or other farmers, whereas 183 (60.2%; n=304) had prior experience of purchasing seed from other farmers. It is the second most important source of seed after own saved seed. Similarly, 15 respondents obtained seed through local markets during the survey year, whereas 97 (31.9%; n=304) had prior experience of purchasing seed from markets or local traders. Farmers confirmed that, although they buy seed from market, they ensured that what is purchased comes from a reputable farmer whom they know and trust. Similarly, it was reported that seed exchange take place among farmers with some form of acquaintances in northwestern Ethiopia (Hailye *et al*., 1998).

Table 2.15 presents the major reasons for sourcing seed from other farmers or traders/markets and the management of seed purchased from these sources. The availability, quality and price of seed were some of the incentives for farmers for acquiring seed locally. They also used this as low cost strategy to buy seed of a new variety, which is quite often not available or expensive to purchase from the formal sector. It also provides an opportunity to assess the performance of the crop before adopting it while observing the variety growing on the neighbours' fields. In Kenya, other farmers were found to be major sources of seed and no difference was observed between small-scale and large-scale farmers in wheat crop (Gamba *et al.,* 1999). It was stated that farmers could lower their transaction costs by obtaining seed from neighbours (Lyon and Danquah, 1998). In contrast, Negatu *et al*. (1992) found the local market as the main source of seed for wheat in central Ethiopia. Some farmers acquired seed from external sources to replace their old seed stock. Louette *et al*. (1997) reported that maize farmers believe in changing seed of the same local landrace to maintain the productivity of their crop.

Most farmers who used seed from other farmers or from market did carry out seed cleaning and informally checked germination before they planted the seed. Moreover, most farmers who sourced seed locally from other farmers purchased well ahead of planting time whereas those who sourced seed from the market mostly bought seed

Table 2.15. Farmers' perception and management of seed from local sources (other farmers and local traders; Frs=number of farmers).

Farmers' perception/seed purchase	Other farmers (n=41)		Traders/ markets (n=15)		Seed management	Other farmers (n=41)		Traders/ markets (n=15)	
Perception of seed sources	Frs	%	Frs	%	*Seed cleaning*	Frs	%	Frs	%
Seed available on time	2	5	2	13	Not clean seed	3	7	8	53
Seed quality is good	20	49	3	20	Seed cleaning	36	88	7	47
Seed price is cheap	4	10	2	13	*Purpose of seed cleaning*				
No own seed	8	20	7	47	Remove inert matter	13	32	2	13
CS[1] not available	10	24	3	20	Remove weed seeds	23	56	6	40
CS is expensive	7	17	2	13	Remove small seeds	8	20	2	13
No cash/credit to buy CS	2	5	1	7	*Equipment used*				
New variety	5	12	2	13	Hand winnowing	31	76	6	40
Replace old seed	2	5	1	7	Hand sieving	5	12	2	13
Others (yield, maturity)	3	7	2	13	*Seed treatment*	0	0	0	0
Frequency of purchase					*Check germination*	18	44	3	20
Every 2 years	1	2	1	7	*Methods of payment*				
Every 3 years	2	5	2	13	Cash	31	76	14	93
After five years	1	2	1	7	Seed exchange	10	24	2	13
Occasionally	38	93	12	80	*Satisfied with price*	31	76	9	60
Satisfied with quality	37	90	11	73					

[1] CS = certified seed.

around planting time when the price of grain was quite higher than at harvest time, at least probably by 1.5 times. Most of the transactions were in cash, particularly from the market, although seed exchange was also practised with other farmers.

Farmers claimed travelling as far as 20 km to buy seed locally, although about 80% of them travelled a distance of less than 10 km. In one incident the farmer had sourced seed of the new variety from a distance of over 100 km through family acquaintances. These are rather isolated incidents happening in rural areas and greatly contributing to the local variety diffusion over long distances. In northwestern Ethiopia, farmers in the highland zone travelled at least twice the distance (9 km) compared to farmers in the intermediate zone (5 km) for purchasing seed of modern varieties (Hailye *et al*., 1998). Thiele (1999) also reported that most potato seed flows in the Andes is within 10-15 km although long distance travels are common in some countries such as Peru. Poor infrastructure and lack of access to institutional services such as the extension, input providers and markets are some of the main reasons why the informal sector had a greater role in the seed supply of the country.

On-Farm Seed Sources Producing and retaining seed on-farm was the most economic approach provided that new varieties with superior agronomic or quality attributes desired by farmers were not available on the market and no biophysical constraints that are detrimental to seed quality on the farm occurred. In case of wheat there is little evidence to suggest a decline in yield through continuous use of seed of the same variety if farmers follow sound crop production procedures. As a result for most cereal crops including wheat, own saved seed is the major source for planting both in developing and developed countries.

Farmers' perception of own saved (retained) seed is presented in Table 2.16. They considered the quality of on-farm produced seed as equal or greater than seed purchased from elsewhere (43.3%; n=263) and did not see any justification for changing the seed unless to acquire a new variety on the market (6.5%). Some farmers did not want to change their variety at all because of its preferable food quality attributes (3.8%). The timely availability of seed and the costs were also considered important though minimal. On the other hand seed shortage (39.2%), high price and lack of cash/credit remained the major reasons for not sourcing seed from the formal sector. There is also lack of confidence in the quality of seed from the formal sector (7.2%) and lack of varietal adaptation (4.6%) which further discouraged farmers from purchasing seed of modern varieties. Ensermu *et al*. (1998) also found that lack of seeds (41.7%) followed by seed price (35%) were considered as most important seed supply constraints in southeastern Ethiopia. Almost all farmers (92.7%) who used seed retained on-farm were satisfied with the quality of their seed.

Table 2.16. Farmers' perception of own saved (retained) wheat seed in Ethiopia (n=263; Frs=number of farmers).

Why farmers use own saved seed	Frs	%	*Why farmers not buy CS [1] seed*	Frs	%
Seed available on time	6	2	Variety not adaptable	12	5
No extra cost	7	3	Poor certified seed quality	15	6
Seed quality is good/better	114	43	Certified seed is expensive	98	37
Certified seed not available	103	39	No cash/credit to buy certified seed	69	26
Keep own variety	10	4	No information on seed	2	1
No new/better variety	17	7	Have fresh certified seed	17	7
Others (new field)	6	2	Others	15	6

[1] CS = certified seed.

Seed Retention/Replacement Seed retention refers to a continuous uninterrupted use of the same seed lot for planting once a farmer purchased fresh seed of the modern variety or local landrace from outside sources. It is one of the most common seed acquisition strategies and enables farmers to maintain any inter- and intra-crop diversity that exists on their farms. The number of years seed was retained on farm varied from crop to crop and depended on the farmers' decision to change seed and the availability from external sources. The number of years wheat seed saved on farm is presented in Table 2.17 and in some instances goes beyond 20 years. The majority of farmers, however, acquired their seed during the last five years, although this is not necessarily showing a higher seed replacement rate. About 30% of the farmers acquired seed from external sources during the 1997/98 cropping season, whereas 44% kept their seed for one year, 22% for two years and 20% for three years (Table 2.17). Seed of local landraces or obsolete varieties were kept on the farm for longer period than modern varieties. In 1994, Bishaw *et al.* (1994) found that 21% of wheat farmers saved their seed for 6-10 years and 14% saved seed for 11-15 years. Gamba *et al.* (1999) reported that in Kenya seed retention period had a negative impact on the adoption of new wheat varieties whereas seed selection has a positive impact on adoption.

According to Brennan and Byerlee (1991), the optimal period for varietal replacement depends on yield gain of new varieties, yield loss of old varieties, and risk of changing the variety. Hesisey and Brennan (1991) cited sources suggesting that the annual rate of estimated yield loss due to use of retained seed in self-pollinated crops ranges from 0.25% for wheat in Pakistan and to 1.6% for wheat in Nepal and 1.6 for

Table 2.17. Number of years seed saved by bread and durum wheat farmers (n=438) in Ethiopia.

Years	Arsi		West Shoa		North Shoa		East Gojam		Total	
	Responses	%	Responses	%	Responses	%	Response	%	Response	%
0	60	13.7	12	2.7	11	2.5	8	1.8	91	20.8
1	51	11.6	28	6.4	15	3.4	39	8.9	133	30.4
2	37	8.4	14	3.2	7	1.6	8	1.8	66	15.1
3	48	11	8	1.8	2	0.5	2	0.5	60	13.7
4	7	1.6	6	1.4	-	-	1	0.2	14	3.2
5	6	1.4	8	1.8	4	0.9	1	0.2	19	4.3
6 - 9	7	1.6	6	1.4	5	1.1	2	0.5	20	4.6
≥10	2	0.5	7	1.6	20	4.6	6	1.4	35	8
Total	218	49	89	20.3	64	14.6	67	15.3	438	100

rice in India. Therefore, there is little incentive for farmers for regular purchase of certified seed of wheat except for acquiring a new variety. However, most farmers recognize the consequences of recycling seed and associate this with decline in yield, diseases and contamination with weeds (Ensermu *et al*., 1998).

The rate of varietal replacement is estimated by the age of varieties in farmers' fields, measured in years since releases and weighted by the area under each variety (Brennan and Byerlee, 1991). In the early 1990s, the weighted average age of wheat varieties in Ethiopia was in the range of 12-16 years (Byerlee and Moya, 1993). In 1995, Beyene *et al.* (1998) calculated a weighted average age of 13 years in the Wolmera district of central Ethiopia; and also reported that 24 to 45% of the farmers believe that new varieties could give good yield for a period of two to three years. Henderson and Singh (1990) reported a period of five years elsewhere in Ethiopia.

The longevity of wheat varieties is also constrained because of the breakdown of resistance to rust diseases, which is in the range of 5 to 7 years (Brennan and Byerlee, 1991; Byerlee and Moya, 1993). The most productive varieties such as Dashen and Batu became susceptible within a very short period of time after their official releases although they persisted in production outside the recommendation domain. In contrast, the most popular wheat variety Enkoy remained in production for over two decades before its importance started to decline due to susceptibility to stem rust. As described earlier, the high varietal and seed replacement rates observed could be attributed to the availability of new wheat varieties and the strong extension package programme promoted by the Government.

Local Seed Flows Apart from growing wheat for consumption and marketing, farmers also produced seed for own use or sale to others. Almost all farmers had a long established culture and experience of exchanging seed among themselves, but 144 farmers who grew modern wheat varieties were found selling seed on purpose to other farmers informally on various arrangements. Such group of farmers could be regarded as 'suppliers of introduced seed' as described by Louette *et al*. (1997). The seed transactions were between relatives (39.6%; n=144), neighbours (51.4%), other farmers (46.5%) or sales to traders/local markets (3.5%). It appears there is flow of information and diffusion of varieties and seeds among farmers without little hindrance as indicated elsewhere from local social networks dependent on close kinship ties (Lyon and Danquah, 1998) or farmers' reluctance in information exchange on crop production due to traditional beliefs in some farming communities (Tripp and Pal, 1998). Most of these transactions were carried out through seed exchange/barter (61.8%), cash (56.9%) or gift (10.4%). Gemeda *et al.* (2001) reported that bartering as the most common maize seed exchange mechanism among farmers in central and western Ethiopia. Likewise, seed exchange is also the most common mode of transaction among wheat farmers in northwestern Ethiopia (Hailye *et al*., 1998). Although most farmers who purchased seed locally reported paying cash for their seed in 1997/98 crop season, there is still a dominant culture of traditional form of trade in rural Ethiopia. Most farmers are constrained of cash particularly at planting time and payment in kind or later at harvest time appears to be the most convenient arrangements.

Seed production is attractive particularly if the variety is new and available in limited quantities, because the grain will fetch better prices due to high demand from other farmers. Ensermu *et al*. (1998) reported that the price of new modern varieties was at least 32% higher than the seed from the formal sources because of the limited availability on the market. In one interview a farmer confided that, 'I grow new varieties as soon as they are available and sell the seed to fellow farmers at a higher price before everyone grabs what ever small quantity of seed is available'. This statement illustrates a remarkable analysis of wheat seed market at local level. First, demand for seed exists when there is a new variety on the market. Second, once farmers get access to the variety there is less interest to buy fresh seed regularly. Third, a regular injection of seed of a new variety is more important for diffusion than continuously producing seed of the same variety. Fourth, there are farmers with knowledge of the local seed market and willing to invest at the initial stage to introduce new varieties. Fifth, the assumption of introducing small seed enterprises at local level may not be as easy and attractive as it sounds, because of stiff market competition from own seed produced on-farm by farmers.

Farmers' Seed Management Do farmers perceive any difference and make distinction between grain they use for consumption or planting? Is there any concern of seed quality problems among farmers? If so, how do they manage their seed differently from grain? Understanding these issues lead us to design alternative strategies in delivering seed of better quality to farmers or try to improve on-farm seed production techniques to resolve quality constraints at local level.

The on-farm seed management practices are often the reflection of farmers' perception and the value they attach to seed planted to raise the next year crop. These appreciations and expectations of seed quality are given in Table 2.18. Ninety two percent of farmers (n=304) recognized the difference between grain and seed and some of them translated that into purity (60.2%; n=304), freedom from weeds (18.16%), intact seed with good germination (18.4%), big kernel size (11.5%), no disease or insect damage (10.2%) and no admixture with seed of other varieties of the same crop (3.3%). Henderson and Singh (1990) also reported similar observations elsewhere in

Table 2.18. Farmers' perception of seed quality and seed management practices (n=304).

Farmers' perception	Farmers	%	*Seed management*	Farmers	%
Purity (cleanliness, etc.)	183	60.2			
Free from weeds/other crops	55	18.1	Clean seed	252	82.8
Good quality (intact seed, germination)	56	18.4	Select seed	204	67.1
Big kernel size	35	11.5	Store seed separately	197	64.8
No disease/insect damage	31	10.2	Check seed quality[1]	103	33.9
No mixture with other varieties	10	3.3	Treat seed	10	3.5

[1] Indirect assessment of seed quality.

central Ethiopia. Some of the criteria farmers use to define seed quality include freedom from impurities, diseases, and adaptation to local environment (Hailye *et al.*, 1998).

Farmers' positive perception of seed urged them to practise specific seed management approaches to maintain the quality of their wheat seed through selection, cleaning, treatment, storage or direct/indirect assessment of seed quality (Table 2.18). The responsibility to manage and execute these operations on the farm is shared between men and women, who have a distinctive role to play. Likewise, women play an important role in on-farm potato seed management (Thiele, 1999) and marketing (Benteley and Vasques, 1998) in the Andean region.

Plant and/or Seed Selection Farmers' selection of seeds or plants is empirical through critical observation of plants or seeds taking into account the best criteria that expresses their understanding of the performance of the crop in question and its use value and seldom involve any specific physical measurements. Selection is a dynamic process adapting the variety or a local landrace to a continuously changing crop production environment. It also requires continuous monitoring of the entire life cycle of the crop coupled with regular observation of the characteristics that farmers consider very useful based on their long-term experiences. Farmers practise selection up to four stages in the crop production cycle: (a) selection of a particular field or part of the field towards the end of the crop season; (b) selection of individual plants with good plant morphology such as plant height, ear size, etc. from standing crops; (c) selection before or during threshing based on grain yield, grain size, grain colour, etc.; and (d) selection during storage or prior to planting based on freedom from pest damage, less weed contamination, good grain size, etc. About two-thirds (67.1%;

n=304) of the wheat growers practised a combination of different selection methods, stages, criteria and responsibilities to discriminate between grain used for consumption or planting on their farm (Table 2.19). However, most of the selection practices were intuitive or indirect. For example, from those farmers who practised selection few based their selection on plants (3.4%; n=204) or ears (2.5%) and most of them selected grains (82.4%). Women significantly contributed to the seed selection process whereby they made decisions alone (4.9%) or jointly with men (31.4%). Bajracharya (1994) reported that women play a key role in on-farm seed management such as crop selection, seed selection and seed storage in Nepal.

Table 2.19. Farmers' plant/seed selection practices and the criteria used for selection.

Farmers seed selection (n=304)			Criteria used for selection (n=204)			
	Farmers	%		Very important	Im-portant	Less important
Not select for seed	100	32.9	Early maturity	3.4	2.0	1
Select for seed	204	67.1	Non-shattering	0.5	2.5	0
			Non-lodging	5.0	1.0	0
Method of selection[1]			Disease resistance	11.3	3.4	1
Field or section of field	33	16.2	Pest resistance/			
Select plants	7	3.4	Weevil free	6.9	2.0	0
Select ears	5	2.5	Plant height	7.8	1.5	0
Select grain	168	82.4	Ear size	14.2	6.4	0
			Grain yield	67.6	1.5	0
Time of selection[1]			Grain size	37.3	6.4	0
Planting	16	7.8	Grain colour	24.5	8.8	0
Before harvesting	59	28.9	Marketability	29.6	10.3	0
Post-harvesting/			Storability	3.4	0.5	0
Threshing	140	68.6	Food quality			
Storage	3	1.5	(preparation)	25	4.9	1
			Food quality (taste)	17.6	0	1
Responsibility for selection[1]			Straw yield	2	1	0
Men	130	63.7	Straw quality	1.5	2.5	0
Women	10	4.9	Others[2]	19.6	0	0
Both	64	31.4				

[1] Percentages are calculated on 204 farmers who practise selection;

[2] Grain quality/free of weed and other variety seeds /no rain damage.

Selection of field or section of field was usually made at planting or later in the season. A crop from new land was believed to be of good seed quality because of better plant nutrition and freedom from weed seed contamination. Moreover, fields identified for seed received adequate agronomic practices such as land preparation, application of fertilizers, proper weed control, etc. Selecting part of the field of standing crops at maturity before or at harvesting is similar to mass selection where good standing crops with less damage from pests, less contamination from weeds, etc. are identified and bulk harvested for use as seed later in the season.

Most farmers selected grain and usually after harvest on threshing floors, in storage or right before planting time. The selection criteria were consistent and again reflected farmers' knowledge and were based on easily observable characters such as grain yield, grain size, grain colour (e.g., marketability), and food quality (e.g., malting). In the latter the role of women in selection was reflected strongly. Farmers kept seed from fields free from pests, non-lodging crops, sound seed free from frost, rain or insect damage, etc., but not necessarily evaluated pest resistance, lodging tolerance of the particular variety and so did not select on these criteria. Yirga *et al.* (1992) reported that farmers practise selection usually before harvest where patches within fields that are free from weeds or good crop stands having large spikes or seed pods are selected for seed. Farmers' criteria, although indirect, imitated the criteria used by breeders such as plant height, early maturity, tolerance to biotic stress, grain yield, etc. Similar selection practices have been reported for wheat (Beyene *et al*., 1998; Ensermu *et al*., 1998) and maize (Gemeda *et al*., 2001) in Ethiopia; and for rice in the Philippines (Fujisaka *et al*., 1993). In maize, selection of ears appears to be the most common practice in Mexico where the selection criteria is based on big clean ears and big kernels but also indirectly for other agronomic characters of the crop (Louette and Smale, 2000).

During the field survey a handful of farmers were encountered who practised a methodological approach in seed or plant selection. These farmers selected plants that appeared to be different in the standing crops out of curiosity usually at maturity using whole or part of the plant as selection criteria which included clusters of vigorous plants/tillers, plant height, ear size, grain size, etc., where selected plants were collected, threshed and stored separately. During the next planting season the seeds were planted separately and critically observed throughout the entire plant growth period for any agronomic advantages including yield. If the farmer was convinced of any benefits the seed was multiplied and used on a larger scale. Ensermu *et al.* (1998) also reported an interesting observation where a farmer collected left over seed from his neighbours' field and started multiplying the seed of the modern variety. If farmers apply such meticulous selection pressure on the variety adopted, the structure of the variety may change significantly over time. Therefore, this will raise the fundamental question of whether seed replacement is of any practical relevance to farmers.

Seed Cleaning and Treatment The main purpose of seed cleaning is to improve the physical quality of the seed by removing inert matter, weeds and other crop seeds, broken seeds or disease/insect damaged seed. Seed cleaning is carried out at different stages, right after threshing of the crop using wooden implements *(menshe*, *layda*) or at a later stage just before planting using home made tools (*sefed, wonfit*). Winnowing at threshing time is a two-stage process, first threshed wheat grain is separated from the rough straw and second, grain is further purified from fine straw, inert materials, shrivelled or broken seeds. In traditional wheat farming systems of Ethiopia this is the most common practice except when grain is combine harvested. In both cases a complete removal of inert matter or contaminants is not possible.

About 52% and 17% of the farmers, respectively, cleaned their seed by hand-winnowing or hand-sieving at planting time using hand made tools to increase purity, reduce weed contamination or even remove insect damaged grains, etc. The *wonfit* is used to remove very small particles and rather ineffective in removing bigger materials and weeds because of small diameter of the holes. The *sefed* is used for hand cleaning and accompanied by hand picking of bigger particles including soil clods or thrash from the grain. However, such cleaning tools are ineffective in removing the impurities and weeds to a desired level of seed quality. Both operations are cumbersome and labour intensive and therefore less popular. Badebo and Lindeman (1987) found a high level of weed contamination in farmers' seed, as high as 700 noxious weed seeds per kg of seed in Arsi region. Men are mostly responsible for winnowing after threshing and women are mainly carrying out cleaning of the seed at planting time.

Most farmers cleaned seed to remove contaminants such as inert matter (chaff), weed and other crop seeds, shrivelled or damaged seeds (Table 2.20). About 47.4% farmers in the intermediate zone and 48.9% in the highland zone clean their seed to remove weeds (Hailye *et al*., 1998). In Ethiopia, on-farm chemical seed treatment is virtually unknown or negligible (3.3%). On the contrary, about 76 and 61% of the small-scale and large-scale farmers, respectively use chemical seed treatment in Kenya (Gamba *et al*., 1999). In the past as a general policy, ESE distributes treated seed only to the state farms not to the peasant sector to avoid risk of chemical hazards. Some research reports, however, suggested the use of chemical treatment as an alternative solution against seed-borne diseases (Hulluka *et al*., 1991). For example, organo-mercury and thiram were found effective against common bunt and benomyl against fusarium head blight of wheat in Ethiopia (Andenew, 1988).

The most interesting seed management tools observed was the informal assessment of physiological quality of seed before sowing where women are the major source of information (Table 2.21). One third of farmers (34.2%; n=304) used different innovative approaches to determine the viability and germination of their seed lots before planting. Traditionally wheat can be used for local brewing where the grain is malted by the womenfolk and the information is passed on to their male counterparts if it malts properly and therefore can be used for seed. There are a few ingenious farmers who soak/moist their seed in water for a day or two, place seed in soil in the garden or plant early part of the field to observe whether the seed germinates and establishes itself or not. Some other farmers used visual inspection of the grain to make sure whether the seed is intact, dry and without rain damage or insect infestation or not combine harvested. This indicates the existence of refined on-farm seed management practices developed over centuries and still exercised by traditional farmers.

Table 2.20. Farmers' seed cleaning and treatment practices in Ethiopia (n=304; Frs=number of farmers).

Seed cleaning and treatment			*Purpose of seed cleaning*		
	Frs	%		Frs	%
Not cleaned	36	11.8	Improve quality/remove inert matter	129	42.4
Purchase cleaned seed	16	5.3	Remove weeds/other crops	174	57.2
Seed cleaning	252	82.9	Remove small/broken/damaged seed	34	11.2
Hand winnowing at harvest	38	12.5	Reduce seed rates	5	1.6
Hand winnowing at planting	141	51.6	Remove insect damaged/diseased seed	12	3.9
Hand sieving at planting	53	17.4			
Machine cleaning at planting	4	1.3	*Seed treatment*	10	3.3

Table 2.21. Informal assessment of physiological seed quality in Ethiopia (n=104).

Seed quality assessment methods	Farmers	%
Soak/moist seed in water	17	16
Free/no damage from pests	22	21
Visual inspection (intact/dry/no rain damage)	21	20
Local malt preparation	34	33
Early planting part of small plot	8	8
Not combine harvested	1	1
Plant few seeds in the garden	1	1

Seed Storage and Management In Ethiopia, information on storage for grains in general and for seed in particular is very scanty (Tsega, 1994). Moreover, information on influences of the traditional grain storage structures on pest infestation and loss of seed quality is limited. In general, pest infestation not only reduces the grain weight, but also destroys seed viability. It was observed that 261 farmers (85.9%; n=304) had some experience of storage pest problems. Weevils and rodents were the two most important storage pest problems identified and 45.1, 9.9 and 30.9%, respectively reported weevils, rodents or both as threats to grain and seed storage (data not shown). Hailye *et al*. (1998) also reported that weevils and rodents are among most important seed storage problems in northwestern Ethiopia. In a previous survey it was indicated rodents as more problematic than weevils (Yirga *et al*., 1992). In India, high level of weevil attack on wheat seed under traditional storage structures was also reported with significant reduction in physiological seed quality (Kashyap and Duhan, 1994).

The grain storage structures, management practices, and the role of gender is presented in Table 2.22. Most farmers stored seed separately (64.8%; n=304) from grain, and used both traditional and modern approaches in pest control before or after infestation. Several types of locally made traditional storage structures used for grain storage were observed. *Gotera* was the most common and popular grain storage structure both for those who stored seed and grain together (77.5%) or separately (66%) (Table 2.22) and usually kept in the backyard outside the house. In contrast smaller capacity structures such as, *gota, debegnt* and *gushigush* are purely made of wooden materials/mud and plastered with cow dung and could be kept inside the house for storing a smaller quantity of seed. Beyene *et al.* (1998) found that 80% of the farmers store seed separate, but the majority (84%) keep seed in sacks whereas the remaining percentage keep seed in local storage structures. However, these structures are neither insect nor rodent proof and considerable damage was observed on seed sampled from farmers. Previous studies found *gotera* as the most popular storage structure and weevils as most prevalent storage pests of small cereal grains in Ethiopia (Bishaw *et al*., 1994; Woldeselassie, 1999). Tsega (1994) also found that 34 and 13.2% of farmers used *gotera* or *gota* for seed storage, respectively.

Cleaning infested seed, sun drying or changing the storage facilities are common traditional storage management practices. However, use of chemicals (usually contact insecticides) was popular (35-40%), although availability, use of actual recommended rates and application methods remained problematic. Wider use of chemicals for seed storage pests is reported for wheat (Woldeselassie, 1999) and for maize (Gemeda *et al*., 2001) in Ethiopia and wheat in India (Kashyap and Duhan, 1994). Generally disinfections of traditional structures are difficult to achieve and infestation might have started from grain stored from the previous season. The role of both men and women

Table 2.22. Farmers' seed storage and management practises in Ethiopia.

Seed storage & pest control	Store seed separately (n=197)		Not store seed separately (n=107)	
	Farmers	%	Farmers	%
	197	64.8	107	35.2
Storage structures				
Polypropylene bag	16	8.1	3	2.8
Jute bag	26	13.2	1	0.9
Gotera	130	66.0	83	77.5
Debegnt	14	7.1	12	11.2
Gota	5	2.5	8	7.5
Gushigush	5	2.5	0	0
Barrel	1	0.5	0	0
Pest control measures				
No pest problem/control	25	12.7	35	11.5
Sun drying	40	20.3	30	28.0
Cleaning	45	22.8	49	45.8
Chemical	68	34.7	44	41.1
Traditional	19	9.6	8	7.5
Responsibility				
Men	89	45.2	45	42.1
Women	26	13.2	15	14.0
Both	82	41.6	47	43.9

was equally significant and both shared the responsibility of managing the seed storage.

2.10. Concluding Remarks

The study revealed interesting results of the Ethiopian agricultural sector in general and the wheat seed industry in particular. The adoption and diffusion of modern bread wheat varieties and associated technologies appear to be higher than for other crops, although largely remain informal. However, given the diversity and complexity of agro-ecological zones and farming systems overlaid by diversity in socio-economic conditions of the farmers, agricultural research is lagging behind in solving the major production constraints of Ethiopian agriculture. The present agricultural package programme had managed to introduce farmers to recent technologies. The government policy towards meeting food self-sufficiency is highly appreciated, but largely flawed due to several structural problems in land policy. The agricultural policy is still unable to provide sound and long-term sustainable development in the peasant sector.

Several wheat varieties have been released by agricultural research. The majority of farmers has knowledge of modern varieties and has positive perception about their agronomic characteristics. However, farmers have doubts on tolerance of these new varieties to plant diseases and insect pests and subsequently suffered crop losses due to frequent rust epidemics. This becomes a major problem and as a result led farmers reverting to older varieties. Therefore, plant breeders are required to continue developing and releasing several varieties with durable resistance and also match the varietal attributes most wanted by farmers. Moreover, the current wheat recommendation domains are based on altitude and rainfall pattern where it is practically difficult to delineate such variation at the farm level. It is possible for farmers growing varieties in sub-optimal recommendation domains. Plant breeders should use new innovative approaches such as agro-climatic analysis or geographic information systems to identify and target germplasm for specific variety testing, release and recommendation domains. These research results should be explicitly communicated to farmers through an effective extension programme.

The adoption of fertilizers and herbicides is high, in terms of farmers using the technology continuously. Most farmers, however, are applying below the optimum rates to get the desired level of benefits. Shortage of inputs, input prices, output prices and lack of access to credits are some of the limiting factors cited by farmers for full level technology adoption. At present where input prices are rising and output prices are falling (in non-drought years), it would be difficult for farmers to adopt the full package of wheat production technology to exploit the yield potential of new varieties. Therefore, generation of technology should focus on site-specific recommendation and economic threshold coupled with input efficient varieties to derive economic benefits.

Ethiopia is one of centres of diversity of tetraploid wheats where a considerable wealth of genetic variability and diversity exists on the farm. Until recently this wealth of germplasm was maintained and nurtured by farmers. In recent years there was a dramatic shift in adoption of modern bread wheat varieties in predominantly durum wheat growing regions of the country as farmers are striving to maximize production and achieve food security from diminishing and meagre land resources. The practice if continued unabated will seriously threaten the existence of durum local landraces as in Syria (Chapter 3). Efforts should be made both to conserve the germplasm and develop durum varieties with acceptable yield and agronomic potential for farmers to adopt them.

Subsistence farmers grew many different crops and varieties to maintain their household food security and there is little tendency to specialize and concentrate in production of cash crops at the expense of other food crops. Moreover, farmers are knowledgeable about their production environment and constraints and demand specific varietal characteristics to manage different competing enterprises on the farm. Agricultural research should take into account the integration or complimentarity of different enterprises on the farm rather than developing single enterprise technology that is suitable for commercial agriculture.

Despite over four decades of agricultural research in the country, the wheat seed supply system still remains informal. The formal seed sector over its twenty years of existence could achieve the provision of less than 10% of the seed used by farmers each year. The Ethiopian Seed Enterprise (ESE) remains the only public sector organization involved in major seed production and distribution operation of public varieties. The national seed policy framework supports the role of the private sector to participate in the seed industry. However, unfair competition from the public sector through subsidy and government interventionist policy remains one of the main bottlenecks for entry of the private sector and to diversify the seed sector. For example ESE expanded its operation of hybrid seed production, despite the existence of a private seed company with long experience in the hybrid maize seed sector.

The formal seed sector deals with a handful of varieties with wider adaptation which normally remain unpopular at local levels. Moreover, in self-pollinated crops such as wheat most farmers rely on retained seed for planting and therefore it is difficult to predict effective demand or market for certified seed. Farmers are more interested to acquire new variety than regular purchase of fresh certified seed from the formal sector. Therefore, the formal sector should design an innovative approach of injecting seed of new varieties to the informal sector as a strategy to accelerate and achieve rapid diffusion.

The informal sector played a significant role in farmer-to-farmer diffusion of varieties and higher adoption of bread wheat across the country. Moreover, farmers practise an acceptable level of selection and management of their wheat seed and face no significant problem in loss of wheat seed quality on the farm. However, there is room to improve the quality of seed produced on-farm. Although yield losses from seed-borne diseases is not yet properly quantified and the intensity varies from region to region and year to year depending on weather condition, there is ample evidence of farmers suffering from significant reduction in grain yield and quality. The introduction of simple seed cleaning and/or treatment equipment could be useful to raise the quality of seed produced at the local level.

In much of the literature, it was estimated that the durum wheat occupies a larger area than bread wheat in terms of total area under wheat production, i.e., 60 and 40%, respectively for durum and bread wheat. However, most of the recent surveys in major wheat production regions of the country show high adoption rate of bread wheat varieties across the regions. It is, therefore, believed that the area under durum wheat is less than what is expected even in much remote regions of the country. In Kenya, Gamba *et al.* (1999) found that actual field surveys showed higher adoption rates of improved wheat varieties than what has been suggested in the literature. A detailed nationwide survey would be useful to quantify the actual area coverage of durum and bread wheat.

It is generally accepted that the development of the national seed industry requires an integration or strong linkage of the formal and informal sectors operating at maximum efficiency. National governments should play a pro-active role by providing stable and flexible policy, regulatory, technical and institutional support that promotes the development of diverse, competitive and viable seed industry.

CHAPTER 3

Farmers' Wheat (*Triticum* spp.) and Barley (*Hordeum vulgare* L.) Seed Sources and Seed Management in Syria

Farmers' Wheat (*Triticum* spp.) and Barley (*Hordeum vulgare* L.) Seed Sources and Seed Management in Syria

3.1. Abstract

A total of 206 wheat and 200 barley farmers in the 1998/99 and 1997/98 cropping seasons, respectively, were interviewed in the Aleppo, Raqqa and Hasakeh governorates in northeastern Syria. Wheat farmers had better awareness of modern varieties (100%), agronomic packages (100%), fertilizers (99%), herbicides (97%) and chemical seed treatment (96%) in comparison to barley growers. Fellow farmers (relatives, neighbours and other farmers) were the major source of information for modern varieties, agronomic packages and fertilizers followed by the formal extension service. The majority of farmers grew modern wheat varieties (86.8% from the recommended list, 2.2% 'obsolete' and 10.6% non-recommended), applied fertilizers (99.5%), herbicides (92.7%), seed treatment chemicals (90.3%) and insecticides for control of storage pests (40.8%) leading to self-sufficiency in wheat production. Although a wide range of modern bread and durum wheat varieties were adopted, Cham 3 and Cham 6 were found predominant and each was grown by over 20% of the farmers across the three regions replacing earlier releases. In comparison, the awareness (36%) and use (0.5%) of modern varieties and associated technologies such as herbicides (3.5%), insecticides (2.5%) and fertilizers (56%) were very low for barley growers, maybe partly due to lack of adaptable varieties and lack of fertilizer recommendations for drier areas. Farmers identified several technological and socio-economic criteria for adopting and continuously growing a particular wheat or barley variety on their farm. Almost all farmers were satisfied with yield and believed that the wheat varieties they grew were suitable and adapted to their growing conditions. Non-lodging, grain size and food quality were good agronomic qualities of wheat varieties presently grown. Interestingly high yield, lodging resistance, drought tolerance (yield with less water) and frost tolerance appeared to be varietal characteristics farmers are seeking from new bread and durum wheat varieties. There is a strong desire to find alternative varieties responding to higher inputs and at the same time maintain good agronomic characteristics such as tolerance to lodging and shattering. Similarly, grain yield, grain size, grain colour, feed quality and marketability are the agronomic traits farmers recognize as important in Arabi Aswad and they seek modern barley varieties meeting such criteria including disease resistance and drought tolerance. In any given year, the informal farmer-to-farmer seed exchange was the main source of seed for planting wheat and barley crops. The formal sector was an initial source of modern wheat varieties for 59.6% of the farmers, through ACB (50.4%), GOSM (6.6%) or co-operatives (2.6%) and almost a quarter of the farmers obtained certified seed for planting wheat in 1998/99 crop season underlining the strength of the formal sector in Syria. However, the majority of sample farmers sourced their wheat seed informally whereby 59.3% used retained seed or sourced off-farm from neighbours (12.5%) and local traders/markets (4.4%) for planting wheat during the survey year. Similarly, the majority of farmers growing barley got their current seed stock informally from relatives (32.5%), other farmers (22.5%), neighbours (13%) or traders/local markets (18.5%). All seed for planting barley during the 1997/98 crop season was obtained informally, either retained seed (82.5%) or off-farm from other local sources (17.5%). Wheat and barley farmers recognized the difference between grain and seed for planting and as a result practised different management practices to maintain seed quality on the farm. Most wheat farmers practised on-farm selection (53.9%), cleaning (91.9%), chemical treatment (90.3%), separate storage (64.1%) or informal assessment of seed quality (4.4%) when seed was obtained informally. Similar on-farm seed management approaches were also followed for barley seed except for chemical treatment (6.5%). The adoption and diffusion of modern bread and durum wheat varieties and associated technologies were substantially higher than for barley crop. However, given the complex and stressful marginal environment where barley is grown agricultural research is lagging behind in solving the major production constraints of the farmers. It is imperative, however, for the government to put in place alternative strategies to address and strengthen the agricultural research, transfer of technology, input delivery, marketing and grain pricing responsive to the needs of barley growers. Within this context, it is important to recognize the role of the national seed system, both formal and informal, to create a competitive, efficient and sustainable seed industry.

Key words: Syria, wheat, *Triticum* spp., barley, *Hordeum vulgare*, formal seed system, informal seed system, seed source, seed selection, on-farm seed management.

3.2. Introduction

Syria is situated between longitude 33° W and 48° E and between latitude 3.4° S and 15.4° N. It covers an area of 18.5 million ha of which 5.7 million ha is cultivated. Most of the cultivated area (83%) is rainfed. The country is divided into five major agricultural stability zones based on average annual rainfall: Zone 1 (>350 mm); Zone 2 (250-350 mm), the annual rainfall not less than 250 mm every two thirds of years monitored; Zone 3 (250 mm), the annual rainfall is not less than 250 mm every half of the years monitored); Zone 4 (200-250 mm), the rainfall is not less than 200 mm in half of the years monitored; and Zone 5 (desert and steppe <200 mm). About 15, 13, 7, 10 and 55% of the area is located within Zone 1, 2, 3, 4 and 5. Syria has a typical Mediterranean climate with cold and humid winters and dry hot summers which is highly diverse and agro-climatically variable.

According to the statistical abstracts, the agricultural sector contributes 20-25% to the national economy and employs 28.5% (a male to female ratio of 1:2) of the labour force in 1999 (CBS, 2000). Syria has an estimated population of 17.5 million and one of the highest population growth rates in the Middle East region.

Syria is located in the Fertile Crescent, the centre of crop domestication and the cradle of agriculture. Syrian farmers are at the forefront of agricultural experimentation for millennia where they select and improve crops adaptable to one of the harshest environmental conditions in the region (ICARDA *et al.*, 1999). Accordingly, the genetic variability and diversity of local landraces that exists today are the testimony to the ingenuity of traditional agriculture that existed in the region.

The main crops are cereals (primarily wheat in the wetter areas (300-600 mm) and barley in the drier areas (250-350 mm), in rotation with food legumes such as chickpea, lentil and forage legumes. Wheat, legumes and summer crops are more predominant in Zone 1 and 2 whereas barley can be grown in Zone 2, but solely in Zone 3 and 4 under rainfed condition. According to recent statistics, on average, cereals, legumes, oilseeds and industrial crops cover 46, 3.6, 0.5 and 9.1% of the cultivated land, respectively (Table 3.1). Drought, frost and heat stress at anthesis are major abiotic production constraints for crop production.

3.3. Government Agricultural Policy

Wheat and barley are the most important commodities for food and animal feed, respectively. The government agricultural policy, however, attaches high priority to wheat production with express purpose of improving the livelihood of rural population and dire need for achieving food self-sufficiency. The development, adoption and diffusion of modern wheat varieties suitable to Syrian conditions and associated technologies including institutional (extension and credit facilities) and infrastructural (mechanization and irrigation) support were given very high priority (Mazid *et al.*, 1998). Farmers were encouraged to increase production through use of modern varieties, chemical fertilizers, herbicides and pest control measures. The Government provided support for credits, mechanization and irrigation facilities.

3.4. Wheat and Barley Production Trends

Wheat (bread and durum) and barley are the two principal cereal crops grown, both in terms of area and production (Table 3.1). Wheat and barley production fluctuates enormously due to severe abiotic (drought, frost, heat) and biotic (diseases, insects) stresses. Wheat is planted on 1.5 million ha with an average annual production of about 3.5 million tonnes with an overall average close to 2.5 t ha^{-1}. It is grown mainly in Zone 1 (350-600 mm), Zone 2 (250-350 mm) with supplementary irrigation and in fully irrigated areas. About 70% of the wheat area is devoted to durum wheat, whereas the remaining is bread wheat. In the mid 1950s the wheat area was 1.3 million ha and this has increased to 1.8 million ha at the end of the last century, an increase of 38%. From 1973 to 1990 wheat area and production were characterized by a decline in total area, increased use of modern varieties, expansion of irrigated area and yearly fluctuation in total production. However, from the early 1990s there was a dramatic increase both in wheat area and production (Mazid *et al.*, 1998) and production has more than tripled for durum wheat (Shehadeh, 1998).

The national average wheat yield has increased from 600 kg to 2.5 t ha^{-1}. But average grain yield under rainfed condition varies between zones; it ranges from 3 to 5 t ha^{-1} in Zone 1 to 1.2 to 2.5 t ha^{-1} in Zone 2. There is an expansion in the area of irrigated wheat: 40% of the wheat area uses supplementary irrigation and this is associated with a drastic increase in the use of modern varieties. Average yield under irrigated conditions is significantly higher than under rainfed conditions and may reach as high as 6 to 7 t ha^{-1}.

Barley is the second most widely grown cereal crop in Syria. It is predominantly grown in environments where rainfall is variable and low (between 200-300 mm). From 1955 to 1999, the total barley production area has increased from 467,000 ha to nearly to 2 million ha. Allocation of wheat production to wetter and irrigated areas, increased monocropping (less fallowing), increased demand for livestock feed and expansion of barley cultivation to low rainfall marginal areas led to such an increase in barley acreage (Table 3.1). The average grain yield ranged between 1 t ha^{-1} in Zone 2 to 0.5 t ha^{-1} in Zone 3, far below the Central and West Asia and North Africa (CWANA) average of 1,225 kg ha^{-1} or world average of 2,188 kg ha^{-1}. There is no significant breakthrough in developing modern varieties adaptable to low input and marginal conditions where barley is a major crop.

3.5. Wheat and Barley Consumption Trends

In the West Asia and North Africa (WANA) region, wheat is a major staple crop for millions of rural and urban population. Wheat, particularly durum wheat is used in preparation of a variety of traditional foods such as leavened flat bread (*khiboz)*, *burghul*, *frekeh* and *couscous*. *Burghul* is cracked wheat grain that could be cooked/steamed and *frekeh* is prepared from parched immature wheat kernel. Although traditional varieties are still preferred and still persist in cultivation in a few

Table 3.1. Area, production and yield of major crops grown in Syria from 1995/96 to 1999/00 crop season.

Area and production	1995	1996	1997	1998	1999	Average
Area in ha ('000)						
All crops	7861	6988	7365	7296	6668	7235
Cereals	3680	3249	3413	3341	3071	3351
Wheat	1644	1619	1761	1721	1603	1670
Barley	1963	1550	1572	1543	1414	1608
Legumes	253	244	258	313	238	261
Oilseeds	46	39	42	42	30	40
Industrial crops	275	287	319	336	312	306
Production in tonnes ('000)						
All crops	14341	13800	10764	12858	8863	12125
Cereals	6093	5989	4322	5270	3300	4995
Wheat	4184	4080	3031	4112	2692	3620
Barley	1705	1653	983	869	426	1127
Legumes	251	245	181	297	100	215
Oilseeds	28	28	20	26	19	24
Industrial crops	2081	1804	2228	2285	2327	2145
Yield in tonnes ha^{-1}						
All crops	1.8	2.0	1.5	1.8	1.3	1.7
Cereals	1.7	1.8	1.3	1.6	1.1	1.5
Wheat	2.5	2.5	1.7	2.4	1.7	2.2
Barley	0.9	1.1	0.6	0.6	0.3	0.7
Legumes	1.0	1.0	0.7	0.9	0.4	0.8
Oilseeds	0.6	0.7	0.5	0.6	0.7	0.6
Industrial crops[1]	7.6	6.3	7.0	6.8	7.5	7.0

Source: CBS, 2000;

[1] Sugar beet yield was 44.9, 43.5, 42.3, 41.9 and 44.4 for the five years.

pockets in marginal production environments, the modern varieties appear to be accepted by the majority of farmers. Bread wheat is also a principal staple crop of WANA including Syria where the average person consumes more than 170 kg yr^{-1}, the highest in the world. The dependence on wheat combined with rapid population growth and increasing desertification makes this region the world's highest wheat importer.

Barley is used as a feed and forage crop; it plays a major role in livestock crop production systems. In Syria, barley grain and straw are almost entirely utilized as feed for small ruminants particularly sheep, and thus crop and livestock management are closely interlinked. The rising demand for livestock products consequently requires increasing livestock population, thereby increased demand and consumption of feed barley in the form of grain or straw.

3.6. Structure of National Seed Industry

In Syria (as elsewhere), the national seed system is composed of formal and informal sectors. In Chapter 1, we have defined the formal and informal sectors and described what constitutes the national seed industry. In this section we look into those components within the Syrian context.

3.6.1. Formal Seed Sector

The formal seed industry in Syria consists of the national agricultural research systems, seed production and supply organizations, agricultural input supply organizations, agricultural extension services and rural development agencies.

Agricultural Research Contrary to centuries old tradition of crop improvement and seed selection, the emergence of scientific agricultural research was relatively late and started in the 1940s. Initially the Ministry of Agricultural and Agrarian Reform and its affiliated organizations carried out limited agricultural research. In 1964, the Directorate of Agricultural and Scientific Research (DASR) was formally established and given the responsibility to formulate agricultural research policy by identifying constraints limiting agricultural development in the country (ICARDA *et al.*, 1999). DASR is responsible for research primarily on agricultural and horticultural crops and associated disciplines such as agronomy, plant protection and socio-economics and has eight research stations sufficiently covering the key agro-ecological zones of the country. Agricultural research on crop improvements constitutes the largest activity of the DASR which accounts 60%. Since 2002, the agricultural research system has been reorganized and the General Commission for Scientific and Agricultural Research (GCSAR) was established replacing DASR. The Supreme Council of Sciences is officially mandated to define and implement the national scientific research policy and oversee the functioning of the agricultural research institutions.

In addition, there are two regional/international agricultural research centres with focus on widely ranging agricultural issues operating from Syria: the Arab Center for Semi Arid Dry lands (ACSAD) and the International Center for Agricultural Research in the Dry Areas (ICARDA). Both centres have a very strong collaborative research from which Syrian farmers are benefiting.

Wheat and Barley Research Most research on variety improvement has been concentrated on main cereal crops such as wheat, barley and maize, due to strong emphasis on national priorities to achieve food security through sustainable crop and livestock production. Although wheat research began in the early 1950s, organized breeding programmes only started in earnest with the establishment of the DASR in the 1960s. The breeding programmes focus on: (i) improving the performance of local landraces; (ii) use of local landraces and wild relatives in the breeding programmes; and (iii) selecting, screening and identifying segregating germplasm with tolerance to abiotic and biotic stresses in a regional multi-location testing in Syria. The main breeding objectives both in wheat and barley are aimed at improving local landraces and developing new genotypes adapted to different agro-ecological zones. Shehadeh (1998) summarized the abiotic stresses (erratic rainfall, high temperature during grain filling, cold or frost damage during grain filling) and biotic stresses (diseases such as rusts, septoria, bunts, bacterial stripe and insects such as stem sawfly, aphids and sunni bug) for durum wheat. Some of these stresses more or less also equally apply to bread wheat and/or barley.

Agricultural Extension The Agricultural Extension Department of the Ministry of Agriculture and Agrarian Reform is responsible for transfer of technology. The Department has regional offices attached to the agricultural bureau from provincial to district levels where the extension agents are responsible for transmitting the technology to farmers. Mazid (1994) indicated that many extension offices are well spread in rural areas, although contacts with farmers and their role in the transfer of technology appeared to be minimal. However, most of the extension agents located in rural areas also practise part time farming and may play a very crucial role if properly motivated.

Wheat and Barley Technology Transfer The recommended packages for wheat production include use of modern varieties, application of chemical fertilizers, herbicides, pesticides and irrigation (where facilities are available). The joint DASR/ICARDA collaborative programme initiated since the inception of ICARDA in 1977 plays a significant role in the transfer of technology. The collaborative programme conducts on-farm variety trials to identify adaptable crop varieties of wheat and barley for Syrian conditions and demonstrates new technologies to farmers. Syrian farmers benefited very much from such collaborative research work.

Agricultural Input Supply In Syria, the Agricultural Credit Bank (ACB) is responsible for the bulk supply of inputs including credit and financial provisions for state, co-operative and private farmers. The ACB has 114 branches distributed throughout the country. The redistribution of inputs to farmers is effected through service co-operatives where the majority of farmers are members. For example, seed marketing is carried out through ACB which sells seed to farmers on credit with 7% interest rate which is still the responsibility of the government. At present the provision of fertilizers (since late 1990s) and herbicides and pesticides become liberalized where the private sector become responsible for provision of these inputs on competitive basis.

National Seed Policy The commitment of the Syrian Government in increasing agricultural production to achieve food self-sufficiency defines the importance given to the national seed industry. Seed is at the centre stage of national campaigns and is given full support through allocation of adequate material and financial resources. Prior to the mid 1970s, there was no formally organized seed production for agricultural crops in the country except for cotton. In 1975, the Ministry of Agriculture and Agrarian Reform (MAAR) established the General Organization for Seed Multiplication (GOSM). The organization became the sole parastatal corporation entrusted with primary responsibility for seed production and supply of all strategically important agricultural crops. The strategy led to a significant contribution in increasing agricultural productivity by promoting the use of high quality seed of improved varieties by making it available at relatively low prices (at cost or little profit).

Seed Laws and Regulations The General Organization for Seed Multiplication is the only government institution dealing with seeds of agricultural crops. The GOSM is entrusted with the responsibility both for seed production and quality control being the only national agency in the country. Therefore, at present there are no laws, rules and regulations that address issues related to varieties and seeds and no independent seed certification agency exists.

Variety Development The Directorate of Agricultural and Scientific Research (now the General Commission for Scientific and Agricultural Research, GCSAR) is the only public organization with the mandate for variety development of both wheat and barley crops in close collaboration with the regional and international organizations such as ACSAD and ICARDA. ICARDA has a regional and global mandate for wheat and barley improvement, respectively and runs a well-defined strategy to enhance sustainable crop production through germplasm improvement in close co-operation with NARS in the region. Desirable genes from various germplasm sources including local landraces and their wild relatives are introduced to wheat and barley breeding lines. These lines are intensively selected for abiotic and biotic stresses and agronomic performance to identify promising lines. These promising lines are distributed to NARS for evaluation, testing and selection under specific environments. The Syrian NARS are direct beneficiaries from their proximity to and long-term association with ICARDA as these materials are tested under some of the major agro-ecological zones of the country.

Wheat is grown in relatively better-endowed environments under rainfed conditions in Zone 1 where adequate moisture is available or in Zone 2 where supplemental irrigation is practised to overcome any seasonal moisture shortfall. The major objectives of wheat breeding are to improve productivity by developing new varieties with increased yield, better grain quality, tolerance to biotic (diseases and insects) or abiotic (drought, thermal) stresses and which respond better to use of inputs including irrigation where applicable.

Barley is a typical crop for marginal environments where yields are limited by abitotic and biotic factors. In recent years, population pressure and options in mechanization have even pushed barley production to the most marginal areas, where yields are declining. The barley research objective is therefore focused to reverse declining barley production by identifying improved varieties which can better withstand abiotic and biotic stress and give more stable and better quality grain and straw yields than the local landraces widely grown in the country.

Variety Release The General Commission for Scientific and Agricultural Research (GCSAR) is responsible for variety evaluation on its own or through joint collaborative activities with ICARDA or ACSAD. Promising lines of wheat and barley identified by GCSAR will be tested in different agro-ecological zones of the country in on-farm verification trials along well adapted commercial varieties before they are proposed for release. If a variety is found to be better performing in yield and other agronomic characters compared to the standard check, a detailed report is prepared and submitted to the National Variety Release Committee established by the Ministry of Agriculture and Agrarian Reform (MAAR). The Committee is chaired by the Minister of MAAR and composed of representatives from relevant departments of the Ministry, General Commission for Scientific and Agricultural Research, General Organization for Seed Multiplication and the universities.

Each year, the Committee examines and reviews detailed testing reports of candidate varieties based on the request of GCSAR. If a candidate variety shows better value for cultivation and use, the Committee advises the Minister of MAAR to release. After a variety has been released, GOSM obtains breeder seed to start initial seed multiplication. The GCSAR/ICARDA collaborative on-farm trials have identified and released several wheat and barley varieties suitable for Syrian conditions since its inception upon the establishment of ICARDA in 1977 (Shehadeh, 1998).

The variety release system is not formally organized and operates on ad hoc basis, but there is no technical bottleneck in the release system once the Committee makes the decision. The assumption is that farmers are represented through the Ministry of Agriculture and relevant institutions responsible for agricultural development in the country.

Seed Production Since 1976, the General Organization for Seed Multiplication is the only public sector institution dealing with seed production of agricultural (cereals, legumes, oilseeds), industrial (cotton, sugar beet) and horticultural (potato) crops. Although the government policy fully supports the seed industry, the participation of the private sector in so called 'strategic crops' such as wheat, barley and cotton is non-existent. In 1978, GOSM supplied 13% of the wheat seed requirement (Bailey, 1982) and by the mid 1980s it distributed 88,000 tonnes of wheat seed (Al-Ashram, 1990). During the 1994-1999 period, the average seed distribution was 227,869 t yr^{-1} out of which 168,540 tonnes (74%) is seed of agricultural crops (Table 3.2). Wheat and barley seed occupy 94 and 3.4% of agricultural seeds distributed, respectively. If the total seed distribution of all crops is considered, the percentage of wheat and barley seed drops to 69.5 and 2.5%, respectively. Further analysis showed that the proportion of barley seed production gradually dropped from around 8% in 1992 to 1.4% in 1998,

Table 3.2. Quantity of seed distributed (tonnes) by the General Organization for Seed Multiplication from 1994-1999.

Crops	1994	1995	1996	1997	1998	1999	Average	%
Wheat	165,125	166,519	175,478	150,000	139,376	154,266	158,461	69.5
Barley	9,535	4,129	5,507	4,800	3,500	6,986	5,743	2.5
Maize	1,635	1,540	1,498	1,557	1,548	812	1,432	0.6
Faba bean	305	172	145	340	168	242	229	0.1
Lentil	2,008	887	1,417	2,730	400	1500	1,490	0.7
Chickpea	238	387	600	555	580	1470	638	0.3
Soybean	165	211	2,031	552	100	209	545	0.2
Ground nut	14	1	1	0.1	-	-	3	0.0
Potato	32,210	36,912	16,581	18,567	28,839	32,771	27,647	12.1
Cotton	24,300	26,337	28,264	34,611	36,880	32,536	30,488	13.4
Sugar beet	340	512	413	996	1,209[1]	3,698	1,195	0.5
Total	235,875	237,607	231,935	214,708	212,600	234,490	227,869	100

[1] 853 units of monogerm sugar beet seed.

except in years with severe drought when grain is cleaned, treated and distributed as commercial seed.

3.6.2. Informal Seed Sector

Farmers in the Fertile Crescent were the first to domesticate wheat and barley leading to a settled agriculture. For centuries, they have been selecting, maintaining and cultivating local landraces and retaining and exchanging seed with other regions. Syrian farmers are in the forefront of such long experience and have a wealth of indigenous knowledge of informal seed systems. The informal seed system is dynamic and broadly encompasses the processes or intricacies of crop production in the short-term and the improvement and maintenance of genetic resources in the long-term. However, that traditional indigenous knowledge is under threat due to modernization, mechanization and intensification of agriculture.

In Syria, the informal seed sector includes individual private farmers, their relatives, neighbours and local grain/input traders who in one way or another are involved in local seed exchange and/or trade. Local level seed production and distribution by non-governmental organizations (NGOs) are non-existent.

3.7. Objectives

Wheat and barley are two principal cereal crops grown in Syria. Both crops are considered strategic, because of the government policy for self-sufficiency in agricultural and livestock production. The two crops, however, provide very contrasting circumstances in terms of agro-ecological adaptation, farming systems, production, utilization as well as adoption of modern agricultural inputs such as improved varieties, fertilizers and pesticides. Wheat is a main staple food crop grown in relatively better environments whereas barley is used as feed or forage crop grown in less favourable environment, but as an important component in crop-livestock farming systems.

There is a very strong wheat variety development and seed production programme. The adoption and diffusion of modern wheat varieties is believed to be higher than that of other cereal crops. Several varieties have been developed, released and disseminated to farmers with recommended production packages (Hamblin *et al*., 1995; Shehadeh, 1998; Mazid *et al*., 1998, 2003). Tutwiler *et al. (*1997) indicated that promising barley varieties combining relatively high and stable yield potential under stress conditions have been selected and released. Associated agronomic practices such as proper tillage, sowing method and date, seed rate, other techniques have been developed and tested, and recommendations have been formulated for different agro-ecological zones. However, the mechanisms for transferring the barley technology to farmers were either inadequate or nonexistent (Tutwiler *et al.*, 1997). However, there is limited information on farmer's perception of improved varieties and their seed sources and management practices.

Mazid *et al.* (1998) argued that most of the academic studies on technology adoption assume that the developed technology is appropriate and suitable to farmers and tend to focus on defining the characteristics of the farmers, wishing to adopt such technology without due consideration whether or not the technology is suitable to the needs of the farmers. The study of wheat and barley seed systems will provide an interesting comparison of two crops where the pattern of technology adoption is at different stages. The main purpose of the study is to investigate the extent of adoption and diffusion of modern wheat and barley varieties released by the national agricultural research systems, farmers knowledge and perception of released varieties and to understand farmers seed source and management practices.

Therefore, the main objectives of the research were to:

- Study wheat and barley seed systems in Syria to understand the functioning of the national seed sector with particular reference to the informal sector.
- Study and characterize farmers' perception and adoption of modern varieties and associated technologies and criteria for adoption of new varieties to assist breeders to focus on farmers' preferences.
- Study and document farmers' indigenous knowledge of on-farm plant and seed selection, farmer's seed sources and seed management practices as a means to strengthen and develop responsive seed delivery systems.

3.8. Methodology and Data Collection

A questionnaire was designed to gather information on farmers' perception, adoption and diffusion of modern varieties; farmers' seed sources, seed selection and management; and technical (varietal acceptability, seed quality) and socio-economic factors limiting adoption (holding size, credit facilities, input supply, etc.).

3.8.1. Study Areas

The three most important wheat and barley production zones were selected based on the secondary data available from the Central Bureau of Statistics. The three provinces together accounted for nearly 65% of wheat and 78% of barley area in the country based on the annual statistics previous to the survey years.

The Aleppo, Raqqa and Hasakeh governorates in northwestern Syria were selected for both wheat and barley seed system studies (Fig. 3.1). These governorates apart from being representing the major wheat and barley growing zones, also provide some contrasting situations in terms of farming systems and proximity to the main institutions that are responsible to provide basic services in agriculture. The Aleppo governorate represents the major wheat and barley growing areas in the northern part of the country where the headquarters and basic seed farm of the General Organization for Seed Multiplication are located. The Raqqa and Hasakeh governorates represent the major barley and wheat growing areas in northeastern parts of the country. Most of the commercial seed produced by the General Organization for Seed Multiplication should be transported over long distances for distribution and the availability and timely delivery could be a constraint.

3.8.2. Sampling Procedures

A multistage purposive random sampling procedure was followed from higher to lower administrative levels, with farmers being sampling units. A four stage sampling procedure was adopted. The four stages involved selection of provinces, districts, villages and wheat and barley farmers. Within each district Zones 1 and 2 were targeted for wheat production whereas for barley Zones 2, 3 and 4 were selected.

The following approaches were used for sampling the survey area:

First stage: Three major wheat and barley growing provinces were selected from all wheat growing regions in the country, with each province's probability of selection made proportional to the area planted to wheat in the province. This self-weighing sampling procedure resulted in the selection of provinces located in 3 of the country's 14 provinces.

Second stage: Within each of the three selected provinces, two major wheat or barley producing districts were selected at random from among all districts considered as main wheat or barley production districts based on the proportional area planted to wheat or barley in the districts.

Third Stage: Within each of the two selected districts, two enumeration areas were randomly selected once again in proportion to the area of wheat grown in the enumeration areas.

Fourth Stage: Within the enumeration areas, villages and wheat or barley growing farmers were randomly selected based on the list of farmers from the agricultural extension offices. The village is the smallest administrative unit and headed by a chief of the village.

3.8.3. Data Collection

A team of three enumerators and one supervisor conducted the survey. A training course was organized for the enumerators which included a discussion of the objectives of the survey, a detailed question-by-question review of the survey instrument, instructional sessions on interviewing techniques and practice interviews with farmers. After the training the questionnaire was pre-tested during the first day of the survey and further discussed with the enumerators. At the end of each day all questionnaires were checked with the enumerators and clarifications made.

The survey was carried out during October-November in the 1997/98 crop season for barley and during November-December in the 1998/99 crop season for wheat. These periods coincide with the main barley and wheat planting time in the country.

For the wheat seed system study a total of 206 farmers were surveyed, distributed over three provinces, six districts, 61 villages located in different regions of the country (Fig. 3.1). The proportion of wheat farmers from Aleppo, Raqqa and Hasakeh, respectively, were 36.4, 15.0 and 48.5%. The proportion of wheat farmers sampled from Zone 1 and Zone 2 were 33 and 67%, respectively. In each village a minimum of 2 farmers were interviewed and a sample of 1000 g seed was withdrawn from the farmers' seed material intended for planting.

In case of barley a separate 200 farmers were surveyed distributed over three provinces, eight districts and 59 villages (Fig. 3.1). About 47.0%, 23.5% and 29.5% of barley farmers were from Aleppo, Raqqa and Hasakeh provinces, respectively. Moreover, 47.0%, 37.5% and 25.5%, respectively, were from the Zone 2, 3 and 4 production areas of the country.

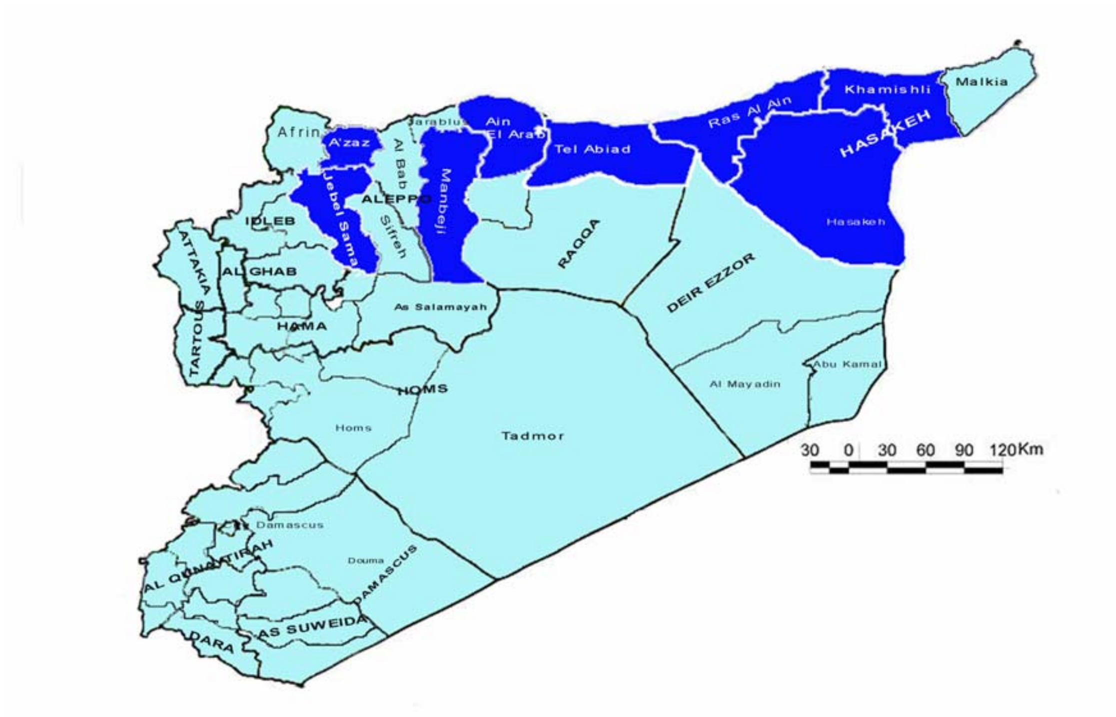

Fig. 3.1. Wheat and barley seed systems study areas (in black) in major crop production regions in northeastern Syria.

3.9. Results and Discussion

3.9.1. Demographic and Socio-Economic Factors

Agriculture is the main source of income for all farmers, although barley farmers in drier zones were involved as migratory seasonal labourers in cotton harvesting for off-farm income generation. Wheat farmers are relatively less likely to be involved in seasonal labour migration from their villages.

About 88% (n=206) of wheat growers interviewed owned land whereas those on government land were about 11%. Similarly, 95% (n=200) of farmers growing barley owned land, whereas the remaining were using government land, but had no legal property rights. In the past, the Government nationalized rural land and redistributed it among farmers. In some areas the land still remains under the government ownership.

Since 1965, the policy encouraged mechanization of agricultural operations. In recent years, the level of mechanization in wheat and barley cultivation has dramatically increased in Syria due to the intensification of agriculture. Almost all farm-level operations such as land preparation, planting and harvesting are carried out by machinery, except in very isolated pockets in the mountainous ranges, stony or very small fields. About 52% of wheat and 34% of barley growers owned tractors individually or shared them with relatives or business partners. The number of farmers who owned combine harvesters was relatively low (less than 5 and 9%, for wheat and barley growers, respectively). Mazid (1994) also found that 29% of barley growers owned tractors and 10% combine harvesters. The farm machineries were also rented to other farmers during the planting or harvesting periods. For example, tractors were hired for land preparation and planting on cash payment whereas the combine harvesters were rented for in kind payments equivalent to 10% of the total grain harvest.

The mean age of wheat and barley farmers surveyed was in the mid 40s (45.5 for wheat and 47.4 for barley) evenly distributed over different age groups and with long experience in farming. For example, the proportion of farmers with over 50 years of age and of those who were involved in agriculture was around 36% of the total number of farmers surveyed with long experience in farming. It also showed the involvement of a relatively younger generation of farmers engaged in agricultural production. Issa (1991) found that 50% of the wheat farmers surveyed were over 50 years old. Similarly, earlier studies found that the age of barley growers ranged from 18 to 80 years with an average of 46 years and with large families (Mazid, 1994). About 86% of farmers in the case of wheat and 94% in the case of barley were married with a mean number of children of 7.1 and with a 1:1 female to male ratio of the children, similar for both groups.

There was a substantial difference in education levels between wheat and barley producers. Wheat farmers who were illiterate constituted one quarter whereas those who did read and write were 54% and those with formal education (elementary or secondary school) were nearly 20% of farmers surveyed. Barley farmers who were illiterate – not able to read or write – constituted 46.5% whereas literate farmers – who did read and write – constituted 44.5%. The remaining 9% had formal education (elementary or secondary school). This in no way suggests that barley growers were more disadvantaged than their wheat growing counterparts, but the remoteness of some barley growing areas might explain the differences. Mazid (1994) found a slightly larger proportion of farmers (60%) who could read and write but his sample did not include farmers from Zone 4. These differences in the level of education might also influence the level of uptake and adoption of modern technologies generated by agricultural research and transferred to farmers by the extension services.

3.9.2. Gender Participation in Wheat and Barley Production

In rainfed Mediterranean agriculture labour requirement is seasonal and particularly high during land preparation and planting and at the end of the cropping cycle at harvesting. In wetter areas weeding requires additional labour where wheat is grown. In Syria agricultural production is undergoing a high rate of mechanization and intensification during the last three decades. In the 1970s, most farmers were using traditional land preparation, planting and harvesting methods, particularly for barley production in marginal areas. In the 1990s, agricultural production changed significantly with the availability of farm machinery and improved production technology including the provision of agricultural inputs such as seed of modern varieties, fertilizers, pesticides and irrigation facilities. The mechanization and intensification of agriculture brought a significant shift in traditional farm operations and use of family labour on the farm. Land preparation, planting and harvesting become mechanized where the machinery is owned individually/jointly or hired. At planting labour is required for cleaning the seed, filling the planter with seed and/or fertilizer mixture and at harvest for packaging and removing the harvested grain from the field. The farmer provides the labour by himself including the family or by hiring labourers during these operations.

Fifty four percent of wheat farmers (n=206) and 34% of barley farmers (n=200) owned tractors and the remaining hired machinery for land preparation and planting. Similarly, 5% of wheat growers and 9% of barley farmers owned combine harvesters and the rest of the farmers hired them for harvesting wheat or barley. Al Ashram (1990) cited that almost all land preparation for all crops, 90% of planting, 95% for harvesting (including threshing) of wheat and barley was mechanized by the mid

1980s. The findings of the survey were consistent with this information where tractors or combine harvesters were used for all field operations with very few exceptions on small landholdings.

According to Tulley (1990) most societies have at least a partial division of labour by sex and age, of varying rigidity. He reported that in northwestern Syria, previously men were responsible for land preparation and planting whereas the women carried out weeding and spreading manures, but both men and women took part in harvesting and threshing. Al-Ashram (1990) reported that in the mid 1980s human labour (family and hired) constituted less than 10% of the production cost for barley and wheat; in agricultural commodities such as cotton and sugar beet this proportion was substantially higher. Most female labour was used for picking cotton and clearing the cotton fields for planting the next crops, usually cereals, during the winter season. It was also observed that male farmers in barley production zones particularly in Zones 3 and 4 worked as migratory labourers for cotton picking in other areas to supplement their income.

While most crop production operations which demand high labour are now mechanized, 47.5%, 48.5% and 83.5% of farmers, respectively reported that men provided supervision or assistance in one form or another during land preparation, planting and harvesting operations of the barley crop (Table 3.3). Moreover, 58%, 65.5% and 91.5% of farmers also hired additional male labourers to assist in these operations in the same order. The latter refers to the usually male combine operator and his assistance. Barley is hardly weeded and a minority of farmers reported that they used men, women, children or labourers for hand weeding. The involvement of women and children in all these operations was less than 5% including weeding where family labour needs for these enterprises on the farm is substantially reduced (Table 3.3). While the participation of men both in land preparation and planting both for wheat and barley was almost similar, the minor difference comes from weeding wheat where the role of women and children in these activities appeared to be higher than for barley (Table 3.3). The role of women and children in overall operations for barley production appeared to be minimal in the survey areas. Al-Ashram (1990) reported that for cereals where most of the operations are mechanized, males contributed 56% of total hours and 87% of hired labour compared to women.

3.9.3. Cropping Pattern and Land Allocation

Area Allocation for Wheat In Syria wheat is mainly grown in Zone 1 and Zone 2 under rainfed conditions and sometimes with supplementary irrigation in Zone 2. In other zones it is uneconomic to produce wheat without full irrigation because of moisture

Table 3.3. Participation of different categories of labour in wheat and barley production in Syria (n=206).

Crop	Labour category	Land preparation		Planting		Weeding		Harvesting	
		Farmers	%	Farmers	%	Farmers	%	Farmers	%
Wheat	Men	86	42	82	40	61	30	11	5
	Women	10	5	0	0	39	19	0	0
	Children	3	2	2	1	26	13	0	0
	Labour	123	60	126	61	69	95	195	95
Barley	Men	95	48	97	49	18	9	167	84
	Women	2	1	10	5	5	3	1	1
	Children	12	6	16	8	7	4	2	1
	Labour	116	58	131	66	9	5	183	92

limitation. Most wheat farmers with access to irrigation water usually plant at least twice, once during the main rainy season under rainfed condition and once with full irrigation during the summer season. Therefore, farmers with access to irrigation facilities usually grew cotton, potato, sugar beet or vegetables as an additional crop in summer. Almost all wheat fields are planted with cotton during the summer season. The number of crops grown per farm can be divided into two categories such as winter crops sown during October to December and summer crops sown in February or later (Table 3.4). In case of wheat the total farm area is based on the area of winter crops as most of the summer crops are planted on area previously planted with winter crops after harvesting.

The mean farm area for wheat producers varied between provinces, i.e., 10.4, 8.9 and 23.4 ha, for Aleppo, Raqqa and Hasekeh provinces, respectively. The overall average wheat area was 9.9 ha (SD=9.9) the mean durum and bread wheat area was 9.1 and 7.8 ha, respectively. Earlier studies found variation in average farm size as well as area allocated to wheat and barley production in different regions of the country (Mazid *et al*., 1998; Mazid, 1994). Al-Ashram (1990) indicated that the land reform laws of 1958 and 1963 specified the upper limits of property owned by each farmer based on agricultural production zones. As a result, the area of holding size with less than 25 ha increased from 30% of the total farm area before the reforms to 93% afterwards (the farm area over 100 ha is 0.23%).

Most farmers grew a wide range of crops on the farm during the winter and summer seasons, i.e., sequentially rather than at one time (Table 3.5). However, one fifth of the farmers (21%) grew only one crop, either bread or durum wheat. Farmers who grew two crops were one third (37%) whereas those growing three crops were about one

Table 3.4. Major crops grown and land allocation by wheat growers during 1998/99 crop season (n=206).

Crop	Aleppo	Raqqa	Hasakeh	No. of farmers	%	Mean area (ha)	SD
Durum wheat[1]	56	13	71	140 (139)	67.9	9.1	8.2
Bread wheat[1]	32	20	49	101 (100)	49.0	7.8	9.5
Barley	34	10	12	56	27.2	11.0	33.5
Lentil	45	-	18	63	30.6	5.5	6.0
Chickpea	14	-	1	15	7.3	2.6	2.2
Faba bean	6	2	1	9	4.4	2.1	1.4
Maize	-	2	1	3	1.5	2.5	0.7
Sunflower	1	-	-	1	0.5	4	na
Potato	7	1	-	8	3.9	2.1	1.3
Sugar beet	3	1	1	5	2.4	2.3	2.0
Vegetables	9	-	1	10	4.9	2.8	3.5
Cumin	4	-	-	4	38.8	3.4	3.8
Cotton	18	30	32	80	1.9	7.9	8.2
Tree crops	7	-	-	7	3.5	5.8	3.9
Total (winter crops)	75	31	100	206	100	13.9	12.8
Total (summer crops)	33	31	33	96	46.6	3.5	6.7

[1] Figures in parentheses show number of farmers when outliers of over 100 ha were removed.

Table 3.5. On-farm diversity of crops grown by wheat farmers in Syria.

Province		Number of crops grown per farm (n=206)							
		1	2	3	4	5	6	7	Total
Aleppo	Farmers	4	17	28	23	-	2	1	75
	%	5	23	37	31	-	3	1	100
Raqqa	Farmers	1	18	7	3	2	-	-	31
	%	3	58	23	10	7	-	-	101
	Farmers	38	42	17	3	-	-	-	100
	%	38	42	17	3	-	-	-	100
Total	Farmers	43	77	52	29	2	2	1	206
	%	21	37	25	14	1	1	1	100

quarter (25%). A mere 14% grew four crops. The major crops grown were wheat and cotton followed by wheat and barley.

Agricultural mechanization and intensification have led to reduction of inter- and intra-crop diversity on the farm where farmers concentrate on optimization of the crop enterprises to achieve maximum benefits. Farmers focus on producing crops that provide better return using their comparative advantage and, therefore, limit their production operation within their resource endowments and existing market opportunities. However, the agricultural sector is in transition and quite a significant number of farmers are still growing a variety of crops, more in case of wheat growers than in barley. The main difference between wheat and barley growers is the lack of alternative crops in the more marginal environments of Zones 3 and 4 where barley is grown.

Area Allocation for Barley The crops grown and area allocated for barley producers is presented in Table 3.6. The mean crop area for barley growers was 24.4 (SD=24.4) whereas the mean area allocated for barley production was 17.14 (SD=17.4). Almost 66% of farmers grew less than the mean area allocated for barley production. The higher standard deviations observed were due to some farmers who had an area of over 100 ha grown contiguously as part of family land ownership particularly in Raqqa governorate.

The major crops and number of varieties grown by farmers sampled for barley survey is given in Table 3.7. Farmers grew as many as six crops including barley, bread wheat, durum wheat, lentil, lathyrus and cotton. A substantial number of farmers (38%) grew barley only as compared to 53% of farmers who grew at least two crops. In addition to barley, about 45.5 and 19.5% of farmers grew modern bread and durum wheat varieties, respectively, mainly in Zone 2 of Aleppo governorates. In much drier

Table 3.6. Main crops grown and land allocation by barley growers during the 1997/98 crop season (n=200).

Crops grown	Aleppo	Raqqa	Hasakeh	Total		Land allocation		Number of
	No of farmers growing			Farmers	%	Area	SD	varieties
Barley[1]	94	47 (45)	59 (58)	200 (197)	100	17.4	17.5	3
Bread wheat	61	19	11	91	45.5	8.2	10.6	6
Durum wheat	7	12	18	39	19.5	10.9	16.9	8
Lentil	6	-	-	6	3.0	2.2	1.47	2
Lathyrus	5	-	-	5	2.5	4.0	3.46	1
Cotton	1	1	2	4	2.0	4.6	1.15	2

[1] Figures in parentheses show number of farmers when outliers of over 50 ha were removed.

Table 3.7. On-farm diversity of crops grown by barley farmers in Syria.

Province	Number of crops grown per farm (n=200)			
	1	2	3	4
Aleppo	26	58	9	1
Raqqa	18	26	3	-
Hasakeh	32	22	5	-
Total	76	106	17	1
%	38	53	8.5	0.5

areas of Zone 3 in Raqqa and Hasakeh governorates most farmers grew barley crop only as wheat production is not economic. This limitation is most probably due to the problem of water availability and crops that are adaptable to the drier areas of Zone 3 and 4 where expansion in barley production is taking place. A similar result was found where more farmers planted non-cereal crops in Zone 2 than in Zone 3 (Mazid, 1994). In Ethiopia about one half of the farmers (47%) grew four crops and one third (36.7%) grew three crops in addition to barley showing more on farm crop diversity (Woldeselassie, 1999).

From 200 farmers who grew barley, 55% also planted modern bread and durum wheat varieties, but they still continued using local landraces of barley crop. Similarly, in Ethiopia although 61.3% of barley growers surveyed adopted modern bread wheat varieties, they also continued cultivating local landraces with no intention of adopting modern barley varieties (Woldeselassie, 1999). The main limitations appear to be not farmers' lack of awareness but rather lack of adaptable varieties that meet their preferences.

3.9.4. Wheat and Barley Production Technology Packages

Agricultural production technology packages are targeted according to agro-ecological zones and crops where the use of high inputs is favoured for modern varieties and favourable environments. The use of modern agricultural technologies and application of irrigation, fertilizers and pesticides have been recommended for wheat production based on the target environments and less so for barley crop.

Sources of Information Farmers use as many multiple sources of information as possible through local social network or from outside sources to acquire knowledge about new agricultural production technologies. The information obtained will be analysed and possibly validated through their own experimentation or through the experiences of their neighbours or other farmers before being adopted and applied on a wider scale.

Wheat farmers had better information regarding modern varieties (100%), agronomic packages (100%), fertilizers (99%), herbicides (97%) and fungicides for seed treatment (96%) in comparison to barley growers (Table 3.8). Fellow farmers (relatives, neighbours and other farmers altogether) were the major source of information for varieties, agronomy and fertilizers. The farmer-to-farmer information exchange played an important role in lateral diffusion of modern varieties as evidenced from wheat seed sources found in this study. Tripp and Pal (1998) also found that other farmers followed by shopkeepers were the major sources of information for hybrid pearl millet growers particularly within villages in Rajasthan, India. On the other hand agricultural extension was the single most important source of information for herbicides (52%), seed treatment chemicals (34%) and modern wheat varieties (22%). Farmers' long years of farming experience also played an important role in using appropriate agronomic packages (32%) and fertilizers (23%) for wheat production. Farmers have good knowledge of the crop production environment and their needs and can make appropriate decisions on varieties they plant and agronomic practices they apply for crop production. There was no variation between regions and zones in access to information among wheat growers.

Table 3.8. Farmers' source of information and awareness of wheat technology packages (%; n=206).

Access to information	Modern variety	Agro-nomy	Ferti-lizers	Herbi-cides	Fungi-cides[1]	Pesti-cides	Grain storage
Have information							
Farmers	206	206	204	200	197	124	115
%	100	100	99	97	96	60	56
Source of information							
Media (TV & radio)	4	3	1	2	2	1	0
Research	5	6	6	6	6	1	0
Extension	22	20	35	52	34	18	11
Relatives	9	16	10	7	4	4	10
Neighbours	18	12	10	5	5	6	7
Other farmers	24	16	10	5	5	4	5
Traders	1	0	0	8	19	11	2
Others[2]	20	32	23	6	9	8	11

[1] Seed treatment (chemical stores);

[2] Others include ACB, GOSM, co-operatives and own experience.

Slightly fewer wheat farmers had information on insecticides (60%) and grain storage (56%). Most of the wheat produced is sold to the government due to attractive price and less grain is stored on farm as compared to barley grain which is kept on the farm as livestock feed. Moreover, epidemic levels of insect outbreaks are usually controlled through government spray programmes and farmers are less involved in actual field sprays for insect control.

About 94, 79, and 71% of the barley farmers have sufficient information about the agronomic practices, fertilizer use and application, and grain storage, respectively (Table 3.9). Barley grain is kept on the farm as part of livestock feed and, therefore, information on storage appeared to be important. In all three cases the informal sources of information such as relatives, neighbours or other farmers appeared to be of major importance for information flow compared to the formal extension services.

Among barley growers only one third of them heard about improved varieties and use of pesticides (herbicides, fungicides and insecticides) for barley production; the formal sector being the main source of information. Although 36% of farmers heard about improved barley varieties none had tried growing them because of lack of varietal adaptability, seed availability or farmers' preferences. In comparison to farmers in Zones 2 and 3, farmers in Zone 4 (n=31) were less aware of the new barley technology including modern varieties (19%), fertilizers (52%) and herbicides (29%)

Table 3.9. Farmers' source of information on barley varieties and agronomic packages (%; n=200).

Access to information	Modern variety	Ferti-lizers	Agro-nomy	Herbi-cides	Pesti-cides	Grain storage
Have information						
Farmers	72	159	187	62	62	141
%[1]	36	79	94	31	31	71
Source of information						
Media	2	1	1	1	2	1
Research	2	1	2	1	-	-
Extension	6	36	18	12	16	14
Relatives	5	11	40	1	2	20
Neighbours	8	17	23	3	1	13
Farmers	6	7	9	4	2	4
Traders	-	-	-		2	2
Experience	2	5	3	2	1	5

[1] Figures may exceed 100% as farmers may use multiple sources of information.

where use of such inputs was discouraged as part of government agricultural policy. It should be noted that about two thirds (65.5%) of farmers sampled for the barley survey also grew bread and durum wheat where they used modern varieties. This suggests that it is lack of technology, not only lack of awareness that limits barley growers in adopting the new technology.

Although the agricultural extension offices are well spread in rural areas and many farmers are aware of their offices and activities only 38% of the farmers visited the extension service offices and only 23% of the farmers had ever been visited by an extension agent (Mazid, 1994). Moreover, many farmers owned radio and television where formal extension programmes were broadcasted, but the informal sources of information such as neighbours and other farmers remained very valuable sources of information on modern varieties, agronomic practices and use of inputs. The establishment of an extension offices network alone cannot provide the necessary transfer of technology unless adequate regular training is provided to the staff and linkages made with agricultural research in communicating new technologies to farmers.

Agronomic Practices In the semi-arid drylands of the Mediterranean environment rainfall is erratic with large spatial and temporal variations. Agronomic practices such as sowing dates, seed rates and use of inputs have significant effects on crop establishment, growth and yield of wheat and barley crops. Sowing dates may have substantial effects on water use efficiency by ensuring early crop establishment to achieve maximum yield in wheat and barley production. The recommended optimum sowing dates are mid-October for barley and mid-November for wheat. However, actual planting dates vary according to winter rainfall whereas farmers delay planting to avoid the risk of early drought at seedling stages because of unreliability of initial rainfalls, pre-planting mechanical weed control and risk of frost damage (Pala, 1998). Delayed planting, however, is also associated with low yield and exposes the crop to terminal drought and thermal stress.

Agronomic Practices for Wheat Crops Unlike barley growers almost all wheat farmers (n=206) used inputs such as fertilizers (100%), herbicides (93%), seed treatment fungicides (90) and storage insecticides (41%) as shown in Table 3.10. One-third of the farmers (36%; n=206) planted wheat after the first rains compared to two-thirds who planted after the second or several rains. Most of these farmers have no irrigation facilities and try to exploit available moisture from the first rains. From the total farmers surveyed about 130 had facilities to grow wheat under full (42%) or supplementary (59%) irrigation, thus had some flexibility in planting early or later in the season. Farmers who planted early before the rains all used full irrigation and experienced less risk from dry spells. Those with supplementary irrigation planted after the first rains or slightly later in the season as they had options to supplement moisture in case the rain ends before the season. Pala (1998) indicated that sowing wheat between mid-October to mid-November had no effect whereas delaying planting to late December substantially decreased the yield from 5 to 4 t ha^{-1} in high rainfall areas. He also indicated that most farmers were risk averse in 80% of the time and as a consequence suffered from low yield and could obtain a yield of more than 1.5 t ha^{-1} in only 15% of the area.

In the early 1990s, about 98% of wheat farmers used tractors for land preparation and 69% for planting and 88% combine harvested (Mazid *et al*., 1998). However, land preparation, planting and harvesting of wheat are highly mechanized. About 93% of farmers used drilling machines for planting whereas the remaining used hand broadcast. Moreover, 96% of the farmers hired combine harvesters whereas the remaining owned a combine for harvesting wheat. This showed a significant increase in mechanized planting and harvesting of wheat crops. For example, in Jordan three quarters of wheat farmers still use hand broadcast while one quarter use manual broadcast showing slightly less mechanization of wheat production (Hasan, 1995).

For bread and durum wheat 120 and 150 kg ha^{-1} of seed, respectively, is recommended for rainfed and 150 kg ha^{-1} for both under irrigated conditions. However, the most interesting difference in seed rates was observed between farmers who used irrigation and those who planted wheat under rainfed conditions. The average seed rate for irrigated and rainfed wheat was 335 (SD=49) and 208 (SD=38) kg ha^{-1}, respectively. This was equivalent to 2.3 and 1.7 times (i.e., substantially higher than) the recommended rates. Farmers using certified seed from the formal sector also followed the same trend, although those planting under rainfed conditions used slightly lower seed rates. Under heavy fertilization and irrigated conditions farmers believed that they could achieve maximum yield using high seed rates. Under irrigated conditions the mean seed rates for Aleppo, Raqqa and Hasakeh were 293 (SD=25), 399 (SD=44) and 328 (SD=29) kg ha^{-1}, respectively. Similarly, for rainfed conditions 192 (SD=27), 233 (SD=29) and 224 (SD=42) kg ha^{-1} was reported in the same order.

Farmers tended to use high seed rates for wheat and barley, often as high as 200 kg ha^{-1}. Van Gastel and Bishaw (1994) also found that the average seed rate used for wheat in Aleppo province was 225 kg ha^{-1} where 38% of farmers were using over 200 kg ha^{-1}, considerably higher than the recommended rate. Farmers in all regions and under irrigated conditions used higher seed rates than the recommended packages (Mazid *et al*., 1998). However, research results indicated that the optimum seeding rate is 110 and 100 kg ha^{-1} for wheat and barley, respectively. Economic analysis indicates that the extra return from using these seeding rates for wheat and barley is US$ 20 and 40 ha^{-1}, respectively, which is economic at the farm and national levels. The extra amounts used are unnecessary and using recommended rates could save large quantities of seed every year.

Both fertilizer and herbicides were widely used by wheat farmers. Farmers who used full or supplementary irrigation had the heaviest fertilizer application.

Agronomic Practices for Barley Crop The agronomic practices used by barley growers such as sowing dates and methods, seed rates and use of fertilizers and herbicides are given in Table 3.11. In northern Syria barley planting should start by mid-October and continue until mid-November during normal years when sowing of wheat commences. Some farmers, particularly those in Raqqah and Hasakeh who rented large-scale contiguous areas from other farmers in drier parts of the country, practised dry planting early in the season. The barley crop was planted right after harvest for practical reasons to overcome labour shortage during the planting period which coincides with cotton harvest in October. The majority of small-scale farmers across the three provinces planted barley after the second rains (67%; n=200) when soil moisture is enough to sustain continuous crop growth to avoid replanting in case of dry spell following first showers. However, about 11% of farmers planted barley before the rains in case rainfall is delayed and 18% planted during the first rains. An insignificant number of farmers planted barley later in the season. There was no significant variation among different regions.

Sowing barley is highly mechanized and 94% of the farmers used drilling machines whereas the remaining farmers used hand broadcast. Mazid (1994) found similar results where 63% of farmers use drilling machine and 24% of farmer use machine broadcast with only 10% of farmers using hand broadcasting. However, there is an increase in the number of farmers using drilling machines for planting barley. The recommended seed rate for barley is about 100 to 120 kg ha^{-1} across different regions and production zones. However, the survey showed that the variation in the seed rate among farmers depended on regions and zones. The overall mean seed rate was 200 kg ha^{-1} (SD=67.5) for all farmers, but average seed rates of 255 (SD=49), 161(SD=42) and 143.5 (SD=29.1) kg ha^{-1} were found for Aleppo, Raqqa and Hasakeh provinces, respectively. Farmers in the Aleppo province tended to use higher seed rate as 71% of barley growers both in Zone 2 and Zone 3 planted over 200 kg ha^{-1}. Almost all farmers in Raqqa and Hasakeh were planting slightly less than 200 kg ha^{-1}. Mazid (1994) reported the use of higher seed rates by barley growers: the average seed rate he observed was 182 kg ha^{-1}. He reported that the use of high seed rate was associated with the use of fertilizers and the expected higher yield.

Table 3.10. Agronomic practices used for wheat production in Syria (n=206).

Agronomic practices	Aleppo		Raqqa		Hasakeh		Total	
	Farmers	%	Farmers	%	Farmers	%	Farmers	%
Planting date								
Before rains	-	-	8	26	19	19	27	13
After first rains (Oct)	42	56	1	3	31	31	74	36
After second rains (Nov)	12	16	9	29	39	39	60	29
After several rains (Dec)	21	28	13	42	11	11	45	22
Total	75	100	31	100	100	100	206	100
Planting method								
Hand broadcast	7	9	8	26	-	-	15	7
Machine broadcast	9	12	4	13	3	3	16	8
Drilling	59	79	19	61	97	97	175	85
Total	75	100	31	100	100	100	206	100
Seed rate in kg ha^{-1} (irrigated) [1]								
220-250	4	5	1	3	1	1	6	3
251-300	24	32	0	0	25	23	49	23
301-350	3	4	5	16	42	39	50	23
351-400	-	-	16	50	2	2	18	8
Over 400	-	-	7	22	-	-	7	3
Sub-total	31	41	29	91	70	64	130	60
Seed rate in kg ha^{-1} (rainfed) [1]								
120-150	4	5	-	-	4	4	8	4
151-200	37	49	1	3	13	12	51	24
201-250	4	5	2	6	16	15	22	10
251-300	-	-	-	-	6	6	6	3
Sub-total	45	59	3	9	39	36	87	40
Total	76	100	32	100	109	100	217	100
Fertilizers								
No	-	-	-	-	1	1	1	1
Yes	75	100	31	100	99	99	205	100
Total	75	100	31	100	100	100	206	101
Herbicides								
No	3	4	8	26	4	4	15	7
Yes	72	96	23	74	96	96	191	93
Total	75	100	31	100	100	100	206	100

[1] 11 farmers (1 farmer from Aleppo, 1 from Raqqa and 9 from Hasakeh) planted both irrigated and rainfed wheat.

The use of new agricultural technology for barley production was limited as only half of the farmers used fertilizers (56%; n=200) and few used herbicides (4%) or insecticides (3%). Most farmers who applied fertilizers were from the Aleppo province (99%; n=94) and were in Zone 2 (78.7%; n=94) and Zone 3 (49.3%; n=75). Most farmers did not practise manual hand weeding and herbicide application for weed control in barley production is uncommon. The use of herbicides is less popular in all regions as they were mostly located in relatively drier areas. Farmers in Zone 4 neither used fertilizers nor herbicides. Mazid (1994) also found differences in fertilizer adoption rates between different zones in northwestern Syria with higher adoption rates in Zone 2 than in Zone 3.

Table 3.11. Agronomic practices used for barley production in Syria (n=200).

Agronomic practices	Aleppo		Raqqa		Hasakeh		Total	
	Farmers	%[1]	Farmers	%	Farmers	%	Farmers	%
Planting time								
Before rains	8	9	12	26	2	3	22	11
First rains	18	19	5	11	12	20	35	18
Second rains	63	67	27	57	44	75	134	67
Several rains	5	5	3	6	1	2	9	5
Total	94	100	47	100	59	100	200	101
Planting method								
Hand broadcasting	8	9	-	-	5	8	13	7
Machine drilling	86	91	47	100	54	92	187	94
Total	94	100	47	100	59	100	200	101
Seed rate in kg ha^{-1}								
Up to 100	-	-	5	11	12	20	17	9
101-150	4	4	25	53	30	51	59	30
151-200	23	25	12	26	17	29	52	26
201-250	25	27	5	11	-	-	30	15
251-300	39	42	-	-	-	-	39	20
Over 300	3	3	-	-	-	-	3	2
Total	94	101	47	101	59	100	200	102
Fertilizers								
No	1	1	33	70	54	92	88	44
Yes	93	99	14	30	5	8	112	56
Total	94	100	47	100	59	100	200	100

[1] Percentage figures do not add to 100 because of rounding.

Perception of Soil Fertility Soil fertility is one of the most important factors that affect agricultural production and productivity. Soil amendments such as use of inorganic fertilizers are useful to overcome natural soil deficiency by providing ready-made nutrients to growing crops. However, the use of fertilizer is associated with agro-climatic conditions particularly the availability of adequate moisture. Wheat is grown in the relatively better-endowed environments in Zone 1 and Zone 2. Most farmers considered soil fertility not a major constraint whereas 74% (n=206) had the perception that they could consider the soil fertility of their plots as good (Table 3.12). About 26% of the farmers believed that the soil fertility was a constraint for wheat production. However, they applied significantly more fertilizer than the barley growers because wheat farmers perceived that in favourable areas the use of fertilizer is not risky.

Seventy eight percent of the barley farmers believed that the fertility of their land was medium to low (Table 3.12). Farmers in Zone 3 and Zone 4 considered the fertility of their land medium to low. However, despite such perception the use of inorganic fertilizers was less because most of the farmers perceived the risk of using fertilizers in drier areas with erratic rainfall.

Fertilizer and Herbicide Use and Application In Syria, recommendations for application of inorganic fertilizers are based on agro-ecological zones, both for wheat and barley. Urea (46% N) and ammonium nitrate (30/33% N) are the two most common sources for nitrogen-based fertilizers, the latter more preferable for top dressing due to its immediate availability for growing plants. Super phosphate (46%

Table 3.12. Wheat and barley growers' perception of soil fertility in different regions of Syria.

Perception of soil fertility	Aleppo		Raqqa		Hasakeh		Total	
	Farmers	%	Farmers	%	Farmers	%	Farmers	%
Wheat (n=206)								
Good	55	73	25	81	72	72	152	74
Medium	20	27	6	19	28	28	54	26
Total	75	100	31	100	100	100	206	100
Barley (n=200)								
Good	13	14	18	38	13	22	44	22
Medium	75	80	22	47	38	64	135	68
Poor	6	6	7	15	8	14	21	11
Total	94	100	47	100	59	100	200	101

P_2O_5) is used as source of phosphorus. ICARDA (1992) indicated that a critical level of available phosphorus of about 33 kg P_2O_5 gave around 90% maximum total dry matter production. In wheat, it was also reported that the mean yields of grain and straw across the 70 sites showed highly significant response only to N fertilizer (ICARDA, 1992). The same report concluded that response to phosphorus was non-significant although a trend of yield increase was observed from phosphorus application.

Fertilizer Use and Application on Wheat There was dramatic adoption and use of inorganic fertilizers by almost all farmers (99.5%; n=206). It was found that 97 farmers (47%) applied both nitrogen and phosphorus at planting followed by split application of nitrogen whereas 90 farmers (44%) applied phosphorus only at planting followed by split application of nitrogen with exception of one farmer. However, few farmers applied nitrogen as single fertilizer later in the growing season as split only (5%) or at planting time followed by split application (2%) except one farmer who did not apply split. These combinations of fertilizer use resulted in a situation where 189 farmers (92%) applied super phosphate at planting time compared to 105 farmers (51%) who applied nitrogen at planting time and 201 (98%) farmers who applied nitrogen as split. The adoption of both nitrogen and phosphorus based fertilizers for wheat production was spectacular. Wheat production in wetter and/or irrigated areas coupled with the use of new technology including fertilizers enabled Syria to be self-sufficient in wheat production (Mazid *et al*., 1998).

In general, nitrogen should be applied both at planting time and later during the vegetative growth stage as top dressing whereas phosphorus should be applied at planting time only. Some farmers applied nitrogen at least three times once at planting and twice as top dressing. Five important issues were arising from the application of nitrogen and phosphorus contrary to the general recommendation. First, most farmers applied phosphorus at planting time and some without nitrogen fertilizers (90 farmers). Second, only 105 farmers applied nitrogen at planting time possibly trying to avoid the risk of nitrogen in the absence of sufficient moisture where the crop could not make use of the available nutrients because of late emergence due to low temperatures or if planting was delayed. Third, almost all farmers applied nitrogen fertilizers at the early vegetative stage in February when the crop started tillering and making use of available nutrient and moisture. Fourth, some farmers (26%) particularly those with irrigation facilities, applied nitrogen as split for the second time in late March or early April based on research recommendations. Fifth, farmers used and applied more nitrogen than phosphorus on wheat. Such practices of fertilizer application could be attributed to farmers' perceptions and research recommendations to make better use of the availability of irrigation water to increase production.

The application of fertilizer for wheat production is presented in Table 3.13. Despite different fertilizer recommendation domains, there was no notable difference in terms of the quantity applied between Zone 1 and Zone 2. The proportion of farmers reported applying nitrogen and phosphorus was also similar, although the number for nitrogen (urea) was less in Zone 1 than in Zone 2 (data not shown). This could be attributed to the availability of fertilizers rather than any specific issues.

A total of 189 wheat farmers applied phosphorus at planting, i.e., 62 in Zone 1 and 127 in Zone 2. The recommended rate for phosphorus application for irrigated wheat, Zone 1 and Zone 2, was 96, 46 and 41.4 kg ha^{-1} P_2O_5. This requires applying 200, 100 and 90 kg ha^{-1} of super phosphate, respectively. The mean rate of phosphorus applied was 175 kg ha^{-1} (SD=70) with a range from 50 to 500 kg ha^{-1} showing a wide variation in the amount of phosphate fertilizer used. The average fertilizer use was higher than the recommended rate and a significant proportion of farmers applied more than the recommended rate: 69% used more than 100 kg ha^{-1} super phosphate both in Zone 1 and Zone 2.

Farmers sourced nitrogen from urea (46% N) or ammonium nitrate (30/33% N) both at planting and as split, with more farmers using urea than ammonium nitrate. About 105 farmers applied urea (17 in Zone 1 and 65 in Zone 2) or ammonium nitrate (10 in Zone 1 and 13 in Zone 2) at planting time. The recommended rate for nitrogen application is 138, 92, and 69 kg N ha^{-1} for irrigated wheat, Zone 1 and Zone 2, respectively with 50% to be applied at planting time. This requires an application of 200/300 and 150/200 kg ha^{-1} of urea/ammonium nitrate for Zones 1 and 2, respectively, of which half should be applied at planting.

The overall average urea or ammonium nitrate applied at planting was 139 (SD=92) and 97 (SD=57) kg ha^{-1}, respectively with a range from 50 to 500 kg ha^{-1}. Urea was applied at the rate of 113 kg ha^{-1} (SD=87) in Zone 1 and 145 kg ha^{-1} (SD=116) in Zone 2. Similarly, ammonium nitrate was applied at the rate of 73 kg ha^{-1} (SD=38) in Zone 1 and 115 kg ha^{-1} (SD=63) in Zone 2. The average application of urea was more than the recommended rate of 100 and 75 kg ha^{-1}, respectively, at planting for Zone 1 and Zone 2. On the other hand for ammonium nitrate it was less than the recommended rate of 150 and 100 kg ha^{-1} for Zone 1 and Zone 2, respectively. The overall average application for urea was more by one-third than the recommended rate whereas for the ammonium nitrate it was less by one third (Table 3.13). About 16% of farmers applied more than the recommended rate for urea. It is interesting to note that farmers in Zone 2 applied more urea fertilizer than in Zone 1 probably because of supplementary irrigation.

A total of 201 farmers applied nitrogen as split in the form of urea or ammonium

Table 3.13. Fertilizer use and rate of application for wheat production in Syria (n=206).

Fertilizers	Rate in kg ha^{-1}	Aleppo		Raqqa		Hasakeh		Total	
		Farmers	%[1]	Farmers	%	Farmers	%	Farmers	%
Fertilizer at planting									
	No	4	5	1	3	6	6	10	5
	Yes	71	95	30	97	94	94	195	95
	Total	75	100	31	100	100	100	205	100
Phosphorus	Up to 50	4	5	1	3	1	1	6	3
	51 to 100	12	16	5	16	23	23	40	19
	101 to 150	14	19	6	19	29	29	49	24
	151 to 200	27	36	3	10	24	24	54	26
	201 to 250	7	9	10	32	14	14	31	15
	251 to 300	1	1	3	10	1	1	5	2
	Over 300	1	1	2	7	1	1	4	2
	Total	66	88	30	97	93	93	189	92
Urea/Nitrate	Up to 50	13	17	3	10	9	9	25	12
	51 to 100	9	12	13	42	21	21	43	21
	101 to 150	4	5	5	16	8	8	17	8
	151 to 200	6	8	2	7	3	3	11	5
	201 to 250	0	0	1	3	3	3	4	3
	Over 250	0	0	1	3	4	4	5	2
	Total	32	43	25	81	48	48	105	51
Split application									
	No	2	3	1	3	2	2	5	2
	Yes	73	97	30	97	98	98	201	98
Urea/Nitrate	Up to 50	1	1	1	3	6	6	8	4
	51 to 100	8	11	9	29	15	15	34	17
	101 to 150	22	29	4	13	21	21	50	24
	151 to 200	29	38	8	26	13	13	55	27
	201 to 250	12	16	5	16	17	17	36	18
	251 to 300	1	1	2	6	14	14	17	8
	Over 300	1	1	1	3	11	11	13	6
	Total	74	99	30	97	97	97	201	98

[1] Percentages for the provinces are calculated based on the total number of farmers in each province.

nitrate (Table 3.13). From 132 farmers who used urea, 36 and 96 applied it in Zone 1 and Zone 2, respectively. From 69 farmers who applied ammonium nitrate, 32 and 37 applied it in Zone 1 and Zone 2, respectively. The average quantities of urea and ammonium nitrate applied as split were 208 (SD=89) and 169 kg ha^{-1} (SD=74), respectively. The high average rate could be attributed to one time application by the majority of farmers which is close to the recommended rate for urea, but accounts for two-thirds of the recommended rate for ammonium nitrate. In case of urea 119 farmers (58%; n=206) applied more than the recommended rate of 100 kg ha^{-1} and 26% above the average applied as split. On the other hand 42 farmers (20%) applied less than the recommended rate of 150 kg ha^{-1} for ammonium nitrate.

A total of 56 farmers applied nitrogen as split for the second time later in the season. Thirteen (6%) farmers applied nitrate as a second split (mean 148 kg ha^{-1}; SD=71) whereas 43 farmers (21%) applied urea (mean=166 kg ha^{-1}; SD=56). Earlier studies reported that the majority of wheat farmers in northwestern Syria apply phosphorus (53%) and nitrogen (67%) fertilizers (Issa, 1991). Issa (1991) found that farmers apply 142 kg ha^{-1} phosphorus and up to 262 kg ha^{-1} of nitrogen fertilizers. He also observed variation in the proportion of farmers using fertilizers between different years and the fertilizer application rates used based on rainfall. The present study, however, found higher adoption of fertilizer for wheat production.

The application of fertilizer could be made manually by hand broadcasting, machine broadcast by a spinner or direct drilling by mixing the fertilizer with seed at planting (Table 3.14). Farmers used a combination of these practices both for nitrogen and phosphorus. From those who applied phosphorus at planting 20, 18 and 53% of farmers machine drilled, hand broadcasted or machine broadcasted, respectively. In case of urea or ammonium nitrate, these figures were 13, 13 and 25%, respectively. However, more farmers applied phosphorus by mixing with seed and direct drilling as compared to nitrogen to avoid damage to the seed. Most of the fertilizer was applied before planting by incorporating with soil prior to planting, both in case of phosphorus (54%) and nitrogen (29%). The split application was equally divided between applying in February or early March to April with 45 and 49%, respectively.

Herbicide Use and Application on Wheat The provision of herbicide has been liberalized recently, which allowed import by the private sector increasing the availability on the market. Almost all farmers applied herbicide for wheat production (93%; n=206) compared to barley where only 4% (n=200) used herbicide. Earlier reports indicated that herbicide is the least adopted external input applied by only 42% of farmers although variation exists between different regions (Mazid *et al.*, 1998). This showed a substantial increase in use of herbicide for wheat production.

Table 3.14. Method and time of fertilizer application for wheat production (n=206).

Fertilizer application	At planting				Split		
	Phosphorus		Urea/nitrate		Urea/nitrate		
	Farmers	%	Farmers	%		Farmers	%
Method of application					*Method of application*		
Drilled with seed	42	20	27	13	Hand broadcast	121	59
Hand broadcast	38	18	26	13	Machine broadcast	80	39
Machine broadcast	109	53	52	25	Total	201	98
Total	189	92	105	51			
Time of application					*Time of application*		
Pre-planting	112	54	59	29	Vegetative	92	45
Planting	77	37	46	22	Tillering to booting	101	49
Total	189	92	105	51	Booting to heading	8	4
					Total	201	98

A variety of herbicides were used, namely; Asert, Avenge, U46 Combi, Granstar, Grasp, Illoxan, Topek for control of broad leaf and grass weeds for wheat and barley production. From those who used herbicide 40, 35 and 7% (n=191) applied U46 Combi, Topek and Asert, respectively. Avenge (2%), Granstar (2%), Grasp (2%), Illoxan (3%) were used by few farmers. About 10% of the farmers could not give the exact name of the herbicide used for weed control. U46 Combi is a broad-spectrum broad leaf herbicide for wheat and barley whereas Topek is used to control grass weeds (oats, phalaris, etc.) in wheat only. Asert can be used for both grass and broad leaf weeds, but has a residual effect on legumes, particularly lentil, if planted immediately after the cereal crop.

The rate, time and method of application for two most widely used herbicides U46 Combi and Topek are given in Table 3.15. Almost one-third of the farmers applied U46 Combi at the rate of 1 l ha^{-1} slightly less than the recommended rate of application which is 1.5 l ha^{-1}. For Topek the rate of application was within the acceptable range of 180 to 200 cc ha^{-1}. U46 combi should be applied when the cereal crop reached five leaf stage to the end of tillering whereas for Topek it should be at three leaf stage to stem elongation providing a wide scope for application time. Most application was carried out in March which is the vegetative stage of wheat crop. The majority of farmers used tractor to apply U46 Combi whereas one-third used hand sprayers in case of Topek.

Use of Irrigation for Wheat Production The proportion of farmers using irrigation was

– as expected – less in Zone 1 (12%; n=130) than in Zone 2 (88%) where rainfall is a limiting factor. In Zone 2, the frequency of irrigation was higher (the majority was more than four times) and the intervals between irrigations were shorter as compared to Zone 1. In general, farmers had a tendency to irrigate frequently and excessively because of low cost of water and irrigation facilities.

In Syria, the area under supplementary or full irrigation has expanded tremendously and this played a key role in stabilizing crop production. According to Mazid *et al.* (1998) irrigated wheat area expanded from 9% in 1973 to 20% in the 1980s and 38% in the 1990s and continues to increase. In areas where sufficient rainfall is available farmers use supplementary irrigation particularly later in the season (Zone 1 and Zone 2) whereas full irrigation is used in drier areas with no or insufficient rainfall for crop production. However, irrigation is more used for wheat production than for barley because farmers perceived higher yields and better economic benefits from wheat due the availability of modern varieties which are responsive to higher inputs.

Mazid *et al.* (1998) described that for wheat (durum) the package recommends six times for full irrigation (Al-Furat and Hasskeh), one or two supplementary irrigation (western regions), two to three irrigations in Zone 1, and four irrigations in Zone 2,

Table 3.15. Types and rates of application of herbicides for wheat production (n=206).

Herbicide application		U46		Topek	
		Farmers	%	Farmers	%
Rate of application ($l\ ha^{-1}$)	Up to 0.16	-	-	12	18
	0.17 to 0.20	-	-	12	18
	0.21 to 0.25	7	9	7	11
	0.26 to 0.50	3	4	24	36
	0.51 to 1	46	60	14	21
	1.1 to 1.5	9	12	2	3
	Over 1.50	12	16	2	3
	Total	77	100	66	100
Time of application	Vegetative	0	0	2	3
	February	6	8	9	14
	March	63	82	48	73
	April	8	10	7	11
	Total	77	100	66	100
Method of application	Hand sprayers	6	8	25	38
	Tractor mounted	71	92	41	62
	Total	77	100	66	100

each irrigation with 750 m^3 ha^{-1}. From a total of 206 farmers, one hundred thirty (63%) had access to irrigation water, i.e., 15% in Aleppo, 14% in Raqqa and 34% in Hasakeh provinces, but the majority used supplementary irrigation for wheat production (Table 3.16). The irrigation method used was usually surface/furrow irrigation (91%; n=130) and the frequency was high, ranging between 4 to 6 times (71%) which could be considered as full irrigation. A similar result was observed among wheat growers in Syria where 58% use supplementary irrigation, 39% full irrigation and 3% use both methods (Mazid *et al*., 1998). They also indicated that traditional flooding/surface irrigation was the most commonly used irrigation method whereas only less than 10% used sprinkler irrigation. The traditional surface irrigation may result in waste of precious water resources.

Fertilizer and Herbicide Use on Barley Crop For barley production, in Zone 2 it is recommended to apply 41.4 kg ha^{-1} each for N and P_2O_5. In Zone 3, nitrogen should be applied at a rate of 27.6 kg ha^{-1} and P_2O_5 at a rate of 36.8 kg ha^{-1}. In both cases half of N should be applied at planting and half as split later during the vegetative stage. Most farmers in Zone 3 and 4 do not apply fertilizer to their barley crops. Several authors recognized the need for application of inorganic fertilizer on barley in

Table 3.16. Types and methods of irrigation used by farmers for wheat production (n=130).

Irrigation practices		Aleppo		Raqqa		Hasakeh		Total	
		Farmers	%	Farmers	%	Farmers	%	Farmers	%
Type	Full	10	32	12	41	32	46	54	41
	Supplementary	21	68	17	59	38	54	76	59
	Total	31	100	29	100	70	100	130	100
Method	Surface/furrow	23	74	27	93	68	97	118	91
	Sprinkler	8	26	2	7	2	3	12	9
	Total	31	100	29	100	70	100	130	100
Frequency	1 to 3	26	84	2	7	9	13	37	29
	4 to 6	5	16	26	90	61	87	92	71
	7	-	-	1	3	-	-	1	1
	Total	31	100	29	100	70	100	130	100
Interval	10 to 19	8	26	8	28	23	33	39	30
	20 to 29	15	48	12	41	44	63	71	55
	30 and over	8	26	2	7	3	4	13	10
	Total	31	100	22	76	70	100	123	95

Syria. However, the application is restricted to Zones 2 and 3. Mazid *et al*. (1999) reported that earlier studies indicated low adoption of fertilizer and less credit and policy support for barley production in marginal areas. They indicated that diagnostic surveys in early 1980s showed low use of fertilizer in barley (10%). However, farm level studies indicated that fertilizer use on rainfed barley is profitable and would increase both grain and straw production.

The use of inorganic fertilizers and herbicide for barley production was still limited. Only 56% (inorganic fertilizers) and 4% (herbicides) (n=200) of the farmers applied them. From 112 farmers who used fertilizers on barley, 70 (63%) applied N (urea or ammonium nitrate) and P_2O_5 (super phosphate) at planting and an additionally split application of N (urea or ammonium nitrate) later during the vegetative growth stage. Thirty farmers (27%) applied N and P_2O_5 at planting time only. Similarly, four farmers applied phosphorus only at planting, followed by nitrogen as a split. A mere seven farmers applied either urea (1) or ammonium nitrate (6) as split only. The latter two modes of application were most common in the Raqqa province. The overall number of farmers who applied nitrogen and phosphorus was 112 and 105 farmers, respectively.

From the total number of farmers who used fertilizers (n=112), 94% applied phosphorus at planting time whereas 90% applied nitrogen at planting and 72% as split later in the season (Table 3.17). The mean fertilizer rates used for urea and super phosphate at planting were 73 (SD=35) and 96 (SD=42) kg ha^{-1}, respectively, whereas for the split application of urea or nitrate the average was 70 kg ha^{-1} (SD=41). The average fertilizer used for farmers from Aleppo province was 73 kg ha^{-1} (SD=33) for urea/ammonium nitrate and 96 kg ha^{-1} (SD=41) for super phosphate at planting and 64 kg ha^{-1} (SD=32) as top dressing. Comparison among different provinces appeared to be less valid due to small number of samples from other provinces. The mean urea/ammonium nitrate applied at planting in Zone 2 and Zone 3 was 80 (SD=33) and 61 (SD=35) kg ha^{-1} whereas the super phosphate application was 102 (SD=39) and 83 (SD=45) kg ha^{-1} in the same order. The mean urea/ammonium nitrate applied as top dressing was 70 kg ha^{-1} (SD=42/38) both in Zone 2 and Zone 3. Two thirds of farmers applied less than 75 kg ha^{-1} urea or ammonium nitrate where almost similar trend was followed for split application. On the other hand one third of farmers applied less than or equal to 75 kg ha^{-1} of super phosphate at planting time. In all cases the mean fertilizer used was slightly higher than the recommended rates. In general, farmers applied more fertilizers in Zone 2 than in Zone 3 and used more urea as the main source for nitrogen in both cases. Mazid (1994) found that barley farmers used 45 and 23 kg ha^{-1} of N and P_2O_5, respectively at planting and 30 kg ha^{-1} of N as top dressing with higher adoption rates in Zone 2 than in Zone 3.

Table 3.17. Fertilizer use and rates of application for barley production (n=200).

Rate in kg ha^{-1}	Aleppo		Raqqa		Hasakeh		Total	
	Farmers	%[1]	Farmers	%	Farmers	%	Farmers	%
Use of fertilizers								
No	1	1	33	70	54	92	88	44
Yes	93	99	14	30	5	8	112	56
Total	94	100	47	100	59	100	200	100
At planting-urea/nitrate in kg ha^{-1}								
Less or equal to 50	40	43	4	9	2	3	46	21
51 to 75	28	30	-	-	-	-	28	14
76 to 100	14	15	2	4	-	-	16	8
101 to 150	10	11	-	-	-	-	10	5
Equal to 200	-	-	-	-	1	2	1	0.5
Total	92	98	6	13	3	5	101	55.5
At planting-super phosphate in kg ha^{-1}								
Less or equal to 50	26	28	3	6	2	3	31	16.5
51 to 75	10	11	2	4	-	-	12	6
75 to 100	27	29	3	6	-	-	30	15
100 to 150	29	31	2	4	-	-	31	16.5
Equal to 200	-	-	-	-	1	2	1	0.5
Total	92	98	10	21	3	51	105	52.5
Top dressing-urea/nitrate in kg ha^{-1}								
Less or equal to 50	42	45	5	11	3	5	50	25
51 to 75	11	12	1	2	-	-	12	6
76 to 100	9	10	1	2	1	2	11	5.5
101 to 150	3	3	2	4	-	-	5	2.5
151 to 200	1	1	-	-	1	2	2	1
Over 200	-	-	1	2	-	-	1	0.5
Total	66	70	10	21	5	9	81	40.5

[1] Percentages for the provinces are calculated based on the total number of farmers in each province.

Almost all barley farmers applied both nitrogen and phosphorus fertilizers by mixing the fertilizer with seed and planting at the same time (99%; n=101/105). However, the majority of farmers who applied nitrogen as top dressing used manual broadcasting (93%; n=81) compared to 7% who used machine broadcast. Almost all fertilizer was top dressed during the vegetative stage in February or March.

3.9.5. Farmers' Adoption and Perception of Wheat and Barley Varieties

Wheat Varieties Grown by Farmers In Syria, wheat (particularly durum) is the most important crop from an economic and social point of view. Durum wheat occupies over two thirds of the 1.5 million ha of wheat area in the country and it is more adapted to semiarid climates than bread wheat. Farmers continue to grow durum wheat from ancient times; and as a result ancestors of durum wheat and their wild relatives are still found in certain parts of the country (Shehadeh, 1998).

Hourani was the most widely grown popular local landrace until the mid 1970s before the introduction of modern wheat varieties to the Syrian farmers (Bailey, 1982). Initially, Senator Cappelli (durum wheat variety released in 1937, Italy) and Florence Aurore (bread wheat released in 1932, France) were introduced and cultivated in the country. This was followed by the introduction of CIMMYT first generation modern varieties (1971) such as Mexipak from Mexico. Since the establishment of ICARDA in 1977, eight bread (Cham 2, Cham 4, Cham 6, Cham 8*, Douma 11670*, Bohouth 2, Bohouth 4 and Bohouth 6) and six durum (Cham 1, Cham 3, Cham 5, Cham 7*, Om rabi, Bohouth 5 and Bohouth 7*) wheat varieties have been released through a partnership with the Directorate of Agricultural and Scientific Research until the end of 2002 (*released after survey year). Moreover, some wheat varieties were released by DASR [Bohouth 1 (1980), Gezira 17 (1975), Jouri 69 (1970)] or in co-operation with ACSAD (ACSAD 65, 1987). The list of wheat varieties grown currently by farmers in Syria is presented in Table 3.18.

In the 1998/99 crop season about 62 and 38% of the sample farmers grew durum and bread wheat varieties, respectively, across the survey region in Aleppo, Raqqa and Hasaskeh governorates. This result is similar to the findings of Mazid *et al*. (1998). Farmers grew six modern durum wheat varieties (five recommended, one obsolete) and one local landrace (Table 3.18). Among durum wheat varieties Cham 3 was planted by 26% of farmers (n=273) both in the Aleppo and Hasakeh provinces and followed by Lahan (10%), Bohouth 5 (8.4%) and Cham 1 (5.9%). The proportion of Lahan had increased to nearly 10% despite the fact that the variety was not officially released, but remained widely popular in different regions of the country. Although the variety was officially rejected for release on grounds of late maturity, farmers found that the variety is highly responsive to irrigation and gives higher grain yield. Mazid *et al*. (1998) found that Cham 1 and Cham 3 were the most widely grown varieties, both in terms of durum wheat area (33 and 30% of area) and the proportion of farmers growing them (22 and 24% of farmers), respectively. Van Gastel and Bishaw (1994) also found that Cham 1 was grown by 28% of farmers whereas Cham 3 was grown by 11.1% in the Aleppo province. Since then the proportion of Cham 1 is declining whereas that of Cham 3 has slightly increased.

Similarly, bread wheat growers planted eight modern (five recommended, one obsolete) and two not officially recommended varieties (Table 3.18). In case of bread wheat Cham 6 was planted by 23% of farmers followed by Cham 4 (9.5%), Bohouth 6 (2.2%) and Bohouth 4 (1.1%). If only bread wheat varieties (n=105) were considered the proportion of farmers growing these varieties will be 59, 24.7, 5.7, 2.9%, respectively in the same order. The obsolete bread wheat variety Mexipak was still grown by 1.5% of the total wheat growers (or 3.8% of the bread wheat). Van Gastel and Bishaw (1994) found that Cham 4 was grown by 13.6% of farmers in the Aleppo province.

In 1973, the local landraces accounted for 92% of the wheat area (Mazid *et al.*, 1998); and the area coverage was reduced to 45% by the late 1970s. From 1972 to

Table 3.18. Wheat varieties currently grown by farmers in different regions of Syria (n=273).

Wheat type	Variety	Origin	Year released	No of farmers growing Aleppo	Raqqa	Hasakeh	Total	%
Durum wheat								
Recommended	Cham 1	DASR/ICARDA	1984	16	-	-	16	5.9
	Cham 3	DASR/ICARDA	1987	25	-	46	71	26
	Cham 5	DASR/ICARDA	1994	4	1	6	11	4
	Acsad 65	ACSAD	1987	9	-	9	18	6.6
	Bohouth 5	DASR	1987	1	9	13	23	8.4
Not recommended	Lahan	CIMMYT/ICARDA	-	19	2	5	26	9.5
Obsolete	Gezira 17	DASR	1975	-	2	-	2	0.7
Local landrace	Hamari	Landrace		1	-	-	1	0.4
	Sub-total			75	14	79	168	61.5
Bread wheat								
Recommended	Cham 2	CIMMYT/ICARDA	1984	1	-		1	0.4
	Cham 4	CIMMYT/ICARDA	1986	3	15	8	26	9.5
	Cham 6	CIMMYT/ICARDA	1991	24	3	35	62	22.7
	Bohouth 4	DASR	1987	-	3	-	3	1.1
	Bohouth 6	DASR	1991	3	1	2	6	2.2
Not recommended	Memof	CIMMYT/ICARDA		1	-	-	1	0.4
	Lagous	CIMMYT/ICARDA		2	-	-	2	0.7
Obsolete	Mexipak	CIMMYT	1971	-	-	4	4	1.5
	Sub-total			34	22	49	105	38.5
	Total			109	36	128	273	100

1977, the wheat area was covered by modern wheat varieties such as Mexican (35%), Florence Aurore (5%) and Senator Cappelli (15%) whereas the remaining was covered by the local landraces such as Hamari, etc. (Bailey, 1982). Tutwiler (1995) indicated that in the early 1980s many farmers continued to grow small plots of durum landraces after having adopted new improved varieties on most of their fields, rather for home consumption than for market because of preferences in taste and cooking quality in preparation of traditional foods.

According to Mazid *et al*. (1998) diagnostic surveys in early 1990s showed that 68% of the wheat area was planted to modern durum wheat varieties (10% to local landraces) and 21% to modern bread varieties (1% to local landraces/obsolete varieties). Van Gastel and Bishaw (1994) also found that more than 90% of farmers grew modern varieties of bread and durum wheat in the six districts of the Aleppo province. During the 1998/99 crop season almost all durum and bread wheat area was planted to modern varieties in the survey regions with exception to obsolete varieties removed from the recommended list or local landraces in very isolated pockets (Table 3.18). In the late 1990s virtually all wheat area in Syria, irrigated and rainfed, was planted to modern varieties (Pingali, 1999).

The area under local landraces has declined drastically, both for durum and bread wheat particularly in areas where mechanization and use of irrigation is feasible. The landraces declined from 92% in the early 1970s to 45% by late 1970s. Mazid *et al*. (1994) reported that in early 1990s about 27% of farmers still grew local durum landraces partly because the introduction of modern durum varieties was later than for bread wheat. Van Gastel and Bishaw (1994) reported that less than 10% of farmers still grew local landraces in the Aleppo province. In 1998/99 crop season, the number of farmers growing local landraces was less encountered during the field survey where few farmers were growing them in very isolated areas. In recent years, the local landraces have been abandoned because of the expected high return from modern varieties where the yield and quality of landraces did not provide economic return. The new modern durum wheat varieties are popular with farmers and have replaced the landraces, but they are grown for sale, not for home consumption. In fact, virtually the entire Syrian wheat production is sold, mostly to government agencies that offer attractive prices (Tutwiler, 1995). However, when a specific targeted survey was carried out a wide range of local durum landraces such as Bayadi, Hamari, Hourani, Hourani-Bayadi and Swadi were found in isolated pockets in Aleppo and Idelib provinces. Some of these local landraces were traded over long distances, for example from southern (Dara'a) to northern (Aleppo) parts of the country through local traders.

There are three recommendation domains for wheat production in Syria: Zone 1, Zone 2 and full irrigation (Table 3.19). In Zone 1 and Zone 2 farmers can grow wheat using supplementary irrigation in case rainfall is delayed or short during the season. Cham 1, Cham 2, Cham 4 and Bohouth 6 were recommended for high rainfall areas (Zone 1) and irrigated areas, whereas Cham 3 and Cham 5 were recommended for dry areas with precipitation between 250 to 350 mm per year (Zone 2) (Hamblin *et al*., 1995, Shehadeh, 1998). The latest releases such as Cham 6 and Cham 7 were recommended for cultivation both in Zone 1 and Zone 2. Bohouth 1 and Cham 8 were released exclusively for irrigated conditions. There is a general perception that durum wheat is better adapted to marginal environments and performs better under harsher conditions than bread wheat. However, almost all wheat varieties were grown interchangeably in Zone 1 and Zone 2 despite the recommendation domain and under irrigated and rainfed conditions (Table 3.19). Mazid *et al*. (1998) found that Cham 3 was widely grown in Zone 1 and under irrigated conditions despite the recommendation to grow the variety under rainfed in Zone 2.

Table 3.19. Distribution of bread and durum wheat varieties by agro-ecological zones (n=273).

Varieties	Target environment	Zone 1		Zone 2		Total	
		Farmers	%	Farmers	%	Farmers	%
Cham 1	Irrigated, Zone 1	10	11	6	3	16	6
Cham 2	Irrigated, Zone 1	1	1	-	-	1	0.4
Cham 3	Zone 2	29	32	42	23	71	26
Cham 4	Irrigated, Zone 1	3	3	23	13	26	10
Cham 5	Zone 2	5	6	6	3	11	4
Cham 6	Zone 1 and 2	11	12	51	28	62	23
Acsad 65	Zone 1 and 2	9	10	9	5	18	7
Bohouth 4	Zone 1 and 2	-	-	3	2	3	1
Bohouth 5	Irrigated, Zone 1	3	3	20	11	23	8
Bohouth 6	Irrigated, Zone 1	1	1	5	3	6	2
Gezira 17	Irrigated, Zone 1	-	-	2	1	2	1
Lahan	Not recommended	17	19	9	5	26	10
Mexipak	Irrigated, Zone 1	-	-	4	2	4	
Memof	Not recommended	-	-	1	1	1	0.4
Lagous	Not recommended	-	-	2	1	2	1
Hamari	Local landrace	1	1	-	-	1	0.4
Total		90	100	183	101	273	100

Use of Wheat Variety Mixtures The main reasons for trying varietal mixtures could be part of farmer experimentation and strategy of local germplasm management to enhance the productivity and achieve better yield. It could also be simply pure accidental mixtures during crop production. Twelve farmers (5.8%) reported using variety mixtures of bread and/or durum wheat both of improved and/or local varieties in the range of 2 to 1 proportion. Six farmers reported mixing improved bread and durum wheat varieties whereas three mixed improved durum varieties. One farmer reported improved bread with local durum wheat variety. Two farmers reported mixing two local durum wheat varieties. Evidence from Ethiopia or elsewhere shows farmers using different crop mixtures (Woldeselassie, 1999; Araia, 2001) as part of yield enhancement, resource optimization or food security or on-farm crop diversification. However, none of the farmers reported the clear advantage of these mixtures.

Area Allocation for Wheat Varieties There were no significant differences in terms of area allocated between bread and durum wheat, but more area was allocated to wheat in Hasakeh than in Aleppo or Raqqa, in Zone 2 than in Zone 1 and to durum wheat than bread wheat (Table 3.20). In case an area over 45 ha is excluded (which is uncommon unless rented) the overall mean area for wheat was 8.9 ha (SD=8.1) whereas it was 7.2 ha (SD=6.51) for durum wheat and 6.5 ha (SD=6.3) for bread wheat. In Hasakeh, the overall mean area for wheat was 12.3 ha (SD=10.0), 9.9 ha (SD=6.9) for durum and 8.7 ha (SD=8.3) for bread wheat compared to less than 5 ha in both Aleppo and Raqqa governorates. Similarly, the mean area allocated was 11.0 ha for wheat, 8.3 ha for durum and 5.9 ha for bread wheat in Zone 1. In Zone 2,

Table 3.20. Area allocated for durum and bread wheat production in Syria.

	All wheat (n=206)		Durum wheat (n=140)		Bread wheat (=101)	
Area allocated in ha	Farmers	%	Farmers	%	Farmers	%
Up to 2.5 ha	33	16	21	15	28	28
2.51 to 5 ha	55	27	43	31	31	31
5.1 to 7.5 ha	28	14	15	11	12	12
7.51 to 10 ha	25	12	20	14	10	10
10.1 to 15 ha	26	13	18	13	8	8
Over 15 ha	39	19	23	16	12	12
Total	206	101	140	100	101	101
Mean	9.9		9.1		7.8	
SD	9.1		8.2		9.5	

the average area was 8.5 ha for both wheat types, 6.7 ha for durum wheat and 6.6 ha for bread wheat. Mazid *et al.* (1998) also found variation of area allocated to wheat in different regions of the country. This regional variation in area allocation could be related to the differences of the land holding among farmers and the economic benefits farmers expect from the crop grown.

The trend for allocation of area for wheat production is presented in Fig. 3.2. The highest proportion of farmers allocated less than or equal to 2.5 ha for wheat production throughout the four year period, although the proportion showed a declining trend. There was a consistent increase in the area allocated to wheat in the range of 2.5 to 5 ha from around 20% in 1995 to almost 30% in 1998. In general, the area of less than 5 ha showed a trending up whereas allocation of larger areas (more than 5 ha) was declining.

Perception of Wheat Varieties Wheat growers had an articulated perception of modern varieties they grew on their farms (Table 3.21). Ninety six percent of the farmers (n=206) were satisfied with the wheat varieties they grew and believed that they were suitable and adapted to the local growing conditions. They found the current varieties to be good in the following agronomic characteristics: high yield, non-lodging, grain size, and food quality (Table 3.22). In addition, tolerance to frost, drought, yield with less water and early maturity appeared to be important traits of wheat varieties.

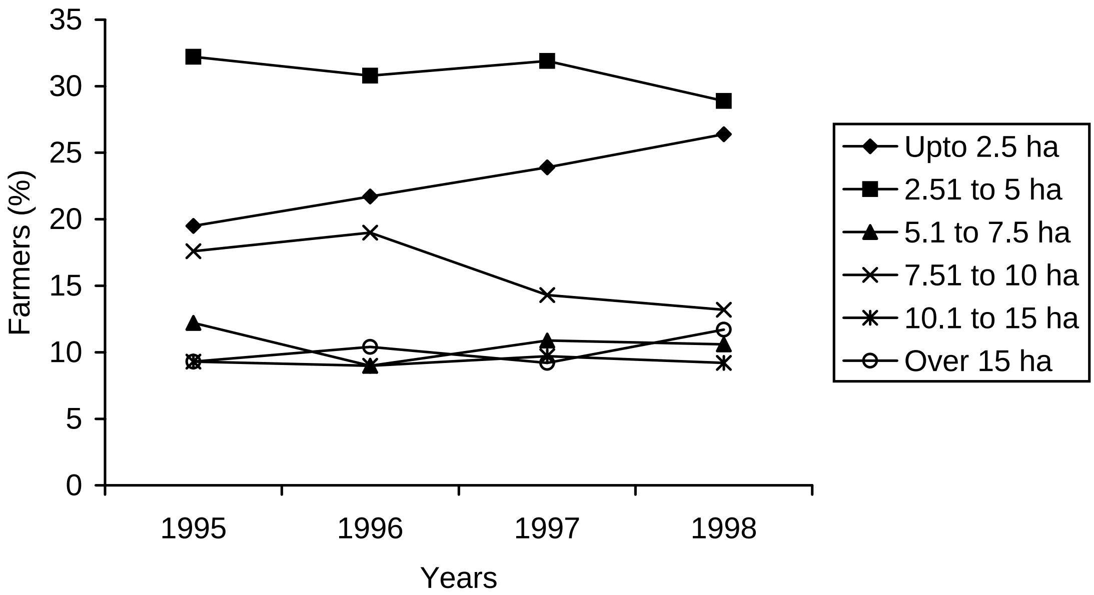

Fig. 3.2. Patterns of area allocation for durum and bread wheat production in Syria.

Table 3.21. Farmers' perception of selected wheat varieties currently grown in different regions of Syria (n=272).

Farmers' perception	Cham 1		Cham 3		Cham 4		Cham 5		Cham 6		Acsad 65		Bohouth 5		Lahan		Total[1]	
	1[2]	2[2]	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Grain yield	12	75	48	69	25	96	5	45	59	95	13	72	17	74	20	77	213	78
Grain size	3	19	15	21	5	19	4	36	4	6	7	39	5	22	14	54	61	22
Grain colour	4	25	4	6	3	12	2	18	1	2	2	11	2	9	4	15	24	9
Food quality	1	6	15	21	6	23	1	9	19	31	2	11	2	9	3	12	54	20
Marketability	2	13	7	10	3	12	0	0	6	10	2	11	5	22	0	0	26	10
Straw yield	1	6	3	4	2	8	1	9	0	0	0	0	0	0	1	4	8	3
Straw quality	0	0	6	9	1	4	0	0	0	0	1	6	1	4	1	4	10	4
Lodging tolerance	5	31	9	13	5	19	2	18	21	34	1	6	12	52	9	35	69	25
Shattering tolerance	3	19	3	4	2	8	0	0	3	5	1	6	4	17	2	8	22	8
Frost tolerance	5	31	10	14	1	4	1	9	7	11	1	6	2	9	9	35	37	14
Drought tolerance	0	0	9	13	1	4	1	9	6	10	2	11	2	9	1	4	24	9
Disease resistance	1	6	1	1	1	4	0	0	1	2	0	0	1	4	1	4	8	3
Pest resistance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Less fertilizers	1	6	0	0	0	0	0	0	1	2	0	0	0	0	0	0	2	1
Less water	0	0	10	14	6	23	3	27	9	15	4	22	0	0	1	4	38	14
Low soil fertility	0	0	3	4	0	0	1	9	1	2	2	11	0	0	0	0	7	3
Early maturity	2	13	3	4	2	8	2	18	4	6	1	6	1	4	0	0	15	6
Heat tolerance	0	0	2	3	0	0	0	0	1	2	0	0	1	4	0	0	4	1
Plant height	0	0	3	4	1	4	0	0	1	2	0	0	0	0	0	0	5	2
Others	0	0	7	10	2	8	3	27	4	6	5	28	1	4	3	12	28	10
Total	16	100	70	100	26	100	11	100	62	100	18	100	23	100	26	100	272	100

[1] Figures include all varieties grown by farmers;

[2] 1 and 2 are number of farmers and %, respectively.

Cham 3 was rated highly for its high yield, grain quality, food quality, tolerance to frost, tolerance to drought and better response to moisture. Lahan was appreciated for its high yield, good grain size, tolerance to lodging and frost. Among bread wheat varieties, Cham 4 was rated highly for yield, but low for other agronomic characteristics. On the other hand Cham 6 was rated highly for grain yield, food quality, tolerance to lodging and better yield with limited water. Tutwiler (1995) indicated that evidence from North Africa and Syria supports farmers' decision to grow a particular wheat variety was primarily based on its yield levels and economic returns.

Table 3.22. Farmers' perception and criteria for adoption of modern wheat varieties (%; n=206).

Varietal characteristics	Most important	Important	Less important
Grain yield	86	1	0
Grain size	15	4	0
Grain colour	2	0	0
Marketability	8	1	0
Food quality	3	2	0
Strong straw	2	0	0
Straw yield	1	1	1
Straw quality	1	1	0
Disease resistance	9	2	1
Lodging resistance	41	2	1
Shattering resistance	7	2	0
Frost resistance	18	1	0
Drought tolerance	16	1	1
Pest resistance	2	0	0
Yield without /less fertilizer	2	1	0
Yield with less water	22	2	0
Performance in poor soil	1	0	0
Early maturity	2	0	0
Heat tolerance	2	1	0
Others (tillering, plant height, ear size, etc.)	8	2	0

Moreover, shattering and lodging appeared to be factors farmers considered most important. However, the opinion on lodging was equally divided between very good and very poor, most probably based on the practical experience during crop production. The existing varieties were rated as very poor for both criteria by 33.1% and 17.3% of the farmers, respectively. Under irrigated condition farmers usually applied very high amounts of fertilizers to maximize production and productivity to the extent possible. As a result they experienced lodging which is apparently more affected by management than by varietal characteristics only. Similarly, mechanical harvesting of wheat might result in shattering of crops particularly if harvesting was delayed due to lack of equipment. Therefore, there is a strong desire to find alternative varieties with better response to higher inputs and at the same time maintain good agronomic characteristics such as tolerance to lodging and shattering.

Unlike for barley, grain colour and marketability appeared to be less important in wheat. At present, neither the government who purchases wheat grain nor the flour industry pays a premium price for grain colour. Generally all bread and durum wheat varieties are of white or amber colour and are acceptable for making both local foods and industrial products. The present arrangement for marketing wheat grain is attractive because of government price incentives as most farmers produce the grain for market rather than for own consumption (Tutwiler, 1995). Modern varieties can be used both for preparation of traditional foods and industrial wheat products and there is no premium price for grain quality.

Farmers' perception on productivity of wheat varieties was influenced largely by variation in the amount and distribution of rainfall during a particular year. Farmers who were entirely dependent on rainfall expected fluctuation both in production and productivity of wheat varieties they grew. There was a general perception of increased productivity of wheat as shown in Fig. 3.3. About one third of the farmers expected a wheat yield in the range of 1 to 3 t ha^{-1} and the proportion was decreasing. A larger proportion of farmers expected a wheat yield of 3 to 5 t ha^{-1} while one-fifth of farmers (< 20%) expected a yield of over 5 t ha^{-1}. This perception might arise from adoption of new and high yielding varieties and continued expansion of wheat area under supplementary or full irrigation.

Interestingly high yield, lodging resistance, yield with less water, frost tolerance, and drought tolerance appeared to be varietal characteristics farmers were seeking for in new bread and durum wheat varieties (Table 3.22). The strong preference for these characteristics might reflect the satisfaction of farmers with other varietal characteristics of the existing varieties in terms of food quality, grain colour, grain size

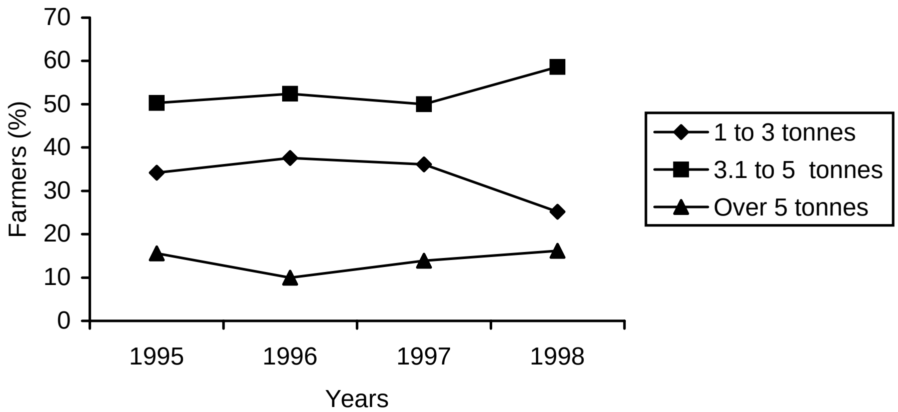

Fig. 3.3. Farmers' perception of productivity of currently grown wheat varieties in Syria.

and other agronomic criteria. Moreover, maximizing production as a result of agricultural intensification becomes a major criterion for adopting new varieties whereas lodging tolerance is a response to mechanization of farm operation particularly during harvesting. The continuing decline in availability of irrigation water and erratic rainfall were major concerns for farmers who seek alternative varieties for drought tolerance. Tripp (2000) indicated that adoption of modern varieties could be influenced by yield, disease resistance and particularly early maturity which is quite useful for drought prone areas. He indicated that early maturing sorghum, pear millet, bean and groundnut varieties were widely adopted in response to drought conditions compared to long-maturing local landraces, thus providing better marketing and price opportunities.

Barley Varieties Grown by Farmers The development of crop varieties with high yield and yield stability for marginal environments that is similar to typical barley production areas in northwestern Syria is a challenging task. Such areas are highly diverse and agro-climatically variable. Severe drought, thermal stress at maturity accompanied by spatial and temporal variations in rainfall remain major barley production constraints. The crop improvement programme at ICARDA was engaged in methodological approaches of barley breeding for over a decade and uses local landraces and their wild relatives in the breeding programme. ICARDA collaborates with the national agricultural research systems including the Directorate of Agricultural and Scientific Research (DASR) which are the direct recipients of the germplasm for further evaluation and testing at national level.

From 1981 to 1994 a total of seven modern varieties of barley have been recommended and released in Syria. It was reported that in 1981 the DASR released improved selections from Arabi Aswad and Arabi Abiad, two local barley landraces in Syria. ACSAD 60, ACSAD 68 and ACSAD176 were also released by ACSAD in 1984 (However, it was not clear whether the former two were officially released during this period). The Syrian national programme also selected and evaluated pure lines from barley landraces such as Arabi Abiad and Arabi Aswad in collaboration with ICARDA. Four barley varieties Badia (1985), Furat 1(1987), Furat 2 (1991) and Arta (1994) were formally released from this collaborative programme. Arta was a selection from Arabi Abiad and was recommended for release in 1994 (Hamblin *et al*., 1995). It was reported that the average long-term yield of Arta was 13-29% higher than that of the Syrian barley landraces. Moreover, four barley varieties Furat 3, Furat 4 and Furat 5 (2000) and Furat 7 (2002) were also released, the former one by DASR the latter three through DASR/ICARDA collaborative programme after the survey year. Furat 2 and Arta were released for northwestern (Aleppo, Idlib, Hama) and southern (Dara'a) Syria (Michel, personal communication). The modern barley varieties such as Arta, Furat 2 and Furat 4 were released for Zone 2, whereas Furat 3, Furat 5 and Furat 7 were recommended for Zone 3.

Despite such long lists of barley varieties released at the national level none of them were widely adopted; and possibly were rejected because of lack of adaptability and farmers preferences. During the survey it was found that almost all farmers in different provinces and zones grew Arabi Aswad (99%; n=200), Arabi Abiad (0.5%) and Furat 1 (0.5%) in northeastern Syria. Tutwiler *et al*. (1997) reported that the main constraints of using improved barley varieties are farmer's lack of knowledge about the availability and preferences regarding the grain colour, not the cost of adopting modern varieties. They also found variation in adoption among farmers who participated or not participated in the demonstrations and among the components of package itself. Similarly, in Niger despite great efforts in variety development and release many farmers grew local landraces and improved varieties occupied less than 2% of the national pearl millet area (Ndjeunga, 2002). In contrast, farmers in Ethiopia grew a large number of modern varieties (6) and local landraces (14) of barley crop (Woldeselassie, 1999), although two varieties constituted about one third (36%) of the total sample. Moreover, 33% grew modern varieties with significant differences between regions (almost all farmers who grew modern varieties were in southeastern regions). The existence of a malt factory and the contractual production arrangement with farmers has led to a higher adoption of modern malt barley varieties in the southeastern region compared to the northwestern region of the country.

The possible explanations for low level adoption of modern barley varieties in Syria could be: (i) modern barley varieties might not be yielding as high as it would be claimed from on-station and on-farm trials, (ii) grain quality of modern varieties might not meet the quality and other attributes preferred by farmers; (iii) barley is a marginal crop and farmers are reluctant and risk averse to try new varieties with no prior history of adaptation to their harsh environments; and (iv) different grain price policy incentive encouraging allocation of more resources to wheat production at the expense of the barley crop. Mazid (1994) found a single farmer who adopted a modern barley variety in northwestern and northeastern Syria substantiating these findings. Since its inception, the General Organization for Seed Multiplication has been involved in multiplication and distribution of local landraces of barley across much of the country. During the 10 years period from mid 1980s to 1990s the organization distributed on average 219, 254 tonnes of seed of which wheat and barley occupied 63.4% and 4.3%, respectively, with great fluctuations from year to year, particularly for barley seed caused by weather conditions. Until the early 1990s the demand for barley seed was slightly high (see Table 3.2) because of cheaper seed price and high government grain price which was equivalent to the wheat grain price. However, in the early 1990s the introduction of a different grain price for wheat and barley led to a dramatic decline in demand for barley seed and the majority of farmers reverted to the use of on-farm saved seed. It was previously reported that the diversity of local barley landraces collected from Syria and Jordan was tremendous in terms of agronomic characters (Ceccarelli *et al*., 1987) and disease resistance (van Leuer *et al*., 1989). The effect of such large-scale movement of local landraces by the formal sector on the genetic diversity of the barley landraces presently grown in the farmers' fields will be explained later in this thesis (Chapter 6).

The area allocated to barley production in 1997 is given in Table 3.23. The mean area allocated for barley production was 17.1 ha (SD=17.4) with large variation among farmers. The mean barley area for Aleppo, Raqqa and Hasakeh were 12.7 (SD=12.7), 28.0 (SD=25.8) and 14.3 (S=12.3) ha if farmers with more than 100 ha are excluded. Almost 50% of the farmers planted less than 10 ha and one third between 10 and 20 ha. Twenty percent of the farmers grew more than 20 ha, among whom a few of them grew over 100 ha.

From the 200 farmers surveyed, 89, 93.5, 97 and 100% planted barley in 1994, 1995, 1996 and 1997, respectively (the remaining did not plant barley or fallowed their land). Most farmers grew barley continuously year after year except in a few cases where it was rotated with legumes (lentil, lathryus) or fallowed (e.g., in Raqqa). Tutwiler *et al*. (1997) reported a similar trend towards continuous barley cultivation instead of fallowing. Mazid (1994) found that only 13.5% of farmers are fallowing whereas the majority practices continuous cropping of barley, mainly due to availability and use of fertilizers.

Almost all farmers who planted barley grew predominantly the same local landrace, Arabi Aswad, with no significant changes in the pattern of varieties. Furat, an improved barley variety released by the national programme, was planted by one

Table 3.23. Area allocated for barley production by sample farmers (n=200) in Syria.

Area in ha	Aleppo	Raqqa	Hasakeh	Farmers	%
0.5 to 5	20	3	16	39	20
5.1 to 10	32	10	16	58	29
10.1 to 20	31	13	14	58	29
20.1 to 30	6	5	8	19	10
30.1 to 40	3	6	1	10	5
40.1 to 50	1	3	3	7	4
Over 50	1	7	1	9	5
Total	94	47	59	200	102

farmer only and not widely adopted. The origin and identity of the barley variety called Franci is not known; the farmer claimed that he obtained the seed from his neighbour when he planted the variety. This variety is no more grown by farmers. There is no clear picture in area allocated to barley production, mean grain yield and grain price, although the general line shows an upward trend.

Use of Barley Variety Mixtures Local landraces grown by farmers are believed to be a mixture of several pure lines evolved through time with high degree of heterogeneity and variability. Moreover, when farmers acquire new germplasm, it may physically mix, cross, etc. with existing materials and become part of the local germplasm pool. However, farmers' deliberate experimentation of using different variety mixtures is rare. Five farmers attempted to use mixtures of two and/or six row barley varieties. Two farmers mixed Arabi Aswad with white six row barley (one farmer in 2:1 proportion) while two farmers mixed Arabi Aswad and black six-row barley (one farmer in 1:1 proportion). Farmers reported that both six-row barley varieties were introduced informally from elsewhere to the region sometime ago, but abandoned due to lack of adaptation and they were no more grown in recent years. Another farmer mixed Arabi Aswad with Arabi Abiad in a 1:1 proportion, both of which are local landraces, the former black seeded and the latter white seeded. However, farmers did not find better performance or any advantage from the experience and abandoned the practice.

Perception of Barley Varieties The majority of farmers surveyed had a very positive perception of the local landrace barley and some of them continued growing it for generations without replacing it with modern varieties (Table 3.24). About one third of the farmers saw no disadvantage of the variety they grew. Grain yield, grain size, grain colour, feed quality and marketability were the major factors farmers recognized as important varietal characteristics of Arabi Aswad. Over half of the farmers (57%) believed the barley variety gave good and stable yield over years under very erratic rainfall and stressful conditions. The feed quality appeared to be the second most important characteristic mentioned by 41% of farmers (n=198) as crop-livestock farming is crucial for the majority of farmers. In terms of feed quality one farmer contended that livestock fed with Arabi Aswad gave higher production and better quality milk compared to livestock fed with other local or modern barley varieties. This profound positive perception of the farmer is difficult to substantiate. Although most scientists argue that there is no difference in the feed quality between the black and white seeded barley local landraces, the perception of the farmer should be appreciated if adoption of modern varieties bred by the formal sector is to succeed.

Table 3.24. Farmers' perception of local barley landrace Arabi Aswad (%; n=198).

Agronomic characteristics	Very good	Good	Poor	Very poor
Grain yield	57	8	-	2
Grain size	35	6	1	1
Grain colour	27	3	2	1
Feed quality	41	6	-	1
Marketability	28	4	1	-
Storability	1	1	-	-
Straw yield	7	4	1	-
Straw quality	9	3	1	1
Strong straw	5	1	-	-
Lodging resistance	1	2	2	2
Shattering resistance	1	1	-	-
Frost resistance	4	1	1	2
Drought tolerance	7	1	2	4
Disease resistance	5	1	2	5
Pest resistance	-	-	-	1
Less need for fertilizer	3	1	-	1
Less need for water	4	1	2	14
Performance in poor soil	2	1	-	-
Uniformity of plants	1	1	-	-
Plant height	2	1	-	-
Tillering capacity	1	1	-	-
Spike length	1	1	-	1

The grain colour is associated with the marketability of the barley grain for feed or seed through local market channels. Since black seeded barley varieties are preferred it would be difficult to shift production to other barley types which are less popular and do not meet the farmer preferences. It was found that farmers who were surveyed used barley grain for feeding their livestock (91%), sale surplus on the market (85%) and use it for seed (46%). Tutwiler *et al.* (1997) reported a trend towards commercial barley production in the drier areas of Syria. He indicated that two thirds of the farmers produce barley for sale through government and private marketing channels and the remaining one-third use barley to feed their flocks on the farm.

Therefore, from the survey results it can be concluded that: (i) farmers are explicit in their demand for specific quality traits they seek in a particular crop; (ii) plant breeders should appreciate these quality traits and incorporate them in the breeding programmes; (iii) plant breeders should develop appropriate varieties that meet farmers' perceptions; and (iv) the extension service should demonstrate and convince the farmers to adopt the new varieties. A more concerted effort is required to transfer the technology through farmer participation and evaluation.

Farmers' Preferred New Barley Varieties for Adoption The perception of farmers of the modern barley variety is given in Table 3.25. Grain yield was reported to be the most important factor by 65% of the farmers (n=200), followed by grain colour (44%) and grain size (37%). Feed quality and marketability came at a distant fourth and fifth place and were considered important by 19 and 12% of farmers, respectively. However, farmers generally made a strong link between grain colour and marketability as

Table 3.25. Farmers' perception and criteria for adoption of modern barley varieties (%; n=200).

Criteria for adoption	Most important	Important	Less important
Grain yield	65	1	0
Grain size	37	3	1
Grain colour	44	4	1
Feed quality	19	6	1
Marketability	12	2	0
Storability	1	1	0
Straw yield	4	6	0
Straw quality	3	4	2
Strong straw	2	2	0
Lodging resistance	6	1	0
Shattering resistance	1	0	0
Frost resistance	4	0	0
Drought tolerance	7	1	0
Disease resistance	11	1	1
Pest resistance	1	0	0
Yield with less fertilizer	1	0	0
Yield with less water	11	1	0
Performance in poor soil	2	0	0
Plant height	4	0	0
Purity	5	0	0
Early maturity	6	0	0
Salt tolerance	5	0	0

well as grain size and feed quality as had already been observed when they valued their local landrace along these lines. It was found that participatory plant breeding in barley had identified grain yield, kernel weight, spike length and plant height as the most important selection criteria by farmers when compared to straw yield (Ceccarelli *et al*., 2000).

The other most important factors that came to light were farmer's interest for modern varieties with tolerance to diseases and better yield under less moisture conditions. In recent years, most barley growers are suffering from a plant disease locally known as *Abu Elawi* causing head sterility, wilting of growing crops and substantial reduction in grain yield. Khatib *et al*. (2000) reported that based on preliminary survey the incidence of the disease is considered to be associated with the gall nematode (*Anguina* spp.), although this is not yet fully confirmed. An average incidence of 23.4% and associated yield loss of 11.2% was reported in fields with head sterility by the same authors. Given the erratic rainfall and limited water availability, farmers were also interested in adopting modern varieties which better withstand these conditions and give good and stable yield. Some other criteria of lesser importance were early maturity, plant height, straw yield and crop uniformity. It was surprising to find that straw yield and quality were not given high priority despite its use as livestock feed.

3.9.6. Farmers' Seed Sources and Seed Management

In Chapter 2 of this thesis, a detailed account of farmers' seed source has been given for wheat in Ethiopia including the technical and socio-economic interplay in deciding a particular source of seed. The pattern of seed acquisition is rather complex as farmers can source seed of different crops or different varieties of the same crop from various sources at the same time or at different times. Cromwell *et al*. (1993) recognized three types of farmers in terms of seed sourcing, i.e., those who source seed off-farm because of choice, necessity or seed insecurity. In general farmers have four major sources of seed for planting (Chapter 2): (a) own saved seed from the previous years; (b) seed obtained from other farmers (relatives, neighbours); (c) seed purchased through local trading (markets or grain traders); and (d) the seed purchased from the formal sector. There are many technical and socio-economic factors that influence farmers to obtain seed from a particular source and these may include farmers' anticipated benefits and interest to meet household food security; the availability of reliable information on source, quantity and quality of the seed; the proximity and timely availability of the seed; the price and risks associated with the seed purchased. In many circumstances most of the seed is sourced informally at the local level. For example, Walker and Tripp (1997) found that the proportion of seed obtained from a particular source differed among farmers, crops, seasons, regions and countries.

Wheat Seed Sources and Perceptions The local seed system varies greatly even for the same crop based on the agro-ecology of the production environment as well as the socio-economic situations and cultural background of farmers. For example, in some surveys it was found that richer farmers tend to use own saved seed compared to the less endowed farmers who are more prone to sourcing seed informally from outside out of necessity (Tripp, 1997a). On the other hand the reverse could be true where richer farmers could afford to purchase seed off-farm such as from the formal sector, whereas the small-scale and less resourced farmers revert to use their own saved seed. The rate and intensity of using a particular seed source, however, is subject to many influences. From several field surveys it was observed that there was no single source of seed on the farm and farmers may use multiple seed sources even for the same crop or variety based on various technical and socio-economic factors. Apart from own saved seed wheat farmers source seed off-farm from the formal sector, other farmers, local traders or local markets. These local seed supply and diffusion mechanisms are mostly based on existing traditional channels of information exchange within and between communities involving a wide range of transaction mechanisms including gifts, seed swaps, in-kind seed loans or exchange of labour (GTZ and CGN, 2000). The perception of farmers from these different wheat seed sources is outlined in the following sections.

Initial Seed Sources for New Wheat Varieties In any farming community particularly in developing countries, there is a wide range of community based seed acquisition strategies. Table 3.26 presents the initial seed source of bread and durum wheat varieties grown by farmers in Syria. All farmers surveyed were growing a wide range of modern varieties of wheat and thus were expected to be more familiar with seed from the formal sector. Unlike barley the main initial seed source of new wheat varieties was the formal sector where ACB, GOSM and Co-operatives altogether accounted for nearly 60% (i.e., 50.4, 6.6 and 2.6%, respectively) of the sample farmers. The informal seed acquisition from relatives, neighbours and other farmers (27.5%) or local trading (12.9%) still played a significant role in diffusion of modern varieties. Tetlay *et al.* (1991) found that in Pakistan up to two thirds of farmers acquired seed of modern wheat varieties from informal sources such as neighbours or other farmers. Similar results were also reported from Ghana where other farmers were major initial seed sources for modern maize varieties (Tripp, 1997a).

However, in 1998/99 crop season, almost two thirds of farmers (59.3%; n=273) sourced their seed on-farm for planting wheat crop (Table 3.26). About 24% of

Table 3.26. Initial seed source of wheat varieties and seed source in 1998/99 crop season. ACB, GOSM and farmers' co-operatives altogether constitute the formal sector.

Initial seed sources of wheat varieties (n=272)			Wheat seed sources in 1998/99 crop season (n=273)[1]		
Source	Counts	Responses (%)	Source	Counts	Responses (%)
ACB	137	50	ACB	36	13
GOSM	18	7	GOSM	12	4
Co-operatives	7	3	Co-operatives	17	6
Relatives	2	1	Neighbours/other		
Neighbours	28	10	farmers	34	13
Other farmers	45	17	Local traders/markets	12	4
Local traders/markets	35	13	Own seed	162	59
Total	272	100	Total	273	100

[1] One farmer sourced seed of the same variety from two different places.

farmers sourced seed from formal sector through ACB (13.2%), co-operatives (6.2%) or GOSM (4.4%), whereas less than 5% got their seed through local traders. Van Gastel and Bishaw (1994) found similar results where over 50% of wheat farmers used own seed, 25% sourced from neighbours and 19% from the formal sector. Hasan (1995) also found that in Jordan the majority of wheat farmers (58.3%) also used on-farm saved seed compared to seed from external sources such as certified seed (34.1%) and other local sources. During the 1998/99 crop season, 86, 13 and 1% of the wheat farmers (n=206) in Syria obtained their bread and durum wheat seed from one, two and three sources, respectively. Mazid *et al*. (1998) found that on average 10% of the farmers use more than one seed source for planting wheat with the a range from 6% (lowest) in Zone 1 to 13% (highest) where farmers use supplementary irrigation.

Perception of Wheat Seed Source from Formal Sector The ACB and GOSM have 93 and 26 seed sale points distributed in major crop production regions of the country. Among these, 45 for ACB and 14 for GOSM are located within the provinces surveyed. The farmers' co-operatives redistribute the seed received from the ACB. The formal sector appeared to be the second most popular source for wheat seed: one third of farmers got their seed in 1998/99 crop season. The major providers were the Agricultural Credit Bank (56%; n=65) and farmer's co-operatives (27%) whereas almost one-fifth of the farmers purchased seed directly on cash from the General

Organization for Seed Multiplication (18%). Mazid *et al.* (1998) found a relatively high proportion of farmers who sourced durum wheat seed from the formal sector with higher percentage in irrigated than rainfed areas. Table 3.27 presents farmers' views for sourcing wheat seed from the formal sector, distance travelled and time seed purchased. Farmers had a very high appreciation and highly valued the quality of certified seed from the formal sector. Most of them appreciated the seed quality (58%) and perceived that it also gives high yield (22%) compared to on-farm saved seed. The other main incentives for farmers buying certified seed was to replace an old variety or buy fresh seed as indicated by 16 and 24% of farmers, respectively. Hasan (1995)

Table 3.27. Farmers' perception of formal seed source, distance travelled (km) and time seed purchased (n=65).

	Farmers	%
Seed sources		
ACB	36	55.6
Co-operatives	17	26.7
GOSM	12	17.8
Why purchase certified seed		
Replace old variety	10	16
Replace old seed	16	24
Better seed quality	38	58
Better grain yield	14	22
Cheap price	1	2
No own seed	3	4
Others (credits)	7	11
Distance travelled		
Up to 10 km	22	33
10.1 to 20 km	20	31
20.1 to 30 km	4	7
30.1 km to 40 km	4	7
40.1 to 50 km	10	16
Over 50 km	4	7
Time seed purchased (month of the year)		
8 to 9	7	11
10	14	22
11	32	49
12	12	18

reported that wheat farmers in Jordan buy certified seed because of positive perception of seed quality (cleaned, treated), expected high yield or as part of regular purchase of seed.

The majority of farmers who purchased seed from the formal sector indicated that certified seed was always available, properly cleaned, properly treated and were satisfied with quality. Van Gastel and Bishaw (1994) found that 18% of farmers purchased seed from the formal sector and all were satisfied with the quality including the cleaning and treatment of the certified seed. However, only 36% of farmers were satisfied with the price of certified seed distributed. Radwan (1997) indicated that although seed is distributed at cost or at nominal profit for some crops in Syria, farmers still consider the price of seed too high.

Although few farmers had travelled up to a maximum of over 50 km to buy certified seed, one third of farmers each travelled up to 10 km (33%) and 20 km (31%). Tetlay *et al*. (1991) found that 80% of the farmers who sourced seed of new varieties from other farmers got the seed withina 5 km radius. The seed was purchased later in the season in October (22%), November (49%) or December (18%). Delayed delivery due to the short gap between harvesting and planting period presented logistic problems and farmers had to wait until the seed became available at the local ACB or co-operative store for distribution. The presence of relatively large numbers of sale points or distribution points and availability of seed however offsets the problem of delayed delivery and encourages many farmers to use certified seed.

The frequency of seed replacement rate among certified wheat seed users was high. About 67% of farmers (n=65) who acquired certified seed in 1998/99 claimed purchasing seed from the formal sector every year. The rest would not buy seed every year but most of them reported buying certified seed at a more regular interval of three years. In contrast less than 5% of sorghum and pearl millet farmers were willing to buy seed regularly (Rohrbach, 1997). The high price of seed and the high quality of own saved were the main reasons for farmers not buying seed regularly from the formal sector. For example in Ethiopia, high seed price found to be the main constraint to adopting improved wheat varieties (Kotu *et al*., 2000). Mazid *et al*. (1998) reported that farmers in irrigated areas are highly dependent on seed from the formal sector supplied by the General Organization for Seed Multiplication.

In Syria, the relatively high use of certified seed can be explained by five possible factors: (a) sustained government policy and effort in promoting the use of modern varieties and certified seed; (b) low price of certified seed which is provided at production cost, although farmers still consider formal sector seed expensive; (c) adequate seed production and distribution facilities and rural infrastructure guaranteeing easy access; (d) farmers' perception of certified seed in terms of quality and yield potential; (e) adequate grain marketing procedures where the whole production can be delivered to government depots at premium prices; and (f) as a matter of choice or convenience where the seed could easily be purchased from the formal sector later in the season with less demand for any on-farm seed storage.

Perception of Local Off-Farm Wheat Seed Sources Although only 12% of farmers (n=206) sourced seed from other farmers during the 1998/99 seed survey about 52% of them previously had an experience of getting seed from other farmers. Similarly, 4% of farmers sourced seed from local traders or markets in the same year whereas 27% of them purchased from local traders in previous years. Since the number of farmers who sourced seed off-farm locally from other farmers or traders was small, the data were pooled and presented here. The results indicated that even in situations where modern varieties are highly adopted farmer-to-farmer exchange remains the main diffusion mechanism for new crop varieties.

From 46 farmers who sourced off-farm seed locally, 50% got their seed from other farmers whereas the remaining 26 and 24% got their seed from neighbours and traders, respectively (Table 3.28). Farmers cited several reasons for sourcing seed off-farm locally such as perception of good seed quality (57%), timely availability (13%), lack of own seed (15%) or interest to change the variety grown or seed planted (11%). From wheat growers who sourced seed from other farmers (8%) in Jordan most farmers claimed that the timely availability (55%) and adaptation of variety grown by other farmers (19%) were the main reasons for acquiring seed from these sources (Hasan, 1995).

Some of the farmers who provided seed for others were contract seed growers for the GOSM (6 out of 34 farmers). Contract growers could serve as potential sources for varietal diffusion of new varieties. For example, the Ethiopian Seed Enterprise was previously multiplying cereal seed, particularly *tef* seed, with smallholder farmers' co-operatives where they could retain up to 15% of the production and use or sale seed to other neighbouring farmers to assist the diffusion of new varieties. The approach assisted in wider diffusion of modern *tef* varieties which otherwise would be difficult to achieve through the formal sector.

Moreover, farmers who rented combine harvesters also played an important role in the diffusion of varieties and seeds among farmers. Farmers who rented the combines are usually paid in kind (up to 10% of the total harvested yield) where the grain sometimes could be used as seed for planting or sold to other farmers. The widespread diffusion of Lahan in most wheat growing areas could be attributed to such a phenomenon. A farmer in Raqqa province acknowledged that he obtained seed of Lahan from an adjacent province in Hasakeh through such arrangement and introduced the variety to his village, a remarkable long distance seed exchange and varietal diffusion mechanism. Some of the reasons for farmers buying seed off-farm locally were lack of own seed (15%), cheap price (13%) and an interest to try new varieties (11%).

The time of purchasing seed was quite well distributed over the six-month period from harvest to planting with no specific trend for seed purchased from either neighbours or traders. The distance travelled by the farmers purchasing seed from traders ranged from 3 to 40 km.

On the other hand farmers who sourced off-farm seed locally gave several reasons for not purchasing certified seed from the formal sector. Lack of availability, quality and price of certified seed together accounted for over two thirds of farmers (59%; n=46) for not sourcing seed from the formal sector (Table 3.28). Hasan (1995) reported similar reasons for wheat growers in Jordan, although the proportion varies slightly.

Some farmers mentioned lack of access to credit as an impediment for not purchasing seed from the formal sector. In general there are circumstances where all

Table 3.28. Farmers' perception of wheat seed sourced from neighbours or local traders/markets (n=46).

Why farmers source seed from neighbours/traders			Why farmers not source certified seed		
	Farmers	%		Farmers	%
Seed available on time	7	13	Poor certified seed quality	5	11
Seed quality is good	26	57	Certified seeds not available	11	24
Seed price is cheap	6	13	Certified seeds is expensive	16	35
No own seed	7	15	No cash to by certified seed	6	13
Certified seed not available	4	9	No credit to by certified seed	3	7
Try new variety or change seeds	5	11	No idea of certified seed	3	7
Others (combine rent /labour)	9	20	Others (process/indebted)	7	15
Time seed purchased (month)			*Distance travelled (for seed purchased from traders)*		
6	8	17	3 km	2	13
7	8	17	5 km	3	25
8	5	11	10 km	2	13
9	7	15	27 km	2	13
10	6	13	30 km	2	13
11	9	20	40 km	2	13
12	3	7			

members of a farmers' association or co-operative are penalized because few farmers default on credit payments. Similar situations also exist in Ethiopia where farmers' co-operatives have to pay at least 95% of their credits before they are eligible to get additional credits from government to purchase inputs such as seeds and fertilizers for the next planting season (Beyene *et al*., 1991). Such requirement of group obligations appeared to be a problem in many circumstances where farmers are organized into government style associations or co-operatives without the genuine desire and representation of their interests. Moreover, the bureaucracy of going through all the procedures to get seeds and inputs on credit obliged some farmers to use other alternative seed sources.

From 46 farmers who sourced wheat seed off-farm locally, 74% purchased seed from other farmers and 26% from traders. Eight farmers purchased certified seed (cleaned and treated) from traders whereas ten purchased cleaned, but not treated seed (except one) from other farmers. All the remaining farmers cleaned and/or treated their seed before planting which indicated widespread use of chemical seed treatment.

All farmers (100%; n=46) who sourced seed locally either from other farmers or from traders were satisfied with the quality (Table 3.29). However, only 59% of farmers considered the price reasonable. The mean seed price from other farmers was 12.1 SYP kg^{-1} (SD=0.29) whereas mean seed price from traders was 16.1 SYP kg^{-1}

Table 3.29. Mode of payment and frequency of purchase from other farmers/traders (n=46).

Local level seed transaction mechanisms	Farmers	%
Satisfied with seed quality	46	100
Mode of payment for seed		
Cash	40	87
Credit paid in cash	5	11
Labour exchange/payment for harvest	2	4
Satisfied with seed price	27	59
Neighbour seed price SYP kg^{-1} (average)[1]	12	0.3
Trader seed price SYP kg^{-1} (average)	16	0.2
Frequency of purchase from neighbours/traders		
Always from other farmers	4	9
Once every 3 years	17	37
Once every 5 years	5	11
Occasionally	20	44

[1] SYP=Syrian Pound.

(SD=0.2). The higher mean seed price for seed from traders was due to purchase of certified seed through other farmers. Some farmers get the seed from formal sector on credit and sell it to local traders who will resell the seed to others. Such practice was encountered in some places and the exact motive of selling certified seed obtained from formal sector to traders is not clear except to raise money to overcome immediate cash constraint. The transactions for seed purchase were through cash payment (87%), credit for cash repayment (11%), labour exchange (2%) or payment for harvest (2%).

The frequency of seed purchased from other farmers or traders was low. While 8.7% of farmers reported sourcing seed from outside every year, 37% purchase seed every three years, 10.9% every five years and the remaining 43.5% occasionally purchased seed from outside sources. This rather reflects farmers' desire and not necessarily a general practice since seed sourcing externally could be influenced by several technical and socio-economic factors.

Perception of On-Farm Wheat Seed Sources Producing and retaining seed on-farm is the most economic approach provided that new varieties with superior agronomic or quality attributes are not on the market and no biophysical constraints that are detrimental to seed quality on the farm. In case of wheat there is little evidence to suggest a decline in yield through continuous use of seed of the same variety if farmers follow sound crop production procedures. As a result for most cereal crops including wheat, own saved seed is the major source for planting both in developing (Chapter 2) and developed countries (Stanelle *et al.*, 1984).

About 61% of farmers (n=127) believed that own saved seed produced on farm was of good or better quality (Table 3.30). A significant number of farmers used retained seed because they considered certified seed involves extra cost, not available on the market, difficult and long bureaucratic procedures to obtain it or did not see any merit

Table 3.30. Farmers' perception of on-farm retained wheat seed (n=127) in Syria.

Why farmers source seed on-farm			Why farmers not source certified seed		
	Farmers	%		Farmers	%
Seed quality is good	77	61	Certified seed is expensive	59	47
Seed available on time	14	11	Certified seed not available	21	17
No extra seed cost	7	6	Poor certified seed quality	6	4
Certified seed not available	12	9	No cash/credit to buy certified seed	19	15
Difficult procedures to obtain	7	6	Not aware of certified seed	2	2
Variety not adapted	3	2	Own saved seed is good	13	10
Others (not interested, etc.)	10	8	Others	7	6

of purchasing it when the variety was not adapted to their condition. In contrast, however, the price of seed remained the single most important factor for farmers not purchasing certified seed (47%). Lack of credit or cash, poor seed quality and lack of awareness altogether accounted for the remaining proportion of farmers not buying certified seed. The overall perception of farmers for seed retained on-farm was very high. The two most critical factors for sourcing seed on-farm are the perception of seed quality and price of certified seed. In Ethiopia, lack of alternative seed sources, adaptation of own local varieties and good quality of own seed were the main reasons for the majority of barley farmers who used retained seed on the farm (Woldeselassie, 1999). In Jordan seed system studies found that 34.1% of farmers sourced wheat seed on-farm (Hasan, 1995) whereas the figure is over 85% for lentil (Al- Faqeeh, 1997) showing greater variation between crops. This variation is to some extent influenced by the development of the seed sector for a particular crop.

All farmers who used retained seed cleaned their seed manually using wire mesh sieves (85%) or mobile cleaning machines hired from service providers (15%). Almost all farmers who used cleaning machines were in Hasakeh where the service is well spread and available compared to other provinces. This could be attributed to the availability of small-scale mobile cleaners fabricated by a metal workshop in one of the nearby towns in Khamishli district. This could be one of the potential small enterprises to provide cleaning and treatment services to farmers in rural areas.

Local Wheat Seed Flow or Diffusion Local seed exchange with relatives, friends, neighbours or other farmers is a key for not only acquiring seeds but also for introducing new crops and varieties from elsewhere and increasing the crop and varietal diversity on the farm. Bajracharya (1994) reported the role of women as key players in such endeavour in Nepal. About 50% of the farmers (n=206) indicated that they exchanged seed of modern varieties of wheat with other farmers for planting purposes (Table 3.31). However, the local level seed exchange for wheat was slightly lower than for barley. The main reasons for such lower local level seed exchange could be attributed to high varietal turnover and seed replacement rate from the formal sector. From farmers who reported the experience of selling seed informally through local trading (n=103), the major recipients were other farmers (70%), neighbours (69%), relatives (49%) or local grain traders (2%). Similarly, most of the transactions for the seed were in the form of cash payment (97%) or gift/seed exchange (3%), once again showing the importance of cash economy in rural areas. Farmers are more inclined using cash transactions in comparison to traditional exchange mechanisms as observed elsewhere as they are becoming integrated to the commercial market. Tetlay *et al*. (1991) also found that three quarter of farmers who sourced wheat seed from

Table 3.31. Local flow or diffusion of seed of modern wheat varieties among farmers (n=206).

Local level seed transaction mechanisms	Farmers	%
Local seed sale		
Not sale/exchange seed	103	50
Sale or exchange seed	103	50
Users of local seed exchange		
Relatives	50	49
Neighbours	71	69
Other farmers	72	70
Others (traders)	2	2
Mechanism of exchange		
Cash	100	97
Others (gift, seed exchange)	3	3

other farmers paid cash, whereas the remaining use other traditional exchange mechanisms. Mugedza and Musa (1996) reported that even among communal farmers of Zimbabwe, free seed handouts are not common (except for relatives) and neighbours and farmers from other villages had to purchase seed sometimes at nearly twice the local grain price.

Wheat Seed Retention/Replacement There are several factors which influence farmers' decision to change variety and/or seed. Heisey and Brennan (1991) listed factors that farmers perceive as important for changing seed such as improvements in production potential of certified seed, deterioration in seed retained from the grain crop, seed and grain prices, base yield levels, interest rates, learning costs, and risk premium. Mpande and Mushita (1996) reported that about 53% of the farmers perceived changes in their varieties in terms of declining yield and increased susceptibility to diseases over the years; and expected more changes in sorghum varieties than in pearl millets.

In Syria, the rate of wheat seed replacement, both from formal and informal sources, appeared to be high. During the survey year the majority of farmers sourced seed off-farm, with the highest proportion from the formal sector and followed by seed from relatives, neighbours or other farmers. In general, almost all farmers replaced their wheat seed stock within the last five years. In 1998/99 crop season, from a total of 206 farmers who planted wheat, 41% obtained fresh certified seed or changed their seed informally; 35% retained seed for one year; 14% for two years; 8% for three years; and 2% for four years (Table 3.32). Such quick seed replacement rates are

Table 3.32. The number of years wheat seed retained (saved) by farmers (n=273) in Syria.

Number of years	Aleppo		Raqqa		Hasakeh		Total	
	Farmers	%	Farmers	%	Farmers	%	Farmers	%
0	51	47	17	47	43	34	111	41
1	27	25	10	28	58	45	95	35
2	20	18	6	17	11	9	37	14
3	6	6	2	6	14	11	22	8
4	1	1	1	3	1	1	3	1
5	2	2	0	0	0	0	2	1
Over 5	2	2	0	0	1	1	3	1
Total	109	100	36	100	128	100	273	100

considered very high even by the standards of the formal sector which requires a four to five year seed replacement for self-pollinated crops. Van Gastel and Bishaw (1994) found frequent seed renewal rates among wheat seed farmers in Syria where nearly 80% replace seed within the period of three years. Cromwell *et al.* (1993) cited that over 75 and 40% of farmers growing soybean and beans, respectively, replaced their seed within less than five years. Such high rate of seed replacement is quite useful provided new varieties are released frequently and the seed is available on the market. Byerlee and Moya (1993) reported a high wheat varietal replacement rate for Syria probably due to such quick seed exchange among farmers. Mazid *et al.* (1998) also found an average age of 6.8 years for wheat in Syria which is an indicator of quick varietal turnover and adoption of new varieties by farmers.

Barley Seed Sources and Perceptions The 'primary diffusion' of new varieties from seed production organizations to farmers is accomplished by the formal sector through wholesale or retail distribution by various institutions. However, even in situations where the formal sector is well developed, the greatest diffusion of new crop varieties is achieved through the informal sector, which is responsible for 'secondary diffusion' among the majority of farmers. This is particularly true for self-pollinating crops such as wheat and barley; and in less favourable areas where the formal sector fails to reach farmers.

In Syria, the national seed programme advertises available seed of different crops through public media and sales seed at cost price to encourage certified seed use by farmers (Radwan, 1997). Seed is marketed directly by GOSM or by the Agricultural Co-operative Bank (ACB) through the farmers' co-operatives. GOSM is a parastatal seed corporation and is responsible for direct sale of seed to farmers on cash whereas the ACB is the marketing arm of the Ministry of Agriculture and Agrarian Reform and is responsible for financing rural credit to purchase agricultural inputs including seeds.

Initial Barley Seed Sources Table 3.33 presents the initial seed sources and the seed source in the 1997/98 crop season for planting barley in Syria. The majority of farmers growing barley initially sourced their current seed stock used informally from relatives (32.5%; n=200), other farmers (22.5%), neighbours (13%) and traders/local markets (18.5%). However a significant minority (13.5%) obtained their initial barley seed from GOSM, ACB or research organization, all which are formal sector institutions. This confirms the involvement of GOSM in production and distribution of seed of local landraces of barley. The pattern of barley seed source over a four-year period was not significantly different. The majority of farmers (>85%) used their own seed whereas seed from the formal sector, other farmers and from local traders or markets accounted for less than 15%. The figure indicated that the informal seed source accounted for over 95% of barley seed in Syria in any given year.

The General Organization for Seed Multiplication reported that it has distributed a total of 4214 t of barley seed probably all to the state farms in the 1997/98 crop season. This constituted 92.5% of Arabi Aswad a predominantly grown local landrace and three modern varieties (Badia: 3.7%, Furat 1: 0.1% and Furat 2: 3.7%) mainly recommended for the western and southern parts of the country. According to the national agricultural statistics the area for barley production in the 1997/98 crop season was estimated at 1,572,200 ha (CBS, 2000). At the seed rate of 100 kg ha^{-1}, this would cover a mere of less than 3% of the total barley area for the season probably skewed to the northwestern and southern regions of the country. During the 1997/98 crop season none of the sample farmers in the survey area purchased barley seed from the formal sector. It was not surprising not to find a single barley grower who sourced his seed

Table 3.33. Initial seed source of barley landraces and seed source in 1997/98 crop season (n=200).

Initial seed source	Farmers	%	Seed source in 1997	Farmers	%
Formal sector[1]	27	14	Formal sector	0	0
Neighbours/other farmers	71	36	Neighbours/other farmers	22	11
Local traders/markets	37	19	Local traders/markets	13	7
Relatives	65	33	Own saved seed	165	83
Total	200	100	Total	200	100

[1] Formal sector refers to GOSM, ACB and agricultural research organizations.

from the formal sector in Zones 2, 3 and 4. A similar result was also observed in Ethiopia where almost all barley growers (95%) sourced their seed on farm particularly in northwestern parts of the country (Woldeselassie, 1999). In Jordan, Al-Faqeeh (1997) reported that the major sources of lentil seed were their own seed saved from previous season (85%) or seed from their neighbours (12%) or certified seed (3%). Ndjeunga (2002) also reported that the major source of pearl millet seed in Niger was from own saved seed (88%) followed by seed from other farmers (15%), local market (4%) and development agencies (2%) with an increasing share of on-farm retained seed in more reliable harvest years and this was consistent across different agro-ecological regions and village accessibility.

Farmers' Perception of Local Off-Farm Barley Seed Sources In the previous years 27%, 57% and 22.5% of farmers had indicated to source seed from the formal sector, other farmers and local trading, respectively on several occasions and for various reasons. However, during the survey year 82.5% of farmers (n=200) used their own seed for planting the barley crop whereas almost one-fifth sourced their seed from other farmers (11%) or local trading (6.5%). In 1997, no single farmer purchased seed from the formal sector. There was a declining trend of barley purchase from the formal sector since the difference in grain price was introduced between wheat and barley in the early 1990s.

Since the number of farmers who purchased seed off-farm during the survey year was small, data for farmers, who sourced seed from other farmers, and those who purchased from traders/markets were pooled together for analysis (Table 3.34). The main overriding factor for sourcing seed from outside was lack of own seed (80%) followed by perception of seed quality (20%). Farmers had a positive perception of seed from their neighbours/other farmers or traders where 20% indicated that the quality of seed purchased was good. The major constraint for purchasing seed from the formal sector was the price, given the increased seed price to grain price ratio for barley.

The management of barley seed sourced off-farm locally is presented in Table 3.35. The majority of farmers cleaned the seed purchased from other farmers or local trading, although 17% claimed the seed was cleaned when purchased. The main purpose of cleaning was to remove dirt and inert material (63%), remove weed seeds (26%) or broken/small seeds (17%) from the seed lot used for planting. Cleaning was done by hand using local sieves, although two farmers used mobile machines hired from seed cleaners and treated their seed (3%). No farmer checked the germination of the seed purchased from other farmers. A large majority was satisfied with the quality of seed sourced from outside their farm informally.

Table 3.34. Farmers' perception of local off-farm source for barley seed (n=35).

Why farmers source seed from neighbours			Why farmers do not source formal seed (SC)		
Reasons	Farmers	%	Reasons	Farmers	%
No own seed	28	80	Formal seed is expensive	30	83
Seed quality is good	7	20	Formal seed not available	1	3
Seed available on time	4	11	Shortage of cash	4	11
Own seed not good	1	3	Lack of awareness	1	3
Exchange old seed	1	3	Others (small quantity)	1	3
Price is cheap	1	3	Certified seed is expensive	3	14

Table 3.35. Management of barley seed obtained off-farm from neighbours or local traders (n=35).

Seed management	Farmers	%
Purchased clean seed	6	17
Not clean seed	4	11
Seed cleaning	25	71
Purpose of seed cleaning		
Remove inert matter	22	63
Remove weed seeds	9	26
Remove small and broken seeds	6	17
Facilitate easy planting	2	6
Equipment used		
Hand sieving	23	66
Machine cleaning	2	6
Seed treatment	2	6
Check germination	0	0
Satisfied with seed quality	33	94

The time seed purchased both from other farmers or markets was well distributed over a six-month period from harvesting the crop in May or June to planting time in October or November (Table 3.36). However, slightly more farmers purchased seed right at harvesting time or closer to the planting time rather than earlier in the season particularly from traders. Most of the transactions were by direct cash payment (83%), credit for cash repayment (14%) or in kind (3%). Sperling (1998) reported that most of the bean seed sourced off-farm in Rwanda was obtained through purchase from local

Table 3.36. Time seed purchased (month of the year) and distance travelled (km) by farmers (n=35).

Month of the year	5	6	7	8	9	10	11		
Farmers (%)	5.7	25.7	5.7	14.3	5.7	28.6	14.3		
Distance travelled (km)	0	3	4	12	15	20	35	45	50
Farmers (%)	8.3	8.3	8.3	8.3	16.7	16.7	8.3	16.7	8.3

markets, neighbours or traders and that there was little free exchange of seed even among relatives. In our case 83% of the farmers were satisfied with the price of seed purchased from their neighbours and/or traders. The distance travelled to buy barley seed from local market or traders was up to 50 km, but about two thirds of the farmers travelled less than 25 km. In Syria, the rural infrastructure appears to be relatively better and farmers can afford to travel and purchase inputs. Cromwell *et al*. (1993) cited that farmers in Malawi walk over 30 km for bean seed and five day's travel in Nepal for potato seed acquisition. This is both the reflection of poor rural infrastructure development in terms of seed distribution and farmer's desire in acquiring the new variety.

Perception of Local On-Farm Barley Seed Sources Although farmers obtain seed off-farm for various reasons they are more likely to use retained seed particularly for self-pollinating crops such as barley where the quality of seed can be maintained easily on the farm (Table 3.37). 165 barley growers (82.5%; n=200) used own saved and among them 144 (87%; n=165) were satisfied with the quality of own saved seed. Over fifty percent of farmers considered the quality of own saved better or equal to seed from other seed sources including the formal sector. Moreover, timely seed availability (27%), cost of seed (6%), lack of improved variety (4%) and small quantity of seed required (2%) were some of the reasons for sourcing seed on the farm. The most overriding issue for farmers not buying seed from the formal sector was seed price (71%), shortage of cash (15%) and lack of credit (4%). Lyon and Danquah (1998) cited that farmers who use their own seed stock do not incur transaction costs. Although not clearly indicated, the complete absence of modern barley varieties contributed to farmers not sourcing seed from the formal sector. In Ethiopia, lack of alternative seed sources (57%), adaptation of local varieties (41%) and good quality of own seed (2%) were the main reasons for barley farmers to use seed retained on the farm (Woldeselassie, 1999).

Almost all farmers who used own saved seed cleaned their seed (95%) using sieves (96%). The main purpose of cleaning was to remove inert matter (80%), remove

Table 3.37. Farmers' perception of on-farm retained (own saved) barley seed (n=165).

Why farmers source seed on-farm			*Seed cleaning and treatment*		
Perception	Farmers	%	Management	Farmers	%
Seed available on time	45	27.3	Not clean seed	8	4.8
Good seed quality	90	54.6	*Seed cleaning*	157	95.2
No extra seed cost	10	6.1	Hand cleaning	151	96.2
Small seed quantity	3	1.8	Machine cleaning	6	3.8
No improved variety	6	3.6	*Purpose of cleaning*		
Others	10	6.1	Remove inert matter	124	80.0
Why farmers not source formal seed			Remove weeds/other crops	65	41.9
Certified seed is expensive	117	71.3	Remove small/thin seeds	16	10.3
No cash to buy certified seed	25	15.2	Remove broken seeds	16	10.3
Lack of credit	7	4.2	Remove shrivelled seeds	3	1.9
No new variety	5	3.0	Remove insects	8	5.2
Lack of awareness	3	1.8	Facilitate planting	27	17.4
Poor seed quality	5	3.0	*Seed treatment*	11	6.7
Lack of seed	2	1.2	*Germination*	6	3.6

weeds and other crops (42%) or to facilitate mechanical planting (17%). A very small number of farmers used seed treatment for barely where only 11 (7%) treated seed either with Quinolate (5), Vitavax (2) or other chemicals (4) by mixing the seed and the chemical with a shovel. Six farmers tried to check the germination of barley seed before sowing by planting seed in the backyard or a box filled with soil. This was a separate incident in one of the driest areas where farmers are concerned whether there is sufficient rainfall to sustain the germination of their barley seed.

Local Barley Seed Flow or Diffusion Cromwell *et al.* (1993) identified five key characteristics of local seed diffusion mechanisms. Accordingly, in comparison to the formal sector, they are traditional, informal, operate at community level, use various exchange mechanisms and are of small quantities. Apart from being informal the exchange mechanisms used and the quantity of seed required are important elements in serving the interest of the community in terms of their seed needs. Although all barley farmers use a landrace the practice of local level seed exchange was surprisingly high (Table 3.38). Despite common perception 57.5% of the farmers (n=200) reported selling their local barley as seed for other farmers. However, the retention of barley seed on the farm by some farmers usually for longer period of time might have contributed to slightly lower local level seed turnover compared to that. Among

Table 3.38. Local flow or diffusion of barley seed among farmers (n=200) in Syria.

Local level seed transaction mechanisms	Farmers	%
Local sale of seed (n=200)		
Not sale seed to other farmers	85	42.5
Sale seed to other farmers	115	57.5
Users of local seed market (n=115)		
Relatives	53	46
Neighbours	61	53
Other farmers	74	64
Mechanism of exchange (n=115)		
Cash	102	89
Seed exchange	15	13
Gift	13	11
Barter	1	1

farmers who sold barley to others (n=115) relatives, neighbours or other farmers constitute 46%, 53% and 64% of the recipients, respectively. Most of the transactions whether with relatives or other farmers were mainly based on cash (88.7%) and less with seed exchange (13%), gift (11.3%) or barter (0.9%). On the contrary, Rohrbach (1997) found that about 80% of local seed exchange mechanism among sorghum and pearl millet communal farmers in southern Zimbabwe was in the form of free gifts; and relatives and other farmers accounted for nearly 30% of the seed supply. He also noted that this could be influenced by the amount of seed exchanged which is very small (less than 2 kg) compared to other crops where the transactions are on cash or barter.

Barley Seed Retention/Replacement The mean number of years barley seed was saved by farmers was 6.7 (SD=8.4). Contrary to common knowledge and despite the fact that all farmers were growing a local landrace there was a moderately high turnover of barley seed (Table 3.39). About two thirds of the farmers replaced their seed during the last five previous years and the figure reached 85% when the previous 10 years were considered. Three possible scenarios might explain such high turnover for seed of the local barley variety, i.e. availability of seed from the formal sector, government grain price and frequent droughts. First, in the past the formal sector used to provide seed of a local landrace at a relatively cheaper price thus encouraging farmers to buy cleaned and treated seed. Second, the government grain price for barley prompted farmers to sell their produce and buy seed or feed on the market at a reduced price.

Table 3.39. The number of years barley seed is retained on-farm by farmers (n=200).

	Aleppo		Raqqa		Hasakeh		Total	
Number of years	Farmers	%	Farmers	%	Farmers	%	Farmers	%
0	20	21	4	9	11	19	35	18
1	10	11	11	23	2	3	23	12
2	9	10	7	15	5	9	21	11
3	2	2	5	11	6	10	13	7
4	3	3	4	9	8	14	15	8
5	7	7	5	11	8	14	20	10
6 to 9	7	7	3	6	9	15	19	10
10	17	18	3	6	4	7	24	12
11 to 19	11	12	3	6	5	9	19	10
≥20	8	9	2	4	1	2	11	6
Total	94	100	47	100	59	100	200	100

Third, frequent droughts and crop failures particularly in marginal areas forced some farmers to seek seed from outside sources. However, when different grain and seed prices for barley were introduced farmers opted to use their own seed and a significant drop of seed purchase from the formal sector was observed except in years with drought. Tutwiler *et al*. (1997) indicated that barley farmers tend to sell all their barley grain at high price to the government and buy cheap grain on the market to feed their animals. These factors had an influence on farmers to frequently change or purchase seed from outside sources.

Despite frequent droughts and crop failures in marginal environments where barley is the principal crop, about 25% of the farmers still retained barley seed on the farm for over 10 years. Mpande and Mushita (1996) indicated that for example sorghum and pearl millet farmers in Zimbabwe keep enough seed for two cropping seasons as security against droughts, although the quantity varies depending on the harvest. They also reported a continuous loss of local germplasm due to repeated droughts. This phenomenon might explain the survival of two barley local landraces with better adaptation to the extremely harsh and stressful barley growing environments across Syria. This is a testimony to the intrinsically dynamic nature of the informal sector and its resilience to environmental stresses to meet farmers' seed needs at local levels. For example, 30% of the farmers who used own saved barley seed in Ethiopia retained the same seed lot for over nine years (from 2-30 years) continuously while some of them claimed it as valuable legacy inherited from their ancestors (Woldeselassie, 1999). Similarly, Cromwell *et al*. (1993) quoted data from Nepal where farmers typically replace wheat seed every seven years, open pollinated maize every 10 years and rice seed every 20 years.

3.9.7. Farmers' Plant/Seed Selection and Management

Wheat and barley farmers in Syria usually demand varieties that combine different attributes such as high and stable yield, tolerance to biotic stresses (pest and disease resistance), abiotic stresses (drought, frost and cold tolerance). Some farmers, particularly small-scale farmers producing for household consumption, may require varieties with low use of external inputs and suitable for traditional food preparation (in case of wheat). A broader understanding of farmers' seed management practices is an important component of research oriented at developing strategies for local seed system to improve access to and use of appropriate varieties and good quality seed. Empirical evidence shows that farmers select crops and manage seeds based on their indigenous local knowledge. For most farmers, plant and seed selection is part of a crop production system rather than an isolated activity. However, the time of selection in the crop production cycle and the subsequent seed processing and storage practices determine the quality of seed selected.

Farmers' Perception of Seed and Grain Farmers have high appreciation for seed used for planting and 98% (n=200) of wheat growers distinguish the difference between grain and seed. They attributed the difference of the seed in terms of its cleanliness (53%), seed treatment (18%), freedom from weeds (31%), freedom from diseases (9%), good germination (6%) and big seed size (13%). The majority of wheat farmers practise cleaning (90%), applied chemical treatment (89%), separate storage (64%), made selection (54%) and check germination (4%) of seed used for planting. Likewise, from 200 barley growers, 99% recognize the difference between grain and seed. Apparently, 17% attributed the difference to purity, 9.5% to kernel size, 2.5% treatment, 2% quality and 1% freedom from weeds. As a result most farmers clean their seed (91%), store seed separately from grain (76%) and select seed during planting (46%). However, few farmers applied chemical treatment (7%) and checked germination of barley seed before planting (3%).

Farmers' Plant/Seed Selection of Wheat and Barley Crops Seed selection is part of on-farm seed management practice (Walker and Tripp, 1997). Farmers practise plant or seed selection at up to three stages in the crop production cycle: selection of ears or plants in the field of standing crops before or at harvest; selection of grain/ears on threshing floors; and selection of grain for sowing from threshed grain in store at planting time. The decision to use a particular seed lot for planting is a long process requiring continuous observation and evaluation rather than an isolated one-time incident or decision. Farmers monitor the entire crop growth in the field, later at harvesting/threshing time or during storage to differentiate between the seed that can be used for planting and the grain that can be used for other domestic purposes. Such an elaborate methodological approach for plant or seed selection could still persist in traditional farming systems where outside influence is minimal. However, the practice is rapidly disappearing and becoming less relevant for small grain cereal crops such as wheat and barley particularly where commercial agriculture predominate as farmers are increasingly dependent on seed from the outside sources such as the formal sector.

Wheat Seed Selection Over 50% of the farmers claimed practising wheat seed selection (Table 3.40). The majority of farmers decided what seed to use based on selection of a field or section of a field of the standing crops (87%; n=111) and usually before (6%) or at harvesting time (87%). Similar results were reported for sorghum and pearl millet where seed selection is mostly carried out in the field and at threshing time (Mpande and Mushita, 1996) which provides an opportunity for farmers to evaluate the crop for agronomic characteristics such as lodging, tolerance to pests, etc. The most important

Table 3.40. Farmers' practice and criteria for wheat plant/seed selection (n=206).

Plant/seed selection	Farmers	%	*Selection criteria (n=111)*		
Not select for seed	95	46		Farmers	%
Select for seed	111	54	Early maturity	5	5
Method of selection[1]			Shattering resistance	3	3
Field or section of field	96	87	Lodging resistance	5	5
Select grain	14	13	Disease resistance	20	18
Select ears	8	7	Pest resistance	3	3
Select plants	2	2	Plant height	12	11
Others	2	2	Ear size	38	34
Time of selection[1]			Grain yield	19	17
Planting	6	5	Grain size	36	32
Before harvesting	7	6	Grain colour	8	7
Harvesting	96	87	Marketability	1	1
Storage	1	1	Straw quality	2	2
Responsibility for selection[1]			Freedom from weeds	80	72
Men	109	98	No mixtures/off types	7	6
Both (men and women)	2	2	Cleanliness of field	5	5

[1] Based on farmers who select seed (n=111).

selection criteria were freedom of the standing crops from contaminating weed plants (72%), ear size (34%), grain size and disease tolerance (rather absence of disease) whereas other factors remain to be of less importance. These criteria were used for making a decision which grain to harvest from which field/plot and which should be kept for seed than individual ear selection, as is the case with maize, sorghum or pear millet reported elsewhere where individual plant heads or ears are selected and kept for seed (Mpande and Mushita, 1996; Walker and Tripp, 1997). Moreover, they also reported that grain yield, grain colour, grain size, early maturity, drought tolerance and a combination of them as the criteria used by farmers in seed selection (Mpande and Mushita, 1996).

Barley Seed Selection Almost one-half of the farmers (49.5%; n=200) claimed practising barley seed selection for planting purposes (Table 3.41). The majority of farmers based their selection criteria on the combination of the situation of standing crops in the field and the grain quality at harvesting time. They decided which field or part of field could be harvested and further evaluated the product in terms of other criteria to differentiate between grain used for planting, livestock feed or sell in markets.

The most important selection criteria were manifold including yield, grain characteristics and freedom of the standing crops from contaminating weed plants. Seed selection was undertaken by deciding which field or section of a field (79%; n=99) to harvest for seed usually before (20%) or at harvesting time (76%). About 69% (n=99) of farmers considered grain size as the most important factor to determine whether to use the grain for seed or other purposes. Grain colour (42%) or grain yield (41%) at harvest or ear size (22%) of the standing crop were also considered important selection criteria in deciding the seed used for planting barley crop.

The freedom from weeds came as important second criterion (56%) as most farmers had serious problems with weed infestation in barley growing areas of the country. By doing so farmers may be indirectly selecting for plants that have some inherent resistance to weeds as new evidence suggests varietal differences in crops such as wheat for suppressing weeds (Rizvi *et al.*, 2002). The agronomic factors most valued by plant breeders such as early maturity, tolerance to biotic stresses were not considered to be highly important, both as selection or adoption criteria by farmers due to the difficulty to assess these characteristics. Selection for these characteristics is rather indirect. For example the absence of infection rather than the level of pest resistance of the variety is considered a selection criterion by farmers. This does not preclude that some farmers are using these criteria in their selection. Walker and Tripp (1997) reported little seed selection in the field for maize and cowpea in Ghana (less than 4%) compared to sorghum and cowpea in Zambia where 18 to 25% of farmers

Table 3.41. Farmers' practice and criteria for barley plant/seed selection (n=200).

Plant/seed selection	Farmers	%	*Criteria for selection (n=99)*	Farmers	%
Not select for seed	101	51			
Select for seed	99	50	Grain yield	41	41
Method of selection[1]			Grain size	68	69
Field or section of field	79	79	Grain colour	42	42
Select grain	23	23	Marketability	4	4
Select plants	8	8	Feed quality	3	3
Select ears	1	1	Straw yield	4	4
Stage of selection[1]			Straw quality	1	1
Standing crops	19	20	Plant height	13	13
At harvesting	75	76	Ear size	22	22.2
At planting	5	5	Non-shattering	1	1
Responsibility for selection[1]			Disease resistance	3	3
Men	95	96	Early maturity	10	10
Women	0.0	0.0	Free of weeds/cleanliness	55	56
Both (men & women)	4	4	Free of other crops/ varieties	5	5

[1] Based on farmers who select seed (n=99).

selected seed on the farm. Field selection was based on large head, large seed and absence of disease and early maturity based on the crop whereas post-harvest selections were based on size of grain, cob or pod and its conditions (cleanliness, good appearance and freedom from insects). In case of cowpea, they also found that the way the crop was stored on the farm, whether threshed or unthreshed, influenced the selection practices.

Most of the farmers interviewed both for the wheat and barley seed system study were growing both crops particularly in Zone 2 where similar attitudes and approaches were applied to both crops, although wheat farmers appeared to have slightly better awareness of the criteria for modern plant breeding. Seed selection started from choosing the right field to the conditions of the standing crops in the field to grain quality characteristics at harvesting, during storage and at planting time singularly or in combinations based on the knowledge and perception of individual farmers. These selection criteria may not bring significant shift on the genetic combinations of the variety as most plants are harvested together, but might contribute to some invisible changes in the compositions of the variety. For example the selection of a field could be attributed to its past or present crop management history such as rotation, fertilization, irrigation which is translated to properly rotated, fertilized or irrigated field where the crop stand, grain yield and grain quality (size) could be good. For example, early maturity means a field which has matured properly because it might have been planted early, thus the crop escapes drought, thus, the production is good in terms of grain yield and grain size. Resistance to pests means the absence of infestation with insects or infection with pathogens while in the field or in store (although in places where storage pests are prevalent a seed lot with less/no infestation might indicate some degree of resistance). However, farmers can relate each of their selection criteria with their life time experiences to differentiate between good and poor quality seed. Seed selection, therefore, is also interlinked to crop or plant selection.

The role of women in seed selection and management processes appeared to be less visible compared to that of wheat in Ethiopia (Chapter 2), vegetables in Bangladesh (Shah and Nuri, 2000) or the case in Nepal (Bajracharya, 1994) where they play an important role. The increased use of combine harvesters (harvesting and threshing) substantially reduced the female labour contribution to wheat and barley production (Ashram, 1990) while previously women were involved in hand harvesting (Tully, 1990) and therefore directly contributed to the selection and maintenance of wheat and barley seed on the farm. Mazid (1994) reported that about 64% of farmers shared their barley production decision with their immediate family members (including their spouses). In another study, it was found that women were responsible for most of the on-farm cleaning of barley seed (Daniela Mangione, personal communication) although men did not largely acknowledge this practice. Another study cited from Nepal (Bajracharya, 1994) indicated that although women farmers' contributions to on farm work and decision making on the average was 57%, the agricultural development officers (men) perceived that the contribution of women was low (11-23%) compared to the rating of female development officers (62%), a clear reflection of a gender bias. Although men did not largely acknowledge the role of women because of social taboos, some farmers confide privately that most of the on-farm activities such as seed selection, cleaning and storage are joint responsibility of both men and women. In practical terms, women contributed indirectly to plant and/seed selection both in wheat and barley crops. A generally held view of traditions that women are more engaged in household activities than in farming contributes to this underestimation.

In Syria, the plant and/or seed selection practised in wheat and barley can be summarized as follows: (i) no methodological approaches were observed in plant selection both in wheat and barley crops; (ii) farmers' seed selection for planting was anecdotal and not systematic and largely influenced by field observation at harvesting or planting time; (iii) the intensification and commercialization of agriculture both in wheat and barley production is leading to loss of traditional practice of plant/seed selection; (iv) the high rate of seed renewal and varietal turnover resulting from availability of better adapted wheat varieties relieved farmers searching for improvement in existing varieties; (v) no significant variation in plant and/or seed selection between wheat and barley growers was observed, although barley farmers still used mostly local landraces; and (vi) role of women in decision making process of plant/seed selection was limited, although their contribution was high in on-farm seed cleaning and management.

On-Farm Seed Cleaning and Treatment From a farmer's viewpoint, seed selection and cleaning are closely interlinked both aimed at improving the quality of the planting material to meet specific standards. In technical terms seed cleaning (or in broader terms processing) is an elaborate post-harvest operation and may include seed drying (removing excess moisture), grading (removing impurities), treating (protection against pests), packaging and storage. In some circumstances, on-farm seed cleaning is no more than winnowing the seed after harvesting where the method does not guarantee selection of uniform grain sizes (Mpande and Mushita, 1996). In others, seed cleaning is on-farm seed management where detailed seed cleaning techniques are employed to maintain seed quality (Mugedza and Musa, 1996) or an elaborate seed treatment technique where traditional practices are employed to protect the seed against storage pests (Monyo *et al*., 2000). In general, it is an effort to ensure that the seed used for planting is well established in the field and will raise a good crop. Seed cleaning was a very common seed management practice both for wheat and barley seed sourced locally from neighbours, other farmers or traders as well as seed retained on the farm.

Wheat Seed Cleaning and Management From 206 farmers who were surveyed in the 1998/99 crop season, 186 (90%) reported that they cleaned and treated their wheat seed for planting in case they sourced seed from other farmers or used retained seed (Table 3.42). The remaining farmers indicated that they purchased cleaned and treated seed from government or traders. Therefore, all wheat growers surveyed reported using cleaned and treated wheat seed either from formal sector or through on-farm seed management.

Forty-five farmers (22%) used cleaned and treated certified seed sourced from the formal sector. The remaining 161 farmers (78%) sourced seed from other farmers, traders or used their own seed where most of the seed was cleaned and/or treated by farmers themselves (five farmers purchased cleaned and treated certified seed from traders and eight purchased cleaned seed from other farmers). Most farmers (n=161) used manual cleaning with sieves (78%) and the main purpose was to remove inert matter (38%), weeds (42%), broken seeds (34%), and seeds of other crops such as

Table 3.42. On-farm wheat seed management (cleaning and treatment) by farmers (n=161) in Syria.

	Own seed	Traders	Other farmers	Total	%
Seed cleaning and treatment					
Purchased clean seed	-	5	8	13	8
Cleaned seed	127	2	19	148	92
Method of cleaning					
Hand sieving	108	2	15	125	78
Machine cleaning	19	-	4	23	14
Purpose of cleaning					
Remove inert matter	50	2	9	61	38
Remove weed seeds	59	-	8	67	42
Remove small seeds/good size	20	-	4	24	15
Remove broken seeds	45	-	9	54	34
Easy planting	4	-	-	4	3
Remove other crop seeds/barley	31	-	-	31	19
Seed treatment					
Purchased treated seed	-	5	-	5	3
Treat seed	127	2	27	156	97
Germination	7	-	2	9	6

barley seed (19%). The striking difference between wheat and barley seed management was the extent of chemical treatment used by farmers.

Few farmers were concerned about the physiological quality of their seed and tested the germination of their seed (6%). This does not necessarily mean that farmers do not attach value to this seed quality characteristic, but they did not either experience the problem or consider it as a cause for poor crop establishment. Walker and Tripp (1997) also reported that only 10% of farmers considered poor field establishment associated with poor seed quality, although the figure can reach 25% among cowpea farmers in Ghana. It is possible to introduce simple and practical germination test methods using cheap and locally available materials and make farmers aware of these methods. For example, Mathur and Talukder (2002) used jute mats as a 'quick method' for germinating rice seed in Bangladesh and this was found to be the quickest test completed within seven days compared to other formal methods.

In commercial agriculture chemical seed treatment is becoming one of the cheapest and most economic measures to limit the spread of seed-borne diseases (Diekmann, 1993). In Syria, the availability of the chemicals induced wheat growers to use seed treatment probably influenced by the practices of the formal sector. On-farm chemical seed treatment was widely practised whereby almost all farmers treated their seed before planting (76%) except those who purchased treated seed (24%). In Jordan on-farm wheat seed cleaning and wide spread use of seed treatment chemicals was reported for seed sourced from other farmers or retained on the farm (Hasan, 1995). It was found that 64 and 62% of seed sourced informally was cleaned and treated on the farm, respectively. However, Stanelle *et al*. (1984) reported that seed treatment was practised by 36% of the wheat farmers, but more targeted towards areas with high rainfall and humidity where disease problems were anticipated which was not necessarily the case in Jordan and Syria. On the contrary, although 56 farmers (27%; n=206) planted barley as a second crop along wheat none reported applying chemical treatment to their seed before planting.

A wide range of chemicals, locally produced or imported, was available for use for seed treatment by farmers who sourced seed locally (Table 3.43). From 156 farmers who treated their seed on farm the most popular fungicide for seed treatment was Quinolate (69%) followed by Agrospor 60 (19%). The former is a general purpose broad spectrum copper sulphate based fungicide whereas the latter is composed of mancozeb. Both are recommended for the control of seed-borne diseases in cereals. Vitavax is a carboxin based systemic fungicide for control of loose smut in cereals Farmers reported that control of seed-borne diseases particularly of smuts (73%) was the main objective of applying seed treatment. The chemical, usually in powder form, is first diluted in water and then mixed with seed manually on tarpaulins using shovels

Table 3.43. Types and rates of chemicals used for wheat seed treatment by farmers (n=156) in Syria.

Rate in g/100 kg	Amco 8	Agrospor 60	Quinolate	Vitavax	Others[1]	Total	%
100	3	12	15	1	-	31	20
101 to 199	-	3	6	2	-	11	7
200	1	6	40	1	3	51	33
250	-	4	21	-	3	28	18
251 to 300	-	1	12	-	3	16	10
Over 300	-	3	12	-	2	17	11
Do not know	-	-	1	-	1	2	1
Total	4	29	107	4	12	156	100
%	3	19	69	3	8	100	

[1] Others include products of Syria (6), Turkey (2), unknown (4).

(87%) whereas mobile cleaners were used to treat the rest. A mere 12% of farmers reported taking the necessary safety precautions while treating the seed.

The recommended rate for seed treatment is 100 g for Amco 8 and 200 g each for Agrospor 60 and Quinloate for 100 kg of wheat seed. However, the rate applied ranged from 100 g to 540 g of chemical for 100 kg of wheat seed. About 33% and 18% of farmers applied 200 and 250 g per 100 kg seed, respectively. Almost one-fifth of the farmers applied 100 g per 100 kg seed.

The main constraints in seed treatment were the formulation of chemicals available; the method and rates of application; precautions on safety measures; and lack of adequate equipments and knowledge in handling pesticides. Seed treatment, mixing the seed and the chemical by shovels on the ground with apparently little or no safety measures was the most common practice. Most farmers did not have adequate knowledge of the chemicals (could not identify the name of the chemical except by its colouring matter), application and efficacy of the chemicals. Moreover, sub-standard

Table 3.44. On-farm barley seed management (cleaning and treatment) by farmers (n=200) in Syria.

Seed cleaning/treatment	Seed source			Total	
	Own seed	Traders	Other farmers	Farmers	%
Not clean seed	8	2	2	12	6
Purchased clean seed	0	0	6	6	3
Clean seed	157	11	14	182	91
Method of cleaning					
Hand cleaning	151	11	12	174	87
Machine cleaning	6	0	2	8	4
Purpose of cleaning					
Remove inert matter	124	11	11	146	73
Remove weeds/other crops	65	2	7	74	37
Remove small/thin/shrivelled seeds	19	1	0	20	10
Remove broken seeds	16	0	5	21	11
Remove insect infested seeds	8	0	0	8	4
Facilitate planting	27	0	2	29	15
Seed treatment					
Not treat seed	146	10	13	169	85
Treat seed	11	1	1	13	7
Germination	6	0	0	6	3

chemicals without proper formulation and of unknown origin were also available on the market. Adequate extension programme for seed treatment would be beneficial for the farmers in increasing the efficacy, targeting the organisms and reducing the cost and pollution of the environment.

Barley Seed Cleaning and Management The seed cleaning and treatment of barley seed is presented in Table 3.44. After harvesting the majority of farmers usually select the bigger, however, undamaged grains using locally manufactured tools. 91% of farmers (n=200) cleaned their barley seed before planting. Manual cleaning using a wire mesh sieve is most common and practised by 87% of farmers whereas few used locally manufactured mobile cleaners (4%). The main purpose of cleaning was to remove dirt/inert matter (73%), followed by removing weeds and other crops (37%). Seed cleaning was also used to facilitate machine planting by removing inert matter to allow free flow of seed (14.5%) or as part of removing insect infested grains (4%). Surprisingly, fewer farmers practised chemical seed treatment in barley than in wheat. From 13 farmers who treated their barley seed, seven used Quinolate and two used Vitavax to control seed-borne diseases. In Ethiopia, nearly 90% of barley growers who retained seed on the farm or purchased seed from neighbours cleaned their seed using locally manufactured hand tools (Woldeselassie, 1999). But the traditional seed cleaning was not efficient in removing weeds and inert matter from the seed lots. None of the farmers used seed treatment as well.

Germination is an important aspect of seed quality determining crop establishment. However, there is little evidence to suggest that farmers use elaborate techniques in determining the germination capacity of seed. Very few farmers reported that they planted barley seed in the backyard to check germination before planting. One farmer reported an incident where he planted barley seed in a box with soil to check germination for the first time as he suspected the quality of his seed lot. This is a separate incident rather than a general practice followed by farmers. Mugedza and Musa (1996) also reported that farmers did not consider germination as important in their perception of sorghum seed quality. This is contrary to the results found in Ethiopia for wheat crops (Chapter 2).

Seed Storage and Management In the WANA region including Syria, dry weather conditions with low relative humidity during summer make seed storage relatively easy. However, storage pests remain the most critical and destructive problem for on-farm grain storage. Most insect pests such as weevils are cosmopolitan and found both in tropical and temperate regions of the world. Grain storage on the farm is more common for barley than for wheat because the grain is used as animal feed. Some reports indicated that farmers sell their produce to the government and buy grain/seed cheap on the market.

In traditional subsistence agriculture, farmers use a wide range of locally available natural seed treatment techniques to control storage pests (Mugedza and Musa, 1996; Monyo *et al*., 2000). However, the use of contact insecticides and fumigants becomes possible when farmers have access to the chemical and can afford the costs of application.

Wheat Seed Storage and Management Almost similar results to that of barley were observed in 1998 wheat seed survey in Aleppo, Raqqa and Hasakeh governorates. It was found that 64% of farmers stored their seed separate from grain whereas the remaining (36%) stored grain and seed together (Table 3.45). Walker and Tripp (1997) found that farmers in Zambia tend to separate their sorghum, bean and groundnut seed whereas farmers in Ghana are less predisposed to such practice for their maize and cowpea seed. The way the crop is stored may influence the storage strategy as more farmers in Ghana threshed their cowpea than in Zambia.

Sixty four percent of wheat farmers reported experiencing storage pest problems slightly less than that of barley growers because less wheat grain is stored on the farm,

Table 3.45. On-farm wheat seed storage and management practices by farmers (n=206) in Syria.

Seed storage practices	Farmers	%	Seed storage practices	Farmers	%
Store seed separately	132	64	*Not store seed separately*	74	36
Polypropylene bag	52	39	Polypropylene bags	24	32
Jute bag	75	57	Jute bag	48	65
Both	5	4	Both	2	3
Control of storage pests			*Control of storage pests*		
No infestation	48	36	No infestation	28	38
Sun drying	15	11	Sun drying	6	8
Cleaning	42	32	Cleaning	20	27
Change/dispose seed	15	11	Change/dispose seed	14	19
Dusting or spraying	28	21	Spraying	10	14
Fumigation	32	24	Fumigation	17	23
Responsibility for storage			*Responsibility for storage*		
Men	111	84	Men	68	92
Women	6	5	Women	3	4
Both (men and women)	15	11	Both (men and women)	3	4

where farmers dispose almost all their produce directly to the government because of favourable prices. Moreover, many farmers frequently changed their seed for planting by purchasing from external sources particularly the formal sector and as a result practised less on-farm seed storage and therefore experienced less pest problems. From those farmers who had storage pest problems (n=131), 62%, 40% and 5% of farmers reported that weevils, khapara beetle and rodents, respectively, were serious pests. Earlier reports indicated that all three pests were confirmed as serious grain storage problems in Syria.

Almost all grain and seed was stored in jute bags, polypropylene bags or both whether the seed was stored with grain or separately showing the disappearance of traditional storage practices. The use of polypropylene bags was more common in wheat than for barley as farmers might have re-used packages from certified seed delivered to them. In addition to other containers, jute or polypropylene sacks were reported to be the most common seed storage materials in Ghana and Zambia for maize, cowpea and groundnut seed (Walker and Tripp, 1997). Farmers were more careful in handling wheat seed on-farm than in handling barley seed. Traditional storage pest control methods such as sun drying, cleaning or changing/disposing the infested seed are still practised although becoming less popular through time. However, there is an increasing trend to use chemicals for storage pest control. About 21% and 24% of farmers (n=132) storing seed separately used contact insecticides (dusting/spraying) or fumigation for pest control, respectively. These two chemical control methods constituted 14% and 23% for farmers (n=74) who did not store seed separate in the same order. Walker and Tripp (1997) found that cereal and legume farmers in Ghana and Zambia used a combination of traditional and modern storage pest control methods. They reported that farmers in Ghana are more inclined to use seed protectants more on cowpea (78%) than on maize (48%) compared to farmers in Zambia who did apply less so and no chemical at all for crops such as sorghum, although insects found to be the main causes for seed damage on the farm.

In case of wheat there is wide spread use of chemical control for storage pests. Both contact insecticides and fumigants are available on the market. In the past methyl bromide has been widely used for large-scale grain storage whereas farmers have been using phostoxin tablets. The type, rate and method and equipment for application raise fundamental questions of efficacy and safety. In general the inappropriate use of chemicals has led to the development of pesticide resistance worldwide. Likewise, in Syria the strains of kahpra beetle (*Rhizopertha dominica*) collected from various grain storage facilities across the country had shown different levels of pesticide resistance (Niane, 1991).

Barley Seed Storage and Management During 1997 barley seed survey in Aleppo, Raqqa and Hasakeh governorates, 74% of farmers (n=200) reported experiencing storage pest problems. From those who had storage pest problems 83%, 14% and 10% of farmers (n=148) reported that khapara beetle, weevils and rodents, respectively, were serious pests. A survey of grain and seed storage facilities in northwestern Syria found that the khapara beetle was the most widespread and destructive storage pest (Niane, 1991). Moreover, it was found that three-quarters (76%; n=200) of farmers store seed separate from grain whereas the remaining one-quarters store grain and seed together (Table 3.46). Moreover, grain/seed storage in jute bags in the house is the most common practice for both groups of farmers who store grain and seed together or separately accounting for more than 94% of the respondents. Traditional storage structures much quoted elsewhere such as baskets, clay pots, glass jars or tins (Mpande and Mushita, 1996; Walker and Tripp, 1997) are uncommon (do not exist) and are not in use because they are irrelevant for cereal crops such as wheat and barley where large quantities of seed are required.

Farmers in Syria use both traditional (such as cleaning and sun drying) as well as modern pest control measures to manage storage pests on the farm. Woldeselassie

Table 3.46. On-farm barley seed storage and management practices by farmers (n=200) in Syria.

Seed storage practices	Farmers	%	Seed storage practices	Farmers	%
Store seed separate	152	76	*Not store seed separate*	48	24
Polypropylene bag	0	0	Polypropylene bag	1	2
Jute bags	143	94	Jute bags	45	94
Local bins	5	3	Local bins	1	2
Bulk	4	3	Bulk	1	2
Control storage pests			*Control storage pests*		
No infestation/control	44	29	No infestation/control	10	21
Sun drying	27	18	Sun drying	13	27
Cleaning	57	38	Cleaning	14	29
Chemical	2	1.3	Chemical	24	50
Dispose/change seed	13	9	Dispose/change seed	0	0
Others	9	6	Others	2	4
Responsibility for storage			*Responsibility for storage*		
Men	134	88	Men	38	79
Women	9	6	Women	4	8
Both (men and women)	9	6	Both (men and women)	6	13

(1999) reported traditional practices such as heat treatment, drying seed in the sun, winnowing to remove live insects, changing the storage structures or disposing infested seed as well as use of chemicals (contact insecticides and fumigants) as most common strategies for control of grain storage pests for barley crop in Ethiopia.

In Syria, both studies on wheat and barley seed industry revealed interesting and contrasting situations in terms of farmers use and perception of new varieties, adoption of improved agricultural technologies, and on-farm seed management practices. In general there is strong government commitment and support to raise food self-sufficiency and food security in strategic crops. This policy influenced the adoption of improved agricultural technologies differently across crops, farming systems and regions. The adoption and diffusion of modern bread and durum wheat varieties and associated technologies appears to be higher than for barley crop partly because of differences in government policy support and market incentives.

3.10. Concluding Remarks

Syria is located in the Fertile Crescent, the centre of crop domestication and the birthplace of wheat and barley, the two most important principal agricultural crops relevant to global food security. For millennia farmers were selecting, maintaining and growing wheat and barley local landraces adapted to very harsh and stressful environments leading to the development of unique germplasm resources with tremendous wealth of genetic diversity and variability on the farm. The country largely remained a treasure trove of the ancestors and wild relatives of wheat and barley crops. Since the 1970s, however, the introduction of modern varieties particularly of wheat has threatened these precious germplasm resources on the farm, as a result of agricultural mechanization and intensification in previously traditional farming systems. A concerted effort should be made both to conserve these valuable germplasm and make use of these unique genes by incorporating them into modern varieties that will improve wheat and barley production at national and international levels.

In Syria, the adoption of high yielding input responsive modern wheat varieties and associated technologies is spectacular. Within a short period of time the country has become self-sufficient in wheat production and produced surplus for export. The provision of modern wheat varieties combining high and stable yield, the generation and transfer of appropriate agronomic packages for different agro-ecological zones and the expansion of area under irrigation are the driving forces behind this achievement. The success also partly hinges on the existence of strong formal wheat seed supply system where seed of modern varieties is provided at relatively low cost and regularly used by farmers including the necessary complimentary inputs. The wheat case demonstrated the linkage between agricultural research and the formal seed sector in contributing to the achievement of national food security (at least in better-endowed environments of the country) if it is properly backed by strong government commitment and policy environment in providing inputs, marketing arrangements and price incentives. Such strategy should be considered if success has to be replicated in other crops such as barley.

The adoption rates of modern bread and durum wheat varieties and selected technologies have reached a maximum level in major production areas although some farmers continue to grow local landraces in isolated mountainous regions and marginal environments. Therefore, future productivity gains are most likely to come from better adaptation of improved germplasm, better targeting of improved technologies, and improved crop and resource management at the farm level particularly by considering the producers viewpoint especially the conditions for production and marketing experienced by farmers. Syria is producing surplus wheat and is entering international wheat markets where improvements of grain quality for the processing industry and product quality for consumers would be more important than high yield and increased production alone. In the future research should focus not only on yield improvement but also in grain and processing quality and should be supported by premium prices to ensure adoption of modern wheat varieties.

Several modern wheat varieties targeted to specific zones and technological packages were released at the national level, but the varieties were grown interchangeably outside their recommendation domain. For example, varieties targeted for rainfed semiarid conditions were found grown under full irrigation or vice versa where in both cases varieties fail to perform to their expected yield potential leading to yield gaps between research stations and farmers fields. Moreover, farmers' adoption of modern varieties, sowing methods, fertilizer application and irrigation (where available) is high. However, the adoption rates of agronomic practices such as sowing dates, seed rates, fertilizer rates, methods and rates of irrigation were not properly followed despite farmers' awareness of these technologies and need to be addressed properly. It is important to put in place an effective technology transfer mechanism and/or monitoring system to ensure that farmers use varieties and associated technologies accordingly to achieve maximum yield potential and maintain the productivity of wheat varieties.

Barley is a typical crop of marginal environments where yield is limited by severe abiotic and biotic stresses. In recent years, population pressure pushed barley production to more marginal areas and the yield is declining in real terms. Farmers in major barley production areas including northeastern Syria are growing local landraces and depend on informal seed sources although modern barley varieties targeted to different environments (though skewed to western and southern regions) were released and associated technologies have been demonstrated to them. Despite the availability of improved technologies and rapid intensification and commercialization of agriculture in Syria, the barley seed supply system remains largely informal. This could either be attributed to lack of adequate technology transfer mechanisms or the failure of the technology itself in meeting the perception of farmers. A sustained effort is required from developing varieties with better stable high yield, grain and straw quality than the local landraces widely cultivated in the country to designing appropriate technology transfer mechanisms to reverse the declining barley production. To replicate the success as in wheat, the government should find alternative ways of supporting sustained efforts to increase barley production through provision of appropriate policies and price incentives.

The continuous lack of and low adoption of modern barley varieties have led to seeking alternative ways of crop improvement and selection from conventional to participatory plant breeding through farmer participation. The emphasis is to exploit the synergy between science based research and farmers' indigenous knowledge to come up with new barley varieties desired and acceptable by growers and adaptable to highly complex, diverse and risky marginal environments of the country where the barley crop predominates. However, in order to facilitate wider adoption and diffusion of varieties identified through such innovative approaches, the effort should be matched with flexible policy options to allow alternative seed delivery system in the country. Therefore, establishing the linkage between participatory plant breeding and seed supply system is vital if the varieties developed through farmers' participation are expected to yield better impact in increasing barley production and productivity on the farm and the country.

In Syria, the seed supply system for strategic crops such as wheat, cotton, potato and lately for sugar beet is formally organized and predominantly operated by the public sector. The seed system is strongly supported by the government, strongly linked to the formal sector and is functioning quite well. However, the same system failed to provide substantial impact for crops such as barley that is adapted to marginal environments and food legumes and forage crops. Moreover, the national seed industry is dominated by the public sector and the participation of the private sector is non-existent. It is important that in the future agricultural policies should consider allowing, in addition to the public sector, the participation of private sector or farmer groups to establish alternative sustainable seed supply systems to meet niche markets for other crops.

Local seed management systems vary greatly being developed and refined over time in response to farmers' circumstances. On-farm seed management including plant/seed selection, cleaning, storage, treatment and exchange could be detailed and complex for certain crops in traditional farming communities whereas in highly intensive modern agriculture it is less sophisticated and purely means retention of seed for the next year planting. The majority of Syrian farmers had shown great skill and perception for on-farm seed management to a different degree of sophistication, although wheat farmers were keen in introducing new technology to their already existing skills. As a result almost all farmers who sourced wheat seed locally used chemical treatment compared to the barley seed where treatment is hardly practised. Moreover, local level small-scale mobile seed cleaning and treatment services are becoming a budding rural enterprise. The government should provide adequate policy, regulatory and technical support to implement a sound on-farm seed cleaning and treatment to improve the efficacy and safety at farm level.

In its simplistic form, the informal seed system refers to an array of local crop production and on-farm seed management strategies (selection, cleaning, storage, treatment, acquisition) to provide domestic household food security in the short-term as well as the selection, improvement and maintenance of the portfolio of germplasm (modern varieties or local landraces) for sustainable crop production in the long-term within farmers agro-ecological, socio-economic and cultural context. The informal seed sector is dynamic though partly location specific. Farmers in Syria have contributed to the wealth of wheat and barley germplasm resources through cultivation of local landraces and exchange with other regions. However, that traditional knowledge is rapidly disappearing because of intensification and mechanization of agriculture, less so in barley than in wheat. However, an effort should be made to recognize its role and integrate it to the formal sector to make the national seed industry more sustainable.

CHAPTER 4

Farmers' Seed Sources and Seed Quality: Physical and Physiological Quality

Farmers’ Seed Sources and Seed Quality: Physical and Physiological Quality

4.1. Abstract

A total of 304 wheat seed samples from Ethiopia and 200 barley and 206 wheat seed samples from Syria were collected from major wheat and barley growing regions during the 1997/98 and 1998/99 crop season to investigate the quality of seed obtained from various sources and planted by farmers. A 1 kg sample was drawn from seed lots intended for planting from each farmer and the questionnaire was filled on farmers’ perception of seed quality including the seed selection and management practices. The physical and physiological quality of seed sampled from farmers was analysed in the laboratory according to the international rules for seed testing. In Ethiopia, the mean physical purity and germination of wheat seed was 98.92 and 96%, respectively and the majority of samples (93%; n=303) reached the minimum purity and germination standards for certified seed 2. The seed obtained from the formal sector had the highest analytical purity (99.4%), but there was no significant difference in analytical purity among different sources such as neighbours/other farmers (98.8%), local traders/ markets (98.6%) or own saved seed (98.9%). However, the mean germination for certified seed (96%) showed weak significant difference from seed obtained from neighbours/other farmers (94%), markets/traders (94%) or own saved seed (96%). In Syria, mean physical purity and germination for wheat was 97.6% and 88%, respectively, whereas for barley the average analytical purity was 95.5% and germination was 86%. The quality of wheat seed samples was comparatively better than that of barley seed samples. The majority of wheat seed samples, i.e., 70.4% (n=206) for physical purity and 78.2% for germination, met the minimum seed quality requirements of certified seed second generation. In case of barley, however, only 10% of samples for physical purity and 72% of samples for germination reached the minimum standard for certified seed 2. There was no significant difference in physical and physiological quality of wheat seed samples obtained from different sources compared to barley where germination from different sources was significantly different. However, highly significant differences in seed quality were observed for seed samples collected from different regions and districts for wheat and barley crops in both countries. Vigour indices showed significant difference among wheat and barley seed samples from different regions and districts, but not among different sources. Simple correlation coefficients showed significant relationships among vigour tests. The standard germination, speed of germination and seedling root length were well correlated with field emergence in wheat and barley in both countries.

Key words: Ethiopia, Syria, barley, *Hordeum vulgare*, wheat, *Triticum* spp., seed quality, purity, germination, vigour, formal seed system, informal seed system, seed source, on-farm seed management.

4.2. Introduction

Seed is a critical input in crop production whether agriculture is practised at commercial or subsistence levels, by large or small-scale producers or in favourable or less favourable environments. Seed quality is one of the many factors that affect the yield potential of a crop. According to Cromwell (1990) there are two distinct and most important components of improved seed: genetic information contained within the seed and its physical and physiological attributes. The genetic quality is the most determinant to the performance of other quality factors and response to inputs and management. Hampton (2002), defined seed quality 'as standard of excellence in certain characteristics or attributes that will determine the performance of the seed when sown or stored'.

Seed quality is a sum total of many aspects including genetic, physical purity and physiological quality (Cromwell, 1990; Tripp and Van der Burg, 1997). There are four key seed quality attributes which may be explicitly identified: (a) genetic quality – (i) the inherent genetic information contained in the seed which provides the potential for higher yield, better grain quality, greater tolerance to biotic or abiotic stresses, (ii) varietal identity, i.e., the transfer of seed of desired variety from the breeder to the farmer through successive generations of seed multiplications; (b) physiological quality – the viability, germination and vigour of seed which determines the germination and subsequent seedling emergence and crop establishment in the field as well as the storage potential of the seed lot; (c) physical quality – analytical purity, freedom from other crop/weed seeds contamination, seed size, seed weight and seed lot uniformity; and (d) health quality – absence of infection with seed-borne pests (fungi, bacteria, virus, etc.) or contamination with noxious weeds (including parasitic weeds). Measurement of quality can only be possible against a set of standards defined by the industry and possibly backed by national or international regulations. Hampton (1998) defined a standard as 'a document specifying nationally or internationally agreed properties of a product'.

Seeds, which embody the genetic potential of plants, determine the upper limits on plant yield and, therefore, the productivity of other agricultural inputs as well (Jaffee and Srivastava, 1994). For seed to play a catalytic role in crop production it should reach farmers in good quality state. Apart from the genetic make-up, however, environmental conditions under which the seed is grown and seed management practices affect quality. Several environmental factors such as soil conditions, nutrient deficiency during plant growth, water stresses, high and low temperatures and pest damage may affect quality by reducing viability and vigour at physiological maturity (Agrawal, 1986). The availability, access, and use of seed of adaptable crop varieties are determinant to the efficiency and productivity of other packages in increasing crop production. It was reported that use of certified seed increased yields from 0.5 dt ha^{-1} for rye to 3 dt ha^{-1} for winter wheat in Poland (Oleksiak, 1998). However, in other crops the difference could be substantial as reported for virus-free potato seed from the formal sector outyielding seed from the informal sector by at least 10% to 22% (Thiele, 1999).

In Chapter 1, we have defined the framework of the national seed system and distinguished between two different sectors, the formal and informal sectors. The formal sector consists of a set of institutions involved in the multiplication, processing, marketing and quality control of seed offered for sale. Seed quality standards are the features of many national seed programmes and apply for seed production contracts, seed certification, seed marketing, and international seed trade. Accordingly, the seed from the formal sector must meet specific quality standards prescribed by the national regulations. Although seed quality standards may vary between countries they are specified for germination percentage, analytical purity, seed health, etc. (Hampton, 1998). In the formal sector, the technical, administrative, and regulatory framework set by the certification agency provides guidelines that have to be followed to produce good quality seed that meets the specified standards for marketing purposes. In Ethiopia, for example, high standards of seed quality (98% for physical purity and 85% for germination) are required for certified wheat seed production. Similarly, in Syria the minimum physical purity and germination are 97% and 85%, respectively, for both wheat and barley. Apart from good management of the seed crop, proper cropping history, adequate isolation, roguing, prevention of contamination and limitation of number of generations are used to maintain genetic and varietal purity. Laboratory seed tests are conducted to assess key seed quality attributes.

On the other hand, there is a growing recognition of the role of the informal sector which provides the bulk of seed planted by the majority of farmers in developing countries. Several authors stated that over 80% of the crops in developing countries are sown from seed stocks selected and saved by farmers (Almekinders *et al*., 1994; Osborn and Faye, 1991). However, most of the informal seed sector studies were focused on methodological approaches such as policy, regulatory and institutional framework and little attention was given to the technical aspects of seed production. The informal seed system operates at the community level and depends on indigenous knowledge of plant selection and seed management practices. The majority of farmers both in Ethiopia and Syria recognized the value of seed in terms of physical quality, germination and health where they clean and (sometimes) treat their seed. Although the concept of a national seed system has now been broadened to include the role of the informal sector in seed supply, there are few attempts made to understand the genetic, physical and physiological quality of seed from this sector (Wright *et al*., 1994; Wright and Tyler, 1994; Walker and Tripp, 1997). Moreover, there is limited information on the influence of the local management practices on the quality of seed used by farmers. Therefore, the main objectives of these studies were to:

- Investigate the quality of seed planted by farmers in different regions;
- Compare quality of seed obtained from different sources;
- Understand seed quality constraints in the informal seed system; and
- Recommend alternatives for improving seed quality at the farm level.

4.3. Materials and Methods

4.3.1. Wheat and Barley Seed Samples

A total of 304 wheat farmers in Ethiopia, and 200 barley farmers and 206 wheat farmers in Syria were interviewed in major wheat and barley growing regions of the country. A stratified sampling procedure was employed based on the proportion of wheat or barley area and number of farmers in each district. A total of three to four regions were covered comprising of six to nine districts for each crop and covering 59-81 villages across the regions. Each farmer was asked about the wheat or barley seed sources, perception of seed quality, agronomic practices and seed management practices for production. After the interview approximately 1 kg sample of wheat or barley seed was collected from each farmer from the seed lot planted or intended for planting for analysis in the laboratory. To bring the seed quality to the same standard, each sample was pre-cleaned to remove dust and small particles before laboratory tests were conducted. Seed samples were fumigated against storage pests and kept under ambient conditions until tested for seed quality.

4.3.2. Laboratory Tests

All samples collected during the survey were analysed for seed quality (physical purity, species purity, weed contamination, thousand seed weight, germination, vigour, etc.). All tests were conducted according to ISTA rules and tests outside tolerance were repeated (ISTA, 1996). All physical purity and physiological quality tests were conducted at the seed testing laboratory of the Ethiopian Seed Enterprise, Addis Ababa, Ethiopia and the seed testing laboratory of ICARDA in Aleppo, Syria. The seed testing was carried out in 1998 for wheat in Ethiopia, and in 1999 for wheat and barley in Syria.

4.3.3. Physical Quality

Number Count Test (other crop and weed seeds) The whole sample of 1 kg was subjected to a number count test and the number of other crops and noxious weeds were recorded in each sample (ISTA, 1996). For wheat other crops (bread wheat in durum wheat or durum wheat in bread wheat, barley, cultivated oats, etc.) and noxious weeds (wild oats, *Lolium*, *Bromus*, *Sinapis arvensis*, etc.) were recorded.

Analytical Purity Test From each sample two replicates of 60 g were analysed (ISTA, 1996). The samples were divided into three (pure seed, other crop seed, and inert matter) in Syria or four fractions (pure seed, other crop seed, weed seed and inert matter) in Ethiopia. After analysis, the percentage of each fraction (based on weight) was calculated, the type of other crops and weed seeds identified and their numbers recorded.

Thousand Seed Weight (TSW) In Ethiopia, eight replicates of 100 seeds each were weighed from the pure seed fraction (ISTA, 1996). The coefficient of variation was calculated to assess the acceptability of the test and the thousand seed weight was calculated. In case of wheat and barley in Syria two replicates of 1000 seeds were counted using a seed counter and the average seed weight was calculated.

4.3.4. Physiological Quality

Germination Test Four replicates of 100 seeds were planted from each sample in sterilized sand media (Ethiopia) or pleated paper (Syria). After planting seeds were placed in a germination room maintained at 20 °C for 8 days for wheat or 7 days for barley according to ISTA Rules (ISTA, 1996). At the end of the incubation period the germination boxes were removed and the seedlings were evaluated (Bekendam and Grob, 1979). Both normal and abnormal seedlings as well as fresh ungerminated (dormant) and dead seeds were recorded and the average calculated based on the final count. In some instances, the results of the germination test were used to evaluate seed vigour (see seedling vigour classification, first seedling count, seedling shoot and root length, etc.).

Vigour Tests: Speed of Germination Four replicates of 25 seeds were planted from each sample and kept at 20 ± 1 °C for a maximum of 12 days in an incubator in Ethiopia and in a germination room in Syria until no further germination took place. Each day normal seedlings were removed at predetermined size and time until all seeds capable to produce normal seedlings had germinated. An index was calculated by dividing the number of seedlings removed each day by the number of days in which they were removed (Maguire, 1962).

Vigour Tests: First Seedling Count During the germination test, the first counts were made and the number of normal seedlings recorded (fourth day after planting). Later on the final count was made on the eighth day as in standard germination tests and a total number of normal seedlings was recorded (Agrawal, 1986).

Vigour Tests: Seedling Vigour Classification At the end of the standard germination test, the normal seedlings were classified into two categories as vigorous seedlings, and low vigour seedlings. Vigorous seedlings were normal seedlings with strong, well developed and dark green plumule and strong primary root. Low vigorous seedlings were normal seedlings with short or stunted plumule or coleoptile with limited damage or < 5 cm.

Vigour Tests: Seedling Shoot and Root Length The seedling shoot length and seedling root length were assessed after the final count in the standard germination test. Ten normal seedlings were randomly selected from each replicate. The shoot length was measured from the point of attachment to the cotyledon to the tip of the seedling. Similarly, the root length was measured from the point of attachment to the cotyledon to the tip of the root. The average shoot or root length was computed by dividing the total shoot or root lengths by the total number of normal seedlings measured (Fiala, 1987).

Vigour Tests: Seedling Dry Weight The seedling dry weight was measured after the final count in the standard germination test. Ten seedlings randomly selected from each replicate were cut free from their cotyledons and placed in envelopes and dried in an oven at 80 ± 1 °C for 24 hours. The dried seedlings were weighed to the nearest milligram and the average seedling dry weight was calculated.

Vigour Index 1 and Vigour Index 2 For each sample two vigour indexes were calculated. Seedling Vigour Index 1 was calculated by multiplying the normal germination with the average sum of shoot length and root length after seven/eight days of germination and Vigour Index 2 by multiplying the standard germination with mean seedling dry weight.

4.3.5. Field Emergence (FE)

In Ethiopia, wheat was planted at the rate of 30 g per plot in 6 rows of 2.5 m length with a spacing of 0.2 m between rows on 3 and 4 July 1998/99. In Syria wheat was planted at the rate of 60 g for bread wheat and 70 g for durum wheat in 8 rows of 2.5 m length and with the spacing of 0.25 m between rows on 4 and 6 January 1999/2000. Barley was planted at the rate of 50 g per plot of 8 rows of 2.5 m length with the spacing of 0.25 cm on 1 and 4 December 1997/98 at Tel Hadya experimental farms, respectively. In all experiments seedling emergence was measured twice, first once emergence was stabilized and the second two weeks after the first count on an area of 1 m^2.

4.3.6. Data Analysis

Analysis of variance was performed on laboratory test results using the Genstat 6.1 statistical package where completely randomized design was employed to assess the significance and the LSD (0.05%) was used to separate the means among different treatments. Simple Pearson correlation coefficients were calculated to assess the association among different vigour indices and field emergence.

4.4. Results and Discussion

The wheat and barley farmers obtained seed from four different sources: the formal sector, neighbours/other farmers, traders/markets or own saved seed. Both in wheat and barley the major source of seed for planting was seed retained on the farm, which was managed by farmers either through seed selection, cleaning, treatment or separate storage.

4.4.1. Wheat Seed Quality in Ethiopia

In Ethiopia, the quality standards of wheat require that certified seed should meet minimum physical purity and germination standards before marketing. Accordingly wheat seed lots should have a minimum physical purity of 97% and a minimum germination of 85% for certified seed second generation (Table 4.1). The regulation also restricts maximum percent contamination of other crop seeds (0.2%), weed seeds (0.05%) and inert matter (2%) for certified seed second generation.

Physical Seed Quality-Purity Farmers prefer uniform crops not contaminated with other crop species and weeds, which reduce the quantity and quality of their product. Analytical purity is the first seed quality attribute recognized in a seed trade to protect farmers against the use of impure (adulterated) seed which is contaminated with other crop species, weed seeds or inert matter (Thomson, 1979). In any seed certification scheme every seed lot offered for sale is routinely tested for analytical purity.

The purity test determines the weight and the nature of the contaminants present in the seed sample and by inference that of a seed lot it represents (ISTA, 1999). During analysis the sample is divided into three fractions: pure seed of the named variety, other crop seeds and inert matter for international trade and reported on a percentage weight basis (ISTA, 1999). However, for national purpose the sample can be divided into four

Table 4.1. Minimum national certification standards for wheat seed production in Ethiopia.

Seed standards	Breeder and Pre-basic Seed	Basic Seed	Certified Seed 1	Certified Seed 2
Pure seed (minimum, %)	98	98	97	97
Other crop seeds (maximum, %)	0.03	0.05	0.1	0.2
Weed seeds (maximum, %)	-	0.01	0.02	0.05
Infected seeds (maximum, %)	-	0.02	0.03	0.05
Inert matter (maximum, %)	1	2	2	2
Germination (minimum, %)	90	90	85	85
Moisture content (maximum, %)	13	13	13	13

fractions by separating the other crop seeds into cultivated crops and weeds.

The physical quality of wheat seed samples collected from different regions and sources are presented in Tables 4.2 and 4.3. The average physical purity of wheat seed was 98.92% with a range from 77.18 to 99.99%. There were significant differences in physical purity between different wheat growing regions ($p<0.05$). The highest mean analytical purity (99.22%) was observed in North Shoa and East Gojam. Similarly, wheat seed lots collected from different districts showed highly significant differences ($p<0.001$) in analytical purity, other crop seed and weed seed contamination (Table 4.2). The highest physical purity was observed in Dodota (99.59%) in Arsi region, followed by Machakel (99.42%) in Eastern Gojam. The means for other crop seeds and weed seeds contamination were 0.14 and 0.29%, respectively. The highest other crop seeds contamination was in Dendi (0.33%) whereas the lowest was in Munesa (0.02%). On the other hand the weed seed contamination was highest in Munesa (0.82%) and Gedeb (0.49%) districts both in the Arsi region.

In this study, the analytical purity analysis showed that only 15 (4.9%) of the 303 samples were lower than 97%, the minimum national seed standard for certified second generation wheat seed in Ethiopia, but only 1% was below the 95% standard for certified seed 4 and commercial/emergency grade seed (ICARDA, 2002). A mere 12 samples (3.9%; n=303) mostly from the Arsi region were with inert matter contamination of more than 2% prescribed in the standard (all ten samples related to low purity). Alemayehu *et al.*, (1999a) also reported that most of the samples collected from farmers satisfied the physical purity standards set for wheat seed production in Ethiopia. Similarly, Stanelle *et al.* (1984) found high analytical purity of wheat seed collected from farmers in USA. However, Woldeselassie (1999) found significant differences in physical purity, other crop seed and weed seed contamination of barley

Table 4.2. Physical purity of wheat seed collected from major wheat growing districts in Ethiopia.

Districts	Composition by weight (% 120 g^{-1})			Contamination by number (Number of seeds kg^{-1})						1000 seed weight (g)
	Anal. purity	Crop seeds	Weed seeds	Barley	Other crops	*Avena*	*Lolium*	*Bromus*	Common weeds	
Gedeb	97.55	0.178	0.483	25.4	2.8	53.4	248	11.2	143	31.57
Munessa	98.17	0.017	0.816	4.2	0.1	130.9	308	8.3	215	29.80
Hetosa	99.11	0.106	0.306	26.8	1.1	51.6	253	5.0	115	36.14
Dodota	99.59	0.032	0.195	2.6	2.6	3	139	0.2	145	38.06
Dendie	98.96	0.326	0.177	18.5	42.6	10.9	74	0.4	22	39.73
Chelia	99.31	0.177	0.219	27.2	0.6	15	102	0.03	4	40.47
Ensaro Wayu	99.22	0.169	0.245	0.4	16.7	5.7	170	0.2	8	36.14
Hulet Eju	99.16	0.085	0.136	10.9	8.0	7.8	75	0.02	3	32.35
Machakal	99.42	0.053	0.140	5.9	1.5	3.4	79	0	1	30.05
Mean	98.92	0.136	0.293	15.3	8.5	30.0	165	2.9	72	35.36
LSD (0.05)	0.80	0.116	0.166	15.23	28.09	34.78	131.7	6.67	114.7	2.23
Significance	<0.001	<0.001	<0.001	<0.001	<0. 006	<0.001	<0.001	<0.001	<0.001	<0.001

seed samples collected from different regions of Ethiopia. He found that the majority of seed samples collected from northwestern Ethiopia (42% to 58%) remained below the analytical purity standard of the formal sector whereas those collected from southeastern Ethiopia (94% to 96.3%) met the minimum national purity standards for barley. Such differences could be attributed to farmers' seed management practices as well as the area of production particularly the presence and/or contamination with weed seeds.

About 38%, 12.5% and 0.3% of the wheat seed samples (n=303) did not have contamination from other crop seeds, weed seeds and inert matter, respectively. Moreover, 79.5%, 40.3% and 94.4% of the samples matched the minimum requirement for other crop seed, weed seed and inert matter contamination, respectively. However, combining the whole range of physical purity standards, i.e., analytical purity (≥97%), other crops (≤0.2%), weed seed contamination (≤0.05%) and inert matter (≤2%) for certified seed 2, only 109 samples (35.9%) would match the wheat certified seed 2 standard. Contamination with weed seeds appeared to be the major constraint for seed samples not meeting the standard. Stanelle *et al.* (1984) found that wheat seed samples from 1984 had higher physical purity and less inert contamination compared to samples a decade earlier (in 1973), but increased weed seed

Table 4.3. Physical purity of wheat seed collected from different seed sources in Ethiopia.

Seed sources	Composition by weight (%120 g^{-1})			Contamination by number (Number of seeds kg^{-1})						
	Anal. purity	OCS[1]	WS	Barley	Other crops	*Avena*	*Lolium*	*Bromus*	Common weeds	TSW
Government	99.41	0.030	0.106	2.9	3.9	2.5	43	1.3	6	37.26
Neighbours/Farmers	98.59	0.176	0.257	30.1	0.7	63.3	143	8.2	98	35.01
Traders/Markets	98.89	0.237	0.330	20.1	4.4	51.3	155	13.9	144	34.40
Own saved	98.91	0.135	0.305	15.0	9.4	28.8	173	2.2	71	35.26
Mean	98.92	0.135	0.293	15.4	8.5	30.0	165	2.9	72	35.32
LSD (0.05)	0.893	0.128	0.192	17.16	30.58	42.2	146.7	7.3	128.5	3.26
Significance	0.447	0.065	0.095	0.042	0.870	0.055	0.202	0.004	0.375	0.47

[1] OCS = Other crop seeds; WS = Weed seeds; TSW= Thousand seed weight (g).

contamination reduced the number of samples reaching the standard.

The average physical purity of seed sourced from the formal sector was 99.41% compared to seed obtained from the informal sector such as other neighbours/farmers (98.76%), traders/markets (98.58%) or own saved seed (98.92%) as shown in Table 4.3. The seed obtained from the formal sector had the highest analytical purity, but the lowest mean contamination in terms of percentage (weight) or number of other crop seeds and noxious weeds. Almost all certified seed samples maintained the analytical purity percentage, other cop seeds and inert matter contamination except for weed contamination. Moreover, nearly 85% and 95% of own saved seed maintained the minimum analytical purity and inert matter contamination, but only 11.8% maintained the minimum weed seed contamination. There was no significant difference between the analytical purity or the percentage of other crop seeds and weed seeds among different sources. The results showed that the physical quality of seed from the informal sector was equal or comparable to the seed from the formal sector. Similarly, no significant difference was reported for analytical purity and other crop seeds contamination for seed samples collected from different sources in barley (Woldeselassie, 1999) and wheat (Ensermu *et al*., 1998) in Ethiopia. On the contrary, earlier studies in Jordan found significant differences between seed obtained from the formal and the informal sectors (other farmers or own saved seed). Hasan (1995) found that in wheat certified seed had significantly higher purity percentage compared to seed from other sources except in other crop seed contamination. Al-Faqeeh (1997) also found that certified seed had significantly higher analytical purity in lentil compared to seed from other sources. It should be noted that the Ethiopian seed certification standards put in place alternative options for distribution of seed in case of emergency situations. The standards for commercial or emergency seed is lowered to 95% purity and 80% germination and almost all of the wheat seed samples collected from farmers during the survey met these standards without any problems.

Weed Seed Contamination In a certification programme, contamination of the seed crop with other crop or weed seeds of similar physical characteristics is restricted because cleaning alone will not sufficiently remove such contaminants. As a result, national seed regulations are set to minimize the risk of contamination from specific other crop seeds and weeds. Accordingly weed seeds could be classified into three basic categories, namely: restricted (objectionable) weeds (not permitted), noxious weeds (permitted with specified standards) and common weeds (no standards for restrictions). The presence of such crop and weed seeds is determined by examining relatively bigger seed sample (e.g., 1 kg for wheat and barley), because analytical purity tests do not reveal the extent of contamination as percentage by weight varies among weed seeds. For example a contamination of 1% by weight in a 1 kg seed sample may contain 500 or 800 seeds of *Avena fatua* or *Ranunculus arvensis*, respectively (Thomson, 1979). In Ethiopia, the national seed regulation requires that wheat seed should be free from other crop seeds and noxious weeds such as *Avena*, *Bromus, Lolium* spp., etc.

The contamination of other crop seeds and weed seeds (number of seeds kg^{-1}) is presented in Tables 4.2 and 4.3. A total of 13 crop species and 15 weed species were found in wheat seed lots collected from different regions of the country with a minimum of 1 and a maximum of 11 species $sample^{-1}$. In contrast, Woldeselassie (1999) found 10 crop and 7 weed species in barley seed samples collected from different regions of Ethiopia. Similarly, 4 crop species and 13 weed species were found in lentil seed samples collected from farmers across Jordan (Al-Faqqeeh, 1997) and 20 weed species were found in rice seed samples collected from farmers in one area in Philippines (Fujisaka *et al*., 1993). The average number of other crop species, weed species and total of all other species found $sample^{-1}$ were 1.49, 3.38 and 4.48 species, respectively. Woldeselassie (1999) found three to four other species $sample^{-1}$ in barley seed.

About 69.8 and 36.8% of the wheat seed samples (n=303) were contaminated with barley and other crop seeds, respectively. Hasan (1995) found that 82.3% of the wheat seed samples were contaminated with barley seed in Jordan. It was observed that mean contamination with other crop seeds was significantly different ($P<0.001$) among districts. The overall mean contamination with barley seed was 16 grains 1 kg^{-1}

sample with the highest mean contamination of 27 grains kg^{-1} in Chelia (West Shoa) and Hetosa (Arsi) followed by 25 grains kg^{-1} in Gedeb also in the Arsi region. Samples from North Shoa showed the least contamination with barley seed. The presence of cultivated crop seeds reached a maximum of 248 barley seeds kg^{-1}. Some of the highest levels of contamination with barley seed were observed on samples of local landraces rather than on modern varieties because some farmers were using fresh seed recently acquired from the formal sector. All wheat farmers surveyed grew barley as a second crop where contamination may happen in the field due to lack of proper crop rotation, at threshing floors or in storage facilities. However, none of the farmers surveyed grew wheat-barley mixtures, the most common practice in northern parts of Ethiopia (Woldeselassie, 1999). The presence of other crop seeds was low in terms of number of seeds present or number of samples contaminated although in individual cases contamination as high as 713 other crop seeds per kg was observed in some seed lots collected from farmers. While barley contamination was found throughout all regions and districts contamination from other crops remained localized. For example, the presence of grass pea was more common in samples collected from districts in West Shoa than in samples from other regions.

The number of samples with wild oats, *Lolium*, *Bromus* and common weeds contamination was quite high and the level of contamination was significantly different between districts ($P<0.001$). In total, 74.9%, 88.8%, 24.4% and 70.3% of the wheat samples (n=303) had contamination with wild oats, *Lolium*, *Bromus* and common weeds, respectively. The three important noxious weeds, *Avena, Bromus, Lolium* were found in samples from all districts, but were significantly more abundant in samples collected from districts in Arsi region. Kolk (1979) stated that *Avena* spp. and *Lolium temulentum* were the two most important weeds in wheat and barley cultivation in Ethiopia. Although the maximum number of seeds kg^{-1} of wheat sample could go as high as 489 for *Avena*, 1448 for *Lolium* and 150 for *Bromus*, the average contamination was relatively low (Tables 4.2 and 4.3). Similarly, the same districts in Arsi also had the highest number of common weed seeds $sample^{-1}$ compared to districts in other regions. Badebo and Lindeman (1987) found on average of 706, 359 and 83 seeds kg^{-1} of noxious weeds, other common weeds and other crops, respectively, in seed samples collected from farmers in the Arsi region. On the other hand they also found that seed from basic seed multiplication fields had substantially lower contaminations of 14, 15 and 4 seeds kg^{-1} of noxious weeds, common weeds and other crop seeds, respectively. Woldeselassie (1999) also found that 96.7% (n=300) of barley seed samples collected from farmers in Ethiopia were contaminated with weed seeds. He reported that on average contamination with *Avena* ranged from 44 to 73 seeds $sample^{-1}$ and that of *Lolium* from 68.3 to 207.3 seeds $sample^{-1}$ in barley crops collected from different parts of the country. Our level of contamination is comparable to these results.

The number of *Avena* and *Lolium* in seed lots collected from the Arsi region was high compared to that of other regions. The cereal monoculture where wheat and/or barley production predominates and the use of selective broad leaf herbicides is widespread, led to the distribution of such grass weeds across the region (Sahile and Workiye, 1994). More wild oats contamination was found with seed lots from improved varieties compared to local materials. Seed contaminated with weeds could be the means for introduction and dissemination of noxious weeds. For example, it was indicated that the introduction of wild oats in Egypt and wild sorghum in Sudan in wheat was attributed to contaminated seed (Mohamed, 1996). In Ethiopia, the widespread use of commercial seed appeared to be the main causes for spread of wild oats particularly in the state farms in Arsi region.

In the purity analyses, the highest other crop seeds (barley) and weed seed contaminations were observed in seed lots collected from other farmers/neighbours, traders/markets or own saved seed as compared to seed from the formal sector (Table 4.3). Although the certified seed from the formal sector had a lower average percentage and number of other crop and weed seed contaminations it was not significantly different from seed obtained from other sources except for contamination with barley, *Bromus* and wild oats ($P<0.05$). Moreover, weed contamination was higher for seed obtained from other farmers or markets as compared to own seed (except in case of *Lolium*). Fujisaka *et al.* (1993) also found similar results where own seed had fewer weed seeds compared to seed obtained from other farmers.

A wide range of broad-leaf and grass weeds was recorded in wheat in Ethiopia, (Fessehaie, 1985; Tanner and Sahile, 1991; Girma *et al.*, 2000). The most widespread broad-leaf species in wheat (and barley) are *Amaranthus bybridus, Convolvulus arvensis, Datura stramonium, Galingosa parviflora, Galium spurium, Guizotia scabra, Medicago polymorpha, Polygonum nepalense* and *Scorpiurus muricatus*. The most important grass weeds include *Avena abyssinica, A. fatua* and *A. sterelis, A. strigosa, Bromus pectinatus, Lolium temulentum, Pahalaris paradoxa, Setaria pallidefusca* and *Snowdenia polystachya*. However, it should be noted that 25.1%, 11.2%, 75.6% and 29.6%, respectively of the wheat seed samples were free of *Avena, Lolium, Bromus* and common weeds such as *Guzotia scabra, Galium* spp. *Polygonium, Plantago, Phalaris, Datura stramonium,* and *Setaria* which are prevalent in most wheat growing areas of the country.

Apart from weed seeds found during quality analysis, farmers were also asked to identify major problematic weeds they encountered in wheat crop production. They reported that grass weeds such as wild oats (31.3%; n=304), *Lolium* (3.6%), *Snowdenia* (48.4%), *Phalaris* (16.4%), *Setaria* (2.3%) were important. Among grass weeds, wild oats was reported in all regions although the majority of cases were from farmers in Arsi and West Shoa regions. Moreover, *Snowdenia* (except region 3), *Lolium* and *Phalaris* (except region 4) and *Setaria* (except regions 3 and 4) were also reported. Broad-leaf weeds such as *Guzotia* (63.2%), *Galium* (14.1%), *Medicago polymorpha* (7.6%), *Amaranthus* (3%), *Datura* (2.3), *Plantago* (13.8%) and *Galingosa* (3.3%) were also reported as important weeds. *Guzotia* and *Plantago* were reported from all regions whereas *Datura* and *Medicago* from three regions (except region 4); *Galium* and *Amaranthus* were reported mostly from Arsi and West Shoa region (except regions 3 and 4). Girma *et al.* (2000) reported that farmers ranked weeds as the third most important yield reducing factor and indicated broad-leaf weeds (*Galium, spurium, Guzotia scabra)* and grass weeds *(Snowdenia polystachya*, *Avena fatua, Lolium temulentum* and *Bromus pectinatus)* as problematic in wheat production in the Arsi region which conforms with the quantitative analysis. Yirga *et al*. (1992) also reported *Avena fatua, Guzotia scabra* and *Snowdenia polystachya* as important weeds in Kulumsa area of Arsi region. Beyene and Yirga (1992a) reported *Guzotia scabra, Phalaris paradoxa* and *Plantago lanceolata* as major weeds of wheat in central Ethiopia.

In Ethiopia, it was reported that the critical time for weed competition in wheat is between three to four weeks after planting. Moreover, yield losses due to weeds were reported to be 36.4% (Fessehaie, 1985). Weeds are major crop production constraints in wheat and quality seed should be free from this biotic stress. The use of cleaned seed showed that seed purity had a significant impact on grain yield compared to weeding either by hand or hoe (Tanner and Sahile, 1991). In Sudan, it was reported that a 0.5% proportion by weight of *Convolvulus arvensis* seed in wheat seed planted would result in 6 plants m^{-2} in the field and reduce yield by 67% (Mohamed, 1996). Therefore, the provision of seed of high physical quality is of paramount importance in crop production.

Thousand Seed Weight A grand mean of 35.34 g with minimum and maximum values of 25.08 and 49.87 g, respectively were obtained for the thousand seed weight (Table 4.2). There were significant differences ($P<0.001$) in thousand seed weight between samples of seeds collected from different districts (Table 4.2), but not between seed samples from different sources (Table 4.3). Wheat seed samples collected from East Gojam showed the least whereas those from West Shoa showed the highest thousand seed weight, where some of the samples collected are represented by durum wheat varieties. The least thousand seed weight was from samples collected from Munessa district in the Arsi region (with the mean of 29.89 g) and the highest from Chelia in West Shoa (40.47 g). Moreover, varietal differences have been observed and found to be significant (P<0.001). The mean seed weight was 35.32 g with a range from 31.63 g for HAR 1685, a bread wheat variety, to 46.83 g for Boohai, a durum wheat variety. About 47% of the wheat samples were below the mean thousand seed weight. Apart from varietal differences, inter-plant competition for light, water, and nutrient and the effect of diseases may contribute to a wide range of seed size within a seed lot. Similarly seed size also varies due to the location on an inflorescence which reflects differences in flowering time (main and side branches) and nutrition of the developing seeds (basal and apical flowers). Ensermu *et al*. (1998) and Alemayehu *et al*. (1999a) also found significant differences in thousand seed weight among wheat varieties collected from farmers and attributed the differences to the precursor crops and level of weed infestations. In wheat, seed size or weight found to be correlated with seedling emergence and yield in wheat under late sown condition (Khah *et al*., 1989).

Physiological Seed Quality-Germination A germination test when conducted accurately according to internationally standardized rules indicates the percentage of seeds, which have produced normal seedlings, abnormal seedlings and which failed to produce seedlings (because they are dead or dormant). Germination capacity indicates the percentage of pure seed fraction that produces normal seedlings under optimal conditions in the laboratory test and by inference the field planting value under favourable environment in the soil (ISTA, 1999). Germination capacity combined with analytical purity can be used to determine the proportion of seed, which can produce normal seedlings in the field called the pure live seed (PLS). The pure live seed is used to express seed quality and can be employed to choose among different seed lots.

The physiological quality of wheat seed samples was presented for different districts (Table 4.4) and different sources (Table 4.5). The overall mean germination was 96% with a range from 68 to 100%. The wheat samples collected from the southeastern, central and northwestern parts of the country showed remarkably high germination percentages with few samples below the standard; differences were highly significant (P<0.001) between different regions, districts and seed sources (Tables 4.4 and 4.5). Average germination was the highest in North Shoa and East Gojam (98%) whereas seed samples from Arsi showed the lowest value (95%). At district level the mean germination ranged from the lowest in Hetosa (93%) to the highest in Machakal (98%) in East Gojam region. The total number of samples with a germination percentage and pure live seed of less than 85 is eight (2.6%; n=303) and nine (3%) samples, respectively (Table 4.4). The physiological quality of seed obtained from different geographic regions may vary because of the environmental effects during the formation, development and maturation of seed. Grass and Burris (1995) found that environmental factors such as high temperature had variable effect on germination but

Table 4.4. Physiological quality (germination) of wheat seed collected from major wheat growing districts of Ethiopia.

Districts	Mean germination (%)	Percent of samples with germination of ≥85%	Pure live seed (PLS)	Percent of samples with PLS of ≥ 85
Gedeb	95	98	93	95
Munessa	94	100	92	100
Hetosa	93	92	93	92
Dodota	98	100	97	100
Dendie	97	100	93	100
Chelia	94	92	93	92
Ensaro Wayu	98	100	98	100
Hulet Eju	98	100	98	100
Machakal	96	100	96	100
Mean	96		95	
LSD (0.05)	1.3		4.2	
Significance	<0.001		<0. 001	

Table 4.5. Physiological quality (germination) of wheat seed collected from different sources in Ethiopia.

Seed sources	Germination (%)	Percent of samples with germination of ≥ 85%	Pure live seed (PLS)	Percent of samples with PLS of ≥ 85
Government	96	100	95	100
Neighbours/Farmers	94	94	93	94
Traders/markets	97	100	96	100
Own seed	96	97	95	97
Mean	96		95	
LSD (0.05)	1.5		4.6	
Significance	<0.041		0.786	

caused a significant reduction in seedling vigour in durum wheat varieties.

The mean germination for certified seed was 96% compared to seed obtained from neighbours/other farmers (94%), markets/traders (94%) or own saved seed (96%) as shown in Table 4.5. Most of the samples met the minimum wheat seed standard for certified 2. Ensermu *et al.* (1998) also found similar results where almost all wheat samples collected from farmers reached the minimum germination standards for certified seed. Alemayehu *et al.*, (1999a) also reported that germination of seed samples (with few exceptions) met the minimum standard for certified wheat seed production in Ethiopia. There was a slightly significant ($P<0.05$) difference in germination among seeds obtained from different sources. However, Hassan (1995) found no significant differences between certified wheat seed and that obtained from other farmers or own saved seed. Al-Faqeeh (1997) found that certified seed had significantly higher germination in lentil compared to seed from other sources. Woldeselassie (1999) also found a very significant variation in germination of barley seed collected from different regions and sources. Moreover, contrary to our findings, he reported that the majority of samples (nearly 90%) were below the average germination percentage prescribed for certified seed of barley. It was noted that the unusually extended rainfall during crop maturity and at harvesting time contributed to loss of physiological quality of seed due to pre-harvest sprouting. In hard red wheat, Foster *et al.* (1998) indicated that sprouting was highly correlated with reduced germination before and after accelerated aging and reduced emergence from deep planting, but not with field emergence and yield. It was concluded that wheat seed damaged due to incipient sprouting could be used with caution within a year and under normal planting conditions (Foster *et al.,* 1998). Similarly, Ndjeunga (2002) also reported high average germination (88%) for sorghum seed samples collected from farmers in Niger with no difference across agro-ecological zones, but only half of the samples (n=192) showed over 87.5% germination.

The pure live seed results for wheat seed samples collected from different sources are presented in Table 4.4. The mean pure live seed was 95% with ranges from 92% to 98% and was found to be significant at district level, but not for samples from different sources.

Physiological Seed Quality-Vigour Seed vigour is a quantitative characteristic, controlled by several factors that affect the germinating seed or subsequent seedling emergence, growth and establishment. Seed vigour is affected by genetic factors; environment and mother plant nutrition; stage of maturity at harvest; mechanical damage to embryo or seed coat; seed size; senescence; and attack by pests (Thomson, 1979). Differences in seed vigour have been observed both in wheat and barley. Seed lots with similar germination may respond differently if subjected to adverse field conditions due to variation in seed vigour. Contrary to germination, vigour indicates the capacity of seed lots to germinate quickly and completely with subsequent uniform seedling establishment in a wide range of environments (TeKrony and Egli, 1991). Generally high germination capacity is believed to be associated with high vigour and poorly germinating seeds must be rejected (Thomson, 1979).

TeKrony and Egli (1991) summarized that the effect of seed vigour on yield depends on the stage of harvest of crops. There is a consistent positive correlation between seed vigour and yield in crops harvested during vegetative growth (lettuce, cabbage, turnip, carrot) or early reproductive growth (tomato, pea). However, for annual crops harvested at full reproductive maturity (seed), there is no relationship between seed vigour and yield under normal conditions unless when there is low plant population or in later than normal plantings. Similarly, Khah *et al.* (1989) also found that low vigour spring wheat seed produced lower yields only when it resulted in low plant populations or when planting was later than normal sowing time.

The standard germination has been accepted as universal indicator of seed quality for marketing purposes (Barla-Szabó and Dolinka, 1988) because of its simplicity, repeatability and reliability. However, standard germination tests failed to predict field emergence under adverse field conditions for example in wheat (Baalbaki and Copeland, 1987). Several physiological and biochemical laboratory tests have been suggested for vigour tests (Steiner *et al*., 1989). For example, the measurement of plumule growth as a vigour test for cereals has been suggested for wheat and barley (Perry, 1977), So far not a single test, whether physical, physiological or biochemical, proved successful under variable field conditions even for a single species (Hampton and Coolbear, 1990). As a result multiple vigour tests have been suggested for predicting field emergence (Steiner *et al*., 1989).

Several physiological tests such as standard germination, seedling vigour classification, speed of germination, first seedling count, seedling shoot length, seedling root length and seedling dry weight were measured to assess the vigour of wheat seed lots collected from farmers (Tables 4.6 and 4.7). The mean standard germination was 93% indicating good germination of all samples tested for vigour. The speed of germination and first count measures the rate at which the seeds are germinating and those seedlings with higher index or highest germination on first count are expected to show rapid germination and seedling emergence and to escape adverse field conditions. Furthermore, it is assumed that seedlings with well-developed shoot and root systems would withstand any adverse conditions and provide better seedling emergence and seedling establishment in the field. Significant variations were observed in all vigour indices except seedling root length, seedling dry weight and vigour index 2 among seed lots collected from different regions and districts, but not from different sources (Table 4.6). Wheat seed samples from Dodota gave the highest values for standard germination, seedling vigour classification, and first seedling counts and root length though the latter was not significant. Seedling vigour classification into vigorous and non-vigorous categories showed the highest significant variation where the results from Ensaro Wayu

Table 4.6. Physiological quality (vigour) of wheat seed collected from major wheat growing districts of Ethiopia.

Districts	SG[1] (%)	SVC (%)	FSC (%)	SPG	SL (cm)	RL (cm)	SDWT (g)	VIG1	VIG2
Gedeb	86	71	82	12.65	9.32	9.55	0.050	1624	4.3
Munessa	87	81	83	12.63	9.46	9.42	0.052	1646	4.6
Hetosa	91	80	87	12.43	8.70	9.51	0.066	1669	6.1
Dodota	97	93	95	12.52	9.28	10.06	0.056	1872	5.5
Dendie	94	34	92	12.44	8.81	9.77	0.094	1741	8.8
Chelia	88	82	85	11.30	8.32	9.65	0.071	1585	6.1
Ensaro Wayu	97	55	94	13.52	8.73	9.98	0.067	1803	6.5
Hulet Eju	95	93	94	12.53	9.64	10.33	0.054	1903	5.1
Machakal	95	92	92	12.51	8.49	9.25	0.054	1676	5.1
Mean	93	71	90	12.54	8.85	9.78	0.067	1730	6.2
LSD (0.05)	3.5	13.2	5.1	0.57	0.76	0.79	0.345	159	3.2
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	0.17	0.136	<0.001	0.096

[1] SG=standard germination; SVC=seedling vigour classification; FSC= first seedling count; SPG=speed of germination; SL=seedling shoot length; RL=seedling root length; SDWT=seedling dry weight; VIG1=vigour index 1; VIG2=vigour index 2.

and Dendie showed the least, i.e., 55% and 34%, respectively. The lowest vigour index 1 was recorded for samples collected from Chelia with 1585 mainly because of low shoot length.

There is no variation in vigour indices from different seed sources except in root length and vigour index 1 (Table 4.7). Although not significant, wheat seed samples obtained from market/traders gave the highest values for standard germination, first seedling count, seedling shoot length, seedling root length, seedling dry weight and vigour index 1 and 2. However, there is some degree of inconsistency in ranking the seed lots in terms of vigour by the different tests for seed obtained from different districts and sources.

Simple correlation coefficients of physiological tests and field emergence for wheat are presented in Table 4.8. Standard germination, speed of germination, first seedling count, root length and seedling dry weight were significantly correlated with each other and field emergence. Seedling vigour classification did not correlate with most vigour tests or field emergence, but negatively correlated with seedling dry weight. Foster *et al.* (1998) reported significant correlation between germination test and field emergence of previously sprouted hard red wheat. Similarly, significant correlations

Table 4.7. Physiological quality (vigour) of wheat seed collected from different sources in Ethiopia.

Seed sources	SG[1] (%)	SVC (%)	FSC (%)	SPG	SL (cm)	RL (cm)	SDWT (g)	VIG1	VIG2
Government	92	75	89	12.86	8.62	9.35	0.056	1662	5.1
Neighbours/Farmers	92	86	89	12.92	9.38	8.48	0.054	1635	5.0
Markets/Traders	97	73	96	12.42	9.76	11.38	0.089	2047	8.6
Own seed	93	70	90	12.51	8.84	9.82	0.067	1733	6.2
Mean	93	71	90	12.55	8.85	9.78	0.066	1730	6.2
LSD (0.05)	5.8	23.3	8	0.97	1.13	1.14	0.050	239	4.7
Significance	0.52	0.29	0.486	0.39	0.21	<0.001	0.570	0.026	0.504

[1] SG=standard germination; SVC=seedling vigour classification; FSC= first seedling count; SPG=speed of germination; SL=seedling shoot length; RL=seedling root length; SDWT=seedling dry weight; VIG1=vigour index 1; VIG2=vigour index 2.

Table 4.8. Simple Pearson correlation coefficients between vigour tests and field emergence in wheat, Ethiopia.

Laboratory tests	SG[1]	SVC	SPG	FSC	SL	RL	SDWT	VIG1	VIG2	FE
Standard germination	1	0.092	0.43**	0.97**	0.16	0.51**	0.65**	0.71**	0.21*	0.50**
Vigour classification		1	–0.18	0.09	0.09	–0.04	–0.23*	0.07	–0.25*	–0.11
Speed of germination			1	0.36**	0.07	0.15	0.29**	0.28**	0.13	0.50**
First seedling count				1	0.12	0.51**	0.63**	0.69**	0.20**	0.43**
Shoot length					1	0.59**	0.47**	0.74**	0.01	0.12
Root length						1	0.62**	0.89**	0.13	0.30**
Seedling dry weight							1	0.75**	0.23**	0.32**
Vigour index 1								1	0.15	0.39**
Vigour index 2									1	0.09
Field emergence										1

*, ** Significant at P<0.05 and P<0.01, respectively; [1]SG=standard germination; SVC=seedling vigour classification; FSC= first seedling count; SPG=speed of germination; SL=seedling shoot length; RL=seedling root length; SDWT=seedling dry weight; VIG1=vigour index 1; VIG2=vigour index 2; FE= field emergence.

have been reported between standard germination, shoot length, root length, seedling dry weight and field emergence in pigeon pea (Ram *et al*., 1991). They reported no correlation between root and shoot length with field emergence which is similar to our results where shoot length did not correlate with field emergence.

In Chapter 2, it was found that the majority of Ethiopian farmers indicated differences between wheat seed used for planting and grain and noted that quality seed should have high purity (60.2%), should be free from other crop and weed seeds (18.1%), should be intact and have good germination (18.4%), should have big kernel size (11.5%), should be free from diseases or pest damage (10.2%) and should not be mixed with other varieties (3.3%). The evidence from the results of the wheat seed samples tested in the laboratory suggests that farmers can produce high quality seed comparable to that from the formal sector. Therefore, the formal sector should identify potential seed quality aspects, which could attract farmers to purchase fresh certified seed stock regularly. Any certified seed with lower quality than that of farmers' seed may not induce farmers to purchase seed from the formal sector. It is also important that the formal sector identifies seed quality constraints of the informal sector and assists farmers in improving the quality of on-farm produced seed.

4.4.2. Wheat and Barley Seed Quality in Syria

In Syria, the General Organization for Seed Multiplication prescribed internal seed quality standards for seed to be marketed (Table 4.9). Accordingly, the wheat and barley certified seed 2 from the formal sector is required to have a minimum of 98% analytical purity and 85% germination (ICARDA, 2002). Moreover, for certified seed 2 contaminations by number should not exceed 20 grains kg^{-1} with other crop seeds and noxious weed seeds and contamination by weight should not be more than 0.25% for common weed seeds and 2% for inert matter.

Almost all farmers growing wheat or barley recognize the difference between grain and seed for planting. For example, from 206 wheat growers, 98% observed the difference between grain and seed and attributed these differences to cleanliness from impurities (53%), seed treatment (18%), freedom from weeds (31%), freedom from diseases (9%), good germination (6%) and seed size (13%).

Physical and Physiological (Germination) Seed Quality The analytical purity and germination of wheat and barley seed samples collected from different districts are presented in Table 4.10. The physical purity of wheat seed samples collected from different districts was not significant, although the germination percentage was found to be highly significant ($P<0.001$). For wheat the overall average physical purity was 97.59% (with a range from 79.94 to 99.95%) and mean germination was 88 (with a range from 23 to 99%). The majority of seed samples, i.e., 70.4% (n=206) for physical purity and 78.2% for germination were above the minimum seed quality requirements of the formal sector. A total of 56% (n=206) wheat seed samples maintained the minimum purity and germination standards for certified seed second generation in

Table 4.9. Minimum certification standards for wheat and barley seed production in Syria.

	Seed class				
Seed standards	Nucleus	Foundation	Registered	Certified Seed 1	Certified Seed 2
Pure seed (minimum %)	98	98	98	98	98
Other crop seed (maximum, no/kg)					
Other crop species	3	6	10	20	20
Other varieties	1	2	4	6	6
Weed seeds (maximum, %)	0.25	0.25	0.25	0.25	0.25
Other weeds (maximum, no/100 g)	10	10	20	20	20
Inert matter (maximum, %)	2	2	2	2	2
Infected seeds (maximum, no/kg)					
Bunt balls (maximum, no/kg)	8	20	20	20	20
Germination (minium, %)	85	85	85	85	85

Syria. Moreover, 76.7% of samples have less inert matter contamination than prescribed in the standard. Further analysis indicated that only three samples have less than 90% physical purity and 20 samples less than 80% germination. The mean physical purity and germination was the highest in Ras Al-Ain in Hassaskeh governorate. Although most wheat seed samples met the minimum physical purity and germination of the formal sector, samples from Azaz and Jebel Saman in Aleppo province showed the least number of samples reaching the standard.

The physical purity and germination were highly significant among barley seed samples collected from different regions and districts (P<0.001). In barley, the overall mean physical purity was 95.47% (range 83.36% to 99.44%), below the minimum standard and the mean germination was 86% (range 16% to 99%). The majority of samples (90%; n=200) recorded less than the minimum physical purity standard of 98%. Furthermore, only 27% of samples had less than 2% inert matter requirement and fewer less than 0.05% required for weed contamination. On the other hand about 72% of samples had a germination capacity of 85% or more, the minimum requirement prescribed as the national standard. When the physical purity and germination standards are combined only 9% of the barley samples reached the minimum seed quality requirement for certified seed 2 in Syria. However, only nine samples showed less than 90% physical purity and 38 samples less than 80%

germination. The mean physical purity and germination was the highest in Ras Al-Ain and Hasakeh districts, respectively, both in Hasakeh province (Table 4.10). However, none of the samples from Al-Bab met the minimum purity standard, and only a few (3 to 19% of samples) from the other districts did. In general samples from Ain El-Arab, El-Bab and Manbeji in Aleppo province once again had the lowest number of samples which met the minimum physical purity and germination standards.

The pure live seed for wheat and barley was calculated to further check the quality of seeds. In wheat about 155 samples (75.2%; n=206) had a pure live seed proportion of more than 85% whereas in barley 111 samples (55.5%; n=200) had a pure live seed proportion of more than 85%. This indicates that barley seed quality was comparatively lower than wheat seed quality because of low analytical purity of barley seed samples. It is important that realistic and acceptable seed certification standards are set for the formal sector instead of unreasonably high and unachievable standards.

Weed Seed Contamination Several weed species such as *Avena* spp., *Convolvulus arvensis, Lisea syriaca, Lolium temulentum, Myagrum perfoliatum, Phalaris* spp., *Sinapis arvensis, Setaria* spp. are considered noxious weeds and their presence is restricted in seed production (ICARDA, 2002). Moreover, in the formal sector, wheat seed contamination with barley (or vice versa) and other small grain cereals above certain standards is prohibited. About one third of wheat seed samples (n=206) were not contaminated with any restricted other crop seeds, although four other crop species were identified, barley being the predominant crop species. The mean number of barley seeds sample^{-1} was 6 seeds in 120 g (with a range from 0 to 123 seeds). About 50% of samples had potentially more than the acceptable level of contamination with barley seed. No significant difference ($P<0.001$) was found among wheat seed samples collected from different provinces, districts and seed sources for contamination with barley. However, the highest mean contamination was observed on retained seed or seed obtained from other farmers compared to seed from the formal sector. Fifty eight percent of wheat samples were contaminated with noxious weeds with 44% of samples with potential contamination over the minimum standards. *Avena* spp., *Lolium temulentum, Myagrum perfoliatum,* and *Phalaris* spp. were found more regularly in samples collected throughout the major wheat growing areas of the country compared to *Convolvulus arvensis*, and *Lisea syriaca*. The mean contamination with all noxious weeds was 5 seeds per 120 g (range 0 to 114). For wild oats (range 0 to 23) and *Lolium* (0 to 54) species the mean was each 2 seeds per 120 g with high variation among the samples. About 41 (26% in excess of standard) and 28 (18%) of wheat samples were contaminated with wild oats and *Lolium* weed species, respectively. A total of eleven common weed species were identified with up to a maximum of five weed species

Table 4.10. Physical and physiological quality of wheat and barley seed collected from different districts in Syria.

Wheat					Barley				
Districts	Purity (%)	% with purity of ≥98%	Germination (%)	% with germination ≥ 85%	Districts	Purity (%)	% with purity of ≥98%	Germination (%)	% with germination ≥85%
Azaz	98.17	64	84	66	Ain El-Arab	95.22	9	81	49
Sema'an	97.97	68	87	68	Manbeji	95.90	9	84	64
					Al-Bab	93.94	0	88	69
Tel Abiad	95.18	71	86	87	Raqqa	94.43	13	90	87
					Tel Abiad	96.01	19	84	78
Khamishli	98.69	87	86	70	Khamishli	95.42	18	82	64
Hasakeh	96.76	51	89	87	Hasakeh	94.94	3	92	97
Ras Al-Ain	98.74	90	94	94	Ras Al-Ain	96.02	13	90	87
Mean	97.59		87		Mean	95.47		86	
LSD (0.05)	2.44		4		LSD (0.05)	0.61		5.4	
Significance	0.039		<0.001		Significance	<0.001		<0.001	

sample^{-1} for wheat seed. Some of the common weed species identified were *Brassica, Cephalaria*, *Centaurea, Galium*, *Polygonum*, *Scorpiurus, Vaccaria*, and medics. However, their presence was sporadic and only one third of the samples had contamination with these weeds.

From 200 barley seed samples collected across different regions 42% had no contamination with any restricted other crop seeds (wheat, etc.). Fifty eight percent of samples were contaminated with wheat seeds with the mean of 6 seeds per 120 g (with the range from 0 to 230 seeds). Moreover, 40% of the samples had the potential contamination with wheat seed in excess of the prescribed standard. The level of contamination was not significant among different regions, districts and seed sources. However, seed obtained from other farmers and retained on the farm had the highest average level of contamination. Almost all barley seed samples (97%; n=200) were contaminated with noxious weeds and all potentially with excess than the standard. *Avena* spp., *Lolium temulentum, Myagrum perfoliatum, Phalaris paradoxa* and *Convolvulus arvensis* were prevalent in samples collected from major barley growing areas. Contamination with wild oats and *Lolium* was found in 43% and 97% of the barley seed samples, respectively with the mean contamination of 5 and 288 seeds per 120 g in the same order. A total of 30 common weed species have been identified in barley seed samples and none of the samples were found without common weed contaminations. The most common weed species include *Brassica, Centaurea, Echinaria, Galium, Lavatera, Neslia, Papaver, Medicago, Trifolium* and *Vaccaria*.

Most wheat and barley seed samples were contaminated with other crop seeds (including weed seeds) and inert matter in varying proportions. In case of wheat, however, 17% of seed samples were not contaminated with other crop seed or weed seeds. The number and level of contamination of barley seed samples was significantly higher than that of wheat seed samples. This indicates better on-farm seed management of wheat compared to barley seed retained or obtained from other local sources. Fujisaka *et al.* (1993) found that 97% (n=70) of rice seed samples collected from farmers in the Philippines were contaminated with weed seeds. He reported that 26 to 79% of rice seed samples were contaminated with four major weeds with a range of 56 to 110 seeds sample^{-1}.

Farmers indicated that wild oats (*Avena* spp.), wild mustard (*Brassica* spp.), *Lolium* spp. and *Sinapis arvensis* were the major weed problems in wheat. About 79.5%, 54% and 10% of farmers considered wild oats, wild mustard and *Lolium*, respectively as major weed problems in wheat production. Wild vetch and *Cephalaria* were reported important by 3.4% and 4.4% of the farmers. In case of barley 27.5%, 24%, 12.5% and 9% of farmers considered wild oats, wild mustard, wild lentil and wild barley as major weed problems. Farmers' perception and qualitative assessment of weed problems in crop production fields matched well with the results obtained from the quantitative analysis of seed samples collected and tested in the laboratory. Girma *et al.* (2000) also reported farmers assessment of weed problems confirms well with the results of weed surveys in wheat production areas in Ethiopia.

Wheat seed samples were obtained both from formal and informal sectors whereas all barley samples were obtained from the informal sector (neighbours/farmers, markets/traders or own saved). The physical and physiological quality of wheat and barley seed obtained from different sources is presented in Table 4.11. Comparison of germination potential of seed from formal and informal sources showed no significant difference in the quality of wheat seed lots obtained from different sources except for barley seed ($P<0.05$). Ninety six percent of seed samples (n=45) from the formal sector matched the minimum physical purity for wheat seed certification, substantially higher than seed from other sources (e.g., 60.6% for own saved seed). On the contrary only 73% of wheat samples from the formal sector maintained the minimum germination requirement compared to 80% for seed from the informal sector. Van Gastel and Bishaw (1994) also found similar results on quality of wheat seed obtained from different districts and seed sources in the Aleppo province where all samples from the formal sector maintained the minimum purity standards, but lower in terms of

Table 4.11. Physical and physiological quality (germination) of wheat and barley seed collected from different sources in Syria.

Wheat					Barley				
Seed source	Purity (%)	% samples with purity of ≥98%	Germi-nation (%)	% samples with germi-nation of ≥85%	Seed source	Purity (%)	% samples with purity of ≥98%	Germi-nation (%)	% samples with germi-nation of ≥85%
Government	99.03	96	88	73	Government	-	-	-	-
Farmers	97.88	67	86	81	Farmers	94.97	0	88	82
Traders	99.30	100	92	86	Traders	95.44	8	92	85
Own seed	96.93	61	87	80	Own seed	95.54	12	85	70
Mean	97.59		87		Mean	95.47		86	
LSD (0.05)	3.88		7		LSD (0.05)	1.05		4.8	
Significance	0.087		0.506		Significance	0.405		0.014	

germination percentages. In the same study, about 36% of samples from the formal sector did not meet the certified seed requirement compared to 6% for seed from the informal sector (Van Gastel and Bishaw, 1994). Walker and Tripp (1997) reported no significant difference in germination between own saved seed and seed obtained off-farm from informal sources for cowpea in Ghana and sorghum and cowpea in Zambia. However, significant differences were found for maize seed in Ghana and cowpea in Zambia (Walker and Tripp, 1997), but a large proportion of the maize (up to 54%) and cowpea (up to 22%) seed samples did not reach the national seed standard for respective crops.

There were substantial differences in the quality of wheat and barley seed used for planting. While the majority of wheat seed samples matched the minimum physical purity and germination standards, a substantial proportion of barley samples in Syria did not match the minimum purity and germination standards. Considering the formal seed requirement for physical purity (≥98%) germination (≥85%), weed seed contamination (≤0.25%) and inert matter contamination (≤2%) a significant number of wheat seed samples achieved the national standard (69%). On the other hand, a large number of barley seed samples (about 90%) failed to meet the standard. These differences in seed quality may arise from the way farmers manage and perceive the quality of the wheat and barley seed used for planting. It appears that farmers give higher priority to wheat than barley seed management.

From the wheat and barley results it can be concluded that: (a) the seed from the formal sector may have the highest physical purity compared to seed obtained from other neighbours/farmers, traders/markets or own saved seed; (b) the seed from the formal sector - although it has high physical purity - performs relatively less in terms of physiological quality (germination); (c) the seed obtained from the informal sector may have lower physical purity, but performs relatively better in terms of germination; and (d) seed from the informal sector could exhibit high quality that could be comparable to that of the formal sector. This confirms the findings of Van Gastel and Bishaw (1994) who reported that seed samples from the formal sector had higher analytical purity than samples from the informal sector, but relatively lower germination percentages. Moreover, wheat seed samples both from the formal and informal sector showed better physical purity and germination compared to earlier results (Van Gastel and Bishaw, 1994). Similar results were observed for rice in the Philippines (Fuijsaka *et al.,* 1993) and for wheat in USA (Stanelle *et al.*, 1984) when compared to earlier studies in 1985 and 1973, respectively.

Thousand Seed Weight The overall average thousand seed weight for barley seed was 32.6 g ranging from the lowest of 28.8 g to the highest 39.7 g. In case of wheat the mean thousand seed weight was 40.06 g with a minimum of 30.3 g and maximum of 53.4 g. There was no significant difference found for samples collected from different climatic zones or seed sources, in wheat and barley. However, in barley, significant difference in seed weight was observed between different districts.

Physiological Seed Quality-Vigour The standard germination, speed of germination, seedling root length, seedling shoot length and seedling dry weight were used to assess the wheat and barley seed vigour (Table 4.12). There were highly significant differences ($P<0.001$) for all vigour test measurements for wheat and barley except for seedling dry weight in barley. The results are consistent with the findings for wheat seed samples collected from different regions and districts in Ethiopia (see Table 4.6 above). The wheat seed samples from Jebel Sama'an district in Aleppo consistently gave the highest seedling shoot length, seedling dry weight and vigour index 1. The barley seed samples from Ras Al-Ain had the highest speed of germination, shoot length, and root length. It was noted that the speed of germination of barley was the lowest compared to that of wheat in Syria and Ethiopia.

The speed of germination and seedling dry weight were the only vigour indices showing highly significant differences between different seed sources for wheat seed samples (Table 4.13). Shoot length (significant for barley), root length (significant for wheat) and vigour index showed inconsistent results for wheat and barley seed lots.

Table 4.12. Physiological quality (vigour) of wheat and barley seed collected from different districts in Syria.

	Wheat					Barley					
Districts	SPG[1]	SL (cm)	RL (cm)	SDWT (g)	VIG1	Districts	SPG	SL (cm)	RL (cm)	SDWT (g)	VIG1
Azaz	3.50	12.35	9.67	0.135	1947	Ain El-Arab	1.32	14.31	14.13	0.133	2313
Sema'an	3.83	14.71	10.46	0.150	2173	Manbeji	1.12	13.36	13.13	0.117	2225
						Al-Bab	1.16	12.67	12.1	0.098	2180
Tel Abiad	3.84	11.23	9.42	0.122	1966	Raqqa	1.22	14.68	14.31	0.106	2607
						Tel Abiad	1.17	12.55	12.4	0.112	2112
Khamishli	3.86	13.00	9.84	0.121	2070	Khamishli	1.32	14.55	12.64	0.107	2239
Hasakeh	3.86	9.45	11.25	0.124	1860	Hasakeh	1.37	14.07	12.61	0.109	2462
Ras Al-Ain	4.02	11.19	9.72	0.111	1962	Ras Al-Ain	1.38	14.79	13.49	0.114	2562
Mean	3.78	11.91	10.08	0.128	1985	Mean	1.26	13.16	13.78	0.115	2317
LSD (0.05)	0.19	0.79	0.57	0.01	101	LSD (0.05)	0.12	0.84	0.98	0.03	109
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	Significance	<0.001	<0.001	<0.001	0.096	<0.001

[1] SPG=speed of germination; SL=seedling shoot length; RL=seedling root length; SDWT=seedling dry weight; VIG1=vigour index 1.

Table 4.13. Physiological quality (vigour) of wheat and barley seed collected from different sources in Syria.

	Wheat					Barley					
Seed sources	SPG[1]	SL (cm)	RL (cm)	SDWT (g)	VIG1	Seed source	SPG	SL (cm)	RL (cm)	SDWT (g)	VIG1
Government	3.949	12.28	10.12	0.122	1997	Government	-	-	-	-	-
Farmers	3.702	11.52	9.55	0.124	1974	Farmers	1.321	14.22	13.73	0.136	2469
Traders	4.066	12.17	9.33	0.119	1982	Traders	1.275	14.42	13.15	0.109	2525
Own seed	3.686	11.8	10.30	0.134	1981	Own seed	1.245	13.67	13.08	0.113	2280
Mean	3.782	11.91	10.08	0.128	1985	Mean	1.255	13.16	13.78	0.115	2317
LSD (0.05)	0.261	1.258	0.82	0.013	144	LSD (0.05)	0.1099	0.77	0.88	0.024	190
Significance	<0.001	0.22	0.004	<0.001	0.961	Significance	0.206	0.04	0.189	0.056	0.003

[1] SPG=speed of germination; SL=seedling shoot length; RL=seedling root length; SDWT=seedling dry weight; VIG1=vigour index.

The remaining vigour indices did not show any variation among seed sourced from different sources, once again in conformity to wheat seed samples from Ethiopia.

For wheat simple linear correlation for standard germination and vigour tests and field emergence are given in Table 4.14. Simple correlations calculated among laboratory vigour tests indicated that all tests were correlated with each other. Among laboratory vigour tests only standard germination, speed of germination and seedling root length were significantly correlated with field emergence. Steiner *et al.* (1989) reported significant correlation between seedling shoot length, seedling root length and seedling dry weight in wheat. Similar results were also reported for lentil where standard germination, speed of germination and seedling dry weight was correlated with field emergence (Makkawi *et al.*, 1999). In our study, however, seedling shoot length, and seedling dry weight (including seedling vigour index) did not correlate with field emergence. Makkawi *et al.* (1999) also reported that shoot length did not correlate with field emergence in lentil.

Table 4.15 describes the relationship between different vigour tests and field emergence in barley. The standard germination and most other vigour tests showed significant correlations to each other. Standard germination and speed of germination correlated well with most other vigour tests except with the root length for the former and root length and seedling dry weight for the latter. Most of the vigour indices such as speed of germination, shoot length and seedling dry weight did not show any correlation with field emergence. Root length had negative correlation with field emergence. However, standard germination was the only vigour index with significant correlation with field emergence in barley. Kim *et al.* (1994) reported significant correlation between standard germination and speed of germination in field emergence in barley, the latter when seed was artificially aged for a period of 6 or 8 days.

In the formal sector, several vigour tests such as standard germination, speed of germination, root length, shoot length and seedling dry weight have been employed for evaluation of seed quality and including field emergence. The results of correlation coefficients both in wheat and barley indicate the association between vigour tests in seed samples collected from farmers in quantifying the quality of the seed and its planting value.

4.4.3. Farmers' Seed Management and Seed Quality

The majority of seed samples collected from farmers during the survey, 86.2% (n=304) of wheat from Ethiopia, 61.7% (n=206) of wheat and 82.5% (n=200) of barley from Syria, were from those farmers who used own seed retained on the farm. Farmers who obtained seed informally used indigenous seed management practices such as seed selection, cleaning, treatment or storing seed separate to improve the

Table 4.14. Simple Pearson correlation coefficient between vigour tests and field emergence in wheat, Syria.

	SG[1]	SPG	SL	RL	SDWT	VIG1	VIG2	FE
Standard germination	1	0.88*	0.54*	0.66**	0.47**	0.78**	0.59**	0.45**
Speed of germination		1	0.67**	0.69**	0.48**	0.83**	0.58**	0.50**
Shoot length			1	0.51**	0.75**	0.89**	0.77**	0.19
Root length				1	0.69**	0.79**	0.70**	0.32*
Seedling dry weight					1	0.77**	0.97**	0.003
Vigour index 1						1	0.85**	0.36
Vigour index 2							1	0.11
Field emergence								1

*, ** Significant at P<0.05 and P<0.01, respectively;

[1] SG=standard germination; SPG=speed of germination; SL=seedling shoot length; RL=seedling root length; SDWT=seedling dry weight; VIG1=vigour index 1; FE=field emergence.

Table 4.15. Simple Pearson correlation coefficients between vigour tests and field emergence in barley, Syria.

Laboratory tests	SG[1]	SPG	SL	RL	SDWT	VIG1	VIG2	FE
Standard germination	1	0.55**	0.14*	0.13	0.03	0.76**	0.34*	0.26**
Speed of germination		1	0.25**	0.23**	0.002	0.53**	0.18*	0.13
Shoot length			1	0.72*	0.24**	0.69**	0.27**	0.04
Root length				1	0.24**	0.70**	0.26**	–0.04
Seedling dry weight					1	0.19**	0.95**	0.03
Vigour index 1						1	0.41**	0.16*
Vigour index 2							1	0.11
Field emergence								1

*, ** Significant at P<0.05 and P<0.01, respectively;

[1] SG=standard germination; SPG=speed of germination; SL=seedling shoot length; RL=seedling root length; SDWT=seedling dry weight; VIG1=vigour index 1; FE=field emergence.

quality of their planting materials (Table 4.16). A comparison has been made on physical and physiological quality of seed from those farmers who retained seed on the farm and who indicated using different seed management practices (Table 4.16). In most cases, the mean physical purity, germination and pure live seed (PLS) of samples from farmers who did practise a particular seed management or not were found to be

not sufficiently different (data not shown). However, there was a large difference in the number of samples, which maintained the minimum physical purity, and germination standards for certified seed. The results indicated that seed cleaning of wheat in Ethiopia, harvesting methods and seed cleaning of barley and seed treatment of wheat in Syria showed significant differences in viability or germination of seed lots ($P<0.05$). On the contrary, it was reported that the crop variety (local or improved), form of seed storage (shelled/unshelled), seed storage facilities (containers), seed selection, pesticide treatment (or use of admixture including smoking), age of the seed, moisture content of the seed and the region from which the samples were collected had significant effects on germination of maize, beans, cowpea, soybean and ground nut in Ghana, Malawi and Tanzania (Wright *et al*., 1995).

Machine harvesting may predispose seed to mechanical damage and loss of germination compared to traditional manual harvesting and threshing. Proper adjustment of equipment and adequate seed moisture content at harvesting are critical in reducing seed damage. There was some variation in seed quality based on crop harvesting practices followed by farmers. Although the mean physical purity and germination of wheat and barley seed lots from farmers who machine harvested their crops were slightly lower, the seed quality was comparable to manually harvested seed lots both in Ethiopia and Syria (data not shown). However, the number of samples that reached the minimum standard required for certified seed of wheat and barley was substantially lower for samples harvested mechanically (Table 4.16). The difference was more pronounced in physical purity than in physiological quality. Fujisaka *et al.* (1993) found that rice seed samples from farmers who used manual harvesting and threshing had higher physical purity compared to those which were machine harvested particularly in terms of weed contamination. Moreover, low germination of mechanically harvested durum wheat seed was reported in Algeria (Lakhdar *et al*., 1998) and Morocco (Grass and Tourkmani, 1999). The agro-climatic differences that exist in various countries might have contributed to some of these variations in physiological seed quality.

Seed cleaning is based on most prevalent physical characteristics of seed such as size, shape and weight and the contaminating impurities (Boyd *et al.*, 1975). Seed cleaning improves purity by removing inert matter contaminants and germination by removing mechanically damaged seeds. The cleaning efficiency in removing these contaminants, however, requires special skill and equipment. There was no significant difference in mean physical and physiological quality of seed samples collected from farmers who cleaned their seed or those who did not practise cleaning (Table 4.16). In Ethiopia 86% and 97% of seed samples from farmers who clean their seed met the minimum physical purity and germination standards whereas the proportion was 77% and 80% for wheat and 10% and 69% for barley in Syria, respectively. The generally poor quality of barley seed samples was recognized and this contributed to the lower percentage of samples meeting the standard. This indicates some weaknesses in the efficiency of the traditional seed cleaning equipment in removing the major contaminants. It should also be noted that cleaning alone could not bring the quality of poor seed to a desired level and should be coupled with adequate agronomic practices for seed production. However, the small number of samples from uncleaned seed lots might not give conclusive evidence for barley samples in Syria.

Table 4.16 shows that a significant number of farmers who used own seed applied chemical treatment for wheat (n=127; Syria), checked germination informally (n=94; Ethiopia) or applied irrigation for wheat production (n=84; Syria). Chemical treatment improves physiological quality of seed by protecting them against seed- and/or soil-borne pathogens. Germination was significantly better for treated seed and the mean germination for wheat seed and for farmers who practised treatment was 87.5% while 79.5% of the samples reached the minimum certified seed requirement. Moreover, of 59 treated seed samples collected from farmers, 83% met the minimum germination requirement. In Ethiopia, comparison of the results showed no difference on average germination of wheat samples between farmers who did check germination or not i.e. 96%. Similarly, no difference in mean germination was observed between seed samples collected from farmers who did or did not apply irrigation in Syria, except in the number of samples which reached the minimum requirement (83% for irrigated versus 72% for non-irrigated samples). There was no difference in thousand seed weight between irrigated and non-irrigated samples either.

The storage environment has a significant influence on the quality of seed particularly on germination if seed would be predisposed to deteriorative factors such as high moisture, high temperature or infestation with storage pests. In Ethiopia, a traditional bin made of interwoven bamboo/sticks internally plastered by a mixture of clay mud and cereal straw (*gotera*) is the most popular storage facility whereas farmers in Syria used polypropylene bags or jute bags for storage whether seed for planting was stored separately or in bulk with grain. In Ethiopia the storage period extends over a minimum of seven months (November to June) while in Syria for over five months (June to November) during a period of low relative humidity. Wheat and barley germination results showed no significant difference among seed lots stored together with grain or separate using different storage structures. In Nepal investigation on traditional storage practices showed that wheat seed samples stored on farm in mud structures increased in moisture content with associated drastic fall in germination during storage under conditions of high humidity and temperature (Tripathi and Powell, 1999). On the contrary (Tsega, 1994), found that in the highlands of Ethiopia loss of viability between harvesting time and after seven months of storage was minimal with net increase in moisture content both in wheat and barley seed samples. In our studies most of the wheat seed samples collected from farmers in Ethiopia maintained high standards of germination compared to that of wheat and barley seed samples from Syria. This could be attributed to differences in storage facilities where in Syria most of the wheat and barley seed was stored in polypropylene or jute sacks. Tsega (1994) found that legumes (lathyrus and lentil) stored in sacks showed the highest loss of germination compared to other traditional storage facilities. Moreover, Wright *et al*. (1995) indicated that sacks were less suitable for storage of treated or untreated maize seed in Ghana. In general, seeds in jute or polypropylene sacks are vulnerable to pest attack and change in moisture content relative to the ambient temperature and relative humidity which has detrimental effect on the physiological quality of seed. Wright *et al.* (1995) indicated that moisture content had significant effect on germination, and the higher the moisture content the lower the germination of on-farm saved seed.

Several workers have reported a decline in germination due to storage pests. Apart from seed storage facilities, analyses were also made on germination of wheat and barley seed samples between farmers who indicated having storage pest problems or not. The mean germination in all cases was comparable between farmers who had storage pest problems or not. The results may indicate that farmer's seed storage management practices may not necessarily contribute significantly to the improvement of the physical and physiological quality of the seed. Kashyap and Duhan (1994) reported *Sitophilus oryzae* and *Rhizopertha dominica* as most prevalent wheat seed storage pests in humid areas; and insect damaged seed had exhibited significant reduction in physiological seed quality.

4.5. Concluding Remarks

In the formal sector, quality control is a key component of seed production. Several regulatory, technical and managerial measures are undertaken where standardized procedures and specific guidelines are employed to produce quality seed. Apart from good agronomic management practices the crop is inspected and the harvested seed is cleaned (often treated) and tested to bring the seed to a certain uniform quality standard for marketing purposes. However, in the informal sector seed production is largely dependent on the farmers' indigenous knowledge and best management practice in the art of seed saving. Literature is abundant on the quality of seed produced from the formal sector whereas studies dealt with the quality of seed produced by the informal sector are rather limited. This chapter contributes to our understanding of the quality aspects of seed from the informal sector.

The wheat and barley seed samples collected from farmers in major crop production regions showed remarkable significant regional differences in terms of physical purity and physiological seed quality. Seed samples collected from certain regions performed comparatively well in terms of seed quality attributes. These differences in seed quality could be attributed to variations in environmental conditions under which the crop is produced and crop management practices followed by farmers. Almost all seed samples from Ethiopia reached the minimum physical purity and germination standards prescribed for the formal sector, whereas a substantial proportion of samples particularly of barley in Syria did not meet the standards. In Syria most farmers use machine harvesting compared to farmers in Ethiopia who predominantly use manual harvesting, threshing and winnowing handling small quantities of seed. Wright *et al.* (1995) also found significant variation in the physiological quality of seed collected from different regions in several African countries. Fujisaka *et al.* (1993) reported that manual threshing produced cleaner seed than did machine harvesting in terms of physical quality. Therefore, it can be safely concluded that the differences in seed quality observed across the regions could arise from the environmental conditions under which the crop is produced and the crop harvesting and threshing practices followed by farmers.

The physical and physiological seed quality tests did reveal variation in the quality of seed obtained from different regions whereas the same test did not show any significant difference in the quality of seed obtained from different sources. The majority of seed samples from the formal sector matched the minimum standards, but were not significantly different from seed from the informal sources. Wheat and barley seed samples collected from informal seed sources from farmers following different crop management practices produced seed of the same quality as or of better quality than seed from the formal sector. A substantial proportion of seed samples from the informal sector also reached the minimum physical and physiological quality of the formal sector. The results show that there is no evidence to suggest that seed from the informal sector is largely inferior to that of the seed from the formal sector. From these results it can be summarized that: (a) the seed from the formal sector may have the highest physical purity compared to seed obtained from other neighbours/farmers, traders/markets or own saved seed; (b) the seed from the formal sector although having high physical purity showed some weaknesses or performed relatively low in terms of physiological quality (germination); (c) seed from the informal sector could exhibit high quality that could be comparable to that of the formal sector; and (d) the seed obtained from the informal sector may have lower physical purity, but performs relatively better in terms of germination.

The results of seed quality from the informal sector raise fundamental issues on the quality parameters of the formal sector. The seed produced by the formal sector should be of superior quality to that of the informal sector to persuade farmers to purchase seed from external sources. The seed should also provide incremental yield or benefit compared to seed obtained on-farm or informally through local exchange mechanisms. At present national seed standards are set for physical and germination where seed testing is practised as a routine. Germination tests quite often fail to predict performance of the seed lot under adverse field conditions. Moreover, there is still limited knowledge on the relationship between laboratory tests on the subsequent seedling emergence, crop establishment, yield and yield components. This implies that seed quality aspects and laboratory tests should be responsive to the needs of farmers. In the future, seed quality aspects should be of predictive nature to assess the field planting value of the seed lot and the benefits accrued from the use of certified seed from the formal sector. Therefore, in addition to conventional laboratory test for germination, vigour tests that predict field performance should be incorporated in the seed quality tests.

Most farmers who used own saved seed on the farm or obtained seed through local exchange mechanism employed different seed management practices such as seed selection, seed cleaning, seed treatment or separate storage. Farmer's seed selection and processing practices appear to be relatively effective in at least producing seed, which is as clean as that found from the formal sector. However, such generalizations conceal the fundamental weaknesses of the traditional seed management practices that need to be addressed in terms of improving quality of seed in the informal sector. In general, comparison across a wide spectrum of on-farm seed management practices did not yield significant differences on the quality of seed obtained from the informal sector. It appeared that the cleaning efficiency of traditional equipment in removing contaminants including noxious and common weeds from the seed is obviously low. Considering the informal sector as a major supplier of seed for planting, it is imperative to improve the quality of seed produced on the farm. Therefore, making available locally designed and manufactured simple and cheap cleaning and treatment equipment would help farmers produce quality seed used in the informal sector.

In general, farmers use high seed rates sometimes as high as two to three fold sometimes in the assumption that the quality of their planting material is low. The evidence from the wheat and barley seed samples suggests that the quality of seed produced in the informal sector is of comparatively high purity and germination with certain limitations. Lack of awareness led farmers to incur extra cost without any substantial benefit. It is important that farmers are encouraged to employ simple techniques of producing quality and provided with 'best practice' on-farm seed production guidelines to improve the quality of seed produced and used in the informal sector.

Seed quality standards are key feature of a quality assurance programme in the national seed industry, although they may vary between countries. Many national programmes prescribe exceptionally high standards often imported from elsewhere without due consideration to the level of agricultural and seed industry development of the country. The standard for certified seed for wheat and barley in Ethiopia and Syria requires a minimum of 97-98% analytical purity and 85% germination for marketing certified seed second generation. For example, Delouche (1982) suggested that a minimum germination of 70% is sufficient for small-scale farming conditions. If such criterion is considered, most of the seed samples from the informal sector performed well and could easily match the minimum standard required for planting wheat and barley crop. It is important that national seed programmes define realistic seed quality standards that would enable the formal sector to produce enough quantity of seed to meet national demand. Moreover, such reasonable standards would encourage the operation of alternative local level seed production and delivery systems.

CHAPTER 5

Farmers’ Seed Sources and Seed Quality: Seed Health Quality

Farmers' Seed Sources and Seed Quality: Seed Health Quality

5.1. Abstract

A total of 200 wheat seed samples from Ethiopia and 206 wheat seed samples and 200 barley seed samples from Syria were surveyed during the 1997/98 and 1998/99 crop seasons to study the seed health quality of the seed obtained from various sources and grown by farmers in different regions. The survey was carried out to assess the occurrence, geographic distribution and frequency of wheat and barley seed-borne diseases and health quality of seed planted by farmers. The samples were tested in the laboratory using different seed health testing methods recommended by the International Seed Testing Association (ISTA).

In Ethiopia, several seed-borne fungi were recorded from wheat seed samples collected across different regions. From a total of 304 samples checked for seed health quality, 84%, 31%, 74%, 13%, 52% and 31% were infected by *Drechslera sativum*, *Fusarium avenaceum*, *F. graminearum*, *F. nivale*, *F. poae* and *Septoria nodorum*, respectively. Among all fungal pathogens isolated from wheat seed, 84% of samples were infected with *Drechslera sativum* at an average infection level of 1.85% (range from 0 to 6%). *F. graminearum* was predominant among *Fusarium* species where 74% of the samples were infected with mean infection rate of 1.54%. The number of samples infected (31%) and the level of infection (0.5%) was the lowest with *Septoria nodorum*. Infection with loose smut (34 samples) and common bunt (7 samples) and seed gall nematode (26 samples) was very low. The wheat seed from the formal sector consistently showed less infection for most of the pathogens. Several storage fungi were also recovered during the seed health testing including *Alternaria* spp., *Aspergillus* spp., *Cladosporium* spp., *Curvularia* spp., *Mucor* spp., *Nigrospora* spp., *Penicillium* spp. and *Trichothecium* spp. which are prevalent across regions. There was a strong positive correlation with some *Fusarium* species and abnormal and dead seeds during germination tests. From wheat seed samples collected in Syria, 68 and 14% of the samples were infected with common bunt and loose smut, respectively. The average loose smut infection was 0.79%. Almost all barley seed samples were also infected with covered smut (85%) and loose smut (83%) in varying proportion. The highest infection rate of 18% was recorded for loose smut of barley. Seed health quality of wheat was found to be better than of barley in terms of the proportion of samples infected (frequency) and the level (intensity) of infection. There were significant differences ($P<0.001$) in the mean infection levels across different regions and districts in Ethiopia and Syria for both crops. In Ethiopia, there was a significant difference ($P<0.001$) in infection levels for most of the pathogens from different seed

sources compared to Syria where there was no significant difference for seed samples from different sources. The results of the present study will provide some insight into the health quality of wheat and barley seed in sub-tropical environments of Ethiopia and Syria.

Key words: Ethiopia, Syria, wheat, *Triticum* spp., barley, *Hordeum vulgare*, seed health quality, formal seed system, informal seed system, seed source, on-farm seed management.

5.2. Introduction

In Ethiopia, plant diseases are considered to be among the major crop production constraints in terms of reducing wheat crop yield (Gebremariam *et al*., 1991b; Bekele, 1985). Stewart and Yirgou (1967) and Kidane (1982) published an index of important plant diseases such as pathogenic (rusts, smuts, septoria, fusarium, helminthosporium) and saprophytic fungal diseases of wheat in Ethiopia. A total of 35 fungal, three bacterial and one viral diseases and four nematode pests have been reported on wheat (Hulluka *et al*., 1991; Andenew, 1988; Bekele, 1985). Among these plant pathogens *Drechslera* spp., *Fusarium* spp., *Septoria* spp., *Tilletia* spp. and *Ustilago* spp., bacterial diseases (*Cornybacterium*, *Pseudomonas* and *Xanthomonas*) and a gall nematode (*Anguina tritic*) appeared to be problematic seed-borne diseases. The presence of bunt (*Tilletia caries* and *T. foetida*), loose smut (*Ustilago tritici*), glume blotch (*Septoria nodorum*), scab or head blight (*Fusarium graminearum*, *F. longipes*, *F. semitectum*), *F. dimerum,* barley yellow dwarf virus and gall nematode (*Anguina tritici*) were reported from earlier studies (Hulluka *et al.,* 1991; Bekele, 1985). Fusarium head blight was found as a major threat to wheat production under high rainfall conditions (Bekele and Karr, 1997). *Septoria* and *Helminthosporium* spp. were found widely in southeastern and central wheat production areas but at low to moderate levels whereas fusarium head scab was a serious problem in the Arsi and Bale regions (Gebeyehu *et al.*, 1990).

Similarly, Mamluk *et al*., (1992) provided a detailed and updated list of cereal, food legume and forage and pasture crop diseases and insect pests in Syria. A list of several seed-borne diseases has been reported from Syria (Mamluk *et al*., 1990; Mamluk, 1991). Accordingly, common bunt (*Tilletia caries* and *T. foetida*), loose smut (*Ustilago tritici),* flag smut (*Urocystis agropyri*), *Septoria* spp. (*Septoria nodorum* and *S. passarini*) of wheat; and covered smut (*U. hordei*), loose smut (*U. nuda*), barley leaf stripe (*Pyrenophora graminea*), flag smut (*Urocystis agropyri*), net blotch (*Pyrenophora teres*), scald (*Rhynchosporium secalis*) for barley are prevalent in Syria

(Mamluk *et al.*, 1990; Mamluk, 1991; Mamluk *et al.*, 1992; El-Ahmed, 1999).

In general, epidemiological and yield loss assessment studies are lacking for most seed-borne diseases. The global losses due to seed-borne diseases are estimated at 12% potential production (Agarwal and Sinclair, 1987), but some studies have indicated variable yield losses at regional or national levels (Besri, 1983; Agarwal, 1986; Mamluk, 1991; Neimann *et al*., 1980). In Ethiopia, some studies on wheat indicated losses of up to 29% from eyespot (Bekele and Semane, 1983) and 5% from common bunt (Neimann *et al*., 1980). Mamluk *et al.*, (1990) reported sporadic occurrence of loose smut of wheat in Syria with a maximum of up to 5% infection in the field which corresponds to an equivalent amount of yield loss.

There is a continuous threat to agricultural production from evolving or introduced diseases and pests, quite often causing substantial economic losses. Wheat and barley are two major cereal crops of worldwide importance and are affected by several pathogens known to be seed-borne, including fungi (*Drechslera* spp., *Fusarium* spp., *Tilletia* spp., *Septoria* spp. and *Ustilago* spp.); bacteria (*Cornybacterium*, *Pseudomonas* and *Xanthomonas*); and gall nematode (*Anguina tritic*). These seed-borne diseases are very important not only from national but also from international perspective because of their worldwide distribution and losses they incur in crop production (Wiese, 1987; Mathre, 1987). Planting healthy seed is one of the most important disease management strategies in reducing economic losses in crop production.

Seed quality is a multiple concept comprising several components (Thomson, 1979). In Chapter 4, we identified key seed quality attributes: (a) genetic quality, (b) physical quality, (c) physiological quality, and (d) health quality. Seed health is one of the most important attributes of seed quality and indicates the freedom from infection or contamination with seed-borne pests, namely: fungi, bacteria, viruses, nematodes, insects and mites including noxious or parasitic weeds (Diekmann, 1993; Hampton, 2002). Seed health testing is conducted to serve several purposes, i.e. to determine field planting value, investigate causes of low germination, make decisions on pesticide treatment, assess prevalence of diseases in a survey or detect quarantine pests, (ISTA, 1996; Abdelfattah, 1994).

Seeds can serve as a vehicle for the dissemination of plant pathogens resulting in serious disease out-breaks. Seed-borne pathogens are infectious agents with a potential to cause a disease of seedlings and plants. They can be transmitted as contaminants with seed or on seed surface or through seed infection which could be in the pericarp, endosperm or embryo (Diekmann, 1993). Infected seeds may fail to germinate, have low germination capacity, may produce abnormal seedlings and may result in reduced seedling vigour affecting its planting value. For example wheat seeds severely infected by karnal bunt (*Neovossia indica*) either fail to germinate or produce a greater percentage of abnormal seedlings (Singh and Krishna, 1982; Singh, 1980). Rennie *et al.* (1983) stated that *Septoria nodorum* could reduce both laboratory germination and seedling emergence in the field particularly at low temperatures. There are also reports on the effect of seed-borne diseases on plant growth. Agarwal and Gupta (1989) cited from earlier reports that in wheat, loose smut (*Ustilago tritici*) infected plants produced fewer tillers and reduced tiller height. Moreover, field crops are subject to yield or quality loss due to attack from seed-borne pathogens during growth or in storage (Wiese, 1987; Agarwal, 1986). Mamluk (1991) reported 5 to 7% yield loss due to common bunt in West Asia and North Africa region alone. Moreover, infection with certain pathogens causes discolouration, shrivelling, etc., reducing grain quality (Wiese, 1987; Agarwal, 1986; Shetty, 1992).

Seed-borne diseases have a special significance because the pathogens are spread in close association with the host (sometimes exclusively with seed), are capable of carry-over for several years, and have a potential for long distance spread into new areas and uniform distribution of inoculums in the field. Seed health has been used as a tool to control seed-borne diseases. Seed certification schemes have become extremely valuable among other means in prevention of seed-borne diseases. A seed certification scheme includes a combination of field inspection, seed health testing and seed treatment measures to produce disease free seed for planting purposes. As a result national seed programmes set seed health standards for certification purposes (Kashyap and Duhan, 1994; Diekmann, 1993; Besri, 1983). Some disease surveys and reports indicated the presence of seed-borne diseases on wheat in Ethiopia (Hulluka *et al.*, 1991; Niemann *et al.*, 1980) and wheat and barley in Syria (Mamluk, 1991; Mamluk *et al.*, 1992). However, it should be noted that most national seed programmes in the West Asia and North Africa region have seed quality standards for purity and germination, but few countries have standards for seed health certification (ICARDA, 2002). Moreover, even in countries where such standards exist, they still remain incomplete because they either lack field or seed quality standards for seed health certification (ICARDA, 2002; Abdelfattah, 1994; Besri, 1983). Hampton (2002) indicated that over 80% to 90% of all laboratory seed testing are concentrated on physical and physiological seed quality. As a result both certified and non-certified seeds are infected by seed-borne diseases in excess of the prescribed standards indicating the ineffectiveness of seed certification programmes in meeting the seed health requirements partly due to lack of expertise and facilities (Abdelfattah, 1994; Besri, 1983). It is worth to note, however, that the majority of wheat and barley seed planted comes from the informal sector where awareness of health quality varies among farmers. Therefore, it is important to have adequate information on occurrence and geographic distribution of seed-borne diseases to have a clear understanding of the seed health quality problems both in the formal and the informal sector.

In literature, information is available on seed production and other quality parameters, though information on seed health status is rather limited (Kashyap and Duhan, 1994; Fujisaka, *et al*., 1993). More importantly, information on seed health quality of seed from the informal sector is scanty (see Chapter 4). Therefore, the present study is aimed at assessing the health quality of seed obtained from different sources and planted by farmers, the occurrence and distribution of seed-borne pathogens associated and the effect of seed management practices followed by them. Therefore, the main objectives of this study were to:

- Investigate the health quality of seed planted by the farmers;
- Make comparison of health quality of seed obtained from different sources;
- Understand seed health quality constraints of the informal seed system; and
- Recommend alternative options for improving seed health quality at the farm level.

5.3. Materials and Methods

5.3.1. Wheat and Barley Seed Samples

As part of seed supply studies, a total of 304 wheat farmers in Ethiopia and 200 barley farmers and 206 wheat farmers in Syria were interviewed in major wheat and barley growing regions of the country during the 1997/98 and 1998/99 cropping seasons. A stratified sampling procedure was followed from higher to lower administrative levels, farmers being considered as sampling units. A total of three to four regions were covered comprising of 6 to 9 districts for each crop and covering 59-81 villages across the regions. Farmers were asked about the wheat or barley seed sources, perception of seed quality, agronomic practices and seed management practices for production of both crops. After the interview a sample of approximately 1 kg of wheat or barley seed was collected from each farmer from the seed lot planted or intended for planting for analysis in the laboratory. To bring the seed quality to the same standard, each sample was pre-cleaned to remove dust and small particles before laboratory tests were conducted. Seed samples were fumigated against storage pests and kept under ambient conditions until tested for seed health.

Laboratory Tests All wheat and barley seed samples collected during the survey were analysed for seed health. All tests were conducted according to ISTA rules prescribed for each pathogen under investigation (ISTA, 1984). Freezing blotter test, agar plate test, centrifuge wash test and embryo test were employed to detect major seed-borne pathogens of wheat and barley. All seed health tests were conducted at the seed quarantine testing laboratory of the Ethiopian Agricultural Research Organization in

Holetta, Ethiopia, and the seed health testing laboratory of the Genetic Resources Unit of ICARDA in Aleppo, Syria.

Freezing Blotter Test A deep-freezing blotter test was used to assess infection with *Fusarium* spp. and *Drechslera sativum* (ISTA, 1984). Four hundred seeds, 4 replicates of 100 seeds, from each sample were planted in germination boxes using a blotter paper (pleated paper in Syria) moistened by distilled water and incubated in a germinator for 24 hours at 20 °C for seed to imbibe water. The imbibed seed was transferred to a deep freezer at −18 °C overnight. The seeds were incubated at 20 °C for 7 days with near UV light in alternating cycles of 12 hours light and 12 hours darkness to stimulate sporulation (Agarwal and Sinclair, 1987). Examination of seeds was carried out after 7 days of incubation under a stereoscope microscope. The infected seedlings were counted and the pathogens were identified based on mycelium and spore morphology and characteristics.

Agar Plate Method The agar plate method was used to assess the infection of *Septoria nodorum* due to its sensitivity to ultra violet light and incubation procedures (Mathur and Lee, 1978). Four hundred seeds from each sample were pretreated by 1% aqueous solution of sodium chloride (NaCl) for 10 minutes and then rinsed with sterilized water. The seeds were plated on Petri dishes and incubated at 22 °C for 7 days in 12 hours of alternating cycles of daylight and darkness. After 7 days the seeds were further incubated for another 4 days in 12 hours cycle of darkness and near ultra violet light. Using pycnidia count and colony characteristics the seeds were assessed for *Septoria nodorum* infection (ISTA, 1984 (sheet 19)).

Centrifuge Wash Test The centrifuge wash test was conducted to assess common bunt contamination (*Tilletia* spp.) for wheat and covered smut (*Ustilago hordei*) for barley. From each sample 50 g seed of four replicates were sampled. Each replicate was mixed with 50 ml sterilized water in a conical flask. About 0.15% liquid soap was added to suspend the spores (ISTA, 1984; sheet 53). The mixture was shaken for 5 minutes using a rotary shaker and then centrifuged at 2000 rpm for 10 minutes. The water was decanted and 0.5 ml of water added to the remaining suspension. Drops of the suspension were transferred to a counting chamber (ISTA, 1984; sheet 53). The spore load was counted under a compound microscope and their numbers per g of seed were determined. In Syria, however, 400 seeds of 4 replicates of 100 seeds were used based on the procedures of the Seed Health Laboratory of ICARDA to detect low level contamination of spores for germplasm exchange purposes (Siham Assad, personal communication).

Embryo Count Test An embryo count method was used both for detection of loose smut of wheat (*Ustilago tritici*) and barley (*Ustilago nuda*) (ISTA, 1984). A working sample of approximately 2000 seeds each for wheat or barley was soaked in 1 liter 5% fresh solution of NaOH containing 200 ppm tryphan blue at 20 °C for 24 hours. After soaking, the entire sample was washed in warm water and agitated to facilitate the separation of embryos from the endosperm and passed over a set of sieves (2.5 mm and 1 mm mesh to collect the endosperm and the embryo, respectively). The sample was transferred to a funnel closed with rubber tube and stop cork and covered with a mixture of lactophenol and water (3:1 by volume). Finally the embryos were cleared by transferring them into fresh lactophenol and boiled for 30 seconds. Embryos were immersed in fresh glycerol, arranged in rows in grooved Perspex plates and examined using a stereoscope microscope with sub-stage illumination. Embryos with loose smut mycelium were counted as infected (ISTA, 1984; sheets 25 and 48) and the percent loose smut infection was calculated based on the number of embryos examined.

Wheat Gall Nematode Two replicates of 50 g from each sample were taken and examined under a stereomicroscope and seeds with nematode galls were separated and counted (ISTA, 1984; sheet 54). To confirm the presence of the nematodes, suspected seeds were soaked in water for about 1 h and cut open. The materials were transferred to clean water and were observed under microscope where a mass of whitish cloudy material containing mobile and infective juvenile could be observed (ISTA, 1984; sheet 54).

Saprophytic Fungi During the seed health testing many storage fungi recovered from wheat seed samples were also observed and their presence recorded.

5.3.2. Field Emergence

In Ethiopia, wheat was planted at the rate of 30 g per plot in 6 rows of 2.5 m length with a spacing of 0.2 m between rows on 3 and 4 July 1998/99. In Syria wheat was planted at the rate of 60 g for bread and 70 g for durum in 8 rows of 2.5 m length and with a spacing of 0.25 m between rows on 4 and 6 January 1999/2000. Barley was planted at the rate of 50 g per plot of 8 rows of 2.5 m length with a spacing of 0.25 m on December 1998/89. In all experiments seedling emergence was measured twice, first once emergence was stabilized and the second time two weeks after the first count on an area of 1 m^2.

5.3.3. Data Analysis

The statistical analysis of the data from the laboratory test was based on a completely randomized design using Genstat statistical package and the LSD (0.05%) was used to find the significance between tests and to separate the means among different treatments. Simple Pearson correlation coefficients were calculated to quantify the association among different seed health tests, physiological tests (germination and vigour) and field emergence.

5.4. Results and Discussion

Seeds are considered the basic input for crop production and should be free from seed-borne diseases. Otherwise infected seed may introduce foci of primary infection in the field which cause disease outbreaks. Adverse effects may relate to interference in normal crop growth and development giving rise to reduced yield and quality. With destructive diseases the extent of crop loss will be directly related to incidence (e.g. cereal loose smut in wheat and barley).

5.4.1. Wheat Seed Health in Ethiopia

The Ethiopian seed certification standards require that maximum permitted percent infection for seed-borne diseases are zero infection for breeder/pre-basic seed; 0.02% for basic seed; 0.03% for certified 1; 0.05% for certified 2, certified 3 and certified 4; and 0.1% for commercial/emergency seed (ICARDA, 2002). The wheat seed-borne diseases indicated in the standard include common bunt, loose smut, head blight and glume blotch. However, the standard neither specifies the minimum infection levels permitted in the field nor the type of diseases to which the laboratory seed standard applies except the list of pathogens mentioned above. It is also worth to mention that seed health testing is neither carried out as a routine practice nor facilities are available to conduct the test. In situations where seriously low germination is observed and seed health related issues are suspected seed samples could be sent to other co-operating laboratories for detection of the problem.

Dreschlera, Fusarium and Septoria spp. Table 5.1 presents seed-borne pathogens recovered from wheat seed samples collected from major wheat production regions of the country revealing the occurrence and wide spread distribution of some of the important seed-borne diseases. Almost all seed-borne diseases identified during the test were reported throughout the major wheat growing regions except for *Septoria nodorum* from Ensaro-Wayu in North Shoa and Machkal from East Gojam regions. There was also significant difference on health quality of wheat seed samples from different regions and districts. From a total of 304 samples checked for seed health 84%, 31%, 74%, 13%, 52% and 31% of the wheat seed samples were infected by *Drechslera sativum*, *Fusarium avenaceum*, *F. graminearum*, *F. nivale*, *F. poae* and

Septoria nodorum, respectively. Wheat seed samples from the Arsi region consistently gave higher levels of infection for all except few seed-borne pathogens.

The number of samples infected and the level of infection with *Drechslera sativum* was the highest across the regions (0.91% to 2.43%) and districts (0.45% to 2.93%) with a mean of 1.85% (0% to 6%). The highest infection was observed on seed samples from Gedeb, Munesa and Hetosa districts from Arsi region in southeastern Ethiopia. Paul *et al.* (1994) also recorded the highest infection (2% to 13%) of *Drechslera sativum* from wheat seed samples collected from northwestern Ethiopia. The results confirm the presence of the pathogen in different wheat growing regions of the country.

A total of five *Fusarium* spp. were isolated from wheat seed collected from farmers and occasionally more than one species isolated from each sample. *F. graminearum* appeared to be predominant and followed by *F. poae, F. avenaceum* and *F*. nivale both in terms of frequency (number of samples infected) and intensity (the level of infection). The highest infection of 1.58% (with a range from 0% to 6%) was observed for *F. graminearum* among other species where 74% of the samples were infected. Head scab caused by *Fusarium* appeared to be a major wheat production problem in the Arsi region (Hulluka *et al*., 1991). The results indicated relatively higher infection from seed samples in southeastern Ethiopia which is consistent with earlier reports where the pathogen was considered a serious threat to wheat production (Gebeyehu *et*

Table 5.1. Seed health quality (% infection) of samples collected from major wheat growing regions of Ethiopia.

Districts	*Drechslera sativum*	*Fusarium avenaceum*	*Fusarium graminearum*	*Fusarium nivale*	*Fusarium poae*	*Septoria nodorum*
Gedeb	2.90	0.91	2.58	0.37	1.26	0.47
Munesa	2.18	1.07	1.96	0.23	1.57	0.61
Hetosa	2.47	0.75	2.48	0.04	0.98	1.14
Dodota	1.88	1.18	1.85	0.19	1.10	0.73
Dendie	1.62	0.19	1.28	0.07	0.84	0.70
Chelia	1.88	0.32	1.37	0.15	0.78	0.46
Ensaro Wayu	0.91	0.08	0.71	0.52	0.51	0.00
Hulet Eju	1.32	0.39	0.79	0.13	0.63	0.05
Machakal	0.45	0.11	0.36	0.20	0.43	0.00
Mean	1.85	0.56	1.58	0.21	0.90	0.50
LSD (0.05)	0.35	0.28	0.35	0.32	0.32	0.24
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

al., 1990). Clear *et al.* (1996) also found *F. graminearum* as the most commonly isolated pathogen of 11 *Fusarium* spp. where from 2% to 71% of the samples were infected showing greater regional variations in Canada. Moreover, the same report indicated that oats had relatively lower infection compared to wheat where up to 38% of the samples were infected.

Bekele and Kar (1997) found high levels of *Fusarium* infection of wheat seeds produced in 1987 and stored under various conditions at research centres, seed farms, state farms and farmers' stores in different regions of Ethiopia where 35% to 63% of the samples were infected with infection levels ranging from 1% to 17%. Seventeen and thirteen *Fusarium species* were identified from stored seed and field samples, respectively where *F. avenaceum F. graminearum* and *F. nivale* were the dominant species in the field samples and *F. avenaceum, F. lateritium* and *F. equiseti* were more commonly isolated from stored seed samples (Bekele and Kar, 1997). Fusarium head blight (scab) was found to cause up to 90% head blight in years with extended rainy seasons (Bekele, 1985). The average infection level with *Fusarium avenaceum, F. nivale,* and *F. poae* was 0.56%, 0.21% and 0.9%, respectively where the number of samples and average infection appeared to be relatively low. However, in earlier studies *F. avenaceum* is reported to cause up to 20% infection in wheat (Kidane, 1985). Moreover, 4.1% and 98% fusarium infection on bread and durum wheat varieties was reported, respectively, but seed samples from farmers showed less infection compared to materials from the research stations with the susceptible varieties. In nearly all cases, *Fusarium* spp. are known to cause head scab among which *Fusarium graminearum, F. avenaceum* and *F. nivale* are predominant (Wiese, 1987). It is important that some control strategies would be put in place to avoid such dangers in years with heavy rainfall where high head blight infections are expected.

In case of *Septoria nodorum* the mean infection level of 0.5% was the least compared to other pathogens. Moreover, the number of wheat seed samples infected was among the lowest (30.6%). Wheat seed samples collected from Ensaro-Wayu and Machakal districts in North Shoa and East Gojam, respectively showed no infection by septoria glume blotch. Paul *et al.* (1993) also identified no *Spetoria nodorum* from 21 wheat seed samples collected from northwestern Ethiopia except on two samples from Gondor region with infection rate of 1%. In Morocco, it was also reported that only 20% of non-certified seed was infected by *S. nodorum* with an infection level of up to 1% (Besri, 1983).

The seed health quality of wheat seed samples obtained from different sources is presented in Table 5.2. Infection by seed-borne diseases was observed across different sources, i.e., formal sector, other farmers, local traders/markets and own saved seed and appeared to be significant except for *Fusarium avenaceum*. The level of pathogen infection for seed lots from the formal sector appeared to be consistently lower than from other sources except for *F. nivale* and *F. poae.* On the other hand samples obtained from other /neighbours/farmers or traders/markets had the highest level of seed infection across the seed-borne pathogens tested except for *F. nivale*. However, it is worth to mention that 19%, 69%, 87%, 49% and 69% of the own saved seed samples (n=263) were not infected with *Drechslera sativum*, *F. avenaceum*, *F. graminearum*, *F. nivale*, *F. poae* and *Septoria nodorum*, respectively. Kidane (1985) and Eshetu and Kar (1997) reported that infection with certain *Fusarium* spp. from farmer's fields appeared to be lower than from research stations or state farms. Abdelfattah (1994) also isolated several pathogenic fungi from wheat seed samples collected from farmers throughout Jordan among which *Alternari, Fusarium, Helminthosporium* spp., etc. were most common. Mean infection with *Septoria nodorum* blotch was low for certified seed (0.1%) compared to seed obtained from other farmers (0.56%), traders (1.1%) or own saved seed (0.49%) and found to be significant (Table 5.2).

Loose Smut and Common Bunt Common bunt (*Tilletia caries* and *T. foetida)* and loose smut (*Ustilago tritici*) of wheat are spread worldwide and are associated with losses in crop production and quality. The number of samples infected and level of infection with loose smut of wheat was also low (Table 5.3). About 34 samples (11.1%; n=304) were infected and the mean infection was 0.1% ranging from 0 to 2.1% (SD=0.02). No infection was reported from certified seed, but one sample each for seed obtained from neighbours and traders and the remaining 32 samples from own saved seed were infected. All infected samples had loose smut infection in excess of the standard for any category of seed and about 38% of infected samples (n=34) had an infection level

Table 5.2. Seed health quality (% infection) of wheat seed samples from collected different sources in Ethiopia.

Seed sources	*Drechslera sativum*	*Fusarium avenaceum*	*Fusarium graminearum*	*Fusarium nivale*	*Fusarium poae*	*Septoria nodorum*
Government	1.63	0.47	1.45	0.32	0.95	0.10
Farmer/neighbours	2.47	0.52	2.03	0.09	1.34	0.56
Markets/traders	2.32	0.63	2.0	0.03	1.05	1.10
Own seed	1.80	0.57	1.55	0.22	0.86	0.49
Mean	1.85	0.56	1.58	0.21	0.90	0.50
LSD (0.05)	0.43	0.32	0.34	0.27	0.35	0.28
Significance	<0.001	0.83	0.008	0.051	0.007	<0.001

of equal or greater than 1%. Most of the infection was observed on modern bread wheat varieties (Batu, Dashen, ET 13, HAR 710, Pavon) and durum wheat local landraces (Baherseded, Shemet). Although loose smut infection was low, it was found across different regions and districts of the country. Loose smut infection has been reported previously in wheat fields in the Arsi, Gojam, and North Shoa regions (Hulluka *et al*., 1991). Moreover, an infection of 1 to 10% was also reported during diseases surveys in other regions (Hulluka *et al*., 1991). Abdelfattah (1994) found that 75.7% of wheat samples (n=346) were infected with loose smut and certified and non-certified seed had a significant difference in loose smut infection. He reported that certified seed lots had lower contamination compared to seed from informal sources where embryo infection of 0.15% and 0.56% was observed, respectively.

The number of samples infected and level of infection was extremely low particularly for common bunt of wheat (Table 5.3) and no infection was observed on certified seed. Seven (2.3%; n=304) wheat seed samples were found contaminated with *Telletia* spp. It was found that *Tilletia foetida* was predominant even on few samples that were infected which is consistent with previous reports (Yirgou, 1967).

Table 5.3. Percent infection of wheat seed samples with loose smut, common bunt and gall nematode in Ethiopia.

	Loose smut		Common bunt		Gall nematode	
Districts	Samples infected (%)	Mean infection (%)	Samples infected (%)	Spores per g of seed	Samples infected (%)	Mean infection (%)
Gedeb	12	0.08	5	5.79	17	1.02
Munesa	23	0.25	0	-	18	0.93
Hetosa	4	0.05	2	0.52	23	1.48
Dodota	7	0.07	0	-	3	0.17
Dendi	13	0.10	7	54.6	7	0.29
Chelia	11	0.09	0	-	0	-
Ensaro Wayu	13	0.10	5	5.46	3	0.16
Hulet Iju	12	0.19	0	-	0	-
Machakal	21	0.09	0	-	0	-
Total (% infection)	11		2		9	
Mean infection		0.10		7.1		0.50
Minimum infection		0		0		0
Maximum infection		2.10		1400		13.50
SD		0.3		83.1		1.8

Three wheat seed samples from Arsi, two each from West Shoa and North Shoa were found to have bunt contamination whereas no sample was infected from East Gojam. The average spore count per g of seed ranged from 25 to 1400 spores (SD=83). Infection was observed only on Dashen, an obsolete modern variety in the Arsi region, and on local durum wheat varieties in West and North Shoa region. The highest mean spore load was observed on a local variety known as Baghede with an average of 1400 spores per 1 g of seed. In comparison to previous surveys conducted in the country the number and level of contamination was surprisingly very low. Paul *et al.* (1994) also found that most of the wheat seed samples from northwestern Ethiopia contained bunted grains. Kidane (1985) reported that the number of spores found per seed was 49, 1623 and 1554 from wheat seed samples collected in Arsi, West Shoa and Gojam regions, respectively. Neimann *et al.* (1980) also documented the occurrence and distribution of common bunt of wheat throughout the highlands of Ethiopia. They reported that 81% of the samples were infected and up to 10% of seed samples collected were found to have high spore contamination and estimated a yield loss of 5% due to common bunt nationwide. Neimann *et al.* (1980) concluded that under favourable environmental conditions a natural bunt contamination of 100 spores per sample (approx. 100 m/100 g seeds) could cause 70% or more infection whereas under unfavourable conditions up to 1000 spores/sample may be required. Besri (1983) reported that bunt contamination with 500 and 1500 spores/seed resulted in 0.5% and 21% infection in hard wheat in Morocco depending on the environmental condition and susceptibility of the variety.

Wheat Gall Nematode Wheat gall nematode (*Anguina tritici*) is one of the most important seed-borne diseases in Ethiopia. Similar to bunt and loose smut, the infection of gall nematode was low in terms of number of samples infected and level of infection (Table 5.3). Only 26 (8.6%; n=304) wheat seed samples were found to be infected with a mean nematode gall count of 0.5 per 50 g of seed (with a range of 0 to 13.5). All samples infected were from the informal sources except one sample of certified seed. From 26 wheat seed samples infected with gall nematode 89% of samples were from the Arsi region. Earlier plant disease surveys also found high level of infection of wheat seed by gall nematode in the same region or elsewhere in the country (Hulluka *et al.*, 1991). Infection of gall nematode was observed both on modern bread wheat varieties (Batu, ET 13, HAR 710, Pavon) and local durum landraces (Gotoro). Infection was reported across different regions and districts of the country.

The likely explanation for low occurrence of common bunt, loose smut and gall nematode in wheat could be attributed to the environmental conditions under which the crops were grown prior to the survey year which may have influenced disease infection. Moreover, the wide spread use of modern commercial varieties with some tolerance to these diseases might have contributed to this, although there is some evidence to suggest that the modern varieties were also found to be susceptible to common bunt (Bekele, 1985) and other seed-borne diseases. In Scotland, for example, Rennie *et al.* (1983) indicated that in a disease survey over three years period some seed-borne pathogens occur less frequently in different years. Therefore, the low number of wheat seed samples found infected with some seed-borne diseases does not seem to suggest the absence of the pathogens and requires periodic surveys and monitoring of the diseases.

Saprophytic Fungi Several saprophytic fungi were also recovered during the seed health testing, including *Alternaria* spp., *Aspergillus* spp., *Cladosporium* spp., *Curvularia* spp., *Mucor* spp., *Nigrospora* spp., *Penicillium* spp. and *Trichothecium* spp. which were found from samples across the regions. Khanzada and Jamilkhan (1987) also isolated such pathogens from seed in Pakistan. Some of these species are pathogenic and may drastically reduce germination percentage or cause seed rots or seedling infections while others are non-pathogenic. Tadesse *et al.* (1992) isolated 15 fungi associated with black point on durum wheat among which the predominant ones were *Alternaria tenuis* and *A. tenuissima.* Infection with black point (*Alternaria, Fusarium*, and *Helminthosporium* spp.) starts before harvest and increases if grain is stored under moist or wet conditions and this also favours the development of storage molds (Wiese, 1987). Chemical treatment of harvested seed can improve germination and decrease infection of seedlings grown from diseased seeds. Paul *et al.* (1994) reported that *Alternaria*, *Cladosporium*, *Curvularia*, *Fusarium* and *Penicillium* were found to reduce root and shoot length. Abdelfattah (1994) also isolated saprophytic fungi (*Aspergillus*, *Cladosporium, Penicillium, Rhizopus*) from wheat seed samples collected throughout Jordan. In sorghum seed collected from farmers it was reported that the incidence of most prevalent fungi ranged from 12% to 25% and the percentage infection per seed sample was estimated to average 8% (0% to 26%) (Ndjeunga, 2002). But none of the fungi identified poses or serious threat to germination as all of them were contaminants or non-pathogenic.

Seed-borne diseases are major crop production constraints in terms of reducing wheat crop yield (Gebremariam *et al*., 1991b; Bekele, 1985). Hulluka *et al.* (1991) and Bekele (1985) cited from earlier sources the presence of bunt (*Tilletia caries* and *T. foetida*), loose smut (*Ustilago tritici*), glume blotch (*Septoria nodorum*), scab or head blight (*Fusarium graminearum, F. longipes, F. semitectum*), *F. dimerum,* Barley Yellow Dwarf Virus (BYDV) and gall nematode (*Anguina tritici*). An extensive disease survey in central and southeastern wheat production areas found *Septoria* and *Helminthosporium* spp. widely distributed but at low to moderate levels whereas fusarium head scab was reported as a serious problem in southeastern (Arsi and Bale) regions (Gebeyehu *et al.*, 1990). Fusarium head blight was identified as a major threat to wheat production in Ethiopia under high rainfall conditions that are favourable to the disease development (Bekele and Karr, 1997). Moreover, several saprophytic fungi such as *Alternaria* spp., *Cladosporium* spp., *Helminthosporium* spp. and *Phoma* spp. were also isolated from wheat seeds. Paul *et al.* (1994) and Tadesse *et al.* (1992) identified 32 and 15 seed-borne fungal mycoflora associated with wheat seed in north western and experimental station in the central highlands of Ethiopia. Moreover, Hulluka *et al.* (1991) reported that 15 fungal species were isolated from wheat seed collected from farmers and experimental stations in central Ethiopia among which the genera of *Alternaria*, *Helminthosporium*, *Fusarium*, and *Phoma* are predominant. The results of seed health tests confirm earlier reports of disease situations in the country.

Simple correlation coefficient was calculated to quantify the association between seed-borne infection and other seed quality factors such as germination, abnormal seedlings and dead seeds (Table 5.4). Significant negative correlation (P<0.01) was observed between standard germination and infection with seed-borne pathogens such as *Drechslera sativum, Fusarium graminearum* and *Septoria nodorum* while on the other hand weak positive association was observed between abnormal and dead seeds and infection with these pathogens. Seeds associated with *D. sativus* either failed to

Table 5.4. Simple correlation coefficients between germination, vigour and health quality and field emergence of wheat seed in Ethiopia.

Laboratory tests and field emergence	DS	FA	FG	FN	FP	SN	LS	AT
Standard germination	–0.25**	–0.04	–0.20**	0.09	–0.04	–0.17**	0.03	–0.08
Abnormal seedlings	0.17**	0.01	0.18**	–0.07	0.01	0.18**	–0.03	0.08
Dead seeds	0.28**	0.06	0.19**	–0.09	0.06	0.13**	–0.02	0.08
Speed of germination	–0.18**	–0.02	–0.12**	0.12**	–0.06	–0.17**	0.03	–0.03
Seedling shoot length	0.06	–0.02	0.09	–0.04	0.11	–0.09	–0.02	–0.16
Seed ling root length	–0.19	–0.03	–0.15	–0.03	–0.11	–0.12	–0.01	–0.04
Seedling dry weight	–0.13	–0.15	0.05	–0.13	–0.09	0.02	–0.01	–0.01*
Field emergence	–0.38**	–0.09	–0.32**	0.01	–0.35**	–0.27**	0.12	–0.01

*, ** Significant at P<0.05 level and P<0.01, respectively. [1] DS=*Drechslera sativum;* FA=*Fusarium avenaceum*; FG=*Fusarium graminearum*; FN= *Fusarium nivale*; FP=*Fusarium poae;* SN=*Septoria nodorum*; LS=loose smut; AT=*Anguina tritici*.

germinate or produced abnormal seedlings (Paul *et al*., 1994). Infection with *S. nodorum* was also reported to be significantly associated with reductions in thousand seed weight in years with high disease incidence (Shah *et al*., 2002). According to Paul *et al*. (1994), except *Aspergillus* spp. and *Fusarium moniliforme*, all fungi isolated from wheat reduced root and shoot length. *Fusarium avenaceum*, and *F. poae* and *Anguina tritici* showed a negative correlation with standard germination and a positive correlation with abnormal seedlings and dead seeds, but neither of the two associations was significant. Similar results were also reported from Ethiopia where *Fusarium* and *Penicillium* spp. were positively correlated with ungerminated seed and abnormal seedlings and negatively correlated with germination percentage (Paul *et al.*, 1994). Tadesse *et al.* (1992) also found that black point infection was positively correlated with abnormal seedlings and dead seeds, but showed negative correlation with germination in durum wheat. However, they reported that only correlation with normal germination was significant compared to other parameters. It is evident that wheat seed samples infected with seed-borne pathogens have relatively lower germination and increased abnormal seedlings and dead seeds.

Table 5.4 also presents simple correlation coefficients between seed and seedling vigour and seed-borne infection in wheat samples and field emergence. Significant negative correlation was observed between speed of germination and infection with *Drechslera sativum, Fusarium graminearum* and *Septoria nodorum.* Moreover, significant negative association was also observed between field emergence and seed infection with these three pathogens showing the negative effect of seed-borne diseases on field emergence. Rennie *et al*. (1983) reported that *Septoria nodorum* affects germination and seedling emergence. It was observed that, however, no significant association was found between seedling shoot length and seedling root length. On the contrary, Tadesse *et al.* (1992) and Paul *et al.* (1994) found significant reduction in seed and seedling vigour such as shoot and root length due to black point infection and other fungal pathogens isolated from wheat seed.

In Ethiopia, plant pathology research was started in the 1930s (Bekele, 1985). In the late 1960s the index of plant diseases was published (Stewart and Yirgou, 1967). At present considerable progress has been made in terms of general pathological research and disease surveys (Gebeyehu *et al*., 1990; Hulluka *et al.*, 1991). However, seed pathology and seed health research are still sporadic. The first seed health testing station was started by IAR in 1973 as part of quarantine measures for germplasm exchange (Kidane, 1985). There is neither basic epidemiological research nor are systematic yield loss assessment studies conducted on seed-borne diseases. A very limited number of studies were conducted to screen seed treatment chemicals and their efficacy under laboratory and greenhouse conditions. The results identified a number of seed treatment chemicals (Vincit 200, Panoctin 200 and Vitaflo 250, Vitavax, Prochlorazand sportak Delta) as satisfactory against *Fusarium, Septoria, Heminthosporium* and *Tilletia* spp. (Hulluka *et al.,* 1991). Moreover, control of common bunt and the profitability of chemical seed treatment had been demonstrated at the farm level in Arsi and Shoa region of Ethiopia (Bekele, 1985). However, the use of seed treatment was never introduced to the small-scale peasant sector except for large-scale government owned state farms due to limited availability of the chemicals.

Farmers' Perception of Plant and/or Seed Health Quality During the field interviews, farmers identified plant diseases as major constraints for wheat crop production. About 77% of the farmers (n=304) across the region indicated rusts as major threat compared to only 7.4% for smuts. It is worth to note that farmers had long experience with periodic outbreak of rust epidemics with devastating consequences particularly in the Arsi region where modern bread wheat varieties are widely adopted and grown. In contrast few farmers perceive seed-borne diseases such as bunts, smuts and gall nematodes as important which could be attributed to their low level occurrence, difficulty to recognize the diseases or consider the losses incurred insignificant in crop production. For example, although several fungi were isolated from wheat seed samples collected from northwestern Ethiopia in the previous studies the level of infection was comparatively low. In this study, the seed health testing results also revealed that only 11.2% and 8.6% of the samples were infected with loose smut and gall nematode and in very low proportion although the occurrence is reported across the regions. Moreover, the level of infection with *Dreschlera sativum, Septoria nodorum* and *Fusarium* spp. appeared to be low for farmers to detect the impact of these seed-borne diseases. It is important that further detailed studies carried out to substantiate these findings as these are outside the scope of the current research.

5.4.2. Wheat and Barley Seed Health in Syria

The Syrian national programme prescribed seed health quality guidelines for production of certified seed of wheat and barley. For certified seed 2, the field standard allows one bunt or loose smut infected plant per 1000 plants (0.1%) during crop seed inspection and 20 bunt balls per 1 kg of seed for visual inspection during seed testing (ICARDA, 2002). Moreover, the list of quarantine pests has been issued under the plant quarantine regulations for import of germplasm and seed (El-Ahmed, 1999). It is anticipated that any certified seed second generation beyond this infection level is rejected for seed use. The implementation of these guidelines, however, is rather limited due to lack of properly trained manpower and adequate facilities. It is worth to note that almost all barley seed during the 1997/98 crop season and the majority of wheat seed planted in 1998/99 crop season were obtained from informal sources.

Loose Smuts of Wheat and Barley Wheat and barley seed samples collected from different zones, regions and districts showed significant differences (P<0.001) in seed health quality (Table 5.5), except for loose smut of wheat from different agro-climatic zones. In wheat, 86.4% of samples were found free of loose smut infection. Wheat samples from Zone 1 had relatively higher infection rate (0.85%) compared to samples from Zone 2 (0.76%), although it was not statistically significant. Moreover, 61% of samples (n=28) from Zone 1 were infected with loose smut whereas the reminder was from Zone 2 showing the association between rainfall and disease infection. Kashyap and Duhan (1994) also found that the incidence of karnal bunt, loose smut and black point were greater in humid than in dry zones of Haryana state in India. Most samples from the humid zones failed to meet the certification requirement due to loose smut (70.8%) and karnal bunt (25.5%) infection whereas seed from drier areas had slightly less rejection levels (Kashyap and Duhan, 1994).

It appeared that all infections with loose smut of wheat (*Ustilago tritici*) are localized and found on seed samples from Hasakeh and Khamishli districts with overall average infection of 0.79%. In Hasakeh, 28.2% (n=39) of samples were infected with loose smut with a mean infection rate of 2.65%. Meanwhile in Khamishli the number of samples infected and mean infection rate was 56.7 % (n=30) and 1.95%,

Table 5.5. Seed health quality (% infection) of wheat and barley seed samples collected from different districts in Syria.

Loose smut of wheat			Loose smut of barley		
Districts	Samples infected (%)	Mean infection (%)	Districts	Samples infected (%)	Mean infection (%)
Azaz	0	0	Ain El-Arab	98	42.6
Sema'an	0	0	Manbeji	97	20.6
			Al-Bab	88	25.4
			Raqqa	100	14.7
Tel Abiad	0	0	Tel Abiad	75	4.8
Khamishli	57	1.95	Khamishli	91	6.1
Hasakeh	28	2.65	Hasakeh	52	2.4
Ras Al-Ain	0	0	Ras Al-Ain	67	3.9
Mean		0.79	Mean		17.9
LSD (0.05)		1.20	LSD (0.05)		11.0
Significance		<0.001	Significance		<0.001

respectively. In both cases the level of infection was more than most national standards prescribed for certified seed second generation in WANA region (ICARDA, 2002). Mamluk *et al.* (1990) reported sporadic incidence of loose smut in wheat production fields, in Zone 1, Zone 2 and irrigated areas of Syria with records not exceeding 5% of plants examined. The results are in agreement with our findings where low numbers of samples were found infected with loose smut. Moreover, they also reported less frequent diseases such as *Septoria nodorum* which were not identified during the wheat seed health tests.

On the other hand, 83% of barley seed samples were infected with loose smut (*Ustilago nuda*) with an average infection rate of 17.9% The infection was found to be significant ($P<0.001$) among seed samples collected from different agro-climatic zones and regions. The average level of infection was found to be 24.2%, 14% and 8.5% in Zone 2, Zone 3 and Zone 4, respectively where over 75% of the samples were infected across all zones (75% to 90% of the samples). The level of infection showed decreasing trend along low moisture regimes. At district level samples from Ain El-Arab had the highest infection level (42.6%) followed by samples from Al-Bab (25.4%) and Manbeji (20.6%). In low input agriculture where barley is the main crop, most of the farmers still do not use certified seed and/or chemical treatment for every planting season (Mamluk, 1991) which might have contributed to such a high level loose smut infection.

The seed health quality of wheat and barley seed obtained from different sources is presented in Table 5.6. The frequency and intensity of loose smut infection in wheat appeared to be low and not significantly different among different sources. About 10% to 15% of the samples were infected from different sources. The lowest average infection was observed from own saved (0.14%) and followed by seed from the formal sector (0.22%). The wide spread use of chemical treatment both in the formal and informal sector on wheat seed used for planting could possibly contribute to such low number and level of smut infection. Mamluk *et al*. (1990) reported sporadic occurrence of loose smut of wheat with a maximum of up to 5% infection in the field. Loose smut of wheat was also observed on wheat wild relatives *Aegilops* in Syria (Mamluk *et al.*, 1992). The difference in loose smut infection between certified and non-certified wheat seed was also observed in Morocco (Besri, 1983), Scotland (Rennie *et al*., 1983) and Jordan (Abdelfattah, 1994). In Morocco, almost one third of the certified (31.3%; n=32) and non-certified (33.4%; n=21) wheat seed samples were infected with loose smut and both had high level of infection in excess of the standard indicating the inefficiency of the certification scheme (Besri, 1983). In Jordan, certified (61.5%; n=109) and non-certified seed (82.3%; n=237) were also infected with loose smut of wheat (Abdelfattah, 1994). The reports from Jordan and Morocco

Table 5.6. Seed health quality of wheat and barley seed obtained from different sources in Syria.

Seed sources	Loose smut of wheat		Loose smut of barley	
	Samples infected (%)	Mean infection (%)	Samples infected (%)	Mean infection (%)
Government	11.1	0.22	-	-
Farmers	14.8	0.52	81.8	19.5
Traders	14.3	1.08	92.3	18.0
Own saved	14.2	0.14	82.4	17.7
Total	13.6		83	
Mean		0.79		17.9
LSD (0.05)		1.98		13
Significance		0.22		0.94

show the ineffectiveness of national seed certification scheme in combating the threat of seed-borne diseases.

We found that infection with loose smut of barley was almost the same among seed obtained from different sources in the informal sector with mean infection level of 17.9%. In our result 83% of the samples had more than 0.5% infection with loose smut of barley. In Morocco, 55.6% of certified and 75% of non-certified seed were infected with loose smut of barley; and seed both from the formal and the informal sources had higher level of infection. About 33.3% of certified seed and 50% of non-certified seed had over 0.4% infection of loose smut of barley where the certification scheme was found ineffective in reducing the infection of loose smut. On the other hand Rennie *et al.* (1983) reported low infection of loose smut of barley in certified seed, but infection of up to 2% in farm saved seed in Scotland showing the effectiveness of seed certification scheme.

Taking into consideration some seed health standards for loose smut of wheat and barley suggested by the national certification schemes across the WANA region (ICARDA, 2002), the results of the wheat and barley seed samples would yield an interesting comparison. Although most countries had no seed health certification standards, few countries has established standards as strict as allowing a maximum of 0.05% seed infection whereas others still allow 0.2% infection for certified seed second generation. If seed health standards for both wheat and barley are relaxed to allow the highest level of infection at 0.2%, none of the loose smut infected wheat and barley seed samples could meet the standards except those with zero infection.

Common Bunt of Wheat and Covered Smut of Barley The Seed Health Laboratory of ICARDA is responsible for testing large numbers of outgoing and incoming germplasm materials at the International Center for Agricultural Research in Dry Areas (El-Ahmed, 1999). The Seed Health Laboratory has set its internal procedures and standards to detect exceptionally low levels of infection particularly for pathogens of quarantine significance in Syria or for collaborating national agricultural research systems in respective countries of its mandate region or beyond. Accordingly, zero contamination with covered smut (*Ustilago hordei*), flag smut (*Urocystis agropyri*), dwarf bunt (*Tilletia controversa*), karnal bunt (*Neovossia indica*) and 5 teliospores sample^{-1} for common bunt (*Tilletia caries* and *T. foetida*) were allowed during washing tests (with 400 seeds, i.e., 4 replicates of 100 seeds) based on Syrian quarantine regulation. Therefore, contamination with covered smut and common bunt was evaluated on these criteria and no quantitative spore count was made per seed in Syria and any interpretation of the results are within these limitations.

From 206 wheat seed samples 68% were found contaminated with common bunt spores (*Tilletia caries* and/or *T. foetida*) across different regions, districts and sources. The average count per sample analysed was 12 spores (SD=19) if samples with extremely high spore count were removed. Wheat seed samples with zero, 1 to 5 spores, 6 to 10 spores, 11 to 50 spores or 51 to 100 spores sample^{-1} accounted for 32%, 14%, 13%, 23%, 5% of the total number of samples, respectively. There was no difference on the number of samples contaminated between samples collected from Zone 1 or Zone 2 where only 30% each were free from contamination. At district levels samples from Azaz and Jebel Saman had the highest percentage of samples with no contamination whereas 70% to 80% of samples from Ras Al-Ain in Hasakeh province were contaminated with common bunt spores. From the total wheat seed samples about 12.6% had extremely high proportion of common bunt contamination.

Mamulk *et al.* (1990) stated that common bunt is one of the most widespread seed-borne diseases in Zone 1, Zone 2 and irrigated areas (in more than 50% of the fields surveyed) and represents a threat to wheat production partly associated with mechanical harvesting and use of susceptible cultivars. During field surveys common bunt with a severity of up to 60% and an estimated yield loss of 5-7% was reported (Mamulk, 1991). They also found that the most severely affected regions were in Hasakeh and Khamishli confirming our findings. Yarham and McKowen (1989) reported that *Tilletia tritici* spores released at harvest from an infected crop serve as a potential source of infection in adjacent fields where healthy wheat seed was planted. In a field experiment it was also found that common bunt spores were found to travel up to 1000 m from source of heavily infected fields (http://www.hgca.com). The evidence suggests a long distance common bunt contamination where it is necessary to follow appropriate practises to produce healthy seed crop.

The proportion of samples with no common bunt contamination was 42% for seed from the formal sector compared to samples from the informal sector where only 25% to 30% of seed from other farmers, traders or own saved seed has zero contamination. There was a significant difference in the number of spores per sample between the different sources. With the tolerance level of 5 spores per samples about 46% of samples are considered meeting the requirement for bunt contamination and if this increases to 10 spores per sample 59% of the wheat seed samples are within the tolerance level. However, it should be noted that both certified and non-certified seed has spores in excess of these tolerance levels. Besri (1983) also found similar results where certified seed has the lowest common bunt spores contamination compared to non-certified seed. Abdelfattah (1994) reported that 20% of wheat seed samples (n=346) were contaminated with common bunt spores where 18.3% (n=20) and 55.3% (n=131) certified and non-certified seed, respectively had bunt contamination. Moreover, there was a significant difference between certified and non-certified seed with average of 150 and 1830 spores per seed, respectively. He also found significant correlation between the number of teliospores per seed and the incidence of common bunt disease development in pot experiments. Earlier studies suggest that seed lots with 4 to 20 spores per seed should be treated with chemicals whereas lots with more than 20 spores per seed should be rejected (Neergarad, 1977). In some European countries, current threshold levels recommend seed treatment if 1 or more spores per seed were found with common bunt (*Tilletia caries*) contamination.

The large number of fungal sori during visual inspection of barley seed samples revealed the presence and wide spread contamination with covered smut (*Ustilago hordei*). Qualitative data shows that 85% (n=200) of seed samples had covered smut contamination where all samples (100%) from Aleppo and Raqqa had the contamination irrespective of the agro-climatic zones. A limited number of samples were found free of covered smut (15%; n=200) mainly from Zone 3 and Zone 4 in Hasakeh (21 from 33 samples) and Ras Al-Ain (9 from 15 samples) districts both from the Hasakeh province. The majority of the seed obtained from informal sources were contaminated with covered smut of barley. However, from the 30 samples which were not contaminated, 87% were from own saved seed. In Morocco, (Besri, 1983) found that all non-certified seed (100%) were contaminated with covered smut and had high numbers of covered smut spores compared to only 38% of samples for certified seed which had also low spore contamination. Although losses from covered smut of barley are rare where seed treatment is practised, economic losses are still high where farmers do not use treated seed such as in the Middle East (Mathre, 1987; Mamluk, 1991). The frequency of contamination, however, showed a wide spread problem and continued threat of covered smut in barley production in Syria.

Flag smut (*Urocystis agropyri)* has been identified from 11 barley seed samples (5.5%; n=200), i.e., five from Raqqa and six from Hasakeh provinces. The presence of flag smut was reported earlier on barley (Azmeh and Kousaji, 1982) and on wheat (Mamluk *et al.*, 1990) in Syria. Since then the presence of flag smut was not reported on the barley crop and inoculation of flag smut spore isolates from weeds did not produce any infection on cultivated barley which requires further investigations (Ahmed El-Ahmed, personal communication). Mamluk *et al.* (1990) reported, however, flag smut attack on modern varieties and local landraces of wheat and their wild relatives *Aegilops crassa* and indicated the teliospore similarity of the pathogens isolated from wild relatives and cultivated wheat. Contamination with common bunt (*Tilletia caries* and *T. foetida*) of wheat was also observed on at least 5% of barley seed samples. However, the contamination of common bunt on barley seeds could be attributed to mechanical harvesting where farmers are using the same machinery for both crops and contamination coming from adjacent wheat crops during harvesting period.

Fusarium spp. and *Helminthosporium* spp. have been isolated from four (2%, i.e., one in Aleppo and three in Al-Raqqa) and two (1%, i.e., one each in Aleppo and Hasakeh) barley seed samples (n=200), respectively, with very negligible infection levels (<0.75%). The fungal species identified are mainly associated with barley black point in irrigated areas (Ahmed El-Ahmed, personal communication). The number and level of infection are not high given the low number of farmers using irrigation for barley production.

Table 5.7 presents a simple correlation coefficient between physiological quality and health quality of wheat and barley seed in Syria. Loose smut infection showed very weak positive correlation with germination percentage and very weak negative correlation with abnormal seedlings and dead seeds. Moreover, the correlation of loose smut infection was neither significant with germination percentage nor with abnormal seedlings. Similarly, loose smut infection did not show any significant relationship with any vigour tests and field emergence.

In barley the situation was different where loose smut infection showed negative correlation with germination percentage, but positive correlation with abnormal seedlings and dead seeds during the germination tests and both correlations were significant at $P<0.01$. Similar results were obtained as in wheat where loose smut infection did not correlate with seed vigour or seedling emergence in the field except for root length. Mathre (1987) indicated that loose smut infected barley seed is fully germinable without visible alteration on seedling morphology.

Several wheat and barley seed-borne diseases were reported from Syria. Accordingly, common bunt (*Tilletia caries* and *T. foetida*), loose smut (*Ustilago tritici)*, flag

Table 5.7. Simple correlation coefficient between germination, vigour and health quality and field emergence of wheat and barley seed in Syria.

Laboratory tests and emergence	Loose smut of wheat	Loose smut of barley
Standard germination	0.0	–0.25**
Abnormal seedlings	–0.02	0.25**
Dead seeds	0.01	0.21**
Speed of germination	0.07	–0.05
Shoot length	–0.06	0.12
Root length	0.05	0.17*
Seedling dry weight	–0.01	0.05
Field emergence	0.13	–0.02

*, ** Significant at P<0.05 level and P<0.01, respectively.

smut (*Urocystis agropyri*), *Septoria* spp. (*Septoria nodorum* and *S. passarini*) of wheat; and covered smut (*U. hordei*), loose smut (*U. nuda*), barley leaf stripe (*Pyrenophora graminea*), flag smut (*Urocystis agropyri*), net blotch (*Pyrenophora teres*), and scald (*Rhynchosporium secalis*) of barley are prevalent in Syria (Mamluk *et al*., 1990; Mamluk, 1991; Mamluk *et al*., 1992; El-Ahmed, 1999). Bacterial leaf streak, (*Xanthomonas campestris* pv. *translucens*, bacterial leaf blight (*Pseudomonas syringae* pv. *syringae*), barley stripe mosaic virus (BSMV) and seed gall nematode (*Anguina tritici*) were also reported from Syria and the region. In Syria, for example, Mamuluk *et al*. (1990) indicated that in a four year disease survey some of the pathogens occurred less frequently than others including seed-borne diseases. Despite such a long list of pathogens no serious attempt has been made in addressing the problems of seed-borne diseases through concerted research, neither through breeding varieties for disease resistance nor through developing appropriate technologies for disease control. However, resistance against seed-borne diseases has been reported from local landraces or wild relatives of wheat (Mamluk, 1991). Apart from occasional disease surveys no systematic or methodological studies were conducted in epidemiology and the impact on economic losses incurred by seed-borne diseases in Syria. Moreover, the use of seed dressing chemicals was reported in general terms rather than in detailed field studies (Mamluk, 1991) on their efficacy of disease control. There is a general lack of information with regard to on-farm seed health management practices. In general seed pathology remained at the edge of plant pathological research in terms of resource allocation and expertise.

Farmers' Perception of Plant and/or Seed Health Quality From a total number of wheat seed growers, 67 (32.5%; n=206) considered plant diseases as a major constraint for wheat production. About 56.7%, 8.9% and 2.9% indicated smuts, black point and nematodes as important diseases which are considered seed-borne. In our survey, no test has been made for wheat seed gall nematode owing to the availability of another detailed survey conducted during the same period in Aleppo and Raqqa provinces. The survey found significant differences between different wheat species (bread and durum wheat), agro-climatic zones (Zones 1 and 2), provinces, irrigated and non-irrigated crops, rotated and non-rotated fields, spikes and grains and years (Ismail *et al.,* 2000). An infection of up to 60% of the fields and 2% of the seed samples collected from grain purchasing centres or from farmers was reported.

In barley, 17% and 26% of farmers (n=206) mentioned smuts and *Abua Elawi* as important disease problems encountered for crop production. From 52 farmers who reported the problem of *Abu Elawi* 42 farmers were from Ain Al-Arab, Manbeji and Al-Bab districts of the Aleppo province, although the problem was also reported from Tel Abiad and Hasakeh districts. In 1996, field surveys confirmed the wide spread problem of head sterility in barley fields and found correlation between head sterility and the presence of gall nematode in the same districts in northern Syria (Khatib *et al.,* 2000). The same authors have reported an average incidence of 23.4% and estimated average yield loss of 11.2% in Al-Bab, Manbeji, etc., areas of northern Syria.

In Syria, wheat and barley seed samples collected from different regions and districts showed significant variation in seed health quality. The frequency (number of samples infected) and intensity (level of infection) of wheat and barley seed samples from different regions and sources were remarkably different. First, the majority of barley seed samples (n=200) were contaminated with covered smut (85%) and infected with loose smut (83%). On the other hand from 206 wheat samples 68% had bunt contamination and only 13.6% had loose smut infection. In both cases, wheat seed samples had the lowest number of samples infected compared to barley. Second, in wheat loose smut infection was observed from the Hasakeh province (Hasakeh and Khamishli) whereas barley loose smut infection was observed throughout the three regions with the highest infection in Aleppo province. Third, in both wheat and barley crops seed samples from wetter zones had relatively higher infection rate compared to samples from drier areas and this was significant for barley loose smut infection. Fourth, farmers perceived that the problem of smut infection was considered less for wheat compared to that for barley confirming that their perception of disease diagnosis as observed in the field was well matched with actual constraints as identified through seed health quality tests. Fifth, farmers applied better management practices for wheat seed compared to barley seed where almost all farmers who used own saved seed applied chemical seed treatment compared to 6.5% in barely. In low input agriculture where barley is used as a sole crop most farmers still do not use certified and/or treated seed for every planting season (Mamluk, 1991). Sixth, although chemical seed treatment was widely used for wheat there was still a continuous threat from common bunt contamination which could be associated with lack of appropriate chemicals and wide spread use of mechanical harvesting. It is worth mentioning that the majority of farmers from whom the wheat and barley seed samples were collected grew both crops. In Chapter 4, we found that the physical and physiological quality of wheat appeared to be relatively better than of barley seed used for planting. Therefore, a similar conclusion can be drawn on the seed health quality of wheat and barley seed in Syria. The seed health quality of both certified seed from the formal sector and non-certified seed from the informal sources is cause of concern in crop production.

5.4.3. Farmers' Seed Management and Seed Health Quality

As stated in previous chapters farmers employed different seed management practices to ensure the quality of their seed for planting purposes (Table 5.8). The most important seed management factors with profound effect on seed health quality were harvesting methods, seed cleaning, seed treatment and seed storage. In Ethiopia,

Table 5.8. Farmers' seed management and seed health quality (% infection) of wheat seed in Ethiopia.

Farmer's seed management	Number of samples	DS[1]	FA	FG	FN	FP	SN	LS	AT
Hand harvesting	204	1.4	0.38	1.14	0.17	0.63	0.30	0.11	0.21
Machine harvesting	59	2.47	0.92	2.10	0.19	1.05	0.86	0.09	1.66
No seed selection	88	1.59	0.51	1.33	0.13	0.7	0.36	0.11	0.19
Seed selection	175	1.63	0.50	1.37	0.2	0.74	0.46	0.10	0.71
No seed cleaning	30	1.13	0.3	0.93	0.27	0.8	0.27	0.08	0.37
Seed cleaning	233	1.68	0.53	1.41	0.16	0.72	0.45	0.11	0.56
No seed treatment	253	1.62	0.49	1.37	0.18	0.73	0.44	0.09	0.56
Seed treatment	10	1.50	0.70	0.90	0.10	0.7	0.10	0.29	0
Not check germination	169	1.64	0.55	1.34	0.17	0.75	0.38	0.12	0.57
Check germination	94	1.59	0.41	1.38	0.19	0.68	0.51	0.09	0.48
Not store separate	103	1.64	0.47	1.44	0.14	0.74	0.39	0.08	0.32
Store seed separate	160	1.61	0.53	1.30	0.20	0.72	0.45	0.12	0.68

[1] DS=*Drechslera sativum;* FA=*Fusarium avenaceum;* FG=*Fusarium graminearum;* FN=*Fusarium nivale;* FP=*Fusarium poae;* SN=*Septoria nodorum*; LS=loose smut; AT=*Anguina tritici*.

analysis of variance among farmers' seed management practices such as harvesting methods, seed selection, seed cleaning, separate storage showed that only the harvesting method has significant effect on germination and infection with seed-borne pathogens. Harvesting methods may predispose the seed to mechanical damage, chemical seed treatment injury and later to fungal invasion or insect infestation during seed storage. Machine harvested seed consistently gave the highest infection across different seed-borne diseases identified indicating the contribution of mechanical damage to disease infection. Lakhdar *et al.* (1998) found that mechanically damaged seed had lowest germination and increased fungal infection in durum wheat in Algeria. On the contrary other seed management practices did not significantly differ in the level of disease infection or contamination. However, selected, cleaned and treated seed had a lower number of samples infected or contaminated compared to samples not selected, cleaned or treated.

Farmers who practise selection either on standing crops or grain use visual observations in deciding which crop or grain to put aside for seed for planting purposes. They can easily discard standing crops severely attacked by diseases in the field or seeds shrivelled due to pathogenic infection in the field or infected with storage fungi or seeds infested with storage insects if the damage is clearly and relatively visible. However, it would be less likely for farmers to have sufficient knowledge in identifying some seed-borne pathogens associated with the seed either in the field or in harvested grain which require special skill and expertise. Therefore, it would not be surprising to observe less effect of selection on disease infection. Farmers' knowledge in producing healthy seed is limited. It was reported that only 7% of farmers practised roguing diseased plants in bean fields in Uganda (Grisley, 1993) and few farmers practised selecting diseases free potato tubers for seed in the Andes (Thiele, 1999).

During seed cleaning impurities such as inert matter, weeds, broken seeds and small seeds are removed. Apart from screening impurities cleaning also appeared to improve health quality by removing shrivelled seeds heavily infested with seed-borne fungi, particularly if infection occurred during crop maturity. Cleaning wheat seed lots infected with varying levels of *Fusarium* spp. using a gravity table had improved the germination (74% to 88%) and decreased the proportion of infected and shrivelled seeds (Gutormson *et al.*, 1993). The use of fungicide treatment improved the seed quality of both the original sample and cleaned seed fractions. However, the results from Ethiopia and Syria appear to be inconsistent for different pathogens. While in some wheat and barley seed lots cleaned seed appeared to have a low level of infection in others un-cleaned seed appeared to have high quality once again demonstrating the inefficiency of the traditional cleaning practices used by farmers and differences among individual farmers. The storage environment has an effect on physiological and health quality particularly if seed is stored under high relative humidity, moisture content or temperature which encourages infection with quality reducing storage fungi or storage insect pests. Kashyap and Duhan (1994) found that insect damage on wheat seed embryo substantially reduced germination and seedling vigour with subsequent increase in abnormal or dead seeds. In Ethiopia, infection with *Drechslera* and *Fusarium* species did not differ for seed stored separate under different traditional storage facilities such as polypropylene bags, jute bags, *gotera*, *gota*, etc. However, several saprophytic fungi were isolated from wheat seed collected from farmers although its association with traditional storage facilities is not determined. In Syria, there was no significant difference in mean infection or contamination between wheat and barley seed lots selected, cleaned, treated and stored separately although the number of samples from better managed seed lots showed less number of samples infected (Table 5.9). It is also believed that the wide spread use of mechanical harvesting contributed to covered smut and bunt contamination although the differences were presented qualitatively. However, harvesting methods ($P<0.001$) among seed samples for loose smut of barley (0.53% vs 1.14%) and storage practices ($P<0.05$) for loose smut of wheat (2.28% vs 0.38%) showed significant differences. Wheat and barley loose smut are exclusively seed transmitted and infection could occur in the field before harvest and it is difficult to ascertain the probable causes of the differences observed. The results on seed management practices did agree well with previous results on physical and

Table 5.9. Farmers' seed management and health quality (% infection) of wheat and barley seed in Syria.

Farmers' seed management	Loose smut of wheat		Loose smut of barley	
	No of farmers	%	No of farmers	%
Hand harvesting	5	0.2	99	0.53
Machine harvesting	122	1.1	66	1.41
No seed selection	56	1.2	82	0.75
Seed selection	71	1.0	83	1.02
No seed cleaning	-	-	8	0.72
Seed cleaning	127	1.1	157	0.89
No seed treatment	-	-	154	0.89
Seed treatment	127	1.1	11	0.72
Not check germination	120	1.1	159	0.89
Check germination	7	0.0	6	0.75
Not store separate	47	2.3	41	0.89
Store seed separate	80	0.4	124	0.89

physiological seed quality of wheat and barley seeds collected from different sources.

Wheat seed samples treated by farmers showed better germination (90 vs 86%), speed of germination, seedling shoot length, seedling root length, but comparatively reduced field emergence. Moreover, treated seed has low bunt contamination, but slightly higher loose smut infection when compared to untreated seed. Although farmers indicated that the main purpose for seed treatment was to control smut infection, it was observed that most of them use general purpose broad spectrum chemicals which are ineffective in controlling systemic infection such as loose smut compared to common bunt which is located on the surface of the seed (Chapter 3). Few farmers (2.6%; n=156) indicated using Vitavax which is effective against loose smut infection. Abu-Yahya (1997) found significant difference in yield and yield components and reduction in number of spores per g between treated and untreated common bunt infected wheat seed lots in Jordan, although the treatment caused reduction in plant height.

It should be noted that farmers employ a range of, if not all combinations of, seed management practices such as seed selection, cleaning, treatment, fumigation, separate storage or checking germination. Some farmers may practise selection, cleaning and chemical treatment whereas others do not select, but clean and treat their seed or could only clean their seed but may not separate the storage. These are intricate issues and they need to be disentangled to isolate a specific management practice that affects seed quality. The results presented here would provide some information on the wider context of the seed health quality situation of wheat and barley in Ethiopia and Syria. However, we still lack information on the seed health quality of most important bacterial and viral diseases such as barley mosaic dwarf virus which is found to be widely distributed, and causing substantial crop losses both in wheat and barley crops throughout the region.

Modern varieties provide the genetic potential for increasing agricultural production and certified seed is a catalyst and basic input of delivery mechanism, but non-healthy seed may introduce foci of primary infection in the fields which cause disease outbreaks that result to substantial yield losses. Seed-borne pathogens my adversely affect crops by interfering in normal growth and development leading to reduced yield and/or quality. Sometimes the extent of crop loss will be directly related to the incidence of the disease (e.g., loose smut in wheat and barley). Moreover, the crop product may also be destroyed or its quality impaired through discolouration and shrivelling of seeds associated with pathogenic infection. Therefore, it would be very important that farmers provided with good quality healthy seed for crop production to avoid economic losses where seed health could be an integral part of quality assurance programme.

5.4.4. Implications for Future Research

In assessing the status of health quality of wheat and barley seed planted by farmers, the presence of major seed-borne fungi was revealed on a wider scale both in Ethiopia and Syria. The presence of the pathogens demonstrated that the modern wheat varieties released for commercial production or barley local landraces are susceptible to existing seed-borne diseases. The existence of virulent pathogens and susceptible host could lead to a greater potential for disease outbreak and threat to economic losses under circumstances of favourable weather conditions. In Ethiopia, Neimann *et al.* (1982) estimated national yield loss of 5% because of common bunt, whereas an infection of up to 10% has been reported for loose smut (Hulluka *et al.*, 1991) where the rate of infection is proportional to loss in crop yield. In Syria, estimated yield losses of 5-7% for common bunt (Mamulk, 1991) and an infection level of 5% with loose smut in the field had been reported (Mamluk *et al.*, 1990). Apart from such sporadic disease surveys and reports on the occurrence of the pathogens, systematic yield loss assessment studies to quantify economic losses from seed-borne diseases are lacking in both countries. A concerted effort should be initiated to conduct well co-ordinated comprehensive surveys to identify major seed-borne pathogens to determine their economic importance in crop production. Furthermore, detailed loss assessment studies should be designed in which results from such studies will help in setting priorities for research on control measures.

Seed certification is an integral part of quality assurance programme where seed lots are judged against a set of quality standards prescribed by the national regulations. However, most national regulations and certification schemes appeared to focus on relatively simple verifiable standards such as physical and physiological quality of seed (Hampton, 2002). In recent years, official field and seed standards have been introduced in Ethiopia as part of a quality assurance programme whereas in Syria production guidelines has been recommended for internal use by the national seed programme (ICARDA, 2002). However, the standards for seed health lack clarity in defining the important seed borne diseases and the prescribed tolerance levels for wheat and barley seed production. Moreover, neither the field inspection services nor the seed testing laboratories had sufficient facilities and adequately trained manpower to sanction the seed health standards prescribed in the guidelines. Regulations and standards for certification alone would not improve the seed health quality where special skills are required unless it is properly backed by trained and skilled personnel and facilities to enforce the standards (Besri, 1983). In view of the importance of the seed-borne diseases and the level of infection observed from wheat and barley seed samples, it is therefore imperative to suggest that both national seed programmes in Ethiopia and Syria introduce appropriate seed health certification programmes

(Hewett, 1979). It is important that field inspection of growing crops is linked with results of laboratory seed testing and adequate provisions made for training and facilities to ensure seed health quality.

The design and deployment of seed-borne disease management strategies require an understanding of the relationship between seed infection and disease development in the field and the economic losses incurred (yield or grain or seed quality). However, the role of pathogenic seed-borne pathogens in affecting seedling emergence and subsequent crop establishment, their contribution to development of disease epidemics in the field and their effect in causing yield and quality loss in cereals in general and wheat and barley in particular is limited especially under Ethiopian and Syrian conditions. Moreover, several pathogens are known to be both seed and/or soil borne but the relative importance of seed or soil-borne inoculum in disease development is also less understood. There is lack of adequate knowledge and information on correlation between the results of laboratory tests and infection in the field and the economic threshold for applying seed treatment chemicals. Several factors influence the development of the disease in the field among which the inoculum potential, the site of inoculum, susceptibility of the host, and the environmental conditions are key players (Colhoun, 1982). For example correlation between naturally and artificially contaminated wheat seed and subsequent common bunt infection of the crop was significant only under green house conditions but not under field conditions (Neimann *et al.*, 1980) indicating the influence of the weather on the degree of disease development. Therefore, efforts should be made to understand disease epidemiology and the economic threshold to establish tolerance level for seed-borne diseases.

Since the introduction of organomercury in the 1930s and later of systemic fungicides in the 1960s (Edington *et al*., 1980) chemical seed treatment became one of the most effective and economic methods for reducing losses caused by plant diseases and insect pests seed being used as the delivery mechanism. In many countries the wide spread use of effective seed treatment chemicals led to substantial reduction or elimination of threats from seed-borne diseases (Rennie *et al.*, 1983; Jørgensen, 1983). In Syria, chemical seed treatment is applied regularly by the formal sector and informal sector (except for barley seed from the informal sector). On the other hand, in Ethiopia large-scale seed treatment is restricted to seed production and for certified seed sold to the state farms only whereas seed for the peasant sector is not treated. Moreover, there is limited information on economic benefits of seed treatment under different crop production and management practices. It was reported that seed-borne diseases are not only a threat to wheat production but could also be introduced to new areas through infected seeds as observed in irrigated areas of Syria (Mamluk *et al*., 1990) and elsewhere. In light of results from recent studies it is, therefore, important to conduct systematic seed treatment studies and appraise its current status and provide alternative options to introduce on-farm seed treatment. In both cases designing simple application techniques and provision of information through an extension programme is important to emphasize the safety measures associated with chemical seed treatment.

Seed production should be concentrated in environments free of diseases and pests to make available healthy seed to the farmers. Rennie *et al.* (1983) reported that the majority of wheat seed sown in Scotland is grown in England to avoid contamination by field fungi. However, such arrangements are not always practical for a number of reasons. Instead the use of chemical treatment to control seed-borne pathogens becomes a routine practice as part of seed health management program. The beneficial effects of seed treatment on disease control and increased yield and yield components of infected seed lots are obvious (Abu-Yahya, 1997). However, studies elsewhere also have demonstrated no benefit of seed treatment on crop establishment or yield when a crop sown is free from seed-borne diseases (Paveley and Davies, 1994). Certification schemes set tolerance levels to check the spread of diseases by recommending seed treatment regimes based on infection levels. Agarwal (1983) indicated that seed lots up to 0.5% infection with loose smut were certified without seed treatment and those with infections between 0.51% and 2% were treated whereas those over 2% are rejected for seed multiplication. Jørgensen (1983) also reported that results of over 15 years were monitored to quantify seed-borne infection to establish a threshold for seed treatment to reduce the need for routine seed treatment for barley certified seed production in Denmark. In view of concerns for reducing production costs, environmental pollution and food safety resulting from wide spread use of agricultural pesticides new strategies of seed health management practices are emerging where application of seed treatment should be based according to needs rather than as a routine practice (http://www.hgca.com). Therefore, it is suggested that routine seed treatment should be avoided and should be based on seed health testing results.

The widespread use of chemical seed treatment in some parts of the world dramatically reduced the threat of some of the important seed-borne diseases such as bunts and smuts. As a result less emphasis in breeding resistant varieties against seed-borne diseases led to the distribution of susceptible modern varieties (Mamluk, 1991; Agarwal and Gupta, 1989). However tolerance or resistance to seed-borne diseases is reported from local landraces, breeding populations or commercial varieties (Agarwal and Gupta, 1989; Mamluk, 1991 Rennie *et al*., 1983). Therefore one inevitable conclusion could be for national programmes to make concerted effort in breeding commercial varieties resistance to prevalent major seed-borne diseases as part of an integrated disease management approaches to minimize production losses and reduce large-scale and regular use of seed treatment chemicals.

The globalization of the world economy, advances in biotechnology research and increased regimes in intellectual property rights protection reinforced the role and interest of multinational companies in seed trade to exploit the economics of scale at international levels. In the past 20 years, there is a growing trend in the amount of commercial seed lots that are traded across international boundaries (Le Buanec, 1996). Moreover, there are regional efforts for harmonization of regulations on varieties and seeds to encourage regional trade. However, seed quality standards are sometimes misused and abused and serve as non-tariff trade barriers (Hampton, 1998) particularly in terms of seed health quality where quarantine regulations are strictly imposed without realistic pest risk assessment regimes. Seed pathology should be able to serve the needs of the seed industry where realistic standards should be set and enforced.

5.5. Concluding Remarks

Despite considerable progress in terms of general plant pathological research and disease surveys seed pathology and seed health research are still sporadic both in Ethiopia (Hulluka *et al.*, 1991) and Syria (Mamluk *et al.*, 1991). There is no concerted effort to undertake basic epidemiological research and conduct yield loss assessment studies on seed-borne diseases of cereal crops in general and wheat and barley in particular to determine their economic importance. Apart from limited field surveys there is general lack of knowledge and information on the health status of seed planted by farmers. The present health quality tests of seed planted by farmers showed the occurrence and the extent of geographic distribution of major seed-borne fungi of wheat and barley in both countries. This chapter contributes to our understanding of the seed health quality and associated problems of wheat and barley seed from the formal and informal sectors. Further studies would be required to understand the extent of seed health problems with bacterial and viral diseases of wheat and barley.

The seed health quality of wheat and barley seed samples collected from farmers showed significant inter-regional differences (regions, districts, agro-climatic zones) in terms of the frequency (number of samples infected) and the intensity (level of infection per sample) of infection with different seed-borne pathogens. These differences could be attributed to environmental factors, farmers' seed management practices or their interactions. Seed samples collected from wetter regions had the highest infection compared to seed lots from the drier regions. In Ethiopia, for example, wheat seed samples from Arsi showed higher mean infection with *Drechslera*, *Fusarium* and *Septoria* spp. compared to seed samples from other regions. Similarly, infection of wheat and barley with loose smut showed a decreasing trend along with drier moisture regimes in Syria. Such regional differences associated with high rainfall areas have been reported from Canada (Clear, 1996), Ethiopia (Bekele and Karr, 1997) and India (Kashyap and Duhan, 1994). Therefore, crop production regions with high moisture regimes provide favourable environment for pathogen infection and disease development and thus more likely contributing to produce seed of low health quality. Therefore, seed production should be targeted in areas with less disease pressure to maintain seed health quality or assist farmers to apply better on-farm seed management practices.

The seed health tests revealed variation in the quality of wheat and barley seed collected from different sources. Seed samples both from the formal and informal sectors were found infected with seed borne diseases in different frequency and intensity. However, significant differences were found for few pathogens only (e.g. *Drechslera*, *Fusarium* and *Septoria* spp.). Non-significant results were also obtained for physical and physiological tests on samples collected from various seed sources (Chapter 4). All seed samples infected with loose smut of wheat or barley from formal or informal sources were in excess of the minimum health quality standards prescribed for seed certification across the West Asia and North Africa regions. Besri (1983) and Abdulfattah (1994) also found that both certified and non-certified seed were infected with seed-borne disease of wheat in excess of the standards. There are fundamental weaknesses in seed health quality both from formal and informal sources. Therefore, the results indicate the failures of national seed certification schemes in combating the threat of seed-borne fungal diseases and the need to strengthen them to be become more effective in producing healthy seed.

In Syria, the seed health quality between wheat and barley seed samples and farmers' seed management practices were remarkably different. From the results it can be summarized that: (a) most barley seed samples (over 80%) were infected with loose smut (*Ustilago nuda*) whereas slightly over 10% of wheat seed samples were infected with loose smut (*Ustilago tritici*); (b) barley loose smut infection was observed throughout the three regions whereas for wheat it was observed mainly from Hasakeh province; (c) barley growers perceive smut as major problem compared to wheat growers and this is well matched with seed health quality tests; and (d) wheat farmers practise better seed management compared to barley growers to ensure seed health quality. Almost all wheat farmers apply chemical seed treatment for seed retained on the farm or obtained informally compared to 6.5% in case of barely. In low input agriculture where barley is grown most farmers still do not use certified and/or treated seed (Mamluk, 1991). Such on-farm seed management practices might have contributed to better seed health quality for wheat compared to barley. Therefore, as a general rule it is imperative to introduce alternative seed management practices to improve the seed health quality at the farm level both in Ethiopia and Syria.

Seed health is an integral component of seed quality and important element of the formal sector seed production and certification scheme. The seed health quality tests have demonstrated the extent of the problem of seed-borne diseases both in formal and informal sectors. The Ethiopian seed certification standards require that maximum permitted percent infection for seed-borne diseases for different classes of certified (ICARDA, 2002). Many countries in West Asia and North Africa also have introduced quite often exceptionally high seed health certification standards. In many instances, the standards neither specify the minimum infection levels permitted in the field nor the type of diseases to which the laboratory seed standard applies except the list of pathogens. Moreover, seed health testing is neither carried out as a routine practice nor facilities and expertise are available to conduct the test. It is important that national seed programmes define realistic seed health quality standards and introduce routine seed health testing that would enable the formal sector to produce enough quantity of healthy seed to meet farmers' demand.

CHAPTER 6

On-Farm Wheat and Barley Diversity in Ethiopia and Syria

Chapter 6

On-Farm Wheat and Barley Diversity in Ethiopia and Syria

6.1. Abstract

Analysis of spatial diversity, temporal diversity and coefficient of parentage (COP) were carried out and measurements of agronomic and morphological traits were employed to explain the diversity of wheat and barley varieties or local landraces grown by farmers in Ethiopia and Syria. Farm level surveys showed low spatial diversity of wheat and barley where only a few dominant varieties appeared to occupy a large proportion of the wheat and barley areas. The majority of farmers also grew these few varieties. In Ethiopia, the five top wheat varieties were grown by 56% of the sample farmers and these varieties were planted on 80% of the total wheat area. In Syria the five top wheat cultivars occupied 81% of the wheat area and were grown by 78% of the sample farmers. In the case of barley one single local landrace was grown in the entire survey area. The weighted average age of wheat varieties was high with an average of 13. 8 years for bread wheat in Ethiopia and 10.8 years for wheat in Syria showing low temporal diversity or varietal replacement by farmers in both countries. The COP analysis showed that the average and weighted diversity of bread wheat in Ethiopia was 0.76 and 0.66, respectively; it was low because most of the modern varieties were related. In Syria bread wheat had the lower average diversity and weighted diversity (0.73 and 0.42) compared to durum wheat. Variance component analysis showed significant variations that existed for desirable agronomic characteristics such as plant height, grain yield, and yield components (kernels per spike^{-1}, seed weight) among wheat and barley varieties and/or local landraces. The principal component analysis explained better most of the variations that existed among the varieties and local landraces. The variation among barley genotypes was less obvious. The variation that existed among the local landraces offered broad opportunities for using the genotypes with desired agronomic characteristics in plant breeding programmes to develop varieties suitable for different agro-ecological zones in each country. Cluster analysis based on agronomic and morphological traits grouped the modern varieties and local landraces into separate clusters.

Key words: Ethiopia, Syria, barley, *Hordeum vulgare*, wheat, *Triticum* spp., genetic diversity, spatial diversity, temporal diversity, coefficient of parentage, local landraces.

6.2. Introduction

The crop genetic resources, a combination of weedy species, wild relatives and domesticated crops (including landraces and modern varieties) form the pool of genetic diversity available in a given agro-ecosystem shaped through centuries of natural and/or human selection. Such crop genetic diversity is very important from agro-ecological, agronomic, economic and socio-cultural perspectives. First, it offers opportunities for domestication of wild species into cultivated crops to diversify and broaden the base of our food crops. Second, it provides variation for selection among plant populations for crop improvement by modern plant breeders or through traditional farmer selection practices. Third, it allows those concerned with plant genetic resources to formulate and develop strategies for *in-situ* and/or *ex-situ* germplasm conservation and maintenance. Fourth, it provides farmers or producers with a wide range of choices to select varieties adapted to their specific niche environments.

Crop genetic diversity refers to variation within a plant, between plants of the same species, and between different crop species (Almekinders *et al*., 1995). However, it is argued that the definition of diversity across disciplines could be problematic because the criterion and scales for measurements and their relationships are weak (Smale *et al.,* 1996). Smale *et al.* argued that biological scientists measure diversity using genealogical analysis or indicators (coefficient of parentage), analysis of agronomic or morphological characteristics using G × E interactions, and indices of gene frequencies using biochemical or molecular tools whereas social scientists use the number of varieties within a given crop species (numerical), proportion of area planted to group of cultivars (spatial) and the rate of variety replacement (temporal) by farmers using both farm level surveys and/or secondary data. Spatial diversity indicates the number of varieties grown per unit farm, area, community or region and the proportion of area occupied by each variety. Temporal diversity indicates the sequential changes in crop varieties (or sequential varietal releases by plant breeders) assessing the changes taking place through introduction or withdrawal of varieties by individual farmers or farming communities. At present a combination of different approaches and tools are used to analyse the genetic diversity of crops (Duvick, 1984; Brennan and Byerlee, 1991; Smale *et al*., 1996). According to Duvick (1984) farmers are using at least three kinds of diversity: diversity in space, diversity in time and diversity in reserve (genotypes in breeding pools, breeding materials exchanged among breeders, etc.). Moreover, genetic diversity of crops can be measured through examination of cultivar morphology (Souza and Sorrells, 1991), molecular markers (Cox *et al*., 1985) or origin or parentage analysis (Martin *et al*., 1991) or a combination of these tools (Almanza-Pinzón *et al*., 2001; van Beuningen and Busch, 1997b). The coefficient of parentage (COP) was used to measure genetic diversity in wheat (Souza *et al*., 1994) and rice in

Nepal and India (Witcombe *et al*., 2001).

The Fertile Crescent is believed to be the centre of crop domestication and agricultural innovation where farming started as early as 10,000 years ago. The domestication of barley followed that of wheat from their wild relatives to cultivated crops. Primitive forms and wild relatives of wheat and barley still exist in the wild throughout the Middle East and the Mediterranean region. Following their domestication both crops including the agricultural techniques were introduced to many regions (old and new) and now have become principal crops of economic importance worldwide. Farmer selection produced increased genetic diversity in the form of distinct landraces or traditional varieties with different genetic characteristics within the cultivated crop species. Syria is located in the 'centre of origin' of wheat and barley (Damania *et al*., 1998) whereas the Ethiopian highlands are considered the 'centre of diversity' for wheat (Demissie and Habtemariam, 1991; Tesemma and Belay, 1991) and barley crops. Earlier studies, for example, have described the diversity of barley local landraces from Syria in terms of agronomic performance (Ceccarelli *et al*., 1987) and disease resistance (van Leur *et al*., 1989). Tesfaye *et al*. (1991) also reported the morphological diversity of durum wheat landraces from the central highlands of Ethiopia. Such valuable genetic diversity of plant resources is rapidly declining due to natural and human activity.

Since the establishment of the national agricultural research systems in the mid 1960s (ICARDA *et al*., 1999) several modern crop varieties including selections from local landraces have been released for commercial production in Ethiopia (Geberemaraim, 1991b; Belay and Tesemma, 1991) and Syria (Mazid *et al*., 1998). The extent of adoption and diffusion of modern varieties for wheat has been described in Chapter 2 for Ethiopia and for wheat and barley in Chapter 3 for Syria. Today, there is great concern over the loss of genetic diversity, particularly with the substitution of a diverse set of genetically variable crop landraces with few genetically uniform modern varieties particularly in areas of crop domestication and centres of genetic diversity such as Syria and Ethiopia, respectively. Although the loss of biodiversity is largely due to replacement of local landraces by 'improved' varieties, population pressure, urbanization and environmental degradation such as recurrent droughts, overgrazing and desertification are also contributing to the decrease in natural genetic variability. The present study describes the diversity of wheat and barley crops available on the farm using different indicators.

Abundant information is available on classical diversity studies for crop genetic resources/core collections (Demissie and Habtemariam, 1991) or for quantifying variation within and between geographic regions and populations (Kebebew *et al*., 2001a) or for specific agronomic traits (Belay *et al*., 1993) or morphological traits

(Tesfaye *et al*., 1991). However, information on the status of genetic diversity at the farm level is rather limited (Witcombe *et al*., 2001; Souza *et al*., 1994). Some recent diversity studies were reported particularly on Ethiopian wheat (Kebebew *et al*., 2001a) but information on on-farm genetic diversity is rather limited in both countries. The present study is not a classical genetic diversity study *per se* but aimed at assessing the on-farm wheat and barley diversity using different approaches and tools. Therefore, the main objectives of this study were to:

- Measure the spatial and temporal diversity of wheat and barley varieties planted by the farmers, and
- Investigate the agronomic and phenotypic traits diversity of wheat and barley varieties used by farmers.

The spatial diversity, temporal diversity, coefficient of parentage analysis and measurements of agronomic and morphological traits were employed to explain the diversity of wheat and barley varieties or local landraces grown by farmers in Ethiopia and Syria.

6.3. Materials and Methods

6.3.1. Wheat and Barley Varieties

From 304 wheat seed samples collected from different parts of Ethiopia during the 1997/98 crop season, 50 samples representing 13 bread wheat (7 modern, 6 obsolete or local landraces) and 12 durum wheat (1 modern, 11 local landraces) were selected and planted for two seasons during the 1998/99 and 1999/00 crop seasons to assess the wheat genetic (agronomic and morphological) diversity. The bread wheat included recommended varieties (Dashen, ET 13, HAR 1685, HAR 1709, HAR 710, K6295, Pavon) and obsolete varieties or local landraces (Batu, Israel, Kenya, Goli, Menze, Zombolel). All durum wheat materials were local landraces (Baghede, Baherseded, Enat sende, Gojam gura, Gotoro, Key sende, Legedadi, Nech shemet, Rash, Shemet) except Boohai which is a modern variety.

Similarly, from 204 wheat seed samples collected from different parts of Syria during the 1998/99 crop season about 60 seed samples representing 6 bread wheat (5 modern, 1 obsolete) and 7 modern and 5 local landraces (represented by 1, 4, 4, 5 and 7 populations) were selected and planted for two seasons during the 1998/99 and 1999/00 crop seasons to assess the genetic diversity of wheat. The modern bread wheat varieties included recommended varieties (Cham 2, Cham 4, Cham 6, Bohouth 4 and Bohouth 6) and an obsolete variety (Mexipak). The durum wheat materials included modern varieties (ACSAD 65, Bohouth 5, Gezira 17, Cham 1, Cham 3 and Cham5, Lahan) and local landraces collected from isolated areas (Bayadi, Hamari, Hourani and

Swadi). Since all barley seed samples collected from farmers were identified as one local landrace, Arabi Aswad, two seed samples from each village were selected where 50 samples were planted at two contrasting environments at Tel Hadya (Zone 2) and Breda (Zone 3) representing two major agroclimatic zones where barley is one of the major crops.

6.3.2. Field Experiments

The modern varieties and local landraces were grouped into bread and durum wheat and planted separately to study the diversity among the varieties using agronomic and morphological (phenotypic) characteristics. The wheat samples were planted in an alphagen design with three replications for two consecutive years (2 replications for barley). In Ethiopia both bread and durum wheat were planted at the rate of 30 g per plot of 6 rows of 2.5 m length with a spacing of 0.2 m between rows on 3 and 4 July in 1998/99 and 2 and 4 July in 1999/00. The experiment was planted at an altitude of 2250 m asl at the Gonde seed farm (8.0°N and 39.1°E) of the Ethiopian Seed Enterprise located in southeastern Ethiopia. The soils in Gonde are termed as ignimbrite (consolidated lava flows), volcanic ash and pumice. The soil texture is light clay with clay (44-47%), silt (28-32%) and sand (23-27%). Fertilizer was applied as per the recommend rate of 100 and 50 kg ha^{-1}, respectively for DAP and Urea. DAP was applied all at planting time while Urea was used as split at tillering stage.

In Syria, bread wheat was planted at the rate of 60 g and durum wheat at 70 g per plot in 8 rows of 2.5 m length with the spacing of 0.25 m between rows on 6 January 1998/99 and 28 November 1999/00, all at the ICARDA experimental farm at Tel Hadya in northern Syria. Barley was planted at the rate of 50 g per plot of 8 rows of 2.5 m length with the spacing of 0.25 m on 1 and 4 December 1998/89 at the Tel Hadya and Breda experimental farms, respectively. The soils at the ICARDA research stations are classified as thermic Calcixerollic Xerochrept (Ryan *et al.*, 1997). Fertilizer was applied at the rate of 180 and 150 kg ha^{-1} of ammonium nitrate and triple superphosphate at Tel Hadya both for wheat and barley. In addition, N was applied as top dressing at the rate of 120 kg ha^{-1} for wheat at Tel Hadya. In Breda 90 kg each of ammonium nitrate and 60 triple superhosphate were applied ha^{-1} for barley, all at planting time.

The agronomic and/or morphological characteristics were recorded on a plot basis in the field or after harvest. Agronomic characteristics measured included days to flowering, days to heading, days to maturity, grain yield, biomass yield, plant height, spike length, number of spikelets spike^{-1}, number of kernels spike^{-1} and thousand seed weight. Morphological characteristics were measured visually on a plot basis or on a group of plants as described by UPOV (1981 and 1988) defining the methods, scales and crop growth stages for scoring.

The following agronomic and morphological characteristics were recorded during the field experiments:

Agronomic characteristics (on a plot basis or on 10 randomly selected plants)

- Days to heading (days): number of days (counted from first effective date of rainfall to) when 75% of the plants were heading in the plot;
- Days to flowering (days): number of days (counted from first effective date of rainfall to) when up to 50% of the plants flowering in the plot;
- Days to maturity (days): number of days (counted from first effective date of rainfall to) when 90% of plants reaching physiological maturity in the plot;
- Grain filling period (days): number of days to maturity minus number of days to heading;
- Plant height (cm): length of randomly selected plants measured from the ground (excluding the awns) at maturity;
- Number of tillers plant^{-1}: number of tillers of randomly selected plants counted at maturity;
- Grain yield (g): grain weight of four middle rows harvested at maturity and measured after threshing and cleaning;
- Biomass yield (g): biomass (straw and grain) weight of 4 middle rows harvested and weighed at maturity;
- Spike length (cm): length measured from base of spike to top excluding the awns at maturity;
- Number of spikelets spike^{-1}: number of spikelets on randomly selected plants counted at maturity;
- Number of kernels spike^{-1}: number of kernels counted on randomly selected plants per spike at maturity;
- Thousand seed weight (g): weight of 1000 seeds calculated at 12% moisture content.

Morphological or phenotypic characteristics (observed on plot basis or 10 randomly selected plants)

- Growth habit: scored as prostrate, semi-prostrate, intermediate, semi-erect, erect;
- Plant characteristics: hairiness of uppermost node (HUN), glaucocity of ear neck (GN), zigzagness of neck (ZICN);
- Leaf characteristics: auricle colouration, glaucocity of leaf sheath and lower leaf blade;
- Glume characteristics: glume colour (GC), beak length (BL), shoulder shape (SHSH), shoulder width (SHW);

- Ear characteristics: ear shape (ES), ear colour (EC), awn condition (presence or absence), awn colour (AC);
- Grain characteristics: grain colour (GC), grain shape (GS), brush hair (BRH).

In barley, however, the number of days to flowering, tillers per plant, plant height, grain yield, spike length, number of kernels per spike and ear density (ratio of grains to spike length) were recorded.

Some of the quantitative characteristics were measured on a scale of 1 to 9. For example for growth habit the score will be erect (1), semi-erect (3), intermediate (5), semi-prostrate (7) and prostrate (9). The qualitative characteristics were measured on a discontinuous basis such as absent (1) or present (2). For example, ear shape could be scored as tapering (1), parallel (2), semi-clavate (3), clavate (4) or fusiform (5). It should be noted that more morphological characteristics were scored in Syria than in Ethiopia.

6.3.3. Data Analysis

Several approaches were employed to measure the wheat and barley varietal diversity at the farm level including field surveys and field experiments.

Survey data Farmers were asked about the wheat or barley varieties they grew and the area under each variety. The number of farmers growing these varieties was assessed as part of the seed system study reported in the previous four chapters. The number of varieties grown by each farmer and the proportion of area under each variety was used to measure the spatial and temporal diversity on the farm. The weighted average age of varieties was used to estimate the temporal diversity of the varieties (Brennan and Byerlee, 1991) grown during the 1997/98 and 1998/99 crop season in Ethiopia and Syria, respectively. Moreover, measuring the varietal diversity also requires information on the genetic relatedness between varieties. The matrix of coefficients of parentage (COP) among the released wheat varieties was generated using the International Wheat Information System version 4 computer program (Payne *et al*., 2002). The COP measures the theoretical genetic relationship between two varieties based on the analysis of their pedigrees. St. Martin (1982) defined the algorithm for calculating COP: (i) the COP of each unique wheat variety with itself is one, and two varieties without common parentage is zero; and (ii) each parent contributes equally to the progeny, and any unrelated parents has a relationship of 0.5 with the progeny; (iii) each variety without a known pedigree is unrelated (COP=0). The average diversity is the average value of the COP among all cultivars (including the COP of a cultivar with itself) grown within each year and region subtracted from 1 (Souza *et al*., 1994). The weighted diversity is determined from a matrix of the COPs where each cell in the matrix is weighted by the proportion of the area grown to each variety and the weighted mean COP is subtracted from 1 (Witcombe *et al*., 2001).

Experimental data The data from the field experiments was statistically analysed using the residual maximum likelihood estimation (REML Genstat 6.1) to test the significance of variation among the genotypes and to estimate variance components. Moreover, the data was pre-standardized to overcome differences in measurements used for recording data before carrying out the multivariate analysis (principal component analysis and cluster analysis). Principal component analysis was performed using the correlation matrix to define the patterns of variation among the varieties or local landraces or the collection sites based on the mean of agronomic and phenotypic traits measured during the study using the SPSS 11.1 statistical software and the graph plotted with NTSYSpc 2.1 software. Clustering was made using the hierarchical cluster analysis. Euclidean distance was used as cluster distance measure and the clustering method was unweighted pair group using arithmetic average (complete linkage used for barley) using NTSYSpc 2.1. The actual data matrix was compared with a calculated cophenetic value matrix to evaluate the degree of fitness between the two matrices (r) to perform Mantel test (Mantel, 1967).

6.4. Results and Discussion

6.4.1. Wheat Diversity in Ethiopia

In Ethiopia, the average rainfall for 1998/99 and 1999/00 was 794 and 682 mm, respectively, showing greater variation in the amount and distribution at the experimental site between the two seasons (Table 6.1). In both years, exceptionally high and extended rainfall during crop maturity and at harvesting period resulted in lodging and loss of grain yield of modern wheat varieties and local landraces. In the 1999/00 crop season, high incidence of yellow rust was observed particularly on local landraces leading to substantial yield loss.

Spatial Diversity of Wheat Varieties Farmers grow different crops and varieties from different agro-ecological, agronomic, economic, and socio-cultural context to maximize on-farm productivity and ensure household food security. In Chapter 2, we have reported relatively higher species diversity on the farm where most farmers grew a wide range of cereal, legume and oilseed crops. In 1997, sampled wheat farmers either grew bread wheat (83.2%), durum wheat (7.9%) or a combination of both wheat types (8.9%). Table 6.2 shows the number of bread and durum wheat varieties grown

Table 6.1. Average monthly minimum and maximum temperature and rainfall during 19998/89 and 1999/00 crop seasons at Gonde basic seed farm, Ethiopia.

Months	1998/99				1999/00			
	Rainfall mm	Max °C	Min °C	Average °C	Rainfall mm	Max °C	Min °C	Average °C
January	82.0	22.18	9.55	15.9	3.50	22.31	7.38	14.8
February	80.4	23.75	11.18	17.5	4.50	25.47	8.65	17.1
March	28.8	25.13	11.40	18.3	27.0	24.36	10.73	17.5
April	45.8	26.73	12.45	19.6	26.7	26.36	11.31	18.8
May	78.5	25.70	12.40	19.1	60.0	25.43	11.38	18.4
June	66.2	24.58	11.76	18.2	98.3	24.08	11.18	17.6
July	96.1	20.20	11.30	15.8	96.1	22.00	12.03	17.0
August	67.8	20.00	10.90	15.5	148.6	21.00	11.70	16.4
September	164.5	21.30	11.10	16.2	112.7	na[1]	na	na
October	81.2	21.50	10.70	16.1	104.4	na	na	na
November	2.6	21.88	9.80	15.8	0	na	na	na
December	0	21.71	na	15.6	0	na	na	na
Total/mean	793.9	22.90	11.10	15.6	681.8			

[1] Data not available because of malfunctioning of the equipment.

per farm. The number of wheat varieties grown by an individual farmer was low showing little varietal diversity. If both bread and durum wheat varieties are considered together 72%, 24% or 4% of farmers grew one, two or three varieties, respectively. In case the two wheat species are considered separately, the number of farmers growing one variety will be 70% for bread wheat (n=280) and 82% for durum wheat (n=51). Similarly, farmers growing two varieties dropped from one-third to one quarter for bread wheat and to 16% for durum wheat. In Arsi, relatively more farmers had better choice and access to newly released varieties and as a result grew more than two varieties. In other regions more farmers grew modern bread wheat varieties along with local durum wheat landraces as these varieties were newly introduced to the regions. Lack of choice of varieties with different agronomic characteristics would be one possible indication of growing less number of varieties by farmers. Similar results were also reported where 73% of farmers grew a single wheat variety in southeastern Ethiopia (Ferede *et al*., 2000). Negatu *et al*. (1992), however, reported slightly higher number of varieties per farmer where over 50% grew more than one variety in the central highlands of Ethiopia, although no distinction was made between bread and durum wheat varieties. Stanelle *et al*. (1984) also found that 32% of farmers planted

Table 6.2. The number of bread and durum wheat varieties grown by sampled farmers (n=331) in Ethiopia.

Number of	Arsi		West Shoa		North Shoa		East Gojam		Total	
varieties	Farmers	%	Farmers	%	Farmers	%	Farmers	%	Farmers	%
All wheat										
1	75	53	55	77	56	93	53	90	239	72.2
2	55	39	14	20	4	7	6	10	79	23.9
3	11	8	2	3	-	-	-	-	13	3.9
Total	141	100	71	100	60	100	59	100	331	100
Bread wheat										
1	75	53	44	81	30	97	48	89	197	70.4
2	55	39	9	17	1	3	6	11	71	25.4
3	11	8	1	2	-	-	-	-	12	4.3
Total	141	100	54	100	31	100	54	100	280	100
Durum wheat										
1	-		11	65	26	90	5	100	42	82.4
2	-		5	29	3	10	-	-	8	15.7
3	-		1	6	-	-	-	-	1	2.0
Total	-		17	100	29	100	5	100	51	100

two varieties and 27% planted three or more wheat varieties owing to the availability of many wheat varieties with diverse characteristics to spread the risk of wheat crop production. The general assumption that small-scale farmers are growing diverse crop varieties fitting to different niches is not clearly evident both for wheat or other crops grown by farmers. However, at the community level farmers were growing relatively more varieties as in 62 out of 81 villages where sample farmers were growing from 2 to 4 different wheat varieties or local landraces. Given the fact that farmers are planting even one variety on different plots in the village one could possibly find a mosaic of fields with different varieties/landraces at a time showing some degree of spatial diversity on the farm.

Fig. 6.1 shows the pattern of the top ten wheat varieties grown by farmers over a four-year period from 1994/95 to 1997/98 crop season. About 40 modern and farmer varieties of bread and durum wheat were grown across the region by sampled farmers during the 1994/95 to 1997/98 crop season. The total number of wheat varieties grown slightly decreased because some local landraces were dropped as farmers were adopting new bread wheat varieties instead. The total number of wheat varieties grown by sampled farmers dropped from 40 in 1994 to 31 in 1997; and these included durum

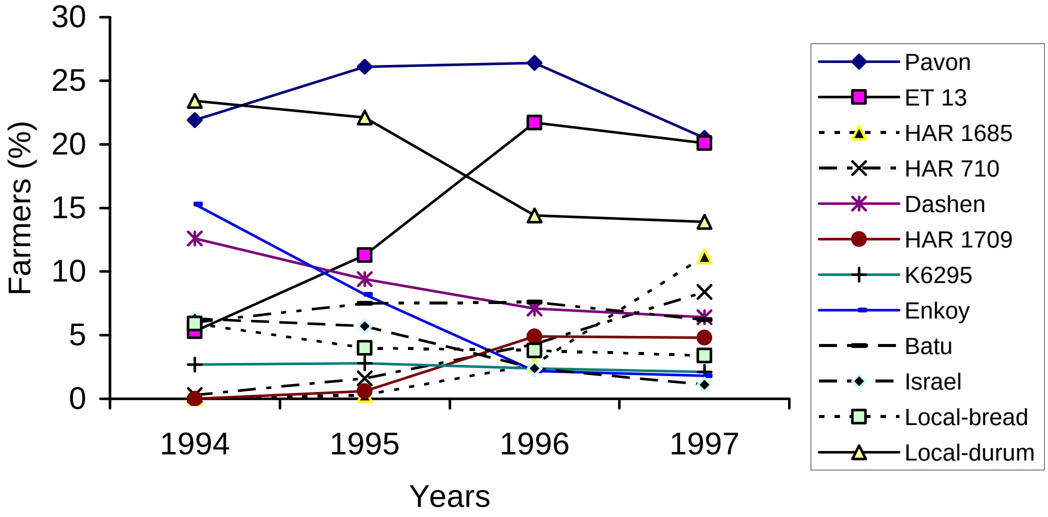

Fig. 6.1. Patterns of bread and durum wheat varieties grown by sample farmers in Ethiopia.

landraces such as Atekere, Agere, Bire, Boydo and Wasma. During the four year period, the five major bread varieties were grown by 44.9% (lowest in 1996) to 66% (the highest in 1997) of wheat farmers. In 1994, the bread wheat varieties Pavon, Enkoy, Dashen, Batu and Israel were planted by 62.1% of farmers. In 1997, the top five varieties altogether were planted by 66.2% of farmers, among which Pavon and ET 13 alone were grown by 40.6% of the farmers, followed by HAR 1685 (11.2%), HAR 710 (8.4%) and Batu (6.2%). The average over four year period was 56%.

In 1997, about 86% of sampled farmers grew bread wheat varieties whereas the remaining 14% planted durum wheat varieties. The proportion of farmers growing Dashen and Enkoy dropped from nearly one third in 1994 to less than 10% in 1997. On the other hand, the percentage of farmers' growing Pavon and ET13 showed an upward trend increasing from 27.2% to 40.6%, in the same period. Throughout the period Pavon appeared to be a single dominant variety planted by over 20-25% of the farmers. Batu also remained among the top five bread wheat grown by survey farmers.

The percentage area of the top ten wheat varieties grown by farmers over a four-year period is shown in Fig. 6.2. There was a steady increase of area allocated for wheat production by sampled farmers over the years (almost by 50%). This happened as most of the farmers were introduced to modern varieties and at the same time growing their local landraces in decreasing proportion. The five top wheat varieties on average occupied 80% of the wheat area planted during the four year period. In 1994, Pavon, Enkoy, Dashen, Batu and Israel in decreasing order accounted for nearly 80% of the wheat area planted by farmers. In 1997 Pavon and Batu still remained at the top

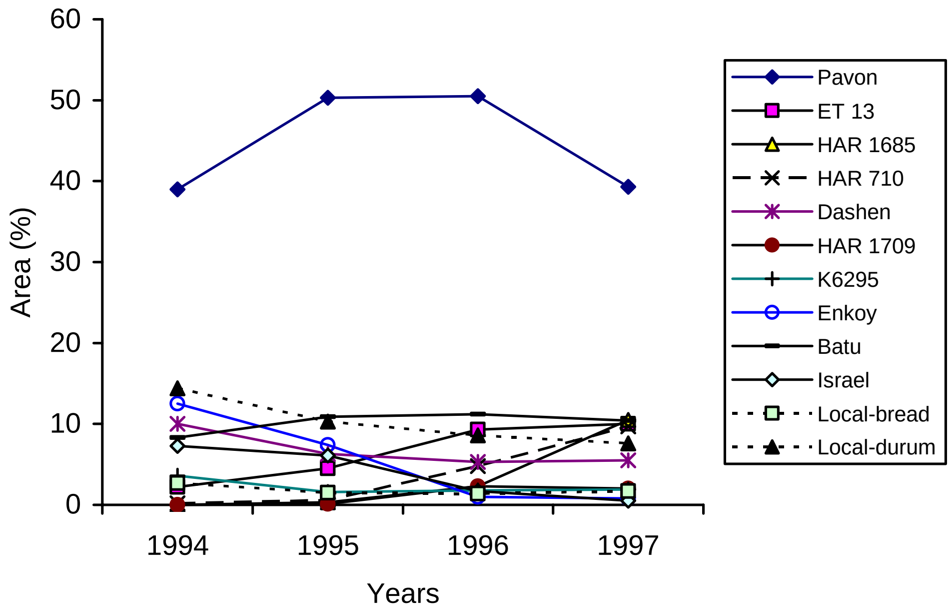

Fig. 6.2. Patterns of area allocation for bread and durum wheat varieties by sample farmers in Ethiopia.

whereas the older varieties or local landraces such as Dashen, Enkoy and Israel were replaced by the new varieties. The newer 'HAR' varieties accounted for over one fifth of wheat area. Pavon remained dominant occupying 40 to 50% of the wheat area grown by sampled farmers over the four year period. Negatu (1999) also reported that in central Ethiopia three modern wheat varieties were grown on 53% of the wheat area and the most widely grown variety ET 13 was planted by 74% of sample farmers on 51% of the wheat area. In another survey it was reported that six dominant varieties covered 92.5% of the total wheat area grown by sample farmers in the Arsi region (Ferede *et al*., 2000). Much higher level cultivar concentration was reported from South Asia where a single wheat variety occupied up to 70% in Pakistan and 75% in Bangladesh (CIMMYT, 2001). The area allocated to local bread and durum landraces declined over the years from 18.3 and 14.4%, respectively in 1994 to 12.6 and 7.6% in 1997 in the same order. Kotu *et al.* (2000) found that wheat farmers in southeastern Ethiopia are decreasing the area of their local landraces as compared to that of modern varieties.

The important features observed from the survey were: (a) decline in the proportion of local bread and durum landraces; (b) decrease in previously most popular varieties such as Dashen and Enkoy as they became susceptible to diseases; (c) increase in the proportion of previously less popular varieties such as Pavon and ET 13; and (d) a continuous increase of newly released 'HAR' varieties which was not evident in previous surveys. Negatu *et al.* (1992) also found that 94% of sampled farmers in predominantly durum wheat production zones in the central highlands grew only few modern bread and durum wheat varieties. About 63% of these farmers were formerly used to grow as many as 27 durum local landraces, but abandoned them primarily due to lack of seed availability and their susceptibility to plant diseases and insect pests. Hailye *et al.* (1998) also found that farmers in northwestern Ethiopia had formerly reported growing 13 types of mostly durum local landraces, which were now abandoned because of their susceptibility to rusts, moisture stress and low soil fertility.

It should be noted that the number of varieties grown by individual farmers was rather low given the number of released wheat varieties and local landraces cultivated in Ethiopia. Moreover, a small number of varieties occupied the highest proportion of area allocated to wheat and they were also grown by a large number of farmers. Varietal concentration indicates the percentage distribution of crop area by cultivar (spatial diversity) and measured by the area planted to a dominant cultivar and the area planted to the top five cultivars. Accordingly, these results indicate high varietal concentration reflecting low on-farm diversity of bread wheat in Ethiopia. On the other hand, there was not a single local landrace which substantially dominated the area of wheat production. Different local durum landraces were grown quite evenly across the districts.

Temporal Diversity of Wheat Varieties During the last five decades, several modern varieties of bread (49) and durum (16) wheat were recommended or released for use by farmers (Gebremariam, 1991b; Tesemma and Belay, 1991; NSIA, 2000) with an average frequency of 13 varieties per decade for the highly diverse agro-ecological regions of the country (Fig. 6.3). Among these, eleven bread and three durum varieties were released during or after the survey year. The average wheat varietal release was 1.3 modern varieties per year from 1950 to 2000. There is substantial difference in the average release per year between durum (0.3) and bread wheat (1.0) varieties. These numbers at least indicate more choices for modern varieties of bread compared to that of durum wheat. During the wheat seed survey sample farmers grew nine bread wheat varieties (including some later releases) on the recommended list compared to one recommended durum wheat variety. Souza *et al.* (1994) reported an average release of 1.5 varieties per year in the Yaqui valley of Mexico. The performance of the Ethiopian national research programme appeared to be satisfactory given the average annual total wheat releases of 80 varieties per year by NARS of developing countries between 1986 and 1990 (Evenson and Gollin, 2003).

The availability of recommended varieties alone would not imply diversity, if they were not available at the farm level and grown by farmers. The weighted average age

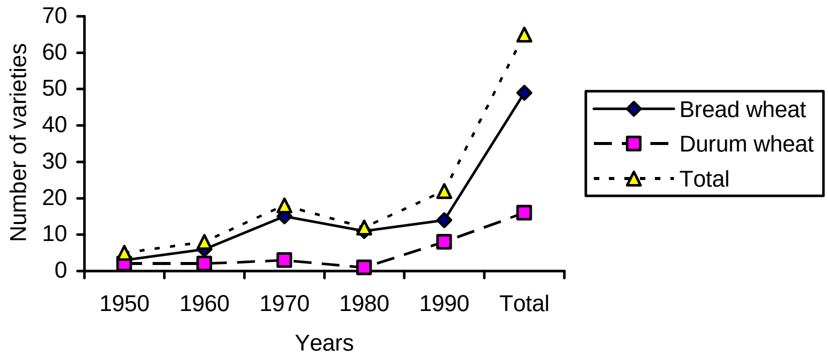

Fig. 6.3. The number of modern varieties of bread and durum wheat released in Ethiopia from 1950 to 2000.

(WA) of varieties is a useful tool for measuring the temporal diversity of the crop (Brennan and Byerlee, 1991; Smale *et al.*, 1996). The weighted average age of varieties is used to estimate the rate of varietal replacement, based on the average age of varieties grown by farmers in a given year since release, weighted by the area planted to each variety in that year (Brennan and Byerlee, 1991). Based on this formula, the WA could be computed for a given year (*t*), as follows:

$$WA_t = \sum_i P_{it} R_{it} \ ,$$

where, P_{it} is the proportion of area sown to variety *i* in year *t*, and R_{it} is the number of years at time *t* since the release of variety *i*.

In 1997, the WA calculated for modern bread wheat for which information on year of release is available, showed a low level of varietal turnover, in the range of 13.4 years (Table 6.3). Beyene *et al.* (1998) also found 13 years of WA for bread wheat varieties in central highlands of Ethiopia. Similarly, the WA of 11 years was also reported for wheat varieties in northwestern Ethiopia (Hailye *et al.*, 1998). These figures indicate that although Ethiopian farmers are growing modern varieties of bread wheat, they are slow in changing to new varieties released in recent years or having difficulty to get quick access to improved seeds. The present WA was closer to 13 years (Smale *et al.*, 1996), but lower in contrast to the previous assumption of up to 16 years of varietal replacement described by Moya and Byerlee (1993). Ethiopian farmers had long seed retention period which had a negative impact on adoption of new varieties (Gamba *et al.*, 1999) thus increasing the WA of varieties on the farm. The most probable cause for slightly lower WA could be the release of new varieties and farmers willingness to adopt them replacing most popular 'old generation' wheat varieties such as Dashen and Enkoy

Table 6.3. The weighted average age (WA) of bread wheat varieties currently grown by farmers in Ethiopia.

Variety	Year variety released	Years since release	Mean area (ha) in 1997	WA
Dashen	1984	13	0.80	1.09
Enkoy	1974	23	0.39	0.94
ET13	1981	16	0.46	0.77
HAR 1685	1995	2	0.87	0.18
HAR 1709	1994	3	0.38	0.12
HAR 710	1995	2	1.06	0.22
K6295	1980	17	0.86	1.53
Pavon	1982	15	1.78	2.80
Batu	1984	13	1.57	2.14
HAR 416	1987	10	0.75	0.79
Kenya	1954	43	0.61	2.75
Total				13.35

which become susceptible to yellow rust and leaf rust diseases, respectively. Previously modern varieties such as Enkoy remain dominant for over two decades in major wheat production regions of the country. The breakdown of resistance could induce farmers to change promoting varietal replacement and increasing the temporal diversity at the farm level (Souza *et al*., 1994; van Beuningen and Busch, 1997a; Hailye *et al*., 1998). In the 1990s, the WA of wheat varieties ranged from less than four years in the Yaqui valley of Mexico to over 10 years in the Punjab of Pakistan, with a global average of seven years (Brennan and Byerlee, 1991). In general high WA is a combination of many factors reflecting slow rate of variety development by the agricultural research, ineffective variety release and registration system, poor promotion or popularization of new varieties or lack of access to seed of new varieties.

Although several modern durum wheat varieties were released by the national agricultural research system none of them were encountered in Arsi region where bread wheat is most popular among farmers because of its high yield potential. Moreover, only a single improved variety was found in traditionally durum wheat growing areas of the country in central and northwestern regions reflecting lower adoption of modern varieties on the farm. This indicates the underlying failure of the crop improvement programme in developing modern varieties that meet farmers' adoption criteria or the weakness of national seed system in providing seed of these varieties to farmers. On the other hand, sample farmers were growing a wide range of durum wheat as many as 15 local landraces across the regions. It is estimated that over 80% of durum wheat area in Ethiopia is covered by local landraces consisting of mixtures that exhibit genetic variation for various quantitative and qualitative traits (Tesemma and Bechere, 1998). It is believed that such landrace mixtures constitute the major on-farm diversity of durum wheat in Ethiopia (Belay *et al*., 1993; Kebebew *et al*., 2001a) where 20 or more morphotypes (agrotypes) still exist all in one field (Tesemma and Bechere, 1998).

At present a significant proportion of the total wheat area in developing countries is planted to modern varieties, including early generation tall improved varieties and/or second-generation short stature modern varieties (Pingali, 1999). However, the rate of varietal replacement of the old generation improved varieties is slow where farmers could not benefit from investment made in developing new varieties with superior yield potential owing to time lag between the release of the variety and its adoption by farmers. A rapid rate of varietal replacement in farmers' fields not only leads to higher returns to plant breeding research by increasing adoption but also increase genetic diversity if varieties are from diverse parentage (Brennan and Byerlee, 1991).

Coefficient of Parentage of Wheat Varieties During the field survey it was found that the majority of the sampled farmers extensively grew modern bread wheat varieties. Most of these varieties, however, were introductions from CIMMYT, Kenya or selections from Ethiopian local landraces with some common parents or ancestors. Table 6.4 presents the coefficient of parentage (COP) which measures the degree of relatedness among varieties (Payene *et al*., 2002). The COP values vary from as low as 0.071 (between Batu and Enkoy) to 0.383 (between Dashen and HAR 1685). Most of the recently released wheat varieties not only related to each other, but also to the recommended or 'obsolete' varieties still grown by farmers. Pavon, the most widely grown variety has high COP values of 0.274 each with HAR 416 and HAR 1685 and Dashen (0.297). HAR 1709 has high COP value with HAR 416 (0.281). Dashen also had the highest COP values with HAR 1685 followed by Pavon and HAR 416. The COP data and the proportion of area occupied by each variety were used to measure the average diversity and the weighted diversity of bread wheat varieties deployed in farmers' fields (Souza *et al*., 1994; Witcombe *et al*., 2001).

First, the COP data was used to measure the average diversity of bread wheat varieties in farmers' fields. Here bread wheat varieties with unknown association with current varieties (e.g., Kenya) or those considered local landraces (e.g., Israel) were excluded, although some of them still occupied more than 0.1% of the total wheat area in the 1997/98 cropping season. The most popular bread wheat variety ET 13 has Enkoy as one parent and therefore a maximum COP value of 0.5 was assigned between the two varieties assuming they are from unrelated parents. Likewise, K6295

Table 6.4. The coefficient of parentage[2] matrix of modern bread wheat varieties currently grown in Ethiopia.

	Batu	Dashen	Enkoy	ET 13	HAR 416	HAR 710	HAR 1685	HAR 1709	K6295	Pavon
W[1]	0.115	0.061	0.009	0.111	0.002	0.107	0.116	0.022	0.021	0.436
Batu	1	0.184	0.007	0	0.147	0.071	0.144	0.073	0	0.152
Dashen		1	0.008	0	0.231	0.096	0.383	0.116	0	0.297
Enkoy			1	0.5	0.009	0.005	0.008	0.005	0	0.01
ET 13				1	0	0	0	0	0	0
HAR 416					1	0.091	0.197	0.281	0	0.274
HAR 710						1	0.083	0.045	0	0.122
HAR 1685							1	0.098	0	0.274
HAR 1709								1	0.5	0.137
K6295									1	0
Pavon										1

[1] W= proportion of area occupied by each variety used for calculating the weighted diversity;
[2] COP values for ET 13 and K6295 are assumptions.

also has Romany as one parent similar to HAR 1709 and, therefore, a COP value of 0.5 was assumed between the two varieties. However, these figures appeared high and it is unlikely that the parents of these varieties came from unrelated ancestors. The average wheat diversity among cultivars grown in an area is measured by subtracting the mean coefficient of parentage from 1 (Souza *et al*., 1994; Witcombe *et al*., 2001) and higher values indicate higher diversity. Accordingly, the average diversity of wheat varieties of known parentage calculated from the COP matrix would be 0.76, if ET 13 and K6295 were excluded from the matrix. If ET 13 and K6295 are, however, kept in the matrix with COP values of 0.5 with Enkoy and HAR 1709, respectively and unrelated to all other varieties the average diversity of wheat varieties grown by farmers would be 0.81 showing slight increase (6%) in diversity. These results are comparable to similar diversity studies elsewhere for crops such as barley for varieties grown between 1971 and 1990 (Martin *et al*., 1991).

Second, the COP data and the proportion of area occupied by each variety were used to measure the weighted diversity of bread wheat varieties. The weighted diversity measures not only the relatedness but also the area occupied by the varieties; and therefore robust criteria to measure the diversity at the farm level. The bread wheat varieties with known COP values and with the proportion of area of more than 0.1% were included for calculating the weighted diversity. Batu, Dashen, Enkoy, ET 13, K6295 and the 'HAR' series altogether accounts for nearly 90% of the total wheat area during the 1997/98 crop season. We calculated the weighted diversity by the formula (d= 1−WRW′) where the COP (R) value in each cell in the matrix is weighted by the proportion of area occupied by each variety (where W is a vector and W′ a transpose). Accordingly, the weighted diversity of bread wheat varieties was 0.66. The weighted diversity is expected to be lower than the average diversity particularly if higher number of varieties is related (because of high average COP values) as seen from the COP values in Table 6.4. It should be noted that, however, fewer varieties dominated the wheat production area. Pavon is predominantly grown by nearly 40% of the farmers in 1997/98 crop season and closely followed by ET 13 which is less related to most of the recommended and newly released varieties. Witcombe *et al*. (2001) found that both the average and weighted diversity increased following participatory variety selection approaches with farmers where previously a single variety predominated the crop area and, thus, lowered the diversity at the farm levels. They reported that weighted diversity increased from 0.26 to 0.61 in the India project site due to releases and adoption of unrelated and diverse varieties following the participatory variety selection.

Agronomic and Morphological Traits Diversity Table 6.5 presents the summary of descriptive statistics including the means, minimum and maximum values, standard error of mean of bread and durum wheat varieties planted over two seasons in the 1998/99 and 1999/00 crop seasons. The number of tillers plant^{-1} ranged from 2 to 10 with an average of 4 for both bread wheat varieties. Tillering is the most important yield component of wheat varieties in this area and most liked by farmers because of the potential it offers for better weed control. Although the average number of days to heading appeared to be similar, the bread wheat varieties had a slightly longer period to heading than durum wheat materials. There was a clear distinction in plant height with local bread wheat varieties such as Menze, Zombolel, Goli and ET 13 (selection from Ethiopian germplasm) having the highest plant height (over 100 cm) and modern varieties such as Batu, Dashen, Pavon, Enkoy and 'HAR' showing shorter plant height (<100 cm). The average grain filling period between bread and durum wheat appears to be similar, but bread wheat varieties had wider range than durum local landraces with short gain filling period. Belay *et al.* (1993) reported that local landraces of durum wheat had short grain filling period. Tarekegne *et al.* (1996) also found that in bread wheat varieties plant height was reduced significantly, while the days to anthesis was significantly increased over the period of varietal releases since 1949.

Among the bread wheat varieties Pavon gave the highest grain yield followed by K6295 and Enkoy whereas Boohai (the modern variety) was the highest yielder among durum wheat close to the expectations farmers gave during the field survey. Experi-

Table 6.5. Range, mean, standard error of mean for eight agronomic traits of bread and durum wheat varieties over two crop seasons (1998/99 and 1999/00 crop season).

Agronomic characteristics	Bread wheat			Durum wheat		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Number of tillers plant^{-1}	2	10	4.2 ± 0.2	2	10	4.3 ± 0.1
Days to heading (d)	49	97	67 ± 1.0	51	78	67 ± 0.4
Days to maturity (d)	114	147	131 ± 1.1	114	147	132 ± 0.8
Grain filling period (d)	21	82	64 ± 1.4	47	84	66 ± 0.8
Plant height (cm)	72	128	94.3 ± 1.3	65	115	90.9 ± 0.9
Grain yield (kg ha^{-1})	1050	7590	3702 ± 109	250	5550	2381 ±121
Biomass yield (kg ha^{-1})	3750	10000	7343 ± 123	6384	9375	6384 ± 123
Number of grains spike^{-1}	19	53	36.0 ± 0.8	5	57	30.4 ± 0.9
Thousand seed weight (g)	22.8	45.7	33.5 ± 0.5	8	53.09	27.2 ± 0.8

mental stations yields ranging from 5 to 7 t ha^{-1} were reported earlier for modern wheat varieties (Tarekegne, 1996a). The number of kernels spike^{-1} and the thousand seed weight among bread and durum wheat appeared to be also different. Almost all bread wheat varieties had higher number of kernels spike^{-1} and higher thousand seed weight than durum wheat varieties and were, therefore, widely accepted by farmers because of high potential yield. Alemayehu *et al.* (1999b) reported substantially higher number of grains per spike but results similar to ours for thousand seed weight for recently released bread wheat varieties. In general, durum wheat local landraces have low thousand seed weight compared to modern varieties (Belay *et al*., 1993).

The wide range in the extreme values of each of the traits studied particularly among the modern varieties will provide farmers an opportunity to make a choice of genotypes that will fit best to their niche environments. Moreover, the variation that exists among the local landraces offers broad opportunities for using the genotypes with desired agronomic characteristics in the plant breeding programme to develop varieties suitable for different agro-ecological zones of the country.

Correlation Coefficient Analysis The correlation coefficients between agronomic and morphological traits are presented in Table 6.6. In bread wheat correlation among the traits was not only weak but also insignificant with few exceptions. The correlation between days to heading and thousand seed weight was highly significant and negative ($P<0.01$). Grain filling period had a highly significant negative correlation with days to maturity and a highly significant positive correlation with thousand seed weight. Similarly, plant height was negatively correlated with number of kernels per spike ($P<0.01$)

Table 6.6. Simple Pearson correlation coefficient of agronomic and morphological traits for bread wheat (matrix above diagonal) and durum wheat (matrix below diagonal).

	TIL	DTH	DTM	GFP	PH	GYD	BYD	NKS	TSW
Tillers plant^{-1} (TIL)	-	–0.26	0.03	0.26	–0.18	0.03	0.13	–0.23	0.40
Days to heading (DTH)	0.10	-	0.12	–0.99**	0.26	–0.03	–0.03	0.09	–0.63*
Days to maturity (DTM)	0.40	0.28	-	0.44	0.24	0.11	0.28	0.03	–0.01
Grain filling period (GFP)	0.09	–0.90**	0.17	-	–0.21	0.16	0.08	–0.09	0.64**
Plant height (PH)	–0.16	–0.53	0.07	0.57	-	0.23	0.56*	–0.66**	–0.03
Grain yield (GYD)	0.28	–0.86**	0.07	0.91**	0.57	-	0.51	–0.11	0.16
Biomass yield (BYD)	0.48	–0.13	0.51	0.37	0.09	0.46	-	–0.51	0.37
Number of kernels spike^{-1} (NKS)	0.12	–0.77**	0.21	0.88**	0.70*	0.89**	0.48	-	–0.45
Thousand seed weight (TSW)	0.28	–0.77**	0.25	0.90**	0.50	0.94**	0.51	0.91*	-

* and ** are significant at $P<0.05$ level and $P<0.01$, respectively.

and a significant positive correlation with biomass yield ($P<0.05$). The negative association between plant height and number of kernels is obvious as modern bread wheat varieties with short plant height had long spikes and thus more grains as compared to tall local landraces with short spike length associated with a low number of kernels spike^{-1}. A positive association is expected between plant height and biomass yield because the taller the plants the more is the biomass yield. Moreover, some of the modern bread wheat varieties had high tillering capacity and therefore produced more biomass yield comparable to the local landraces.

In durum wheat, days to heading were significantly, but negatively correlated with grain yield and yield components such as the number of kernels spike^{-1} and thousand seed weight. Grain filling period had highly significant positive correlation with grain yield, number of kernels plant^{-1} and thousand seed weight, but highly significant negative correlation with days to maturity. However, grain yield was significantly ($P<0.01$) correlated with the number of kernels per spike and thousand seed weight. Moreover, the number of kernels spike^{-1} was positively and significantly correlated with thousand seed weight. Belay *et al.* (1993) also reported results similar to our findings where days to heading had significant negative correlation with grain yield, number of kernels and thousand seed weight; and the grain yield had significant positive correlation with number of kernels and thousand seed weight in durum wheat landraces from central Ethiopia. They also found a highly significant negative association between grain filling period and days to maturity, but a positive association with thousand seed weight which is similar to our results. The kernel weight was reported as an important yield component in durum wheat landraces (Belay *et al*., 1993).

Variance Component Analysis Variance component analysis revealed little significant differences among the bread and durum wheat varieties for agronomic characteristics except for days to heading for bread wheat and thousand seed weight for durum wheat and phenotypic characteristics such as growth habit, grain colour and grain shape for both wheat types (data not shown). The estimates of variance components showed the contribution of collection sites towards the patterns of variation that existed among the genotypes which is more pronounced for durum local landraces compared to the modern bread varieties. This is well understood given the recent introduction of modern varieties to their collection sites and where any variation is expected from the genotypes other than the effect of collection sites. Estimates of variance components showed that the patterns of variation among the genotypes were attributed to the collection sites (provinces and districts) from the lowest of 36% for grain yield to 74% of the variation for plant height among the durum varieties and local landraces, although this is not significant in all cases. Tesfaye *et al.* (1991) also found that diversity among local durum landraces from central Ethiopia was attributed to their collection sites (districts) rather than variation within the populations.

However, by dropping the collection sites from the model, almost all the agronomic characteristics measured such as plant height, grain yield, biomass yield, number of kernels spike^{-1} and thousand seed weight showed remarkable significant variation among the genotypes. Therefore, there was a significant difference ($P<0.001$) among bread wheat varieties for tillers plant^{-1}, days to heading, grain yield, number of kernels spike^{-1} and thousand seed weight. Days to maturity and biomass yield were not significant among bread wheat varieties. Likewise, durum wheat varieties showed significance differences ($P<0.001$) for days to heading, grain yield, and thousand seed weight. Number of kernels spike^{-1} was significant at $P <0.01$. The number of tillers plant^{-1}, days to maturity and biomass yield was not significantly different among the durum wheat varieties. On the contrary significant difference on number of tillers plant^{-1} was observed among local landraces of wheat collected from central Ethiopia and suggested as useful agronomic trait from crop improvement (Belay *et al*., 1993).

Principal Component Analysis The principal component analysis was made to estimate the relative contribution of the different traits studied towards the overall agronomic and phenotypic variations among the local durum landraces. The principal component analysis showed that the first three components with eigenvalues more than unity altogether explained 84% of variation among 11 durum wheat local landraces for 12 agronomic and phenotypic characteristics studied (data not shown). The first, second and third components each accounted for 44%, 22% and 18% of the variation, respectively. Plant height, grain yield, number of kernels spike^{-1} and thousand seed weight were most important agronomic characteristics contributing to the first principal component. The phenotypic characteristics such as growth habit, ear shape, grain colour and grain shape were important for the second component. According to Demisie and Habtemariam (1991) Ethiopian durum wheat landraces exhibited an enormous variation in spike form, spike density, awn size and glume colour and glume hairiness. The third component was associated with days to maturity, tillers plant^{-1} and biomass yield. Ayana and Bekele (1999) also found that plant height and days to 50% flowering as important agronomic characteristics for classifying sorghum germplasm in Ethiopia.

The distribution of durum wheat local landraces along the first two axes of the principal components is presented in Fig. 6.4. The first principal component is more important in separating the durum wheat local landraces as compared to the second component. The extreme right of the first component was occupied by Boohai, a modern variety developed from germplasm materials introduced from CIMMYT compared to other local landraces which are known to be of Ethiopian origin. The first principal component differentiated the low yielding local landraces from high yielding modern varieties based on grain yield and yield components such as number of kernels spike^{-1} and thousand seed weight. Belay *et al.* (1993) reported that local landraces were later in days to heading and maturity and had lower kernel weight compared to Boohai, a

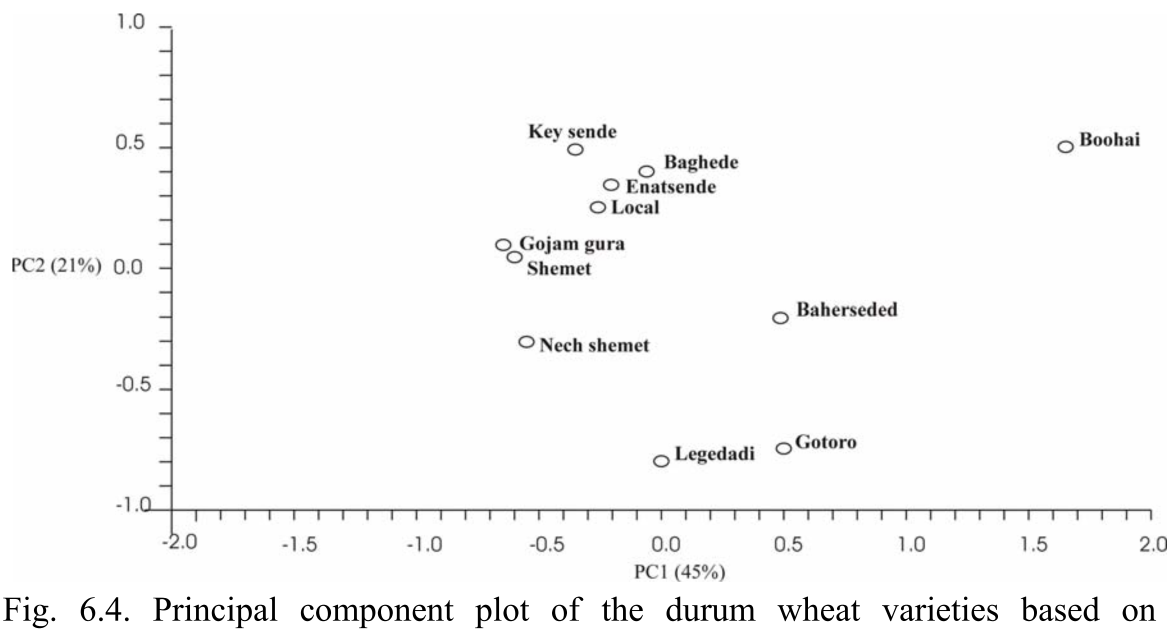

Fig. 6.4. Principal component plot of the durum wheat varieties based on 12 agronomic and phenotypic traits.

modern variety. The second component was able to separate early maturing landraces from late maturing genotypes. Gotoro and Legedadi occupied the extreme negative values of the second component and appeared to head earlier compared to other genotypes. Baherseded, Shemet and Nech shemet head slightly later than other genotypes. Landraces such as Baghede, Enat sende, Gojam gura and Key sende ('red' grain) as the name suggests could be separated from others on seed colour. Belay *et al.* (1995) reported that local landraces exhibited a wide range of colours from white, red/brown to purple coloured grains; and the purple-grain landraces have useful agronomic traits such as early maturity, shorter height, higher fertility, tillering capacity and harvest index. However, most of the modern wheat varieties had amber colour (Alemayehu *et al.*, 1999b) with few exceptions such as Enkoy and K6295 with red kernels.

In case of bread wheat the principal component analysis showed that the first four components with eigenvalues more than unity accounted for 74% (22%, 21%, 18% and 12%, respectively) of the variation among the varieties (data not shown). The first component was associated with plant height and ear shape whereas the second component with agronomic characteristics such as days to maturity, grain yield, biological yield and phenotypic characteristics such as ear colour and grain colour. The third component was associated with agronomic traits such as tiller plant^{-1} and thousand seed weight and the fourth with number of kernels spike^{-1}.

Cluster Analysis Clustering based on agronomic and phenotypic traits revealed three clusters separating the recently introduced modern variety (Boohai) and long established local landraces (Fig. 6.5). The correlation between the cophenetic value matrix and actual matrix data was very high (0.91) indicating a very good fit of the cluster analysis performed. The durum wheat local landraces were not all clustered along their region of geographic origin based on the morphological triats. Baherseded, Gotoro and Legedai were collected from West Shoa and were clustered together but differently from Bagehede and Key sende which were collected from the same region. Enate sende, Gojam gura and Shemet all from North Shoa were within the same subcluster with another unidentified local landrace from the same region. However, Nech shemet was clustered with Gojam gura instead of Shemet. The durum wheat landraces from North Shoa were heading late, had low grain filling period and low grain yield. Kebebew *et al.* (2001a) also reported that durum landraces collected from central and southeastern Ethiopia were not clustered along their collection sites or geographic origin. Instead, durum landraces with similar vernacular names collected from different sites or geographic regions were clustered together than those local landraces from the same collection sites or geographic regions. Ethiopian durum wheat landraces exhibited

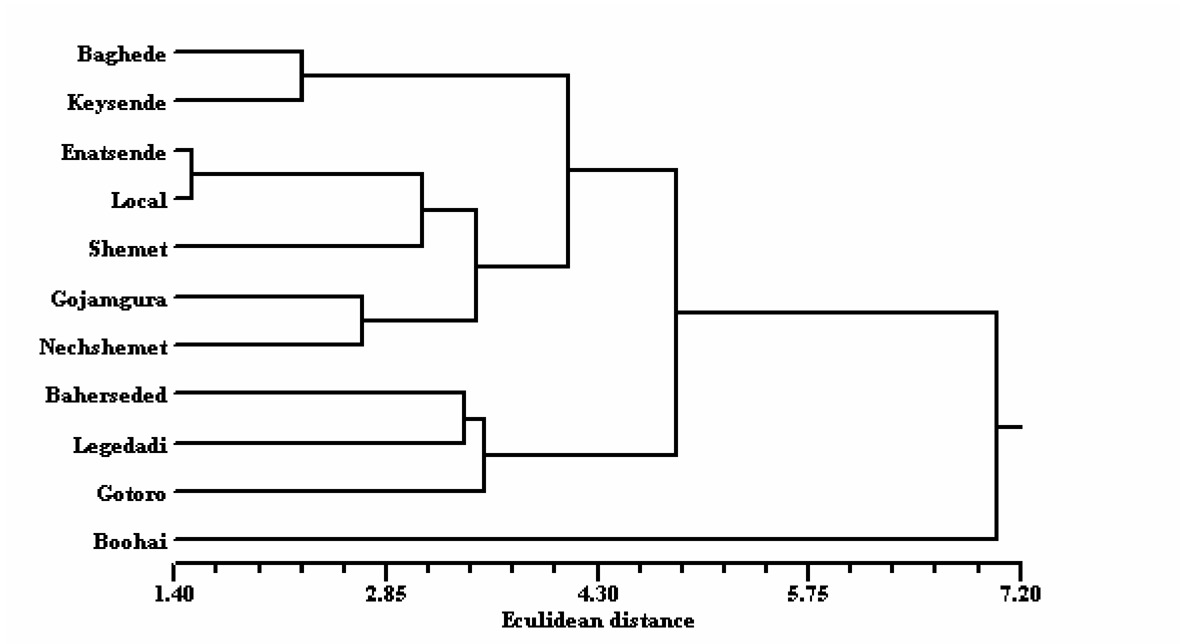

Fig. 6.5. Dendrogram showing the clustering of durum wheat local landraces collected from farmers in Ethiopia.

tremendous diversity for some phenotypic characteristics such as grain colour ranging from white to purple colour. Local landraces such as Baghede, Enat sende, Gojam gura and Key sende ('red' seeded wheat as the name suggests) were grouped together within the same subcluster because of their patterns of grain colour mixtures. Tesfaye *et al.* (1991) reported that a high proportion of landraces had purple seed colour across different districts. Some local landraces such as Tikur sende are used for specific purposes such as for brewing local beer or spirits (Kebebew *et al.*, 2001a) while white coloured ones are used for social or religious festivities. The prefixes such as *'key'* (red), *nech* (white), *tikur* (black), *sergegna* (white and red mixture) are useful folk taxonomy in classifying local landraces based on the proportion of grain colour mixtures not only in wheat but also in other crops such as barley (Kebebew *et al.*, 2001b) in Ethiopia. Local names could be used to describe the performance or to indicate the original source of local landraces. Moreover, farmers may coin new names for modern varieties and some varieties are better known by their adopted name than their release or pedigree names. For example a new bread wheat variety, HAR 1685 is identified popularly by farmers as *Quobsa* because of its high yield.

Clustering separated the varieties into six clusters (data not shown). Israel, one of the 'oldest' popular local bread wheat of unknown origin was placed completely distinct from the rest of the group. The local variety had the highest thousand seed weight and unique phenotypic characteristics in terms of ear shape and awn condition compared to other bread wheat varieties. In Cluster 2, Enkoy and K6295 were grouped together because of their unique red grain colour as compared to all bread wheat varieties with white to amber colour including local bread wheat varieties (Alemayehu *et al*., 1999b). This is in contrast to local durum landraces where variable grain colour is most common. ET 13 and Goli had the highest plant height and were, therefore, grouped together in Cluster 3 while Zombolel, another local variety, stood alone in Cluster 5. However, the clusters did not match the clustering constructed from the COP values.

In summary, Ethiopia has immense heritage and diversity of biological and physical environments. The Ethiopian farmers are growing durum wheat for a millennium and the country was recognized as a centre of diversity for tetraploid wheats (Demissie and Habtemariam, 1991) while the bread wheat is comparatively of recent introduction (Gebremariam, 1991b). The national bread wheat breeding programme has benefited substantially from the introduced germplasm from the IARCs. As a result, plant breeders have made good achievement in developing varieties acceptable to farmers at least in favorable production areas. There is substantial increase in bread wheat area and production in traditionally durum wheat growing regions of central and northwestern Ethiopia. At present, the high adoption and diffusion rate of modern varieties coupled with recurrent drought in traditionally durum wheat growing areas of the country are threatening the existence of local landraces and leading to loss of such immense diversity (Chapter 2 and this Chapter). Moreover, the predominance of a few bread wheat varieties calls for concern in a country where devastating rust epidemics are common features of crop production. There seems to be an urgent desire for appropriate conservation measures to be undertaken for the durum wheat landraces and at the same time diversify the choice of bread wheat varieties available to farmers.

The diverse agro-ecology and long history of association with the wheat crop and its production under a variety of socio-economic and cultural situations led to the evolution of highly diverse forms of local landraces which could be of practical benefit for crop improvement. Several workers reported the diversity of quantitative and qualitative characteristics of the Ethiopian wheats (Demissie and Habtemariam, 1991; Belay *et al*., 1993, Tesfaye *et al*., 1991). Durum wheat landraces such as Enat sende and Nech shemet from North Shoa were identified by farmers as having frost tolerance characteristics (Kebebew *et al*., 2001a). Moreover, purple seeded wheat matures earlier and has higher tillering capacity than other colour types and a good adaptation to water-logged soil conditions in high-altitude areas (Kebebew *et al*., 2001b). Monomorphism for awn condition (presence or absence) was also reported for local landraces which is similar to our findings, a useful trait for tolerance to plant diseases (Tesfaye *et al*., 1991). It was suggested, however, that durum wheat crop improvement would be possible through indirect selection for tiller numbers plant^{-1} and thousand seed weight or direct selection for yield *per se* (Belay *et al*., 1993). Moreover, alternative breeding strategies led to the development of 'composites' with up to 20-25% more yield than local landraces and 10-15% more than modern varieties (Tesemma and Bechere, 1998). The study has shown that the few wheat varieties, particularly the durum wheat local landraces collected from farmers, were diverse in agronomical and phenotypic characteristics offering greater opportunities for developing germplasm adapted to the varied agro-ecology and diverse end uses and consumer preferences. This would contribute towards the maintenance of genetic diversity on the farm and counter balance the ensuing genetic erosion.

6.4.2. Wheat and Barley Diversity in Syria

The long-term average rainfall for Breda and Tel Hadya experimental farms are 253 mm (42 seasons) and 340 mm (21 seasons), respectively. In 1997/98 the onset of the rainy season started early in September and extended to May the next year with the highest rainfall during the months of January, March and April where the season's average was close to 90% for Breda and about 120% for Tel Hadya showing

Table 6.7. Average monthly temperature and rainfall during 1997/98, 1998/99 and 1999/00 crop seasons at Breda and Tel Hadya experimental stations, Syria.

	Breda		Tel Hadya					
	1997/98		1997/98		1998/99		1999/00	
Months	Rainfall mm	Average °C	Rainfall mm	Average °C	Rainfall mm	Average °C	Rainfall mm	Average °C
September	17.8	22.8	18.1	24.0	0	26.5	0.7	25.4
October	18.0	19.3	36.3	20.4	2.2	21.2	10.1	21.0
November	10.8	12.1	37.9	13.7	38.6	15.5	7.6	12.7
December	29.4	8.4	62.3	9.0	88.4	9.6	22.4	8.7
January	47.2	5.7	83.6	6.6	39.5	8.3	110.3	5.8
February	17.0	7.4	37.6	7.7	51.4	9.7	38.1	7.0
March	38.6	10.0	59.3	10.5	62.0	11.8	41.3	10.6
April	39.2	16.4	63.7	16.2	25.1	15.9	29.9	17.3
May	9.4	21.0	11.7	20.4	0	23.1	0.3	21.0
June	0	26.4	0	26.8	0	26.5	0	27.0
July	0	30.5	0	30.5	0	29.9	0	31.1
August	0	31.9	0	31.0	0	30.8	0	29.6
Total/mean	227.4	17.7	410.5	18.1	307.2	19	260.7	18.1

comparatively better harvest year. In the next two years the seasonal rainfall was 90 and 77% of the long-term average rainfall for Tel-Hadya. The latter was a poor crop season with bad harvest for rainfed agriculture in many parts of the country. In 1998/99 crop season the wheat experiments were planted later in the season than the normal planting time.

Spatial Diversity of Wheat Varieties In 1998, from 206 wheat farmers sampled 50.9, 32.0% and 16.9% grew durum, bread or both wheat varieties, respectively. About 16 wheat varieties (eight each of durum and bread wheat) were found grown by farmers excluding the local landraces. The number of wheat varieties grown per farm is given in Table 6.8. The diversity of wheat varieties on the farm was exceptionally low both for bread and durum where 96 and 84% of the farmers, respectively, planted only one variety. Few farmers (4% for bread wheat and 16.5% for durum) planted more than one wheat variety. Similarly, the picture remained the same if both bread and durum wheats were taken into account as well. In Hasakeh and Raqqa wheat farmers were more inclined to concentrate on single varieties than in Aleppo probably because of relatively large areas for mechanization. Mazid *et al.* (1998) found a low level varietal

Table 6.8. The number of bread and durum wheat varieties currently grown by farmers (n=241) in Syria.

Number of varieties	Aleppo		Raqqa		Hasakeh		Total	
	Farmers	%	Farmers	%	Farmers	%	Farmers	%
All wheats								
1	72	82	32	94	110	92	215	89
2	11	13	2	6	9	8	22	9
3	5	6	0	0	0	0	5	2
Total	88	101	34	100	119	100	241	100
Bread wheat								
1	30	94	20	95	47	98	97	96
2	2	6	1	5	1	2	4	4
3	-	-	-	-	-	-	-	-
Total	32	100	21	100	48	100	101	100
Durum wheat								
1	42	75	12	92	63	89	117	84
2	9	16	1	8	8	11	18	13
3	5	9	-	-	-	-	5	4
Total	56	100	13	100	71	100	140	101

diversity for durum wheat with an average of 1.4 varieties per farm. Rohrbach (1997) also found that although the number of sorghum and pear millet varieties per small-holder farming area was 6.4 and 3.8 varieties, respectively about 71% of sorghum and 73% of pearl millet growers planted one variety only. On the other hand reports from elsewhere show high varietal diversity on the farm where 81% (n=75) and 60% (n=35) of farmers, respectively grew more than 2 varieties of sorghum and pearl millet, although the diversity of other (minor) crops was less (Mpande and Mushita, 1996). Louette *et al.* (1997) also reported that in traditional maize production areas of Mexico farmers grew between one and seven maize varieties during each season and on average more than two varieties per season probably because of the diverse end uses for the grain. However, from 26 maize varieties grown by farmers four local varieties were planted by the majority of farmers and almost occupied 80% of the maize area, showing low spatial diversity even in traditional farming systems.

At the community level the number of varieties grown was fairly low compared to Ethiopia. In the survey area 33 out of 61 villages grew a single bread or durum wheat variety. More farmers in Hasakeh tended to grow a single variety because this was associated with a government policy of ‘closed’ areas in producing some wheat varieties as part of export promotion to meet certain grain quality standards. The wisdom of such practice is not clear in case of breakdown of disease resistance. However, the rapid technological changes in agricultural production in general and cereal production in particular might contribute to monocropping and use of limited number of varieties at the farm level. The five possible points that may explain the phenomenon could be (a) a trend towards intensification of agriculture where productivity is a more important incentive for farmers than diversity of crops and products, (b) the ease of crop management where all field activities could be undertaken in a single operation for a specific crop variety rather than different varieties competing for labour and resources, (c) lack of differences among wheat varieties fitting specific niche environments, (d) the lack of difference in yield and agronomic management among existing wheat varieties, and (e) ease of marketing wheat grain at a premium price to the government without any specific market quality requirements.

The proportion of farmers growing the top six varieties of wheat varieties over a four-year period from 1995/96 to 1998/99 cropping season is presented in Fig. 6.6. The total number of wheat varieties grown remains the same, although few durum local landraces such as Dahabi and Hamari were dropped as farmers are adopting new varieties. On the other hand, few bread varieties (Lagous and Memof) entered production, before they were officially released. Memof was later released as Cham 8 in 2000. This demonstrates the spectacular leakage of some successful modern varieties from research stations without going through formal release and registration

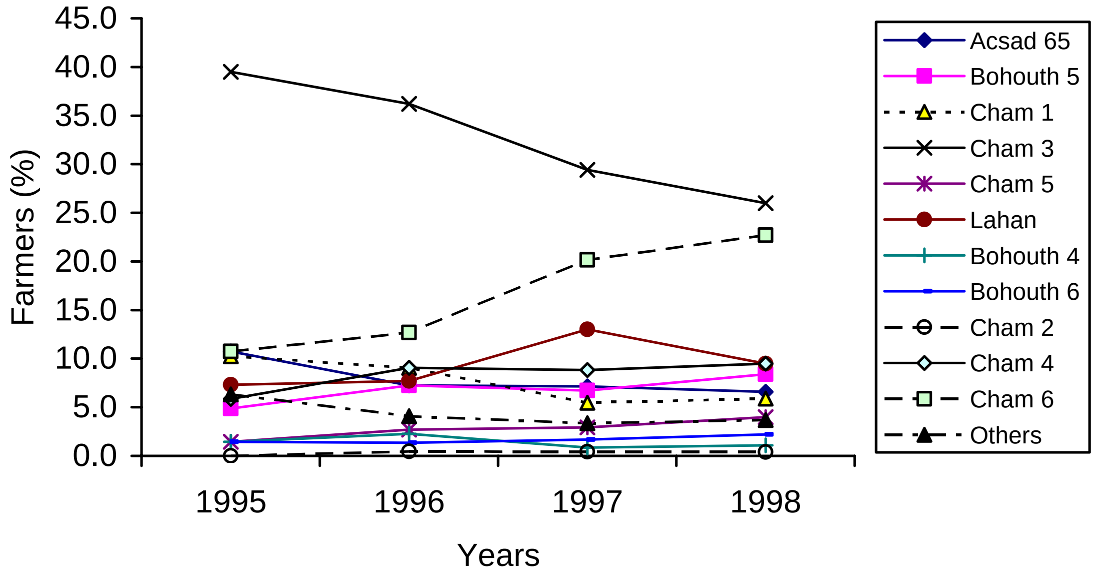

Fig. 6.6. The pattern of bread and durum wheat varieties grown by farmers in Syria.

procedures (Cromwell, 1990), which can be exemplified by Lahan variety in Syria. Lahan, a durum wheat variety, was not officially released by the national agricultural research system due to its late maturity (15 days late) and high water requirement. However, the variety was very popular with farmers because of its high response to inputs and therefore spreading through lateral farmer-to-farmer seed diffusion mechanisms. The variety is suitable for irrigated areas and gave a grain yield advantage of 16% and 4% over Gezira 17 and Cham 1 durum wheat varieties, respectively.

The top five wheat (bread and durum) varieties, on average, were planted by 77.7% of the farmers. ACSAD 65, Cham 1, Cham 3 and Lahan among durum wheat and Cham 6 among bread wheat varieties remained dominant. Cham 3 was a single most popular variety, although it dropped significantly from around 40% in 1995 to 25% in 1999, if both wheat types were considered together. These percentages would be substantially higher if the two wheat species considered separately. The proportion of farmers growing early generation modern durum wheat varieties was declining (Fig. 6.6). ACSAD 65 and Cham 1 were grown by less than 10% of the farmers. On the other hand the proportion of Bohouth 5, Cham 5, and Lahan was increasing as farmers were adopting new varieties released in the 1990s. In case of bread wheat Cham 4 and Cham 6 remained popular with the farmers and the proportion showed an upward trend (Fig. 6.6). The number of farmers growing these two varieties doubled over a four-year period from 5 to 10% for Cham 4 and from 10 to 20% for Cham 6. The older

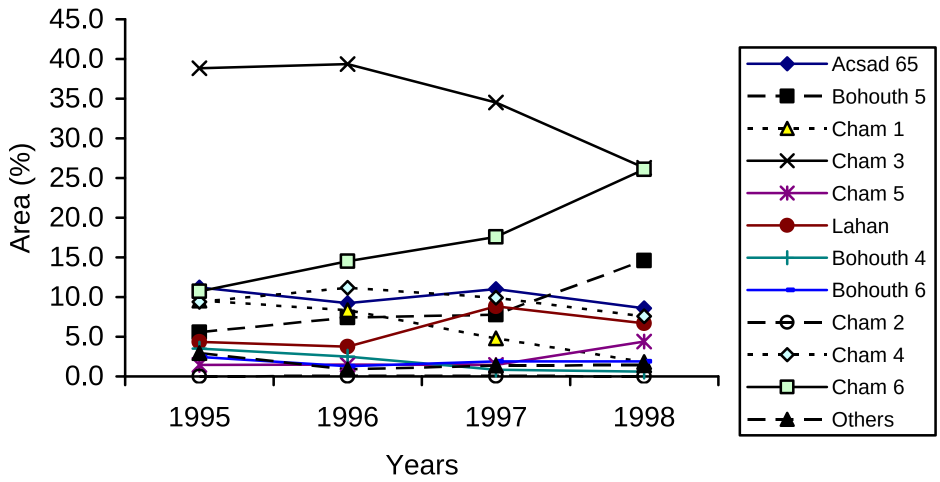

Fig. 6.7. The pattern of bread and durum wheat area grown by farmers in Syria.

bread wheat varieties and earlier releases such as Cham 2 and Mexipak were grown by less than 5% of the farmers surveyed. If one discounts few 'obsolete' varieties and local landraces in isolated pockets, the entire population of wheat growers planted a handful of bread and durum wheat varieties. In the early 1990s, Mazid *et al.* (2003) also found that Cham 1 and Cham 3 covered about 63% of the durum wheat area and was planted by 56% of the farmers showing high level of varietal concentration.

Fig. 6.7 presents the area allocated to top bread and durum wheat varieties grown over a four year period by sampled farmers. The proportion of area allocated appeared to be consistent with the national statistics, 71% for durum and 30% for bread wheat. However, the durum wheat area is trending downward whereas that of bread wheat is on the increase. As indicated in Chapter 3, the availability of irrigation facilities enabled farmers to grow bread wheat varieties outside their recommendation domains in less rainfall areas increasing the scope for on-farm crop diversification. However, on average the top five bread and durum varieties together occupied about 80.7% of the wheat area. Among durum wheat varieties, Cham 3 occupied the largest proportion of area although this trend is declining over the four year period from around 40% to nearly a quarter of the area in 1999. ACSAD 65 and Cham 1 were also in the declining trend whereas the newer varieties such as Bohouth 5 and Cham 5 were showing an upward trend as farmers seeking new varieties. Lahan, a non-recommended durum wheat variety still occupied about 10% of the wheat area, exhibiting the resilience of informal seed diffusion system. In case of bread wheat Cham 6 appeared to cover the highest proportion of the area followed by Cham 4.

The most interesting observation during the field survey was the situation of durum local landraces. Most farmers acknowledged that in the past local landraces such as

Bayadi, Dahabi, Hamari, Hourani, Swadi were extensively grown. At present, the landraces were virtually replaced by modern varieties that are high yielding and responsive to improved management practices including use of fertilizers and irrigation water in all major wheat production areas of the country. All traditional landraces were tall and had a problem of lodging under high input conditions and, therefore, did not present economic benefits to those farmers investing in new technologies. In contrast, local durum landraces are still under cultivation in isolated pockets where some farmers still use traditional practices including the use of organic fertilizers (manures) and no seed treatment. A comparison made between the local landraces and modern varieties showed an interesting result. Farmers recognized that modern varieties give high yield and disease resistance but give low straw yield and quality (short plant height) and have high requirement for water and inputs. On the other hand, the landraces give low yield, but excellent grain quality, good tolerance to frost, heat and shattering and high straw yield and quality. Farmers claim the landraces have excellent quality in preparation of traditional foods, i.e., soft grains, less time for cooking, less ingredients and above all an excellent taste. Moreover, most of the landraces were mainly grown for home consumption where there are differences in the household use. Some local landraces are more preferred for *burghul* and *kibbe* than for *frekeh* which gives farmers an incentive to grow them. The landraces also have a range of kernel colour and size: white for Bayadi, red for Hamari and black/dark for Swadi. Apart from home consumption, farmers also sell the grain of local landraces within the village or local traders who often pay premium prices compared to grain of modern varieties.

The important features observed are: (a) the dramatic decline in the proportion of area under local durum landraces and their complete replacement with modern varieties; (b) decrease in the area of previously dominant durum wheat varieties such as Cham 1 and Cham 3 as more farmers adopting newer releases; (c) increase in the proportion of bread wheat varieties such as Cham 4 and Cham 6; and (d) the persistence of older varieties such as Mexipak and Cham 1 in the farming system. It can be observed that bread and durum wheat production is dependent on few selected modern varieties where traditional local landraces were being completely replaced in major wheat growing regions. These results once again demonstrated a high degree of cultivar concentration where the vast majority of farmers grew few varieties covering a large expanse of land.

Temporal Diversity of Wheat Varieties From 1970 to 1998, eight durum and six bread wheat varieties have been released by the national agricultural research system in Syria with an average of 4.7 varieties per decade. There was not much difference in the number of modern varieties released between the two wheat types. However, there was remarkable adoption and diffusion of these limited number of bread and durum wheat varieties by the majority of farmers.

In the previous section we used the weighted average age (WA) of varieties to estimate the rate of varietal replacement (temporal diversity) of bread wheat varieties in Ethiopia based on formula developed by Brennan and Byerlee (1991). In Syria, the WA calculated for wheat was close to 11 years (Table 6.9) with no difference between the two wheat types. The figure is higher than the previous report of 6.8 years (Mazid *et al.*, 1998). Moya and Piedad (1993) estimated a range of 6 to 8 years weighted average age for wheat varieties, although recent literature showed a much higher figure of 12.7 years (Smale *et al.*, 1996). In the 1970s, the area planted to improved wheat was dominated by introductions from elsewhere (Mazid *et al.*, 1998 and 2003; Bailey, 1982). However, at present the percentage of farmers growing modern varieties and area covered with new varieties released in the late 1980s and early 1990s is higher than for improved tall varieties introduced previously (Mazid *et al.*, 2003). Farmers in Syria tend to replace modern wheat varieties in relatively shorter period of time and therefore obtain better benefit from newly released varieties compared to farmers in Ethiopia or elsewhere. At present, the high average age of varieties and predominance of few varieties indicate low on-farm varietal diversity. The WA may likely continue to increase unless new and

Table 6.9. The weighted average age of bread and durum wheat varieties currently grown in Syria.

Variety	Year released	Years since release	Mean area (ha) in 1998	Weighted average age
Acsad 65	1987	11	11.31	1.47
Bohouth 5	1987	11	15.03	1.96
Cham 1	1984	14	2.66	0.44
Cham 3	1987	11	8.74	1.14
Cham 5	1994	4	9.50	0.45
Gezira 17	1975	23	5.00	1.36
Bohouth 4	1987	11	4.67	0.61
Bohouth 6	1991	7	7.42	0.62
Cham 2	1984	14	0.50	0.08
Cham 4	1986	12	6.87	0.98
Cham 6	1991	7	9.92	0.82
Mexipak	1971	27	2.75	0.88
Total				10.82

well-adapted and high-yielding varieties with better grain quality are released and adopted by farmers. For example, after the survey year the national agricultural research system released two bread and three durum wheat varieties for commercial crop production.

Coefficient of Parentage of Wheat Varieties The plant breeding programme of wheat in general and of durum wheat in particular was successful in developing varieties that are adapted to stress environments and at the same time responsive to better management practices (Mazid *et al*., 2003). As a result almost all wheat farmers in Syria have adopted modern varieties of both bread and durum wheat. Similar approaches as for Ethiopia were used to measure the average diversity and the weighted diversity of bread and durum wheat varieties grown by farmers. The coefficient of parentage for bread wheat varieties is given in Table 6.10. Cham 2 has high COP values in decreasing order with Mexipak (0.420), Cham 4 (0.332) and Bohouth 6 (0.248), but the area under the variety was insignificant compared to other varieties and therefore excluded from the COP analysis. The bread wheat varieties have a mean COP of 0.27 (excluding Cham 2). Therefore, the average diversity calculated based on the mean COP was 0.73 showing values comparable to similar diversity studies of bread wheat varieties based on COP analysis. Souza *et al.* (1994) measured the average and weighted diversity of bread wheat in two contrasting environments of two developing countries. They found the average diversity of 0.75 and 0.78, respectively, in Yaqui Valley (Mexico) and Punjabi (Pakistan) for spring wheat varieties grown from 1981 to 1990. The persistence of old varieties may increase the average diversity but may reduce the temporal diversity of varieties. Much higher average diversity was reported for other crops elsewhere (Martin *et al*., 1991). The weighted diversity, however, was 0.42 showing a very low diversity of bread wheat varieties at the farm level. This is understood given the fact that Cham 6 was the dominant variety grown by almost 70% of bread wheat producers followed by Cham 4 (21%).

In durum wheat, however, the COP values are unknown except between ACSAD 65 and Cham 1 (0.188). Cham 5 (42%), Bohouth 5 (23%) and Lahan (11%), which occupied a large proportion of the durum wheat area, appeared to be unrelated to each other. The average diversity of 0.85 would be obtained if all durum varieties with over 0.1% wheat area would be considered and kept as unrelated for the COP analysis (data not shown). The average diversity is higher with unrelated varieties compared to when many related varieties are grown. However, excluding varieties that are not related from the analysis will increase the mean COP and will reduce the average diversity of durum wheat substantially. The weighted diversity for durum wheat calculated based on the proportion of area of wheat varieties grown was 0.73. The weighted diversity was higher

Table 6.10. The coefficient of parentage matrix for bread wheat currently grown varieties in Syria.

	Cham 4	Cham 6	Bohouth 4	Bohouth 6	Mexipak
W[1]	0.207	0.711	0.016	0.052	0.014
Cham 4	1	0.070	0	0.169	0.290
Cham 6		1	0	0.068	0.077
Bohouth 4			1	0	0
Bohouth 6				1	0.239
Mexipak					1

[1] Proportion of wheat area planted to each variety used for calculating the weighted diversity.

Table 6.11. Mean, minimum, maximum, standard error of mean for agronomic traits of bread and durum wheat varieties/landraces in Syria.

Agronomic characteristics	Bread wheat			Durum wheat		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
No of tillers plant^{-1}	0.4	6.9	2.85 ± 0.1	1	5	2.18 ± 0.1
Days to heading (d)	103	121	110 ± 0.6	87	117	103 ± 0.5
Plant height (cm)	46	83	60.1 ± 0.9	43	117	71.3 ± 1.2
Grain yield (kg ha^{-1})	322	2310	1124 ± 40	518	2120	1271 ± 22
Biomass yield (kg ha^{-1})	858	9297	5847 ± 170	2845	9948	6498 ± 119
Spike length (cm)	6.3	13.8	9.26 ± 0.1	4.8	8.9	6.62 ± 0.1
No of spikelets spike^{-1}	16	26.4	19.6 ± 0.2	14	30.9	20.2 ± 0.2
No of kernels spike^{-1}	18.8	43.8	31.2 ± 0.7	15.3	39.0	25.6 ± 0.4
Ear density (ratio)	1.8	3.1	2.1 ± 0.02	1.9	4.2	3.1 ± 0.03

in durum wheat compared to that of bread wheat because of the difference in the number of unrelated varieties grown by farmers. Beuningen and Busch (1997a) indicated that for cultivars of self-pollinating species with known pedigree, a COP can provide an estimate of genetic similarity and can be used as indicator of relative genetic diversity within and between populations and growing regions.

The average and weighted diversity using the COP analysis indicate that durum wheat varieties were more diverse compared to those of bread wheat. The main factors contributing to these differences could be: (a) in durum wheat farmers plant more unrelated varieties compared to bread wheat which contributes to high average diversity; (b) the proportion of area planted by durum varieties is more than that of bread wheat contributing to higher weighted diversity; and (c) there are relatively more durum wheat variety releases compared to that of bread wheat.

Agronomic and Morphological Traits Diversity Most of the agronomic traits measured showed variation within and among bread and durum wheat varieties (Table 6.11). The average number of days to heading was 109 with a range of 103 to 121 days for bread wheat whereas the number of days was relatively shorter for durum wheat varieties. Variation in days to heading and maturity will provide the scope for flexible date of planting under rainfed conditions where the onset of rain quite often is unpredictable in dry areas. Bread wheat varieties had shorter plant height (46 to 83 cm) with an average of 60 cm compared to durum wheat varieties with an average of 71 cm and a range of 43 to 117 cm. This difference could be attributed to the presence of local durum landraces which were consistently taller than the modern durum varieties. There is a large variation in grain yield and biomass yield within the bread and durum wheat varieties. Modern durum wheat varieties consistently gave higher yield than local landraces, although few local materials gave comparable grain yield. Cham 3 and Lahan (not released) gave the highest grain yield among modern durum varieties. On the other hand, the local landraces exhibited the highest biomass yield, higher than the modern durum wheat varieties. Mexipak, the oldest improved variety, gave the lowest grain and biomass yield among bread wheat compared to recently released varieties.

The average spike length and number of spikelets spike^{-1} for bread wheat were 9.3 cm (with a range from 6.3 cm to 13.8 cm) and 19.5 cm (range from 16.0 cm to 26.4 cm), respectively. In case of durum wheat the average spike length was 6.6 cm and the number of spikelets was 20.2. These results were in agreements with previous studies conducted in Syria. Kayyal *et al*. (1995) found significant differences for grain yield components and grain quality traits among released and promising bread and durum wheat varieties in Syria. He found on average 105 days for days to heading, 140 days for days to maturity, 74.4 cm for plant height, 6.3 cm for spike length, 17.1 spikelets per spike, 43.3 g for thousand seed weight and 2819 kg ha^{-1} for grain yield. Such genetic variations among bread and durum wheat varieties offer great opportunity for crop improvement and increasing the yield potential of wheat in dry areas.

Correlation Coefficient Analysis The correlation coefficients among agronomic traits were presented for bread and durum wheat in Table 6.12. In bread wheat plant height had a positive and significant correlation ($P<0.05$) with grain yield and biomass yield, but a highly significant negative correlation ($P<0.01$) with days to heading. Days to heading were negatively correlated with biomass yield ($P<0.05$). Grain yield had strong and positive correlation with biomass yield. In durum wheat more association was

observed among agronomic traits compared to bread wheat. The number of tillers per plant had positive and strong significant correlation with grain yield ($P<0.05$) and biomass yield ($P<0.01$). In durum wheat, the plant height had a negative, but significant correlation with grain yield and number of spikelets and kernels spike^{-1} ($P<0.01$) and spike length ($P<0.05$), possibly because of the taller local landraces with less yield and short spike length. Grain yield had a positive and significant correlation with number of spikelets per spike ($P<0.01$). Similarly, the spike length had a positive and significant correlation with the number of spikelets. The presence of two types of genotypes within the experimental plots led to variation in morphological traits. In an earlier study, Kyyal *et al*. (1995) reported a negative non-significant correlation between yield and days to heading, days to maturity, plant height and spike length (except spikelets per spike) among recommended wheat varieties and promising lines in Syria. They also found positive correlation between spike length and number of spikelets; spike length and seed weight; and days to heading and maturity; and spike length and days to maturity. However, a negative association was reported for days to maturity with number of plants and spikelets m^{-2}. Such variation and association of agronomic traits with yield and yield components has far reaching implications for breeding bread and durum wheat varieties with desired varietal characteristics for farmers to adopt and use them.

Variance Component Analysis The variance component analysis showed more variation among durum wheat varieties (Table 6.13) than among the bread wheat varieties (data not shown) for agronomic traits measured. The greater variation among durum wheat observed was mainly due to inclusion of local landraces collected from isolated sites. A significant difference ($P<0.001$) was observed among bread wheat varieties in terms of tillers per plant, plant height, spike length and ear density over the two crop seasons, but not in days to heading, spikelets spike^{-1}, kernels spike^{-1}, grain yield and biomass yield. However, grain yield in 1998/99 and days to heading in 1999/00 were significant showing the effect of seasonal variation. Similarly, durum wheat varieties exhibited a significant difference ($P<0.001$) for days to heading, number of tillers plant^{-1}, plant height and spike length and spike density (Table 6.13). For grain yield, however, the significance was at $P<0.05$. There was no significant difference among durum varieties for biomass yield and number of spikelets spike^{-1}. The variety × year interaction was significant for days to heading, plant height and number of spikelets spike^{-1}. The estimates of variance components revealed that the patterns of variation among bread wheat (data not shown), durum wheat varieties and local landraces were due to genotype differences rather than to the effect of their collections sites (provinces, districts, etc.). This is not surprising given that most of the varieties grown were of recent introduction to the production sites.

Principal Component Analysis In durum wheat a number of local landraces collected from isolated sites from Aleppo and an adjacent province from Idelib were planted along modern varieties to study the pattern of agronomic and morphological variation. The principal component analysis showed that the first six principal components with eigenvalues of more than unity accounted for about 79% of the total variation among durum wheat varieties and local landraces for the 23 agronomic and morphological traits studied. The first, second and third components (25.5%, 22% and 11.5%, respectively) altogether accounted for a cumulative 52% of the variation. The first principal component was associated with important agronomic traits such as days to heading and grain yield and phenotypic traits such as beak length and cross section of the neck. The second component was associated with plant height and phenotypic traits such as flag leaf sheath glaucocity, glaucocity of the neck and ear colour and the third with auricle colour. The fourth component was associated with agronomic traits such as spike length and number of spikelets spike^{-1} and phenotypic characteristics such as awn and grain colour. The number of tillers plant^{-1} and biological yield were associated with the fifth component whereas the six component was associated with phenotypic characteristics such as shoulder width and shape of the glume.

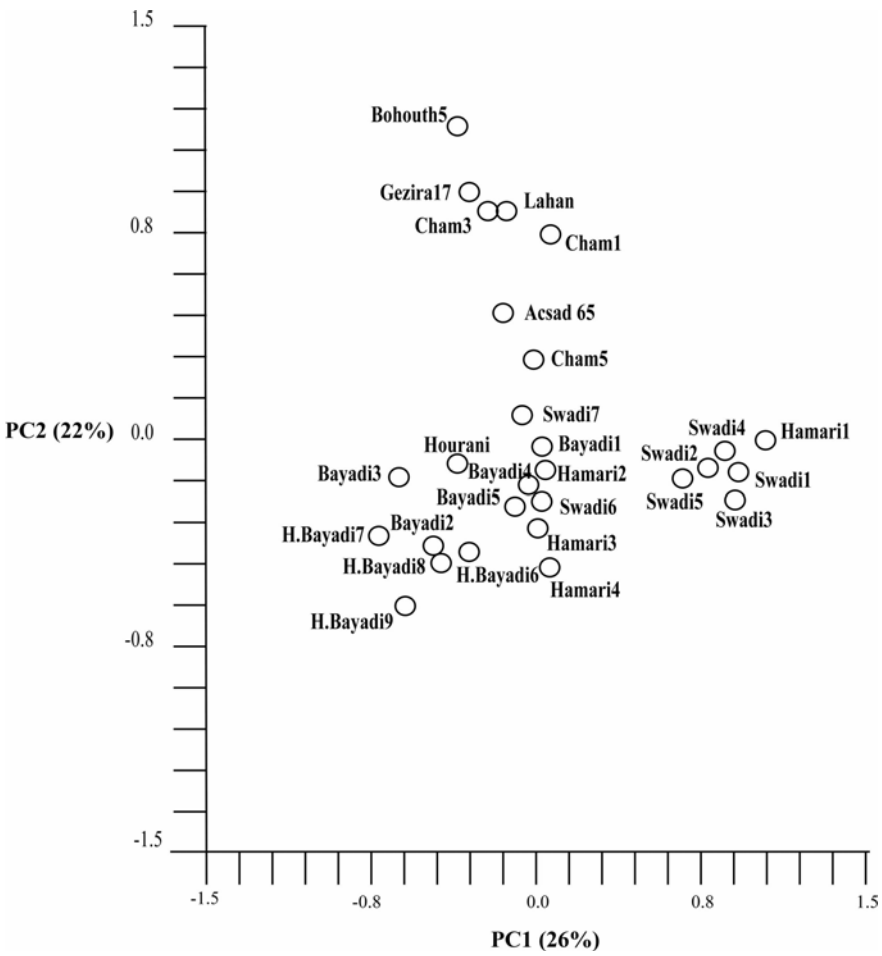

Fig. 6.8. Principal component coordinate of durum wheat varieties and landraces from Syria.

Fig. 6.8 shows the distribution of durum wheat varieties and local landraces along the first two axes of principal components. The durum wheat local landraces such as Swadi collected from Aleppo and Idelib provinces occupied the right extreme of the first component with positive scores. The first component was able to separate the durum wheat varieties and local landraces on agronomic traits such as days to heading and phenotypic traits such as awn colour and glume colour. Local landraces with long days to maturity and with darker glumes and grain colour occupied the positive scores whereas those with shorter days to maturity and light colour occupied the negative scores of the first component. The second component was able to separate the modern wheat varieties from local landraces based on plant height. Modern varieties usually with shorter plant height occupied the top extreme of the second component whereas local landraces with long plant height occupied the lowest axis of the second principal component. The principal component analysis explained most of the variation that existed within durum wheat genotypes.

Cluster Analysis Hierarchical cluster analysis based on average values of 23 agronomic and phenotypic traits resulted in clustering the durum wheat varieties and local landraces into two major clusters and four subclusters (Fig. 6.9). The correlation between the cophenetic value matrix and actual matrix data was very high (0.79) indicating a very

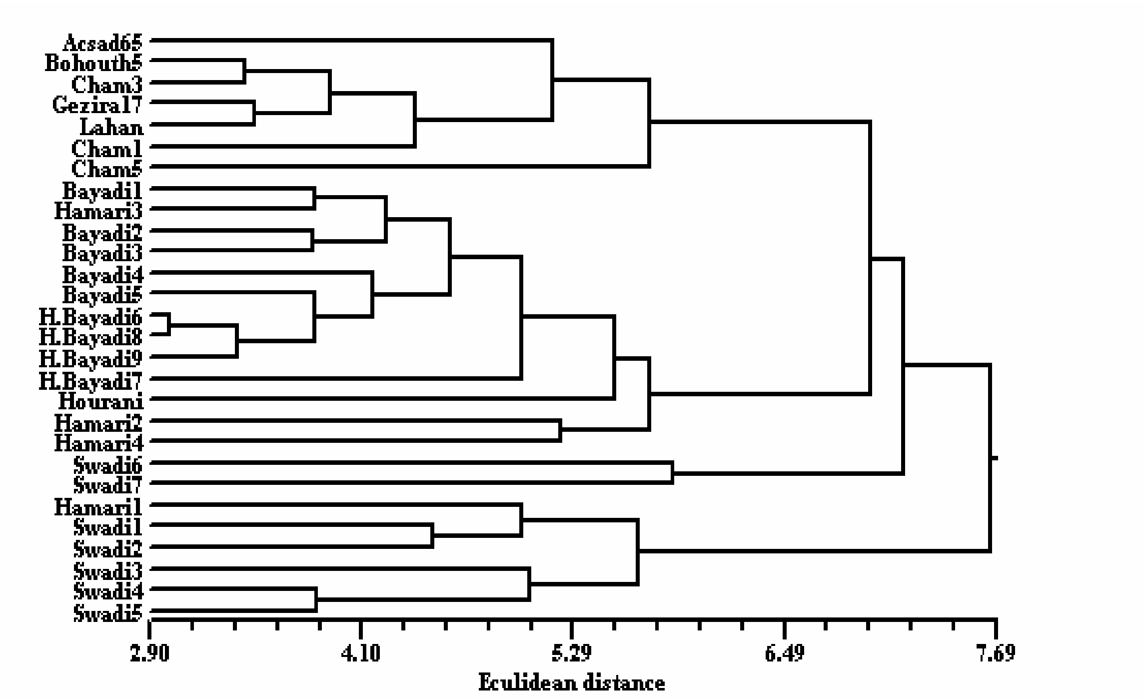

Fig. 6.9. Dendrogram showing the clustering of durum wheat varieties and local landraces collected from farmers in Syria.

good fit of the cluster analysis performed. The Swadi local landraces were distinct and form a separate subcluster particularly because of days to maturity and phenotypic characteristics as they all exhibited intermediate beak length, brush hair of grain and other glume characteristics. However, within the Swadi subcluster materials collected from Aleppo and Idelib were clustered separately. All modern durum wheat varieties (Acsad 65, Bohouth 5, Cham 1, Cham 3, Cham 5, Gezira 17 and Lahan) fall within the same subcluster mainly because of shorter plant height and high flag leaf sheath glaucocity (waxiness). These varieties were clustered within the Bayadi-Hourani sub-cluster probably because of their original breeding history where local landraces were incorporated. Local landraces such as Bayadi, Hamari and Hourani-Bayadi were clustered together showing some degree of similarity as compared to Swadi which was clustered separately. Moreover, Hamari1 collected from Aleppo clustered with Swadi from Aleppo instead of Hamari from Idelib. This may indicate the existence of distinct genotypes within local wheat populations. Hourani, a once popular durum wheat local landrace, was clustered separately within the Bayadi-Hourani subcluster which probably shows its distinctive nature. Some farmers claimed that the seed for Hourani is usually sourced from southern Syria. The Hamari landraces were rather dispersed and clustered within two subclusters. The information generated in morphological traits diversity could be of interest to germplasm conservation or those whose interest is for identification of the varieties for seed certification purposes or intellectual property protection. The most important ones are agronomic traits diversity which could be of immediate use by the breeders. Earlier studies showed that Syrian durum landraces were diverse but also grouped with materials from other countries such as from Algeria, Greek and Tunisia (Impiglia *et al.*, 1998).

6.4.3. Spatial and Temporal Diversity of Barley Varieties

Arabi Aswad was the single most predominant barley local landrace grown by sampled farmers over a four-year period in Aleppo, Raqqa and Hasakeh governorates of northeastern Syria. From 200 farmers surveyed, 89, 94, 97 and 100% planted barley in 1994, 1995, 1996 and 1997, respectively. Furat, a modern barley variety released by the national programme, was planted by one farmer only (0.5%) and not widely adopted in the survey area. From 1981 to 1997 a total of seven modern barley varieties have been released by the national agricultural research system for use by farmers, an average of 3.5 and 0.4 varieties per decade or per year, respectively. Despite such long list of modern varieties released none of them were widely adopted; and possibly rejected because of farmers preferences and lack of adaptability (Chapter 3). There was no significant change in the pattern of varieties grown, area allocated for production and average yield of barley crop, although the trend appeared to be increasing. Barley is grown in areas with low annual rainfall having greater spatial and temporal variation in terms of the amount and distribution of rainfall (Ceccarelli *et al*., 1987). The majority of farmers surveyed grow barley continuously year after year with few exceptions where the crop is rotated with legumes (lentil, lathyrus) or the land is fallowed. There is a growing trend towards continuous barley cultivation instead of fallowing (Tutwiler *et al*., 1997) partly due to the availability of and use of fertilizers (Mazid, 1994).

In Syria, two distinct barley local landraces, Arabi Abiad (white seeded) and Arabi Aswad (black seeded) are grown widely throughout the country. However, these local landraces are cultivated entirely in two geographically different parts of the country. Arabi Abiad is mostly cultivated in western and northwestern parts of the country including the governorates of Aleppo, Hama, Homs and Idelib. These areas are relatively wetter compared to the interior and northeastern part of the country. Arabi Aswad is popular in northeastern part of the country where major production areas are located in Aleppo, Raqqa and Hasakeh governorates and where the barley seed supply study was carried out in 1997/98 crop season. The present expansion in barley production is taking place in this region where more marginal land is brought under cultivation. Arabi Aswad is adapted to relatively drier areas than Arabi Abiad and in most circumstances the majority of farmers grow a single local landrace with low on-farm varietal diversity. The popularity of the black seeded barley in the dry environment could be due to their adaptation to the dry areas (Ceccarelli *et al*., 1987). In contrast, farmers in Ethiopia grow a large number of modern varieties (six) and local landraces (fourteen) showing high diversity of barley crop (Woldeselassie, 1999). However, two local landraces (35.9%) and one modern variety (14.3%) were planted by half (50%) of the sample farmers in southeastern and northwestern parts of the country. Within each region, one local landrace and one modern variety accounted for 60% of sample farmers in the southeastern region whereas one local landrace was planted by over a third of farmers (37%) in the northwestern region. In Ethiopia, barley is used as a food crop where different local landraces are grown for different end uses (Kebebew *et al*., 2001b). Similarly, Tripp (1997a) and Cromwell and Tripp (1994) cited that as many as over 60 rice landraces have been recognized in a farming community in Sierra Leone and individual farmers grew a relatively large number of local landraces (4-8) fitting to different micro-environments and household consumption needs. Sperling (1998) also cited from other sources that farmers in Rwanda grew bean mixtures of as many as 3 to 30 components with individual farmers growing two or three different varietal blends.

Empirical evidence shows that farming communities maintain many crops and varieties not for the sake of diversity *per se* but because of the multiple and diverse end uses. The need to use different crops or varieties for preparation of different foods or its cultural and aesthetic values could be the driving force for diversification of crops. In Syria, the primary use of barley is for livestock feed. The crop is grazed green or the grain and straw is used as livestock feed after harvest during the dry season. One may question why there is a need for farmers to keep the diversity of barley on the farm. Is there any feed quality trait of different barley landraces that improves the performance of the livestock? Is there any feed quality trait from different barley landraces that could improve the quality of the livestock products? Is there any agronomic quality trait of different barley landraces that matches with different soil types, rainfall patterns? After all, is there any outstanding demand or need to maintain diversity of barley crop other than its agronomic performance in terms of more grain and biomass yields for the animal feed?

The on-farm spatial and temporal diversity of barley crop appeared to be limited in scope given the number of landraces grown and the area planted with each variety. However, barley is grown in the Fertile Crescent for millennia. And these local barley landraces have been subjected to natural and human selection and found to be adapted to one of the harshest and stressful environments characterized by drought, cold, heat, salinity and therefore expected to have tremendous genetic diversity (Ceccarelli *et al.*, 1987; van Leur *et al.*, 1989). According to Ceccarelli *et al.* (1987) the presence of different genotypes within the barley landraces or populations conditioned them to cope with different stresses of different magnitude in achieving yield stability in harsh environments. Such latent diversity could only become apparent when new plant diseases and pests or environmental changes challenge these local land races. In Syria, participatory plant breeding has been initiated in barley as a means of identifying new varieties that match farmers' preferences. Adoption of such varieties by farmers would be expected to increase on-farm varietal diversity if new varieties occupy specific niches in the diverse farming system. This would increase overall production as each niche becomes occupied increasingly by the best-adapted new variety.

Agronomic and Morphological Traits Diversity About 50 barley seed samples collected from farmers representing 25 villages were planted at two sites. Table 6.14 presents the mean, minimum, maximum values and standard error of mean of six agronomic characteristics measured during the field experiments showing greater variability. The mean time to flowering was rather stable with an average of 103 days although some genotypes showed a potential of early flowering under both environments. The mean spike length was 7.4 cm with a range from 4.9 cm to 9.9 cm whereas the average number of kernels spike^{-1} was 20.4 seeds with a range of 14.89 to 26.40 seeds showing greater variation within the genotypes. Moreover, the local

Table 6.14. Average, minimum, maximum and standard error of mean of agronomic traits for barley genotypes in Syria (planted at Breda and Tel Hadya in 1997/98 crop season).

Agronomic characteristics	Breda	Tel-Hadya	Breda and Tel Hadya		
			Minimum	Maximum	Mean ± SE
Days to flowering (d)	103.7	103.1	100	108	103.4 ± 0.1
Number of tillers plant^{-1}	0.79	1.43	0.26	3.04	1.12 ± 0.03
Spike length (cm)	6.23	8.37	4.94	9.92	7.31 ± 0.09
Number of kernels spike^{-1}	18.1	22.7	14.9	26.4	20.4 ± 0.19
Ear density (ratio)	2.91	2.70	2.35	3.39	2.80 ± 0.01
Grain yield (kg ha^{-1})	1030	2150	625	3405	1592 ± 49

landraces showed greater variability and yield plasticity ranging from 630 to 3410 kg ha^{-1}. Ceccarelli *et al*. (1987) did not find a large variation, though significant, between collection sites for both days to heading and days to maturity among barley landraces collected from Syria and Jordan. They also found variation among the genotypes for spike length and grain yield and these characteristics were found most associated with each other within and between different collection sites. On the other hand the number of tillers per plant and ear density showed lesser variability.

The barley genotypes responded differently in terms of agronomic performance in the two environments when grown at Breda and Tel Hadya showing the effect of genotype by environment interaction and the possibility of yield improvement through selection. All genotypes responded positively to the Tel Hadya environment where relatively more number of tillers plant^{-1}, higher spike length, more kernels spike^{-1} and a higher grain yield were recorded than in Breda. The days to flowering appeared to be similar in both locations. The materials were planted slightly later than the recommended date of planting for barley which may have affected days to flowering.

Variance Component Analysis Variance component analysis was done to measure the significance and contribution of sources of collection (provinces, districts, and collection sites) on variability in agronomic characteristics of barley landraces. There was a significant difference among genotypes for days to flowering, number of tillers plant^{-1} and number of kernels spike^{-1} across the two locations (Table 6.15). Significant difference was observed for days to flowering for genotypes collected from different districts, although not significant at each growing site. Moreover, barley genotypes collected from different provinces showed significant differences for spike length and number of kernels spike^{-1}. Ceccarelli *et al.* (1987) also found significant difference for spike length among barley genotypes both between and within collection sites. The estimates of variance components of collection sites to variation in barley landraces were found to be minimal (data not shown). The highest contribution was observed for the number of tillers plant^{-1}, followed by grain yield and number of grains spike^{-1}.

Principal Component Analysis The variance component analysis revealed limited information on source of variation among barley genotypes and the effects of collection sites on their agronomic performance. A principal component analysis was made using a correlation matrix to define the patterns of variation both between barley genotypes and between their regions of origin. The principal component analysis showed that the first three components with eigenvalues greater than unity accounted for about 74% of the total variation among 50 barley local landraces for the six quantitative traits (tillers plant^{-1}, days to flowering, grain yield, spike length, number of kernels spike^{-1} and ear density) studied (data not shown). The first, second and third components accounted for 33%, 23% and 18% of the total variation, respectively. The most important characteristics of the first component were spike length and the number of kernels spike^{-1}, important agronomic traits for yield of the barley crop. The number of grains spike^{-1} and ear density (the ratio of number of grains to the spike

Table 6.15. Significance (P) level for comparison of barley genotypes and their partitioning into sources of collection in Syria (planted at Breda and Tel Hadya in 1997/98 crop season).

	Tillers plant^{-1}	Days to flowering	Grain yield	Spike length	Kernels spike^{-1}	Ear density
Genotypes	0.030	<0.001	0.810	0.240	0.030	<0.001
Location × Genotypes	0.332	<0.001	0.888	0.071	0.254	0.010
Province	0.496	<0.001	0.841	0.004	0.022	0.173
District	<0.001	<0.003	0.581	0.880	0.296	0.130
Sub-district	0.299	0.054	0.642	0.459	0.253	0.391
Village	0.774	<0.001	0.973	0.660	0.129	0.14
Farmer	0.125	<0.001	0.315	0.304	0.215	0.015
Location × Province	0.226	0.191	0.911	0.244	0.141	0.300
Location × District	0.091	0.027	0.857	0.224	0.059	0.424
Location × Sub-district	0.228	<0.001	0.544	0.255	0.410	0.686
Location × Village	0.477	<0.001	0.980	0.960	0.913	0.179
Location × Farmer	0.645	<0.001	0.380	0.016	0.147	0.002

length) was an important character for the second component. Days to flowering and grain yield were important characteristics for the third component.

To study the regional pattern of variation principal component analysis was further made using the means of collections sites (villages) for the six quantitative characteristics. The first two principal components with eigenvalues above unity accounted for 59% of the variations. Fig. 6.10 gives the relationship of the barley genotypes based on the first two axes of the principal components. The two principal components were able to separate the barley genotypes collected from different villages almost equally, although the separation did not follow the geographical patterns. The barley genotypes collected from the Aleppo province were almost found in all four quadrants compared to samples collected from Hasakeh and Raqqa provinces. Some barley genotypes collected from Aleppo appeared to occupy the extremes of first principal component axis (positive scores) and the second principal axis (positive and negative scores). Apparently the first principal component differentiated the barley genotypes on spike length and the number of kernels spike^{-1}. Genotypes with high scores for these characters were on the left side from the origin

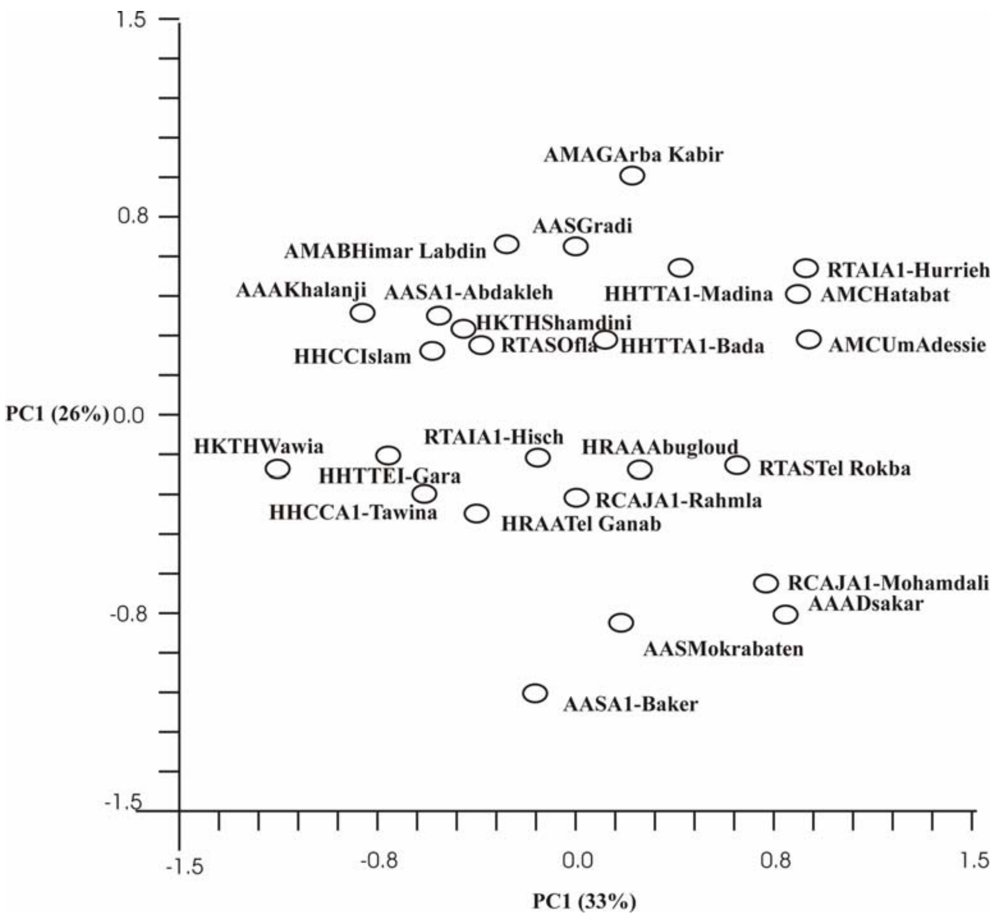

Fig. 6.10. Principal component plot of 50 barley genotypes based on the mean of collection sites (villages) for six quantitative characteristics.

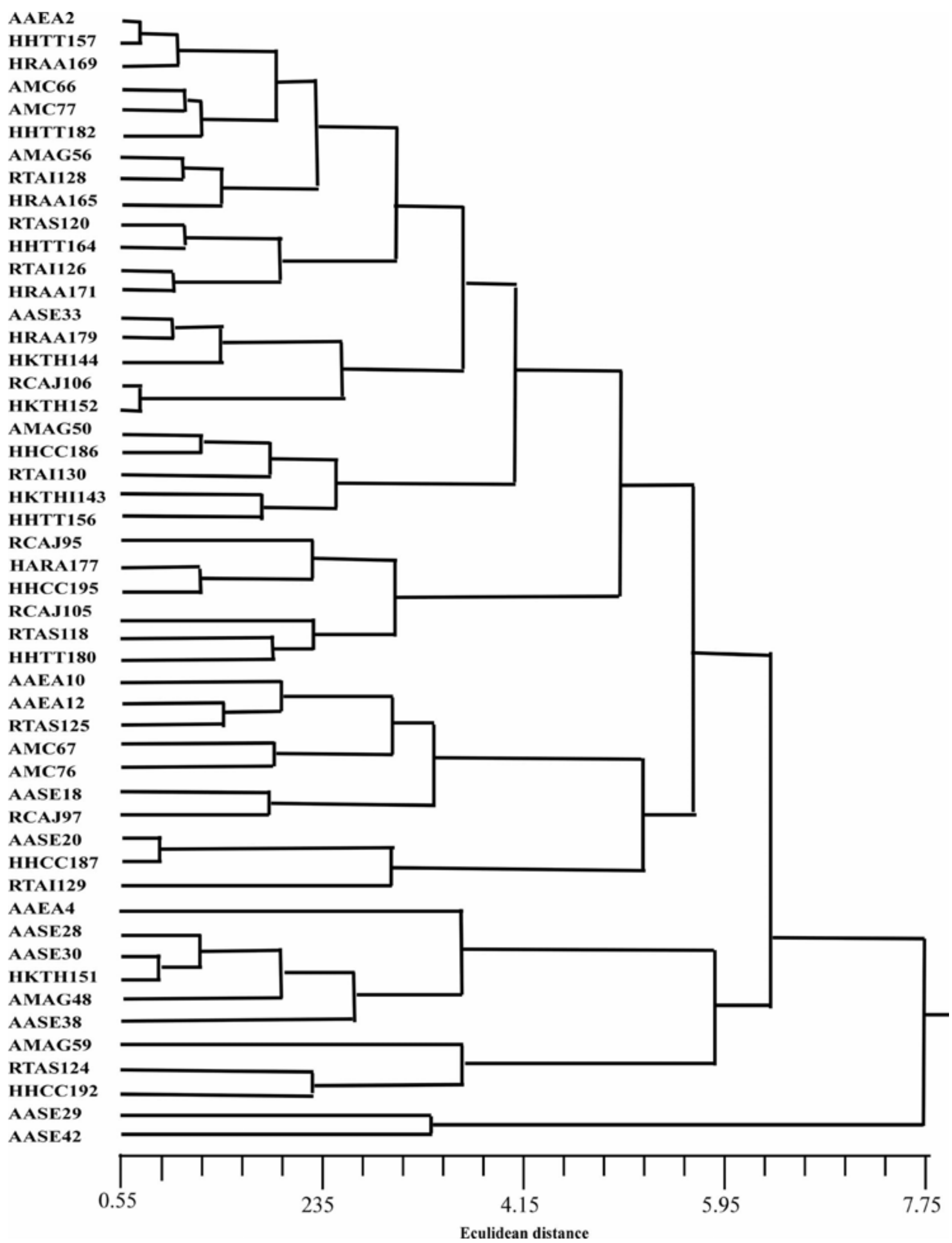

Figure 6.11. Dendrogram showing the clustering of 50 barley genotypes collected from Syria based on six agronomic characters (A=Aleppo, R=Raqqa and H=Hasakeh).

whereas those with low values are on the right side. The second principal component was able to separate genotypes based on the days to flowering and ear density. Moving towards the bottom of the axis of the second component we find genotypes with longer days to flowering whereas the opposite was for genotypes with shorter days to flowering. The materials from Hasakeh and Raqqa provinces had a tendency of occupying the middle of the two principal components with few exceptions. The results may indicate that the materials from Aleppo province are more diverse compared to the materials collected from Hasakeh and Raqqa provinces.

Cluster Analysis Fig. 6.11 presents a dendrogram showing the clustering of barley genotypes based on six quantitative traits averaged over two locations. Clustering resulted in grouping the 50 barley genotypes into two major clusters and six subclusters each varying from 2 in the smallest to up to 15 in the broadest classes. The first cluster consists of two barley genotypes (AASE29 and AASE42) both collected from Manbeji in Aleppo province clustered separately from the rest of the local landraces; and they were low yielding among the whole genotypes. In Subcluster 1, barley genotypes such as AMAG59, RTAS124 and HHCC192, all three from different provinces, were grouped together based on the tillering capacity, the highest being exhibited by RTAS124 collected from Raqqa. In Subcluster 2, genotypes such as AAEA4, AASE28, AASE30, AASE38, HKTH151 (from Hasakeh) were clustered together. The materials in Subclusters 1 and 2 had more tillers plant^{-1} and slightly more kernels spike^{-1} compared to materials from other sites. AMC66, AMC 77, HHTT182 along AAEA 2, HRAA169 AND HHTT157 were grouped under one subcluster (6) and they exhibited high yield compared to other genotypes. The genotypes within the clusters did not cluster according to the geographic origin of collection sites. There was no clear cut clustering as genotypes from different zones, provinces, districts and villages were clustered together. At least two barley genotypes collected from the three provinces were present in all subclusters showing limited differentiation among the genotypes to their region of origin. For example, barley materials collected from Aleppo province in Zone 2 (AAEA2) were clustered along with genotypes collected from Hasakeh in Zone 3 (HHTT157 and HRAA169). Likewise most of the barley genotypes collected from the same province, district and sub district, but adjacent villages were not exactly clustered together. Two barley landrace samples collected from Zone 4 in Raqqa (RCAJ95 and RCAJ105) were not clustered with each other or with samples collected from Zone 4 in Hasakeh. However, one interesting feature observed was that most samples from different provinces, but adjacent districts were grouped together under one subcluster.

Clustering did not differentiate barley genotypes from different collection sites in Syria into the regions of geographic origin. Such lack of strong regional differentiation observed by the cluster analysis could be partly from seed flow between regions. In Chapter 3, we have reported that most of the barley seed was obtained through informal sources where exchange of seed took place among farmers or from traders over long distances particularly bringing seed from nearby provinces and districts. Accordingly this reflects the movement of barley local landraces across regions and production zones. During the field survey some farmers reported having purchased barley seed for planting from a nearby province or district instead of their hometown. The informal exchange of barley germplasm among regions could be one of the reasons for such lack of clarity on the clustering of genotypes to specific regions of origin.

The lack of clear-cut variability indicators among barley genotypes collected from different parts of the country is surprising given earlier studies by Ceccarelli *et al*. (1987). There could be five possible points contributing to this limited variation among the genotypes as well as the effect of collection sites. First, the number of agronomic characters used for the experiment was small with anticipation of greater variability among the landraces which happen to be not the case. Second, the barley materials collected did not come from distant places, but rather within contiguous or adjacent provinces and districts where a continuous sampling would create a morphological continuity compared to materials in previous studies selected from geographically distant regions. Third, barley seed samples were collected from farmers compared to earlier collection where ears were sampled from the growing crops. Fourth, the materials used for study were all black seeded local landraces and did not contain any white seeded barley. Fifth, the General Organization for Seed Multiplication was involved in seed supply of local barley landraces in Syria particularly prior to 1991 where demand for barley seed was high because of subsidized price. Such large-scale seed multiplication and distribution of landraces may contribute to the narrowing of previously existing variability in the field. In general, these findings should be interpreted with great caution. It is worthwhile, however, to undertake further genetic diversity studies to observe the changes in the genetic structures of barley landraces currently grown using both molecular and morphological characters and compare them to earlier results to substantiate these findings. This would assist in studying the genetic and population shifts of local landraces and populations with the introduction of commercial agriculture.

In summary, the Syrian national agricultural research system in collaboration with the International Center for Agricultural Research in Dry Areas (ICARDA) made a spectacular success story in developing varieties that are adapted to stress environments and at the same time responsive to better management practices (Mazid *et al*., 2003). The government policy support coupled with availability of modern varieties and adequate infrastructure in irrigation facilities makes Syria become self-sufficient in wheat production. With the continuous integration of Syrian farmers to commercial crop production and marketing and the changing food habits of rural population the landraces would be the losers. This success story is not without cost where large areas previously grown to traditional varieties and landraces are now completely replaced by contiguous expanse of land planted to uniform modern bread and durum wheat varieties. Moreover, some of these modern varieties are grown by a large number of farmers. Apart from the landraces, the wild relatives and progenitors of both wheat and barley are being threatened by extinction.

While we are 'baffled' by the very rapid disappearance of the local durum wheat landraces the persistence of a couple of traditional barley varieties throughout the country remains a mystery. In Chapter 3, we found that one third of the farmers saw no disadvantage of the Arab Aswad and at least for the time being had shown little intention to replace it with other modern varieties. The majority of farmers were satisfied with grain yield, grain size, grain colour, feed quality and marketability of the local landrace. The Syrian national agricultural research system is still grappling with methodological approaches for barley improvement to diversify the portfolio of varieties available to farmers through scientific plant breeding and very recently with some participatory flavour. Crop diversity is a dynamic process managed by farmers involving the introduction and incorporation of new crops or varieties or a withdrawal of existing crops or varieties to adapt to the technological and environmental changes (Bellon, 1996). It would be interesting to understand the persistence of the traditional barley varieties through a methodological approach of social science than a mere biological approach alone.

6.5 Concluding Remarks

Syria is the centre of origin and domestication for tetraploid wheat and barley whereas the Ethiopian highlands are considered the centres of diversity of tetraploid wheats and barley where a considerable wealth of genetic variability and diversity still exists on the farm. The complex, risky and dry areas of Syria and diverse agro-ecology of Ethiopia coupled with a long history of association with the crop under a variety of socio-economic and cultural situations led to the evolution of highly diverse forms of these crops. Until recently this wealth of genetic diversity has been maintained by generations of farmers. However, the introduction of modern agriculture brought a dramatic shift in wheat production practices in both countries. Since the mid 1990s, almost all wheat production areas are covered by modern varieties in Syria (Pingali, 1999). Few local landraces are grown on small areas in very isolated pockets and remote areas by the poorer section of the society despite their preferences for preparing traditional foods (Rahmouna Khelifi, personal communication). In Ethiopia, there was a remarkable increase in the adoption of modern bread wheat varieties in predominantly durum wheat growing regions of the country as farmers are striving to maximize production and achieve food security from diminishing and meager land resources (Chapter 2). In both countries the wide spread adoption and diffusion of modern varieties (bread and durum wheat in Syria) and bread wheat in Ethiopia could lead to the complete replacement of these valuable genetic resources - the loss of durum local landraces. The loss of landraces also leads to loss of local or indigenous knowledge in crop improvement and maintenance. It is important to design an innovative and integrated genetic resources conservation, maintenance, enhancement and utilization strategies and approaches that could meet the aspiration and food security of the majority of farmers that depend for their livelihood on these crops. It is desirable that the national governments and all stakeholders participate in formulating and targeting the interventions.

The national agricultural research systems made a spectacular progress and achievement in developing modern varieties of bread wheat and durum (only in Syria) wheat that meet farmers' preferences. In contrast, there is little headway in crops like durum wheat in Ethiopia and barley in Syria where local landraces still dominate the agricultural landscape. Not only lack of success in developing modern varieties, but also farmers rejected those varieties released by the national programmes and the area under improved varieties is negligible. The Ethiopian durum wheat production areas are characterized by highly varied micro-environments caused by topography, soil type, soil moisture (water-logging) and temperature and frost whereas the dry and marginal barley production areas of Syria had high spatial and temporal variation in terms of temperature and rainfall. In an apparent effort to circumvent the failure of conventional crop improvement programme alternative breeding strategies have been initiated for many crops in marginal areas with or without farmer participation. In Syria participatory approaches for barley have been initiated (Ceccarelli *et al*., 2000) whereas an alternative breeding strategy is suggested for durum wheat in Ethiopia (Tesemma and Bechere, 1998; Worede, 1992). The preliminary result with participatory plant breeding on barley is promising in Syria. Therefore, the national agricultural research systems should introduce and institutionalize participatory approaches (participatory variety selection and/or participatory plant breeding) as a means of identifying new varieties that farmers prefer and link this with formal plant breeding and seed production activities. Adoption of such varieties by farmers not only enhance productivity but also maintain and improve on-farm varietal diversity of durum wheat and barley crops.

The agronomic and phenotypic studies revealed a wide range of variation for each of the traits studied particularly among the modern bread wheat varieties that will provide farmers an opportunity to make a choice of genotypes that will fit best to their niche environments. Moreover, the variation that exists among the local landraces offers broad opportunities for using the genotypes with desired agronomic characters in the plant breeding programme to develop varieties suitable for different agro-ecological zones of the country. In Ethiopia, past efforts to use exotic germplasm in developing durum wheat varieties with wider adaptation to the local conditions met with little success (Tesemma and Bechere, 1998; Belay *et al*., 1993) and the locally adapted germplasm remains under exploited in the national breeding programme (Worede, 1992). Therefore, the national agricultural research system should incorporate the local landraces into their breeding programme and develop location specific varieties that meet farmers' requirements and also increase on-farm diversity.

The spatial diversity, temporal diversity, coefficient of parentage analysis and measurements of agronomic and morphological traits were employed to explain the diversity of wheat and barley varieties or local landraces grown by farmers in Ethiopia and Syria. While the spatial diversity and temporal diversity indicates the domination of few selected varieties in terms of area coverage the agronomic and phenotypic measurements showed the remarkable variation that existed both among modern varieties and local landraces that would provide broader opportunities for use in crop production or crop improvement. Since different measurements and scales were used to define diversity it would be difficult to ascertain a set of common indicators and their interrelationships that would satisfy both the biological scientists and social scientists concerned with biodiversity issues. It is imperative that a multidisciplinary approach is undertaken to address the problem and develop a common framework for assessing genetic diversity that would enable policy changes required to enhance the conservation and utilization of these resources to the benefit of farmers and the society at large.

This study was not meant to measure wheat and barley diversity *per se* or intended to investigate the patterns of diversity from the geographic or agro-ecological context. It was rather an attempt to look into the agronomic and morphological traits diversity of sets of varieties currently used by farmers and any specific traits that are associated with farmers' considerations or preferences for particular group of varieties or landraces. For example, one clear example is farmers' demand for black seeded barley varieties in drier areas of Syria. Ceccarelli *et al.* (1987) reported that black seed colour in barley is associated with drought tolerance, vigorous early growth, taller plants and early maturity all which are important agronomic characteristics for dry areas. These are some of the agronomic characters Syrian barley farmers are exactly seeking from new varieties that would be adopted along the local landraces currently grown widely throughout the country.

CHAPTER 7

General Discussion

Chapter 7

General Discussion

7.1. Introduction

The chapters presented in this thesis provide data on the performance of the wheat and barley seed systems in Ethiopia and Syria, from agricultural technology generation and transfer to its adoption and diffusion among farmers and local level alternative strategies used by the farming communities. This synthesis will analyse the overall performance of the individual components of the national seed systems and will examine the interactions between the components. It highlights the importance of the linkages between agricultural research, technology transfer, seed supply and underlines the role of private sector and local seed systems in seed industry development. An attempt will be made in identifying key elements of these findings and illustrate future strategies in improving the efficiency of the national seed system in both countries.

7.2. Role of Agriculture in the National Economy

Agriculture is the main economic activity both in Ethiopia and Syria with varying proportion in its contribution to gross domestic product, employment generation, export earning and provision of raw input to the industrial sector. In Ethiopia, agriculture contributes 50% of gross domestic product, provides employment for over 85% of the population, supplies 90% of the export commodities and 70% of raw materials to the industry (MEDC, 1999). Subsistence farming dominates the agricultural sector accounting for 97% of the cultivated area and more than 90% of total agricultural output (MEDC, 1999).

In Syria, the agricultural sector contributed 20-25% to the national economy and employed 28.5% of labour force in 1999 (CBS, 2000). The introduction and wide spread use of mechanization in farm operations and the development of irrigation infrastructure have transformed the agricultural sector. There is rapid progress in commercialization and intensification of agriculture, as the country is becoming self sufficient in food production and drawn to the international wheat trade (Tutwiler, 1995).

Wheat and barley belong to the most important crops in terms of area coverage and grain production both in Ethiopia and Syria. Wheat is the principal food crop grown in both countries whereas barley is used as food in Ethiopia and as a feed crop in an integrated crop-livestock farming system in Syria. Although the problems differ in magnitude, erratic rainfall, recurrent drought, scarcity of arable land, fragmented landholdings or degradation of natural resources caused by soil erosion, overgrazing and desertification are undermining agricultural growth and sustainable food production in both countries. There are serious challenges for achieving national food security in strategic crops while reducing environmental degradation and the depletion of natural resource base. Modern agriculture is expected to contribute towards these noble goals if properly supported by stable policy environment and government commitment.

7.3. Conceptual Framework

During the last half-century greater effort was made to establish formal sector institutions in genetic resources conservation (*ex-situ*), agricultural research, technology transfer and national seed programmes in many developing countries. The approach put in place the basic infrastructure and facilities for agricultural research and national seed programmes and managed to provide technology to farmers in favourable environments. However, the failure of the formal sector in bringing significant changes particularly in less favourable environments (often complex, risky, diverse and dry areas) and for small scale resource poor farmers shifted the emphasis on finding alternative ways of technology generation and transfer that will compliment the formal sector. There is growing recognition and interest in farmer participatory approaches in genetic resources conservation (*in-situ*), participatory plant breeding and informal seed sector and the appreciation of their complimentary roles to the formal sector. Thus, at present two interacting seed delivery systems are recognized: the formal and informal sectors (Fig. 7.1). The borderline between the formal and informal sector, however, is imprecise (Turner, 1996; Cromwell, 1997). For example the formal sector may depend on genetic resources collected from farmers (local landraces) to develop modern varieties. However, these new varieties will re-enter the informal sector as 'improved' germplasm pool and diffuse among the farmers through farmer-to-farmer seed exchange. The function and roles of the formal and informal sector depend to some extent on the agro-ecology, the crop and the development of the agriculture and seed sector in the country.

The development of a diverse, effective, efficient and sustainable national seed system responsive to the need of the farmers would at least require the following components in place (Fig. 7.1): (a) adoption of flexible policy/regulatory environment supporting the diversification of the national seed system; (b) generation and transfer of appropriate technology relevant to the farming systems; (c) visible economic benefits and provision of services to encourage adoption and diffusion of the technology by farmers; and (d) existence of appropriate support institutions to ensure implementation of policies, technology generation and transfer. The provision of adequate financial support, adequate infrastructure, linkages among different institutions and the flow of information will underpin the success of the agricultural research and seed programme development.

The policy/regulatory environment, the availability of relevant agricultural technology, the support institutions and the socio-economic factors have a profound effect on the development of the national seed industry (Louwaars, 2002; Turner and Bishaw, 2000; Almekinders and Louwaars, 1999). The interactions between these factors determine the extent of the functioning of the formal and informal seed sector operations (Fig. 7.1). The national seed policy should be viewed within the framework of government policy to ensure the development of the agricultural sector in general and the seed sector in particular. The policy and regulatory environment defines the organizations, functions and linkages among the institutions involved in the seed sector and the mechanisms for co-ordinating the activities and monitoring the progress of the national seed industry. The generation and transfer of the relevant technology are dictated by the strength of the national institutions involved in agricultural research and the extension services and the establishment of an effective mechanism to ensure the participation of stakeholders in the technology development and transfer process. The socio-economic conditions of the farmers and economic environment under which they

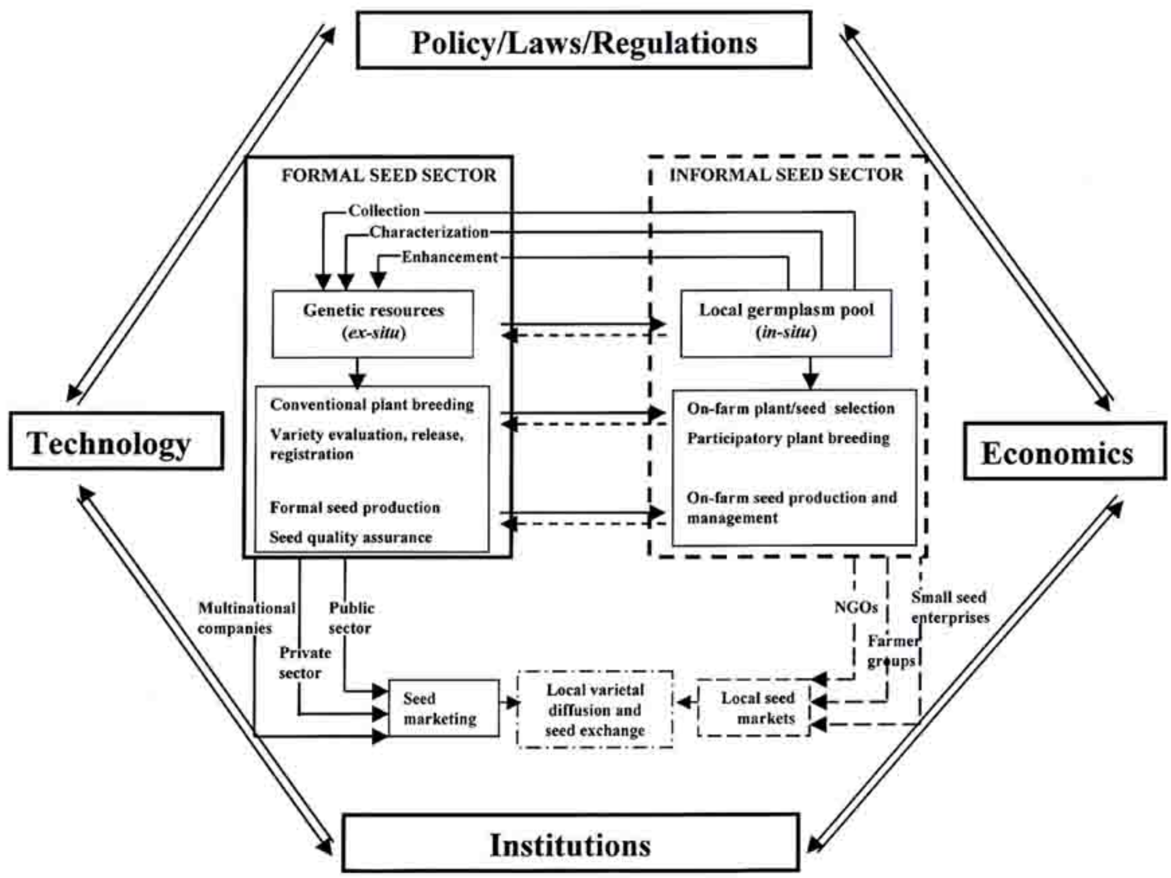

Fig. 7.1. The national seed system, interrelationships and suggested linkages (formal sector activities (single solid lines), informal sector activities (single broken lines), linkages (one solid and one broken lines), and interactions (double solid lines)).

operate determine the extent of adoption and use of new technology. Farmers benefit from the new technology hinges on the provision of credit services and creating a favourable economic climate encouraging them to invest in agricultural inputs. In the following sections (and later in the document) these issues will be examined further from the national perspective with some regional and international flavour in agricultural research-seed programme development continuum.

7.3.1. Formulation of National Seed Policy

Seed has three functions as a means for genetic resources conservation, as technology transfer mechanism and as a commercial entity. This triple function presents challenges in formulating national seed policy due to the competing interests of different stakeholders at national and international levels (Louwaars, 2002). There are no blue prints on what type of policy should be formulated at a country level, but it is important that such policies enhance agricultural development and are compatible with international agreements particularly in promoting the national interests of the country. In developing a national seed policy framework one must recognize and address the functions of seed stated earlier. First, the policy should address the issue of genetic resources conservation, ownership and protection, access and exchange of genetic resources and options for equitable sharing of potential benefits that may arise from germplasm conservation or exchange. Second, the policy should recognize the emerging role of biotechnology and the protection of intellectual property rights as a strategy to attract private sector participation and investment in the seed sector or as part of international obligations (e.g., WTO/TRIPs). Third, the policy must allow the diversification of the national seed sector recognizing the role of local seed production and marketing through various forms of small seed enterprises (Kugbei and Bishaw, 2002) and the role of the informal seed sector (Almekinders and Louwaars, 1999). The policy must support fair competition and 'level' playing field for both the public and private seed sector and alternative local seed schemes. Turner and Bishaw (2000) advocated a regional seed policy initiative to create wider market opportunities to attract private sector investment particularly for the multinational seed companies operating across countries. Such policy framework would have a great relevance both to Ethiopia and Syria which are endowed with huge wealth of genetic resources and vested interest in attracting domestic or foreign private sector investment to diversify the seed sector.

According to McMullen (1987) '*government policies in the developing world created a situation where an inefficient public seed sector dominates, local private companies are struggling entities, and international seed companies operate at sub-optimal levels that cannot properly contribute to the agricultural development of the country*'. This statement is as valid as 25 years ago. In the 1990s, national policy and strategy documents on biodiversity, agricultural research and seed sector have been developed for Ethiopia and institutions implementing such polices either established or strengthened in line with the new mandates. The national seed industry policy explicitly recognizes the role of the private sector and the informal sector in the seed business. In Syria, while the support and commitment of the government towards agricultural development is very strong, to date there is no clear policy document available. In general the government took full responsibility for seed provision of strategic crops with no private sector and informal sector initiatives. The formation of a policy unit or a representative and transparent advisory council with an overall responsibility for policy formulation plays a crucial role in seed sector development. The unit or the council would assist the government in establishing policies, defining functions, co-ordinating activities and monitoring the progress of the national seed industry. Such policy unit or national seed advisory council will fill the institutional vacuum and help government in reviewing polices and setting priorities for the seed sector. Tripp (1997c) described the formation of such units as steps towards formulation of effective seed policy.

7.3.2. Formulation of National Seed Laws and Regulations

In recent years, issues pertaining to regulatory reforms have received greater attention given their importance in the diversification of the national seed system (Louwaars, 2002; Tripp *et al.*, 1997; Tripp, 1995). In the past, most national seed laws and regulations were focused on promoting the predominant role of the public sector. At present, the seed regulatory reforms should consider the emergence of more diverse seed sector including the roles of the private sector and the local seed systems. The challenges for regulatory reform in the seed sector are the balancing act to provide an effective framework for promoting seed system diversification (Tripp, 1997b). These reforms may affect:

- variety regulations for testing, release and registration;
- seed regulations prescribing standards for quality control and certification;
- quarantine regulations for exclusion of exotic pests;
- international seed trade regulations setting procedures for import/export;
- plant variety protection to stimulate private sector investments; and
- lately bio-safety regulations pertaining to safe movement of transgenic crops.

These regulations may restrict the range of varieties available, the quality of seed marketed and the movement of varieties and seeds within or across national boundaries, thus severely limiting opportunities for regional or global seed trade. The success of these reforms are underpinned by four guiding principles as described by Tripp *et al.* (1997):

- the technical efficiency in defining the procedures and methodology to be followed,

- relevant standards that meets the need of the diverse seed sector,
- participation of the stakeholders in the decision making process, and
- the transparency in implementing the regulations impartially.

Variety regulations for evaluation, release and registration remain one of the major stumbling blocks in limiting the choice of varieties available to the farming communities in many developing countries. The criteria, conduct and management of variety testing and evaluation are most often handled single-handedly by the national agricultural research system and lack co-ordination and participation of stakeholders (extension, farmers). The variety regulations modelled on experiences of the developed seed industries may require long testing periods and comprehensive distinctness, uniformity and stability (DUS) and value for cultivation and use (VCU) tests for new varieties to be released and registered for seed production – *compulsory variety registration.* Moreover, the governments allow only varieties that are officially registered and listed in a country – *single country lists*. Such compulsory variety registration and single-country lists limit the choice of varieties available to the farmers. Moreover, the criteria promote few varieties with wider adaptation than release of many varieties with specific adaptation. On the other hand particularly subsistence farmers in marginal environments are interested in varieties with a broad genetic base and with the capacity of population buffering to environmental stresses. Moreover, varieties developed through participatory approaches may not meet the strict DUS criteria currently used for releasing varieties but may be favoured by farmers for their agronomic merits. Such varieties should be exempted from strict DUS criteria (or regulated differently) and evaluated only for their agronomic value and farmers' preferences. The criteria for evaluation and registration should accommodate less uniformity (heterogeneous populations) and a wide range of varieties with specific adaptation for less favourable environments. An alternative approach for variety registration and release should have flexibility by allowing companies (public or private) releasing and marketing seed of new varieties based on their own performance assessment – *voluntary variety registration.* Moreover, the regulation should allow accepting varieties that are listed in other neighbouring countries with similar agro-ecological zones – *multi-country lists*. In India, variety registration and performance testing are compulsory for public varieties, but voluntary for the private sector (Tripp and Louwaars, 1997). Similar approaches are being adopted in other countries with varying degrees of control (Louwaars, 2002). It is imperative to develop flexible regulations to cope with situations at national level, and harmonized at the regional level to promote global seed trade. These could increase the flow of new varieties to farmers by moving from a compulsory to a voluntary release and registration system and from single-country to multi-country (or regional) variety lists to benefit from public or private sector research within and outside the country.

Seed regulations prescribe the standards and procedures for quality control and certification to ensure that the seed offered for sale meets high standards of genetic, physical, physiological and health quality. It involves varietal certification through field inspection of growing crops and laboratory testing of quality attributes with express purpose to serve both the interests of the seed producers and their clients, the farmers. Many seed regulations in developing countries are modelled on European system and require comprehensive quality control by an independent agency and do not allow sale of seed that is not officially checked for quality and certified – *compulsory seed certification*. However, many countries found it difficult to establish and run a comprehensive and compulsory seed certification because of limited resources. Tripp and van der Burg (1997) in their review of the seed quality control in developing countries identified lack of efficiency, unrealistic standards, lack of participation from the stakeholders and lack of transparency in its implementation as the key weaknesses of the current system. On the other hand, some countries like the USA follow a truth-in-labelling system together with effective enforcement of the regulations to suppress any deceit at the point of sale – *voluntary seed certification*. The seed companies are obliged to declare the quality of seed offered for sale and farmers can judge for themselves what to buy. Voluntary seed certification provides opportunities in cutting costs and allowing market forces to operate by giving more responsibility for quality control to the seed producers. It encourages large and/or small firms to enter the seed market on own brand names offering a range of products for farmers. Most countries by moving from the currently applied inflexible and restrictive compulsory systems to voluntary certification schemes would stimulate the diversification of seed suppliers. For example in India, certification is compulsory for public sector companies, but the private sector can market the seed under *truth-in labelling* system (Tripp and van der Burg, 1997). It is also important that the field and seed standards adopted for seed certification are tailored to and reflect the needs and the level of the production technology of a country rather than a high uniform national standard imported from elsewhere. Moreover, a regional scheme standardizing the certification procedures is quite useful for seed sector development.

National *seed trade regulations* governing licensing and procedures for seed import and export are often bureaucratic and may serve as non-tariff trade barriers and need to be reviewed and reformed. *Plant variety protection laws* should be compatible with UPOV convention and WTO/TRIPs agreements to be internationally accepted. While q*uarantine regulations* are justified in protecting the national agriculture, most regulations are outdated, severely restrictive and only serve as non-tariff barriers for seed trade among countries (Gisselquist and Srivastava, 1997). It is imperative that such laws are updated based on genuine pest risk assessment and realistic standards in line with International Plant Protection Convention. Governments should play a balancing act between national interests and international conventions or obligations in formulating seed laws and regulations. However, such laws and regulations should clearly support local-level seed-production schemes and exempt it from formal sector regulations.

7.3.3. Harmonizing Seed Laws and Regulations Across Regions

In the past seed laws and regulations were prepared and implemented with specific national interests and with no or little regional interactions. Most national seed laws, however, are replicas of each other (Louwaars, 2002; 1996) with little national flavour. To date, with the increasing globalization of seed trade the existence of unrealistic and inflexible national regulations become a serious impediment for regional integration. Since its inception in 1992 the WANA Seed Network operated by the Seed Unit of ICARDA is promoting harmonization of regulations in the region and this is now increasingly under intense discussion in many international forums (Turner and Bishaw, 2000). Given broadly similar agro-ecology, production environments, and crops at the regional level there are opportunities for countries to pursue a more integrated regional approach to the development of the seed sector. Such harmonized regulations and technical procedures would facilitate the movement of varieties and seeds across boundaries creating a regionally unified market and attract investment from the private sector. At present there are some promising developments aimed at harmonization of regulations in East Africa and Central America. Such regional efforts are also underway within the SADC region in Southern Africa and by ICARDA in the Central and West Asia and North Africa region. Several workers (van Gastel *et al*., 2002; Tripp and Louwaars, 1997, Tripp and van der Burg, 1997) advocated the reforms and harmonization of variety and seed regulations with in-built mechanism for protection of farmers. The regional integration of Ethiopia within the East Africa sub-region and of Syria within West Asia sub-region would appear relevant.

7.3.4. Availability of Relevant Agricultural Technology

Apart from national seed policies and regulations, several technical factors profoundly affect the development of the seed sector (Turner and Bishaw, 2000). The generation and transfer of technology must be client-oriented; and should be integrated into the farming system, evaluated under representative farming conditions, and accepted by farmers before being transferred. The national agricultural research system is expected to generate appropriate technology that is compatible with the farming systems and socio-economic conditions of the farmers. Most often technologies are developed in isolation or as separate components rather than as an integrated package to realize the potential benefits from the efficient use of different combination of new technologies. The most prominent of new agricultural technology is the availability of modern varieties that are adapted to local conditions with acceptable characteristics for use by farmers. Most NARS and public sector seed companies, however, offer a limited range of varieties restricting farmers' choice. It is believed that generating a wide range of modern varieties with clear economic benefits would induce farmers in adopting the new technology. The entry of new private sector companies into the seed market is likely to increase farmers' choice as they seek to gain competitive advantage with new varieties.

The crop production environment will also have an influence on adoption of modern varieties and associated technologies. In situations where there is less perceived risk, farmers may want to experiment with new technology and are more likely to try and adopt them. In Syria, farmers in irrigated areas are more willing to invest and purchase certified wheat seed from GOSM compared to farmers in rainfed areas (Mazid *et al*., 1998). On the other hand, farmers in less favourable or marginal environments are risk averse and less likely to adopt new technology. Moreover, varieties released by formal agricultural research perform better in favourable environments or respond better to external inputs and therefore not useful under marginal environments or in the absence of external inputs (e.g., fertilizers).

7.3.5. Socio-Economic Factors

Any new agricultural technology should bring economic benefits to be adopted and accepted by farmers. Moreover, the provision of inputs, credit services, input and output prices encourage the adoption of modern varieties and associated technologies by farmers. In many countries although farmers are interested in using recommended inputs, these are often not available in sufficient quantity and time to meet their demand to realize the potential of the new variety. In Syria, barley farmers in marginal environments have less access to government credit services to purchase inputs (e.g., fertilizers). Similarly, it was reported that in Zambia the production of rainfed wheat has lagged behind that for irrigated wheat due to lack of credit facilities for small-scale resource-poor farmers in rainfed areas (Mukwavi and Siwale, 1999). Moreover, removal of subsidies may lead to disadoption or inadequate use of fertilizers affecting productivity of the small-scale farmers as observed in Ethiopia and elsewhere (Mukwavi and Siwale, 1999).

Farmers economic circumstances and the production environment also influence the adoption of new technology. Gamba *et al*. (1999) reported that adoption of modern wheat varieties was higher with large-scale farmers and in favourable environments compared to small-scale farmers and in less favourable environments in Kenya. Moreover, where commercial farming predominates and farmers are connected to a market economy they are much more likely to purchase agricultural inputs. In contrast, many subsistence farmers are constrained of cash particularly at planting time and are left with a limited choice of using own saved seed. Ethiopian farmers are practising subsistence agriculture and therefore less likely to purchase certified seed regularly as compared to the Syrian farmers who are willing to invest in agricultural inputs (e.g., certified seed).

Surplus grain production leads to decline in market prices and has a negative influence on the adoption of new technology including varieties and seeds. In many developing countries input prices are high while producer prices are low, reducing farm incomes, hindering farmer investments and discouraging the use of inputs. In recent years, a similar situation was observed in Ethiopia where surplus maize production due to use of modern varieties and improved technology led to the collapse of grain price with serious economic consequences for farmers. As an incentive to farmers increased production should be supported by adequate marketing policies, infrastructure and profitable grain prices. In Syria, a similar approach is followed where farmers are encouraged to increase wheat production through attractive prices offered by the government.

7.3.6. Support Institutions

The creation of the right policy and regulatory environment alone would not guarantee the generation and transfer of technological packages and its adoption by farmers. It is important that the government recognizes the role of institutions in the development process and strengthens existing institutions or establishes new institutions with clear authority and responsibility. These institutions should be provided with basic infrastructure, financial support and manpower for implementing polices/regulations, generating the technology and transferring them to farmers. These institutions may include NARS for research, extension services, seed enterprises, quality assurance agencies, input suppliers, credit services, marketing agencies or rural development agencies. Local level institutions should be identified and strengthened to empower the farmers thereby ensuring their participation in generation, adoption and diffusion of new technology. Moreover, the government should encourage the establishment of civil societies and industry associations and provide them with incentives to fully participate and contribute to the economic development in the agriculture sector. Tripp (2001) reported the role of farmer groups during the early development of modern agricultural sector in UK and USA.

7.3.7. Organizational Linkages

The lack of appropriate linkages among agricultural research and development organizations remains one of the major constraints limiting the progress of the seed industry development (Bishaw and Kugbei, 1997). These institutions, formal or informal, must operate seamlessly and without any bureaucratic delays where the linkage among them is a key factor for success. Therefore, to ensure the flow of information among agricultural research, extension services, seed enterprises and rural development agencies, an appropriate institutional linkage and network should be established to promote the use of modern varieties and seeds by the farming communities. A transparent and participatory approach would contribute to the development of the national seed sector and meet the interest of all stakeholders (see section on linkages).

7.4. Agricultural Research and Technology Generation

In the 1950s, lack of research infrastructure required for effective plant breeding and lack of significant private sector investments in crop improvement research targeting major crops grown in developing countries led to the establishment of the IARCs under the leadership of the Consultative Group on International Agricultural Research (Evenson and Gollin, 2003). Despite a lot of criticism, the ‘green revolution’ of the 1960s provided spectacular evidence of the impact of new technologies, particularly in wheat and rice, which have made a dramatic impact on food security in many countries. The IARCs in partnership with national agricultural research systems (NARS) have played a key role towards increased productivity, poverty alleviation and food security in many developing countries. From 1960 to 1998, an average annual productivity growth of 0.718% has been realized from crop genetic improvement across all crops and regions for IARC mandate crops (Evenson and Gollin, 2003).

7.4.1. Government Support to Agricultural Research

The advent of modern agriculture in Ethiopia and Syria should be studied as a 40 year history since the inception of national agricultural research systems in the mid 1960s and the establishment of the national seed programmes in the mid to late 1970s. Since then a remarkable progress has been made in agricultural technology generation and transfer including the use of modern varieties and associated technologies. In recent years, the agricultural research systems have been reorganized in both countries to better respond to changing climate of economic development. However, some constraints still remain which require attention if the agricultural sector is expected to contribute to economic growth, the national economy and welfare of the farming population.

The government commitments in supporting the agricultural research in Ethiopia and Syria can be realized from the amount of financial resources allocated for research related to crop production. The Ethiopian Agricultural Research Organization (formerly IAR) accounts for 50% of the pRYs (potential research years or equivalent full time researchers) and 59% of the total financial resources (US $8.3 million) allocated to agricultural research for the country during 1997/98 (ICARDA *et al*., 1999). The GCSAR (formerly DSAR) accounted for 36% of the total pRYs and 33% (or US$ 5.2 million) of the total financial resources allocated for research for 1998 in Syria (ICARDA *et al*., 1999). The Syrian NARS would more likely fare better with twice the amount of financial resources allocated to them to discharge their research mandates compared to the Ethiopian NARS given the width and breadth of the geography and agro-ecology of the country.

EARO has an overall responsibility to co-ordinate and to advise government on agricultural research and has a strong collaboration with IARCs. Likewise, GCSAR has good linkages with national organizations and collaboration with international agricultural research centres. The NARS in Ethiopia and Syria benefited substantially from research in the IARCs. In Syria, the Supreme Council of Sciences is officially mandated to define and implement the national scientific research policy, although bears little influence on the functioning of the agricultural research institutions (ICARDA *et al*., 1999). It would be more appropriate to have functional and representative National Agricultural Research Council to formulate policy and co-ordinate the efforts of different institutions at a national level.

7.4.2. Landrace Conservation, Enhancement and Utilization

Located in one of the major centres of origin and diversity of wheat and barley both Syria and Ethiopia remain custodians of valuable genetic resources for humankind (Fig. 7.2). The wheat and barley local landraces have shown tremendous variability and diversity and would serve as valuable gene pools for plant breeders searching for unique genes and/or gene combinations that increase yield or confer resistance to stresses. A recent example for the contribution of local landraces to the economic benefits in agriculture could be cited where a barley landrace from Ethiopia conferred resistance against barley dwarf mosaic virus saving \$160 million year^{-1} in USA and a wheat landrace from Turkey contributing \$50 million year^{-1} to wheat production elsewhere (Perrings, 2001). The replacement of local landraces with genetically uniform modern varieties coupled with habitat destruction and drought (Worede, 1992) remains one of the major threats to loss of plant genetic resources. The loss of local landraces is also accompanied by the loss of genetic information and traditional knowledge developed over centuries in selection and maintenance of these materials. From the results of the field survey, the threat to local durum landraces from modern varieties of

Fig. 7.2. The morphological diversity of wheat from Ethiopia (left; photo: Z. Bishaw; inset durum wheat: O. Porfiri) and spike diversity of durum wheat landraces from Syria (right; photo: ICARDA).

bread and/or durum wheat in Ethiopia and Syria is evident (Chapters 2, 3 and 6). Apart from classical genetic resources conservation (*ex-situ*) two possible approaches could be useful to reduce the threat and continue using the genetic resources for the benefits of the local communities through on-farm conservation and/or use of local landraces in the plant breeding programmes.

First, the existence of durum wheat landraces in specific and isolated sites in Syria would provide an opportunity for on-farm conservation strategies through community participation by providing adequate financial benefits or incentives to the local communities. Farmers reported that the durum local landraces are preferred for preparation of traditional foods and the grain fetches higher prices compared to that of modern varieties. Moreover, the organization of local communities, improving on-farm durum processing techniques, and finding alternative marketing options would add value to the products that would give farmers an incentive to maintain these valuable wealth of genetic diversity on the farm. At present, under the Global Environment Facility funded projects *in-situ* conservation sites targeting wheat (*Triticum* spp., *Aegilopes* spp., landraces) and barley (*Hordeum spontaneum* and landraces) have been identified and are being implemented by ICARDA in collaboration with NARS in Syria. In Ethiopia, a similar approach has been undertaken for wheat and barley (Kebebew *et al*., 2001a and 2001b). While such efforts contribute towards genetic resources conservation, they are rather limited in scope and dependent on donor support. It is important that such efforts should be initiated, maintained and sustained in the absence of the external donor funding through government support and community participation.

Second, despite their stability in performance, landraces are relatively low yielding and often fail to adequately meet the level of production beyond subsistence levels (Tesemma and Bechere, 1998). The successes of the wheat crop improvement in Syria is the incorporation of local landraces in the breeding programme to develop modern varieties that are adapted to dry conditions and have desirable traits for adoption by farmers. A similar strategy would enable the development of modern durum wheat varieties with acceptable quality and performance for the Ethiopian farmers. Linking local durum wheat production with local food processing industries would enhance the economic incentive for farmers growing durum wheat and at the same time reduce the threat from expansion of high yielding bread wheat varieties.

Ethiopia and Syria are signatories of the Convention on Biological Diversity and International Treaty for Conservation of Genetic Resources for Food and Agriculture and Cartagena Protocol on Biosafety (except Syria) and are bound by the convention and the treaty for conservation of genetic resources, to equitable sharing of benefits arising from germplasm exchange and to ensuring the safe movement of living modified organisms (LMOs). Although Syria is not signatory to Cartagena Protocol on Biosafety it has established the Syrian National Biosafety Committee by Decree No 612/99 in 1999 and developed biosafety regulation and guidelines for the country. The impact of such conventions and treaties on germplasm access and exchange remains to be seen in the coming years.

7.4.3. Successes of Conventional Plant Breeding

Formal or conventional plant breeding follows a series of established procedures from the identification, evaluation, release and registration of new crop varieties to their seed multiplication and distribution to the farming communities (Fig. 7.3). The NARS of Ethiopia and Syria in partnership with IARCs managed to develop high yielding and input responsive wheat varieties suitable for favourable environments (Chapters 2 and 3). Since the early 1990s, the use of modern varieties coupled with increased use of external inputs (fertilizers, pesticides) and provision of credit services, farm mechanization and irrigation facilities enabled Syria to become self-sufficient in wheat production raising the average national yield to 2.5 t ha^{-1} (Mazid *et al.*, 2003). Tahir (1997) also reported a yield of up to 4.7 t ha^{-1} for barley in dry areas of Central Asia and West Asia and North Africa region. In Ethiopia, despite low average national wheat yield (1.1 to 1.5 t ha^{-1}) high average yield of up to 4 t ha^{-1} in farmers' fields (Tesemma and Belay, 1991) and 7 t ha^{-1} at research centres (Tarekegne, 1996a) were reported. Moreover, Alemayehu *et al*. (1999a) also reported a wheat yield of up to 7.3 t ha^{-1} in farmers' fields showing the potential for increasing rainfed wheat production in the country. Such high level productivity of modern varieties of bread wheat in Ethiopia and wheat in Syria led to their high adoption and diffusion among farmers

Fig. 7.3. A modern bread wheat variety under seed multiplication in Syria (photo: ICARDA).

showing the success of the conventional plant breeding. In Syria, maintaining high yield and improving the grain quality remain important challenges in wheat improvement as most farmers are drawn into national and international markets (Tutwiler, 1995). In Ethiopia, however, translating the on-station or on-farm average yields into nationwide productivity levels remains crucial in poverty alleviation and achieving food security.

The success of the wheat breeding in both countries, however, was dependent to some extent on the strong support, collaborative research work and free germplasm exchange with the International Agricultural Research Centers. The success of conventional plant breeding in wheat overshadows the poor performance of formal sector in other important crops of particular relevance to farmers in less favourable environments. Apart from bread wheat and maize in Ethiopia and wheat and cotton in Syria, the performance of the formal sector plant breeding is quite limited in scope for other agricultural crops. Similar efforts would be required to ensure success for other cereals and legumes, which are important for food security in Ethiopia and Syria.

7.4.4. Will a Participatory Approach Provide a Solution?

Since the 1990s, participatory approaches became a driving force for agricultural research and rural development. Farmers became increasingly involved in the generation of technology rather than being simple recipients of new agricultural technology. There are many variants of farmer participatory approaches in crop improvement among which two are most prominent. According to Witcombe *et al.* (1996), farmer participatory approaches for identifying or breeding improved crop cultivars can be categorized into participatory varietal selection (PVS) and participatory plant breeding (PPB). In PVS, farmers select finished or nearly finished products (released cultivars, varieties in advanced stages of testing, or advanced non-segregating lines) from plant breeding programmes in their own fields. In contrast, in PPB farmers select genotypes from genetically variable, segregating materials. PPB may be used when PVS has failed, or when conventional plant breeding has not developed or identified a variety suitable for specific, usually harsh, environments.

Conventional plant breeding failed to develop appropriate varieties that are adaptable to local crop growing environment and acceptable by farmers for durum wheat in Ethiopia and for barley in Syria. The main problems associated with less success in marginal environments could be attributed to the highly variable and challenging climate, low government investment targeted in rainfed areas and poor development of market infrastructure (Pingali, 1999). In Ethiopia, for example research in drought prone semi-arid and arid regions is limited (ICARDA *et al*., 1999). Moreover, formal barley crop improvement research is relatively new in many developing countries and under-funded in the large producing countries including Syria (Aw-Hassen *et al.*, 2003). Although no participatory approaches have been reported for durum wheat and barley in Ethiopia there are several reports for the success of participatory plant breeding for other crops elsewhere (Eyzaguirre and Iwanaga, 1996). Ceccarelli *et al.* (2000) demonstrated farmers' capacity in handling segregated populations and in selecting high yielding barley entries under harsh and marginal environments compared to breeders in Syria. Likewise, in Jordan it was reported that under farmers' local conditions, the efficiency of farmers in identifying and selecting high yielding barley genotypes was found to be better than the efficiency of the plant breeders (Dinssa, 2003). Therefore, participatory approaches appeared to

Fig. 7.4. A typical marginal barley growing environment in Syria (photo: Z. Bishaw).

be useful tools in developing varieties that are more likely adopted by farmers than conventional plant breeding for niche environments.

From the outset, participatory selection has to be linked with decentralized seed production and supply programmes (Sperling and Scheidegger, 1995). Government policies and regulations remain a constraint in recognizing the role of participatory plant breeding and scaling up the seed multiplication and distribution to accelerate wider scale adoption and diffusion of new varieties identified by PPB. Therefore national governments must recognize and institutionalize PPB and devise alternative strategies in multiplying and distributing materials identified by farmers through such an approach (Turner and Bishaw, in press). The recognition of PPB and of an alternative delivery system would require government commitment in providing the policy and regulatory environment and financial support for its implementation. Some preliminary reports indicated the positive impact of various forms of participatory approaches in increasing biodiversity and adoption of varieties both in favourable and less favourable environments (Witcombe *et al*., 2001; Witcombe *et al*., 1999). However, despite several technical reports on the success of PPB more analysis is required to assess its economic impacts (Almekinders and Elings, 2001).

7.4.5. On-Farm Diversity of Wheat and Barley Crops

The spatial, temporal and coefficient of parentage analysis showed that a limited range of wheat and barley varieties are grown by farmers. Farm level surveys indicated a few dominant varieties appeared to occupy a large proportion of wheat and barley area and were also grown by the majority of farmers (Chapter 6). The long weighted average age of wheat varieties coupled with estimated short durability of resistance against rust diseases is of great concern. It is important to diversify the portfolio of modern varieties available to farmers to avoid vulnerability to periodic epidemics of rust diseases which was observed in Ethiopia (Badebo and Bayou, 1992). Moreover, breeding strategies should also focus on specific adaptation to encourage release of several varieties rather than few varieties with wide adaptations.

7.4.6. Partnership of NARS and IARCs

The healthy partnership between NARS and IARCs played a significant role in generating productivity enhancing technologies in agriculture sector at least in favourable environments throughout the developing world. This is based on free and unlimited access to improved germplasm exchange network co-ordinated by IARCs (Morris, 2001). According to (Heisey *et al*., 2003), the high cost of crop improvement coupled with the liberalization of the seed sector and the growing importance of intellectual property rights will have a significant impact on plant breeding and on the seed industry in the developing countries. Such efforts have already encouraged private sector participation in high value and profitable crops such as commercial hybrid maize in developing countries leading to competition rather than collaboration due to concerns of intellectual property rights (Morris, 2001).

To date less than 4% of wheat area in developing countries is planted with private sector varieties mostly originated from germplasm of the public sector (Pingali, 1999). In the immediate future there will be no spectacular increase in private sector investments in plant breeding of wheat and barley crops in developing countries. The NARS and IARCs should focus on breeding self-pollinated, high volume and less profitable crops which are of limited commercial value to attract private sector investment but are of significant value for food security of small-scale resource-poor farmers. They should allow the emerging private sector (with limited R&D capacity) an access to improved germplasm and varieties to support the development of the seed industry.

On the other hand, the private sector plant breeding may concentrate on commercial and profitable crops and where the technology is available (e.g., hybrids) to protect the intellectual property rights. A growing trend in commercialization of agriculture, privatization of seed industries, the strengthening of IPRs, reduced public research capacity may change the rules of the crop improvement game in developing countries (Morris and Ekasingh, 2002). The government should provide policy support to encourage private sector participation in research and development. Moreover, public-private partnership should be encouraged to exploit their comparative advantages and complimentarity.

7.5. Designing Appropriate Technology Transfer Mechanisms

Effective technology generation requires the participation of stakeholders such as farmers, extension workers, input distributors and credit service providers in the technology generation processes. Gebrekiros (1980) demonstrated that the development approach in highly varied peasant agriculture such as Ethiopia could be more successful through active participation of the farmers with the researchers and the extension services in identifying and prioritizing the constraints and finding alternative solutions. The NARS in Ethiopia and Syria made attempts to involve farmers in the research process to improve the generation of technology and its adoption. In Ethiopia, previously farming systems research and lately participatory rural appraisal methods are being used for problem identification, needs assessment and to characterize the farming systems in different agro-ecological zones. EARO conducts on-station and on-farm trials and extends the results to farmers through the extension agents. Similarly, GCSAR also conducts extensive on-farm trials in collaboration with ICARDA in evaluating the new variety and associated technologies and transferring the results through the extension services. However, the importance of factors affecting technology adoption varies across the two countries because of differences in endowment of natural resources, policy and socio-economic conditions of farmers.

7.5.1. Sources of Information for New Technologies

Apart from the development of modern varieties several improved agronomic practices have been identified, evaluated and recommended. In Ethiopia, survey results showed that information on modern varieties and improved agricultural technologies are mostly obtained from the formal extension service owing to the recently introduced government extension package programme. On the other hand in Syria the informal farmer-to-farmer flow of information appeared to be more important followed by the formal extension system. Several studies confirmed the importance of the informal sector as a primary source in the flow of information about modern varieties (Tripp and Pal, 1998; Tripp, 2000).

Despite very long and arduous efforts in generating new technology by NARS, the final transfer of technology to farmers rests with a separate institution with no direct role in agricultural research. Moreover, there are no formal linkages between agricultural research and extension services although several efforts have been made in the past particularly in Ethiopia to form research-extension linkages. The development of relevant technology must be coupled with appropriate technology transfer mechanism (Byerlee and Heisey, 1992) where linkages between agricultural research systems, extension services and other stakeholders (seed producers, input providers, credit services, etc.) should be established and strengthened to ensure the flow of information.

7.5.2. Adoption of Varieties and Associated Technologies

Modern wheat varieties and several new crop production technologies such as sowing dates, rates and methods; fertilizer types, rates and application methods; physical and chemical crop protection practices; rates, time and frequency of irrigation have been identified, evaluated and recommended by NARS in Ethiopia and Syria. The adoption of modern wheat varieties appeared impressive owing to farmers' satisfaction with their agronomic performance in terms of high grain yield, grain size, grain quality, food quality and marketability except for durum wheat in Ethiopia and barley in Syria. Moreover, farmers may seek disease resistance (e.g., in Ethiopia) or tolerance to lodging and shattering (e.g., in Syria) based on their own perception of wheat production constraints. Since wheat straw is very important as livestock feed it was suggested to breed for taller bread wheat varieties without compromising grain yield (Tarekegne *et al*., 1996c). On the other hand the adoption of agronomic practices such as seed rates, fertilizer rates and use of pesticides is not consistent with the research recommendations either due to lack of awareness and availability (e.g., insecticides in Ethiopia), lack or limited availability of inputs (e.g., fertilizers and herbicides in Ethiopia) or farmers reluctance to change traditional practices (e.g., high seed rates both in Ethiopia and Syria).

In most cases research results lack agro-ecology-based specific recommendations and are not always evaluated for their socio-economic benefits. For example, in Ethiopia a series of zone-specific on-farm fertilizer response trials have been conducted lately for wheat varieties to derive optimum N and P recommendations in major growing regions (Gorfu *et al.*, 1991) including economic benefits of fertilizer use (Tanner *et al.*, 1999) and herbicides (Negatu and Mwangi, 1992; Tessema and Tanner, 1999). The generation and transfer of location and variety specific agronomic recommendation (seed rates, fertilizers, herbicides, etc.) supported by adequate technology transfer mechanism to ensure adoption would be crucial in enhancing agricultural production and productivity. Lack of specific information on improved crop management practices reported affecting the profitability of wheat production in Ethiopia (Gavian and Degefa, 1996). Efforts in economic analysis of technology packages should be encouraged to ensure its uptake and adoption which otherwise might discourage farmers from applying new technologies or lead to misuse of inputs that is provided through government subsidy. Moreover, the provision of credit services, availability of fertilizers and other inputs at affordable prices will be necessary to create a favourable socio-economic environment for sustainable crop production (Negatu and Mwangi, 1994).

7.5.3. Level of Agricultural Development and Farm Mechanization

In Ethiopia, farmers use centuries old traditional implements to perform different farm operations. An oxen-drawn plough locally called *maresha* is widely used for land preparation, sowing is usually by manual broadcasting, weeding is by hand pulling of plants and harvesting is performed manually by sickle with little or no modern agricultural machinery (Fig. 7.5). In contrast in Syria government policy encouraged mechanization of agricultural operations since the 1960s. To date wheat and barley cultivation (land preparation, planting, harvesting) is almost entirely mechanized, except in very isolated mountainous ranges or very small fields. Ethiopian agriculture is essentially subsistence characterized with traditional technology, low crop productivity and little ownership of farm machinery whereas in Syria commercialization, intensification and mechanization of agriculture are taking place at a rapid pace.

7.6. Maintaining Diversity of National Seed Systems

Agricultural policies aimed at achieving increased productivity and food security must




Fig. 7.5. Ethiopian agriculture characterized by centuries old practice where draught animal and human labour still playing major roles (top left: mixing seed and fertilizer for planting; top right: manual broadcasting; bottom left: oxen-pulled plough (photo: Z. Bishaw); bottom right: manual harvesting of wheat (photo: Oriana Porfiri)).

emphasize strategies that will guarantee the availability of adapted varieties and quality seed to farmers by establishing sustainable seed supply systems through the participation of government, private sector, farmer groups and non-governmental organizations. The creation of the policy and regulatory environment coupled with political will and commitment of the government may bring these changes into reality.

7.6.1. Formal Seed Sector

The formal sector includes usually large-scale commercially organized seed production and distribution operated by the parastatal seed corporations or domestic private seed companies or multinational corporations across the countries. The formal sector is often supported by quality control programmes to ensure quality before marketing the seed.

Performance of Public Seed Sector The Ethiopian Seed Enterprise (ESE) remains the major producer and distributor of commercial seed directly to the state farms and to farmers through service co-operatives, the Ministry of Agriculture, the new extension package programme or international aid agencies and NGOs for emergency seed relief programmes. In recent years, the extension package programme is the major customer of the ESE (up to 80%) while the international aid agencies and NGOs are main clients in years of drought. The analysis of seed distribution over a six-year period from 1994 to 1999 shows that on average 14,205 tonnes of commercial seed was sold by the ESE. It is estimated that the average market value of commercial seed of cereal crops produced by ESE was ETB 40.1 million (US$1= ETB 7.50) with wheat and maize constituting 53% and 43% of the total market value of formal seed, respectively. Moreover, wheat and maize occupied 70% and 22% of the average commercial seed distributed, respectively (Chapter 2). The major cereal crops, which are very important for food security such as *tef*, barley and sorghum altogether occupied only 7.1% of the total commercial seed distribution.

The average area under wheat production during the same period (1994-1999) was 870,600 ha and at the rate of 150 kg ha^{-1} this would require at least 130,590 tonnes of seed for planting. The formal sector managed to supply 9897 tonnes of commercial wheat seed sufficient to plant 65,980 ha (or about 8% of the total wheat area). However, theoretically the formal sector recommends that for self-pollinated crops (e.g., wheat) only 25% of area should be replaced with fresh certified seed every year. Therefore, the wheat seed from ESE would at least cover 30% of the total area that requires seed replacement each year (217,650 ha). Further analysis of the seed distribution by varieties even shows a very limited range of the commercial seed available. From a total of 17 wheat varieties produced by ESE in 1999, the four most popular varieties, ET 13, HAR 1709, HAR 1685 and Pavon altogether occupied 75% of wheat seed (8,445 tonnes) and 47% of the total commercial seed distributed (13,349 tonnes). Likewise, from eight maize varieties on sale two hybrid varieties (BH 660 and BH 140) accounted for 80% of maize seed and 27% of the commercial seed distributed during the same year. In general, the wheat seed distribution statistics illustrate the limited range of varieties and commercial seed available at the national level.

In Syria, the General Organization for Seed Multiplication (GOSM) is one of the major public sector organizations in the agricultural sector with huge investments in seed production, processing and storage facilities across the country. Seed marketing and distribution is handled through the Agricultural Credit Bank (90%) to co-operatives and state farmers or directly by GOSM (10%) to private farms. In 1998, it was estimated that the market value of commercial seed of agricultural crops (excluding cotton, potato, sugar beet) produced by GOSM valued at SYP 2.71 billion (US$ 1= SYP 46) with wheat and barley constituting 92 and 5% of the total commercial value, respectively. From 1994 to 1999, the average seed distribution was 227,869 t yr^{-1} out of which 168,540 tonnes (74%) was seed of agricultural crops (Chapter 3). During the same period, wheat and barley seed occupied 94% (158,461 tonnes) and 3.4% (5,743 tonnes) of agricultural crop seeds distributed, respectively. Moreover, during the six year period the average wheat and barley area was 1.7 and 1.6 million ha, respectively (Chapter 3). At the seed rate of 150 and 100 kg ha^{-1} for wheat and barley, respectively, the average commercial seed distributed would plant about 1.1 million ha of wheat (65%) close to the government target of 70% (Radwan, 1997) and only 57,430 ha for barley (3.6%) of the total area under these crops each year. Moreover, the state farms had the priority over co-operatives and private farms in terms of seed distribution. If the formal sector standard rule of 25% seed replacement rate for self-pollinated crops is considered, the average seed requirement would be 62,625 tonnes for wheat (425,000 ha) and 60,300 tonnes for barley (400,000 ha). Therefore, each year on average 62,625 tonnes of commercial wheat seed is required compared to 158,461 tonnes which is produced showing an excess of 95,836 (158,461–62,625) tonnes. In case of barley each year 60,300 tonnes of commercial seed is required but only 5,743 tonnes is produced showing a deficit of 54,557 (60,300–5,743) tonnes. The figures above show an imbalance of wheat and barley seed production and distribution at the national level. Further analysis of seed production revealed that Cham 4 and Cham 6 among bread wheat (from five varieties) and Cham 3 and Bohouth 5 among durum wheat (from eight varieties) accounted for 62 and 18% of the total wheat seed production in 1998. In previous years the quantity of durum wheat was generally higher than the bread wheat. A single variety of barley (Arabi Aswad) accounted for 85% of commercial seed produced during the same year.

The GOSM produces an excess amount of wheat seed every year considering the recommendation of the formal sector where certified seed should be replaced every four to five years. In general there is no significant yield loss in self-pollinated crops (e.g., wheat) if farmers continuously use own saved (retained) seed of the same variety for several years (Heisey and Brennan, 1991) provided there is no breakdown of resistance to plant diseases and pests. Moreover, the wheat farmers in Syria also follow good on-farm seed management practices such as cleaning and chemical treatment before planting their wheat crop (Chapter 3). Given these facts, the policy of public seed sector encouraging farmers to exercise high annual seed replacement rate with a target of up to 70% nationwide is not necessary. Instead, more effort should be geared towards producing seed of other important crops such as barley and legume crops where the availability of adapted varieties and seed are the major constraints.

From the figures illustrated above, the performance of the formal sector in terms of annual seed supply is small given the financial and institutional support it enjoyed from the government. A huge amount of resource is allocated to produce and market seed of the same recommended varieties. In contrast farmers do not regularly purchase certified seed and are more dependent on informal sources once the modern variety is available within the local farming community. For most farmers the acquisition of a modern variety is by far more important than regular purchase of certified seed from the formal sector. Sometimes, a large quantity of commercial seed is carried over to the next season because of lack of demand for seed of crop varieties produced by the formal sector. Finding alternative strategies to enhance rapid diffusion of new varieties and seeds among farmers remains crucial to realize the impact of crop improvement research. Grisley (1993) suggested a non-commercial approach for crops not handled by the formal sector where seed packs are distributed in small quantities to farmers to encourage informal varietal diffusion and adoption rather than regular seed production and supply for beans in Sub-Saharan Africa. Jones *et al*. (2001) also reported the successful dissemination of a modern pigeon pea variety from injection of seed from a single demonstration trial in Kenya. Farmers' acceptance of the variety due to its determinate growth habit, short stature, bold white seeds and the ease of maintaining seed purity contributed to its diffusion. Such schemes could have relevance for crops not handled by the formal sector or in marginal environments provided farmer-preferred varieties are available either from conventional or participatory breeding approaches. However, this would require a drastic policy shift on the part of the formal sector seed supply.

Participation of Private Sector From the mid 1980s, there has been a strong desire for economic liberalization to stimulate global economic growth and development. These policy shifts brought many changes in the seed industry including policy and regulatory reforms to create an enabling environment to allow the participation of the private sector and to reduce government involvement in seed production. Several approaches were used to diversify the seed sector by privatizing the existing public sector or through entry of private sector (Turner *et al*., 2000; van Gastel *et al*., 1997). Some countries allowed outright privatization of the public seed sector (e.g., Ghana; Lyon and Danquah, 1998), whereas others restructured the existing public sector enterprises to operate efficiently by granting management and financial autonomy (e.g., Egypt; Yousef and Ismail, 2000). Some countries provided the policy and regulatory environment for entry of multinational seed companies and domestic private sector (e.g., Turkey; Pray, 1997).

Van Gastel *et al.* (1997) described the status of the private seed sector in the West Asia and North Africa region.

Since 1992, the Ethiopian government has taken successive macro-economic and sectoral measures liberalizing the economy. The national seed industry policy encourages private sector investment in plant breeding and seed production and marketing. However, after one decade of policy pronouncements, there is only one private sector company operating in the country dealing with hybrid maize showing the inadequacy of the policy environment for private sector participation in the seed industry. In 1991, the Syrian government also enacted the investment law and took liberalization measures for private sector investment in the economy. However, plant breeding and seed production and supply of strategic food and industrial crops remains under the responsibility of the public sector except for the vegetable seed industry.

Wheat and barley are self-pollinated, high volume and less profitable crops and are less likely to attract private sector investment in the immediate future. It is expected for the public sector to continue playing a major role in the wheat and barley seed sector. The governments are also reluctant to withdraw because of their strategic importance as food security crops. It is difficult to anticipate or predict the specifics of future developments in the wheat and barley seed market in developing countries in general and in Ethiopia and Syria in particular, but one thing is certain. As stated earlier the accelerating cost of genetic improvement research, the liberalization of the economy and emerging intellectual property rights may influence the development of the seed industry in the years to come (Heisey *et al*., 2003). Many authors discussed the appropriate roles and functions of public and private sectors in the national seed industry (Jaffee and Srivastava, 1994; Turner *et al*., 2000; van Gastel *et al*., 1997). Forging partnerships through national dialogue would be essential to exploit the comparative advantage of both the public and the private sectors to establish a sustainable seed industry.

Seed Demand and Access to Credit Services During the field survey farmers cited high seed prices, lack of access to credit facilities and lack of seed availability as the main constraints discouraging them for not using commercial seed of wheat and barley from the formal sector. In Ethiopia, farmers have to register their interest to purchase seed through service co-operatives with a down payment of 25% of the total cost of inputs where members get preference over non-member, private farmers. Likewise in Syria, farmers register with the co-operatives, which will process the request to get access to credit for seeds. Private farmers can directly purchase seed from GOSM with collateral on property (e.g., land). Theoretically farmers have access to credit services, but reality proved difficult for ordinary small-scale resource-poor farmers. In general, long and bureaucratic procedures, collective responsibility for the debt of the co-operative, and need for collateral or down payment discouraged many farmers to seek credit for purchase of inputs. Moreover, it is reported that in Ethiopia seed demand and supply will not match because of lack of availability of varieties requested by farmers. Lyon and Danquah (1998) also reported that farmers in Ghana found the credit procedures inconvenient, time consuming and requirements for collateral restrictive to purchase commercial seed. Benteley and Vasques (1998) also observed farmer's lack of knowledge about credit services as a constraint particularly among small-scale farmers in Bolivia. Such situations need improvement to encourage farmers to use the credit facilities available by the government.

Formal Seed Sector Support Services In Ethiopia, the seed law (Ministerial Regulation No. 16/1997) was passed covering varieties and seeds. The Seed Proclamation No. 206/2000 was enacted elaborating the regulations for variety release and registration and seed quality control and certification. Moreover, field and seed standards prepared for 74 crops were officially issued for implementation. The National Agricultural Input Authority (ex NSIA) was given a mandate to implement the variety and seed regulations. However, these regulations will remain unimplemented effectively and efficiently for the years to come given the limited technical and institutional capacity and infrastructure of the implementing agency. In Syria, there are no regulations pertaining to varieties and seeds (except for quarantine). The Ministry of Agriculture and Agrarian Reform and its affiliated institutions organize most activities on an ad hoc basis. Therefore, it is imperative that the national governments take an initiative to develop laws and regulations pertinent to varieties and seeds through appropriate participation and consultations among the stakeholders. Given the limitations of regulatory functions of variety and seed regulations discussed earlier it is important for the government to establish a low-key and cost-effective independent agency that is responsible for variety release and registration and seed certification. The ‘Quality Declared Seed’ scheme developed by FAO with some modifications would be an ideal approach for developing countries by balancing the freedom of seed producers and the protection of the farmers. The agency should ensure that standards are strictly observed and enforced. According to Tripp (1997b) the three basic elements of any regulations are the setting of the relevant norms or standards against which the quality of the product is assessed, the monitoring process to ensure that the standards are observed and the enforcement of the standards or the capacity to impose sanctions. The government should ensure that the seed laws and its subsequent regulations are implemented efficiently, effectively and impartially in a participatory and transparent manner without undermining state legitimacy (Tripp, 1997b).

Investment in Human Resource Development Seed technology is relatively a young science in terms of academic study and teaching (Turner, 1983) and there are limited opportunities for specialization compared to other agricultural related disciplines. More importantly, the changing global seed industry requires experiences in policy formulation, negotiation skills rather than purely technical and management issues. Apparently few people have the qualifications and experience to contribute meaningfully to the progress of the industry. In general, there is lack of trained staff to lead and manage the national seed industry development. It is, therefore, important for each country to develop strategies to correct these deficiencies. Training programmes need to focus on several key issues – seed programme development, seed enterprise development, seed enterprise and financial management, seed marketing, and strengthening of the informal sector.

7.6.2. Informal Seed Sector

The analysis of the wheat and barley seed systems in Ethiopia and Syria demonstrated that the informal sector is not only the principal source of information and initial seed source of modern varieties but also the major supplier of seed for planting of both crops in any given year. Moreover, the study revealed farmers' indigenous knowledge in seed selection and management and their competence in producing quality seed that is comparable to that of the certified seed from the formal sector. Farmers attach high value to the quality of seed used for planting and employed various on-farm management practices such as seed selection, cleaning, chemical treatment and separate storage to improve and maintain quality. Several studies in Ethiopia (Beyene *et al.*, 1998; Ensermu *et al.*, 1998; Woldeselassie, 1999), Syria (van Gastel and Bishaw, 1994) or elsewhere (Hasan, 1995; Gamba *et al.*, 1999) support these findings. The results would enable us to devise alternative approaches in organizing a low-cost seed production and marketing system using farmers' skill to accelerate the adoption and diffusion of modern varieties both from conventional and non-conventional breeding approaches.

Local Seed Sources and Marketing The study clearly demonstrated that the informal sector is the initial source of modern varieties of wheat both in Ethiopia and Syria. It appeared that the traditional informal farmer-to-farmer seed exchange played a key role in lateral diffusion of modern varieties and seeds rather than the formal sector. Moreover, the informal sector was also the main seed source for planting wheat and barley crops in any given year. Farmers' own seed stock retained from the previous season's harvest was the single most important seed source for both wheat and barley crops. For barley, sample farmers were entirely dependent on informal seed sources.

Farmers exchanged, bartered or sold seed of modern varieties to their relatives, neighbours or other farmers which demonstrates the operation of the village seed market. Such group of farmers could be regarded as ‘suppliers of introduced seed’ as described by (Louette *et al*., 1997). Farmers have positive perception of seed sourced informally and reported satisfaction with the quality, an indicator of potential seed market at local level.

On-Farm Seed Quality As stated earlier, the Ethiopian and Syrian farmers have demonstrated their ingenuity in producing wheat and barley seed of good quality. In general most wheat seed samples maintained the minimum seed quality standards of the formal sector. Similar results were reported from Ethiopia (Ensermu *et al*., 1998; Hailye *et al*., 1998) and Syria (van Gastel and Bishaw, 1994). There was no difference in seed quality among different sources except for germination of wheat in Ethiopia and barley in Syria. However, further analysis showed that the informal sector has some weaknesses particularly in barley seed where there is room for improving the traditional on-farm seed management by farmers. Contamination with noxious weeds particularly with wild oats was the major constraint in physical purity. Mechanical harvesting appeared to have some effects both on physical and physiological quality (germination). Moreover, farmers lack specific knowledge about seed health quality problems although almost all wheat farmers in Syria applied chemical seed treatment. A crop specific intervention would be required to improve seed quality problems on the farm.

Farmers used different techniques in evaluating the physiological quality of their seed particularly in Ethiopia where the women played a key role. It is possible to introduce simple and practical purity or germination test methods using cheap and locally available materials and make farmers aware of these procedures. For example, Mathur and Talukder (2002) used jute mats for germination of rice seed in Bangladesh and this was found to be the quickest test compared to other formal germination test methods.

On-Farm Plant/Seed Selection Most wheat and barley farmers practised a combination of different selection methods, stages, criteria and responsibilities to differentiate between grain used for consumption and seed for planting on their farm (Chapter 2 and Chapter 3). In Ethiopia, women played a key role in seed selection as compared to their counterparts in Syria where almost all farm operation are mechanized and their labour contribution to crop production become decreased. However, the selection practices were indirect and seldom involved any specific physical measurements. In general there was no methodological approach in plant/seed selection or any difference between farmers using modern varieties or local landraces. Gamba *et al*. (1999) reported that wheat seed management practices were similar between small-scale and large-scale farmers, although more large-scale farmers had separate fields for seed, practise seed selection at harvest and store seed separately. Wheat and barley are typically self-pollinated crops with little out-crossing where the varietal identity and genetic purity can be easily maintained provided farmers follow certain sound agronomic practices. A simple 'best practice' guideline for seed production to be used by farmers would significantly improve some of the quality constraints observed in the informal sector (Bal and Douglas, 1992).

On-Farm Seed Cleaning Almost all wheat and barley farmers in Ethiopia and Syria who used retained seed or obtained seed informally from local sources recognized the value of physical seed quality and cleaned their seed before planting. The majority of farmers used traditional tools (Fig. 7.6) which in most cases were found in effective in complete removal of impurities thus leading to low physical seed quality. However, some farmers in Syria rented locally manufactured low cost mobile seed cleaners (Fig. 7.6) or brought their seed to some private grain cleaners operating at the village levels. During the field survey some private rural enterprises providing grain-cleaning service at village levels were also observed. Such enterprises could easily be combined with seed cleaning services as a thriving rural enterprise. In Ethiopia, similar approaches of designing, developing and manufacturing low cost seed cleaning (and treatment) equipment to improve quality at farm level would be beneficial for any local level seed production initiatives or for individuals who wish to initiate a private business to provide cleaning services to other farmers. Moreover, making available simple hand-operated cleaning tools affordable by individual farmers could be another alternative.

Fig. 7.6. A locally manufactured mobile seed cleaner compared to a traditional hand tool in Syria (photo: Z. Bishaw).

On-Farm Seed Treatment In Syria, wheat farmers used a combination of different seed treatment chemicals as a routine practice to ensure the health quality of seed obtained informally from local sources. Chemical seed treatment is the most effective and cheapest pest control measures if applied judiciously and effectively. Almost all farmers applied the chemical treatment by mixing it with seed using a shovel apparently with little or no safety measures (Chapter 3 and Fig. 7.7). There are concerns on the formulation and efficacy of chemicals available; the method and rates of application; lack of adequate equipments; and lack of knowledge and precautions on safety measures. Moreover, designing simple hand-operated tools and making them available to farmers would enhance the quality of on-farm treatment (Fig. 7.7). Adequate extension programme for seed treatment would be beneficial for the farmers in increasing the efficacy, targeting the organisms and reducing the cost and polluting of the environment. It is also important to provide guidance and create awareness on production of disease free seed instead of encouraging routine seed treatment. For example, Bekele (1985) cited that in Ethiopia a simple technique of seed cleaning using a ‘flotation method’ was developed to separate wild oats and ergot sclerotia (*Claviceps purpurea*) from barley to improve the physical and health quality for planting the crop in the peasant sector.

On-Farm Seed Storage Gotera is one of the most common traditional grain/seed storage structures in Ethiopia (Fig. 7.8) compared to Syria where almost all farmers use bags for grain or seed storage (Chapter 3). Most farmers recognize the differences between seed and grain and separate them during storage. However, insect pests and rodents are identified as main constraints for on-farm seed storage and traditional practices would not provide adequate protection and infestation with pests could lead to reduction in physiological seed quality. Some reports indicated that insect damaged

Fig. 7.7. On-farm chemical seed treatment of wheat in Syria (left; photo: Z. Bishaw) and a prototype of simple hand-operated equipment (right; photo: ICARDA).

Fig. 7.8. A modified (raised) traditional on-farm grain and/or seed storage facility in Ethiopia (photo: ICARDA).

wheat seed showed reduced germination and vigour (Kashyap and Duhan, 1994). Farmers use traditional practices or some apply contact insecticides or fumigants to overcome storage pest problems. Inappropriate use of chemicals may lead to development of insecticide resistance against most commonly available fumigants (Niane, 1991). An effort should be made to improve on-farm seed storage facilities (Cromwell *et al*., 1993; Osborn and Faye, 1991; Bal and Rajbhandary, 1987) and provide training to farmers in appropriate use of chemicals.

Establishing Small Seed Enterprises Cromwell *et al*. (1993) described several types of local level seed production activities by farmer groups, NGOs, etc. They are mostly operating through external donor support and with a tendency of 'dependency' syndrome with little concern for long-term sustainability. Given the performance of the informal sector described above we would advocate the formation of business oriented small seed enterprises (SSEs) which is consistent with current policy trends towards privatization, decentralization and rural business development (Turner and Bishaw, in press) to ensure long-term sustainability. Kugbei and Bishaw (2002) described the various forms of small seed enterprises (SSEs) and outlined the policy, regulatory, technical and institutional measures and supports required for successful operation of local level seed production. The SSEs may include individuals and groups of farmers, co-operatives and farmer organizations, traders and merchants or NGOs who based on indigenous knowledge and local circumstances design alternative seed delivery mechanism with self-reliance and sustainability as key elements. The local seed production schemes will help to:

- multiply locally tested varieties which are selected according to farmers' local needs;

- link seed demand with seed production at the local level;
- reduce overhead, transport, marketing and distribution costs in order to lower seed price; and
- generate additional income for farmers engaged in local seed enterprises.

For SSEs to succeed, they must have appropriate linkages with formal sector institutions such as agricultural research for foundation seed supply, the formal seed sector to provide quality assurance services and training, credit services to provide capital and the extension service for technical guidance and supervision (Kugbei and Bishaw, 2002; Bal and Rajbhandary, 1987). The SSEs would promote wider adoption and diffusion of modern varieties and associated technologies by bringing the seed to less accessible remote regions or in less favourable environments serving the interests of the predominantly small-scale resource poor farmers. In Ethiopia, the preliminary results of the Farmer-based Seed Production and Marketing (FBSPM) project (Fig. 7.9) was found promising in familiarizing farmers with modern varieties and local seed production initiatives. The approach would be relevant for durum wheat in Ethiopia and barley in Syria where the formal sector was unable to make any headway and the participatory approaches are underway to identify varieties that meet the need of farmers. Farmers should be trained not only in techniques of seed production but also in seed marketing and business management to ensure the sustainability of the enterprise without external support. The SSEs will strengthen the linkage of both formal and participatory plant breeding to the seed supply systems, both through formal and informal seed production channels. They should be allowed to operate loosely without much interference from the stringent regulatory and quality assurance function of the formal sector, however.

7.7. Linkages and Integration of Seed Systems

In Chapter 1, we have defined the seed system; later we described its components within the context of the Ethiopian (Chapter 2) and Syrian (Chapter 3) national seed industry. The existence of formal and informal seed sectors has now been recognized and their complimentary role and integration widely emphasized in an agricultural research and seed programme development continuum (Louwaars, 2002; Almekinders and Louwaars, 1999). Bal and Douglas (1992) emphasized a need to have a clear strategy to understand, improve, and link farmer seed systems to the formal seed system. In the following section the suggested linkages between the formal and informal sectors (Fig 7.1) are discussed in detail.

Fig. 7.9. A farmer wheat seed production field under FBSPM project in Ethiopia (photo: Z. Bishaw).

7.7.1. Linkages in Genetic Resources Conservation

Crop genetic improvement, conventional or participatory, is dependent on the availability and access to genetic resources. The local germplasm pool (local landraces, wild relatives or progenitors) would provide valuable genetic variability to develop varieties with better agronomic performance (high grain yield, quality) or tolerance to stresses (biotic, abiotic). However, there is great concern on the loss of genetic diversity in farmers' fields and the need to devise strategies for plant genetic resources conservation using formal (*in-situ*) or informal (*ex-situ*) approaches. The on-farm germplasm conservation, enhancement (improvement), seed production and distribution reported from Ethiopia was an innovative approach combining different objectives and involving various stakeholders (Tesemma and Bechere, 1998; Worede, 1992). The main purpose was to develop elite local landraces for use by farmers who at the same time ensure their conservation and maintenance on the farm. The approach created a triangular linkage between the national germplasm bank, agricultural research centre and a local NGO in repatriating genetic resources back to the farmers in drought prone areas of the country. However, such a farsighted approach should be strengthened with policy, regulatory, institutional and financial supports form the government for success.

7.7.2. Linkages in Crop Improvement

Theoretically, there should be a strong linkage between formal plant breeding and organized seed supply. In reality however, there is lack of formal linkage between public sector research and seed producers (Lyon and Danquah, 1998). For the diverse and complex environments breeding improved varieties which truly meet farmers' complex need proved difficult without farmer participation. Witcombe *et al*. (1996)

described different levels of participation where plant breeders try to exploit farmers experience in identifying crop varieties suitable to diverse environments. Turner and Bishaw (in press) suggested possible linkages between the conventional and participatory approaches. Accordingly materials identified by farmers could be refined through formal breeding programme or enter formal variety evaluation and release procedures but with less stringent criteria. The collaboration between plant breeders and farmers would strengthen alternative ways of crop improvement for difficult and less favourable environments.

7.7.3. Linkages in Seed Production

Overall performance of the seed sector depends on co-operation and strong linkages between the various institutions and stakeholders. The analysis of the formal sector, however, showed its limitation in providing the choice of varieties and the quantity of seed required by farmers. Most formal sector activities concentrate in favourable environments and function properly where there is good rural infrastructure. On the other hand farmers in remote and less accessible areas or less favourable environments remain isolated from the mainstream seed production and supply. There is a growing interest in alternative approaches to decentralize seed production at local levels through the participation of individual farmers, farmers groups, etc. to encourage diffusion and adoption of modern varieties (Kugbei and Bishaw, 2002). It is important that farmers' seed systems are linked with the formal seed sector, research and extension services. The formal sector not only provides varieties and seeds but also provides technical support (production, processing, and storage) and training required (technical and business management) in producing and marketing good quality seed. Linkages with credit services and financial institutions are also critical for the success of local seed systems. Moreover, the formal sector can also assist by developing appropriate seed cleaning and treatment equipment and storage facilities based on indigenous knowledge that would enhance the quality of on-farm produced seed.

7.7.4. Linkages in Seed Quality Assurance

Seed quality assurance is the main component of the formal sector operation where the quality is judged against a set of standards before certification. Local level seed production and marketing initiatives are widely dispersed and lack access to such resources but they should produce seed of acceptable quality and win the confidence of farmers to market it locally. Farmers should be aware of crop specific factors reducing seed quality and take appropriate measures during production, cleaning, and storage. The formal sector can play a pivotal role by identifying seed quality constraints, conduct adapted research to solve farmer’s problems based on local knowledge and train them in maintaining the seed quality. Such an approach would be useful in adopting appropriate seed quality standards that could be relevant to farmers' requirements. Moreover, the formal sector can provide seed quality assurance services (field inspection and seed testing) in an advisory role to farmers engaged in seed production and marketing and willing to participate in the programme.

7.7.5. Linkages in Technology Transfer System

Historically, the extension services are considered a bridge between agricultural research and farmers delivering information about new technology developed by NARS. Their role in popularizing recommended varieties and associated technologies through demonstration trials should not be overemphasized. Despite this fact, however, the extension services remain the weakest link in the technology generation and transfer process. In many countries, research and extension are operating under different umbrella organizations with no formal linkages and barely participate in any initial evaluation and release of new varieties or technologies. ‘Seed extension’ is not even part of the agricultural extension message. Farmers are advised to use recommended varieties and how to improve yield but not trained on how to produce good quality seed on their farm for planting next years crop. The extension service would be expected to play a greater role particularly in participatory plant breeding approaches and local seed production schemes. Therefore a formalized linkage would be essential between extension, research and seed sector if they are to be effective in transferring the technology to farmers. Research and extension need to be linked and strengthened to increase the flow of information to farmers (Benteley and Vasques, 1998). A positive role of extension agents in seed marketing and distribution by bulk buying and selling seed directly to farmers, as contract producers or as agents for seed dealers or as informal source of seed for maize farmers have been reported from Ghana (Lyon and Danquah, 1998).

This thesis addresses the wheat and barley seed systems in Ethiopia and Syria focusing on informal sector. Despite some limitations and differences between wheat and barley crops, the study demonstrated that: first, small farmers can adopt modern varieties and purchase certified seeds; second, the informal seed networks play a major role in diffusing modern varieties; third, farmers have sufficient experience and knowledge to produce good quality seed; fourth, integration between formal and informal sector is necessary for the development of sustainable seed industry.

7.8. Concluding Remarks

The Ethiopian and Syrian national seed industries differed in their policy, regulatory and institutional arrangements. Because of natural resources, policy, socio-economic differences the importance of factors affecting technology adoption to some extent differed in the two countries. However, the public sector institutions dominated the agricultural research and seed sector with no private sector investment in wheat and barley crops. Experiences elsewhere show that the success of any agricultural development programme hinges on free access to improved germplasm, the development of adaptable varieties with desirable agronomic characteristics fitting to the farming systems, investments in provision of agricultural inputs, adequate infrastructure and the political commitment of the national governments.

In Ethiopia, the new agricultural package programme achieved tremendous progress in familiarizing farmers and in adoption of modern varieties of bread wheat and associated technologies. However, the provision of inputs, credit facilities, and grain marketing remain major policy constraints. Lack of clear policy in grain marketing and pricing would lead to reduced returns and discourage farmers in investing in new technologies. The government Agricultural Development Led Industrialization (ADLI) economic policy so far miserably failed to bring structural transformation of agriculture and to strengthen the manufacturing sector. Moreover, more farmers are suffering from deepening rural poverty with recent estimates of 15 to 20 million Ethiopians experiencing acute food shortages.

For over a decade, the Syrian agricultural sector in general, and the wheat production in particular, has registered remarkable progress and achieved surplus crop production. Most farmers benefited from government policy and responded by adopting new technologies such as modern varieties and associated technologies including fertilizers, agrochemicals, and irrigation water. The challenge is to keep abreast with new technologies, improve the current production and productivity levels and to stay competitive in the wheat sector. The government should also consider alternative options and strategies to replicate the successes achieved in wheat by increasing barley production and productivity. It is expected that the governments of Ethiopia and Syria develop strategies that would allow the diversification of the seed industry where various forms of enterprises are operating side by side and contribute to the overall development goal of the agricultural sector in general and the seed sector in particular. It is hoped that this study would help to contribute towards the dialogue to create awareness and understanding to formulate the policy, regulatory, technical and institutional options to address some of the key issues relevant to the creation of a viable and sustainable seed industry development.

References

Abidin, P.E., F.A. van Eeuwijk, P. Stam, P.C. Struik, D.P. Zhang, M. Hermann and E.E. Carey. 2002. Evaluation of sweet potato (*Ipomoea batatas* (L.) Lam.) germplasm from north-eastern Uganda through a farmer participatory approach. *Actae Horticulturae* 583: 61-68.

Abu-Yahya, A.E.A. 1997. Effect of seed treatment with fungicides on germination and establishment of wheat 'Horani 27' free or infected with covered smut. University of Jordan, Amman, Jordan. MSc thesis. 51 pp.

Abdelfattah, R.Y. 1994. Survey of fungal pathogens transmitted by wheat seeds in Jordan. University of Jordan, Amman, Jordan. MSc thesis. 85 pp.

Adissu, A. 1991. Wheat marketing in Ethiopia, 323-339. *In* Gebremaraim, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Agarwal, V.K. 1983. Quality seed production at Pantnagar, India. *Seed Science and Technology* 11: 1071-1078.

Agarwal, V.K. 1986. Karnal bunt of wheat: A seed borne disease of considerable importance. *Seed Research* 14: 1-11.

Agarwal, V.K. and J.B. Sinclair. 1987. Principles of Seed Pathology, Vol. I. CRC Press, Inc., Florida, USA. 176 pp.

Agarwal, V.K. and M.C. Gupta. 1989. Loose smut of wheat-a threat to seed production. *Seed Research* 17: 55-68.

Agidie, A., D.G. Tanner, M. Liben, T. Dessalegne and B. Kebede. 2000. Farmer participatory evaluation of promising bread wheat production technologies in northwestern Ethiopia, 380-390. *In* Eleventh regional wheat workshop for Eastern, Central and Southern Africa, 18-22 Sep 2000, Addis Ababa, Ethiopia. CIMMYT, Addis Ababa, Ethiopia.

Agrawal, P.K. 1986. Seed vigor: Concepts and measurements, 190-198. *In* Srivastava, J.P. and Simarski, L.T. (eds.) Seed production technology. ICARDA, Aleppo, Syria.

Al-Ashram, M. 1990. Agricultural labor and technological change in the Syrian Arab Republic, 163-183. *In* Tulley, D. (ed.) Labor and rainfed agriculture in West Asia and North Africa. ICARDA, Aleppo, Syria.

Alemayehu, Z., R. Ensermu, B. Yaie. B. Girma, G. Taye and M. Hassena. 1999a. Farmers' feedback on the status of released bread wheat varieties in Chilalo *awaraja*, Arsi Zone, Ethiopia, 106-113. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. CIMMYT, Addis Ababa, Ethiopia.

Alemayehu, Z., B. Yaie, B. Girma, D. Debelo and B. Geleta. 1999b. Ethiopian wheat cultivars and their morphological descriptions: a key to identification of varieties, 581-586. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. CIMMYT, Addis Ababa, Ethiopia.

Al-Faqeeh, T.M. 1997. A survey of lentil seed quality in Jordan. University of Jordan, Amman, Jordan. MSc thesis. 97 pp.

Almanza-Pinzón, M.I., M. Khairallah, P.N. Fox and M.L. Warburton. 2003. Comparison of molecular markers and coefficients of parentage for the analysis of genetic diversity among bread wheat accessions. *Euphytica* 130: 77-86.

Almekinders, C.J.M. and N.P. Louwaars. 1999. Farmers' seed production. Intermediate Technology Publications Ltd, London, UK. 291 pp.

Almekinders, C.J.M. and A. Elings. 2001. Collaboration of farmers and breeders: Participatory crop improvement in perspective. *Euphytica* 122: 425-438.

Almekinders, C.J.M., N.P. Louwaars and G.H. de Bruijin. 1994. Local seed systems and their importance for an improved seed supply in developing countries. *Euphytica* 78: 207-216.

Alemkinders, C.J., L.O. Fresco and P.C. Struik. 1995. The need to study and manage variation in agro-ecosystem. *Netherlands Journal of Agricultural Science* 43: 127-142.

Andnew, Y. 1988. A review of chemical disease control research on wheat in Ethiopia, 251-255. *In* van Ginkel, M. and Tanner, D.G. (eds.) Fifth regional wheat workshop for Eastern, Central and Southern Africa and the Indian Ocean, 5-10 Oct 1987, Antsirabe, Madagascar. CIMMYT, Mexico.

Araia, W. 2001. Mixed cropping of barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*) landraces in the central highlands of Eritrea. Wageningen University, Wageningen, The Netherlands. PhD thesis. 220 pp.

Asamenew, G., H. Beyene, W. Negatu and G. Ayele. 1993. A survey of the farming systems of vertisol areas of the Ethiopian highlands, 29-50. *In* Mamo, T., Astatke, A., Srivastava, K.L. and Dibabe, A. (eds.) Improved management of vertisols for sustainable crop-livestock production in the Ethiopian highlands: Synthesis report 1986-92. Addis Ababa, Ethiopia.

Aw-Hassan, A., K. Shideed, S. Ceccarelli, W. Erskine, S. Grando and R. Tutwiler. 2003. The impact of international and national investment in barley germplasm improvement in the developing countries, 241-256. *In* Evenson, R.E. and Gollin, D. (eds.) Crop variety improvement and its effect on productivity: the impact of international agricultural research. CABI, Wallingford, UK and Cambridge, USA.

Ayana, A. and E. Bekele. 1999. Multivariate analysis of morphological variation in sorghum (*Sorghum biocolor* (L.) Moench) germplasm from Ethiopia and Eritrea. *Genetic Resources and Crop Evolution* 46: 273-284.

Azmeh, M.F and T. Kousaji. 1982. Contributions to the survey of plant diseases in Syria; unreported fungal diseases. 22nd Science Week, Ministry of Higher Education, Nov 1982, Damascus, Syria. 16 pp.

Badebo, A. and Lindeman, P.O. 1987. Seed survey of wheat in Arsi. SEAD Publication No. 4. SEAD, Asela, Ethiopia. 29 pp.

Badebo, A. and W. Bayou. 1992. The importance of stripe rust in the major wheat producing regions of Ethiopia during 1988-90, 196-202. *In* Tanner, D.G. and Mwangi, W. (eds.) Seventh regional wheat workshop for Eastern, Central and Southern Africa, 16-19 Sep 1991, Nakuru, Kenya. CIMMYT, Mexico.

Bajracharya, B. 1994. Gender issues in Nepali agriculture: A review. Research Report No. 25. HMG Ministry of Agriculture/Winrock International Kathmandu, Nepal. 78 pp.

Bailey, E. 1982. An examination of the role of supplementary irrigation in stabilizing wheat production in an area of variable rainfall. University of Reading, Reading, UK. MSc thesis. 120 pp.

Baalbaki, R.Z. and Copeland, L.O. 1987. Vigor testing of wheat and its relationship to field performance, storage and seed quality. *Newsletter of Association of Official Seed Analysts* 61: 15.

Bal, S.S. and. K.L. Rajbhandary. 1987. A model for seed production in remote areas of Nepal. *Seed Science and Technology* 15: 625-632.

Bal, S.S. and J.E. Douglas. 1992. Designing successful farmer-managed seed systems. Development Studies Paper Series. Winrock International Institute for Agricultural Development, Morrilton, USA. 27 pp.

Barla-Szabó, G. and B. Dolinka. 1988. Complex stressing vigour test: a new method for wheat and maize seeds. *Seed Science and Technology* 36: 63-73.

Bekele, E. 1985. A review of research on diseases of barley, teff and wheat in Ethiopia, 79-108. *In* Abate, T. (ed.) A review of crop protection research in Ethiopia. Proceedings of the first Ethiopian crop protection symposium, 4-7 Feb 1985, Addis Ababa, Ethiopia IAR, Addis Ababa, Ethiopia.

Bekele, A. 1991. Biochemcial aspects of wheat for human consumption, 341-352. *In* Gebremariam, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Bekele, E. and Y. Semeane. 1983. Occurrence of eye spot and preliminary loss assessment study in wheat and barley around Holetta, Ethiopia. *Ethiopian Journal of Agricultural Science* 5: 97-107.

Bekele, E. and A.L. Karr 1997. Fusarium head blight in Ethiopian wheat and the identification of species causing the disease. *Pest Management Journal of Ethiopia* 1: 29-36.

Bekendam, J. and R. Grob. 1979. Handbook for seedling evaluation. ISTA, Zürich, Switzerland. 130 pp.

Belaid, A. 2000. Durum wheat in WANA: production, trade, and gains from technological change, 35-49. *In* Royo, C., Nachit, M.M., di Fonzo, N., Araus, J.L., (eds.) Proceedings of a seminar durum wheat improvement in the Mediterranean region: new challenges, 12-14 Apr 2000, Zaragoza, Spain. CIHEAM, Zaragoza, Spain.

Belay, G., T. Tesemma, H.C. Baker and A. Merker. 1993. Variation and interrelationships of agronomic traits in Ethiopian tetraploid wheat landraces. *Euphytica* 71: 188-193.

Belay, G., T. Tesemma and D. Mitiku. 1995. Natural and human selection for purple grain tetraploid wheats in the Ethiopian highlands. *Genetic Resources and Crop Evolution* 42: 387-391.

Bellon, M.R. 1996. The dynamics of crop infraspecific diversity: A conceptual framework at the farm level. *Economic Botany* 50: 26-39.

Bentley, J.W. and D. Vasques. 1998. The seed potato system in Bolivia: organizational growth and missing links. Agricultural Research and Extension Network. Network Paper No. 85. ODI, London, UK. 11 pp.

Besri, M. 1983. Seed-borne diseases of wheat and barley in Morocco in relation to seed certification programs. *Seed Science and Technology* 11: 1103-1113.

Beyene, H. and C. Yirga. 1992a. Vertisol farming systems of north Shewa, 79-96. *In* Franzel, S. and van Houten, H. (eds.) Research with farmers: Lessons from Ethiopia. CABI, Wallingford, UK.

Beyene, H. and C. Yirga. 1992b. An adoption study of bread wheat technologies in Wolmera and Addis Alem areas of Ethiopia, 254-259. *In* Tanner, D.G. and Mwangi, W. (eds.) Seventh regional wheat workshop for Eastern, Central and Southern Africa. 16-19 Sep 1991, Nakuru, Kenya. CIMMYT, Mexico.

Beyene, H., W. Mwangi and W. Negatu. 1991. Research conducted on wheat production constraints in Ethiopia, 17-32. *In* Gebremariam, H., Tanner, D.G. and Hulluka, H. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Beyene, H., H. Verkuijl and W. Mwangi. 1998. Farmers' seed sources and management of bread wheat in Wolmera *woreda*, Ethiopia. CIMMYT, Mexico and IAR, Ethiopia. 22 pp.

Bishaw, Z. and S. Kugbei. 1997. Seed supply in the WANA region: Status and constraints, 18-33. *In*: Rohrbach, D.D., Bishaw, Z. and van Gastel, A.J.G. (eds.) Alternative strategies for smallholder seed supply. Proceedings of an international conference on options for strengthening national and regional seed systems in Africa and West Asia. ICRISAT, Andra Pradesh, India.

Bishaw, Z., A.J.G. van Gastel, K. Shawel and Y. Sahlu. 1994. Seed survey in Ethiopia, 17-26. *In* Seed Unit Annual Report for 1994. ICARDA, Aleppo, Syria. 39 pp.

Boyd, A.H., G.M. Dougherty, R.K. Matthews and K.W. Rushing. 1975. Seed drying and processing, 60-107. *In* Feistritzer, W.P. (ed.) Cereal seed technology: A manual of cereal seed production, quality control, and distribution. FAO, Rome, Italy. Rome.

Brennan, J.P. and D. Byerlee. 1991. The rate of crop varietal replacement on farms: measures and empirical results of wheat. *Plant Varieties and Seeds* 4: 99-106.

Buddenhagen, I.W. and R.A. Richards. 1988. Breeding cool season food legumes for improved performance in stress environments, 81-95. *In* Summerfield, R.J. (ed.) World crops: Cool season food legumes. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Byerlee, D. and P. Hesiey. 1992. Strategies for technical change in small farm agriculture with particular reference to Sub-Saharan Africa, 21-52. *In* Russell, N.C. and Dowswell, C.R. (eds.) Policy options for agricultural development in Sub-Saharan Africa. Proceedings of a workshop, 23-25 Aug 1992, Virginia, USA. CASIN, Geneva, Switzerland.

Byerlee, D. and P. Moya. 1993. Impacts of international wheat breeding research in developing world, 1966-90. CIMMYT, Mexico. 29 pp.

Ceccarelli, S., S. Grando and J.A.G. van Leur. 1987. Genetic diversity in barley land-races from Syria and Jordan. *Euphytica* 36: 389-405.

Ceccarelli, S., S. Grando and R. Booth. 1996. International breeding programs and resource-poor farmers: crop improvement in difficult environments, 99-116. *In* Eyzaguirre, P. and Iwanaga, M. (eds.) Proceedings of a workshop on participatory plant breeding, 26-29 Jul 1995, Wageningen, The Netherlands. IPGRI, Rome, Italy.

Ceccarelli, S., S. Grando, R. Tutwiler, J. Baha, A.M. Martini, H. Salahieh, A. Good-child and M. Michael. 2000. A methodological study on participatory barley breeding. I. Selection phase. *Euphytica* 111: 91-104.

Central Bureau of Statistics. 2000. Statistical abstract 2000: Fifty three years. CBS, Damascus, Syria. 565 pp.

Central Statistical Authority. 1997. Agricultural Sample Survey 1996/97. Volume 1. Report on Area and Production of Major Crops. Statistical Bulletin 171. CSA, Addis Ababa, Ethiopia. 71 pp.

Central Statistical Authority. 1998. Agricultural Sample Survey 1997/98. Volume 1. Report on Area and Production of Major Crops. Statistical Bulletin 189. CSA, Addis Ababa, Ethiopia. 103 pp.

Central Statistical Authority. 1999. Agricultural Sample Survey 1998/99. Report on Area and Production of Major Crops Volume 1. Statistical Bulletin 200. CSA, Addis Ababa, Ethiopia. 111 pp.

Central Statistical Authority. 2000. Agricultural Sample Survey 1999/2000. Volume 1. Report on area and production of major crops. Statistical Bulletin 227. CSA, Addis Ababa, Ethiopia. 73 pp.

CIMMYT. 2001. Research highlights of the CIMMYT wheat program, 1999-2000. CIMMYT, Mexico. 82 pp.

Clear, R.M., S.K. Patrick, R.G. Platford and M. Desjardins. 1996. Occurrence and distribution of *Fusarium* species in barley and oat seed from Manitoba in 1993 and 1994. *Canadian Journal of Plant Pathology* 8: 409-414.

Colhoun, J. 1982. Measurement of inoculum potential per seed and its relation to disease expression. *Seed Science and Technology* 11: 665-671.

Cox, T.S., Y.T. Kiang, M.B. Gorman and D.M. Rogers. 1985. Relationship between coefficient of parentage and genetic similarity indices in the soybean. *Crop Science* 25: 529-532.

Cromwell, E. 1997. Local-level seed activities: Opportunities and challenges for regulatory frameworks, 214-230. *In* Tripp, R. (ed.) New seed and old laws. Regulatory reform and diversification of national seed systems. ODI, London, UK.

Cromwell, E. (ed.). 1990. Seed diffusion mechanisms in small farmer communities: Lessons from Asia, Africa and Latin America. ODI, London, UK. 57 pp.

Cromwell, E. and R. Tripp. 1994. Proximity is a plus: the economics of farmer seed production and distribution in developing countries, 15-23. *In* Hanson, J. (ed.) ILCA/ICARDA research planning workshop on seed production by smallholder farmers, 13-15 Jun 1994, Addis Ababa, Ethiopia. ILCA, Addis Ababa, Ethiopia.

Cromwell, E., E. Friis-Hansen and M. Turner. 1992. The seed sector in developing countries: A framework for performance analysis. ODI, London, UK. 107 pp.

Cromwell, E., S. Wiggins and S. Wentzel. 1993. Sowing beyond the state: NGOs and seed supply in developing countries. ODI, London, UK. 143 pp.

Curtis, B.C. 2002. Wheat in the world, 1-17. *In* Curtis, B.C., Rajaram, S. and Macpherson, H.G. (eds.) Bread wheat: Improvement and production. FAO, Rome Italy.

Damania, A.B., J. Valkun, G. Willcox and C.O. Qualset (eds.). 1998. The origins of agriculture and crop domestication. ICARDA, Aleppo, Syria. 352 pp.

Delouche, J.C. 1982. Seed quality guidelines for the small farmers. Paper prepared for the CIAT Seed Unit workshop, 9-13 Aug 1982. CIAT, Cali, Colombia. 11 pp.

Demissie, A. and G. Habtemariam. 1991. Wheat genetic resources in Ethiopia, 33-46. *In* Gebremariam H., Tanner, D.G. and Hulluka, H. (eds.) Wheat research in

Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Diekmann, M. 1993. Seed-borne diseases in seed production. ICARDA, Aleppo, Syria. 81 pp.

Dinssa, F.F. 2003. Molecular genetic variation, yield and yield components of barley (*Hordeum vulgare* L.) in decentralized participatory breeding in low moisture environments. University of Jordan, Amman, Jordan. PhD thesis. 204 pp.

Dominguez, C.E., S.T. Peske, F.A. Villela and L. Baudet. 2001. Informal seed system: causes, consequences and alternatives. Universidade Federal de Pelota, Brazil. 190 pp.

Douglas. J.E. 1980. Successful seed programs: a planning and management guide. Westview Press, Boulder, Colorado, USA. 302 pp.

Douglas, J.E. 1984. Horizons in seed program and industry development. *Seed Science and Technology* 12: 535-549.

Duvick, D.N. 1984. Genetic diversity in major farm crops on the farm and in reserve. *Economic Botany* 38: 161-178.

Edington, L.V., R.A. Martin, G.C. Bruin and L.M. Parsons. 1980. Systemic fungicides: A perspective after 10 years. *Plant Disease* 64: 19-23.

El-Ahmed, A. 1999. Facilities and safeguards with emphasis on seed at the International Center for Agricultural Research in the Dry Areas, 24-53. *In* Kahn, R.P. and Mathur, S.B. (eds.) Containment facilities and safeguards for exotic plant pathogens and pests. APS, St Paul, Minnesota, USA.

Ensermu, R., W. Mwangi, H. Verkuijl, M. Hassena and Z. Alemayehu. 1998. Farmers' wheat seed sources and seed management in Chilalo *awraja*, Ethiopia. CIMMYT, Mexico and IAR, Ethiopia. 36 pp.

Evenson, R.E. and D. Gollin (eds.). 2003. Crop variety improvement and its effect on productivity: The impact of International Agricultural Research. CABI, Wallingford, UK. 522 pp.

Eyzaguirre, P. and M. Iwanaga (eds.). 1996. Proceedings of a Workshop on Participatory Plant Breeding, 26-29 Jul 1995, Wageningen, The Netherlands. IPGRI, Rome, Italy. 164 pp.

FAO. 1999. Seed production and improvement: assessment for the Near East and North Africa, 27-79. *In* Seed Policy and Programs in the Near East and North Africa. Proceedings of the Regional Technical Meeting on Policy and Programs in the Near East and North Africa. Larnaca, Cyprus, 27 Jun-2 Jul 1999. FAO, Rome, Italy.

Feistritzer, W.P. and A.F. Kelly. 1978. Improved seed production: a manual on the formulation, implementation and evaluation of seed programs and projects. FAO, Rome, Italy. 146 pp.

Ferede, S., D.G. Tanner, H. Verkuijl and T. Gebre. 2000. A study of the adoption of bread wheat production technologies in Arsi zone, 411-426. *In* Eleventh regional wheat workshop for Eastern, Central and Southern Africa, 18-22 Sep 2000, Addis Ababa, Ethiopia. CIMMYT, Addis Ababa, Ethiopia.

Fessehaie, R. 1985. A review of weed science research activities on wheat and barley in Ethiopia, 121-144. *In* Abate, T. (ed.) A review of crop protection research in Ethiopia. Proceedings of the first Ethiopian crop protection symposium, 4-7 Feb 1985, Addis Ababa, Ethiopia. IAR, Addis Ababa, Ethiopia.

Fiala, F. 1987. Handbook of vigour test methods. ISTA, Zürich, Switzerland. 72 pp.

Foster, N.R., L.A. Burchett and G.M. Paulsen. 1998. Seed quality of hard red wheat after incipient pre-harvest sprouting. *Journal of Applied Seed Production* 16: 87-91.

Friis-Hansen, E. 1992. The performance of the seed sector in Zimbabwe: An analysis of the influence of organizational structure. ODI, London, UK.

Fujisaka, S., R.A. Guino, R.T. Lubigan and K. Moody. 1993. Farmers' rice seed management practices and the resulting weed seed contamination in the Philippines. *Seed Science and Technology* 21: 149-157.

Gamba, P., C. Ngugi, H. Verkuijl, W. Mwangi and F. Kiriswa. 1999. Wheat farmers' seed management and varietal adoption in Kenya, 53-62. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. CIMMYT, Addis Ababa, Ethiopia.

Gavian, S. and G. Degefa. 1996. The profitability of wheat production in Ethiopia: The case of Tiyo w*oreda* in Arsi zone. *Ethiopian Journal of Agricultural Economics* 1: 38-62.

Gebeyehu, G., 1988. Grain yield stability of bread wheat cultivars in the highlands of Ethiopia, 61-65. *In* van Ginkel, M. and Tanner, D.G. (eds.) Fifth regional wheat workshop for Eastern, Central and Southern Africa and the Indian Ocean. 5-10 Oct 1987, Antsirabe, Madagascar. CIMMYT, Mexico.

Gebeyehu, G., M. van Ginkel, T. Kebede, M. Haregewoin, R. Desta, A. Bainbridge, M. Hulluka. Y. Andenew, D. Tadesse, A. Gorfu and A. Badebo. 1990. Wheat disease survey in Ethiopia in 1988, 153-165. *In* Tanner, D.G., van Ginkel, M. and Mwangi, W. (eds.) Sixth regional wheat workshop for Eastern, Central and Southern Africa, 2-6 Oct 1989, Addis Ababa, Ethiopia. CIMMYT, Mexico.

Gebeyehu, S., K. Muminjanov, A. Mwilawa, K. Rijal, S. Subramaniam and L. Weili. 2002. Food Security in a breadbasket: Food security among households in the different agrocecological zones in Arsi Negelle *woreda*, Ethiopia. Working Document Series 100. ICRA, Holland and EARO, Ethiopia. 171 pp.

Gebre, H., A. Tarekegne and E. Asmare. 1988. Preliminary indications on the importance of yield limiting factors on wheat, 189-193. *In* van Ginkel, M. and Tanner, D.G. (eds.) Fifth regional wheat workshop for Eastern, Central and Southern Africa and the Indian Ocean, 5-10 Oct 1987, Antsirabe, Madagascar. CIMMYT, Mexico.

Gebrekiros, F. 1980. Search for alternatives of agricultural development strategy under the varied conditions of peasant production in Ethiopia: A case study in Ada *wereda*. *Ethiopian Journal of Agricultural Research* 2: 115-127.

Gebremariam, H. 1991a. Wheat production and research in Ethiopia, 1-15. *In* Gebremariam, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Gebremariam, H. 1991b. Bread wheat breeding and genetics research in Ethiopia, 73-93. *In* Gebremariam, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Geleta, B., H. Gebremariam, G. Gebeyehu, T. Tesemma and M. van Ginkel. 1992. Stability of yield and harvest index of improved varieties of bread wheat in Ethiopia, 56-63. *In* Tanner, D.G. and Mwangi, W. (eds.) Seventh regional wheat workshop for Eastern, Central and Southern Africa, 16-19 Sep 1991, Nakuru, Kenya. CIMMYT, Mexico.

Geleta, B., A. Gorfu and G. Gebeyehu. 1994. Wheat production and research in Ethiopia constraints and sustainability, 18-25. *In* Tanner, D.G. (ed.) Eighth regional wheat workshop for Eastern, Central and Southern Africa, 7-10 Jun 1993, Kampala, Uganda. CIMMYT, Addis Ababa, Ethiopia.

Geleto, T., E. Elias and D.G. Tanner. 1990. The effects of different sowing dates and fertilizers on the agronomic characteristics of three Ethiopian varieties of bread wheat, 191-197. *In* Tanner, D.G., van Ginkel, M. and Mwangi, W. (eds.) Sixth regional wheat workshop for Eastern, Central and Southern Africa, 2-6 Oct 1989, Addis Ababa, Ethiopia. CIMMYT, Mexico.

Geleto, T., D.G. Tanner, T. Mamo and G. Gebeyehu. 1995. Response of rainfed bread and durum wheat to source, level and timing of nitrogen fertilizer on two Ethiopian vertisols. I. Yield and yield components. *Communications in Soil Science and Plant Analysis* 26: 1773-1794.

Geleto, T., D.G. Tanner, T. Mamo and G. Gebeyehu. 1996. Response of rainfed bread and durum wheat to source, level and timing of nitrogen fertilizer on two Ethiopian vertisols. II. N uptake, recovery and efficiency. *Fertilizer Research* 44: 195-204.

Gemeda, A., G. Aboma, H. Verkuijl, W. Mwangi. 2001. Farmers' maize seed systems in Western Oromia, Ethiopia. CIMMYT, Mexico and IAR, Ethiopia. 22 pp.

Ghijsen, H. 1996. The development of variety testing and plant breeders' rights in the Netherlands, 223-225. *In* van Amstel, H., Bottema, J.W.T., Sidik, M. and van Santen, C.E. (eds.) Integrating seed systems for annual food crops. Proceedings of a Workshop, 24-27 Oct 1995, Malang, Indonesia. Bogor, CGPRT Center, Indonesia.

Girma, K., S. Maru, A. Gorfu, W. Tilahun and M. Kassaye. 2000. Survey of weed community structure in bread wheat in three districts of Arsi Zone in southeastern Ethiopia, 291-301. *In* Eleventh regional wheat workshop for Eastern, Central and Southern Africa, 18-22 Sep 2000, Addis Ababa, Ethiopia. Addis Ababa, Ethiopia: CIMMYT.

Gisselquist, D. and J. Srivastava (eds.). 1997. Easing barriers to movement of plant varieties for agricultural development. World Bank Discussion Paper No. 367. The World Bank, Washington D.C., USA. 148 pp.

Gorfu, A., A. Taa, D.G. Tanner and W. Mwangi. 1991. On-farm research to derive fertilizer recommendations for small-scale bread wheat production: methodological issues and technical results. Research Report No 14. Addis Ababa, Ethiopia: IAR 37 pp.

Grass, L. and. J.S. Burris. 1995. Effect of heat stress during seed development and maturation on wheat (*Triticum durum*) seed quality. I. Seed germination and seedling vigor. *Canadian Journal of Plant Science* 75: 821-829.

Grass, L. and M. Tourkmani. 1999. Mechanical damage assessment in rejected durum wheat seed lots in Morocco. *Seed Science and Technology* 27: 991-997.

Grisley, W. 1993. Seed for bean production in Sub-Saharan Africa: Issues, problems and possible solutions. *Agricultural Systems* 43: 19-33.

Groosman, A.J.A. 1987. Technology development and the seed industry in north-south perspective: A literature survey. Development Research Institute (IVO). Tilburg, The Netherlands. 111 pp.

Groosman, T., A. Linnemann and H. Wierema. 1991. Seed industry development in a North-South perspective. Pudoc, Wageningen. 107 pp.

GTZ and CGN. 2000. Support for the informal seed sector in development cooperation-conceptual issues. GTZ, Eschborn, Germany. 24 pp.

Gurmu, D., G. Shaka and Z. Bishaw. 1998. The Ethiopian seed industry. *ISTA News Bulletin* 117: 26-31.

Gutormson, T.J., D.G. Curry, M.K. Misra, K.D. Dephart and J.F. Mehuys. 1993. Reducing *Fusarium* spp. levels in soft red winter wheat through gravity separator conditioning. *Iowa Seed Science* 15:1.

Hackleman, J.C. and W.O. Scott. 1990. A history of seed certification in the United Sates and Canada. ASOCA, Raleigh, North Carolina, USA. 97 pp.

Haile, A., W. Negatu and A. B. Retu. 1991. Technology transfer for wheat production in Ethiopia, 277-299. *In* Gebremariam, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Hailye, A., H. Verkuijl, W. Mwangi and A. Yalew. 1998. Farmers' wheat seed sources and seed management in the Enebssie area, Ethiopia. CIMMYT, Mexico and

EARO, Ethiopia. 32 pp.

Hamblin, J., W. Al-Taweel, S.K. Yau, G. Walker, M. Michel and G. Kashour. 1995. The use of data from on-farm trials in planning breeding strategy. ICARDA Cereals Program Discussion Paper. ICARDA, Aleppo, Syria. 24 pp.

Hampton, J.G. 1998. Seed quality standards-their use, misuse and the future. *Journal of Applied Seed Production* 16: 31-48.

Hampton, J.G. 2002. What is seed quality? *Seed Science and Technology* 30: 1-10.

Hampton, J.G. and P. Coolbear. 1990. Potential versus actual seed performance can vigour testing provide an answer? *Seed Science and Technology* 18: 215-228.

Hasan, B.M.A. 1995. A survey of wheat seed quality in Jordan. University of Jordan, Amman, Jordan. MSc thesis. 95 pp.

Hassena, M., Regassa Ensermu, W. Mwangi and H. Verkuijl. 2000. A comparative assessment of combine harvesting vis-à-vis conventional harvesting and threshing in Arsi region, Ethiopia. CIMMYT, Mexico and EARO, Ethiopia. 24 pp.

Heisey, P.W. and J.P. Brennan. 1991. An analytical model of farmers' demand for replacement seed. *American Journal of Agricultural Economics* 73: 1044-1052.

Heisey, P.W., M.A. Lantican and H.J. Dubin. 2003. Wheat, 47-69. *In* Evenson, R.E. and Gollin, D. (eds.) Crop variety improvement and its effect on productivity: The impact of international agricultural research. CABI, Wallingford, UK and Cambridge, USA.

Henderson, P.A. and R. Singh. 1990. NGO-Government links in seed production: case studies from The Gambia and Ethiopia. Agricultural Administration (Research and Extension) Network Paper 14. ODI, London, UK. 27 pp.

Hewett, P.D. 1979. Regulating seed-borne disease by certification, 163-175. *In* Ebbels, D.L. and King, J.E. (eds.) Plant health. Blackwells Scientific Publications, London, UK.

Hulluka, M., G. Woldeab, Y. Andnew, R. Desta and A, Badebo. 1991. Wheat pathology research in Ethiopia, 173-217. *In* Gebremariam, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

IAR. 1990. Yesende ameraret zede lelmat seratognch memeria (Wheat production guidelines for extension agents (in Amharic)). IAR, Addis Ababa, Ethiopia. 20 pp.

ICARDA, 1992. Fertilizer use on wheat in northern Syria 1986-1990: Part 1. Collaborative research project. ICARDA, Aleppo, Syria. 138 pp.

ICARDA. 2002. WANA catalogue of field and seed standards (cereals, legumes, oilseeds, forages and vegetables). ICARDA, Aleppo, Syria.

ICARDA, FAO, AARINENA and CIHEAM. 1999. The national agricultural research systems in the West Asia and North Africa region. Eds Casas, J., Solh, M. and

Hafez, H., ICARDA, Aleppo, Syria. 278 pp.

Impiglia, A., G. Nachit, M.M. Nachit, D. Lafiandra, E. Porceddu and L.M. Martin. 1998. Storage proteins in the Mediterranean durum landraces, 309-318. *In* Nachit, M.M., Baum, M., Porceddu, E., Monnevex, P. and Picard, E. (eds.) SEWANA (South Europe, West Asia and North Africa) Durum Research Network. Proceedings of the SEWANA Durum Network Workshop, 20-23 Mar 1995, ICARDA, Aleppo, Syria. ICARDA, Aleppo, Syria.

Ismail, M.F., A. El-Ahmed and M.H. Al-Zainab. 2000. A field survey of wheat seed gall nematode (*Anguina tritici*) in Aleppo and Raqqa provinces, Syria. *Arab Journal of Plant Protection* 18: 9-16.

Issa, M.E.S. 1991. Economics of wheat production in Syria, Faculty of Agriculture, University of Aleppo. Aleppo, Syria. MSc thesis. 147 pp.

ISTA. 1967. Seed Legislation Number. Proceedings of ISTA, Vol. 32 No. 2, Wageningen, The Netherlands. 533 pp.

ISTA. 1984. Handbook on Seed Health Testing. Working Sheets No. 19, No. 48; No. 53 and No. 54, Zürich, Switzerland.

ISTA. 1996. International Rules for Seed Testing 1996. Zürich, Switzerland. 335 pp.

ISTA. 1999. International Rules for Seed Testing 1999. ISTA, Zürich, Switzerland. 331 pp.

Jaffe, S. and J. Srivastava. 1992. Seed system development: the appropriate roles of the private and public sectors. World Bank Discussion Paper No 167. The World Bank, Washington D.C., USA. 109 pp.

Jaffe, S. and J. Srivastava. 1994. The role of the private and public sectors in enhancing the performance of seed systems. *The World Bank Research Observer* 9: 97-117.

Jones, R.B., P.A. Audi and R. Tripp. 2001. The role of informal seed systems in disseminating modern varieties: The example of pigeon pea from a semi-arid area of Kenya. *Experimental Agriculture* 37: 539-548.

Jørgensen, J. 1983. Disease testing of barley seed and application of test results in Denmark. *Seed Science and Technology* 9: 615-624.

Kahre, L. 1990. The history of seed certification in Sweden. *Plant Varieties and Seeds* 3: 181-193.

Kashyap, R.K. and J.C. Duhan. 1994. Health status of farmers' saved wheat seed in Haryana, India: A case study. *Seed Science and Technology* 22: 619-628.

Kayyal, H., H. Abu Hamze and M. Jarrah, M.N. Nachit. 1995. Durum wheat production and quality in Syria, 127-132. *In* di Fonzo, N., Kaan, F. and Nachit, M. (eds.) Durum wheat quality in the Mediterranean region. Proceedings of the seminar on durum wheat quality in the Mediterranean region, 17-19 Sep 1993 Zaragoza, Spain.

CIHEAM, Zaragoza, Spain.

Kebebew, F., Y. Teshaye and T. McNeilly. 2001a. Diversity of durum wheat (*Triticum durum* Desf.) at *in situ* conservation sites in North Shewa and Bale, Ethiopia. *Journal of Agricultural Science, Cambridge* 136: 383-292.

Kebebew, F., Y. Teshaye and T. McNeilly. 2001b. Morphological and farmers cognitive diversity of barley (*Hordeum vulgare* L. [Poaceae]) at Bale and North Shewa of Ethiopia. *Genetic Resources and Crop Evolution* 48: 467-481.

Ketema, S. 1997. Tef *(Eragrostis tef* (Zucc.) Trotter. Promoting the conservation and use of underutilized and neglected crops. 12. IPGRI, Rome Italy. 50 pp.

Khah, E.M., E.H. Roberts and R.H. Ellis. 1989. Effects of seed aging on growth and yield of spring wheat at different plant population densities. *Field Crops Research* 20: 175-190.

Khanzada, A. and S. Jamilkhan. 1987. Efficacy of some detection methods for seed-borne fungi in seed health testing program. *Pakistan Journal of Agricultural Research* 8: 231-235.

Khatib, F., M.H. Al-Zainab and O.F. Mamluk. 2000. Survey of head sterility in barley in northern Syria and its relation to seed gall nematode (*Anguina* spp.). *Arab Journal of Plant Protection* 18: 40-45.

Kidane, A. 1985. A review of research on seed pathology research in Ethiopia, 617-633. *In* Abate, T. (ed.) A review of crop protection research in Ethiopia. Proceedings of the first Ethiopian crop protection symposium, 4-7 Feb 1985, Addis Ababa, Ethiopia. IAR, Addis Ababa, Ethiopia.

Kidane, A. 1982. Additional index of plant diseases in Ethiopia. IAR, Addis Ababa. 17 pp.

Kim, S.H., Z.R. Choe, J.K. Kang, L.O. Copeland and S.G. Elias. 1994. Multiple seed vigor indices to predict field emergence and performance in barley. *Seed Science and Technology* 22: 59-69.

Kolk, H. 1979. Weed seeds, 9-24. *In* Advances in research and technology of seeds. Pudoc, Wageningen, The Netherlands.

Kotu, B.H., H. Verkuijl, W. Mwangi, and D. Tanner. 2000. Adoption of improved wheat technologies in Adaba and Dodola *woredas* of the Bale Highlands, Ethiopia. CIMMYT, Mexico and EARO, Ethiopia. 26 pp.

Kugbei, S. and Z. Bishaw. 2002. Policy measures for stimulating indigenous seed enterprises. *Journal of New Seeds* 4: 47-63.

Lakhdar, L.C., A. Arezki and L Mohamed. 1998. Effect of mechanical damage on germination of durum wheat seed. *Seed Info* 15: 15-16.

Le Buanec, B. 1996. Globalization of the seed industry: current situation and evolution. *Seed Science and Technology* 24: 409-417.

Linnemann, A.R. and G.H. de Bruijn. 1987. Traditional seed supply for food crops. *ILEIA Newsletter* 3: 10-11.

López-Pereira, M.A. and M. Filippello. 1995. Emerging roles of the public and private sectors of maize seed industries in the developing world. CIMMYT Economics Program Working Paper 95-01, CIMMYT, Mexico. 84 pp.

Louette, D. and M. Smale. 2000. Farmers' seed selection practices and traditional maize varieties in Cualapa, Mexico. *Euphytica* 113: 25-41.

Louette, D., A. Charrier and J. Berthaud. 1997. *In-situ* conservation of maize in Mexico: Genetic diversity and maize seed management in a traditional community. *Economic Botany* 51: 20-38.

Louwaars, N.P. 1996. Seed legislation in developing countries: possibilities and pitfalls for seed system development, 77-81. *In* van Amstel, H., Bottema, J.W.T., Sidik, M. and van Santen, C.E. (eds.) Integrating seed systems for annual food crops. Proceedings of a workshop, 24-27 Oct 1995, Malang, Indonesia. CGPRT Center, Bogor, Indonesia. 311pp.

Louwaars, N.P. (ed.) 2002. Seed policy, legislation and law: widening a narrow focus. The Haworth Press Incorporated, New York, USA. 260 pp.

Lyon, F. and S.A. Danquah. 1998. Small-scale seed provision in Ghana: Social relations, contracts and institutions for micro-enterprise development. Agricultural Research and Extension Network. Network Paper No. 84. ODI, London, UK. 10 pp.

Maguire, J.D. 1962. Speed of germination, an aid in selection and evaluation for seedling emergence and vigor. *Crop Science* 2: 176-177.

Makkawi, M., M. El Balla, Z. Bishaw and A.J.G. van Gastel. 1999. The relationship between seed vigor tests and field emergence in lentil (*Lens culinaris* Medik). *Seed Science and Technology* 27: 657-668.

Mamulk, O.F. 1991. Seed-borne diseases of wheat and barley, 40-47. *In* Mathur, S.B. Manandhar, H.K. (eds.) Quarantine for seed. Proceedings of the workshop on quarantine for seed in the Near East, 2-9 Nov 1991, ICARDA, Aleppo, Syria. FAO, Rome, Italy.

Mamulk, O.F., M. Al-Ahmed and M.A. Makki. 1990. Current status of wheat diseases in Syria. *Phytopathologia Mediterranea* 29: 143-150.

Mamluk, O.F., O. Tahhan, R.H. Miller, B. Bayaa, K.M. Makkouk and S. B. Hanounik. 1992. A checklist of cereal, food legume and pasture and forage crop diseases and insects in Syria. *Arab Journal of Plant Protection* 10: 225-166.

Mantel, A. 1967. The detection of disease clustering and generalized regression approach. *Cancer Research* 27: 209-220.

Martin, J.M., T. Blake and E. A. Hockett. 1991. Diversity among North American spring barley cultivars based on coefficients of parentage. *Crop Science* 31: 1131-

1137.

Mathre, D.E. (ed.). 1987. Compendium of wheat diseases. The American Phytopathological Society, St Paul, Minnesota, USA. 78 pp.

Mathur, S.B. and S.L.N. Lee. 1978. A quick method for screening of wheat seed samples for *Septoria nodorum*. *Seed Science and Technology* 7: 925-926.

Mathur, S.B. and M.H. Talukder. 2002. Jute mat, a quick method for testing germination of rice seeds by the farmers in Bangladesh. *Seed Science and Technology* 30: 459-462.

Mazid, A.M.M. 1994. Factors influencing adoption of new agricultural technology in dry areas of Syria. University of Nottingham, Nottingham, UK. PhD thesis. 570 pp.

Mazid, A., R.N. Tutwiler and H. Al-Ahmad. 1998. Impact of modern technologies on durum wheat production in Syria, 88-102. *In* Nachit, M.M., Baum, M., Porceddu, E. Monnevex, P. and Picard, E. (eds.) SEWANA (South Europe, West Asia and North Africa) Durum Research Network. Proceedings of the SEWANA Durum Network Workshop, 20-23 Mar 1995, ICARDA, Aleppo, Syria. ICARDA, Aleppo, Syria. 354 pp.

Mazid, A., E. Bailey and M. Jones. 1999. The effect of fertilizer use on rain-fed barley: A case study from Syria. ICARDA Social Science Paper No. 8. ICARDA, Aleppo, Syria. 28 pp.

Mazid, A., R.N. Tutwiler, H. Al-Ahmed, M.A. Martini and F. Maya. 2003. Impact of modern agricultural technologies on durum wheat production in Syria. Integrated Natural Resource Management Research Report Series No. 3. ICARDA, Aleppo, Syria. 34 pp.

McMullen, N. 1987. Seeds and World Agricultural Progress. NPA. 263 pp.

MEDC. 1999. Survey of the Ethiopian economy: review of post reform development (1992/93-1997/98). Addis Ababa, Ethiopia.

Mekbib, F. 1997. Farmer participation in common bean genotype evaluation: the case of eastern Ethiopia. *Euphytica* 33: 399-408.

Mekuria, M. 1995. Technology development and transfer in Ethiopian agriculture: An empirical evidence, 109-130. *In* Demeke, M., Amha, W., Ehui, S. and Zegeye, T. (eds.) Food security, nutrition and poverty alleviation in Ethiopia: Problems and prospects. Proceedings of the inaugural and first annual conference of the Agricultural Economics Society of Ethiopia, 8-9 Jun 1995, Addis Ababa, Ethiopia. Addis Ababa, Ethiopia.

Mekuria, M., S. Franzel and H. Beyene. 1992. Farming systems research in Ethiopia: evolution, development and organizations, 28-39. *In* Franzel, S. and van Houten, H. (eds.) Research with farmers: Lessons from Ethiopia. CABI, Wallingford, UK.

Monyo, E.S., S.K. Awala, J. Lileka and S.A. Ipinge. 2000. How much trouble a farmer would it take to reserve seed? *International Sorghum and Millets Newsletter* 41: 6.

Mohamed, E.S. 1996. Weed control in wheat, 196-206. *In* Ageeb, O.A., Elahmadi, A.B., Solh, M.B. and Saxena, M.C. (eds.) Wheat production and improvement in the Sudan. Proceedings of the national research review workshop, 27-30 Aug 1995, Wad Medani, Sudan. ICARDA/Agricultural Research Corporation. ICARDA, Aleppo, Syria. 262 pp.

Morris, M.L. 2001. Assessing the benefits of international maize breeding research: an overview of the global maize impacts study, 25-34. *In* Pingali, P.L. (ed.) CIMMYT 1999-2000 world maize facts and trends. Meeting world maize needs: Technological opportunities and priorities for the public sector. CIMMYT, Mexico, D.F.

Morris, M. and B. Ekasingh. 2002. Plant breeding in developing countries: what roles for the public and private sectors? 199-225. *In* Byerlee, D. and Echeverría, R.G. (eds.) Agricultural research policy in an era of privatization. CABI, Wallingford, UK and New York, USA.

Morris, M., M. Mekuria and R. Gerpacio. 2003. Impacts of CIMMYT Maize Breeding Research, 135-158. *In* Evenson, R.E. and Gollin, D. (eds.) Crop variety improvement and its effect on productivity: the impact of international agricultural research. CABI, Wallingford, UK and Cambridge, USA.

Mpande, R. and A. Mushita. 1996. Enhancing a better understanding of local level seed production systems in Zimbabwe. SADC/GTZ, Harare, Zimbabwe. 30 pp.

Mugedza, C. and T. Musa. 1996. Brief review of smallholder seed supply systems in Zimbabwe. SADC/GTZ, Harare, Zimbabwe. 16 pp.

Mukwavi, M.V. and J. Siwale. 1999. Changes in the marketing and pricing policy of wheat in Zambia and effects on national wheat production, 114-118. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. Addis Ababa, Ethiopia: CIMMYT.

Mwanga, J., A. Mussie, W. Mwangi and H. Verkuijl. 1999. Adoption of improved wheat technologies by small-scale farmers in Mbeya district of southern highlands, Tanzania, 39-45. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. Addis Ababa, Ethiopia: CIMMYT.

Nachit, M.M. 1998. Durum wheat breeding research to improve dryland productivity in the Mediterranean region, 1-5. *In* Nachit, M.M., Baum, M., Porceddu, E., Monnevex, P. and Picard, E. (eds.) SEWANA (South Europe, West Asia and North Africa) Durum Research Network. Proceedings of the SEWANA Durum Network Workshop, 20-23 Mar 1995, ICARDA, Aleppo, Syria. ICARDA, Aleppo, Syria.

National Seed Industry Agency. 2000. Crop variety register. Issue No. 3. NSIA, Addis Ababa, Ethiopia. 97 pp.

Ndjeunga, J. 2002. Local village seed systems and pearl millet seed quality in Niger. *Experimental Agriculture* 38: 149-162.

Neergaard, P. 1977. Seed Pathology. Vol. 1 and 2, Macmillan, London, UK. 1187 pp.

Negatu, W. 1999. Impact of improved wheat production technology on food status of farm households in two *woredas* (districts) of Ethiopia: a preliminary assessment, 81-88. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. Addis CIMMYT, Ababa, Ethiopia.

Negatu, W. and W. Mwangi. 1992. On-farm economics of herbicide use on durum wheat in Ada and Akaki *woredas* of Ethiopia, 260-265. *In* Tanner, D.G. and Mwangi, W. (eds.) Seventh regional wheat workshop for Eastern, Central and Southern Africa, 16-19 Sep 1991, Nakuru, Kenya. CIMMYT, Mexico.

Negatu, W. and W. Mwangi. 1994. An economic analysis of the response of durum wheat to fertilizer: Implications for sustainable durum wheat production in the central highlands of Ethiopia, 177-185. *In* Tanner, D.G. (ed.) Eighth regional wheat workshop for Eastern, Central and Southern Africa, 7-10 Jun 1993, Kampala, Uganda. CIMMYT, Addis Ababa, Ethiopia.

Negatu, W. and A. Parikh. 1999. The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru *woreda* (district) of Ethiopia. *Agricultural Economics* 21: 205-216.

Negatu, W., W. Mwangi and T. Tesemma. 1992. Farmers' varietal preferences for durum wheat in Ada, Lume and Gimbichu *woredas*. *Ethiopian Journal of Agricultural Science* 13: 89-100.

Neimann, E., Lemma Kifle and Awgechew Kidane. 1980. Occurrence and importance of bunt (*Tilletia* spp.) on wheat in Ethiopia. *Ethiopian Journal of Agricultural Sciences* 2: 1-11.

Niane, A.A. 1992. Phosphine resistance in field strains of *Rhizopertha dominica* (Fabricius (COLEOPTERA BOSTRICHIDAE) infesting wheat and barley in different storage facilities of Northern Syria (Aleppo). University of Cukurova, Adana, Turkey. MSc thesis. 70 pp.

Oleksiak, T. 1998. wplyw kwalifikowanego materialu siewnego na plonowanie zboz [Influence of certified seeds on cereal yields]. *Biuletyn Instytutu Hodowli i Akilimatyzacji Roslin* 208: 3-9.

Osborn, T. and A. Faye. 1991. Using farmer participatory research to improve seed and food grain production in Senegal. Development Studies Paper Series. Winrock International Institute for Agricultural Development, Morrilton, USA. 25 pp.

Pala, M. 1998. Calibration of CropSyst simulation model and assessment of durum wheat production risk across agroclimatic zones of northwest Syria using simulation/GIS technology, 159-172. *In* Nachit, M.M., Baum, M., Porceddu, E., Monnevex, P. and Picard, E. (eds.) SEWANA (South Europe, West Asia and North Africa) Durum Research Network. Proceedings of the SEWANA Durum Network Workshop, 20-23 Mar 1995, ICARDA, Aleppo, Syria. ICARDA, Aleppo, Syria.

Parsons, F.G. 1985. The early history of seed certification, 3-7. *In* McDonald, M.B. and Pardee, W.D. (eds.) The role of seed certification in the seed industry. CSSA Special Publications Number 10. CSSA, Wisconsin, USA.

Paul, Y.S., B. Hunde, M. Alemu, and M. Ayalew. 1994. Studies on seed-borne mycoflora of wheat in Ethiopia, 305-306. *In* Tanner D.G. (ed.) Eighth regional wheat workshop for Eastern, Central and Southern Africa. 7-10 Jun 1993 Kampala, Uganda. CIMMYT, Addis Ababa, Ethiopia.

Paveley, N.D. and J.M.L.I. Davies. 1994. Cereal seed treatments-risks, costs and benefits, 27-35. *In* BCPC Monograph No. 57. Seed treatment: Progress and prospects.

Payne, T.S., B. Skovmand, C.G. Lopez, E. Brandon and A. McNab (eds.). 2002. The International Wheat Information System (IWIS TM), version 4, 2001. On compact disk. CIMMYT, Mexico, D.F.

Perry, D.A. 1977. A vigor test for seeds of barley (*Hordeum vulgare*) based on measurement of plumule length. *Seed Science and Technology* 5: 709-719.

Perrings, C. 2001. The economics of biodiversity loss and agricultural development in low-income countries, 57-72. *In* Lee, D.R. and Barret, C.B. (eds.) Tradeoffs or synergies? Agricultural intensification, economic development and the environment. CABI, Wallingford, UK.

Pingali, P.L. (ed.). 1999. CIMMYT 1998-99 world wheat facts and trends. Global wheat research in a changing world: challenges and achievements. CIMMYT, Mexico. 82 pp.

Plucknett, D.L. 1991. Saving lives through agricultural research. Issues in Agriculture No. 1. CGIAR. 20 pp.

Pray, C.E. 1997. Public policy, public investment and private investment in seed supply: Experiences in Turkey and India, 211-228. *In* Rohrbach, D.D., Bishaw, Z. and van Gastel, A.J.G. (eds.) Alternative strategies for smallholder seed supply. Proceedings of an international conference on options for strengthening national and regional seed systems in Africa and West Asia. ICRISAT, Andra Pradesh, India.

Pray, C.E. and B. Ramaswami. 1991. A framework for seed policy analysis. IFPRI, Washington D.C., USA. 42 pp.

Radwan, J.E. 1997. The role of pubic seed sector in Syria, 89-93. *In* Rohrbach, D.D., Bishaw, Z. and van Gastel, A.J.G. (eds.) Alternative strategies for smallholder seed supply. Proceedings of an international conference on options for strengthening national and regional seed systems in Africa and West Asia. ICRISAT, Andra Pradesh, India.

Ram, C., O. Singh, R.P.S. Kharb, P. Kumari and T.P. Yadava. 1991. Seedling vigor in pigeon pea. *Seed Science and Technology* 19: 627-631.

Rennie, W.J., M.J. Richardson and M. Noble. 1983. Seed-borne pathogens and the production of quality cereal seed in Scotland. *Seed Science and Technology* 11: 1115-1127.

Rizvi, S.J.H., D. Bazzari, M. Roustii and H. Ketata. 2002. In search of a natural alternative to herbicides in the highlands. *Caravan* 16: 41.

Rohrbach, D.D. 1997. Farmer to farmer seed movements in Zimbabwe: Issues arising, 171-179. *In* Rohrbach, D.D., Bishaw, Z. and van Gastel, A.J.G. (eds.) Alternative strategies for smallholder seed supply. Proceedings of an international conference on options for strengthening national and regional seed systems in Africa and West Asia. ICRISAT, Andra Pradesh, India.

Ryan, J., S. Masri, H. Habib, S. Garabet and J. Diekmann. 1997. Soils of ICARDA's agricultural stations and sites: Climate, classification, physical-chemical properties and land use. ICARDA, Aleppo, Syria. 119 pp.

Sahabat Alam Malaysia (Friends of the Earth Malaysia). 1984. Seed and food security: a seed study report. The Phoneix Press, Penang, Malaysia. 85 pp.

Sahile, G. and W. Tilahun. 1997. Results of a weed survey in the southeastern wheat plain of Asasa *woreda*. *Arem* (EWSS) 2/3: 100-102.

Shah, D.A., G.C. Bergstrom and M.E. Sorrells. 2002. Relationship between wheat seed infection by *Stagonospora nodorum* and seed weight. *Seed Science and Technology* 30: 339-346.

Shah, W.A. and S.J. Nuri. 2000. Local vegetable seed storage and methods and women's participation in development, 91-96. *In* Sillitoe, P. (ed.) Indigenous knowledge development in Bangladesh: Present and future. The University Press Limited, Dhaka 1000, Bangladesh.

Shehadeh, A. 1998. Durum wheat breeding strategy in Syria, 29-32. *In* Nachit, M.M., Baum, M., Porceddu, E., Monnevex, P. and Picard, E. (eds.) SEWANA (South Europe, West Asia and North Africa) Durum Research Network. Proceedings of the SEWANA Durum Network Workshop, 20-23 Mar 1995, ICARDA, Aleppo, Syria. ICARDA, Aleppo, Syria.

Shetty, H.S. 1992. Different types of damage in seeds caused by seed-borne fungi, 53-63. *In* Mathur, S.B. and Jørgensen, J. (eds.) Seed pathology. Proceedings of the CTA Seminar, 20-25 June 1988, Copenhagen, Denmark. CTA, Holland. 411 pp.

Singh, D.V. 1980. A note on the effect of karnal bunt infection on the vigor of wheat seed. *Seed Research* 8: 81-82.

Singh, R.A. and A. Krishna. 1982. Susceptible stage of inoculation of and effect of karnal bunt on viability of wheat seed. *Indian Phytopathology* 35: 54-56.

Smale, M., P. Aquino, J. Crossa, E del Toro, J. Dubin, T. Fischer, P. Fox, M. Khairallah, A.M. Kazi, K.J. Nightingale, I.O. Monasterio, S. Rajaram, R. Singh, B. Skovmand, M. van Ginkel, G. Varughese and R. Ward. 1996. Understanding global trends in the use of wheat diversity and international flows of wheat genetic resources. Economics Working Paper 96-02. CIMMYT, Mexico. 61 pp.

Souza, E. and M.E. Sorrells. 1991. Relationships among 70 North American oat germplasms. I. Cluster analysis using quantitative characters. *Crop Science* 31: 599-605.

Souza, E., P.N. Fox, D. Byerlee and B. Skovmand. 1994. Spring wheat diversity in irrigated areas of two developing countries. *Crop Science* 34: 774-783.

Sperling, L. 1998. The effects of the Rwandan war on crop production, seed security and varietal security: A comparison of two crops, 71-91. *In* Restoring farmers' seed systems in disaster situations. FAO, Rome, Italy.

Sperling, L. and U. Scheidegger. 1995. Participatory selection of beans in Rwanda: Results, methods and institutional issues. International Institute for Environment and Development. Gatekeeper Series No. 51. IIIE, London, UK. 18 pp.

Sperling, L., M.E. Loevinsohn and B. Ntabomvura. 1993a. Rethinking the farmer's role in plant breeding: local bean experts and on-station selection in Rawanda. *Experimental Agriculture* 29: 509-519.

Sperling, L., U. Scheidegger and R. Buruchara. 1993b. Designing bean seed systems for small holders. *ILEIA Newsletter* 9: 24-25.

Stanelle, J.R., R.L. Vanderlip, L.A. Burchett and J.P. Shroyer. 1984. Kansas wheat seed: comparison of the quality of wheat seed planted in 1973 and 1984. *Journal of Applied Seed Production* 6: 62-67.

Steiner, J.J., D.F. Grabe and M. Tulo. 1989. Single and multiple vigor tests for predicting seedling emergence of wheat. *Crop Science* 29: 782-786.

Stewart, R.B. and D. Yirgou. 1967. Index of plant diseases in Ethiopia. Experiment Station Bulletin No. 30. College of Agriculture. Alemaya, Dire Dawa, Ethiopia.

St. Martin, S.K. 1982. Effective population size for the soya bean improvement program in maturity groups 00 to IV. *Crop Science* 22: 151-152.

Stroud, A. and M. Mekuria. 1992. Ethiopia's agriculture sector an overview, 9-27. *In* Franzel, S. and van Houten, H. (eds.) Research with farmers: Lessons from Ethiopia. CABI, Wallingford, UK.

Svajgr, L. 1997. Seed certification in North America, proud history: A perspective on the future. *Seed Technology* 19: 5-10.

Svensson, O., H. Al-Jiboouri and E.J. Fuentes. 1975. Seed certification, 163-202. *In* Feistritzer, W.P. (ed.) Cereal seed technology: a manual for seed production, quality control and distribution. FAO, Rome, Italy.

Tadesse, D., Y.S. Paul and B. Bekele. 1992. Studies on black point disease on durum wheat in Ethiopia, 231-238. *In* Tanner, D.G. and Mwangi, W. (eds.) Seventh regional wheat workshop for Eastern, Central and Southern Africa, 16-19 Sep 1991, Nakuru, Kenya . CIMMYT, Mexico.

Tahir, M., A. Goodchild, H. Pashyani and G. Kashour. 1997. Barley improvement for feed and forage use in continental Mediterranean environments to increase livestock production, 154-167. *In* Haddad, N., Tutwiler, R. and Thomson, E. (eds) Improvement of crop livestock integration in West Asia and North Africa. Proceedings of the regional symposium on integrated crop livestock systems in the dry areas of West Asia and North Africa, 6-8 Nov 1995, Amman, Jordan. ICARDA, Aleppo, Syria.

Tanner, D.G. and G. Sahile. 1991. Weed control research conducted on wheat in Ethiopia, 235-275. *In* Gebremariam, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT. 392 pp.

Tanner, D.G., A. Gorfu and K. Zewdie. 1991. Wheat agronomy research in Ethiopia, 95-135. *In* Gebremariam, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Tanner, D.G., A. Taa and K. Girma. 1999. Determination of economic optimum fertilizer levels using discrete and continuous analytical methods, 273-297. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. CIMMYT, Addis Ababa, Ethiopia.

Tarekegne, A. 1996a. Wheat production technology in Ethiopia, 20-37. *In* Deresa, A. and Seboka, B. (eds.) Research achievements and technology transfer attempts: Vignettes from Shewa. Proceedings of technology generation, transfer and gap analysis workshop, 25-27 Dec 1995, Nazret, Ethiopia. IAR, Addis Ababa, Ethiopia.

Tarekegne, A. 1996b. Effects of seeding date on yield and yield components of bread wheat. *Rachis* 15(1-2): 33-38.

Tarekegne, A., G. Gebeyehu and D.G. Tanner. 1995. Improvement in yield potential of bread wheat cultivars released in Ethiopia from 1949 to 1987. *African Crop Science Journal* 3: 41-49.

Tarekegne, A., G. Gebeyehu, T. Tesemma and D.G. Tanner. 1996. Yield improvement effects on the morpho-physiological characters of bread wheat, 32-42. *In* Sinebo, W., Tadele, Z. and Alemayehu, N. (eds.) Increasing food production through improved crop management. Proceedings of the conference of the Agronomy and Crop Physiology Society of Ethiopia, 30-31 May 1995, Addis Ababa, Ethiopia. IAR, Addis Ababa, Ethiopia.

Tarekegne, A., G. Gebeyehu, T. Tesemma and D.G. Tanner. 1997. The yield of durum wheat cultivars released in the central highlands of Ethiopia between 1967 and 1992. *Sebil* (Ethiopia) 7: 105-114.

Tarekegne, A., D.G. Tanner, T. Tessema and C. Mandefro. 1999. A study of variety by management interaction in bread wheat varieties released in Ethiopia, 196-212. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. Addis Ababa, Ethiopia: CIMMYT.

TeKrony, D.M. and D.B. Egli. 1991. Relationship of seed vigor to crop yield: A review. *Crop Science* 31: 816-822.

Tesfaye, T., B. Getachew and M. Worede. 1991. Morphological diversity in tetraploid wheat landraces populations from central highlands of Ethiopia. *Hereditas* 114: 171-176.

Tesemma, T and G. Belay. 1991. Aspects of tetraploid wheats with emphasis on durum wheat genetics and breeding research, 47-71. *In* Gebremariam, H., Tanner, D.G. and Hulluka, M. (eds.) Wheat research in Ethiopia: A historical perspective. Addis Ababa: IAR/CIMMYT.

Tesemma, T. and J. Mohammed. 1992. Review of wheat breeding in Ethiopia. *Ethiopian Journal of Agricultural Science* 4: 11-24.

Tesemma, T. and E. Bechere. 1998. Developing elite durum wheat landrace selections (composites) for Ethiopian peasant farm use: raising productivity while keeping diversity alive. *Euphytica* 102: 323-328.

Tessema, T. and D.G. Tanner. 1999. Determination of economic threshold densities for the major weed species competing with bread wheat in Ethiopia, 249-272. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. Addis Ababa, Ethiopia: CIMMYT.

Tessema, T., Y. Lemma and B. Admasu. 1999. Qualitative and quantitative determination of weed occurrence in wheat in West Shoa zone of Ethiopia, 160-172. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. Addis Ababa, Ethiopia: CIMMYT.

Tetlay, K.A., P.W. Heisey, Z. Ahmed and A. Munir. 1991. Farmers' sources of wheat seed and wheat seed management in three irrigated regions of Pakistan. *Seed Science and Technology* 19: 123-138.

Thiele, G. 1999. Informal potato seed systems in the Andes: Why are they important and what should we do with them? *World Development* 27: 83-99.

Thomson, J.R. 1979. An introduction to seed technology. Leonard Hill, Glasgow, UK. 252 pp.

Tiruneh, A., W. Mwangi, H. Verkuijl and T. Tesfaye. 1999. Gender differentials in adoption of improved wheat varieties in Ada, Lume and Gimbechu *woredas* of the central highlands of Ethiopia, 31-38. *In* Tenth regional wheat workshop for Eastern, Central and Southern Africa, 14-18 Sep 1998, University of Stellenbosch, South Africa. CIMMYT, Addis Ababa, Ethiopia.

Tripathi, J. and A.A. Powell. 1999. Influence of seed storage on the delivery of quality seed in the informal sector in Nepal, 127-137. *In* Proceedings of the 1999 World Seed Congress, 6-8 Sep 1999, Cambridge, UK. ISTA, Zürich, Switzerland.

Tripp, R. 1995. Seed regulatory frameworks and resource poor farmers: A literature review. Agricultural Administration (Research and Extension) Network Paper No. 51. ODI, London, UK. 53 pp.

Tripp, R. 1997a. The structure of the national seed systems, 14-42. *In* Tripp, R (ed.) New seed and old laws. Regulatory Reform and Diversification of National Seed Systems. ODI, London, UK.

Tripp, R. 1997b. Regulation and regulatory reform, 43-58. *In* Tripp, R (ed.) New seed and old laws. Regulatory Reform and Diversification of National Seed Systems. ODI, London, UK.

Tripp, R. 1997c. The dynamics of seed policy change: State responsibilities and regulatory reform, 157-173. *In* Tripp, R (ed.) New seed and old laws. Regulatory Reform and Diversification of National Seed Systems. ODI, London, UK.

Tripp, R. 2000. Strategies for seed system development in Sub-Saharan Africa: A study of Kenya, Malawi, Zambia and Zimbabwe. Working Paper Series No. 2, Socio-economic and Policy Program, ICRISAT, Bulawyo, Zimbabwe. 56 pp.

Tripp, R. 2001. Seed provision and agricultural development: The institutions of rural change. ODI, London, UK. 174 pp.

Tripp, R. and N.P. Louwaars. 1997. The conduct and reform of crop variety regulation, 88-120. *In* Tripp, R (ed.) New seed and old laws. Regulatory Reform and Diversification of National Seed Systems. ODI, London, UK.

Tripp, R. and W.J. van der Berg. 1997. The conduct and reform of seed quality control, 121-154. *In* Tripp, R (ed.) New seed and old laws. Regulatory Reform and Diversification of National Seed Systems. ODI, UK.

Tripp, R. and S. Pal. 1998. Information exchange in commercial seed markets in Rajasthan. Agricultural Research and Extension Network. Network Paper No. 83. ODI, London, UK. 11 pp.

Tripp, R., N.P. Louwaars, W.J. van der Burg, D.S. Virk and J.R. Witcombe. 1997. Alternatives for seed regulatory reform: an analysis of variety testing, variety regulation and seed quality control. Agricultural Research and Extension Network. Network Paper No. 69. ODI, London, UK. 25 pp.

Tsega, M. 1994. An inventory and investigation of the optimum local seed storage methods in Wello and Shewa administrative regions. SOS/Ethiopia, Addis Ababa, Ethiopia. 39 pp.

Tulley, D. 1990. Labor and the adoption and impact of farm technology, 3-23. *In* Tulley, D. (ed.) Labor and rainfed agriculture in West Asia and North Africa. ICARDA, Aleppo, Syria.

Turner, M.R. 1983. The approach to seed technology teaching at the University of Edinburgh. *Seed Science and Technology* 11: 1303-1309.

Turner, M.R. 1996. Problems of privatizing the seed supply in self-pollinated grain crops. Pages 17-29. *In* van Amstel, H., Bottema, J.W.T., Sidik, M. and van Santen, C.E. (eds.) Integrating seed systems for annual food crops. Proceedings of a workshop, 24-27 Oct 1995, Malang, Indonesia. Bogor, CGPRT Center, Indonesia.

Turner, M. and Z. Bishaw. 2000. Benefits of regional collaboration in seed program development, 649-666. *In* The international conference on seed industry. Proceedings of the international conference on seed industry, 27-30 Mar 2000, Tripoli, Libya. General Authority for Agriculture, Animal and Marine Wealth, Tripoli, Libya.

Turner, M. and Z. Bishaw. (in press). Linking participatory plant breeding to seed systems. *In* Proceedings of international symposium of scientific basis of participatory plant breeding and conservation of genetic resources, 9-13 Oct 2000, Oaxtepec, Mexico. UCLA, Davis, USA.

Turner, M., S. Kugbei and Z. Bishaw. 2000. Privatization of the seed sector in the Near East and North Africa 125-136. *In* Seed policy and programs in the near east and north africa. Proceedings of the regional technical meeting on policy and programs in the Near East and North Africa. 27 Jun-2 Jul 1999, Larnaca, Cyprus. FAO, Rome, Italy.

Tutwiler, R. 1995. Discovering the quality incentive for increasing durum wheat production in West Asia and North Africa, 203-212. *In* di Fonzo, N., Kaan, F. and Nachit, M. (eds.) Durum wheat quality in the Mediterranean region. Proceedings of the seminar on durum wheat quality in the Mediterranean region, 17-19 Sep 1993, Zaragoza, Spain. CIHEAM, Zaragoza, Spain. 284 pp.

Tutwiler, R., M. Martini, A. Khneifis, Y. Sweidan and N. Haddad. 1997. Adoption of improved barley technologies in Syria: Impact of the Mashreq project 1989-94, 467-494. *In* Haddad, N., Tutwiler, R. and Thomson, E. (eds.) Improvement of crop-livestock integration systems in West Asia and North Africa. Proceedings of the regional symposium on integrated crop-livestock integration systems in the dry areas of West Asia and North Africa, 6-8 Nov 1995, Amman, Jordan. ICARDA, Aleppo, Syria.

UPOV. 1981. Guidelines for the conduct of tests for distinctness, uniformity, homogeneity and stability on bread wheat. Geneva, Switzerland. 25 pp.

UPOV. 1988. Guidelines for the conduct of tests for distinctness, uniformity and stability on durum wheat. Geneva, Switzerland. 35 pp.

van Amstel, H., J.W.T. Bottema, M. Sidik and C.E. van Santen (eds.). 1996. Integrating seed systems for annual food crops. Proceedings of a workshop, 24-27 Oct 1995, Malang, Indonesia. CGPRT Center, Bogor, Indonesia. 311 pp.

van Beuningen, L.T. and R.H. Bush. 1997a. Genetic diversity among North American spring wheat cultivars. I. Analysis of the coefficient of parentage matrix. *Crop Science* 37: 570-579.

van Beuningen, L.T. and R.H. Busch. 1997b. Genetic diversity among North American spring wheat cultivars. III. Cluster analysis based on quantitative morphological traits. *Crop Science* 37: 981-988.

van Gastel, A.J.G. and Z. Bishaw. 1994. Seed survey in Syria, 13-16. *In* Seed Unit Annual Report for 1994. ICARDA, Aleppo, Syria.

van Gastel, A.J.G., J. Wadsack and G.R. Manners (eds.). 1997. Privatization of the seed industry in the West Asia and North Africa region. GTZ, Eschborn, Germany.

van Gastel, A.J.G., B.R. Gregg and E. Asiedu. 2002. Seed quality control in developing countries. *Journal of New Seeds* 4: 117-130.

van Leur, J.A.G., S. Ceccarelli and S. Grando. 1989. Diversity of disease resistance in barley from Syria and Jordan. *Plant Breeding* 103: 324-335.

Venkatesan, V. 1994. Seed systems in Sub-Saharan Africa: Issues and options. World Bank Discussion Paper No 266. The World Bank, Washington D.C, USA. 112 pp.

Walker, D.J. and R. Tripp. 1997. Seed management by small-scale farmers in Ghana and Zambia, 207-215. *In* International workshop on seed security for food security, 30 Nov-1 Dec 1997, Florence, Italy. FAO, Rome, Italy.

Wiese, M.V. (ed.). 1987. Compendium of wheat diseases. The American Phytopathological Society, St Paul, Minnesota, USA. 112 pp.

Witcombe, J.R., A. Joshi, K.D. Joshi and B.R. Sthapit. 1996. Farmer participatory crop improvement. I. Varietal selection and breeding methods and their impact on biodiversity. *Experimental Agriculture* 32: 445-460.

Witcombe, J.R., R. Petre, S. Jones and A. Joshi. 1999. Farmer participatory crop improvement. IV. The spread and impact of a rice variety identified by participatory varietal selection. *Experimental Agriculture* 35: 471-487.

Witcombe, J.R. K.D. Joshi, R.B. Rana and D.S. Virk. 2001. Increasing genetic diversity by participatory varietal selection in high potential production systems in Nepal and India. *Euphytica* 122: 575-588.

Woldeselassie, Y.S. 1999. Evaluation of status and quality of barley seed used by the northern and central Ethiopian farmers. University of Jordan, Amman, Jordan. MSc thesis. 65 pp.

Worede, M. 1992. Ethiopia: A genebank working with farmers, 78-94. *In* Cooper, D., Vellv´e, V.R. and Hobbelink, H. (eds.) Growing diversity: Genetic resources and local food security. Intermediate Technology Publications Ltd, London, UK

Wright, M., L. Delimini, J. Luhanga, C. Mushi and H. Tisini. 1995. The quality of farmer saved seed in Ghana, Malawi and Tanzania. NRI, ODA, Chatham, UK. 34 pp.

Wright, M., T. Donaldson, E. Cromwell and J. New. 1994. The retention and care of seeds by small-scale farmers. NRI, ODA, Chatham, UK. 63 pp.

Wright, M. and P. Tyler. 1994. Traditional seed saving practices in northern Ghana and central Malawi. NRI, ODA, Chatham, UK. 55 pp.

Yalew, A., D.G. Tanner, M. Hassena and A. Taa. 1997a. On-farm verification of five advanced bread wheat lines under recommended and farmers' crop management practices in the Ethiopian highlands. *Sebil* (Ethiopia) 7: 159-171.

Yalew, A., D.G. Tanner, R. Ensermu and A. Haile. 1997b. On-farm evaluation of alternative bread wheat production technologies in northwestern Ethiopia. *Sebil* (Ethiopia) 7: 193-204.

Yarham, D.J. and B.M. McKewon. 1989. Airborne spores of *Tilletia caries* as a source of wheat bunt through soil contamination. *Plant Pathology* 38: 612-614.

Yirga, C., H. Beyene, L. Zewdie and D.G. Tanner.1992. Farming systems of the Kulumsa area, 145-157. *In* Franzel, S. and van Houten, H. (eds.) Research with farmers: Lessons from Ethiopia. CABI, Wallingford, UK.

Yirga, C., B.I. Shapiro and M. Demeke. 1996. Factors influencing adoption of new wheat technologies Wolmera and Addis Alem areas of Ethiopia. *Ethiopian Journal of Agricultural Economics* 1: 63-84.

Yirgou, D. 1967. Plant diseases of economic importance in Ethiopia. Experimental Station Bulletin 50. College of Agriculture, Haile Selassie I University, Ethiopia.

Yousef, S. and M. Ismail. 2000. Restructuring government seed centers into private small-scale enterprises in Egypt, 61-71. *In* Kugbei, S., Turner, M. and Witthaut, P. (eds.) Finance and management of small-scale seed enterprises, 26-30 Oct 1998, Addis Ababa, Ethiopia. ICARDA, Aleppo, Syria.

Zegeye, T., G. Taye, D. Tanner, H. Verkuijl, A. Agidie and W. Mwangi. 2001. Adoption of improved bread wheat varieties and inorganic fertilizer by small-scale farmers in Yelmana Densa and Farta districts of northwestern Ethiopia. CIMMYT, Mexico and EARO, Ethiopia. 29 pp.

Zeven, A.C. 1999. The traditional inexplicable replacement of seed and seed ware of landraces and cultivars: A review. *Euphytica* 110: 181-191.

Summary

Introduction
Agriculture is the main economic activity both in Ethiopia and Syria with varying proportion in its contribution to GDP, employment generation, export earning and provision of raw input to the industrial sector. In both countries, wheat and barley belong to the most important principal cereal crops grown since ancient times. In traditional agriculture, plant improvement and seed selection were carried out as an integral part of crop production with no functional specialization. With the development of modern agriculture, plant breeding and seed production evolved into separate disciplines. Seed becomes a key in delivering all agriculture-based new technologies to farmers. In Chapter 1, the general evolution of the seed industry with particular emphasis on developing countries has been outlined and their origins, components, functions and their linkages have been described.

This wheat and barley seed systems study gives an insight into the functioning of formal and informal seed sectors in Ethiopia and Syria.

The national seed industry development
The development and performance of the national agricultural research systems and national seed programs in Ethiopia and Syria should be studied as 30 to 40 years' history following their formal establishment in the 1960s and 1970s, respectively. In Chapters 2 and 3, the evolution and organizations of national seed industry in Ethiopia and Syria, respectively, were reviewed with emphasis on national policy and regulatory support for the agricultural sector in general and the seed sector in particular. The current status and performance of the seed industry have been reviewed based on field level surveys and secondary data taking into account wheat and barley crops grown in contrasting environments. The studies revealed interesting and contrasting situations in terms of farmer's use and perception of new varieties, adoption of improved agricultural technologies, and indigenous on-farm seed management practices.

Farmers' knowledge and use of wheat and barley technologies
There are many factors that influence the technology development including the perception of the scientist, appropriateness to the farming conditions, economic benefits to the farmers and then the means for transferring the technology itself. Since their inceptions in the 1960s, the National Agricultural Research Systems of Ethiopia (Ethiopian Agricultural Research Organization) and Syria (General Commission for Scientific and Agricultural Research) have made a significant contribution in

generating new technologies aimed at raising farm productivity to increase farm income, improve farmers' livelihood and achieve national food security. Apart from modern varieties, several crop production packages have been generated, evaluated and recommended including time, method and rate of sowing; fertilizer types, rates and application methods; physical and chemical crop protection practices; frequency and scheduling of irrigation water (where applicable) for use by farmers. Farmers use multiple sources of information such as the formal sector (extension services, development agencies, research, media broadcast) or from informal sources (own experience, relatives, neighbours, other farmers, traders) to get the right information on varietal or agronomic packages for crop production. It is imperative to note that the majority of Ethiopian farmers surveyed (> 90%) are aware of modern wheat varieties, fertilizers, herbicides, agronomic practices and less so on insecticides and on-farm grain storage. In Ethiopia, the agricultural extension service appeared to be the major source of information and as a result most farmers applied fertilizers (96.7%) and herbicides (63.5%) to their wheat crop. In Syria, wheat farmers had better access to information (>96%) regarding modern varieties, agronomic packages, fertilizers, herbicides and chemical seed treatment in comparison to barley growers. Fellow farmers (relatives, neighbours and other farmers altogether) were the major sources of information for varieties, agronomy and fertilizers. Most wheat farmers apply fertilizers (100%) and a variety of herbicides (93%). In comparison only 56% of barley farmers use fertilizers and 4% apply herbicides.

In Ethiopia, the wheat production guidelines lack variety specific recommendation and are based on altitude and rainfall patterns, although in recent years more detailed advice is emerging on varietal adaptation, agronomic management practices, use of chemical inputs and their economic threshold for wheat production. In Syria, agricultural production technology packages are targeted according to crops and the crop production zones where use of high inputs is encouraged for modern varieties and favourable environments. Use and application of fertilizers, irrigation and pesticides have been recommended for wheat production based on the target environments and less so for barley. In general, most farmers fail to apply specific research recommendations and as result unable to derive the best possible economic benefits of the technological packages for wheat and barley production.

Farmers' adoption and perception of modern varieties

The EARO (Ethiopia) and GCSAR (Syria) have made remarkable progress in developing several modern varieties of wheat and barley associated with high and stable yield, responsive to inputs, tolerant to biotic and abiotic stresses and adapted to the agricultural zones of their respective countries. EARO developed and released 39 bread and 9 durum wheat varieties from 1970 to 1997, at the rate of 1.7 varieties per year for a very diverse agro-ecology of the country. Likewise, GCSAR has developed and released 6 bread and 8 durum wheat varieties over the same period, i.e., 0.5 varieties per year for highly variable, but limited agro-ecological zones of Syria. The adoption and diffusion of modern bread wheat varieties was high in Ethiopia where 76% of the sample farmers grew modern bread wheat varieties from the recommended list and 10% 'obsolete' varieties. This figure will increase to 88% if regions that are growing bread wheat only are considered. In contrast, the number of modern durum wheat varieties released from formal research is limited and commercial seed from the formal sector remains insignificant. Most farmers in traditional durum wheat growing areas of central and northwestern Ethiopia are shifting to bread wheat because of high yield and better agronomic performance including grain colour, grain size and tolerance to pests. As a result only 0.7% of sample farmers planted a modern durum wheat variety whereas 13.3% of farmers grew a wide range of local durum wheat landraces, mostly in West Shoa, North Shoa and East Gojam regions.

In Syria, adoption of both bread and durum wheat varieties is very high where almost 87% of the farmers plant varieties from the recommended list (excluding obsolete or modern varieties not officially released). In case of barley only one farmer planted a modern barley variety (0.5%). The remarkable success of bread wheat in Ethiopia and bread and durum wheat varieties in Syria, however, did conceal the poor performance of the formal sector in meeting the diverse need of durum wheat growers in Ethiopia and barley growers in Syria. Despite an impressive list of released modern varieties on the recommended list none of them were widely adopted; they were possibly rejected because of lack of adaptability and farmers' preferences.

Farmers have identified as many as 26 technological and socio-economic criteria for adopting and continuously growing a particular wheat variety on their farm. However, grain yield, food quality, marketability, grain colour and grain size appear to be most important criteria and transcend all zones. Ethiopian farmers' have experience of devastating rust epidemics which predispose them to look for varieties with resistant to pests. Interestingly, high yield, lodging resistance, drought tolerance (yield with less water) and frost tolerance appeared to be varietal characteristics farmers are seeking from new bread and durum wheat varieties in Syria. There is a strong desire for alternative varieties responding to higher inputs and at the same time maintain good agronomic characteristics such as tolerance to lodging and shattering.

Farmers' seed sources and management

Varietal and seed replacement is a dynamic process affected by farmers' perception about the costs and risks associated with these changes. Small-scale farmers grow as

many diverse crops as possible dictated by their domestic circumstances including the various end uses of the crops and provision of household food security. The alternatives to source seed for a mix of crops and varieties grown are challenging and part of a complex decision-making process. In general farmers have four major sources of seed for planting wheat and barley: (i) own saved seed from the previous years; (ii) seed obtained from other farmers (relatives, neighbours); (iii) seed purchased through local trading (markets or grain traders); and (iv) seed purchased from the formal sector. A clear distinction should be made between demand for variety and demand for seed as well as a difference between transient and regular demand for seed.

Farmers may seek seed from outside sources as a means for acquiring new crops or varieties, but not necessarily regularly buy certified seed from external formal sources. The informal sector remained the major initial seed source for modern varieties of bread and durum wheat crops through a local network of seed exchange and remained the major supplier of seed for planting in any crop season. Although the majority of wheat farmers in Ethiopia adopted new varieties they rely less on the formal sector for their yearly seed supply. The informal sector was an initial source of modern wheat varieties for 58% of the farmers and during the 1997/98 crop season 91.2% of respondents used retained seed or seed obtained from neighbours and traders for planting wheat. In comparison Syrian wheat farmers have better access to seed from the formal sector where nearly 60% of farmers get their initial seed of new varieties; but only 24% of farmers purchased seed from the formal sector in 1998/99 crop season. However, the informal seed acquisition from relatives, neighbours and other farmers or local trading still played a significant role in diffusion of modern wheat varieties (40.4%). More importantly, most of the barley seed for planting comes from the informal sector. Acquisition of seed from external sources particularly from the formal sector is one of the strategies farmers use for replacing ‘old variety or seed’. Most farmers were satisfied with the quality of seed they obtained from formal or local sources and manage them accordingly. Almost all wheat and barley farmers had a long established culture and experience of exchanging seed among themselves informally on various transactional arrangements contributing to the local flow of seeds.

In Chapters 2 and 3, farmers’ perception of seed quality and on-farm seed management was analysed for wheat and barley in Ethiopia and Syria. The majority of wheat and barley farmers recognized the difference between seed and grain (92-99%) and linked these differences mostly to the physical quality of seed such as freedom from inert matter, weed contamination and seed size. The perception for physiological (4-18%) and seed health quality (3-10%) is generally low except in Syria where most wheat farmers use chemical seed treatment. Farmers’ positive appreciation of seed induces them to practice specific on-farm seed management approaches to maintain

the quality of their wheat and barley seed through selection, cleaning, treatment, storage or assessment of seed quality. The responsibility to manage and execute these operations on the farm is shared between men and women, who have a distinctive role to play.

Ethiopian wheat farmers use a variety of options for on-farm seed management including seed selection (67.1%), cleaning (82.8%), separate storage (64.8%) and informal physiological quality assessment (33.9%). Similarly, wheat farmers in Syria also select (53.9%), clean (90.3%), treat (90.3%) and store seed separately (64.1%). Selection of plants or seeds is a dynamic process adapting the variety or a local landrace to a continuously changing crop production environment. It also requires continuous monitoring of the entire life cycle of the crop coupled with regular observation of the characteristics that farmers consider very useful. Farmers practice empirical selection of plants or seeds through critical observation using crop performance criteria although these do not involve specific physical measurements. Plant or seed selection could take place at least in four stages during crop production cycle: selection of the whole field or parts of the field; selection of plants or ears in the field of standing crops before or at harvest; selection of ears/grains on threshing floors; and selection of grains from threshed grain in a storage or at planting time. The most striking difference between wheat and barley seed management was the extent of chemical seed treatment used by wheat farmers in Syria.

Farmers' seed quality

In Chapter 4, wheat and barley seed samples collected from different regions and seed sources were analysed and compared in terms of seed quality. It appeared that the physical and physiological quality of seed did not differ significantly between different sources for individual crops in respective countries except for germination of wheat in Ethiopia and barley in Syria. The formal sector seed occasionally had higher average quality compared to seed from informal sources such as retained seed or seed obtained through local exchange mechanisms. In Ethiopia, the quality of wheat seed from the informal sector was comparable to that from the formal sector both in terms of physical purity and germination where most of the samples (93%) matched the minimum standards set for commercial seed. In Syria, slightly more than half of the wheat seed samples (54%) reached the minimum commercial seed standard. The physical purity of wheat seed from the informal sector (retained seed and from other farmers) was low whereas the germination of formal sector seed appeared to be slightly lower than that of the informal sector. The seed quality of barley seed was the lowest particularly in terms of physical quality where only 9% of the samples met the minimum requirement for commercial seed. However, as most samples were marginally lower than the minimum requirement of the formal sector seed, adjusting the standard slightly downward would make all samples to meet the requirement. However, there is an underlying weakness in the physical quality of seed from the informal sector where traditional cleaning techniques are ineffective in removing most of the contaminants. Contamination with weed seed remains a major problem where most of the samples failed to reach the quality standards prescribed by the national seed program. Introducing appropriate on-farm cleaning techniques could improve quality and minimize contamination particularly with noxious weeds. Moreover, identifying and improving traditional practices of seed quality assessment would help in improving the seed quality at the farm level.

In Chapter 5, the health quality of wheat and barley seed samples was analysed; it showed significant differences between regions and seed sources particularly for some pathogens in Ethiopia. Interestingly, more seed health quality problems were observed in wet or high rainfall areas compared to the drier regions showing the influence of the environment on diseases infection. Several fungal pathogens have been isolated from wheat and/or barley seed samples across the country with varying proportion in the number of samples infected (frequency) and the percentage infection (intensity). In Ethiopia 84, 31, 74, 13, 52 and 31% were infected by *Drechslera sativum*, *Fusarium avenaceum*, *F. graminearum*, *F. nivale*, *F. poae* and *Septoria nodorum*, respectively and more frequently with more than one species. Eighty four percent of samples were infected with *Drechslera sativum* at an average infection level of 1.85%. *F. graminearum* appeared to be predominant among *Fusarium* species where 74% of the samples were infected with a mean infection rate of 1.54%. The number of samples infected (31%) and the level of infection (0.5%) was the lowest with *Septoria nodorum* compared to other pathogens. Infection with common bunt (*Tilletia* spp.), loose smut (*Ustilago tritici*) and ear cockle (*Anguina tritici*) appeared sporadic but was found across all the regions surveyed. In general the percentage infection was low except for common bunt and smut infection in excess of the standard. In Syria, the health quality of wheat seed was found to be better than that of barley seed. In the case of wheat 68% of the samples were contaminated with common bunt (more than or equal to 5 spores/400 seeds) and 13.6% of the samples were infected with loose smut all in excess of the lowest standard set for seed health in the West Asia North Africa region. In contrast, 85 and 83% of barley seed samples were contaminated with covered smut (*Ustilago hordei*) or infected with loose smut, respectively. The average percentage infection rate of loose smut of barley was 18% with all samples in excess of seed health standards in the WANA region. It is believed that the wide spread use of chemical seed treatment in wheat might have contributed to such difference in seed health quality between the two crops.

On-farm varietal diversity of wheat and barley crops

Syria is the centre of origin and domestication for tetraploid wheat and barley whereas the Ethiopian highlands are considered the centres of diversity of tetraploid wheats and barley where a considerable wealth of genetic variability and diversity still exists on the farm. In Chapter 6, the spatial diversity, temporal diversity, coefficient of parentage analysis and measurements of agronomic and morphological traits were employed to explain the diversity of wheat and barley varieties or local landraces grown by farmers. The spatial and temporal diversity of wheat and barley were low as only a few dominant varieties were grown widely and the majority of farmers planted these varieties. The wide spread adoption of modern varieties led to a total replacement of traditional durum wheat landraces in Syria. In Ethiopia the expansion of bread wheat into traditionally durum wheat growing areas appeared to threaten the on-farm diversity of landraces. In contrast, a single landrace was grown throughout the major barley growing areas showing the versatile genotypic plasticity of the barley crop. Tremendous agronomic and phenotypic traits diversity was observed particularly among local durum landraces collected from farmers. It was suggested that desirable agronomic characteristics from locally adaptable landraces incorporated into new breeding lines using alternative crop improvement strategies to increase the choice of varieties available to farmers to counter the effects of genetic erosion and at the same time to increase on-farm diversity and maintenance of the valuable genetic resources.

Synthesis

The synthesis (Chapter 7) describes the main findings of the wheat and barley seed system study in an integrated fashion and suggests alternative ways for the development of an efficient, competitive and sustainable seed industry responsive to the needs of farmers. Moreover, alternative strategies and approaches for the development and/or improvement of local seed systems and its integration with the formal sector has been suggested as a viable option for small-scale resource poor farmers in marginal environments or less accessible isolated and remote areas of the developing countries. The role of policy and regulatory, technological, institutional and socio-economic factors were emphasized from generation of to the transfer of technology to farmers. This study combines formal farmer surveys, laboratory analysis, field experiments and secondary data on seed supply to better understand the functioning of the national seed system.

Samenvatting

Inleiding

In zowel Ethiopië als Syrië is de landbouw de belangrijkste economische activiteit, maar het aandeel in het Bruto Nationaal Product, de werkgelegenheid, de exportopbrengsten en de grondstoffenvoorziening van de industriële sector verschilt sterk voor deze landen. In beide landen behoren tarwe en gerst tot de belangrijkste graangewassen en worden deze reeds sinds de oudheid geteeld. In de traditionele landbouw waren gewasverbetering en zaadselectie integrale onderdelen van de gewasproductie, die zonder functionele specialisatie plaats vonden. Met de ontwikkeling van de moderne landbouw, ontwikkelden de plantenveredeling en de zaaizaadproductie zich tot afzonderlijke disciplines. Zaaizaad ging een cruciale rol spelen bij het beschikbaar maken van nieuwe landbouwtechnologieën. In Hoofdstuk 1 wordt ingegaan op de algemene ontwikkeling van de zaaizaadindustrie, met name die in ontwikkelingslanden. Het hoofdstuk bevat gedetailleerde beschrijvingen van het ontstaan van de zaaizaadindustrie, de functies van de afzonderlijke componenten en hun onderlinge verbanden.

Dit proefschrift behandelt specifiek de zaaizaadsystemen van tarwe en gerst. Het beoogt inzicht te verschaffen in het functioneren van zowel de formele als de informele zaaizaadsectoren in Ethiopië en Syrië.

De ontwikkeling van een nationale zaaizaadindustrie

De ontwikkeling en het functioneren van het landbouwkundig onderzoek en de zaaizaadvoorziening in Ethiopië en Syrië dienen te worden bestudeerd aan de hand van hun geschiedenis in de laatste 30 - 40 jaren. Voor Ethiopië geldt dat zij formeel in de zestiger jaren van de vorige eeuw werden opgericht en voor Syrië was dat in de zeventiger jaren. In de Hoofdstukken 2 (Ethiopië) en 3 (Syrië) worden de ontwikkeling van en de manier waarop de zaaizaadindustrie georganiseerd, is beschreven. De nadruk ligt daarbij op de nationale politiek en regelgeving die de landbouwsector in het geheel en de zaaizaadsector in het bijzonder ondersteunen. Op basis van een overzichtsstudie te velde en secundaire informatiebronnen zijn de huidige status en het functioneren van de zaaizaadindustrie in kaart gebracht, waarbij rekening is gehouden met de gevarieerde milieus waarin de gewassen tarwe en gerst worden verbouwd. Uit deze veldstudies komt naar voren hoe verschillend de situatie is met betrekking tot het gebruik van nieuwe rassen, de ideeën van boeren over nieuwe rassen, de toepassing van nieuwe verbeterde landbouwtechnologieën en de inheemse praktijken van het zaaizaadbeheer op de boerderij.

Bij boeren aanwezige kennis en het gebruik van technologieën in de tarwe- en gerstteelt

Tot de vele factoren die de ontwikkeling van technologieën beïnvloeden behoren de opvattingen van wetenschappers, de geschiktheid van teeltcondities, de economische winst die door de boeren behaald kan worden en de middelen die beschikbaar zijn om de technologieën over te dragen. Sinds de oprichting in de zestiger jaren van de vorige eeuw, heeft het landbouwkundig onderzoek in Ethiopië (Ethiopian Agricultural Research Organization; EARO) en Syrië (General Commission for Scientific and Agricultural Research; GCSAR) in belangrijke mate bijgedragen aan het genereren van nieuwe technologieën die er op gericht waren de landbouwproductiviteit te verhogen. Deze productiviteitsverhoging was nodig om boeren een beter inkomen te verschaffen, hun levensomstandigheden te verbeteren en de nationale voedselzekerheid te verhogen. De introductie van moderne rassen was daarbij belangrijk, maar daarnaast werden ook nieuwe teeltmaatregelen ontwikkeld, getoetst en aanbevolen die in onderlinge samenhang moeten bijdragen aan productieverhoging. Hiertoe behoren verbeterde technieken ten aanzien van tijdstip, methode en dichtheid van zaaien; soorten, hoeveelheden en toedieningswijzen van kunstmest, fysische en chemische gewasbescherming, en frequentie en tijdstip van irrigatie (indien beschikbaar). Boeren benutten verschillende bronnen, zowel uit de formele sector (voorlichting, ontwikkelingsorganisaties, onderzoek, media) als uit de informele sector (eigen ervaring, ervaringen van familie, buren, andere boeren, handelaren) om de juiste informatie te bemachtigen betreffende rassenkeuze en teelttechniek. De meeste Ethiopische boeren (>90%) bleken zich bewust te zijn van het bestaan van moderne tarwerassen, kunstmest, herbiciden en teeltmaatregelen. Een kleiner percentage bleek kennis te hebben van insecticiden en bewaartechnieken op de boerderij. In Ethiopië bleek de nationale voorlichtingsdienst de belangrijkste bron van informatie te zijn. De meeste boeren dienden dan ook kunstmest (96.7%) en herbiciden (63.5%) toe aan hun tarwegewas. In Syrië bleken tarwetelers (>96%) een betere toegang te hebben tot informatie betreffende moderne rassen, teelttechniek, kunstmest, herbiciden en chemische zaaizaadbehandeling dan de gersttelers. Collega boeren (familie, buren en andere boeren) waren de belangrijkste bron voor informatie betreffende rassen, teelttechniek en kunstmest. Vrijwel alle tarwetelers dienden kunstmest (100%) en herbiciden (93%) toe. Van de gersttelers dienden slechts 56% kunstmest en 4% herbiciden toe.

In Ethiopië zijn de teeltadviezen voor tarwe niet rasspecifiek en gebaseerd op hoogte en regenval. De laatste tijd is er echter een ontwikkeling gaande om tevens aandacht te besteden aan rassenkeuze, teelttechniek, gebruik van chemische inputs en de economische aspecten daarvan. In Syrië worden gewasspecifieke teeltmaatregelen voor specifieke productiezones aanbevolen, waarbij een hoog inputniveau wordt geadviseerd voor moderne rassen en gunstige teeltomstandigheden. Dit is met name het geval voor tarwe ten aanzien van het gebruik van kunstmest, irrigatie en pesticiden. Voor gerst is dit in mindere mate het geval. In het algemeen geldt dat de boeren de specifieke aanbevelingen voortkomend uit onderzoek niet toepassen. Als gevolg daarvan zijn de boeren niet in staat om in de tarwe- en gersteelt de hoogste saldi te realiseren.

Het accepteren van en denken over moderne rassen door boeren

Zowel de EARO in Ethiopië als de GCSAR in Syrië hebben belangrijke vorderingen gemaakt in het ontwikkelen van moderne rassen van tarwe en gerst. Dergelijke rassen geven een hoge en stabiele opbrengst, reageren goed op inputs, zijn tolerant voor biotische en abiotische stress en zijn aangepast aan de omstandigheden in de verschillende teeltzones. In de periode 1970 - 1997 werden door EARO 39 broodtarwerassen en 9 durum tarwerassen ontwikkeld en geregistreerd. Dat staat gelijk aan 1.7 rassen per jaar voor een land met een grote verscheidenheid in agro-ecologische omstandigheden. Over dezelfde periode werden door GCSAR 6 broodtarwe- en 8 durum tarwerassen ontwikkeld en geregistreerd. Dat is 0.5 ras per jaar voor de zeer gevarieerde, maar in aantal beperkte, agro-ecologische zones in Syrië. In Ethiopië werden moderne broodtarwerassen zeer goed geaccepteerd en verspreid: van de onderzochte boeren teelde 76% moderne broodtarwerassen die op de lijst van aanbevolen rassen stonden. Daarnaast teelde 10% verouderde rassen. Als alleen naar broodtarwe wordt gekeken dan is het percentage aanbevolen rassen 88%. Daarentegen is het aandeel durum tarwerassen, dat door de formele onderzoeksinstellingen is ontwikkeld, beperkt. Commercieel zaad vanuit de formele sector is ook nog steeds van weinig betekenis. De meeste boeren in de traditionele durum tarwegebieden van centraal en noordwest Ethiopië schakelen over op broodtarwe, omdat dit een betere opbrengst geeft en daarnaast agronomisch beter presteert (betere korrelkleur, grotere korrelomvang, meer ziektetolerantie). Derhalve zaaide slechts 0.7% van de onderzochte boeren een modern durum tarweras, terwijl 13.3% van de boeren een breed palet van lokale durum tarwe landrassen verbouwde. Dit vond vooral plaats in de gebieden West Shoa, Noord Shoa en Oost Gojam.

In Syrië was de adoptie van zowel brood- als durum tarwerassen zeer hoog. Bijna 87% van de boeren zaaide aanbevolen rassen (met uitsluiting van verouderde of nog niet op de mark gebrachte rassen). Er was echter slechts één boer (0.5%) die een modern gerstras verbouwde. Het opvallende succes van de moderne broodtarwerasen in Ethiopië en van de moderne brood- en durum tarwerassen in Syrië verhulde echter dat de formele sector slecht in staat is geweest in de behoefte van de durum tarwetelers in Ethiopië en van de gersttelers in Syrië te voorzien. Ondanks een indrukwekkend aantal moderne rassen op de lijst van aanbevolen rassen bleek geen van deze rassen breed geaccepteerd te zijn. Ze werden waarschijnlijk niet geaccepteerd vanwege een gebrek aan aanpassingsvermogen en omdat ze niet voldeden aan de voorkeur van de boeren.

Boeren hebben maar liefst 26 technologische en socio-economische criteria waaraan voldaan moet worden om een bepaald tarweras op hun bedrijf te accepteren en ook blijvend te verbouwen. In alle zones bleken korrelopbrengst, voedselkwaliteit, vermarktbaarheid, korrelkleur en korrelgrootte verreweg het belangrijkst. In Ethiopië bleken de boeren, vanwege hun ervaring met verwoestende roestepidemieën, ook de ziekteresistentie zeer belangrijk te vinden. In Syrië bleken tarweboeren vooral naar hoge opbrengst, legeringsresistentie, droogtetolerantie (meer opbrengst met minder water) en vorsttolerantie te kijken. Bovendien vinden boeren het erg belangrijk dat moderne rassen goed reageren op verhoging van inputs zonder dat zulks ten koste gaat van de resistentie tegen legeren en zaaduitval.

Bronnen van boerenzaad en het beheer daarvan

Vervanging van rassen en het zaaizaad daarvan is een dynamisch proces dat sterk wordt bepaald door de opvattingen die boeren hebben ten aanzien van de kosten en risico's die met deze vervanging gepaard gaan. Kleinschalige boeren telen een zo groot mogelijke diversiteit aan gewassen. Dit wordt ingegeven door de omstandigheden van hun huishouden (bijvoorbeeld de verschillende benuttingswijzen van het gewas en de mate van voedselzekerheid op huishoudniveau). De alternatieven om zaaizaad te betrekken voor een veelheid van geteelde gewassen en rassen vormen een uitdaging en maken deel uit van een ingewikkeld besluitvormingsproces. In het algemeen beschikken boeren over vier verschillende bronnen voor zaaizaad van tarwe en gerst: (i) eigen boerenzaad, dat is bewaard van de oogst van vorige jaar; (ii) zaad dat is verkregen van collega boeren (familie, buren); (iii) lokaal gekocht zaad (afkomstig van de markt of lokale handelaren); en (iv) zaad dat gekocht is via de formele zaadsector. Bij het bestuderen hiervan dient nadrukkelijk onderscheid gemaakt te worden tussen de behoefte aan een nieuw ras en de behoefte aan nieuw zaad. Tevens dient het verschil in ogenschouw genomen te worden tussen een tijdelijke behoefte en de reguliere behoefte aan zaaizaad.

Boeren kunnen op zoek gaan naar zaaizaad van externe bronnen teneinde nieuwe gewassen of nieuwe rassen te verkrijgen. Zij kopen niet noodzakelijkerwijs op regelmatige basis gecertificeerd zaaizaad uit externe bronnen. De informele sector bleef de belangrijkste bron van zaaizaad, ook voor moderne rassen van brood- en durum tarwe. Dit werkte via een lokaal netwerk van uitwisseling van zaaizaad en bleef de belangrijkste leverancier van zaaizaad voor elk groeiseizoen. Hoewel de meeste

Ethiopische tarwetelers nieuwe rassen accepteerden, waren ze minder afhankelijk van de formele sector voor hun jaarlijkse zaaizaadvoorziening. De informele sector was de initiële bron voor moderne rassen voor 58% van de telers, en gedurende het groeiseizoen van 1997/98 gebruikte maar liefst 91.2% van de tarwetelers zaad dat zij zelf hadden bewaard of dat zij hadden gekregen van buren en handelaren. In vergelijking hiermee hebben de tarwetelers in Syrië een betere toegang tot zaad uit de formele sector: gemiddeld bijna 60% van de telers kregen hun initieel zaaizaad via het aankopen van nieuwe rassen van de formele sector. Dit percentage was echter slechts 24% in het groeiseizoen 1998/99. Het informeel verkrijgen van zaaizaad via familie, buren en andere boeren of via de lokale handel speelde nog steeds een belangrijke rol in het verspreiden van moderne tarwerassen (40.4%). Belangrijker is dat voor gerst het meeste zaaizaad nog steeds uit de informele sector kwam. Het vervangen van een oud ras of oud zaad werd door de boeren meestal gedaan via het kopen van zaad uit externe bronnen, met name uit de formele sector. De meeste boeren waren tevreden over de kwaliteit van het zaad dat zij hadden verkregen uit de formele of lokale bronnen en behandelden het met zorg. Bijna alle tarwe- en gersttelers hadden een langgevestigde traditie van en ervaring met informele onderlinge uitwisseling van zaad. Deze uitwisseling was gebaseerd op verschillende typen transacties en droegen bij aan de lokale voorziening van zaad.

In de Hoofdstukken 2 en 3 zijn de opvattingen van de boeren over zaaizaadkwaliteit en het beheren van zaaizaad op de boerderij geanalyseerd voor tarwe en gerst in Ethiopië en Syrië. De meeste tarwe- en gersttelers waren zich bewust van het verschil tussen zaaizaad en graan. Het verschil tussen de twee koppelden ze meestal aan begrippen als fysische kwaliteit (het vrij zijn van inert materiaal, het vrij zijn van onkruidzaden en de juiste korrelgrootte). Kennis van fysiologische kwaliteit en zaaizaadgezondheid was in het algemeen gering, met uitzondering van de tarwetelers in Syrië, die meestal een chemische zaaizaadbehandeling uitvoerden. De positieve waardering van boeren voor zaaizaad bracht hen er toe speciale bewaar- en behandelingstechnieken toe te passen om de kwaliteit van hun zaaizaad op een hoog peil te houden. Zij pasten selectie, schoning, zaaizaadbehandeling, bewaring en zaadkwaliteitstesten toe. De verantwoordelijkheid voor deze activiteiten werden door vrouwen en mannen gedeeld. Beide seksen speelden daarbij een eigen rol.

De Ethiopische tarwetelers pasten een diversiteit aan zaaizaadmanagement technieken op de boerderij toe. Deze omvatten onder andere zaaizaadselectie (67.1%), schoning (82.8%), aparte opslag (64.8%) en informele toetsing van de fysiologische kwaliteit (33.9%). Tarwetelers in Syrië pasten ook selectie (53.9%), schoning (90.3%), zaaizaadbehandeling (90.3%) en gescheiden opslag (64.1%) toe. Selectie van zaden of planten is een dynamisch proces waarbij het moderne ras of het lokale landras aangepast wordt aan een voortdurend veranderende gewasproductieomgeving. Het maakt het tevens noodzakelijk om continu het gewas in de gaten te houden en regelmatig waarnemingen te doen aan de eigenschappen die de boeren als zeer bruikbaar beschouwen. Boeren passen empirische selectie van planten of zaden toe, door – zonder exacte metingen te verrichten – waarnemingen te doen aan belangrijke kenmerken die iets zeggen over het opbrengend vermogen van het gewas. Plant- of zaaizaadselectie zou in tenminste vier stadia van een gewascyclus kunnen plaatsvinden: selectie van het hele veld of delen van het veld; selectie van planten of aren in het veld vlak voor of tijdens de oogst; selectie van aren of korrels op de dorsvloer; en selectie van gedorst of opgeslagen graan voor of bij het zaaien. Het belangrijkste verschil tussen zaaizaadbeheer van tarwe en gerst was de mate waarin Syrische tarwetelers een chemische zaaizaadbehandeling toepasten.

Kwaliteit van boerenzaad

In Hoofdstuk 4 worden de resultaten beschreven van de analyses op zaaizaadkwaliteit van de zaaizaadmonsters van tarwe en gerst afkomstig uit verschillende regio’s en van verschillende zaadbronnen. Voor beide gewassen bleken in de twee landen geen significante verschillen tussen herkomsten te bestaan ten aanzien van de fysische en fysiologische kwaliteit van het zaaizaad. De enige uitzondering was de kiemkracht van tarwe in Ethiopië en van gerst in Syrië. Het zaaizaad uit de formele sector had soms een hogere gemiddelde kwaliteit dan het zaad uit de informele sector (bijv. zaad dat bewaard /in bezit gehouden was dan wel zaad verkregen via lokale uitwisseling). In Ethiopië was de kwaliteit van tarwezaad uit de informele sector vergelijkbaar met dat van de formele sector voor wat betreft de fysische zuiverheid en de kiemkracht. De meeste monsters (93%) beantwoordden ook aan de minimum eisen zoals die gelden voor commercieel zaad. In Syrië voldeed iets meer dan de helft (54%) van de zaadmonsters aan de minimale kwaliteitseisen voor commercieel zaad. De fysische zuiverheid van het tarwezaad uit de informele sector (in bezit gehouden zaad of zaad afkomstig van andere boeren) was laag. De kiemkracht van het formele zaad was iets lager dan dat van zaad uit de informele sector. De kwaliteit van gerstzaad was het laagst wat betreft fysische kwaliteit; slechts 9% van de monsters voldeed aan de minimum kwaliteitseisen voor commercieel zaad. Aangezien de meeste monsters maar net niet voldeden aan de minimum kwaliteitseisen zou een geringe verlaging van de standaarden er al toe leiden dat alle monsters aan de voorwaarden voldeden. Er is evenwel een fundamentele zwakte in de fysische kwaliteit van zaad uit de informele sector: de traditionele schoningstechnieken blijken niet effectief in het verwijderen van het gros van de onzuiverheden. Vervuiling met onkruidzaden blijft een belangrijk probleem en de meeste zaadmonsters bleken niet aan de kwaliteitseisen zoals voorgeschreven door het nationale zaaizaadprogramma te voldoen. Het invoeren van op de boerderij toepasbare schoningstechnieken zou de kwaliteit kunnen verbeteren en zou de vervuiling, met name met schadelijke onkruiden, kunnen minimaliseren. Bovendien zou het nuttig zijn om aan te geven welke traditionele methodes er zijn voor het vaststellen van zaaizaadkwaliteit en hoe die kunnen worden verbeterd teneinde de zaaizaadkwaliteit op de boerderij te verbeteren.

In Hoofdstuk 5 staan de analyses vermeld van de gezondheidstoestand van de zaaizaadmonsters van tarwe en gerst. Er blijken significante verschillen te bestaan tussen regio's en zaaizaadbronnen, met name met betrekking tot bepaalde pathogenen in Ethiopië. Er blijken meer gezondheidsproblemen te bestaan in de natte gebieden en in de gebieden met een hoge regenval dan in de drogere gebieden. Dit hangt samen met de invloed van het milieu of het vóórkomen van ziekten. Over het gehele land werden er verschillende schimmelziekten aangetroffen in de zaadmonsters van zowel tarwe als gerst. Er werden verschillen aangetroffen in frequentie van aangetaste monsters en in de mate van aantasting. In Ethiopië bleken 84% van de monsters geïnfecteerd met *Drechslera sativum*, 31% met *Fusarium avenaceum*, 74% met *F. graminearum*, 13% met *F. nivale*, 52% met *F. poae* en 31% met *Septoria nodorum.* Vaak was er sprake van infectie met meerdere ziekteverwekkers. Het gemiddelde aantastingsniveau voor *Drechslera sativum* was 1.85%. *F. graminearum* was de belangrijkste *Fusarium* schimmel (74% van de monsters aangetast; gemiddelde aantasting 1.54%). *Septoria nodorum* gaf een lage frequentie van aantasting te zien (31%), terwijl ook de intensiteit van de aantasting gering was (0.5%). Infecties met steenbrand (*Tilletia* spp.), stuifbrand (*Ustilago tritici*) en de nematode *Anguina tritici* bleken sporadisch, maar werden wel in alle onderzochte gebieden aangetroffen. In het algemeen was de infectie-intensiteit laag (beneden de standaard) behalve voor steenbrand en voor stuifbrand. In Syrië bleek de gezondheidstoestand van tarwezaaizaad beter dan van gerstzaaizaad. Bij tarwe bleken 68% van de monsters vervuild met steenbrand (meer dan of gelijk aan 5 sporen per 400 zaden) en 13.6% van de monsters waren aangetast door stuifbrand, alle in een mate die hoger was dan toegestaan voor gezond zaaizaad in de West Azië en Noord Afrika (WANA) regio. Daarentegen waren 85% van de gerstzaadmonsters besmet met steenbrand (*Ustilago hordei*) en 83% met stuifbrand. Het gemiddelde percentage infectie van gerst door stuifbrand was 18%, waarbij al deze monsters uitstegen boven de normen voor gezond zaaizaad zoals die in de WANA regio gelden. Het is aannemelijk dat het wijdverspreide gebruik van zaaizaadontsmetting in tarwe heeft bijgedragen tot het grote verschil in zaaizaadkwaliteit tussen de beide gewassen.

Rassendiversiteit van tarwe en gerst op de boerderij

Syrië ligt zowel in het oorsprongsgebied als in het gebied van eerste domesticatie van tetraploïde tarwe en gerst. De Ethiopische hooglanden worden beschouwd als centra van diversiteit van tetraploïde tarwe en gerst en er is dan ook sprake van een grote rijkdom aan genetische variatie en diversiteit op het boerenbedrijf. In Hoofdstuk 6 werden spatiale diversiteit, temporele diversiteit, afstammingscoëfficiënten en agronomische en morfologische eigenschappen gebruikt om de diversiteit van tarwe- en gerstrassen die door boeren gebruikt werden te verklaren. De spatiale en temporele diversiteit van tarwe en gerst waren laag omdat slechts een beperkt aantal dominante rassen op grote schaal door een meerderheid van de boeren werden geteeld. De algemene acceptatie van moderne rassen leidde tot een totale vervanging van de traditionele durum tarwelandrassen in Syrië. In de traditionele durum tarwegebieden van Ethiopië was sprake van een uitbreiding van de broodtarweteelt ten koste van de durum teelt. Deze ontwikkeling vormt een bedreiging voor de bedrijfsgebonden diversiteit aan landrassen. Daarentegen werd slechts een enkel landras verbouwd in de belangrijkste gerstteeltgebieden. Dit toont aan hoe groot de veelzijdige genotypische plasticiteit van gerst is. De agronomische en fenotypische diversiteit die werd waargenomen in de monsters die waren verzameld bij de boeren (vooral onder de lokale durum landrassen) was enorm. Het is raadzaam om gewenste agronomische eigenschappen die aanwezig zijn in lokaal aangepaste landrassen in te bouwen in nieuwe veredelingslijnen – gebruikmakend van alternatieve strategieën voor gewasverbetering – om de rassenkeuze voor boeren te vergroten teneinde de effecten van genetische erosie tegen te gaan en tegelijkertijd de biodiversiteit op de boerderij te vergroten en waardevolle genetische bronnen te behouden.

Synthese

Hoofdstuk 7 bevat een synthese van de belangrijkste resultaten van de studies betreffende de zaaizaadsystemen van tarwe en gerst. Tevens worden alternatieven aangeduid voor de ontwikkeling van een efficiënte, competitieve en duurzame zaaizaadindustrie die reageert op de behoefte van boeren. Daarnaast worden suggesties gedaan voor alternatieve strategieën en benaderingen teneinde lokale zaaizaadsystemen verder te ontwikkelen of te verbeteren en deze te integreren met de formele sector. Een dergelijke strategie kan een levensvatbare optie zijn voor kleinschalige, hulpbron-arme boeren die moeten werken in marginale of moeilijk toegankelijke gebieden. Voor het ontwikkelen en overbrengen van technologieën naar boeren wordt de rol benadrukt van het beleid en van factoren op het gebied van de regelgeving voor technologie-ontwikkeling en van institutionele en sociaal-economische factoren. Om meer begrip te krijgen over het functioneren van het nationale zaaizaadsysteem zijn in deze studie formele overzichtsstudies, laboratorium analyses, veldproeven en secundaire informatiebronnen over zaaizaadvoorziening gebruikt.

Curriculum vitae

Zewdie Bishaw was born on 10 July 1956 on a family farm in Shoa, central Ethiopia. That association with farming triggered a childhood hobby and lifetime quest for understanding the intricacies of seeds and plants. After completing secondary education in Haile Maraim Mamo Secondary School at Debre Berhan, he joined the Science Faculty of Haile Sellassie I University (later Addis Ababa University) in 1973/74. He graduated with a BSc in Plant Sciences from Alemaya College of Agriculture in 1979 and was employed as academic staff by Addis Ababa University. In 1980, he joined the Ethiopian Seed Corporation (ESC) as an Agronomist and Seed Production Specialist. While at ESC he was sent to pursue a postgraduate degree in Edinburgh University, Scotland, from where he graduated with an MSc in Seed Technology in 1984. In Ethiopia, he worked as a national counterpart with international seed experts in World Bank, IDA, IFAD and FAO seed projects. Before joining the Seed Unit of the International Center for Agricultural Research in the Dry Areas in December 1989, he was the Head of the Seed Quality Control and Seed Processing Departments at the Ethiopian Seed Corporation. Apart from academic education, he attended some key courses/workshops including the Organization and Management of Seed Production and Processing held in Svalöf, Sweden. He also made study tours to the seed programmes in developed and developing countries in Europe, Africa and Asia, respectively. As Seed Technologist he made significant contributions to seed industry development at international levels across the countries of the Central and West Asia and North Africa (CWANA) region and beyond. Moreover, he also organized and attended many international conferences and technical meetings on issues related to seed industry development. He is currently working as Seed Systems Specialist and WANA Seed Network Coordinator with the Seed Unit of the International Center for Agricultural Research in the Dry Areas (ICARDA) based in Aleppo, Syria. He has strong interest in seed policy and regulation, informal seed systems, seed security and human resource development. The Seed Unit of ICARDA is conducting a series of seed systems studies in collaboration with national partners within the Center's mandate in Central Asia and the West Asia and North Africa region. The research described in this thesis was conducted within this framework in collaboration with the national seed programmes of Ethiopia (Ethiopian Seed Enterprise, Addis Ababa), Syria (General Organization for Seed Multiplacation, Aleppo), and ICARDA, Aleppo, Syria, for the fulfillment of the PhD degree under the 'sandwich' fellowship programme of Wageningen University, Wageningen, The Netherlands.