Harnessing Chickpea Value Chain for Nutrition Security and Commercialization of Smallholder Agriculture in Africa

30th January – 1st February 2014
Debre Zeit, Ethiopia

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Cover picture: Performance of high-yielding chickpea varieties on farmers' field under improved management.

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Forward

This proceedings on *'Harnessing Chickpea Value Chain for Nutrition Security and Commercialization of Smallholder Agriculture in Africa'* is the outcome of the First International Chickpea Workshop held in Debre Zeit, Ethiopia – the location which represents the major chickpea growing areas in the country as well as Center of Excellence for the national chickpea research. As it is the first of its kind in that scope, the First International Chickpea Workshop created a vibrant interaction among our global partners and individuals from the chickpea communities. In looking forward, it has been strongly believed that the workshop not only documents what has been achieved by the different interaction levels but also demonstrates that the NARS could play significant role in promoting science and knowledge to resolve agricultural bottlenecks of their own.

Accounting for ~2.5% of world and more than 55% of Africa's chickpea production, Ethiopia stands to the top 10 global chickpea producing countries while it is the 1st producer in Africa. Research advances in breeding and crop management practices over the four decades resulted in the development and release of proven technologies that brought a dramatic productivity increase from less than a tone to close to two tons in just a decade and half, comparable to many high input cereals, which has significantly improved the livelihoods of smallholder farmers. In addition, the crop has emerged as one of the major agricultural export commodities next to coffee, sesame and beans. As a result, Ethiopian chickpea has now been shifted from a simple precursor crop to a principal component of the cropping system that significantly contributed in leveraging poverty reduction.

In general, the chickpea R&D in Ethiopia has recently shown a remarkable progress, which is witnessed by the decision of the Ethiopian Government to award the National Science and Innovation Gold Medal in 2012 for discovery and promotion of chickpea and lentil technologies. I would like to use this opportunity to congratulate all stake-takers involved in chickpea R&D as the achievement was obtained due to concerted efforts of the entire chickpea community.

The reviewers and editors of the proceedings did an extraordinary job of undertaking the painstaking task of editing all the 21 manuscripts presented at the workshop. In addition, the proceedings include several roadmaps for future chickpea R&D which can be used as guidelines for researchers, development workers and policy makers.

Finally, I would like to extend my kind appreciation to sponsors of the workshop and the publication of the proceedings.

Asnake Fikre (PhD)
Director, Crop Research Directorate, and
Chair Organizing Committee of the workshop

Chapter I. General Papers

1. Chickpea Research and Development: Current Status and Future Perspectives in the Semi-arid Tropics

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Chickpea (Cicer arietinum L.) has emerged as the second most important food legume in the world. Research efforts in chickpea have mainly focused on improving the yield potential, resistance to abiotic and biotic stresses, and market preferred seed traits. Significant progress has been made in the development of short-duration varieties that are able to escape terminal drought, tolerance to reproductive stage heat stress and resistance to major diseases. Genomics-assisted breeding has been initiated, and is expected to improve the precision and efficiency of breeding programs. Recent efforts on increasing adoption of improved cultivars by enhancing awareness of farmers and availability of seed have helped in improving productivity of chickpea in some countries of arid-and semi-arid regions such as Ethiopia, Myanmar and Southern India. Limited efforts have been made to improve nutritional quality traits in chickpea, and the opportunities exist for enhancing protein and micronutrient contents. Potential also exists for use of chickpea in preparation of functional foods, nutraceuticals, dietary supplements and cosmetics. Thus, there is a need to bridge the demand-supply gap by increasing productivity and at the same time developing varieties meeting the requirements of the processors for value-added products.

Introduction

Chickpea (*Cicer arietinum* L.) is known in various parts of the country by different names such as *chana*, *gram*, *chhola* and Bengal *gram*. It is the second most important pulse crop in the world, after dry beans (*Phaseolus vulgaris* L.). Chickpea provides 2-3 times more protein than many cereals, constituting major component of the poor peoples' diet of the arid and semi-arid regions of the world. Chickpea provide about 20-24% protein, 4-10% fat, 52-71% carbohydrate, 10-23% fiber and minerals and vitamins. Among essential amino acids lysine, methionine, threonine, valine, isolucine and leucine are major components of seed protein. Chickpea contains considerable amount of vitamins such as B_1 and B_2, ascorbic acid (vitamin C) and niacin also. Thus, chickpea plays an important role in human nutrition. Being a major source of several nutrients for the rainfed farmers, limited efforts have been made to improve nutritional quality traits of chickpea, as the farmers do not get price premium based on nutritional quality of chickpea. Opportunities exist for enhancing protein and micronutrient contents, and reducing flatulence-inducing oligosaccharides.

Chickpea fixes atmospheric nitrogen (about 140 kg/ha) through bacteria (rhizobium) present in their roots, which in turn improves the soil fertility. Thus, the crops sown succeeding the chickpea are also benefited. Due to the tap root system, they open up soil and the extensive leaf drop increases the organic matter in the soil. This crop also has the inherent quality to mine the soil moisture from lower strata of the soil; therefore, they are considerably moisture-stress tolerant. In spite of the variable uses of chickpea in human diet and its importance in maintaining the soil health, the increment in production could not maintain the pace with population growth, which has been increased at much higher rate. Even though the chickpea has been considered a drought tolerant crop, the existing genetic yield potential of chickpea is constrained both by biotic and abiotic stresses. Further, the traditional bushy genotypes are not suitable for mechanical harvesting. Efforts are been made to develop erect, mid-tall plant types bearing effective fruiting branches at a height suitable for machine harvest.

The international trade of chickpea has also increased over time and currently more than 140 countries import chickpea. On an average, 10% of the total chickpea produced enters the international market. Though kabuli type chickpea commands higher price than the desi type, about 80% of the total production and international trade of chickpea is for the desi type. India is the largest producer and consumer of chickpea and also the largest importer till 2013. However, India was a major exporter of chickpea in recent years and its export exceeded import in 2007, 2010 and 2011. The global trends of chickpea area, production and seed yields over the past 5 decades showed a promising improvement (Fig 1). Area of cultivation was varied between 10-12 million hectares, however the average area in the past five years (2008-12) was the highest (12 m ha). Production was very low during 1963-67 (6.25m tons) and gradual increment was observed over the years, and in 2008-2012 chickpea production recorded 10.7 m tons. Similarly, average seed yields of chickpea were very low (552 kg per ha) during 1960s, and over the 50 years, 60% yield improvement was observed.

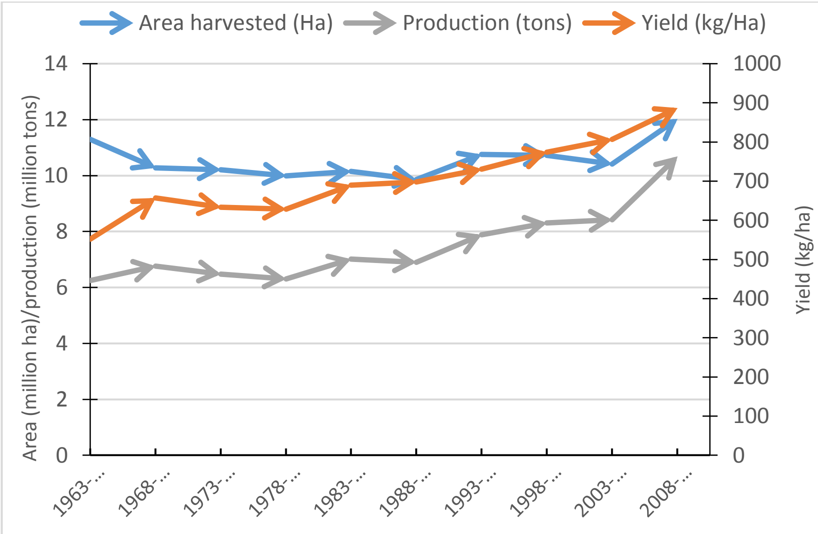

Figure 1: Trends in area, production and yield of chickpea in the world over the past 50 years (1963-2012).

Being the largest producer and consumer of chickpea, the area, production and yields of India directly influence the global chickpea trends. Interestingly the average chickpea area during 2008-12 (8.2 m ha) is almost same as it was in 1963-67 (8.6 m ha), and the area varied between 6-8 m ha over the past 50 years. Similarly production was fluctuated between 4-6 m tons from 1963 to 2007, but recently in the past 5 years (2008-12) the production crossed 7m tons (Fig. 2). The average seed yields showed a progressive increase of 63% over 50 years since 1963-67 (540 kg/ha).

The variation in productivity has clearly established that there is scope for improvement in average yield through increase in yield potential of the varieties and through better crop management technologies. These positive trends resulted from several factors, primarily due to development of early-maturing improved varieties suitable to different growing conditions combined with drought and heat tolerance, and diseases and pest resistance.

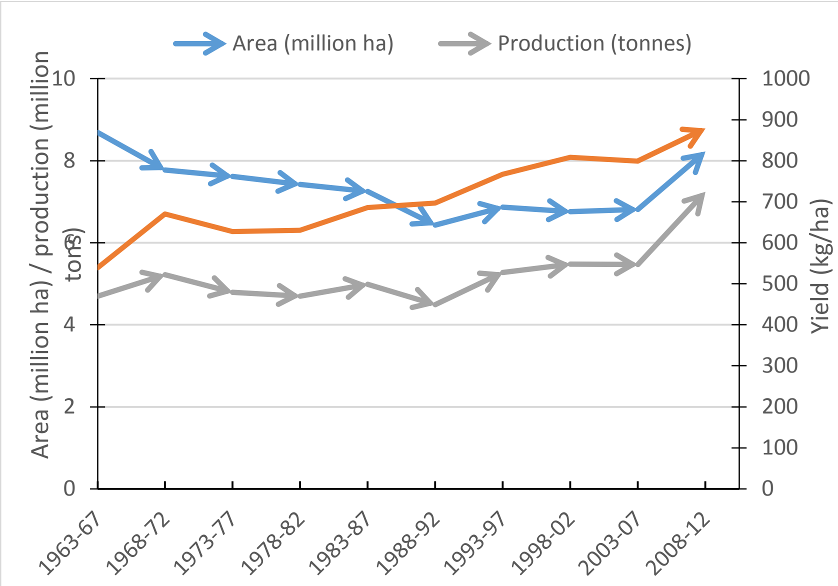

Fig 2: Trends in area, production and yield of chickpea in India over the past 50 years (1963-2012).

Further, chickpea cultivation was severely declined in some traditional chickpea growing countries like Bangladesh, Mexico, Morocco, Spain and Turkey (Fig 3). Among these countries, Turkey had lost highest chickpea growing area of 0.38 m ha (46%) since 1988-92, and followed by Spain (0.2 m ha), Bangladesh (0.13 m ha) and Mexico (0.13 m ha) from the year of highest area recorded in respective countries. Even though Canada has started cultivating Chickpea since 1992, the area reached 0.21 m ha during 1998-02.Since then declining trend was observed and reached to an average area of 57,000 ha in 2008-12. Similarly, Bangladesh had lost 94% of its chickpea growing area since 1973-77. These countries (Fig 3) have recorded a reduction of about 1.0 m ha chickpea area till now (2008-12) from the year of maximum area cultivated.

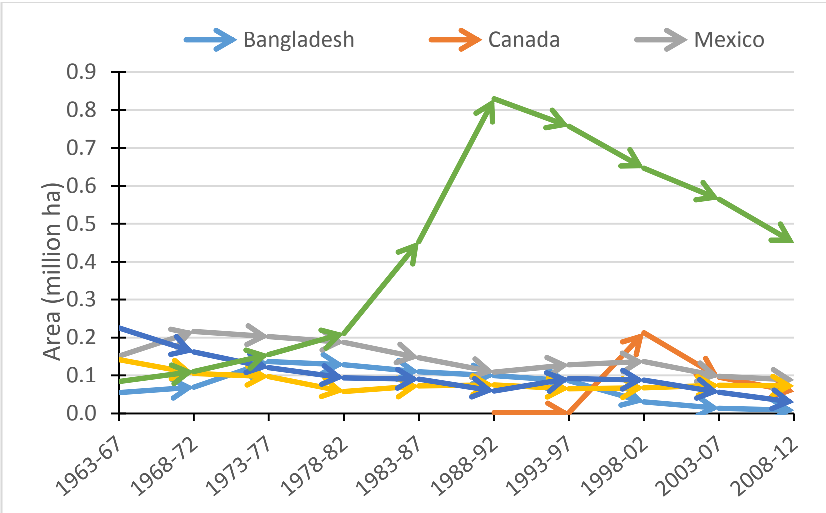

Fig 3: Decreasing trend of chickpea area cultivation in few major countries

Even though cultivation of chickpea recorded a downward trend in some traditional countries, few countries like Australia, Ethiopia and USA have emerged as potential areas of chickpea cultivation and expansion (Fig 4). Myanmar has a long history of growing chickpea since 1960s, the average chickpea area was 0.14 m ha until 2000, and since then the average area increased rapidly to 0.32 m ha during 2008-12. Australia has started cultivating chickpea in 1980, since then area continuously increased over the years and reached to 0.46 m ha during 2008-12. Similarly, Ethiopia and USA also initiated growing chickpea from mid 1990s and reached to 0.22 and 0.05 m ha during 2008-

12, respectively. Together these four countries added an extra 1.0 m ha to the total chickpea area till 2012 (Fig 4).

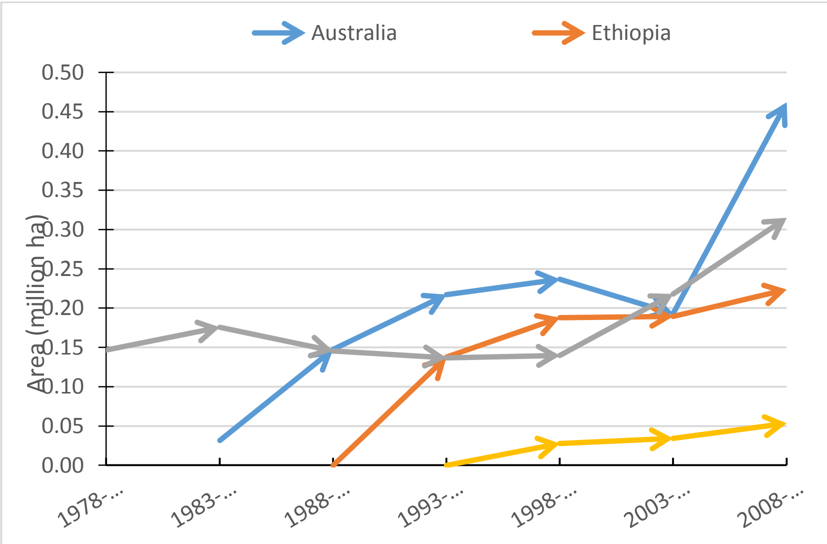

Fig.4: Increasing trend of chickpea area cultivation in few major countries

Chickpea import and export

India is the largest producer (69%) of chickpea followed by Pakistan (5%), Turkey (5%), Australia (5%), Myanmar (4%), Ethiopia (3%), Iran (2%) and Mexico (1%) together contribute 94% production in the world (FAOSTAT 2012). In spite of largest producer of chickpea, India has been the largest importer with 19% in 2012 followed by Pakistan (14%), Bangladesh (13%), UAE (7%), Algeria (5%), Spain (5%), UK (3%) and Jordon (3%). Three South Asian countries India, Pakistan and Bangladesh account for 46% of worlds imports. This indicates that South Asia produces 74% of world production, but it is still deficit in chickpea requirement. On the other hand, Australia (37%) came out to be the largest exporter followed by India

(13%), Mexico (11%), Turkey (7%), Canada (6%), Myanmar (4%), Ethiopia (4%) and USA (3%).

Constraints of chickpea production

The major constraints for slow growth rate of chickpea production and productivity are categorized as follows:

Abiotic stresses: more than 70% area of chickpea is generally cultivated in post rainy season under residual moisture situation, which are characterized by poor soil fertility and low moisture retention capacity as a result crop often faces moisture stress at various growth stages. The rainfall is not only low but also highly erratic and uncertain in rainfed areas. Among the major abiotic stresses affecting chickpea production are drought, low and high temperature, salinity and acidic soils as well as deficiencies of micronutrients.

Biotic stresses: chickpea is prone to high incidence of disease and insect pests. Among diseases, fusarium wilt, root rots, Ascochyta blight and botrytis gray mould are most important. The most dreaded insect pest is gram pod borer, (*Helicoverpa armigera*). The losses may be high (up to 70%) in certain areas in favorable seasons. Integrated Pest Management modules are the best options available to keep this pest under control. Chemical or bio-pesticide for major diseases and insect pests have been evolved and followed by some farmers. The root knot and cyst nematodes are also posing serious threat to chickpea cultivation under sandy loam soil/ light soils.

Socio-economic constraints: similar to other pulses, chickpea has secondary status in the farming system. Thus, farmers grow chickpea on marginal and sub-marginal lands mainly for their own consumption. During the last decade there has been a shift of chickpea area to wheat or even to vegetable crops (like in the case of Northern India nearly 1 m ha chickpea area was replaced by wheat and other commercial crops). Poor crop management practices like untimely sowing, lack of irrigation and weeding, resulting in inadequate plant population, heavy infestation by weeds etc., are other major reasons for poor yield of chickpea. However, with improved varieties and better crop management, yields can be enhanced up to 3.5 t/ ha in semi-arid tropics.

Poor storage facilities: lack of good on-farm storage facilities and the vulnerability of chickpea to stored grain pest results in considerable losses. As most of the farmers use their own saved seed, the quality of seed is not up to the mark in most of the cases. Sowing of pest-damaged seeds and sowing under inadequate moisture conditions are the common reasons behind poor plant population of chickpea at farmers' field.

Lack of policy support: the minimum support price (MSP) announced by the Government is often not commensurate with the cost of production and risks associated with the cultivation of this crop. Even some time MSP is lower than the market prices, which discourage the farmers to grow chickpea. Due to the lack of organized marketing channels and highly fluctuating market prices of this crop make it difficult for farmers to grow more chickpea.

Options for increasing chickpea production

Bringing additional area under chickpea production: vast areas of rice-fallows (about 14 million ha) available in eastern India (Jharkhand, Bihar, Chhattisgarh, Odisha and West Bengal), Bangladesh and Myanmar offer opportunities for expanding chickpea area. Substantial rice-fallow areas are also available in several countries of sub-Saharan Africa. Some of the earlier experiments clearly demonstrated that chickpea is a very best suitable pulse crop for rice-fallows provided suitable varieties and technologies for crop establishment are available. The most important traits required in chickpea varieties for rice-fallows include early to extra-early maturity and tolerance to reproductive stage heat stress.

Enhancing yield by reducing yield gap: under well managed conditions by following proper integrated crop management practices farmers are realizing up to 3.5 t/ha. Chickpea has a potential of yielding 5 tons per hectare (Saxena and Johansen 1988), hence there is a possibility of doubling the average yield of chickpea under well managed crop conditions. Yield is a complex trait controlled by several genetic and environmental factors. Utilizing molecular technologies along with the conventional breeding programs will enhance the selection efficiency and also improves the precision in identifying superior genotypes. Development of location-specific integrated approaches would be needed to bridge the yield gap of chickpea grown in the target regions.

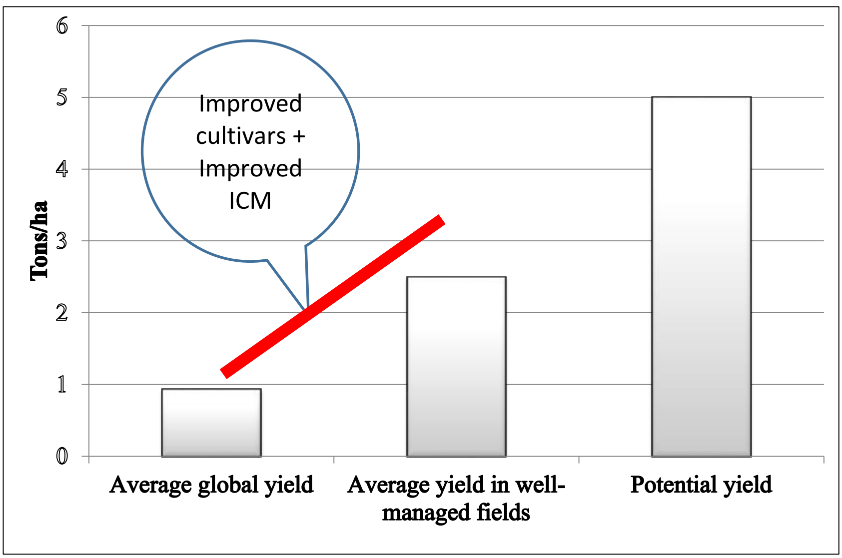

Fig. 5: Yeild (t/ha) of chickpea under different growing conditions

Global priorities in chickpea improvement

Terminal drought: drought stress during the reproductive phase, with increasing severity towards the end of the crop season, is the major abiotic stress of chickpea in arid and semi-arid regions of the world as the crop is generally grown under receding soil moisture conditions with increasing atmospheric temperatures. Early maturity is an important trait for escaping these terminal stresses. Several traits have been used for selection criterion for improving drought tolerance in chickpea. At ICRISAT, breeding lines with enhanced drought tolerance have been developed through marker-assisted breeding.

Reproductive stage heat tolerance: being a cool season crop, chickpea incurs heavy yield losses when exposed to high temperatures ($\geq 35^{0}$C) at the reproductive stage. Many studies on climate change have indicated that the average surface temperatures are expected to raise by 2-5^{o}C, posing a major threat to crop production (including legumes) and agricultural systems worldwide, especially in the semi-arid tropics (IPCC 2007; Hall 2001). Moreover, increase in temperature will have more adverse effects especially on cool-season crops (e.g. chickpea) than the rainy-season crops (Kumar 2006). Efficient field screening and rapid generation advancement methods have been developed for breeding heat tolerant chickpea varieties (Gaur *et al* 2007). These varieties are needed for improving chickpea yields in warm season environments and late sown conditions, expansion of its cultivation to new niches and improving its resilience to the impacts of climate change.

Salinity tolerance: like drought tolerance, salinity tolerance appears to be complex and there are many traits that directly or indirectly contribute to tolerance (Flowers *et al* 2009). Limited efforts have been made in breeding for salinity tolerance in chickpea. Conventional breeding approaches have so far been used where grain yield under salinity was used as criterion for salinity tolerance. One salinity tolerant cultivar of desi type, namely Karnal Chana 1 (CSG 8963) has been released for northwestern parts of India. This variety can be grown in saline soils with 4-6 dS/m EC.

Early maturity: genotypic discrimination in terms of flowering and maturity are apparent in warmer short-season environments than in cooler long-duration environments (Saxena, 1984). Several early flowering germplasm accessions of desi and kabuli types have been identified, and most of these originated from India, Ethiopia, Mexico and Iran (Pundir et al. 1988; Upadhyaya et al. 2007). These are expected to be early maturing, and escape end-of-season terminal drought and heat stresses in tropical, sub-tropical (e.g. South Asian countries) and Mediterranean environments (e.g. Australia). Early maturing lines also escape from end-of-season low temperature stress in the temperate environments (e.g. Canada). In the past decade most of the varieties developed at ICRISAT, Patancheru are early maturing well adapted to short duration environments of Southern India, Myanmar, Ethiopia, Kenya and parts of Tanzania. These varieties fit well in a short window (80-90 d) of cropping season under different cropping systems. Cropping intensity and crop diversification opportunities will enhance by introduction of early maturing chickpea varieties, especially under rainfed areas.

Resistance to fusarium wilt: Fusarium wilt (FW), caused by *Fusarium oxysporum* f. sp. *ciceri*, is the most common problem seen in the chickpea growing areas in the world. Seven races of the pathogen are known and race 1 is the most common. Various resistant sources available in the germplasm have been used for developing wilt resistant varieties in chickpea.

Resistance to foliar diseases: Ascochyta blight (AB) caused by *Ascochyta rabiei* (Pass.) Labr., and Botrytis gray mold

(BGM) are the two most devastating foliar diseases which appears in many chickpea growing countries.**A**B occurs mainly in areas where cool and humid weather prevails during the crop season. The pathogen is known to be highly variable, but a standard set of chickpea differentials has not been established that can help in identification of races. Several sources of moderate resistance have been identified (Singh and Reddy 1993). Progress on breeding for resistance to ascochyta blight has been recently reviewed (Malhotra *et al*. 2003).

BGM, caused by *Botrytis cinerea* Pres., is prevalent particularly in northeastern regions of India, parts of Nepal and Bangladesh where high humidity and mild temperatures prevail during crop growth, particularly at flowering time. The BGM pathogen appears to be highly variable. The genotypes with erect plant type that do not allow buildup of humidity in the plant canopy (e.g. ICCL 87322 and ICCV 88510) are less affected by the disease (Haware and McDonald 1993).

Resistance to Helicoverpa: pod borer (*Helicoverpa armigera* Hubner) is the most important pest of chickpea worldwide. Itis highly polyphagous pest and can feed on various plant parts such as leaves, tender shoots, flower buds, and immature seeds. Breeding for resistance to pod borer remains a challenge due to absence of sources of good level of resistance. Techniques for germplasm screening are now available and many genotypes that show low to moderate level of resistance have been identified (Sharma *et al*. 2003)

Resistance to dry root rot: Dry root rot (DRR) has emerged as a highly devastating root disease of chickpea in central and southern India. So far there is only a moderate level of resistance available in the cultivated germplasm. There is a need to enhance efforts on identifying sources of resistance to DRR in the germplasm of cultivated and wild species and combine resistance to DRR in the varieties developed for central and southern India.

Mechanical harvesting and herbicide tolerance: chickpea farmers in developing countries are gradually enhancing mechanization of farm operations for improving efficiency and reducing cost of cultivation. The farmers are demanding chickpea cultivars which can be directly harvested by combine harvesters. The current semi-spreading chickpea cultivars are not suited to mechanical harvesting because the plant height is not adequate and the branches are close to ground. Development of chickpea cultivars with 30 to 40% more height than the existing cultivars (>45 cm) and semi-erect to erect growth habit will make the cultivars suited to mechanical harvesting. Another trait that can save labour and production cost is herbicide tolerance. Chickpea is sensitive to herbicides and manual weeding is currently the only option for weed control. Development of herbicide-tolerant cultivars can help in controlling weeds economically and also facilitate no-till methods, which help preserve topsoil.

Market preference for grain size: shape, color and size of the grain are the most important traits that determine market price in chickpea. The desi seed is usually consumed as split (dhal) and flour (besan); and kabuli types are generally used in whole grain form. Therefore, the preferred seed traits differ for the two types based on their different forms of consumption. Medium sized seed (16-22 g per 100 seeds) usually with golden yellow seed coat color desi types are mostly preferred. On the other hand, extra-large kabuli chickpea (>55 g per 100 seeds) fetches premium price in domestic and international market. Considering the demand for extra-large kabuli varieties in India and European countries, breeding lines developed at ICRISAT has led to the release of some extra-large kabuli cultivars.

Nutritional enrichment: chickpea is the highest consumed pulse crop in South Asia. In addition to having high protein (20-24%), chickpea is rich in fibre and minerals (phosphorus, calcium, magnesium, iron and zinc). Though wide variation has been observed for protein content (14-30%) in chickpea germplasm, limited efforts have been made to breed for high protein varieties. The high protein chickpea cultivars will improve protein availability to the people by 20 to 25% from the same amount of chickpea consumed.

Adoption and impacts of improved chickpea cultivars

There has been a remarkable increase in production of chickpea in some regions/countries during the past decade. This article describes success stories of enhancing chickpea production in Andhra Pradesh state of India, Myanmar, Ethiopia and Australia. Some of the lessons learned from these success stories can help in enhancing chickpea production in other areas.

Andhra Pradesh state of India

Earlier it was considered that chickpea is not well adapted to this area. Until 1988/89, area under chickpea cultivation in Andhra Pradesh was less than 80,000 ha and yield was less than 0.5 t/ha. The adoption of short-duration, high yielding and disease resistant varieties has brought a revolution in chickpea production in the area during the past decade. Now, area and productivity has increased to more than 600,000 ha and 1.3 t/ha respectively (Fig. 6). About 90% of the chickpea area in Andhra Pradesh is cultivated with improved varieties (e.g. JG 11, KAK 2, JAKI 9218 and Vihar) developed through partnership of ICRISAT and Indian NARS. The desi chickpea variety JG 11, is presently the most popular variety in Andhra Pradesh and grown in over 70% of the chickpea area.

Chickpea cultivation has gone through a transformation from subsistence farming to commercial cultivation in Andhra Pradesh. In addition to food and nutritional security and soil fertility improvement, chickpea is considered as an income generator.

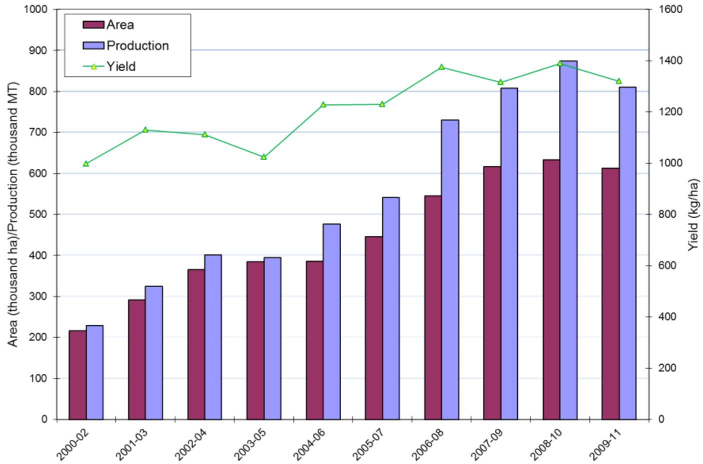

Fig. 6: Trends in area, production and yield of chickpea in Andhra Pradesh (3-year moving averages from 2000 to 2011)

The farmers find chickpea crop very remunerating because of good market price and reduced labor requirement due to increased mechanization. The grain storage facilities are available to farmers in Andhra Pradesh at the local level and at affordable tariff, which help them in avoiding distress selling at the harvest and getting better price of their produce. Andhra Pradesh once considered a low productive state for chickpea due to warm and short-season environments now has the highest yield levels in India.

Myanmar

Chickpea is an important legume in Myanmar, not only for local consumption but also for export earnings. Major chickpea-producing area is the central dry zone which includes Sagaing (46%), Mandalay (26%) and Magway (24%) regions. Chickpea is grown under residual soil moisture in both low-land and upland conditions. In lowland areas, it is grown as a relay or sequential crop after rice, while in upland areas it is grown mostly on fertile soil with a good water holding capacity after sesame, maize, mugbean or fallow. In upland area of Sagaing region, kabuli chickpea area is high, while desi type is dominant in rice-chickpea sequential cropping system. Chickpea is sometimes intercropped with sunflower, where sunflower is used as a trap crop for reducing pod borer infestation.

Eight improved varieties of chickpea, five desi types (Yezin 1, Yezin 2, Yezin 4, Yezin 6 and Shwenilonegyi) and three kabuli types (Yezin 3, Yezin 5 and Yezin 8), have been released in Myanmar through Department of Agricultural Research (DAR). These varieties have high yield potential, short to medium duration, wide adaptation and export quality grain. All these varieties, except Shwenilonegyi, were developed from the breeding materials supplied by ICRISAT. Adoption of improved chickpea varieties was rapid during the past decade and now over 85% of the chickpea area is under these improved varieties. This led to an impressive growth in area and production of chickpea (Fig. 7).

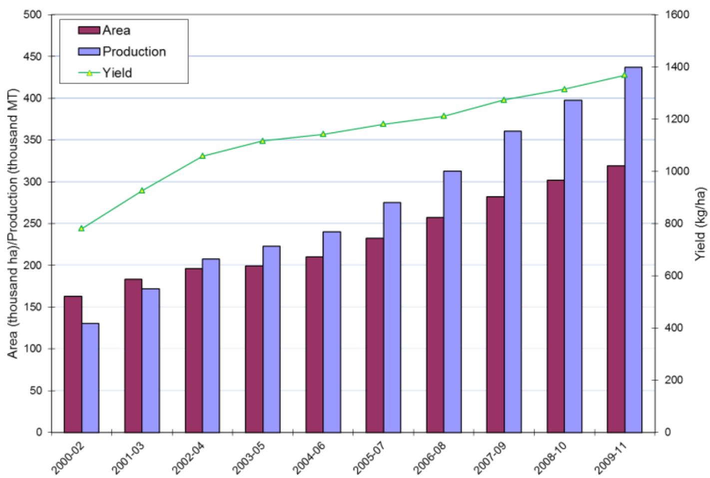

Fig. 7: Trends in area, production and yield of chickpea in Myanmar (3-year moving averages from 2000 to 2011)

During 2001 to 2011, the chickpea production has increased four-fold (117,000 to 467,000 tons) due to two-fold increase in area (164,000 ha to 332,000 ha) and two-fold increase in the productivity (0.71 to 1.40 t/ha). More than 50% of the chickpea area in Myanmar is under kabuli type chickpea which fetches higher price than the desi chickpea in international markets. The extra-early kabuli variety Yezin 3 (ICCV 2) was the most popular variety of Myanmar grown in about 49% area during 2011/12. The second most adopted variety was the heat tolerant variety Yezin 6 (ICCV 92944) covering 18% of the area. Myanmar re-started export of chickpea in 2001 after almost no export of chickpea for two decades, and the average export has been about 50,000 tons (valued at US$22 millions) per year during 2001-2010.

Ethiopia

Ethiopia is the largest producer, consumer and exporter of chickpea in Africa. In 2011, this country has achieved a remarkable growth, and currently among the top ten countries for area (0.23 m ha), production (0.40 m tons), productivity (1730 kg/ha) and export (49,500 tons) of chickpea. Chickpea is mainly grown in four states (Amhara, Oromia, SNNP and Tigry), but 93% of the area is in Amhara (52.5 %) and Oromia (40.5%) states. Chickpea is largely grown rainfed on residual soil moisture. The advantages recognized by farmers in chickpea cultivation include: (a) low input requirements and production cost compared to other crops, (b) low requirement of fertilizers, (c) improvement and sustainability of soil fertility, (d) growing chickpea demand due to increasing domestic consumption and export, and (e) increasing market prices.

The Ethiopian chickpea breeding program has had a strong collaboration with CGIAR centers, namely ICRISAT and ICARDA. Twenty-two improved varieties of chickpea have been released in Ethiopia. Twelve of these varieties were released from the breeding materials supplied by ICRISAT and five from the breeding material supplied by ICARDA. Extensive efforts have been made in promoting the improved cultivars and associated crop production technologies to farmers through participatory evaluation approaches. The adoption of improvedvarieties and technologies has been high in the recent years, which led to a remarkable increase in chickpea production. The major contributor to this increase in production is the improvement in productivity than the expansion in area (Fig. 8).

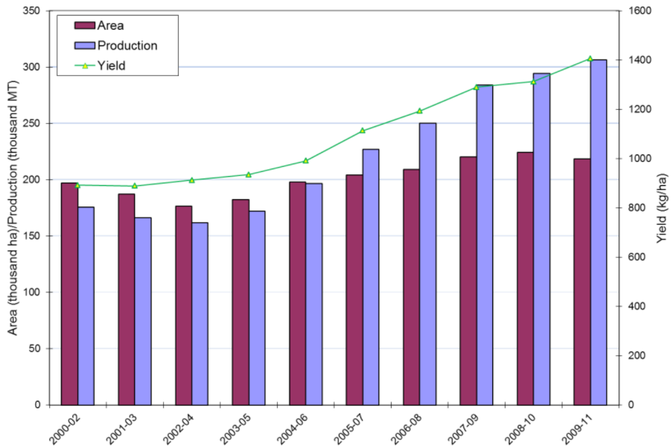

Fig. 8: Trends in area, production and yield of chickpea in Ethiopia (3-year moving averages from 2000 to 2011)

The kabuli types had negligible share in chickpea area two decades ago, but now occupy about one-third of the total chickpea area. Higher price of kabuli chickpea in comparison to desi type in international market has attracted farmers to enhance area under kabuli chickpea. In a recent development, PepsiCo (best known for Pepsi cola and Lays potato chips) in partnership with the U.S. Agency for International Development (USAID) has launched a project in 2011 to boost chickpea production in Ethiopia. This is aimed at developing local businesses that use chickpea and, at the same time, secure a supply of chickpea for Sabra hummus, which PepsiCo owns together with Israel's Strauss Group Ltd. In partnership with the World Food Programme, PepsiCo will also develop a chickpea-based food supplement to target malnourished children in Ethiopia. These initiatives are further expected to enhance chickpea production to help Ethiopian farmers.

Australia

Australia started chickpea cultivation in 1980‘s. The chickpea area increased from 3,000 ha in 1983 to 309,000 ha in 1998. Chickpea was an attractive crop to farmers because they needed a legume break-crop for heavy land, and the high prices for chickpea in international market. Unfortunately, the epidemics of ascochyta disease during 1999 and 2000 changed these scenarios. Overnight chickpea became an expensive, risky and difficult crop to produce. Farmers started abandoning chickpea cultivation and the area declined to 105,000 ha in 2005.

The vigorous breeding efforts led to development of several varieties moderately resistant to ascochyta blight and rapid adoption of these varieties revived the chickpea industry. There has been a remarkable increase in area and production of chickpea in Australia during recent years (Fig. 9). There was a 6-fold increase in area (from 105,000 ha to 653,000 ha) and 4-fold increase in production (123,000 MT to 513,000 MT) during 2005-2011.

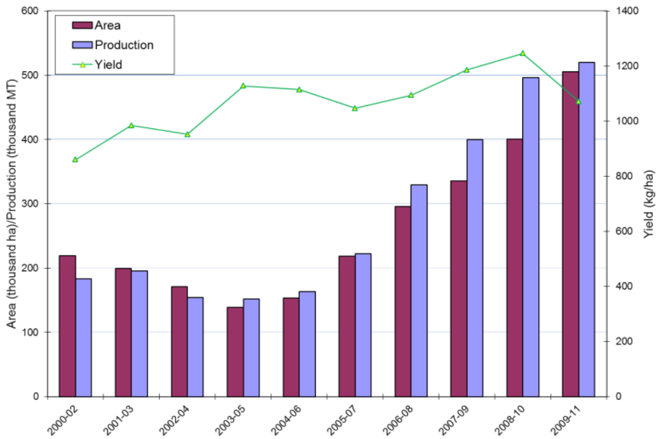

Fig. 9: Trends in area, production and yield of chickpea in Australia (3-year moving averages from 2000 to 2011)

Lessons learned from success stories

It is evident from all success stories that the adoption of improved cultivars with associated integrated crop management practices is the key in increasing chickpea production. The adoption of improved cultivars and crop production technologies continue to remain low in most of the developing countries including several states of India. An improved variety may not be adopted by farmers, if the farmers are not aware of that variety or its benefits and/or the seed of that variety is not available at the local level. Thus, concerted efforts are needed for knowledge empowerment of farmers about the improved cultivars and production practices and enhancing availability of quality seed at the local level by strengthening formal and informal seed systems.

Seed systems

Strengthening the chickpea seed system in developing countries is instrumental in catalyzing the scaling up of foundation and certified seeds, seed delivery testing models, and raising farmer awareness about improved cultivars. The economics of legumes seed production is not attractive enough for private seed sector due to their large seed size resulting in high volume and consequently high costs in transportation and storage. Thus, chickpea seed production was largely dependent and reliable on public seed sector and informal seed systems (seed production by individual farmers and farmers' groups/societies) in countries like India, Bangladesh and Myanmar.

Engaging with a range of seed producers will lead to good impacts and lay strong foundation for seed systems in chickpea. The training of seed producers and the increased availability of basic (foundation) seed through public partners and government research organizations is critical to increase the seed production of chickpea in developing countries. Establishing government policy for country seed road maps will provides a good planning tool for country research teams. Distribution of small seed packs of improved cultivars will increase seed access to millions of farmers particularly women. Knowledge empowerment of farmers through electronic and print media, organizing field days, farmers' fairs, and conducting training programs, demonstrations, and farmer-participatory varietal selection trials (FPVS) will help strengthen the local seed systems and enhance the adaption of new improved cultivars. For sustaining seed production, informal seed systems, community based as well as individual farmer based are instrumental to meet seed requirements and spread of new varieties.

Conclusion

It is hoped that the increasing emphasis on changing chickpea cultivation from subsistence to commercial farming by adoption of improved cultivars and production practices with strong support from donor community and the governmental agencies, increasing global demand and attractive price will further enhance area and production of chickpea in the coming years. Current efforts on development of varieties with enhanced heat tolerance, herbicide tolerance and suitability to mechanical harvesting are expected to have high impacts on chickpea production in the future.

References

FAOSTAT (2012) http://www.fao.org/statistics/en/

Flowers TJ, Gaur PM, Gowda CLL, Krishnamurthy L, Srinivasan S, Siddique KHM, Turner NC, Vadez V, Varshney RK, Colmer TD (2010) Salt sensitivity in chickpea. *Plant Cell Environment*, **33**:490–509.

Gaur PM, Srinivasan S, Gowda CLL and Rao BV (2007b) Rapid generation advancement in chickpea. *Journal of SAT Agricultural Research*,**3**(1). Available online at http://www.icrisat.org/journal/

Haware MP and McDonald D (1993) Botrytis gray mold of chickpea. In: *Recent Advances in Research on Botrytis Gray Mold of Chickpea*: (Eds., Haware MP, Gowda CLL and McDonald D) *Summary Proc. of the Second Working Group Meeting*, ICRISAT, Patancheru, India, pp 3-6.

Hall AE (2001) Crop responses to environment.*CRC Press LLC*, Boca Raton, Florida, pp 197–208.

IPCC (2007) Climate change 2007. The physical science basis, in Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (Eds., Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M and Miller HL), Geneva: IPCC Secretariat.

Kumar S. 2006. Climate change and crop breeding objectives in the twenty first century.*Current Science*,**90**:1053-1054.

Malhotra RS, Baum M, Udupa SM, Bayaa B, Kabbabe S and Khalaf G (2003) Ascochyta blight resistance in chickpea: Present status and future prospects. In: *Chickpea Research for the Millennium*,(Eds., Sharma *et al*). *Proc. Intl. Chickpea Conf.* 20-22 Jan 2003, Raipur, India, Indira Gandhi Agril. Univ., Raipur, India, pp 108-117.

Pundir RPS, Reddy KN and Mangesha MH (1988) ICRISAT chickpea germplasm catalogue: evaluation and analysis, ICRISAT, Patancheru, India.

Sharma HC, Gowda CLL, Sharma KK, Gaur PM, Mallikarjuna N, Buhariwalla HK, and Crouch JH (2003) Host plant resistance to pod borer, *Helicoverpaarmigera* in chickpea. In: *Chickpea Research for the* Millennium (Eds., Sharma *et al*). *Proc. Intl. Chickpea Conf.* 20-22 Jan 2003, Raipur, India, Indira Gandhi Agril. Univ., Raipur, India, pp 118-137.

Saxena NP and Johansen C (1988) Realizing yield potential in chickpea and physiological considerations for further genetic improvement. In: *Proc. of the International Congress of Plant Physiology* (Eds. Sinha *et al*), Feb 15-20 1988, New Delhi, India, pp 279-288.

Saxena, NP (1984) Chickpea. In: The Physiology of Tropical Field Crops. Goldsworthy, PR and Fisher, NM (eds.) Wiley, Chichester, UK, pp. 419–452.

Singh KB and Reddy MV (1993) Resistance to six races of Ascochyta rabiei in the world germplasm collection of chickpea. *Crop Science* **33**:186-189.

Upadhyaya HD, Salimath PM, Gowda CLL and Sube Singh (2007) New early-maturing germplasm lines for utilization in chickpea improvement. *Euphytica,* **157**:195–208.

2. Progresses of chickpea research and development in Ethiopia

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Research advances in chickpea breeding, crop management practices over the last four decades resulted in the development and release of technologies that brought a significant change in the productivity, adaptability and production; thereby improving the livelihood of the small farmers. The national chickpea improvement program in its discourse of endeavor to improve the productivity, quality and adaptability evaluated over 15000 genetic materials and came up with some 20 varieties. Out of these genetic materials, 80% were contributions of the global partnership, particularly ICRISAT and ICARDA. The technology development is substantiated by a consistent 1.5 -2.0% genetic gains on annual basis and more than double yield advantages over the decades. Chickpea in Ethiopia is now shifted from a simple precursor crop to a principal component of the cropping system that significantly contributed to poverty reduction. Business opportunities through organized informal seed system with value of more than 2000 USD/ha is worth mentioning of the income generation power the crop. The current technology package scaling up/out program by different partners at the national level resulted in a dramatic productivity change from less than a tone to 1.9 t/ha in just a decade, which is double of the global chickpea average yield. Case studies showed that farmers who managed to properly apply the best management obtained up to 5 t /ha. Now improved chickpea technologies estimated to accounts for about 40% of chickpea production. By its steady gains the chickpea has maintained a revolution as cited "chickpea green revolution happened in Ethiopia". The gender responsiveness of the gains in the crop is also something special attribute. The future of chickpea is bright that intensification and extensification have still long way to go, and that Ethiopia will take major contributor from the present top ten to top 5 and from 2% present market to more than 10% share keeping the progress.

Key words: research-development, market, germplasm, variety

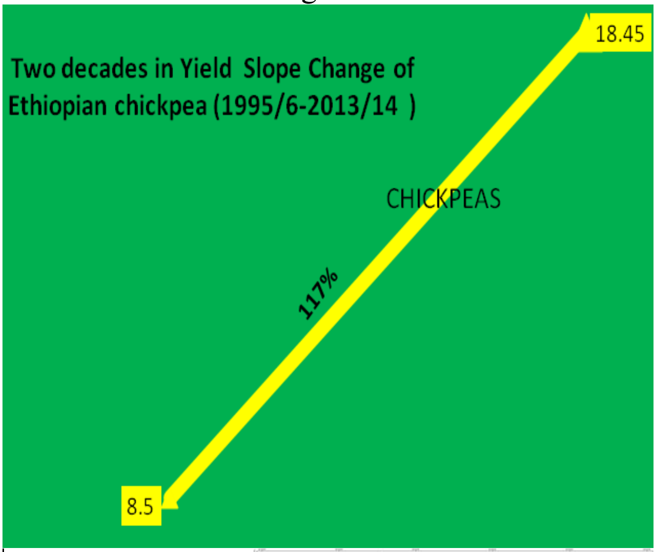
Introduction

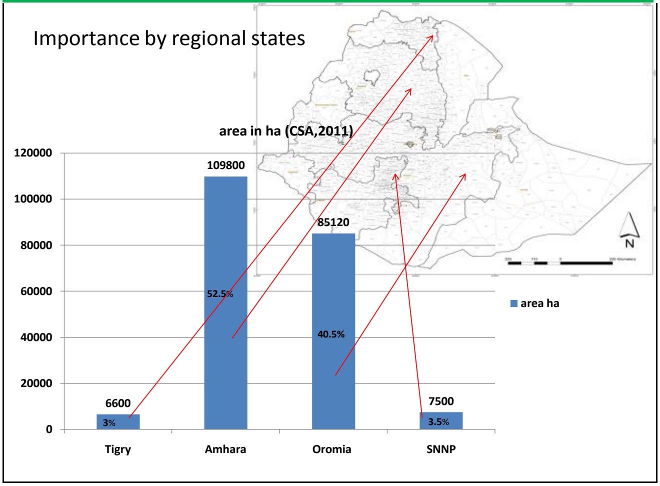
Chickpea is among important commodities accounting for more than 15% of Ethiopian legumes with an area of some 239000ha and with about one million households engaged in its production (CSA, 2014). It is less labor intensive sector compared to many field crops (Minale *et al*., 2009) as its production is towards the end of the cropping season. Chickpea is adapted to cooler agro-ecological environments and vertisols, which are located in the central highlands of Ethiopia.

The crop is known for soil nitrogen enrichment, rotational advantages and less cost of production. It is also important sources of diet, and consumed in Ethiopia in different preparations like snacks, curry, blend to bread/Enjera powder, green pea, and salads to mention some. Chickpea is an important market commodity currently surpassed if not competes tef (*Eragrostic tef*), a crop known for its high market values in Ethiopia. So best technology adopter farming community earns some 1500- 2000 US$/ha on average (Asnake, 2014)

Ethiopia is the leading producer, consumer and seller of chickpea in Africa, and is among the top ten most important producers in the world (Minale et al., 2009). With the emerging situations Ethiopian chickpea production paradigm shift is happening from traditional cultivars to improved varieties and from desi types to the kabuli types as derived by the market system and consumption preferences.

Production volume of chickpea has shown steady improvement over the last decade with currently reaching more than 400 000 tons per annum. The major contributor of this production is the dramatic productivity improvement of the crop than area expansion (Figure 1). The productivity level currently 1.9 t/ha is among the highest records in the world and is double to the global average. The productivity of chickpea in Ethiopia moved by 117% and area expansion by 59% in the two decades period 1995/6-2013/14. The crop production is mainly concentrated in four political regional states with Amhara regional state shares more that 50% and followed by Oromia as indicated in the same figure.





Figur 1: Productivity slope change in Ethiopian chickpea (CRD poster, 2015) & distribution by regions (Asnake, 2014).

Ethiopia exports about 8-12% of its chickpea production, depending on the season, to the global market, and takes some 4-6% market share, as indicated in the Table 1 below. The major market destination is in Asia (India, Bangladesh, Pakistan) sinking some 1/3 of the total volume in export.

Table 1. The top ten chickpea exporter countries in the world

Rank	Country	Average export volume (MT), 2005/2010	Market share (%)	Export as % of domestic production	Unit value (USD/MT)
1	Australia	309,457.17	31.23	86.00	478.96
2	India	117,591.67	11.87	1.87	841.35
3	Mexico	113,196.83	11.43	77.64	945.77
4	Turkey	88,535.33	8.94	16.25	748.10
5	Canada	72,159.83	7.28	56.80	682.55
6	Ethiopia	59,957.17	6.05	23.00	460.63
7	Myanmar	50,618.50	5.11	15.00	538.02
8	USA	27,091.17	2.73	41.60	742.84
9	Russia	22,092.33	2.23	85.00	355.12
10	Tanzania	21,493.50	2.17	67.60	354.87
	Total	**882,193.50**	**89.04**	-	-
	World	**990,779.00**	-	**10.50**	**639.37**

Source: *Compiled from FAOSTAT, 2013 (by Dr Sitotaw F.)*

Approaches

Since the mission of the manuscript was to put established facts in the sector in a structured and synchronized manner so as to make it convenient to users; all published articles, reports and authors own observations have been compiled systematically. The sources to which thorough review assessment were made includes proceedings, journal articles, books, research reports, thesis and communication sources of recent productions.

National chickpea research setups and achievement: spring board to development

Inter/intra disciplines setups and their mode of action and interaction in research are determinant production functions of the crop as each of them counts values of contribution. The crop response curve is maximized either through maximization of each function and/or their combined effects. The illustration below demonstrate that yield is a function of *Genetics* x *Environment* x *Protection* x *Management* (Figure 2). This

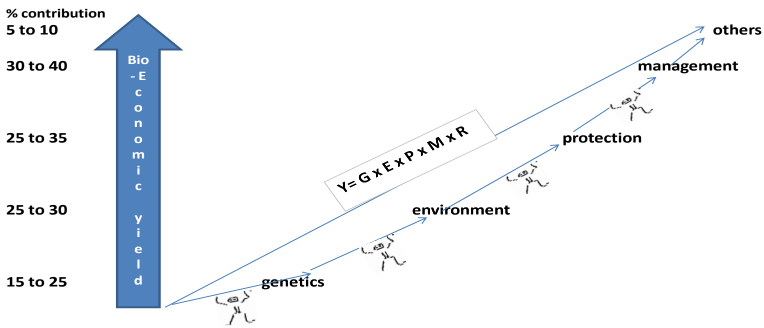


Fig 2: Hypothetical interdisciplinary research effect portray on chickpea vertical bio-economic yield response curve, as shared load by the plant genetics, environmental support, crop protection, crop management and residual factors

implies the genetic response of an-inherent entity, the environment encompassing the climatic agro-ecological and media attributes and the management consisting mainly of fertilization, tillage, cropping system and harvest management, protecting the crop of bio-threats are all operates in an interaction on the expression of resultant yield.

The anticipated picture portrayed in figure 2 above shows all in a shared value of load through independent as well as in synergy, and need not be understood necessarily of a rally action.

The research system in chickpea is hence founded on interdisciplinary and multidisciplinary approach, where each biophysical entity is being studied for maximizing crops response curve. In fact it is complex to gage the proportional role of each carrying the response curve load, though effect depends on certain conditionality and synergy. In this regard the departments of breeding, protection, agronomy and cropping system, in a tandem action flow, have set their designed studies that define the crop in context. Germplasm enhancement is the center of improvement and genetic gains to be achieved. Diversity evaluation from existing accession resources, germplasm line evaluation received from CGIARs, crossing program within the program are the three pillars of breeding tools to work with. Cultivar development processes subsequently is a tandem connectivity action of evaluation of the breeding materials for the genetic constituent of the desired traits of tolerance for important bio-threats, abiotic-threats and some marketability and other parameters. The simple interdisciplinary coherent action arrangement follows: *Germplasm enhanced; evaluation for different biotic/abiotic-threat reaction effected; eligible germplasm advanced; special merits being fixed (yield, adaptation, market, & quality); variety released; socio-economic role defined, and impact measured.* Thus, all the varieties released have got one or more of prevailing traits among the aforementioned catered by respective disciplines. The following table would illustrate some of the important traits attributed by each variety by the time of release for commercial production.

Table 2. List of recurrent varieties in chickpea and associated traits.

Name of variety	Year of release	Institutional source	Genetic background (parentage, pedigree, ancestry)	Year of first significant diffusion	Area of expected coverage (potential) (ha)	Area of actual coverage (ha)	Average yield potential /on-farm/ (kg/ha)	Peculiar trait/s selected
Teketay	2013	ICRISAT	(JG -74 x ICCL - 83105	-	-	-	1600-2200	Yield, wilt & AB tolerance
Dalota	2013	ICRISAT	ICCX-940002-F5-242P-1-1-1	-	-	-	2000-2300	Yield, wilt & AB
Minjar	2010	ICRISAT	(ICCV-92065 X ICCV-88202) X KW-118	-	-	-	2000-4000	Wilt & AB
Acos Dubie	2009	PVT	Monino	2010	2000	6.9	1800	Seed size, high market value
Natoli	2007	ICRISAT	ICCX-910112-6	2009	5000	5.2	3000	Yield, seed quality & RR tolerance
Mastewal	2006	ICRISAT	ICCV-92006	2009	100	5	2000	Better yield & seed quality
Fetenech	2006	ICRISAT	ICCV-92069	2008	-	-	1750	Better yield & seed quality
Yelibe	2006	ICRISAT	ICCV-14808	2012	-	-	1750	Better yield & seed quality
Kutaye	2005	ICRISAT	ICCV-92033	2010	-	-	1640	Better yield & seed quality
Teji	2005	ICARDA	FLIP-97-266c	2009	200	12.2	1750	Yield, seed quality & RR tolerance
Ejere	2005	ICARDA	FLIP-97-263c	2007	5000	295	2250	Yield, AB tolerance & earliness
Habru	2004	ICARDA	FLIP-88-42c	2005	15000	5425	2700	Earliness, yield, AB & RR tolerance

Source: Chickpea TL-II report compilation and national variety release registration book.

Table 2. Continued…

Name of variety	Year of release	Institutional source	Genetic background (parentage, pedigree, ancestry)	Year of first significant diffusion	Area of expected coverage (potential) (ha)	Area of actual coverage (ha)	Average yield potential /on-farm/ (kg/ha)	Peculiar trait/s selected
Chefe	2004	ICARDA	ICCV-92318	2007	7000	764	2450	RR & AB tolerance, yield & adaptation
Shasho	1999	ICRISAT	ICCV-93512	2004	50000	9536	2300	Yield, RR tolerance & adaptation
Arerti	1999	ICARDA	FLIP-89-84c	2004	100000	41436	3350	Extensive adaptation, AB resistance & yield
Kasech	2011	ICRISAT		-	-	-	1800-2000	MS tolerant & seed size
Akuri	2011	ICRISAT		-	-	-	1800-2000	MS tolerant & seed size
Kobo	2012	ICRISAT		2014	-	-	2000	MS tolerant, seed size & yield

Source: Chickpea TL-II report compilation and national variety release registration book.

Given the above end result, it is obvious about 10 thousand germplasm lines have been evaluated in chickpea improvement program life span, sourced from CGIARS, collections and/or germplasm enhancement of the national program, and have to compete for the desired traits before release. If one calculates the 23 varieties thus far released it is like 0.23%; that means simply some 99.67% reject. The recovery rate of variety release has progressively diminished in time, that means the number of germplasm lines used to release a variety is less in the old days, and this has increased significantly , may be 2 to 3 folds, higher in recent as time advances. This has critical implication on the need of innovative breeding approach or application of advanced breeding tools in going forward.

Highlight of some findings with Ethiopian chickpea is imperative on knowledge management and gap filling with in the R4D lineage. On chickpea seed study, Abebe (2013) reported his investigation that seed priming is a viable and sound technology to enhance seed quality and water priming enhanced the germination percentage and seedling vigor index I and electrical conductivity, hence hydro-priming is better technical step-up and economical benefit of chickpea growing farmers.

On Rehizobium association the work of Gemechu *et al* (2013) indicated that Ethiopian chickpea landraces have better genetic potential for improving a number of symbiotic and agronomic characters and commend selection of best individuals within and among the accessions in the breeding program would be expected to be effective. This was supported by Niguse (2013) who have demonstrated the genetic basis of heritability in rehizobium association factor and associated yield gains of 20-30% magnitude in the processes.

As a drought strategic commodity, the study by Seyoum (2014) has illustrated that genotypes superior in drought stand was related to their early phenology, deep rooted potential, high marketable yield which attributed to the total drought tolerance characters and cultivars like ‗Kobo' could be recommended for breeding and production purpose. In the same line genotyping by phenotyping (India, Kenya, Ethiopia) analysis of some 300 genotypes by Thudi and coworkers (2014) reported a total of 18 SNPs from 5 genes (ERECTA, 11 SNPs; DREB, 1 SNP; CAP2 promoter, 1SNP; ASR, 4SNPs and AMDH, 1SNP), significantly associated markers for drought and heat tolerance in chickpea that can be used in molecular breeding for developing superior varieties with enhanced drought and heat tolerance. Towards same goal, by using linkage mapping approach, one genomic region harboring quantitative trait loci for several drought tolerance traits has been identified and successfully introgressed in three leading chickpea varieties, including Ethiopian ‗Chefe' variety, (e.g. JG 11, Chefe, KAK 2) by using a marker-assisted backcrossing approach. A multi-location evaluation of these marker-assisted backcross lines provided several lines with 10–24% higher yield than the respective recurrent parents. Modern breeding approaches like marker-assisted recurrent selection and genomic selection can be employed.

Intra-and inter-row spacing has been evaluated and has suggestion of 10 cm x 20 cm for kabuli cultivars by Shiferaw (2013), following validation. Addisu (2013) and some unpublished work at the national chickpea research had indicated the importance of nitrogen fertilization responses of chickpea, which would re-drive the discourse of fertilization in chickpea.

Asnake and Wendafrsh (Abstract, 2012) have reviewed prospects of pulse in Ethiopia and demonstrated that Ethiopia prospect to produce world standard pulses is verifiable and at least tri-fold from the current volume of 1.3 million ha, with some 90 million USD income revenue mainly comes from the principal lists pulses with derived market breeds like bold and kabuli chickpea, red cotyledon large seeded lentil, white and red beans, extra bold faba beans, mung beans is achievable. They have commented that though the past breeding efforts have resulted in development and release of 150 improved cultivars each with specific desirable market and quality traits, however, value added product development and marketing is far limited.

Research-development linkage

Chickpea is one of the successful commodity of intensification in the production system, as prescribed *"***chickpea intensification is happening in Ethiopia***"* *(http://www.icrisat.org/who-we-are/investors-partners/donor-flyers/Ethiopia.pdf)*. The production volume, on a steady improvement, has been attributed more from yield compared to area increment. If we simply refer the last 20 years, yield has increased by 117% while area of production increased by 59% (CSA 1995-2014). This situation has encouraged chickpea farmers to adopt technologies and kept the sector as choice of attractive agro-business enterprise. The adoption rate of kabuli chickpea, newly introduced in the system some three decades ago, demonstrated competent market values and preference, has risen to 40% over the desi type that was in total coverage. This success has derived a harmonized research and extension linkage in a progressive manner. Seed corridors have been established on the basis of community of practice, leveraging the backup from the research system. The gains in agribusiness model had enhanced the impact level of the commodity; and gave in some cases for the birth of private sectors on seed sector. The agribusiness role of chickpea technologies have also attributed to the socio-economic transformation of adopter farmers. Key elements of the successful responses were:

Technology reputability: varieties along with management packages are passed through rigor of evaluation to biotic, abiotic, input, ecological and marketing responses. At all the steps the biological make up and socioeconomic demands are being assessed in the background of the candidate to be released in to the system. Participatory evaluation among different stakeholders is a warranty card on acceptability, feasibility and suitability of the technology development (evidences derived from Nile valley and TLII projects, data not shown).

Technology promotion: technology promotion based on confidence building via PVS or any other participatory scheme proved uptake rate hastening. The market or profitability, adaptability and early maturing technology backgrounds have got a fast uptake element. This even has much more enhanced effect when the seed system in an innovative manner is established and made accessible at point in time (Aliy, in press).

Seed system and seed business: integration in both seed availability and seed business along with technology promotion improves the effectiveness of the promotion effort. This has been experienced by surrounding farmers of the research centers, who could have immediate accesses and where spearheading adoption and impact can easily be designated in advance of time. Instances of rust resistance lentil, kabuli chickpea, potato, hybrid maize, tef, beans etc have all remarked the advanced applications by the farming community accessibly and lively connected to the research centers, and for obvious reasons.

Agri-bussiness model and market stimulus: Varieties of any level have been validated by the level of competitiveness in the market. By the time if there are already market penetrated varieties, replacement to the preceding is a real challenge. To this end chickpea varieties are being released based on market penetration power. Succession of desi by kabuli type chickpea is mainly of the market power, along with other preferred traits.

Policy support: as cereals are more for food security, pulses do more in the marketing and nutritional security. Both local and export markets are operating with chickpea. The realization of chickpeas role as major export commodity of the country has stimulated policy backups from the government to encourage chickpea production and promotion so as to further compete the global market.

Based on the assertion forwarded, the adoption and innovative application of chickpea technology seems hit a ceiling in some exceptionally innovative farmers' fields with yield has reached as high as 4-5 t/ha. However, if we referee the adoption of the technologies and average gains based on the agro-potential and adoption rate and other indicators, Fikre (2014) has roughly estimated cluster proportion (Fig. 3), based on the total chickpea farming community. Accordingly, some 1/5th have top yield, some 1/4th medium, some 1/3rd natural, and some 1/5th follow marginal production. With regard to the rate of adoption, though there are concerns on biodiversity, it becomes very common to see some varieties like ‗Ararti' considered as local cultivar as it has totally replaced any other locally grown chickpea; for instance in Minjar destrict.

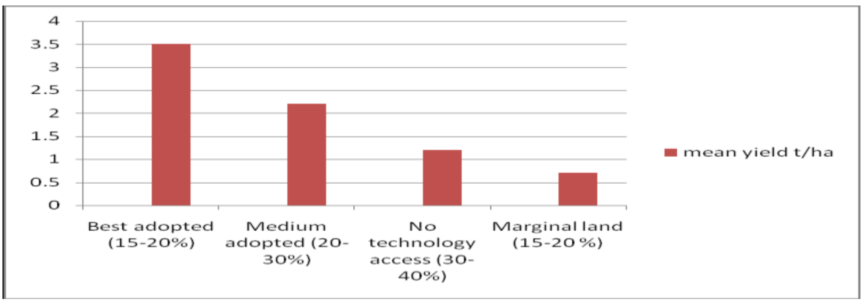


Figure 3: Current Ethiopian chickpea productivity estimates (mean yield, t ha^{-1}) at different levels of technology adoption.

Lessons and the way forward

We have been overwhelmingly impressed by the success rate chickpea has over the last two-three decades. The genetic gain of about 1.5 best expresses the rate of genetic manipulation and its lineage to varieties released in progress. Yet, to come up with super genetic combination and make up varieties is becoming on of the recurring challenges. Thus, the next level of thought should be coming in chickpea improvement. Simply, it requires an innovative thought, advanced tool application, critical management formulation, etc in the improvement programs.

The national average of chickpea is close to 2 t/ha now, one of the top score globally, however this figure still be changed at least to 3 t/ha; provided best chickpea practice are in place combined. Value addition level of chickpea is still limited, agro-industrial application is poor, formal seed system is poorly developed, postharvest management challenge is surfaced, mechanization is far reached hangout, genomic tool application in the national program is yet a gap etc, altogether demands the future R4D should come in a different way.

Acknowledgments

I would like to acknowledge ATA, ICARDA, ICRISAT, FAO, USAID-VOCA, EIAR for their support of the workshop and all technical contributors and organizing team, global and national partners, that all combined to realize the interesting chickpea workshop event of an international scale.

References

Abebe S (2013). Effect of hydro and osmo priming on seed quality and yield of chickpea (*Cicer arietinum* L.). *MSc Thesis, Haramaya University*, 2013.

Addisu A (2013) Response of Chickpea (*Cicer arietinum* L.) Varieties to Rates of Nitrogen and Phosphorus Fertilizer at Debre Zeit, Central Ethiopia. *MSc Thesis, Haramaya University*.

Asnake F and Wondafrash M (2012) Research-development Interface on Pulses Production, Quality and Marketing in Ethiopia. *EPOSPEA, international forum*, Addis Ababa, Ethiopia (Abstract).

Asnake F (2014) An overview of chickpea improvement research program in Ethiopia. *The journal of the International Legume Society*, Issue 3. ISSN 2340-1559; Apdo. 4084, 14080 Córdoba, Spain.

CSA (Central Statistics Authority) (1995-2015). Agricultural Sample Survey Report on Area and Production of Crops Private Peasant Holdings, Meher Season. Addis Ababa, Ethiopia.

Keneni G, Bekele E, Assefa F, Imtiaz M, Debele T, Dagne K, and Getu E (2013) Genetic potential of Ethiopian chickpea (*Cicer arietinum* L.) germplasm for improving symbio-agronomic performances: *A univariate assessment*.

Niguse G (2014). Genetic study of the heritability of nitrogen fixation in Ethiopian chickpea varieties. *MSc Thesis*, Haramaya University.

Seyum A (2014) Evaluation and Characterization of Chickpea (Cicer arietinum L.) Genotypes for Drought Tolerance. MSc Thesis, Bahr Dar University.

Sherif A (in press) Community Based Seed System in Chickpea: Prospects and Challenges. *Proceeding of the First International Chickpea Workshop*, 2014, Deber Zeit, Ethiopia.

Shiferaw M (2013) Response of Kabuli Chickpea (*Cicer arietinum* L.) Varieties to Plant Spacing at Debre Zeit, Central Ethiopia. *Msc thesis*, Haramaya University.

Thudi M, Upadhyaya HD, Rathore A, Gaur PM, Krishnamurthy L, Roorkiwal M, Nayak SN, Chaturvedi SK, Basu PS, Gangarao NVPR, Fikre A, Kimurto P, Sharma PC, Sheshashayee MS, Tobita S, Kashiwagi J, Ito O, Killian A, Varshney RK (2014) Genetic Dissection of Drought and Heat Tolerance in Chickpea through Genome-Wide and Candidate Gene-Based Association Mapping Approaches. *PLOS One*, **9**(5): 96758.

Thudi M, Gaur PM, Krishnamurthy L, Reyazul R. mir, Kudapa H, Fikre A, Kimurto P, Tripathi S, Soren KR, Mulwa R, Bharadwaj C, Datta S, Chaturvedi SK and Varshney RK (2014) Genomics-assisted breeding for drought tolerance in chickpea. *Functional Plant Biology*.

3. An overview of chickpea research and development programs in Kenya: current status, challenges and opportunities

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Chickpea (Cicer arietinum L.) is a relatively new legume in Kenya and is ranked after beans, green grams, pigeon pea, cowpeas, soya etc. It has enormous potential to contribute significantly to food security, balanced diet and poverty alleviation amongst the poor-resource communities in semi-arid areas and cereal growing areas of the Kenyan highlands. The crop is increasingly gaining popularity as alternative legume to be grown during short rains on stored soil moisture. Recent research and promotional efforts in collaboration with ICRISAT has resulted in significant increase and adoption of new improved varieties in dryland highland areas of Rift valley and Eastern Kenya with yields ranging between 0.8-2.5 tons ha-1. Annual production and area covered have also increased in the last 4-5 years both major regions. Similarly, six high yielding varieties have also been released through collaborative efforts of national partners and funding support of BMGF through Tropical legume II (TLII). These varieties includes Chania Desi 1 (ICCV 97105), Chania Desi 2 (ICCV 92944), Saina K1 (ICCV 95423), LDT068 (ICCV 00305), Chania Desi 3 (ICCV 97126) and LTD 065 (ICCV 00108), both of Kabuli and Desi types. These varieties were released based on several farmer and market preferred attributes like high yielding across varied agro-ecozones, Fusarium *wilt resistance, large seeded, drought tolerance and early maturity. Research institutions (Egerton University, KARI, ICRISAT) are currently under intensive efforts to produce Breeder and Foundation seed for supply to seed companies (like Leldet seeds, Faida seeds, Fresco, Agro-Soy and Kenya Seed) and other farmer organization for production of certified seeds for farmers. Several other varieties (ICCV 97306, 92318, 96329, D013, D045) are under*

evaluation in NPT and are being fast tracked for release. Increased seed production through TLII program will also enhance availability of seed to farmers to upscale production. The breeding program is currently focused on addressing the biotic and abiotic constraints (Drought, H.armigera and Aschochyta blight, Fusarium wilt) to exploit the diversity within germplasm developed by ICRISAT and local germplasm. The Genomic resources that have been developed by GCP and ICRISAT (under TLI project) have been used to improve several Kenyan elite lines (Chania Desi 1, Saina K1, Chani desi 2 and LTD065) using Marker Assisted Backcrossing (MABC) and several BC3F2/F3 progenies with better root traits and drought tolerance than parents are been evaluated in several multi-locations. Preliminary findings have shown that marker-assisted breeding for root traits is expected to improve precision and efficiency of breeding for drought tolerance in chickpea. The future strategies and opportunities for enhancing chickpea production in Kenya exist. Key amongst these will be focused on improving the genetic composition targeting production constraints and improvement in yields, Helicoverpa armigera resistance, Ascochyta blight tolerance and upscaling and expansion into new areas like rice-paddy irrigation schemes, promotion of adoption of new varieties, increasing seed production, establishing more seed production units in target areas and utilization.

4. Review of Chickpea Production, Opportunities, and Challenges in Sudan

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Chickpea is an important cash crop and the cheapest source of protein in Sudan. The crop is grown mainly under irrigation and appreciable area is grown under flooded after recession of the flood and in basins. Average area grown to chickpea in recent years reached 20,000 ha. Yields range between 0.83 and 2.8 t/ha depending on weather conditions. Chickpea is traditionally grown in the River Nile State in the northern part of Sudan. It was also introduced and successfully grown in Hawata, New Halfa (East) and Jebel Marra (West) in Sudan. Recently, the crop was grown in appreciable area at Gezira Scheme in the middle of Sudan. The major disease that causes economic losses to the crop is the wilt caused by Fusarium oxysporum f. sp. ciceris. The continuous cultivation of the crop without a sustainable crop rotation has greatly increased disease incidence. Improvement of chickpea in Sudan depends mainly on introduction of breeding lines from ICARDA and to a lesser extent from ICRISAT. Eight genotypes that have high seed yield and good quality were released as commercial cultivars in Sudan. Recently, four genotypes (FLIP 03-59c, FLIP 02-88c, FLIP 00-20 and FLIP 01-6) were found to be highly resistant to Fusarium wilt disease and identified as source of resistance. In northern Sudan, it was recommended that the crop should be sown at 33 plants/m^2 achieved by sowing chickpea at 60 and 10 cm inter and intra-plant spacing with two seeds per hole which is equivalent to 60 kg/ha seed rate.

Key words: Chickpea, River Nile Sate, Fusarium wilt, breeding lines

Introduction

Chickpea is an important food legume crop commodity produced and consumed in Sudan. With other food legumes, are considered as a major source of low cost protein for the middle and low income strata of the population. There are no available estimates on consumption and demand. The evidence, however, is that production is consumed domestically and small imports are reported. In the past chickpea consumption is particularly high during the Holy month of Ramadan (the Muslim fasting month) as an old tradition which is still observed. Now chickpea is becomes one of the food security crops in Sudan as many people depend on Tamia for their breakfast and supper.

Production of chickpea is concentrated in the Northern part of Sudan north of latitude 16 , taking the advantage of the relatively cooler winter in this area. Production is mainly under small private pumps schemes and some big public schemes in the River Nile Sate. Also appreciable area is grown under flooded after recession of the flood and in basins at different parts of the country. It was introduced and successfully grown in Hawata, New Halfa (East Sudan) and Jebel Marra (WestSudan). Recently, the crop was grown in appreciable area at Gezira Scheme in the middle of Sudan (Fig 1).

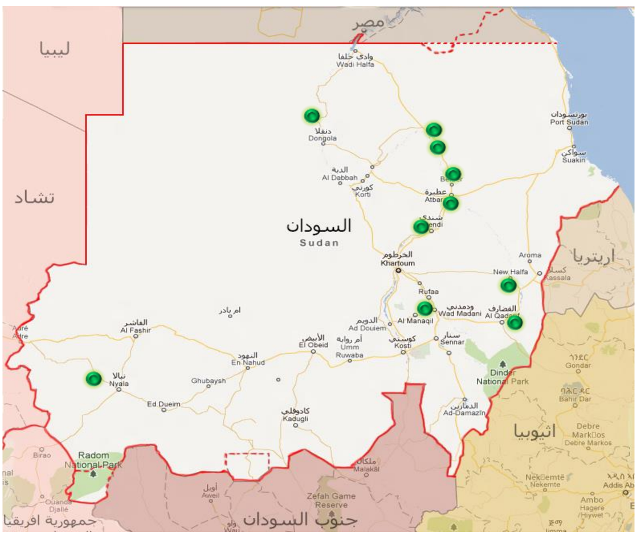

Figure 1. Major chickpea production areas in Sudan

Average area grown to chickpea in recent years reached 20000 ha, and its yields range between 0.83 and 2.8 t/ha depending on cultivars, management and weather conditions. The biotic and abiotic constraints led to significant reductions in the yields of chickpea and other food legumes (Table 1). There is no definite statistic for the area grown by chickpea in the Gezira Scheme, but during 2013/2014 the area is not less than 20000 ha. The crop now becomes one of the most important cash crops for the farmers in Gezira scheme (personal communication).

Table 1. Area (ha) and average seed yield (t/ha) of the main winter crops compared to chickpea during the last three seasons, in the River Nile and Northern States.

Crop	**2010/11**		**2011/12**		**2012/13**	
	Area	GY	Area	GY	Area	GY
Chickpea	15780	2.4	16000	2.0	2596	0.9
Faba bean	44000	2.4	39000	2.3	11874	1.0
Common bean	8200	1.5	6540	1.6	6723	1.0
Wheat	51000	2.3	45000	2.2	13892	1.2

GY=grain yield

Chickpea production constraints in Sudan

Major production constraints include: 1) Poor cultural practices practiced by farmers in most of the area grown by chickpea, 2) lack of high yielding cultivars. Most of the released high yielding cultivars have not found their way to farmers because of seed multiplication problems, 3) yield of chickpea is known to be sensitive to weather conditions, particularly high temperature, insect pest and diseases. The important biotic constraints are wilt and root rot fungal diseases, chickpea chlorotic dwarf virus diseases and African boll warm. Chickpea chlorotic dwarf virus is also responsible for the reduction in productivity of the crop, particularly for early sown crop.

Major Achivements

Evaluation results of chickpea germplasm introduced from ICARDA in the late seventies and early eighties indicated the superiority of the Kabuli line, NEC2491/ILC 1335, over the local check in grain yield by 43% and 24% at Hudeiba(17N ,34E) and Shendi (16N,33E) respectively. According to this finding, this Kabuli line was released as the first kabuli cultivar by the name ‗Shendi-1'in October 1987.The material received from ICARDA/ICRISAT in late eighties and early nineties were screened for grain yield and other desirable agronomic characters under farmer conditions in five locations. The results obtained justified the release of the line ILC915 as anew cultivar to farmers under the name ‗Jebl-Marra-1'.From 1996-1998, six medium and large-seeded genotypes were released as new cultivars under the names: Salawa, Burgieg, Wad Hamid, Hawata, Atmour and Matama, which have high seed yield and good quality (Table 2).

Table 2. Cultivars pedigree and some descriptive characters

Cultivar name	Arabic name	Acc. number	Year of release	Genetic background (Pedigree)	Growth habit	Wilt/root rot disease reaction
Shendi	شندى	ILC 1335	1987	Afghanistan Selection	PR	S
Jabel-Marra	جبل مره	ILC 915	1993	Iran(Vysokoroshyj 30) Selection	SE	S
Wad Hamid	ودحامد	Iccv-2	1996	India-ICRISAT Selection	PR	R
Atmor	عتمور	Iccv-89509	1996	(L 550/Radhey)//(K 850/H 208)	SE	R
Hwata	حوتو	Iccv-92318	1998	(ICCV2/Surutato 77)//ICC 7344	SE	HR
Burgeig	برقيق	Iccv-91302	1998	ICCC32/(K4/Chafa)	SP	HR
Salawa	سلوه	Flip 89-82c	1996	(X87TH 186/ ICCI 4198)//FLIP 82-150C	PR	R
Matama	هتمو	Flip 91-77c	1998	(X89TH7/ILC 1245)//FLIP 82-150C	SP	S

PR= Prostrate, SE= semi-erect, SP= semi-prostrate, S= Susceptible, R=Resistant, HR= Highly resistant

Recently, four genotypes (FLIP 03-59c, FLIP 02-88c, FLIP 00-20 and FLIP 01-6) were found to behighly resistant to Fusarium wilt as their disease incidence ranged from 2.5 to 7.5% and from 0.0 to 3.3% in 2012 and 2013 seasons respectively, and were accepted as a source of resistance (Table 3). Amongest these genotypes, FLIP 03-59, showed high yield and earliness while FILP 06-6 has large seed size and suitable for mechanical harvesting (Noha *et al*, 2013).

Table 3. Agronomic performance of selected chickpea genotypes evaluated under disease-free location across three seasons.

Genotype	**100 seed weight** (g)	**Yield/plant** (g)	**Grain yield** (kg/ha)
FLIP 03-59 C	35.2	18.8	2601.2
FLIP 02-88 C	37.8	12.8	1884.0
ICCV2	25.7	12.9	2492.7
FLIP 02-46 C	41.9	15.1	1754.4
FLIP 00-20 C	34.8	14.9	1937.5
Burgieg	23.0	13.4	2389.6
FLIP 01-6 C	33.7	11.8	1806.6
Salawa	32.1	19.8	2331.2
FLIP 01-32 C	32.2	12.7	1770.3
FLIP 01-37 C	32.4	12.9	1875.3
FLIP 03-107 C	38.8	14.5	2107.4
Shendi	16.0	10.3	1370.3
S.E. ±	1.61**	1.85*	196.90**
C.V. (%)	4.5	35.8	25.6

The major agronomic aspects of chickpea crop were effectively addressed by many research studies. The optimum sowing date was found to be mid November. Planting chickpea on ridges at a plant density of 33.3 plants/m^2, or at seeding rate of 60 kg/hawould give optimum population and maximum grain yield. Similarly, crop nutrition studies addressed particularly nitrogen and phosphorous fertilization and *Rhizobium* inoculation. Response to N fertilization indicated that chickpeaneedsN as a starter dose, while the response to P was found negligible. Response to *Rhizobium* inoculation studies showed that local strains were quiet effective. Irrigation studies showed that frequent irrigation (7-10days interval) through the crop cycle resulted in highest grain yield.The studies also indicated that early termination of irrigation water drastically reduced grain yield by up to 40-60%.

Studies on weed control methods conducted at Hudeiba, Rubatab and Wad Hamid indicated that Goal alone or in a tank mixture with Igran or Gesagard gave satisfactory control of weeds and increased yield over the weedy check treatments. The tank mixture of Dual Gold at 0.4 L/fed + Codal Gold at 0.8 as pre-emergence herbicide in chickpea was performed excellent against grassy, particularly for wild sorghum and broad leaved weeds in chickpea. The estimation on yield revealed significant differences between treated and untreated plots.

Under the project of food security financed by European community and IFAD and ICARDA (EU-IFAD Wheat-legumes project), the project has demonstrated high-yielding varieties of chickpea to farmers mainly in the Gezira region, and other areas in the River Nile State for example, which have performed significantly well in comparison to traditional varieties. The varieties Salawa and Burgeig generated about 4 and 3.8 t/ha, respectively as compared to 1.66 t/haobtained from traditional variety. The project also contributed in disseminating proven technologies and techniques to help the Sudanese chickpea farmers overcome these limitations and raise their productivity.

Challenges and Suggested Solutions

Development of cultivars that are resistant to biotic and abotic stresses neeed to be strengthened further.Improved technologies couldn‘t reach the majority of farmers, and hence supply of seeds and other inputs in the right timewith affordable pricesshould receive due attention by the government.Evaluation of materials under stress conditions such as limited moisture, high temperature and diseases (mostly wilt/root rots) and development of production technologiessuitable to marginal areas should be given high priority. The bulk of chickpea in Sudan is produced under residual moisture conditions. It is felt that more work is needed to develop appropriate technology best fits to this basin irrigation system. Under the current chickpea production system in Sudan, management of economically important diseasessuch as wilt/root rot and viral diseases is essentialimportant, which calls for integrated disease management approach incorporating resistant varieties, seed dressing methods, planting time and irrigation regimes.

References

Ahmed AT (1996) Food legume production situation. In: Salih SH, Ageeb OA, Saxena MC and Solh MB (eds.) Production and Improvement of Cool-Season Food Legumes in the Sudan. Proceedings of the national research review workshop, 27-30 August 1995, Wad Medani, Sudan.

Ali MK, Inanaga S and Sugimoto Y (2002) Sources of resistance to *Fusarium* wilt of chickpea in Sudan. *Phytopathol. Mediterr*,**41**: 163–169.

Noha AM, Ahmed *et al* (2013) Source of resistance to chickpea *Fusarium* wilt disease in Northern Sudan. *The 89thMeeting of the National Pests and Diseases Committee*, December 2013 the yield loss in chickpea.*Tropical Grain Legume Bulletin*, **19**:38-44.

5. Prospects of chickpea improvement research and development in Tanzania: Challenges and opportunities

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Chickpea (Cicer arietinum) is an important cash and nutritionally rich food crop of small scale farmers in Tanzania. It is mainly grown on the vertisol flat plains of Lake Victoria basin (Shinyanga, Mwanza, Mara, Kagera regions). Also grown in Western (Tabora, Kigoma) and North-eastern parts (Arusha and Manyara) of the country. Chickpea is indeed a bonus crop in Tanzania. After harvest of maize/rice in, the land is normally left fallow until the next cropping season (rainy season). Chickpea is planted immediately after the harvest of cereals and grows under residual moisture thus giving farmers a second crop (where only one crop would traditionally be grown) hence income, and nutrition. Total cultivated area and production has increased significantly from 75,000 hectares and 58,000 metric tons in late 1990s to an area of 110,000 hectares and 95,000 metric tons in 2012, respectively. Research on chickpea began with seed money from CGIAR-Canada Linkage Fund (CCLF), which allowed the evaluation of large number of accessions and the selection of potential varieties for further testing. The Tropical Legumes-II (funded by BMGF) gave an impetus to enhance research and through on-farm, FPVS and demonstrations and strengthened seed systems (including QDS) that resulted in landmark fast track release of four varieties(two desi and two kabuli) with improved biological and market qualities. Other salient achievements include establishment of breeding program, institutional capacity building and improved linkage and collaboration within the NARS and International institutions like ICRISAT. Chickpea breeding program thrust is on higher grain yields, resistance to important diseases (Fusarium wilt, collar rot and dry

root rot), early to medium maturity (75 – 110 days) to fit in to cropping systems, and tolerance to soil salinity. Keeping these in mind, research and development efforts has been to breed for disease (especially Fusarium wilt) resistance, develop varieties with farmers & market preferred grain traits, and improve seed production and delivery, networking with concerned stake holders and institutional capacity building. Future prospects are to continue with breeding for consumer preferred grain traits, improve breeder seed production and delivery through implementation of seed road maps, and strengthen collaboration with other research stakeholders.

Chapter II. Breeding & Genetics

6. Chickpea germplasm for use in crop improvement: Approaches and way forward

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Plant genetic resources are the basic raw materials for the genetic gains and an insurance against present and future threats to agricultural production. The ICRISAT genebank at Patancheru, India maintains 20,268 cultivated and wild chickpea accessions. Core (10% of entire collection) or mini core (10% of core or 1% of entire collection), representing diversity of the entire collection of a given species preserved in genebank has been suggested as gateway to enhance use of germplasm in crop breeding. These core and mini core collectionsconsist of 1,956 and 211 accessions, respectively. Further, a global composite collection consisting of 3000 accessions was formed, using data sets and germplasm from ICRISAT and ICARDA genebanks, which was molecularly profiled to form a genotype-based reference set. This reference set consists of 300 genetically diverse accessions, which captured 78% of the 1,683 alleles detected in the global composite collection. Further analysis on this reference set based on 48 and 107 SSRs detected four and nine subgroups. Using mini core collection, a number of trait-specific genetically diverse germplasm with agronomically beneficial traits have been identified for use in chickpea improvement.

Introduction

Cereals and legumes together contribute 2616 million tons to global food production (3,742 million tons of cereals, legumes, oilseeds, roots and tubers, and plantains and bananas), of which legumes contribution is only 2.7%

(http://www.faostat.fao.org; accessed on April 15, 2014). Globally, chickpea is the 2nd most important grain legume (production 11.63 million tons) after bean (production 23.60 million tons) (Fig 1A). South Asia is the leading chickpea producing region, 71.58%, while Africa, Americas, Oceania, and West Asia regions each proportionally contribute 5.47% to 5.99% of the total chickpea production (Fig 1B).

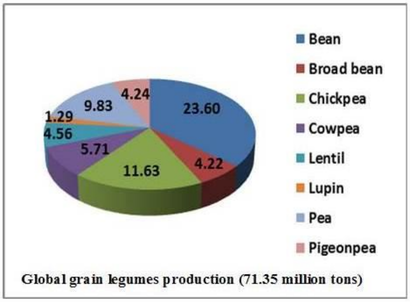

Fig. 1A

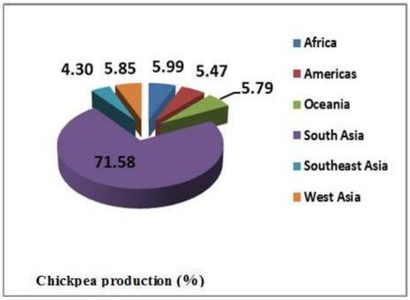

Fig. 1B

Globally chickpea is produced in 55 countries, of which 24 countries (Algeria, Argentina, Australia, Canada, China, Ethiopia, India, Iran, Israel, Italy, Kazakhstan, Malawi, Mexico, Morocco, Myanmar, Pakistan, Russian Federation, Spain, Sudan, Syrian Arab Republic, Tanzania, Turkey, USA and Yemen) in 2012 reported chickpea production of over 10,000 tons. Australia, Canada, Ethiopia, India, Iran, Mexico, Myanmar, Pakistan, Turkey, and USA are the major producers; India being the lead country in chickpea production (Fig 2). Large differences in yield were noted among countries, for example, from 3500 kgha^{-1} in Israel to 250 kg ha^{-1} in Kenya (Figure 3).

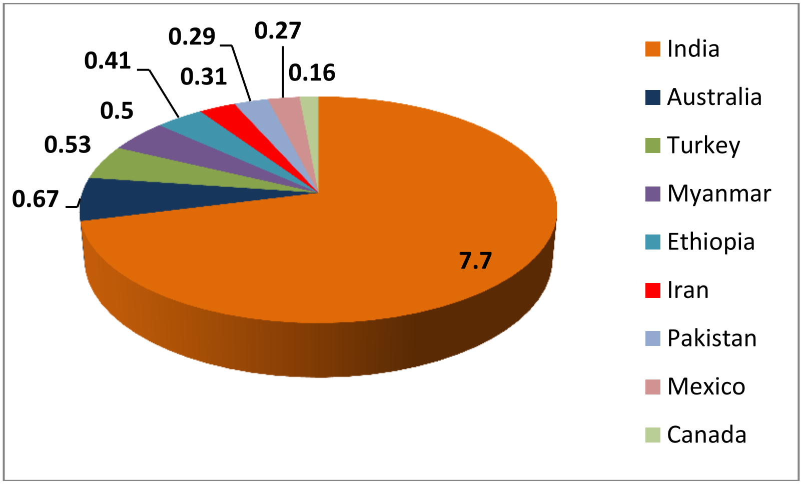

Fig. 2: Contribution (million tonnes) of major producing countries to total global chickpea production (www.faostat.fao.org/; accessed on 15 April 2014)

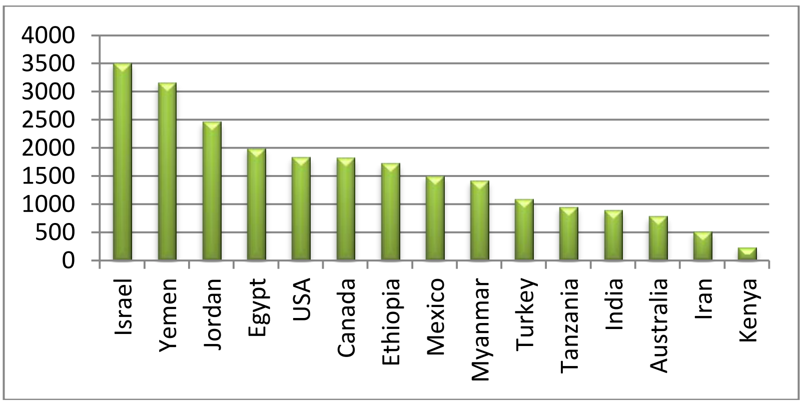

Fig. 3: Variation in chickpea productivity (Kg ha^{-1}) in 15 countries (www.faostat.fao.org/; accessed on 15 April 2014)

Several abiotic (drought, heat, salinity, chilling temperature) and biotic (fusarium wilt, dry root rot, ascochyta blight, botrytis gray mold, pod borer and leaf miner) stress adversely impact chickpea production; together accounting for annual yield loss of US$ 4.4 billion, of which about one third can be recovered through genetic enhancement of yield potential by augmenting the productivity genes and resistance to biotic and abiotic stress (Ryan 1997).

The two most distinct forms of chickpea are desi (small seeds, angular ram‘s head shape, and colored seeds with high percentage of fiber) and kabuli (large-seeds, irregular rounded, owl‘s-head shape, and beige colored seeds with a low percentage of fiber) types. An intermediate pea-shaped type also exists, which is characterized by medium to small and cream colored seeds. Both desi and kabuli are easily hybridized, but there are strong consumer and culinary preferences for the two types (Upadhyaya et al. 2002; Upadhyaya *et al*. 2011).

Grain legumes are characterized by low glycaemic index (GI), and food with low GI are generally associated with several long-term health benefits (http://www.extension.usu.edu). Diets emphasizing dietary pulses have been reported significantly lowered LDL cholesterol levels compared with control diets (Vanessa *et al*. 2014). Chickpea seeds are rich in protein, starch, fiber, minerals, and vitamins, which make it one of the best nutritionally balanced pulses for human consumption (Jukanti *et al* 2012).

Cultivated chickpea has a narrow genetic base (Kumar *et al.* 2004; Upadhyaya *et al*. 2011). The breeders are reluctant to use exotic germplasm because of linkage drag and/or loss of coadaptive gene complex, requiring longer cultivars‘ development time. Thus breeders tend to concentrate on adapted and improved materials avoiding wild relatives, landraces and exotic germplasm available in genebanks (Nass and Paterniani 2000), thereby further narrowing the genetic base as well widening the gap between available genetic resources and their use in breeding programs (Marshall 1989). However, it should be noted that large diversity among chosen parental lines is essential for the success of any recombinant breeding program, specifically when the traits under improvement are quantitative, highly variable and show high G×E interactions. Identification of trait-specific germplasm and their use in recombinant breeding is, therefore, a critical step to develop crop cultivars that meet adverse effects of climate change and variability on agricultural production.

Genebank holding chickpea germplasm globally

Plant genetic resources (PGR) are the basic raw materials required to power current and future progress in crop improvement programs. The use of PGR in crop improvement is one of the most sustainable ways to conserve valuable genetic resources for the future, and simultaneously to increase agricultural production and food security. To date, 100,852 chickpea germplasm accessions are maintained across genebanks globally, with National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and International Center for Agricultural Research in Dryland Areas (ICARDA) contributing 50.5% of the total chickpea germplasm preserved (Table 1). ICRISAT genebank at Patancheru, India houses 20,268 accessions, including 308 wild relatives from 19 *Cicer* species (Fig 4). Other leading genebanks hosted wild *Cicer* species include ICARDA, Syrian Arab Republic (270 accessions from 11 species), ATFCC, Australia (246 accessions from 18 species) and USDA-ARS, Pullman, USA (205 accessions from 22 species).

Table 1. Number of chickpea germplasm accessions preserved in major genebanks globally (http://apps3.fao.org/wiews/; accessed on 15 April 2014).

Country	Institution	Wild *Cicer* # spices	Wild *Cicer* # accession	Cultivated (Landrace)	Total	Collection (%)
Australia	ATFCC	18	246	8,409	8,655	8.6
Ethiopia	IBC	-	-	1,173	1,173	1.2
India	ICRISAT	19	308	19,960	20,268	20.1
	NBPGR	10	69	16,812	16,881	16.7
Iran		-	-	5,700	5,700	5.7
Mexico	IA-Iguala	-	-	1,600	1,600	1.6
Pakistan	PGRP	3	89	2,057	2,146	2.1
Syria	ICARDA	11	270	13,548	13,818	13.7
Turkey	AARI	4	21	2,054	2,075	2.1
USA	USDA	22	205	6,584	6,789	6.7
Total		87	2,136	98,716	100,852	

ATFCC (Australian Temperate Field Crops Collection, Horsham Victoria); IBC (Institute of Biodiversity Conservation, Addis Ababa, Ethiopia); ICRISAT (International Crop Research Institute for the Semi-Arid Tropics Patancheru, India); NBPGR (National Bureau of Plant Genetic Resources, New Delhi, India); NPGBI-SPII (National Plant Gene Bank of Iran, Seed and Plant Improvement Institute, Karaj, Iran); IA-Iguala (Estación de Iguala, Instituto Nacional de Investigaciones Agrícolas, Iguala, Mexico); PGRP (Plant Genetic Resources Institute, Islamabad, Pakistan); ICARDA (International Centre for Agricultural Research in Dry Areas, Aleppo, Sirya); AARI (Aegean Agricultural Research Institute, Izmir, Turkey); USDA-ARS (Western Regional Plant Introduction Station, Pullman, USA).

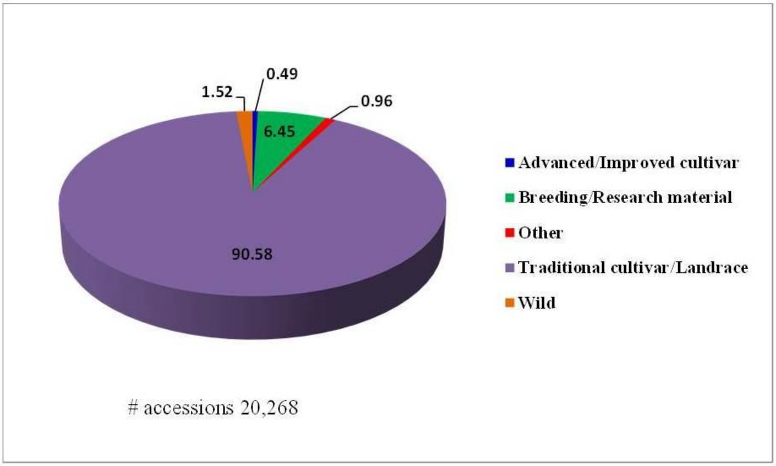

Fig. 4: Biological status (%) of chickpea germplasm conserved at ICRISAT genebank, Patancheru, India. (www.icrisat.org/what-we-do/crops/chickpea/project1/pfirst.asp)

Forming representative subsets to enhance utilization of germplasm in breeding

To date, only limited number of germplasm have been used in cultivar development in most crops, including chickpea. The reasons for the underutilization of germplasm include non-availability of reliable information on traits of economic importance, linkage load of undesirable genes and assumed risks, restricted access to the germplasm collections and regulations governing international exchange, enhanced role of non-additive genetic variation when diverse germplasm is used by the breeders, and lack of robust, cost-effective tools to facilitate the efficient utilization of exotic germplasm in crop breeding (Dwivedi *et al*. 2009; Upadhyaya *et al*., 2011). More importantly, breeders are often reluctant to use exotic germplasm, and end up recirculating their own working collection which will lead to narrow genetic base and ceiling on achievable genetic gain, either due to linkage drag or due to loss of co-adopted gene complex (Ortiz *et al*. 1998) requiring longer generation time in cultivar development.

Core and mini core collections

Reduced subsets such as corecollection, which represents about 10% of the entire accessions (Frankel 1984) and mini core collection (~1% of the entire accessions or 10% of the accessions of the core collection), representing diversity of the entire collection of a given species preserved in genebank, has been suggested as a gateway to enhance utilization of germplasm in crop improvement programs. Using passport, characterization and evaluation data, the representative subsets have been formed in chickpea. The core collection consists of 1,956 accessions (Upadhyaya *et al*. 2001) and the mini core collection 211 accessions (Upadhyaya and Ortiz 2001). These subsets represent adequate biological (desi, kabuli, and pea-shaped types) and geographical (at regional level and countries within region) diversity.

Reference set

ICRISAT in collaboration with ICARDA has developed a global composite collection of 3,000 accessions, which included 1,956 accessions of the ICRISAT core collection, 709 ICARDA cultivated genebank accessions, 39 advanced breeding lines and cultivars, 35 accessions with distinct morphological variants, 20 wild *Cicer* species (*C. echinospermum* and *C. reticulatum*) and 241 accessions with unique traits (Upadhyaya *et al*. 2006). Biologically, this composite collection is composed of 80% landraces, 9% advanced breeding lines, 2% cultivars, 1% wild *Cicer* species and 8% accessions of unknown origin. Geographically, 39% of the composite collection originates from South and Southeast Asia, 25% from West Asia and 22% from the Mediterranean region. Africa and the Americas each contributing 5% of the collection. This composite collection was initially genotyped with 48 polymorphic SSRs to form genotype-based reference set (300 accessions), which captured 78% allelic diversity of the composite collection accessions (1,683 alleles on 2,915 accessions) (Upadhyaya *et al*. 2008). Further analysis with 48 and 107 SSR markers, respectively, detected 4 and 9 distinct subgroups as well variation in allelic richness and diversity (Table 2). Part of this variation could be related to variation in number of SSRs used in the two studies. This reference set, which also included mini core accessions, is thus an ideal germplasm resource for mining allelic variations, association genetics, mapping and cloning of gene(s), and in applied breeding for the development of genetically diverse breeding lines/cultivars with superior yield and enhanced adaptation to diverse environments.

Table 2. Allelic diversity in reference set as detected by 48 and 107 SSR loci in chickpea.

Parameter	48 loci	107 SSR loci
Allelic richness		
Total number of alleles	1212	2254
Polymorphic information content	0.869	0.793
Gene diversity	0.881	812
Heterozygosity (%)	0.009	0.004
Rare alleles	382	666
Common alleles	803	1505
Most frequent alleles	27	83
Unique alleles	476	760
Population structure		
Number of sub-populations	4	9
Biological diversity		
Cultivated species	1160	2147
Desi type	1028	1931
Kabuli type	856	1676
Pea type	339	635
Wild *Cicer* species	252	499
Regional diversity		
Africa	478	894
Europe	128	230
Mediterranean	857	1589
Russian Federation	218	403
North America	216	403
South America	150	306
South & South East Asia	813	1598
West Asia	914	1695
Unknown	230	427

Discovering new sources of variations using representative subsets

Chickpea researchers at ICRISAT and elsewhere have extensively evaluated chickpea mini core collection accessions for agronomic traits and resistance to abiotic and biotic stresses and reported a number of new sources with agronomically beneficial traits.

Variation for early maturity and large seed size: early maturity helps chickpea to avoid heat and drought stress and increases its adaptation especially in the sub-tropics. In a previous study, we identified 28 early maturing accessions, representing wide geographical diversity, using core collection approach, which were further evaluated for maturity and agronomic traits in five environments. ICC# 11040, 11180, 12424, 14648, 16641, and 16644 were reported early maturing, similar to or even earlier than controls, and produced on average 22.8% greater seed yield than the mean of four controls (pod yield, 1340 kg ha^{-1}), with ICC# 14648, 16641 and 16644 having greater 100-seed weight (Upadhyaya et al. 2007). Kabuli chickpeas‘ (100-seed weight greater than 40 g) are late maturing types, and to enhance the adaptation of Kabulis‘ in sub-tropics, it is desirable to identify sources of early maturity in this group. Gowda *et al* (2011) evaluated 65 large-seeded Kabuli‘s for their agronomic performance and yield stability across 5-7 environments and reported two extra-large-seeded (100-seed weight >50 g) lines originating from Mexico, ICC 17109 and ICC 17452, with high yield potential and moderately stable across environments, which can be used in breeding program to develop large-seeded high yielding Kabuli cultivars or used directly for cultivation after evaluating their performance in large scale trials.

Variability for crop growth rate and partitioning: crop growth rate, crop duration and partitioning coefficient significantly impact grain yield in crop plants, including chickpea. Krishnamurthy *et al.* (2013b) reported large variability for crop growth rate and partitioning coefficient among 288 chickpea reference set accessions. Accessions with high crop growth rate and partitioning coefficient were ICC# 1392, 4958, 6263, 7441, 8384, 10309, 10399, 13124, 14199, 14669, 15510, 15606, 15618, 15762, 15802, and 16654. Most of these accessions were from mini core collection. The average grain yields among these accessions ranged from 1725 to 2165 kg ha^{-1}, averaged 1943 kg ha^{-1}; crop growth rate from 2.22 to 2.61 kg ha^{-1} d^{-1}, averaged 2.41 kg ha^{-1} d^{-1}; and partitioning coefficient from 0.81 to 1.03, averaged 0.94. In contrast, accessions with lower crop growth rate and partitioning coefficients, grain yield varied from 476 to 1182 kg ha^{-1}, averaged 935 kg ha^{-1}; crop growth rate from 1.42 to 2.10 kg ha^{-1} d^{-1}, averaged 1.89 kg ha^{-1} d^{-1}; and partitioning coefficient from 0.22 to 0.64, averaged 0.48. Accessions with high partitioning coefficient confer greater tolerance to drought and therefore good source of drought tolerance for use in breeding programs.

Genetic variability for N fixation: symbiotic nitrogen fixation (SNF) is cost-effective and sustainable strategy for nitrogen supply to agriculture worldwide, and the evidence to date suggests sufficient genetic variability for SNF and itsassociated component traits in germplasm collections (reviewed in Dwivedi *et al.* 2014). When assessed the SNF potential of 39 genetically diverse chickpea germplasm from USDA global chickpea core collection together with a commercial cultivar UC-5 in a glasshouse experiment, Biabani *et al.* (2011) detected large variation for proportion of plant nitrogen and total nitrogen fixed, which ranged respectively from 47% to 78% and from 0.020 to 0.084 g; an Iraq landrace accession, ILC 235 (PI 254549) being the highest N fixer. More particularly, it fixed, 121% more N than the total N fixed by UC 5 (0.038 g), which suggests that nitrogen fixation in commercial chickpea cultivar may be improved by introgressing positive alleles from the germplasm. Clearly, there is a need to systematically assay the variation for SNF among the representative subsets (mini core or reference set) reported in chickpea (Upadhyaya and Ortiz 2001; Upadhyaya *et al*. 2008).

Variability for drought tolerance traits: terminal drought is the major constraint to chickpea productivity. $\Delta^{13}C$ is an important trait conferring drought tolerance, which contribute to grain yield under drought stress conditions. When evaluated 280 chickpea reference set accessions for two seasons under drought stressed conditions, the mini core accessions were reported to have high $\Delta^{13}C$ (19.63 - 20.14), with most of these maturing early and producing higher grain yield (1341 – 1992 kg ha^{-1}) and harvest index (0.50 – 0.58) (Krishnamurthy *et al*. 2013a). These accessions were previously reported tolerant to drought (Krishnamurthy et al. 2010). Furthermore, when used drought response index as a measure of drought tolerance, it showed a positive association with crop growth rate, harvest index and the rate of partitioning but negatively associated with water use efficiency (Krishnamurthy *et al*. 2013b). A chickpea landrace accession from Israel, ICC 7571, was found highly tolerant to drought across seasons (Krishnamurthy *et al*. 2013b).

Variability for herbicide tolerance: chickpea is sensitive to many herbicides and therefore use of post-emergence herbicides is limited to manage weeds in chickpeas. Gaur *et al*. (2013) evaluated 278 chickpea reference set accessions for herbicides tolerance and reported large genetic variations among accessions in the mini core collection for tolerance to imazethapyr and metribuzin. In another study, three chickpea mini core collection accessions, ICC# 2242, 2580 and 3325, were reported tolerant to imazethapyr and imazamox herbicides (Taran *et al*. 2010).

Multiple stress tolerant germplasm meeting breeders need: Germplasm with multiple resistant traits, both abiotic and biotic stress, offer breeders opportunities to develop breeding and genetic mapping populations combining multiple resistances into an agronomically improved genetic background. Upadhyaya *et al*. (2013) reported a number of genetically diverse accessions possessing agronomically beneficial traits. For example, a drought and salinity tolerant accession, ICC 3325, possesses resistance to fusarium wilt (FW), legume pod borer (LPB), and herbicide (Odyssey), while ICC 6874, 12155, and 14402, in addition to possessing resistance to drought, heat and salinity, also combine resistance to FW, LPB, or botrytis gray mold (BGM). Likewise, ICC 6279 is resistant to salinity, FW and BGM, while ICC 2580 to drought, salinity and herbicide (Table 3). Further analysis based on 48 SSRs revealed that these accessions were genetically more diverse pairs and agronomically superior than others. Furthermore, they reported a number of genetically diverse germplasm pairs with good agronomic performance and resistance to stress, which may be used in breeding programs to enhance trait values (Table 3).

Table 3. Multiple stress resistance and genetically diverse, agronomically superior chickpea germplasm

Identity	Resistance	Yield (kg/ha)	Diverse pairs	Genetic distance
ICC 2580	Drought, salinity, herbicide	1406	ICC 2580:ICC 3325	0.894
ICC 3325	Drought, salinity, FW, herbicide	1535	ICC3325: ICC6874	0.830
ICC 6279	Salinity, FW, BGM	1351	ICC 6279:ICC 3325	0.894
ICC 6874	Drought, salinity, heat, FW, LPB	1358	ICC 6874:ICC 6279	0.830
ICC 12155	Drought, salinity, heat, FW, BGM	1331	ICC12155:ICC14402	0.851
ICC 14402	Drought, salinity, heat, FW, LPB	1656	ICC14402:ICC3325	0.894

**based on seven seasons evaluations*

Pre-breeding to enhance cultigen's genepool

Pre-breeding, the development of semi-finished product, provides a unique opportunity through introgression of desirable gene(s) from exotic germplasm into genetic backgrounds readily used by the breeders with minimum linkage drag (Sharma *et al*. 2013). The genus *Cicer* contains 44 species including 35 perennials and 8 annual wilds, in addition to *C. arietinum*, the cultivated chickpea. Of these, annual wild *Cicer* species hold a great promise for enriching the diversity in cultigen genepool. For example, resistance to LPB from *C. reticulatum* (Mallikarjuna *et al*. 2007) or BGM from *C. reticulatum* and *C. echinospermum* (Ramgopal *et al*. 2013) have been successfully transferred into cultivated chickpea. Interspecific hybridization has also resulted progenies with improved agronomic performance in chickpea (Upadhyaya 2008). In another study three progeniesoriginating from *C. reticulatum* × *C. arietinum* cross were found resistant to FW and produced 20% higher seed yield than the best-adapted cultivars (Yadav *et al*. 2004). Likewise, a pre-breeding line IPC 71 derived from *C. arietinum* × *C. judaicum* cross showed greater number of primary branches, more pods per plant and green seeds (Chaturvedi and Nadarajan 2010). Researchers at ICRISAT have also extracted several interspecific progenies, originating from cultivated x *C. reticulatum* accession (ICC 17160), which flowered 3-16 days early and yielded similar or greater (3.66 – 3.79 t ha^{-1}) than highest yielding control Annigeri (flowered 43 days, seed yield 3.59 t ha^{-1}) (ICRISAT, unpublished data).

Impact of germplasm in chickpea breeding at ICRISAT

With the formation of reduced subsets (mini core collection or genotype-based reference set) and their molecular profiling led to the identification of large number of genetically diverse germplasm accessions with agronomically beneficial traits for use in chickpea breeding and genomics. For example, germplasm use in chickpea breeding at ICRISAT in comparison to 1993/2002 (177 unique germplasm used to make 1850 crosses) has increased by 18.5% in 2003/2011 (199 unique germplasm used to make 1755 crosses). Further, chickpea breeders at ICRISAT during 1974 to 2008 has so far used 99 unique germplasm or their derivatives (originating through breeding and selection) to develop 3728 advanced breeding lines (designated as ICCVs) with specific attributes, of which 89 have been released as cultivars in 26 countries, while 15 germplasm lines have been directly released as 22 cultivars in 15 countries (Tables 4 &5); all these releases contributing to food, income and nutritional security to millions of farmers engaged in chickpea cultivation in semi-arid tropic regions.

Table 4. List of desi chickpea germplasm released as cultivars.

Country of release	**Accession number**	**Country of origin**	**Released name**
Australia	ICC 14880	India	Hira
Bangladesh	ICC 3274	Iran	Bari Chhola7
	ICC 4998	India	Bina Sola 2
India	ICC 4923	India	Jyothi
Myanmar	ICC 552	India	Yezin 1
	ICC 4944	India	Keyhman
	ICC 4951	India	ICC 4951
Nepal	ICC 6098	India	Radha
Oman	ICC 237	India	ICC 237
USA	ICC 8521	Italy	Aztee

Table 5. List of kabuli chickpea germplasm released as cultivars.

Country of release	Accession number	Country of origin	Released name
Algeria	ICC 11879	Turkey	
	ICC 13816	USSR (former)	Yialousa
Cyprus	ICC 13816	USSR (former)	
Ethiopia	ICC 14808	India	Yelbey
Italy	ICC 13816	USSR (former)	Sultano
Morocco	ICC 11879	Turkey	
	ICC 14911	USSR (former)	
Sudan	ICC 8649	Afghanistan	Shendi
Syria	ICC 11879	Turkey	Ghab 1
	ICC 13816	USSR (former)	Ghab 2
Turkey	ICC 11879	Turkey	
	ICC 14911	USSR (former)	

References

Biabani A, Carpenter-Boggs L, Coyne CJ, Taylor L, Smith JL and Higgins S (2011) Nitrogen fixation potential in global chickpea mini core collection. *Biology and Fertility of Soils* **47**:679–685.

Chaturvedi SK and Nadarajan N (2010) Genetic enhancement for grain yield in chickpea – accomplishments and resetting research agenda. *Electronic Journal of Plant Breeding* **1**:611–615.

Dwivedi SL *et al* (2014) Advances in host plant and Rhizobium genomics to enhance symbiotic nitrogen fixation in grain legumes. *Advances in Agronomy* (In review).

Dwivedi SL, Upadhyaya HD and Gowda CLL (2009) Approaches to enhance the value of genetic resources in crop improvement.The FAO Regional Project ―Capacity building and enhanced regional collaboration for the conservation and sustainable use of plant genetic resources in Asia".

Frankel OH (1984) Genetic perspective of germplasm collection. pp. 61–170. In: Genetic manipulations: impact on man and society, Arber W, Limensee K, Peacock WJ and Stralinger P (eds.), Cambridge University Press, Cambridge, UK.

Gaur PM*et al* (2013) Large genetic variability in chickpea for tolerance to herbicides Imazethapyr and metribuzin.*Agronomy*, **3**:524–536.

Gowda CLL, Upadhyaya HD, Dronavalli N and Singh S (2011) Identification of large-seeded high-yielding stable kabuli chickpea germplasm lines for use in crop improvement. *Crop Science* **51**:198–209.

Jukanti AK, Gaur PM, Gowda CLL and Chibbar RN (2012) Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): a review. *British Journal of Nutrition* 108 (Suppl. 1):S11–S16.

Krishnamurthy L, Kashiwagi J, Gaur PM, Upadhyaya HD and Vadez V (2010) Sources of tolerance to terminal drought in the chickpea (*Cicer arietinum* L.) mini core germplasm. *Field Crops Research,* **119**:322–330.

Krishnamurthy *et al* (2013a) Variation in carbon isotope discrimination and its relationship with harvest index in the reference collection of chickpea germplasm. *Functional Plant Biology,* **40**:1350–1361.

Krishnamurthy*et al* (2013b) Partitioning coefficient – a trait that contributes to drought tolerance in chickpea. *Field Crops Research*, **149**:354–365.

Kumar S, Gupta S, Chandra S and Singh BB (2004) How wide is the genetic base of pulse crops. In: Ali M, Singh BB, Kumar S, and Dhar V (eds.), Pulses in New Perspective. Army Printing Press, Lucknow, India.pp. 211–221

Mallikarjuna N, Sharma HC and Upadhyaya HD (2007) Exploitation of wild relatives of pigeonpea and chickpea for resistance to *Helicoverpa armigera*. *SAT eJournal,* **3**:4.

Marshall DR (1989) Limitations to the use of germplasm collectionsIn: Brown A DH, Frankel OH, Marshall DR, and Williams JT (eds.),The use of plant genetic resources. Cambridge, University Press. pp. 105–120.

Nass LL and Paterniani E (2000) Pre-breeding: a link between genetic resources and maize breeding. *Scientia Agricola,* **57**:581–587.
Ortiz R, Ruiz-Tapia EN and Mujica-Sanchez A (1998) Sampling strategy for a core collection of Peruvian quinova germplasm. *Theoretical and Applied Genetics,* **96**:475–483.
Ramgopal D*et al* (2013) Introgression of botrytis gray mold resistance genes from *Cicer reticulatum* (*bgmr1*$_{cr}$) and *C. echinospermum* (*bgmr1*$_{ce}$) to chickpea (*C. arietinum*). *Plant Genetic Resources* **11**:212–216.
Ryan JG (1997) A global perspective on pigeonpea and chickpea sustainable production systems: Present status and future potential. In: Asthana AN and Ali M (eds), Recent advances in pulses research. *Indian Society of Pulses Research and Development*, IIPR, Kanpur, India. pp. 1–31.
Sharma S, Upadhyaya HD, Varshney RK and Gowda CLL (2013) Pre-breeding for diversification of primary gene pool and genetic enhancement of grain legumes. *Frontiers in Plant Science,* **4**:article 309.
Taran B*et al* (2010) Variation in chickpea germplasm for tolerance to imazethapyr and imazamox herbicides. *Canadian Journal of Plant Science***90**:139–142.
Upadhyaya HD (2008) Crop Germplasm and wild relatives: a source of novel variation for crop improvement. *Korean J Crop Science,* **53**: 12-17.
Upadhyaya HD *et al* (2002) Geographical pattern of diversity for morphological and agronomic traits in the groundnut germplasm collection. *Euphytica*, **128**:191-204.
Upadhyaya HD, Bramel PJ and Singh S (2001) Development of a chickpea core subset using geographic distribution and quantitative traits. *Crop Science,* **41**:206–210.
Upadhyaya HD *et al* (2013) Mini core collection as a resource to identifying new sources of variation for use in chickpea breeding and genomics. *Crop Science,* **53**:2506–2517.
Upadhyaya HD *et al* (2008) Genetic structure, diversity, and allelic richness in composite collection and reference set in chickpea (*Cicer arietinum* L.). *BMC Plant Biology,* **8**:106.

Upadhyaya HD*et al* (2006) Development of a composite collection for mining germplasm possessing allelic variation for beneficial traits in chickpea. *Plant Genetic Resources,* **4**:13–19.

Upadhyaya HD and Ortiz R (2001) A mini core subset for capturing diversity and promoting utilization of chickpea genetic resources in crop improvement. *Theoretical and Applied Genetics,* **102**:1292–1298.

Upadhyaya HD, Salimath PM, Gowda CLL and Singh S (2007) New early-maturing germplasm lines for utilization in chickpea improvement. *Euphytica,***157**:195–208.

Upadhyaya*et al* (2011) Genomic tools and germplasm diversity for chickpea improvement. *Plant Genetic Resources: Characterization and Utilization,***9**(1):45-58.

Vanessa*et al* (2014) Effect of dietary pulse intake on established therapeutic lipid targets for cardiovascular risk reduction: a systematic review and meta-analysis of randomized controlled trials. *Canadian Medical Association Journal*.

Yadav SS*et al* (2004) Breading for improved productivity, multiple resistance and wide adaptation in chickpea (*Cicer arietinum* L.). *Plant Genetic Resources*, **2**:181–187.

7. Tapping Genetic Variation in Chickpea (*Cicer arietinum* L.) Landrace Collections to Enhance Productivity and Farming System Sustainability: What does Ethiopia have to offer?

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Chickpea (Cicer arietinum L.) is originated in South-eastern Turkey and the adjoining areas of Syria. The crop has been grown for multiple purposes since antiquity in Ethiopia and the country is considered as one of the secondary centers of genetic diversity. A large amount of chickpea landrace collections are held at the Institute of Biodiversity Conservation (IBC) in Ethiopia. Recent sample-based molecular and morphological characterization and evaluation of these germplasm accessions unveiled the existence of adequate amount of genetic diversityto be exploited in future chickpea improvement programs.Different eco-geographical origins possessed more or less distinct patterns of genetic diversity at molecular level (but not at phenotypic level), whereas adjacent regions mostly showed tendencies for more genetic similarity. This paper presents the magnitude and pattern of genetic diversity in Ethiopian chickpea landrace collections as a decision support tool for more effective utilization of local genetic resources in future breeding. The need for initiating a planned breeding program for improving traits of economic and ecological significance is discussed.

Key words: *Cicer arietinum*, characterization, Ethiopia, genetic diversity

Introduction

The genus *Cicer* has eight annual and 34 perennial species (Van der Maesen, 1987) of which *Cicer arietinum*is known as the only cultivatedspecies (Millan *et al*., 2006). An earlier study on the cytogenetic relationships of different *Cicer*species indicated that the wild *C. reticulatum* was the progenitor of the cultivated chickpea (Ladizinsky and Adler, 1976) but this proposition could not be reconfirmed with any other study (Ohri and Pal, 1991). The cultivated chickpea belongs to the family Fabaceae (formerly Leguminosae) and subfamily Faboideae. Different chromosome numbers were reported from early cytogenetic studies (van der Maesen, 1987) but it was later confirmed that chickpea is a diploid species having a chromosome number of $2n = 2x = 16$ (van der Maesen, 1987; Upadhyaya *et al*., 2008) with comparatively a small genome size of 740 Mbp (Arumuganathan and Earle, 1991).

Based on the presence of wild relatives, namely *C. reticulatum* and *C. echinospermum*, South-Eastern Turkey and the adjoining areas of Syria is considered as the most probable center of origin for chickpea (van der Maesen, 1987). Archeological evidences showed that chickpea was first domesticated in the Middle East before the late Neolithic period (as early as 3500 BC) in Turkey (Tanno and Willcox, 2006). The crop was probably diffused from its proposed center of origin to different continents of the world by the Phoenicians (The Worldwide Gourmet, 2010). As early as 1520 BC, chickpea was known to be grown in Ethiopia (Joshi *et al*., 2001), which is now considered as one of the secondary centers of genetic diversity for the crop (van der Maesen, 1987).

Chickpea has been grown in the Mediterranean, Southeastern Asia and East African sub-continents since antiquity (Muehlbauer and Tullu, 1997). The crop is grown in over 40 countries of the world on 11 million ha of land from which over 8 million tons of seed is annually harvested (Kassie *et al*., 2009). It is the second important pulse crop after common bean (*Phaseolusvulgaris*) at global level (Graham and Vance, 2003). The top ten world producers of chickpea are India, Pakistan, Turkey, Australia, Iran, Myanmar, Canada, Ethiopia, Mexico and Iraq, with over 93% of the globalproduction (Upadhyaya *et al*., 2008), mostly produced under rainfed marginal situations (Ali *et al*. 2002; Serraj *et al*., 2004; Toker *et al*., 2007).

Chickpea is a strictly self-pollinated crop (Muehlbauer and Tullu, 1997; Romeis *et al*., 2004; Toker *et al*., 2006) with two types of cultivars, *desi* and *kabuli*. The *desi* type has small darker seeds with a rough seed coat while the *kabuli* has larger seeds with lighter colour and a smoother seed coat. Existence of a pea-shaped third type characterizedby medium to small seed size and creamy colour was also recognized (Upadhyaya *et al*., 2008) as a sort of an intermediate type may be emerged as the result of crossing of the two(Muehlbauer and Tullu, 1997). About 75% of the area all over the world is covered by the *desi* and the remaining 25% by the *kabuli* types (Kassie *et al*., 2009). The *desi* type is dominant in Indian subcontinents, Ethiopia, Mexico and Iran while the *kabuli* type is dominant in Southern Europe, Northern Africa, Afghanistan, Pakistan and Chile (Upadhyaya*et al*., 2008; Kassie *et al*., 2009).

Chickpea is produced for different purposes including food, feed and foreign currency earnings. In addition, it replenishes soil fertility as it fixes a substantial amount of atmospheric nitrogen in symbiotic association with two species of root nodule bacteria, namely *Mesorhizobium ciceri* and *Mesorhizobium mediterraneum* (Rivas *et al*., 2006; Willems, 2006). Chickpea may fix well over 100 kg of atmospheric nitrogen ha^{-1} (Crouch *et al*., 2004; Shiferaw *et al*., 2004) with a contribution of over 500,000 MT of nitrogen every year in developing countries (Hardarson, 2004), thereby resulting in significant saving for smallholder farmers from less nitogen fertilizer use (IFPRI, 2010).

Despite the significant economic and ecological importance, the productivity of chickpea in Ethiopia is far below its potential (Bejiga and van der Maesen, 2006). It is assumed that genetic potential yields of chickpea under ideal condition on experimental plots may reach 5 t ha^{-1} (Muehlbauer and Tullu, 1997). Improved varieties released in Ethiopia are reported to yield 2.8 t ha^{-1} on research stations (Kassie *et al*., 2009) and 1.8 t ha^{-1} on farmers' fields (Jarso *et al*., 2011). Nevertheless, the national average yield is low (Kassie *et al*., 2009; CSA, 2011; Jarso *et al*., 2011).

Ethiopia, as the secondary center of genetic diversity for many crops, owns an immense wealth of genetic diversity for many legumes (Hagedorn, 1984). Tanto and Tefera (2006) reported that about 1155 chickpea landrace collections from different eco-geographical origins are held at the Institute of Biodiversity Conservation (IBC) in Ethiopia. Wild relatives, particularly *C. cuneatum*, were known to exist in numerous regions in Ethiopia (Taddesse *et al*., 1994). Breeding progress depends on the magnitude of genetic variability among the genetic materials under consideration, heritability of a given trait in a given environment and the level of selection intensity applied (Falconer, 1989; Hayward and Breese, 1993; Singh, 2002).For effective utilization in breeding programs of the available genetic variability, genetic characterization and evaluation should make an integral part of germplasm collection and conservation programs (Carvalho, 2004).

Genetic characterization and evaluation of the available germplasm not only unveils the magnitude and pattern of genetic diversity available in the germplasm for conservation but also enables the determination of useful genes in germplasm and the possible progresses that can be made through future breeding activities (Arumuganathan and Earle, 1991;

Haywardand Breese, 1993; de Vicente *et al*., 2005). Screening and selection would generate promising genotypes only if the source germplasm is genetically diverse. Crossing is also likely to produce higher heterosis, desirable genetic recombination and segregation in progenies when it is made between genetically diverse parents (Singh, 2002). The theme of this paper,mainly based on a comprehensive study by the first author as part of his PhD thesis (Keneni, 2012),is to report results of an effort made to characterize and evaluate the genetic diversity of Ethiopian chickpea germplasm accessions at molecular and morpho-agronomic levels with the potential and possibilities for genetic improvement for attributes of economic and ecological significance.

Materials and Methods

One hundred fifty five chickpea entries (but only 130 for response to infestation by bruchid) were considered for the study. One hundred thirty nine of these were Ethiopian germplasm accessions collected by IBC, whereas 16 were introductions from ICARDA and ICRISAT. Eight genotypes of the introductions represent improved varieties released in Ethiopia. In addition, three non-nodulating checks (ICC 19180, ICC 19181, and PM 233) were included in the test entries for comparision. The local accessions thus represent over 12% of the 1155 chickpea germplasm collections (Tanto and Tefera, 2006). Description of the test entries is given in Table 1, along with the map of the geographical origins of the Ethiopian materials in Fig 1.

Table 1. Description of the test genotypesdesignated by their accession number

Geographical origin	No of genotypes	Name of genotypes (Serial numbers in bracket stand for designation in this study)
Arsi	13	231327 (1), 231328 (2), 209093 (3), 208829 (4), 209094 (5), 209092 (6), 209096 (7), 209097 (8), 209098 (9), 41002 (10), 207761 (11), 207763 (12), 207764 (13)
East Gojam	13	41268 (14), 41026 (15), 41074 (16), 41075 (17), 41073 (18), 41076 (19), 41021 (20), 41027 (21), 41222 (22), 207734 (23), 41103 (24), 41320 (25), 41029 (26)
West Gojam	13	41015 (27), 41271 (28), 41272 (29), 41276 (30), 207745 (31), 41275 (32), 41277 (33), 207743 (34), 207744 (35), 41273 (36), 41274 (37), 207741 (38), 207742 (39)
North Gonder	13	41316 (40), 41298 (41), 41311 (42), 41313 (43), 41280 (44), 41312 (45), 41315 (46), 41308 (47), 41299 (48), 41046 (49), 41047 (50), 41304 (51), 41303 (52)
South Gonder	12	41295 (53), 41296 (54), 41289 (55), 41290 (56), 41284 (57), 41291 (58), 41297 (59), 41293 (60), 41019 (61), 41048 (62), 41049 (63), 41053 (64)
West Harargie	11	41054 (65), 41052 (66), 209082 (67), 209083 (68), 209084 (69), 209091 (70), 209087 (71), 209088 (72), 209089 (73), 209090 (74), 209081 (75)
East Shewa	13	41159 (76), 41160 (77), 41161 (78), 207661 (79), 207667 (80), 207666 (81), 41141 (82), 207665 (83), 41134 (84), 41128 (85), 41168 (86), 41129 (87), 41130 (88)
North Shewa	13	41110 (89), 207657 (90), 41111 (91), 41106 (92), 207658 (93), 41142 (94), 41207 (95), 41215 (96), 41216 (97), 41066 (98), 41011 (99), 41007 (100), 41008 (101)
West Shewa	13	41186 (102), 209035 (103), 41176 (104), 41175 (105), 41174 (106), 209027 (107), 41170 (108), 41171 (109), 41185 (110), 209036 (111), 41190 (112), 41195 (113), 41197 (114)
Tigray	12	207150 (115), 207151 (116), 207563 (117), 207564 (118), 207894 (119), 207895 (120), 213224 (121), 219797 (122), 219799 (123), 219800 (124), 219803 (125), 221696 (126)
South Wello	13	41114 (127), 212589 (128), 41113 (129), 207659 (130), 207660 (131), 41115 (132), 225878 (133), 225873 (134), 225874 (135), 225877 (136), 207645 (137), 207646 (138), 225876 (139)
ICRISAT	5	ICC 5003 (140), ICC 4918 (141), ICC 4948 (142), ICC 4973 (143), ICC 15996 (144)
National releases	8	Shasho (145), Arerti (146), Worku (147), Akaki (148), Ejere (149), Teji (150), Habru (151), Natoli (152)

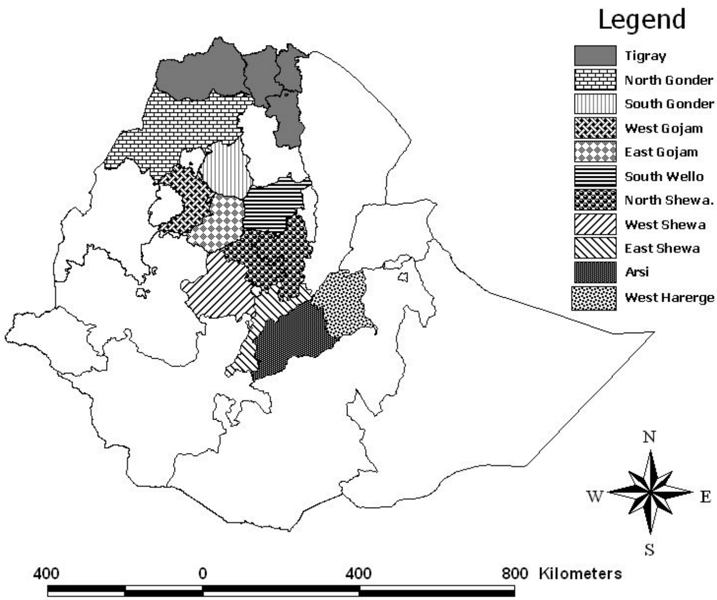

Figure 1. Map of Ethiopia showing the approximate areas of origins (shaded region) of the 139 germplasm accessions (NB: all boundaries are approximate and nothing to do with political borders).

Four experiments were conducted, namely characterization and evaluation of the genotypes for simple sequence repeats (SSR) marker, symbio-agronomic performance, phosphorus upatke and use efficiency and response to infestation by adzuki bean beetle resistance using the same set of genotypes but the last experiment was conducted only with 130 of the genotypes.

For the molecular analysis, DNA was extracted from bulk leave samples of 5-10 plants as suggested by Gilbert *et al.* (1999)using the cetyltriethylammonium bromide (CTAB) method (Doyle and Doyle, 1990). The quality of DNA was tested and the amount in each sample was quantified on agarose gel (1%) and optimized for PCR reactions using a lambda DNA standard, pUC 19 (50 μg). Fifty primers of SSR marker were used for PCR reaction but records were taken only on 33 polymorphic primers. The amplified products were visually scored using binary numbers (1 for presence of band and 0 for absence) (Warburton and Crossa, 2002; Saeed *et al*., 2011). The softwares GeneAlex version 6 (Peakall and Smouse,2006) and Structure version 2.2 Pritchard *et al*. (2000) were used for the analysis of the molecular data.

Charactertirization and evaluation for attributes of agronomic performance and symbiotic nitrogen fixation was conducted under field conditions at two locations (Ginchi and Ambo) during the main cropping season of 2009/10. An effective isolate of *Rhizobium* for chickpea, CP EAL 004, originally isolated by the National Soil Laboratory from a collection of Ada'a District of East Shewa Zone was used for the study.

A randomized complete block design with 4 replications was used. A blanket basal application of phosphorus was made to all plots in the form of triple supper phosphate (TSP) at the recommended rate. Data were collected on both agronomic and symbiotic characters including shoot and grain nitrogen contents. The amount of total nitrogen fixed in shoots and grains of the nodulating test genotypes was estimated by the difference method using a non-nodulating reference check (Smith *et al.*, 1984; Zapata, 1990).

Characterization and evaluation for phosphorus uptake and use efficiency of the same 155 chickpea genotypes was laid down in a randomized complete block design with 2 replications. Each block was divided into two adjacent sub-blocks to accommodate both phosphorus fertilized and unfertilized plots. Whole set of genotypes were planted separately in alternating adjacent sub-blocks with and without phosphorus in side-by-side pairs. One sub-block in each block received basal application of phosphorus in the form of triple supper phosphate (TSP) containing 46% P_2O_5 in water soluble form at the recommended rate and not to the other sub-block. As a source of nitrogen, all genotypes were inoculated with an effective isolate of *Rhizobium* for chickpea, CP EAL 004. All other crop management practices were applied uniformly to all genotypes. Data were collected on attributes of phosphorus uptake and use efficiency including shoot and grain phosphorus contents. The determination of phosphorus content was made using the wet digestion technique (AOAC, 1970) at Holetta Soil Science Research Laboratory. The amount of total phosphorus accumulated in shoots and grains of the genotypes was estimated by the balance method (Cassman *et al*., 1998; Syers *et al*., 2008).

Characterization and evaluation for adzuki bean beetle resistance was conducted in Entomology Laboratories under ambient temperature and relative humidity at Holetta, Ambo and Debre Zeit Agricultural Research Centers, Ethiopia. Adzuki bean beetles were obtained from Holetta Agricultural Research Center (Entomology Research Section) and mass reared in the laboratory at the same center on a bulk of chickpea seeds of one of the susceptible *Kabuli* cultivars, Shasho, under ambient room temperature and relative humidity. Two hundred seeds of each genotype were put in a 250 ml (6 cm x 7 cm) plastic jar with a perforated lid for free air circulation. Fourteen 1-2 day old unsexed adults were randomly selected and placed in each jar. The male to female ratio in this insect being nearly 1:1 (Lemma, 1990), it was assumed that each jar received 7 males and 7 females. The ovipositing adults were kept in the jars for 10 days after introduction and then were removed from the jars. Records on the first progeny were taken until complete adult emergence. The first progeny was removed from the jars in the same way as the initial parents for further evaluation of the level of attack and loss incurred by the second progeny. The experiment was conducted in a randomized complete block design with 3 replications. Data were collected on a number of insect related and seed damage traits.

The SAS computer package (SAS Institute, 1996) was used to test for presence of outliers and normality of residuals in all the cases. Data based on insect count and percentage values were log and ARCSINE transformed, respectively, for statistical analysis when necessary (Little and Hills, 1978; Gomez and Gomez, 1984) and untransformed means were presented otherwise. Data based on nodule (number, weight and nodulation index) were also log transformed to offset heterogeneity (Little and Hills, 1978; Gomez and Gomez, 1984) for statistical analysis (Doughton *et al*., 1995). For combined analysis of variance, the homogeneity of error variance was tested using the F-max method of Hartley (1950), which is based on the ratio of the larger mean square of error (MSE) from the separate analysis of variance to the smaller mean square. Pooled analysis of variance over location was conducted to quantify the total variation among the genotypes. For the studies of symbiotic nitrogen fixation and phosphorus uptake and use efficiency, mean separation at 1% or 5% probability levels was done using Dunkan‘s Multiple Range Test (DMRT) following Gomez and Gomez (1984). However, for response to infestation by the adzuki bean beetle, mean separation was done using Tukey‘s honestly significant difference test as suggested by Sokal and Rohlf (1997).

Clustering of the genotypes was performed by average linkage method or Ward‘s agglomerative hierarchical classification with Euclidian distance (Ward 1963). Points where local peaks of the pseudo F statistic join with small values of the pseudo t^2 statistic followed by a larger pseudo t^2 for the next cluster fusion were examined to decide the number of clusters. Genetic distances between clusters were calculated as standardized Mahalanobis‘s D^2 statistics. The D^2 values obtained for pairs of clusters were considered as the calculated values of Chi-square

(X^2) and were tested for significance both at 1% and 5% probability levels against the tabulated value of X^2 for ‗P' degree of freedom, where P is the number of characters considered (Singh and Chaudhary 1985). Dendrograms were built based on the average linkage method or the Ward's agglomerative hierarchical classification with Euclidian distance (Ward 1963).

For the determination of the existence of useful genes in the germplasm and the possible progresses that can be made through future breeding activities, comparisons were made between selected subsets of the 5% best genotypes and the whole population. The absolute value of Student's t test was calculated to compare genotypic values of the 5% best selected genotypes with mean performances of the base population as:

$$t = \frac{\overline{X} - \mu}{\sigma/\sqrt{n}}$$

Where ($\overline{X}$) is mean of selected genotypes, μ is mean of the base populations, σ is the standard deviation calculated for the base populations and n is the number of genotypes selected from the base population for better performance. The significance of the difference between the population parameter (μ) and sample mean ($\overline{X}$) was tested using t table, i.e. when the calculated value of t is more than the tabulated t value, the difference was considered significant (Singh, 2001).

Results and Discussion

Performance of the genotypes for economic and ecological attributes

Analysis of variance of symbio-agronomic characters, phosphorus uptake and use efficiency and adzuki bean beetle resistance showed significant differences among the genotypes, locations and genotype by location interaction effects for a number of traits. However, genotype by phosphorus level interaction effects were non-significant except in a few cases (data not shown).

A number of landraces superior to introduced and released genotypes were identified for attributes of symbio-agronomic characters but not for seed size where the best genotypes were all from exotic sources. Grain yield performance varied from 31-70 g 5 plants^{-1} and seed size from 82-288 g/1000 seeds. The comparison of the different genotypes with the recently released Natoli variety of chickpea showed the superior performances of a number of landraces for a number of agronomic attributes. The top 5% best accessions for grain yield, for instance, include Acc. Nos. 41274, 207763, 41111, 207742, 231328, 207563, 41053 and 212589. The same accessions were found to be among the best 5% for other agronomic traits like economic growth rate, grain production efficiency, and biomass production rate. Nevertheless, there was no landrace comparable to the improved genotypes for seed size, the top 5% best performing genotypes for this trait being ICC 4918, ICC 5003, ICC 19180, Natoli, Teji, Ejere, Arerti and Habru which are introductions either from ICRISAT or ICARDA. A number of other superior accessions for multiples of other traits of ecological significance were also identified (Table 2).

Table 2. Comparison of mean performances of 5% of the accessions selected for best agronomic performance with Natoli and with mean performances of released varieties

Acc. No.	Mean of selected accession*	Comparative advantage (% over)		Acc. No.	Mean of selected accession	Comparative advantage (% over)	
		Natoli	MRV**			Natoli	MRV
No. of pods (5 plants^{-1})				No. of seeds (5 plants^{-1})			
41289	515a	94.34	105.18	41111	595a	144.86	146.89
41274	497ab	87.55	98.01	207658	575a	136.63	138.59
41215	486a-c	83.4	93.63	41185	566a-c	132.92	134.85
41284	485a-c	83.02	93.23	41274	556a-d	128.81	130.71
209091	480a-d	81.13	91.24	41215	556a-d	128.81	130.71
41015	471a-e	77.74	87.65	ICC 4948	541a-e	122.63	124.48
207563	466a-f	75.85	85.66	207764	535a-f	120.16	121.99
41114	464a-g	75.09	84.86	209084	535a-f	120.16	121.99
Natoli	265u-z	---	5.58	Natoli	243z	---	0.83
MRV	251w-z***	-5.28	---	MRV	241z	-0.82	---
Biomass weight (g 5 plants^{-1})				Harvest index			
41284	224.32a	32.55	45.1	231328	42.88a	29.59	34.21
41274	204.41ab	20.79	32.22	209093	42.58ab	28.68	33.27
207734	198.76a-c	17.45	28.56	209094	42.07a-c	27.14	31.67
41275	194.41a-d	14.88	25.75	41002	40.41a-d	22.12	26.48
Habru	191.06a-e	12.9	23.58	231327	40.27a-e	21.7	26.04
ICC 19180	188.92a-e	11.64	22.2	207764	40.12a-f	21.25	25.57
41185	183.47a-f	8.41	18.67	207741	40.08a-f	21.12	25.45
207563	182.83a-g	8.04	18.26	41115	39.47a-g	19.28	23.54
Natoli	169.23a-m	---	9.46	Natoli	33.09g-w	---	3.57
MRV	154.6b-n	-8.65	---	MRV	31.95j-x	-3.45	---

Table 2. Continued…

Grain production efficiency (g 5 plants^{-1})				Biomass production rate (%)			
207763	70.65a	63.69	57.17	41284	198.82a	37.65	47.06
41111	70.35ab	63	56.51	41274	181.47ab	25.64	34.22
41274	69.71a-c	61.52	55.08	ICC 19180	175.17a-c	21.28	29.56
207742	69.14a-d	60.19	53.82	207734	170.96a-d	18.36	26.45
41053	68.21a-e	58.04	51.75	41275	169.91a-e	17.63	25.67
209093	67.70a-f	56.86	50.61	Habru	169.65a-f	17.45	25.48
207658	67.57a-f	56.56	50.32	207743	162.38a-g	12.42	20.1
219800	66.70a-g	54.54	48.39	207563	161.98a-g	12.14	19.81
Natoli	43.16q-z	---	-3.98	Natoli	144.44b-n	---	6.83
MRV	44.95m-z	4.15	---	MRV	135.2b-o	-6.4	---
Economic growth rate (%)				**Grain yield (g 5 plants^{-1})**			
41274	125.02a	18.6	34.65	41274	70.10a	30.76	42.22
ICC 19180	118.90ab	12.8	28.06	207763	66.05ab	23.2	34
207763	113.75a-c	7.91	22.51	41111	65.16a-c	21.54	32.2
41268	112.48a-d	6.71	21.14	207742	64.22a-d	19.79	30.29
231328	111.83a-e	6.09	20.44	231328	63.62a-e	18.67	29.07
41293	111.58a-e	5.85	20.17	207563	63.10a-f	17.7	28.02
41111	110.44a-f	4.77	18.94	41053	62.59a-g	16.75	26.98
207563	109.29a-g	3.68	17.71	212589	62.52a-g	16.62	26.84
Natoli	105.41a-l	---	13.53	Natoli	53.61a-t	---	8.76
MRV	92.85b-v	-11.92	---	MRV	49.29b-v	-8.06	---

*Figures sharing the same letter(s) or ranges of letters with in the same column are non-significantly different; **MRV = mean of released varieties, ***significance levels of the mean performances for released varieties was approximated from equivalent values of the test genotypes for the same character.

The amount of fixed nitrogen ranged from 13-49% in foliage, 30-44% in grain and 28-40% in total above ground biomass. The top 5% best accessions for total (shoot + grain) nitrogen fixation include Acc. Nos. 41222, 41029, 41021, 41074, 41075, 41129, 41320 and 41026. These landraces could register additional fixation ranging from 19-24% over the standard check, Natoli. There were also some other genotypes which had better fixations either in their shoots (e.g. 41103) or grains (e.g. 207734). Two introductions from ICRISAT, namely ICC 5003 and ICC 4973, were also among the top 5% best fixers of nitrogen in their shoot. The best assimilators of fixed nitrogen were Acc. Nos: 41115, 207659, 219799, 207150, 41277, 41113 and 207894 (Table 3).

The application of phosphorus fertilizer increased a number of ecologically and economically important characters including nodulation and symbiotic nitrogen fixation. Yield increments of 15% at Ambo and 17% at Ginchi were recorded due to application of phosphorus (data not shown). Based on the criteria of nutrient efficiency classification suggested by Gerloff (1977), an efficient cultivar has higher mean performance than the other cultivars under low nutrient supply, while a responder cultivar has higher mean performance under high nutrient supply. Accordingly, 34% of the genotypes were grouped as inefficient, non-responder; 19% as inefficient, responder; 32% as efficient, responder; and 15% as efficient, non-responder (Fig 2).

Table 3. Comparison of mean performances of 5% of the accessions selected for best symbiotic performance with Natoli, a recently released variety, and with mean performances of released varieties.

Acc. No.	Mean of selected accession*	Comparative advantage (% over)		Acc. No.	Mean of selected accession	Comparative advantage (% over)	
		Natoli	MRV**			Natoli	MRV
Shoot N fixation (%)				Grain N fixation (%)			
41222	48.67a	53.73	70.59	41021	43.54a	27.09	22.72
41026	47.29ab	49.37	65.76	41029	43.41ab	26.71	22.35
41074	46.05a-c	45.45	61.41	41222	42.79a-c	24.9	20.6
41103	45.63a-d	44.13	59.94	41074	42.48a-d	23.99	19.73
41075	45.04a-e	42.26	57.87	41320	42.07a-e	22.8	18.57
ICC 4973	42.85a-f	35.34	50.19	207734	42.05a-e	22.74	18.52
ICC 5003	42.80a-f	35.19	50.02	41129	42.04a-e	22.71	18.49
41320	42.11a-g	33.01	47.6	41075	41.75a-f	21.86	17.67
Natoli	31.66b-v	---	10.97	Natoli	34.26e-u	---	-3.44
MRV	28.53f-x	-9.89	---	MRV	35.48b-u	3.56	---
Biomass N fixation (%)				Nitrogen harvest index			
41222	40.20a	23.88	22.75	41115	0.69a	18.97	21.05
41029	40.11ab	23.61	22.47	207150	0.67ab	15.52	17.54
41021	39.86a-c	22.84	21.71	231328	0.66a-e	13.79	15.79
41074	39.31a-d	21.14	20.03	207741	0.66a-e	13.79	15.79
41075	38.85a-e	19.72	18.63	209036	0.66a-e	13.79	15.79
41129	38.70a-e	19.26	18.17	207895	0.66a-e	13.79	15.79
41320	38.54a-g	18.77	17.68	219799	0.66a-e	13.79	15.79
41026	38.46a-g	18.52	17.44	41113	0.66a-e	13.79	15.79
Natoli	32.45e-y	---	-0.92	Natoli	0.58d-z	---	1.75
MRV	32.75d-y	0.92	---	MRV	0.57g-z	-1.72	---

Table 3. Continued…

Shoot N yield (g 5 plants^{-1})				Grain N yield (g 5 plants^{-1})			
41275	1.83a	37.59	45.24	41274	2.46a	35.91	44.71
41103	1.82ab	36.84	44.44	41111	2.34ab	29.28	37.65
41026	1.76a-c	32.33	39.68	207763	2.33a-c	28.73	37.06
207734	1.71a-d	28.57	35.71	207734	2.33a-c	28.73	37.06
41289	1.70a-e	27.82	34.92	207742	2.29a-d	26.52	34.71
41185	1.69a-e	27.07	34.13	ICC 19180	2.28a-e	25.97	34.12
41284	1.67a-f	25.56	32.54	41268	2.23a-f	22.65	30.59
41320	1.66a-g	24.81	31.75	41316	2.22a-g	22.65	30.59
Natoli	1.33a-o	---	5.56	Natoli	1.81a-p	---	6.47
MRV	1.26a-o	-5.26	---	MRV	1.70b-q	-6.08	---
Biomass N yield (g 5 plants^{-1})				Fixed N assimilation efficiency (%)			
207734	4.05a	28.57	36.82	ICC 19180	90.61a	15.38	10.16
41274	3.87ab	22.86	30.74	41115	90.15ab	14.8	9.6
41275	3.80a-c	20.63	28.38	207659	89.74a-c	14.27	9.11
41185	3.80a-c	20.63	28.38	219799	89.03a-d	13.37	8.24
41111	3.75a-d	19.05	26.69	207150	88.74a-e	13	7.89
41284	3.70a-d	17.46	25	41277	88.10a-f	12.19	7.11
41103	3.69a-d	17.14	24.66	41113	87.79a-g	11.79	6.74
41289	3.68a-e	16.83	24.32	207894	87.10a-h	10.91	5.9
Natoli	3.15a-m	---	6.42	Natoli	78.53d-r	---	-4.52
MRV	2.96a-m	-6.03	---	MRV	82.25a-p	4.74	---

*, Figures sharing the same letter(s) or ranges of letters with in the same column are non-significantly different;
**, MRV = mean of released varieties,
***, significance levels of the mean performances for released varieties were approximated from equivalent values of the test genotypes for the same character.

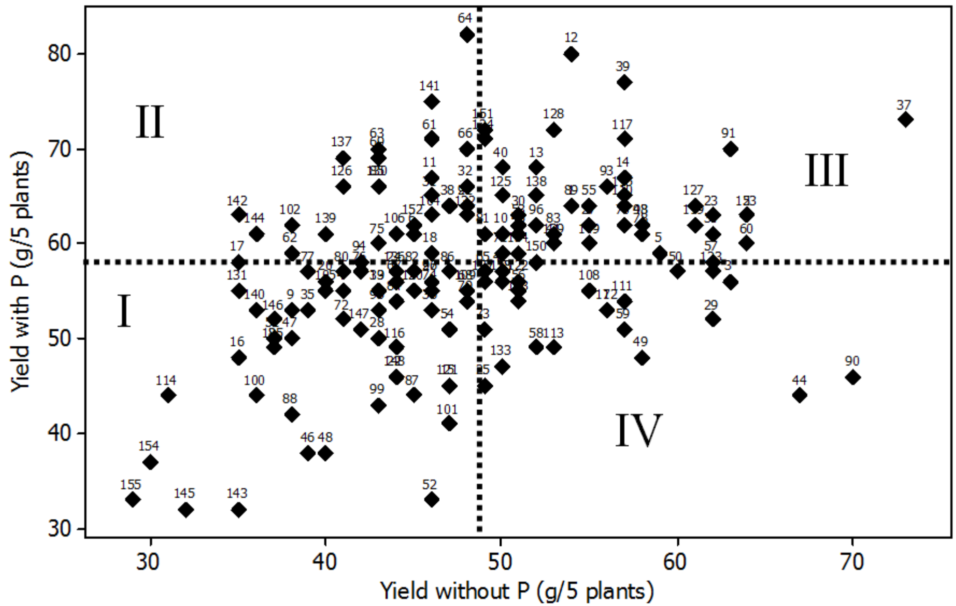

Figure 2. The relationship between grain yield in 155 genotypes grown with and without P at two locations showing different phosphorus response and use efficiency groups: (I) inefficient, non-responder; (II) inefficient, responder; (III) efficient, responder; and (IV) efficient, non-responder. The serial numbers marking the data labels stand for genotypes as given in Table 1.

From this result, it can be implicated that different possible breeding strategies may be sought in order to address different needs under different production domains. First, where farmers can apply adequate amount of phosphorus, varieties that are responsive to soil fertility level may be developed from the responsive sources in order to exploit the yield potential. Secondly, breeding phosphorus efficient chickpea cultivars under phosphorus deficient conditions where farmers cannot afford the application of phosphorus fertilizer could be considered as an alternative strategy. Thirdly, developing genotypes which can compromise and consistently better perform at both high and low soil phosphorus levels could also be a possibility as such categories of genotypes also existed among the genotypes tested in this study (Fig. 2).

The top 5% best efficient, responder genotypes for grain yield in response to phosphorus application include Acc. Nos: 41274, 41111, 207742, 207563, 207763, 231328, ICC 19180 and 41114. Three of these accessions, namely 41274, 207563 and 41111, also repeated best performances as efficient, responder genotypes for biomass weight. Other efficient, responder genotypes for biomass weight include: Acc. Nos. 207743, 41015, 41066, 41185 and Ejere.

Pooled analysis of variance showed significant difference among the genotypes for response characters to infestation by adzuki bean beetle, but complete resistance to adzuki bean beetle was not observed among the genotypes. On the relative basis, Acc. Nos:41320, 41289, 41291, 41134, 41315, 207658, 41103, 41168, 41142, 41174, 41029, 41207, 209087, 231327, 41161 and 41008 showed better partial resistance (Keneni, 2012). This study showed that improving adzuki bean beetle resistance through selection in this gene pool would be difficultbecause of the existence of sources of only partial resistance to adzuki bean beetle. Beyond relative differences, sources of complete resistance to adzuki bean beetlehave not been obtained, maybe because genes for complete resistance to this storage insect are underrepresented or under expressed in Ethiopian chickpea germplasm accessions.

Molecular Diversity for SSR Marker

Molecular analysis of variance (AMOVA) showed a 73% and 27% variation within and among populations, respectively (Table 4). Saeed *et al*. (2011) evaluated diversified populations of chickpea involving cultigens, landraces, internationally developedimproved lines and wild relatives and found relatively lower within population variance of 59% and higher among population variance of 41% as compared to the present results. The relatively higher among population variance obtained could be attributed to the presence of wild relatives included in the study.

Table 4. Analysis of Molecular Variance (AMOVA) showing the distribution of genetic diversity within and among populations of chickpea entries from different sources of origins.

Source of variation	df	SS	MS	Variance		Statistic	Value	P
				Estimated	%			
Among populations (AP)	11	602.36	54.76	3.51	27			
Within population (WP)	143	1361.57	9.521	9.52	73	PhiPT	0.27	0.01
Total (TOT)	154	1963.92	---	13.03	100			

*df stands for degrees of freedom; SS for sum of square and MS for mean of squares

Based on the magnitude of the genetic distance (GD), more differentiations were revealed between the different populations from different geographical regions of Ethiopia and improved genotypes from ICARDA and ICRISAT (GD range = 0.077-0.138, $\overline{X}$ = 0.107). The second largest inter-regional distance range was observed between accessions from Arsi and those from the rest of the sources (GD= 0.081-0.134, $\overline{X}$ =0.106). The highest values of GD (0.138 and 0.134) were recorded between accessions from East Gojam and the improved genotypes and those from Arsi and South Wello in that order. The smallest genetic distance (GD=0.016) was observed between accessions from West Gojam and North Gonder (Table 5). Differences among the original introductions, the nature and degree of both human and natural selection after introduction and/or specificities of ecological and agricultural conditions as major forces of evolution are normally expected to give rise to a distinct form of genetic diversity (Ford-Lloyd and Jackson, 1986; Spagnoletti and Qualset, 1987).

Table 5. Pairwise population Nei's genetic distance showing the magnitude of genetic differentiation between chickpea populations from different sources.

Origin*	**AR**	**EG**	**WG**	**NG**	**SG**	**WH**	**ES**	**NS**	**WS**	**TG**	**SW**
AR	0.000										
EG	0.102	0.000									
WG	0.106	0.039	0.000								
NG	0.089	0.031	0.022	0.000							
SG	0.091	0.053	0.050	0.034	0.000						
WH	0.088	0.049	0.041	0.031	0.036	0.000					
ES	0.136	0.082	0.055	0.069	0.071	0.050	0.000				
NS	0.094	0.064	0.038	0.039	0.050	0.034	0.061	0.000			
WS	0.126	0.077	0.055	0.054	0.073	0.068	0.080	0.064	0.000		
TG	0.125	0.061	0.063	0.058	0.066	0.067	0.084	0.069	0.044	0.000	
SW	0.139	0.096	0.075	0.080	0.092	0.066	0.064	0.059	0.076	0.069	0.000
IC	0.134	0.144	0.106	0.112	0.103	0.113	0.121	0.085	0.095	0.122	0.123

*AR = Arsi; EG = East Gojam; WG = West Gojam; NG=North Gonder; SG=South Gonder; WH = West Harerge; East Shew = ES; North Shewa = NS; West Shewa = WS; TG=Tigray; SW = South Wello; IC=improved cultivars.

Pattern of Molecular Diversity for SSR Marker

The populations from the different sources were grouped into 5 clusters of distinct genetic populations (Fig. 3) showing that they had evolved from different lines of ancestry or derived from independent events of evolutionary forces (genetic drift, mutation, migration, selection and in flux/out flux of genes in the form of germplasm exchange) that separated them into related but different gene pools. The clustering pattern showed the existence of definite pattern of relationships between geographical origins and genetic diversity for microsatellite markers. High levels of intra-regional similarities were observed within each origin or, in other cases, between adjoining geographical origins. Populations from the same geographical origin were observed to characteristically fall exclusively in a single or two clusters.

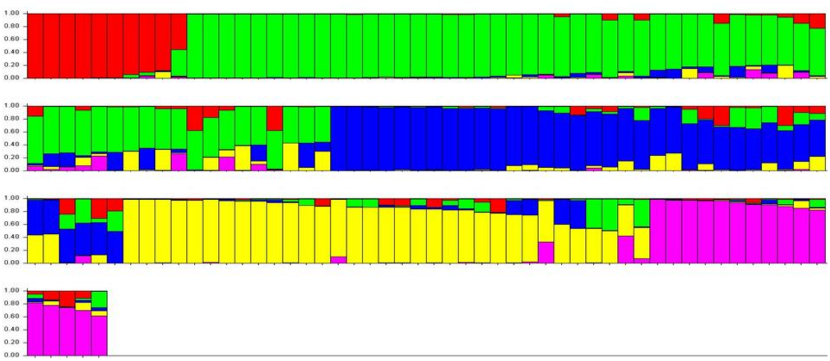

Figure 3. Structure bar-plot of the tested chickpea genotypes from different origins showing the pattern of assignment of the genotypes from the 12 sources of origins into 5 clusters (red = Arsi, green = East Gojam, West Gojam and South Gonder, Blue = West Harargie, East Shewa and North Shewa, Yellow = West Shewa, Tigray and Wello, and pink = introduced).

Some clusters constituted populations mostly from the same geographical origin while others had populations from more than one sources and, hence, the number of entries varied from cluster to cluster. The cross-border similarities between a few adjoining regions may be attributed, at least in part, to seed movements among neighboring regions. The first cluster (C_1), constituted accessions mainly from Arsi and, the last cluster, C_5, constituted almost entirely improved genotypes regardless of being kabuli and desi types. Likewise, the only kabuli type landrace (Acc. No. 41197) collected from West Shewa Zone was grouped in the same cluster with the desi types collected from the same origin rather than with the kabuli types in cluster C_5. This indicated that genotypes from different seed types might have similar genetic background for microsatellite markers provided that they are exposed to similar events of domestication, both natural and artificial selection. The rest of the clusters (i.e. C_2-C_4) comprised accessions from two or more geographical origins grouped together showing closer genetic relationships. The second cluster (C_2) constituted accessions mostly from Gojam and Gonder; the third cluster (C_3) comprised those from Harerge and East and North Shewa while the fourth cluster (C_4) consisted of accessions from West Shewa, Tigray and South Wello.

Conversely, accessions from Tigray and Wello, which are frequently experiencing severe drought, showed a significant level of genetic similarity with accessions from the geographically non-adjoining West Shewa. The latter is in fact among the most important producers of chickpea. East Harerge, another drought-prone region, also shared similar ancestral gene pool with the adjoining East Shewa. The probable reason for these impressive genetic similarities between accessions from Tigray and Wello with those from West Shewa, and those from West Harerge with those from East Shewa and implicitly North Shewa (via East Shewa) could be related to massive seed movements associated with response to recurrent drought.

According to McGuire and Sperling (2008), periodic provision of a huge amount of seeds of many crops including chickpea (as a suitable crop following failure of long-season crops) has a long history in drought-prone areas in Ethiopia. The native accessions in these areas may become genetically eroded and significantly replaced with seeds purchased from other regions.

Cluster analysis for multivariate phenotypic performances

Cluster analysis of the 155 genotypes distinguished six different groups for symbio-agronomic characters, five clusters in the absence and six clusters in the presence of phosphorus fertilizer and 130 chickpea genotypes were primarily grouped into three clusters for response characters to bruchid infestation (Fig. 4). The first cluster, mostly followed by the second cluster, had the largest number of accessions in all the cases. The higher number of clusters when the crop was grown with phosphorus may be a manifestation that the application of phosphorus resulted in better expression of genetic diversity than when phosphorus is not applied.

It is interesting to note from the hierarchical classification of the genotypes using a dendrogram that, no matter how many clusters above two are formed, the two non-nodulating genotypes included as reference checks for symbiotic nitrogen fixation always clustered together into a single group except for cluster analysis based on response characters to bruchid infestation (Fig. 4). The sharp distinctness of the non-nodulating genotypes from all the nodulating genotypes (both landraces and introductions) could be due to the small sample size of the former or due to the fact that the non-nodulating behaviour is associated with agronomic inferiority as reflected in this study.

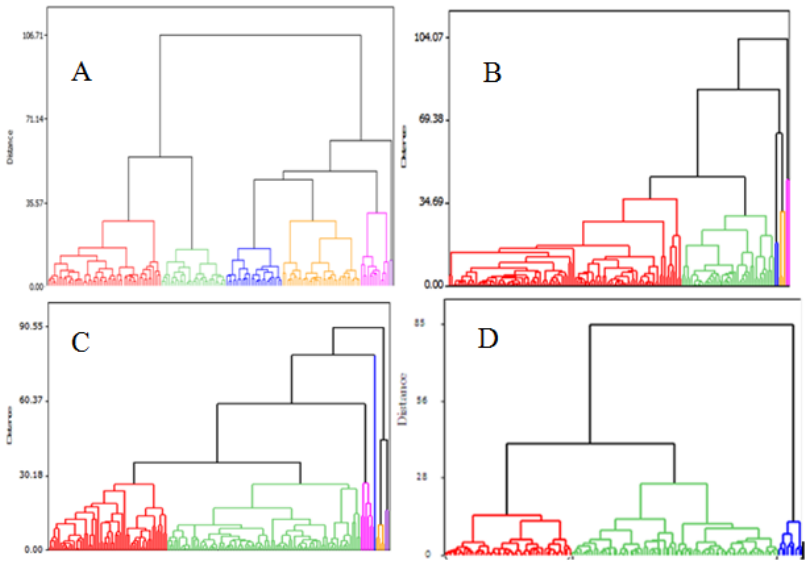

Fig. 4. Dendrograms of hundred fifty five chickpea genotypes (130 for response to infestation by bruchid) built based on attributes of (A) symbio-agronomic characters, P use efficiency without P fertilizer, (C) P use efficiency with P fertilizer and (D) response characters to infestation by adzuki bean beetle. Note that each cluser is marked by a different colour.

Distance analysis for multivariate phenotypic performance

For symbio-agronomic characters, the standardized Mahalanobis D^2 statistics showed existence of high genetic distances among clusters. The first exceptionally divergent D^2 values were obtained between clusters ranging from C_1 to C_5 on the one hand and cluster C6 on the other hand with D^2 value ranging from 25465 to 25744. The uniquely high distance values in this case may stem from the presence of highly contrasting non-nodulating references together with nodulating test genotypes, which resulted in D^2 values disproportionately high among the clusters.

For symbio-agronomic characters, the maximum genetic distance was found between C_4 and C_6 with D^2 = 25744. The second most divergent clusters were C_1 and C_6 with D^2 = 25718 and the third were C_3 and C_6 with D^2 = 25649. The fourth and fifth most divergent clusters were C_2 and C_6 with D^2 = 25612 and C_5 and C_6 with D^2 = 25465, respectively. The most divergent classes separated all genotypes (C_1-C_5) on one side from the non-nodulating references (C_6) on the other side (Table 6). However, it was witnessed that introductions from foreign sources relatively more closely related to the non-nodulating references (D^2 = 25465) than the local landraces (D^2 = 25612-25744) disregarding the contribution of a single Indian introduction which was exceptionally grouped with the landraces in cluster C_2 (Table 6). The local accessions were also more closely related among themselves than with the introductions from foreign sources for both symbiotic and agronomic characters.

In the second category, clusters C_1-C_4 which were comprised of only local accessions with the exception of a single genotype (ICC 4918 in cluster C_2) showed more divergence with cluster C_5 which constituted all improved genotypes introduced from ICRISAT and ICARDA (D^2 = 72-84). Clusters formed by the local accessions (C_1-C_4) more closely related with each other. The distances between the clusters consisting only of landraces may be in part underestimated because of the existence of extremely unique non-nodulating genotypes which were inferior for almost all symbiotic and agronomic traits.

For attributes of phosphorus (P) use efficiency, phenotypic distances (D^2) of the 155 chickpea genotypes ranged from 11 (between clusters C_1 and C_2) to 132 (between clusters C_4 and C_5) when the crop is grown in the absence of phosphorus and from 10 (between clusters C_1 and C_2) to 162 (between clusters

C_4 and C_6) with phosphorus. The maximum pairwise generalized squared distances (D^2) were found between clusters C_4 and C_5 (D^2= 132) without P and between C_4 and C_6 (D^2 = 132) with P. It is interesting to note that C_5 and C_6 constituted the non-nodulating (ICC 19181 and PM 233) references without and with P, respectively. The second most divergent groups in the absence of P were clusters C_3 and C_4 (D^2 = 97) constituting local landraces and introductions, respectively. In the presence of P, the second most divergent groups were in clusters C_4 and C_5 (D^2 = 152), i.e. between a single local accession versus two local accessions and two introductions, respectively. The genetic divergences between a number of other clusters were also highly significant (Table 6).

Comparison of D^2 values in the absence and presence of P showed that, not only the number of clusters increased from five to six with the application of P, but also the D^2 values between some clusters also tended to increase under the latter. More number of clusters and higher cluster distances were obtained when the crop was grown with P compared to when it was grown without P. It is generally believed that more conducive environments may be expected to result in better expression of the genetic potential of the genotypes for the traits under consideration (Rosielle and Hamblin, 1981; Simmonds, 1991; Singh, 2002) despite the controversy that there may be no interrelationship between the type of the environment and the magnitude of genetic variation (Ceccarelli and Grando, 1996).

For response characters to infestation by adzuki bean beetle, the pairwise generalized squared distances (D^2) among the three clusters based on the Mahalanobis's D^2 statistics revealed non-significant ($P>0.05$) inter-cluster distance between clusters C_1 and C_2 (D^2 = 6.30). On the other hand, the maximum distances were found between clusters C_1 with C_3 (D^2 = 154.03) and the second largest distance between clusters C_2 with C_3 (D^2 = 122.90) which significantly ($P \leq 0.01$) diverged from each other (Table 6).

Table 6. Pair-wise generalized squared distances between six clusters constituting 155 chickpea genotypes.

Cluster	C_1	C_2	C_3	C_4	C_5	C_6
Symbiotic N fixation						
C_1	0	12.00	24.00	11.00	84.00**	25718.00**
C_2		0.00	18.00	20.00	78.00**	25612.00**
C_3			0.00	15.00	72.00**	25649.00**
C_4				0.00	81.00**	25744.00**
C_5					0.00	25465.00**
Without P						
C_1	0.00	11.02NS	65.46**	74.06**	60.69**	---
C_2		0.00	42.24**	68.70**	65.26**	---
C_3			0.00	97.05**	57.92**	---
C_4				0.00	132.18**	---
With P						
C_1	0.00	9.94	80.42**	42.05**	50.83**	78.97**
C_2		0.00	97.01**	84.09**	22.90 NS	64.37**
C_3			0.00	116.65**	115.58**	140.52**
C_4				0.00	152.84**	161.88**
C_5					0.00	47.97**
Response to Bruchid						
C_1	0.00	6.30	154.03**	---	---	---
C_2		0.00	122.90**	---	---	---

**, $P \leq 0.01$

Basically, members in clusters with non-significant distance were assumed to have more close relationships with each other than they are with those in significantly distant clusters (Singh and Chaudhary, 1985).Since maximum genetic recombination and variation in the subsequent generation is expected from crosses that involve parents from the clusters characterized by maximum distances, crosses between the landraces and introduced genotypes constituted in divergent clusters are expected to provide relatively better genetic recombination and segregation in their progenies. Selection of parents should, however, consider the special advantages of each cluster and each genotype within a cluster depending on the specific objectives of hybridization. Therefore, this study revealed that the desirable relationship between landrace collections and exotic introductions tends to be mutually complementary.

Geographical pattern of phenotypic diversity

Cluster analysis showed that the introduced genotypes were distinctly grouped into nodulating and non-nodulating types for the traits of symbio-agronomic and phosphorus use efficiency (data not shown). This may be related to their inferior multitrait performance of the non-nodulating genotypes for almost all traits, except maybe seed size. The landraces and introduced genotypes also showed more tendencies to be separated into different clusters. Despite this distinct pattern of variation in a number of cases, however, overlappings were found among local landraces and introductions for particularly attributes of phosphorus use efficiency mostly in clusters C_1 and C_2. The partial overlapping of genotypes across geographical boundaries may indicate that geographical isolation is not the only factor causing genetic diversity (Sharma and Mehta, 1990).

It could not be certain from this study whether the division into the local and improved genotypes at the upper hierarchy is due to differences associated with the divergence in eco-geographical origins of the two groups or whether it is due to differences in the level of prior genetic manipulation to which the improved genotypes have been subjected or both. This is because the effects of differences in origins and levels of prior genetic manipulation have been confounded as all introduced genotypes are improved and, conversely, all local accessions are not improved. Theoretically, the genetic architecture of a population is believed to be the result of breeding system, gene flow within and between populations, isolation mechanisms and prolonged selection by various natural and artificial forces (Chandel and Joshi, 1983). Populations from areas far separated geographically with mountains and valleys, having complex environments and varied ecological conditions are normally expected to accumulate enormous genetic diversity (Chandel and Joshi, 1983; Singh, 2002) as geographical separation with physical barriers and genetic barriers to inter-crossing are believed to give rise to genetic diversity among genetic materials (Singh, 2002).

Unlike results of genetic diversity analysis with SSR marker, in this case, no clear interrelationship was observed between the origins of landraces in Ethiopia and the pattern of genetic diversity as there were a number of accessions from the same source of origin fall into different clusters and accessions from different origins overlapped in the same clusters. This indicated that there was no definite association between sources of origin and clustering pattern at least within the local accessions may be because of extensive seed exchange between farmers or similarity of the initial germplasm introduced to different regions.

Geographic diversity should, therefore, not serve as an index of genetic diversity in selecting suitable parents for hybridization. Jomová *et al*. (2005) also characterized chickpea accessions from four countries and reported that genetic divergence was not apparently related to geographic diversity for morpho-agronomic traits. Contrary to the present finding, in another study, cluster analysis based on morpho-agronomic traits separately grouped the kabuli types from the desi types (Upadhyaya *et al*., 2007) but the kabulis were obviously underrepresented in this study.

Tapping genetic diverssity in landrace collections

The breeding of legume genotypes with better symbiotic N fixation, P use efficiency and resistance to pests could prove one of the dependable approaches to address the problem of the majority of the resource-poor farmers. Such genotypes have been suggestedfor cost effectiveness and agricultural sustainability (Beringer *et al*., 1988; Clark *et al*., 1988; Schmidt, 1988; Witty *et al*., 1988; Pearson*et al*., 1995) with particular relevance under low input and organic agriculture (Gahoonia and Nielsen, 1996; Aryal *et al*., 2003; Burger *et al*., 2008; Löschenberger *et al*., 2008; Osman *et al*., 2008; Wolfe *et al*., 2008).

Comparison of the average performance for respective characters of the selected subsets of top 5% best genotypes ($\overline{X}$) with the average performances of the whole population (μ) for symbio-agronomic characters using t-test revealed possibilities for different level of improvements through selection. Possible improvements through selection for agronomic characters, disregarding phenological characters, ranged from 17% for harvest index to 93% for seed size but the highest possible gain in the latter may be only due to existence of introduced varieties in the test genotypes. Grain yield can be improved by 23% (Table 7). Improvements for symbiotic characters also ranged from 11% for fixed nitrogen assimilation efficiency to 119% for nodule dry weight. Above ground biomass nitrogen fixation can be improved by 18%. The best landrace genotypes for nitrogen harvest index (NHI) were found to be superior by 13.79-18.97% to Natoli and 15.79-21.05% to the mean NHI performance of all the released varieties.

Table 7. Comparison of mean performances of selected subsets ($\bar{X}$) of the 5% best accessions for symbiotic and agronomic characters with the average performances of the whole population (μ) of 155 chickpea genotypes.

Characters	Mean of selected genotypes ($\bar{X}$)	Population parameter (μ)	Change through selection ($\bar{X}$-μ)	Change as % of population parameter(μ)	t
Symbiotic characters					
Nodulation index	2.93	1.43	1.50	104.90	6.05**
No of nodules	25.50	13.21	12.29	93.04	6.66**
Nodule dry weight	918.91	420.19	498.72	118.69	7.18**
Shoot N content	1.48	1.18	0.30	25.42	6.59**
Shoot N fixation	45.06	29.97	15.09	50.35	5.66**
Grain N content	3.90	3.51	0.39	11.11	5.37**
Grain N fixation	42.52	35.95	6.57	18.28	3.67**
Biomass N content	5.35	4.69	0.66	14.07	6.28**
Biomass N fixation	39.25	33.24	6.01	18.08	3.67**
Fixed N AE	88.91	80.28	8.63	10.75	2.46*
Grain N yield	2.31	1.85	0.46	24.86	5.12**
Shoot N yield	1.73	1.25	0.48	38.40	6.59**
Biomass N yield	3.79	3.10	0.69	22.26	5.16**
Nitrogen harvest index	0.67	0.60	0.07	11.67	5.03**
Agronomic characters					
Early vigor	50.66	37.4	13.26	35.45	6.60**
No of pods	483	376	107.00	28.46	5.27**
No of seeds	557	421	136.00	32.30	4.62**
SDW at maturity	137.34	105.87	31.47	29.73	6.61**
Biomass weight	196	152	44.00	28.95	6.43**
Harvest index	40.99	35.15	5.84	16.61	5.91**
GPE	68.75	54.12	14.63	27.03	4.31**
Biomass production rate	174	133	41.00	30.83	6.67**
Economic growth rate	114	92	22.00	23.91	5.52**
Thousand seed weight	220.03	113.8	106.23	93.35	10.35**
Grain yield	64.67	52.53	12.14	23.11	4.97**

** = highly significant ($P \leq 0.01$) and * = significant ($P \leq 0.05$).
SDW = Shoot dry weight, GPE = Grain production efficiency, AE = assimilation efficecy

The comparison of test genotypes for P use efficiencywith the standard variety Natoli, showed the existence of a number of superior landraces for plant tissue phosphorus contents, phosphorus yields, phosphorus uptake and use efficiency and for other agronomic characters including grain yield. This indicated the possibilities for developing superior varieties for P use efficiency by using chickpea landraces collected from Ethiopia as source materials. The t-test also showed highly significant differences between means of the selected subsets of the top 5% best genotypes ($\overline{X}$) and the population parameters (μ) for plant tissue P content, P yields, P harvest index, P use efficiency and other agronomic characters (Table 8).

Comparison of the performance of the selected subsets of the top 5% best with that of the whole population for response to infestation by adzuki bean beetle revealed possibilities for different level of improvements through selection, as selection for resistant accessions significantly changed the mean of the original population in just one cycle at inter-accession levels (Table 9). Selected genotypes scoring least number of eggs and adults, adult recovery, seed weight loss and smallest seed size on the one hand and those with delayed adult emergence, highest number of uninfected seeds (%) and largest seed coat weight (%) as compared to the population means were considered to have better resistace. The t-test showed significant differences between means of the selected subsets of the top 5% best genotypes and the population parameters for different traits except seed weight loss recorded on the second progeny which was not significantly changed through selection. This again indicated that the selected accessions were not true representatives of the population, and almost all characters effectively responded to phenotypic selection (Singh, 2001). Interestingly, none of the improved genotypes stood one among the selected subsets of the top 5% best genotypes for any one of the attributes of resistance.

Table 8. Comparison of the mean performances of selected subsets ($\overline{X}$) of the 5% best accessions for symbiotic and agronomic characters with the average performances of the whole population (µ) of 155 chickpea genotypes

Character	Without P					With P				
	Mean of selected genotype ($\overline{X}$)	Population parameter (µ)	Change through selection ($\overline{X}$-µ)	Change as % of population parameter (µ)	t	Mean of selected genotypes ($\overline{X}$)	Population parameter (µ)	Change through selection ($\overline{X}$-µ)	Change as % of population parameter (µ)	t
Plant tissue P contents and yields										
SPC	0.137	0.076	0.061	80.26	7.95**	0.187	0.123	0.064	52.03	6.65**
GPC	0.240	0.168	0.072	42.86	6.67**	0.296	0.224	0.072	32.14	5.58**
BMPC	0.874	0.612	0.262	42.81	6.90**	1.076	0.828	0.248	29.95	6.03**
SPY	136.538	76.305	60.233	78.94	7.86**	186.738	123.369	63.369	51.37	6.58**
GPY	240.188	168.089	72.099	42.89	6.69**	295.750	223.395	72.355	32.39	5.63**
BMPY	351.350	244.393	106.957	43.76	6.96**	444.888	346.761	98.127	28.30	5.53**
PHI	0.779	0.686	0.093	13.56	4.72**	0.729	0.644	0.085	13.20	4.47**
P uptake and use efficiency										
APUfs	---	---	---	---	---	83.59	65.749	17.841	27.14	5.75**
APUf	---	---	---	---	---	39.74	23.151	16.589	71.66	5.58**
APUs	---	---	---	---	---	59.59	42.574	17.016	39.97	5.86**
PYE	---	---	---	---	---	60.13	45.797	14.333	31.30	5.53**
PPE	---	---	---	---	---	83.03	68.519	14.511	21.18	4.79**

Table 8. Contined…

Character	Without P					With P				
	Mean of selected genotype ($\bar{X}$)	Population parameter (μ)	Change through selection ($\bar{X}$ -μ)	Change as % of population parameter (μ)	t	Mean of selected genotypes ($\bar{X}$)	Population parameter (μ)	Change through selection ($\bar{X}$ -μ)	Change as % of population parameter (μ)	t
Agronomic characters										
NP	483.05	343.11	139.940	40.79	5.70**	538.09	408.40	129.69	31.76	5.58**
NS	538.18	387.52	150.660	38.88	4.81**	621.90	455.35	166.55	36.58	4.82**
SDMW	136.39	94.25	42.140	44.71	7.50**	160.24	117.48	42.76	36.40	6.38**
BMWT	199.68	142.53	57.150	40.10	7.07**	217.10	167.85	49.25	29.34	6.00**
HI	42.71	35.68	7.030	19.70	6.08**	40.90	34.63	6.27	18.11	5.65**
GPE	70.19	49.59	20.600	41.54	5.56**	80.82	59.04	21.78	36.89	5.26**
BPR	174.08	119.45	54.630	45.73	7.37**	200.68	147.19	53.49	36.34	6.38**
EGR	117.41	84.37	33.040	39.16	6.61**	130.85	100.02	30.83	30.82	5.63**
TSW	220.38	115.65	104.730	90.56	9.99**	220.288	111.95	108.34	96.78	10.63**
YLD	66.08	48.21	17.870	37.07	6.04**	75.16	57.25	17.91	31.28	5.53**

[1]SPC = Shoot P content, GPC = grain P content, BMPC = biomass P content, SPY = shoot P yield, GPY = grain P yield, BMPY = biomass P yield, PHI = P harvest index, APUfs = apparent use of P from fertilizer, APUs = apparent use of P from soil, PYE = phosphorus yield efficiency, PPE = phosphorus physiological efficiency, NP = No of pods, NS = No of seeds, SDMW = shoot dry matter weight, BMWT = total biomass weight, HI = harvest index, GPE = grain production efficiency, BPR = biomass production rate, EGR = economic growth rate, TSW = thousand seed weight, YLD = grain yield.

** = highly significant ($P \leq 0.01$) and * = significant ($P \leq 0.05$).

Table 9. Comparison of the mean performances of selected subsets ($\overline{X}$) of the 5% best accessions for response characters to infestation by adzuki bean beetle with the average performances of the whole population (μ) of 130 chickpea genotypes.

Characters	Progeny	Population parameter (μ)	Mean of selected genotypes ($\overline{X}$)	Change through selection (μ- $\overline{X}$)	Changeas % of population parameter (μ)	t
Total No of eggs	First	234	177	57	24.36	3.99**
Days to adult emergence	First	32	33	1	3.13	7.00**
	Second	34	35	1	2.94	4.45**
No of adults emerged	First	160	112	48	30.00	4.52**
	Second	590	465	125	21.19	2.37*
No of uninfected seed (%)	First	31	43	12	38.71	4.90**
Adult recovery (%)	First	70	59	11	15.71	4.49**
1000 seed weight	---	114	90	24	21.05	2.10*
Seed coat weight (%)	---	18	21	3	16.67	2.45*
seed weight loss	First	5	3	2	40.00	2.45*
	Second	7	6	1	14.29	1.23NS

** = highly significant ($P \leq 0.01$), * = significant ($P \leq 0.05$) and NS = non-significant ($P> 0.05$)

Conclusions

The present study revealed that the Ethiopian chickpea landraces had considerable diversity (both at phenotypic and genetic levels) and Ethiopia has alot to offer. Molecular characterization of the chickpea genotypes using SSR marker showed the existence of high genetic diversity and a large number of duplications in Ethiopian chickpea germplasm collections. These duplications maybe reduced using strategies such as systematic bulking and the formation of core collections. Future germplasm collection and utilization strategies should take into consideration the magnitude and pattern of genetic diversity established both at genotypic and phenotypic levels by the present investigation. The eco-geographic pattern of distribution of genetic diversity established in this study may also help as a benchmark in selection of in-situ conservation sites and in the study of chickpea evolution.

The Ethiopian chickpea landraces had considerable significance as sources of genotypes with desirable attributes for symbiotic nitrogen fixation, phosphorus uptake and use efficiency, and resistance to adzuki bean beetle with other agronomic characters. It was possible to identify sources for desirable characters that were superior to the recently released varieties. Genetic enhancement or increasing the frequency of desirable genes of accessions identified as better source materials in this study through purification and selection is likely to produce better genotypes.However, the challenge is that the desirable characters were found to exist distributed among different accessions and a single group or a single genotype combining desirable attributes of symbiotic nitrogen fixation, phosphorus uptake and use efficiency, and resistance to adzuki bean beetle may be of rare occurrence in this gene pool. A series of multiple crossing may be required in order to bring desirable traits distributed among multiple parents into a single genetic background for further selection among the progenies. Introductions from exotic sources should also be included in the parents to be developed from the selected accessions particularly in order to exploit complementary genes, e.g. to improving seed size as an economic trait.

Improving adzuki bean beetle resistance through selection would be more difficult because of the existence of sources of only partial resistance to adzuki bean beetle. Beyond relative differences, sources of complete resistance to adzuki bean beetlehave not been obtained, maybe because genes for complete resistance to this storage insect are underrepresented or under expressed in Ethiopian chickpea germplasm accessions. For improving adzuki bean beetle resistance, evaluation of larger number of germplasm accessions, greater selection intensity and more precise evaluation to capture the very rare gene may be needed. Genetic resources with complete resistance should also be introduced and included into this gene pool.

Finally, the desirable relationship between landrace collections and exotic introductions tends to be mutually complementary. For instance, introductions from exotic sources should be exploited for complementary genesto improve seed size as an economic trait.The easy access to a wide array of improved genotypes developed by the international institutions has, therefore, supported the broadening of genetic base of chickpea breeding in Ethiopia.

References

Ali, M.Y., Krishnamurthy, L., Saxena, N.P., Rupela, O.P. Kumar, J. and Johansen, C. (2002). Scope for genetic manipulation of mineral acquisition in chickpea. *Journal of Agronomy and Crop Science,* **191**:464-472.

AOAC (1970) Official Methods of Analysis, 11th ed., Association of Official Agricultural Chemists (AOAC), Washington, D.C.

Arumuganathan, K. and Earle, ED. (1991). Nuclear DNA content of some important plant species. *Plant Molecular Biology Reporter* **9**:208-219.

Aryal, U.K., Xu, H.L. and Fujita, M. (2003). Rhizobia and AM Fungal Inoculation Improve Growth and Nutrient Uptake of Bean Plants Under Organic Fertilization. *Journal of Sustainable Agriculture*, **21**:27-39.

Bejiga G and van der Maesen LJG (2006)*Cicer arietinum* L. *Plant Resources of Tropical Africa 1: Cereals and Pulses*, pp. 42-46, (Brink, M. and Belay, G., eds). PROTA Foundation, Wageningen, Netherlands/Backhuys Publishers, Leiden, Netherlands/CTA, Wageningen, Netherlands.

Beringer, J.E., Bisseling, T.A. and LaRue, T.A. (1988). Improving symbiotic nitrogen fixation through the genetic manipulation of *Rhizobium* and legume host plants. In: *World Crops: Cool Season Food Legumes*, pp. 691-702, (Summerfield, R.J., ed). Kluwer Academic Publishers, Dordrecht.

Burger H, Schloen M, Schmidt W and Geiger HH (2008) Quantitative genetic studies on breeding maize for adaptation to organic farming. *Euphytica*, **163**:501–510.

Carvalho, M.A. (2004). Germplasm characterization of *Arachis pintoi* Krap. and Greg. (*Leguminosae*). PhD Thesis, University of Florida, USA.

Cassman KG, Peng S, Olk DC, Ladha JK, Reichardt W, Dobermann A and Singh U (1998) Opportunities for increasing nitrogen use efficiency from improvedresource management in irrigated rice systems. *Field Crops Research*, **56**:7–38.

Ceccarelli, S. and Grando, S. (1996). Importance of specific adaptation in breeding for marginal conditions. In: *Barley Research in Ethiopia: Past Work and Future Prospects*, pp. 34-58, Gebre, H. and van Leur, J., eds). Proceedings of the 1st Barley Research Review Workshop, 16-19 October 2003, Addis Ababa: IAT/ICARDA. Addis Ababa, Ethiopia.

Chandel, K.P.S. and Joshi, B.S. (1983). Multivariate analysis in green-seeded pea. *Indian Journal Agricultural Sciences***53**:198-200.

Clark, K.W., Brockwell, J. and Thompson, J.A. (1988). Role of inoculants in improving nitrogen fixation in legumes. In: *World*

Crops: Cool Season Food Legumes, pp. 731-743, Summerfield, R.J., ed). Kluwer Academic Publishers, Dordrecht.

Crouch, J.H., Buhariwalla, H.K., Blair, M., Mace, E., Jayashree, B. and Serraj, R. (2004). Biotechnology based contributions to enhancing legume productivity in resource poor areas. In: *Symbiotic Nitrogen Fixation: Prospects for Enhanced Application in Tropical Agriculture*, pp 47-65, (Serraj, R. ed). Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

CSA. (2011). Area and production of crops in the Meher season. Statistical Bulletin. Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

Dadi, M. (2004). Morphological and RAPD marker variation analysis in some drought tolerant and susceptible chickpea (*Cicer arietinum* L.) genotypes of Ethiopia. M.Sc Thesis, Addis Ababa University, Ethiopia

de Vicente, M.C., Guzmán, F.A., Engels, J. and Rao, V.R. (2005). Genetic characterization and its use in decision making for the conservation of crop germplasm: The role of biotechnology. *In: International Workshop the Role of Biotechnology for the Characterization and Conservation of Crop, Forestry, Animal and Fishery Genetic Resources*, pp 121-128, FAO, FOBIOTECH, ECOGENE, SIGA. Turin, Italy, 5-7 March 2005.

Doughton JA, Saffigna PG, Vallis I and Mayer RJ (1995) Nitrogen fixation in chickpea: II. Comparison of ^{15}N enrichment and ^{15}N natural abundance methods for estimating nitrogen fixation. *Australian Journal of Agricultural Research*, **46**: 225-236.

Doyle, J.J. and Doyle, J.L. (1990). Isolation of plant DNA from fresh tissue. *Focus,* **12**:13-15.

Falconer, D.S. (1989) *Introduction to Quantitative Genetics*. 3rd ed. Longman, London, England.

Ford-Lloyd, B. and Jackson, M. (1986). *Plant Genetic Resources: An Introduction to their Conservation and Use*. Edward Arnold, Australia.

Gahoonia TS and Nielsen NE (1996) Variation in acquisition of soil phosphorus among wheat and barley genotypes. *Plant and Soil,* **178**:223-230.

Gerloff, S. (1977). Plant efficiencies in the use of N, P and K. In: *Plant Adaptation to Mineral Stress in Problem Soils*, pp. 161-174, (Wright, M.J., ed). Cornell Univ. Press: New York.

Gilbert, J.E., Lewis, R.V., Wilkinson, M.J. and Caligari, P.D.S. (1999). Developing an appropriate strategy to assess genetic variability in plant germplasm collections. *Theoretical and Applied Genetics,* **98**:1125-1131.

Gomez, K.A. and A. Gomez. (1984). *Statistical Procedures for Agricultural Research*. John Wiley & Sons. New York.

Graham, P.H. and Vance, C.P. (2003). Legumes: Importance and Constraints to Greater Use.*Plant Physiology,* **131**:872–877.

Hagedorn, D.J. (1984). *Compendium of Pea Diseases*. The American Phytopathological Society and the University of Wisconsin-Madison, USA.

Hardarson, G. (2004). Enhancement of symbiotic nitrogen fixation in grain legumes: selected results from the FAO/IAEA program. In: *Symbiotic Nitrogen Fixation: Prospects for Enhanced Application in Tropical Agriculture*, pp 163-171, (Serraj, R., ed). Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Hartley, H.O. (1950). The maximum F-ratio as a short cut test for heterogeneity of variances. *Biometrika,* **37**:308-312.

Hayward, H.D. and Breese, E.L. (1993). Population structure and variability. In: *Plant Breeding: Principles and Prospects*, pp. 16-29, (Hayward, M.D., Bosemark, N.O. and Romagosa, I., eds). Chapman and Hall, Great Britain.

IFPRI (2010) Pulses value chain in Ethiopia: Constraints and opportunities for enhancing exports. Working Paper. International Food Policy Research Institute (http://www.ifpri.org/sites/default/files/ publications/ethiopianagsectorwp _pulses.pdf).

Jarso M, Keneni G and Wolabu T (2011) Enhancing the technical relevance of pulses and oilseed crops through target oriented breeding. In: *Oilseeds: Engine for Economic Development*, pp. 45-60, (Terefe G, Wakjira A, and Gorfu D, eds.) Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.

Jomová, K., Benková, M., Žáková, M., Gregová, E. and Kraic, J. (2005). Clustering of chickpea (*Cicer arietinum* L.) accessions. *Genetic Resources and Crop Evolution*, **52**:1039–1048.

Joshi PK, Rao P, Gowda CLL, Jones RB, Silim SN, Saxena KB and Kumar J (2001)The World Chickpea and Pigeonpea Economies: Facts, Trends and Outlook. International Crops Research Institute for the Semi-Arid Tropics, Andhra Pardesh, India.

Kassie, M., Shiferaw, B., Asfaw, S., Abate, T., Muricho, G., Ferede, S., Eshete, M. and Assefa, K. (2009). Current situation and future outlooks of the chickpea sub-sector in Ethiopia. ICRISAT and EIAR(http://www.icrisat.org/tropicallegumesII/pdfs/Current_Situation.pdf).

Keneni G(2012)Genetic Potential and Limitations of Ethiopian Chickpea (*Cicer arietinum* L.) Germplasm Accessions for Symbiotic Nitrogen Fixation, Phosphorus Uptake and Use Efficiency and Adzuki Bean Beetle (*C. chinensis* L.) Resistance.

Ladizinsky, G. and Adler, A. (1976). The origin of chickpea, *Cicer arietinum* L. *Euphytica*, **25**:211-217.

Lemma T (1990) The biology and control of the adzuki been beetle (*Callosobruchus chinensis* L.) on chickpea (*Cicer arietinum* L.). MSc Thesis, Alemaya University, Ethiopia.

Little, T.M. and Hills, F.J. (1978). *Agricultural Experimentation: Design and Analysis*. John Wiley and Sons. New York.

Löschenberger F, Fleck A, Grausgruber H, Hetzendorfer H, Hof G, Lafferty J, Marn M, Neumayer A, Pfaffinger, G and Birschitzky J (2008) Breeding for organic agriculture: the example of winter wheat in Austria. *Euphytica*, **163**:469–480.

McGuire, S.J. and Sperling, L. (2008). Leveraging farmers‘ strategies for coping with stress: seed aid in Ethiopia. *Global Environmental Change*, **18:679**-688.

Millan T, Clarke HJ, Siddique KHM, Buhariwalla HK, Gaur PM, Kumar J, Gil J, Kahl G, Winter P (2006) Chickpea molecular breeding: new tools and concepts. *Euphytica*, **147:81**–103

Muehlbauer FJ and Tullu A. (1997). *Cicer arietinum* L: New crop fact sheet(http://www.hort.purdue.edu/newcrop/cropfactsheets/chickpea.html#Origin).

Ohri D and Pal M (1991) The origin of chickpea (*Cicer arietinum* L.): Karyotype and nuclear DNA amount. *Heredity,* **66**:367-372.
Osman, A.M., Almekinders, C.J.M., Struik, P.C. and van Bueren, E.T.L. (2008). Can conventional breeding programmes provide onion varieties that are suitable for organic farming in the Netherlands? *Euphytica,* **163**:511–522.
Peakall, R. and Smouse, P.E. (2006). GENALEX 6: genetic analysis in Excel. Population genetic software for teaching and research. *Molecular Ecology Notes,* **6**:288–295.
Pearson, C.J., Norman, D.W. and Dixon, J. (1995). Sustainable dryland cropping in relation to soil productivity - FAO soils bulletin 72,FAO, Rome.
Pritchard JK, Stephens M and Donnelly P (2000) Inference of population structure using multilocus genotype data. *Genetics,* **155**:945–959.
Rivas, R., Peix, A., Mateos, P.F., Trujillo, M.E., Martínez-Molina, E. and Velá zquez, E. (2006). Biodiversity of populations of phosphate solubilizing rhizobia that nodulates chickpea in different Spanish soils. *Plant and Soil,* **287**:23–33.
Romeis J, Sharma HC, Sharma KK, Das S and Sarmah BK (2004) The potential of transgenic chickpeas for pest control and possible effects on non-target arthropods. *Crop Protection,* **23**:923-938.
Rosielle, A.A. and Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non-stress environments. *Crop Science,* **21**:943-946.
Saeed, A., Hovsepyan, H., Darvishzadeh, R., Imtiaz, M., Panguluri, S.K. and Nazaryan, R. (2011). Genetic diversity of Iranian accessions, improved lines of chickpea (*Cicer arietinum* L.) and their wild relatives by using simple sequence repeats. *Plant Mol Biology Reporter*, dio 10.1007/s11105-011-0294-5.
SAS Institute (1996) SAS/STAT guide for personal computers, version 6.12 edition. Cary, NC: SAS Institute Inc.
Schmidt, E.L. (1988). Competition for legume nodule occupancy: a down-to-earth limitation on nitrogen fixation. In: *World Crops: Cool Season Food Legumes*, pp. 663-674, (Summerfield, R.J., ed). Kluwer Academic Publishers, Dordrecht.

Serraj R, Adu-Gyamfi Rupela OP and Drevon JJ (2004) Improvement of legume productivity and role of symbiotic nitrogen fixation in cropping systems: overcoming the physiological and agronomic limitations. In: *Symbiotic Nitrogen Fixation: Prospects for Enhanced Application in Tropical Agriculture*, pp 67-97, (Serraj, R., ed). Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Shiferaw B, Bantilan MCS and Serraj R (2004) Harnessing the Potentials of BNF for poor farmers: Technological, policy and institutional constraints and research needs. In: *Symbiotic Nitrogen Fixation: Prospects for Enhanced Application in Tropical Agriculture*, pp 3-27, (Serraj, R., ed). Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Simmonds NW (1991) Selection for local adaptation in a plant breeding program. *Theoretical and Applied Genetics,* **82**:363-367.

Singh RK, and Chaudhary BD (1985)*Biometrical Methods in Quantitative Genetic Analysis.* Kalyani Publishers, New Delhi-Ludhiana.

Singh P (2001)Numerical Problems in Plant Breeding and Genetics. Kalyani Publishers, New Delhi, India.

Singh, B.D. (2002) Plant Breeding: Principles and Methods. Kalyani Publishers, New Delhi-Ludhiana.

Smith, A., Elmes, A.E., Howard, R.S. and Franklin, M.F. (1984). The uptake of soil and fertilizer-Phosphorus by barley growing under Scottish climatic condition. *Plant and Soil,* **76**:49-57.

Sokal, R.R. and Rohlf, F.J. (1997). *Biometry: The Principles and Practice of Statistics in Biological Research*. Third Edition. W.H. Freeman and Company, New York.

Spagnoletti, P.L. and Qualset, C.O. (1987). Geographical diversity for quantitative spike characters in a world collection of durum wheat. *Crop Science,* **27**:235-241.

Syers, J.K., Johnston, A.E. and Curtin, D. (2008). Efficiency of soil and fertilizer phosphorus use: Reconciling changing concepts of soil phosphorus behaviour with agronomic information. FAO Fertilizer and plant nutrition bulletin 18. Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00153 Rome, Italy.

Taddesse D, Telaye A, Bejiga G (1994) Genetic resources in Ethiopia. In: Telaye A, Bejiga G, SaxenaMC, SolhMB(eds) Cool season food legumes of Ethiopia. Proceedings of the First National Cool Season Food Legumes Review Conference, 16–20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Aleppo, pp 79–96

Tanno, K., and Willcox, G. (2006). The origins of cultivation of *Cicer arietinum* L. and *Vicia faba* L.: early finds from Tell el-Kerkh, north-west Syria, late 10th millennium B.P.*Vegetation History Archives,* **15**:197-204.

Tanto T and Tefera E (2006) Collection, conservation, characterization and sustainable utilization of grain legumes in Ethiopia. In: *Food and Forage Legumes of Ethiopia: Progress and Prospects*, pp. 15-22, (Ali, K., Keneni, G., Ahmed, S., Malhotra, R., Beniwal, S., Makkouk, K. and Halila, M.H., eds). Proceedings of a Workshop on Food and Forage Legumes. 22-26 Sept 2003, Addis Ababa, Ethiopia. ICARDA, Aleppo, Syria.

The Worldwide Gourmet (2010) Chickpea: All about legumes on the Worldwide Gourmet http://www.theworldwidegourmet.com/ products/ vegetables/chickpea/

Toker C, Canci H and Ceylan FO (2006)Estimation of outcrossing rate in chickpea (*Cicer arietinum* L.) sown in autumn. *Euphytica,* **151**:201–205.

Toker, C., Canci, H. and Yildirim, T. (2007). Evaluation of perennial wild *Cicer* species for drought resistance. *Genetic Resources and Crop Evolution* (DOI 10.1007/s10722-006-9197-y).

Upadhyaya HD, Dwivedi SL, Baum M, Varshney RK, Udupa SM, Gowda CLL, Hoisington D and Singh S (2008)Genetic structure, diversity, and allelic richness in compositecollection and reference set in chickpea (*Cicer arietinum*L.). *BMC Plant Biology,* **8**:doi:10.1186/1471-2229-8-106.

Upadhyaya, H.D., Dwivedi, S.L., Gowda, C.L.L. and Singh, S. (2007). Identification of diverse germplasm lines for agronomic traits in a chickpea (*Cicer arietinum* L.) core collection for use in crop improvement. *Field Crops Research,* **100**:320–326.

Van der Maesen, L.J.G. (1987). Origin, history and taxonomy of chickpea. In: Veneklaas, E.J., Stevens, J., Cawthray, G.R., Turner, S., Grigg, A.M. and Lambers, H. (2003). Chickpea and white lupin rhizosphere carboxylates vary with soilproperties and enhance phosphorus uptake. *Plant and Soil,* **248**:187–197.

Warburton, M. and Crossa, J. (2002). Data analysis in the CIMMYT Applied Biotechnology Center. Second Edition. Mexico, D.F.: CIMMYT(http://apps.cimmyt.org/english/docs/manual/protocols/dataAnalysis.pdf.

Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. *Journal of American Statistical Association,* **58**:236-244.

Willems, A. (2006). The taxonomy of rhizobia: An overview. *Plant and Soil,* **287**:3–14.

Witty, J.F., Rennie, R.J. and Atkins, C.A. (1988). ^{15}N addition methods for assessing N_2 fixation in legumes. *World Crops: Cool Season Food Legumes*, pp. 715-730, (Summerfield, R.J., ed). Kluwer Academic Publishers, Dordrecht.

Wolfe, M.S., Baresel, J.P., Desclaux, D., Goldringer, I., Hoad, S., Kovacs, G., Löschenberger, F., Miedaner, T., Østergård H. and van Bueren, E.T.L. (2008). Developments in breeding cereals for organic agriculture. *Euphytica,* **163**:323–346.

Workeye F (2002) Morphological and biochemical diversity analysis in chickpea (*Cicer arietinum*) landraces of Ethiopia. *MSc Thesis*, School of Graduate Studies, Addis Ababa University.

Zapata F (1990) Field experimentation in isotope-aided studies. In: *Use of Nuclear Techniques in Soil-Plant Relationships*, (Hardarson G. ed) Training course series No 2, IAEA, Vienna.

8. Genetic progresses achieved in Ethiopian chickpea (*Cicer arietinum* L.) breeding program based on grain yield and seed size

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Despite a considerable effort made in Ethiopian chickpea (C. arietinum L.) breeding program, the genetic progresses achieved over time have not been well studied. This study was initiated to assess the rate of genetic progresses achieved so far in Ethiopian chickpea improvement so as to re-design an effective breeding strateyof the future. Twenty four desi and kabuli varieties released in Ethiopia were considered in this study. As estimated from the slope of the graph of linear regression, the absolute genetic progress in grain yield fordesi varieties was ~32 kg ha^{-1}year^{-1}($P\leq 0.001$, R^2=0.725) with relative genetic progress of 2.13% year^{-1}. Conversely, there was insignificant (15.259kg ha^{-1}year^{-1}) (R^2=0.164) genetic progress for kabuli types with respect to grain yield with relative genetic progress of 0.87% year^{-1}. Besides, the absolute genetic progress in termsof 100 seed weight were 0.320gyear^{-1} (R^2=0.626) for desi, and 0.931g year^{-1} ($P\leq 0.001$, R^2=0.764) for kabuli with relative genetic progress of 2.58% and 8.62% year^{-1}, respectively. This study revealed that in grain yield, better genetic progress wasachieved in desis than in Kabulis whereas, remarkable genetic progress in seed size was attained in kabulis than in desis. Therefore, more advanced and diversified genetic introgression through strategic breeding targeting trait of economic importance has to be undertaken for emerging demands both in desi and kabuli chickpeas.

Key words: Chickpea, genetic progress, seed size, regression

Introduction

Chickpea is one of the world principal food legumes, with particular importance in the semi-arid tropics of sub-Saharan Africa and South Asia. Ethiopia is the largest producer of chickpea in Africa accounting for about 46% of the continent‘s production (Kassie *et al*., 2009). It covers about 239,512 hectares of land and more than 409,733 tons of grain is produced annuallywith average productivity of 1.71tons/ha (CSA, 2013).

In Ethiopia, chickpea is produced under wide spectrum of altitude ranging from 1,500 to 2,600 meter above sea level, mainly with residual moisturefrom the main rainy season and in a very few cases using irrigation.Chickpea breeding in Ethiopia was initiated in 1950s (Keneni *etal*. 2011). Since then, a number oflocally collected and newly introduced germplasm have been evaluated to develophigh yielding and wide adaptable varieties.

Through strong collaboration with International Crop Research Institute for Semi Arid Tropics (ICRISAT) and International Center for Agricultural Research in the Dry Areas (ICARDA) ICARDA, a total of 24 varieties along with their management practices have been developed and released by the national chickpea breeding program.

Any breeding program must be periodically subjected to critical analysis with respect to its performance, seeking methodologies that can improve its effectiveness (Faria *et al*. 2013). The efficiency of most plant breeding program is measured through the genetic progress achieved over time in most important agronomic and economic traits.

Despite a considerable breeding efforts were made in Ethiopiachickpea (*Cicer arietinum* L.) breeding program, the genetic progresses achieved for most important agronomic traits have not been well studied and documented. Only two studies were found for evaluating the genetic progress attained from the breeding program (Keneni *et al.,* 2011; Belete *et al.,* 2012).

The previous studies were focused only on small kabuli and desi varieties for few years. Besides, these studies were not exhaustive both in considering all the released chickpea varieties in Ethiopia, and in examining the whole breeding program from its inception. Therefore, the main objective of this study was to critically assess the genetic progress achieved in Ethiopian chickpea breeding program over the last four decades based on most important agronomic traits.

Materials and methods

This study was carried out employing the national variety trial data of chickpea varieties released in Ethiopia through the national chickpea breeding program for the last four decades. These experimental trials were comprises multi-location data obtained from experiments carried out in different federal and regional agricultural research centersin a time period ranging from 1974 to 2013. Twenty four chickpea varieties released by the national chickpea breeding program of Ethiopia were used in this study (Table1).

Statistical analysis

The genetic progress achieved over years from the national chickpea breeding program was estimated by regressing mean values of grain yield and hundred seed weight of each varieties against the year of release of the varieties using PROC REG procedure. The coefficient of linear regression was used to determine the absolute genetic progress in kg ha^{-1} yr^{-1} (Evans and Fisher, 1999). The relative annual rate of genetic progress achieved over years was determined as a ratio of the absolute genetic progress to the corresponding mean value of the first released variety from the breeding program and expressed in percentage.

The functional form of linear relationship between a dependent variable Y and independent variable **X** is represented by the equation:

$$Y = \beta 0 + \beta_1 X$$

Where, Y = the value of the dependant variable,

X = the independent variable,

β0 = the intercept of the line,

β1 = the regression coefficient or slope of line, or the changes in Y per unit change in X.

$\beta_1 = \frac{Cov\ XY}{Var\ X}$, from which the absolute genetic progress is estimated in kg ha^{-1} yr^{-1} (Evans and Fisher, 1999).

Where, Cov = Covariance,

Var = Variance,

X= theyear of variety release,

Y= the mean value of each character for each variety.

Besides, the released varieties were grouped according to their year of release within a decade and the averaged rate of increment of grain yield and seed size over the oldest variety were examined.

Table 1. Desi and Kabuli type chickpea varieties released in Ethiopia from 1974 to 2013.

Ser No.	Variety designation	Origin/source	Year of release	Releasing center*
I.	**Desi type**			
1	DZ-10-11	Ethiopia	1974	DZARC
2	Dubie	Ethiopia	1978	DZARC
3	Mariye	ICRISAT	1985	DZARC
4	Worku	ICRISAT	1994	DZARC
5	Akaki	ICRISAT	1995	DZARC
6	Kutaye	ICRISAT	2005	SARC
7	Mastewal	ICRISAT	2006	DARC
8	Fetenech	ICRISAT	2006	SARC
9	Natoli	ICRISAT	2007	DZARC
10	Minjar	ICRISAT	2010	DZARC
11	Dalota	ICRISAT	2013	DZARC
12	Teketay	ICRISAT	2013	DZARC
II.	**Kabuli type**			
1	DZ-10-4	Ethiopia	1974	DZARC
2	Areti	ICARDA	1999	DZARC
3	Shasho	ICRISAT	1999	DZARC
4	Chefe	ICRISAT	2004	DZARC
5	Habru	ICARDA	2004	DZARC
6	Ejerie	ICARDA	2005	DZARC
7	Teji	ICARDA	2005	DZARC
8	Yelibie	ICRISAT	2006	SARC
9	Acos dubie	Mexico	2009	DZARC
10	Kasech	ICRISAT	2011	SARC
11	Akuri	ICRISAT	2011	SARC
12	Kobo	ICRISAT	2012	SARC

**, DZARC = Debre Zeit Agri. Res. Center, SARC= Sirinka Agri. Res. Center, DARC = Debre Birhan Agri. Res. Center.*

Result and discussion

The results of this study indicated that breeding efforts for the last four decades has made substantial progresses in improving the grain yield and seed size of chickpea varieties in Ethiopia. For the traits considered in this study, the genetic progress achieved over years wasvery distinct for desi and kabuli types.

Desi types: for the last four decades, the genetic progress achieved in grain yield for desi varieties were marvelous and highly significant (*P≤ 0.001)* (Table 3). As estimated from the slope of the graph of linear regression, the absolute genetic progress in grain yield was 31.998 kg $ha^{-1}year^{-1}$(R^2=*0.725*) with relative genetic progress of 2.13% $year^{-.1}$ (Table 3 and Fig.1**A**). This is equivalent to a grain yield increment of 1,279.9 kg ha^{-1} for the last 40 years.

The over years and over locations mean of the released desi varieties also showed a gradual increase in grain yield in parallel with year of release. The average grain yield of desi varieties released in 1980s, 1990s, 2000s and 2010s were 1850, 2200, 2500, 2750 kg ha^{-1} with mean grain yield increment of 23.33%, 46.67%, 66.67% and 82.6% respectively, over the oldest desi variety, DZ-10-11 released in 1962 (Table 2).

Results of different studies in chickpea showed similar results. For desi varieties the annual rate of genetic progress in grain yield was 18.42 kg ha^{-1} yr^{-1} (R^2 =*0.866*) with relative annual genetic progress of 1.16% (Belete *et al.* 2011). Keneni *et al.* (2011) also reported that the annual rate of genetic progress for grain yield in chickpea was 1.42 g per five plants per year or over 21 g/five plants in 15 years (R^2 =*0.45*). Several studies on other crops Viz. common bean (Faria *et al.* 2013), wheat (Khalil *et al.* 2010; Donmez *et al.* 2001), barely (Abeledo *et al.* 2003; Fekadu *et al.* 2011; Ortiz *et al*. 2002; Bulman *et al*. 1993), maize (Duvick, 2005) and many others reported similar trends.

The average annual rate of increase in hundred seed weight for desi varieties was 0.320g which is highly significant ($P \leq 0.01$, R^2=0.626) with a relative genetic progress of 2.58% year^{-1}(Table 3 and Fig.1B). Similarly, the gradual increment of the average hundred seed weight of the varieties in parallel with their year of release implies the presence of positive progress in seed size through unreserved breeding efforts (Table 2). Varieties released in 1980s, 1990s, 2000s and 2010s were showed a hundred seed weight increment of 9.35 (75.4%), 11.55 (93.15%), 14.8 (119.35%) and 15.13 (122%) grams, respectively over the oldest desi variety, DZ-10-11, with mean hundred seed weight of 12.4g. Particularly, desi varieties released in 2000s and 2010s gave a hundred seed weight of 27.2 and 27.53 grams, respectively through continuous efforts in made in the chickpea breeding program. Similarly, in different parts of the world, most desi varieties have 100 seed weight around 22 g, however some large-seeded varieties (>25 g/100 seed) have also been developed through targeted breeding to meet a specific demand (Gaur *et al.*, 2007).

Table 2. Comparison of mean grain yield and hundred seed weight increment of desivarieties released from 1980s to 2010s with the first released variety in 1962.

Variety	Year of release	Grain yield (kg/ha)	100 seed weight (g)	Increment over the first released variety, DZ-10-11			
				Grain yield		100 seed weight	
				Kg/ha	%	g	%
DZ-10-11	1974	1500	12.4	-	-	-	-
Dubie	1980	1850	21.75	350	23.33	9.35	75.4
Mariye	1985						
Wroku	1994	2200	23.95	700	46.67	11.55	93.15
Akaki	1995						
Kutaye	2005	2500	27.2	1000	66.67	14.8	119.35
Mastewal	2006						
Fetenech	2006						
Natoli	2007						
Minjar	2010	2750	27.53	1250	82.6	15.13	122.05
Dalota	2013						
Teketay	2013						

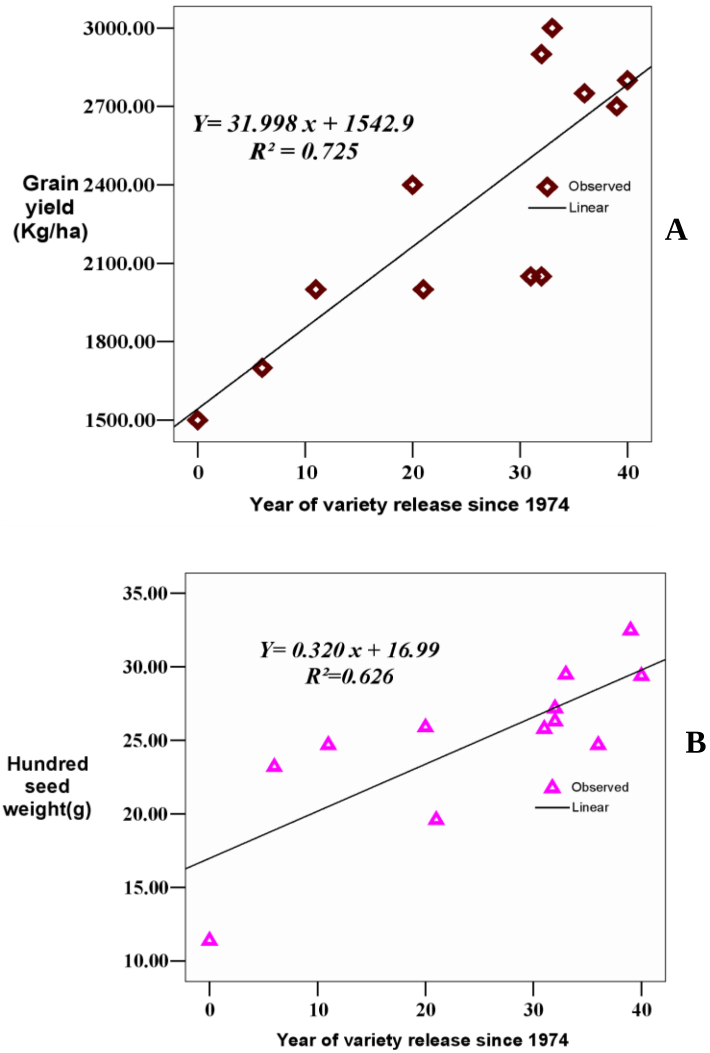

Fig 1: Plot of mean grain yield (**A**) and 100 seeds weight (**B**) of desi varieties against years of release from 1974 to 2013.

Table 3. Estimate of coefficient of determination (R^2), linear regression coefficient (β_1) and annual rate of relative genetic progress (RGP %) of released desi types based on grain yield and seed size from 1962 to 2013.

Trait	Over all mean of varieties	Mean of the oldest variety	Intercept/ Constant	R^2	β_1	RGP/year (%)
GY (Kg/ha)	2320.83	1500.00	1542.9***	0.725	31.998***	2.133
HSW (g)	24.6	12.40	16.99**	0.626	0.320**	2.58

****, **, * linear regression coefficient (β_1) values were significantly different from zero at $P\leq 0.001$, $P\leq 0.01$ and $P\leq 0.05$ respectively*

Kabuli types: The overall mean of the varieties released after 1990s showed a decreasing trend in grain yield increment in parallel with year of variety release (Table 4). The varieties released in 1990s, 2000s and 2010s exhibited grain yield increment of 1450 (82.86%), 775 (44.33%) and 583.3 (33.33%) kg/ha respectively, over the oldest kabuli variety, DZ-10-4 released in 1962. During these periods, the main target of chickpea breeding program was improving the seed size and releasing larger seeded kabuli varieties as demanded by the market. Due to this fact, grain yield showed a decreasing trend for varieties released in 1990s.

In kabulis, there was no significant genetic progress in grain yield for the last four decades (Table 5). Based on the linear regression estimate, the absolute genetic progress achieved in grain yield was only15.259 kg $ha^{-1}year^{-1}$($R^2=0.164$) which is equivalent to 610.36 kg ha^{-1} in 40 years with relative genetic progress of 0.87% $year^{-1}$(Table 5 and Fig. 2A). Likewise, the annual rate of increase in grain yield of kabuli varieties for the last 36 years was 8.42 kg $ha^{-1}yr^{-1}$ (303.12kg ha^{-1}/36 years),which was not significantly different from zero (Belete *et al.,* 2011).

However, in Ethiopia chickpea breeding program remarkable progress has been made in the development oflarge seeded Kabuli varieties.The genetic progress achieved in seed size for the last four decades was very highly significant ($P\leq 0.001$) (Table 5 and Fig 2B). As estimated from the linear regression, the average annual rate of increase ofhundred seed weight was 0.931g ($R^2=0.764$) with a relative genetic progress of 8.6% $year^{-1}$(Fig. 4, Table 5). Late in 2000s and early 2010s, extra large-seeded kabuli varieties such as Acos dubie (~60g per 100 seeds) and Kobo (>45g/100 seeds) were developed. Likewise, Belete *et al* (2012) also found that the annual rate of genetic progress in seed size of kabuli types was 1.00g/100 seeds ($R^2=0.$ 612). Keneni *et al* (2011) also reported that for similar study with five kabuli and three desi varieties, theannual rate of genetic progress in seed size was 9.42 g/1000 seeds. Moreover, the overall mean of thevarieties showed a steady increase in 100 seed weight parallel with their year of release. Varieties released in 1990s, 2000s and 2010s attained hundred seed weight increment of 17.35, 28.7 and 26.6 grams respectively, which is equivalent to 160.7%, 266.0% and 246.3% over the oldest variety released in 1962 (Table 4).

Remarkable genetic progress in seed size was achieved due to the fact that for the last few years chickpea breeding program has mainly focused on the development of a large-seeded Kabulis based on world market demand. Seed size is the most important quality trait for kabuli types as larger seeds fetch high world price premium (Gaur *et al.,* 2007). Keneni *et al* (2011) also reported that better genetic progress was attained for seed size than for grain yield over the last 15 years.

Table 4. Mean grain yield and hundred seed weight increment of released Kabuli typechickpea as compared with the first released variety DZ-10-4.

<table>
<tr><th rowspan="3">Variety</th><th rowspan="3">Year of release</th><th rowspan="3">Grain yield (kg/ha)</th><th rowspan="3">100 seed weight (g)</th><th colspan="4">Increment over the first released variety, DZ-10-11</th></tr>
<tr><th colspan="2">Grain yield</th><th colspan="2">100 seed weight</th></tr>
<tr><th>Kg/ha</th><th>%</th><th>g</th><th>%</th></tr>
<tr><td>DZ-10-11</td><td>1974</td><td>1750</td><td>10.8</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Arerti</td><td>1999</td><td rowspan="2">3200</td><td rowspan="2">28.15</td><td rowspan="2">1450</td><td rowspan="2">82.86</td><td rowspan="2">17.35</td><td rowspan="2">160.7</td></tr>
<tr><td>Shasho</td><td>1999</td></tr>
<tr><td>Chefe</td><td>2004</td><td rowspan="6">2525</td><td rowspan="6">39.5</td><td rowspan="6">775</td><td rowspan="6">44.3</td><td rowspan="6">28.7</td><td rowspan="6">266</td></tr>
<tr><td>Habru</td><td>2004</td></tr>
<tr><td>Ejere</td><td>2005</td></tr>
<tr><td>Teji</td><td>2005</td></tr>
<tr><td>Yelibey</td><td>2006</td></tr>
<tr><td>Acos dube</td><td>2009</td></tr>
<tr><td>Kasech</td><td>2011</td><td rowspan="3">2333.3</td><td rowspan="3">37.4</td><td rowspan="3">583.3</td><td rowspan="3">33.33</td><td rowspan="3">26.6</td><td rowspan="3">246.3</td></tr>
<tr><td>Akuri</td><td>2011</td></tr>
<tr><td>Kobo</td><td>2012</td></tr>
</table>

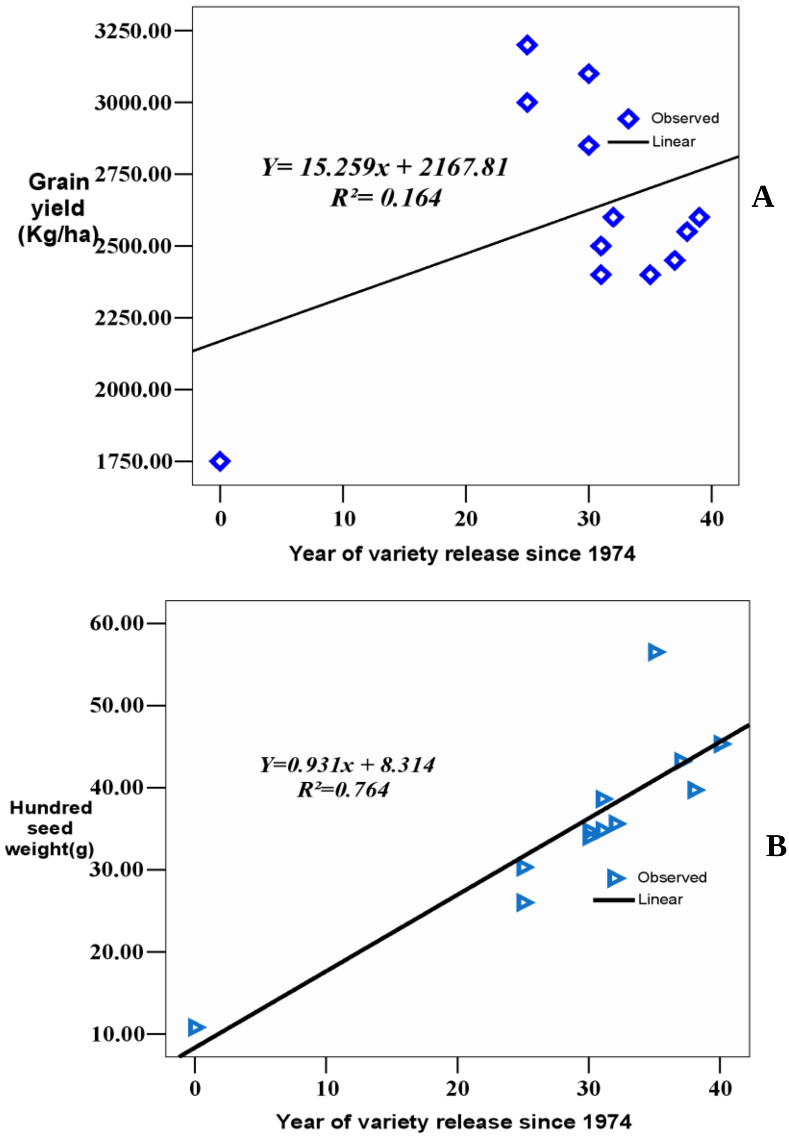

Fig. 2: Plot of mean grain yield (**A**) and hundred seed weight (**B**) of kabuli varieties against years of release from 1974 to 2012.

Table 5. Estimate of coefficient of determination (R^2), linear regression coefficient (β_1), and annual rate of relative genetic progress (RGp %) of released kabuli types in Ethiopia based on grain yield and seed size from 1962 to 2013.

Trait	Over all mean of varieties	Mean of the oldest variety	Intercept/ constant	R^2	β_1	RGP/year (%)
GY (Kg/ha)	2525.00	1750.00	2167.81**ns**	0.164	15.259**ns**	0.87
HSW (g)	34.70	10.80	8.314**	0.764	0.931***	8.62

******, **, *, ns*** = linear regression coefficient (β_1) values were significantly different from zero at P≤ 0.001, P≤ 0.01, P≤ 0.05; and non-significant respectively.
GY = Grain yield, HSW = Hundered seeds weight

Summary and conclusions

Through strong collaboration with ICRISAT and ICARDA, continuous breeding effortshas made substantial progresses inimproving grain yield and seed size of chickpea varieties in Ethiopia.Considerable genetic progress has been achieved in grain yield for desi varieties. The absolute genetic progress in grain yield was significantly high with a relative genetic progress of 2.13% year^{-1}. Similarly, the average annual rate of increase of hundred seed weight per year was enormous with a relative genetic progress of 2.44% year^{-1}.

Conversely, the absolute genetic progress in grain yield for kabulis was insignificant. However,remarkable progress has been made in the development of large-seeded varieties in Ethiopia.The average annual rate of increase of hundred seed weight per year was significantly high with a relative genetic progressof 8.62% year^{-1}. This study confirmed that for grain yield, better genetic progress was achieved in desis than in kabulis; whereas for seed size, a remarkable genetic progress was attained in kabulisthan in desis. Therefore, more advanced and diversified gene manipulation option through strategic breeding has to be undertaken targeting trait of economic importance for emerging demands in both types of chickpeas.

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References

Abeledo LG, Calderini DF and Slafer GA (2003) Genetic improvement of barley yieldpotential and its physiological determinantsin Argentina (1944-1998). *Euphytica,* **130**:325-334.

Belete T, Mekbib F, and Eshete M (2013) Genetic Progress over 36 Years of Chickpea Breeding in Ethiopia*:* Genetic Gain in Grain Yield and Associated Traits of Chickpea (*Cicer arietinum* L.) in Ethiopia. LAP LAMBERT Academic Publishing. 172pp.

Bulman P, Mather DE, and Smith DL (1993) Geneticimprovement of spring barley cultivarsgrown in eastern Canada from1910 to 1988.*Euphytica*, **71**:35-48

CSA (2013) Central Statistical Agency, Agricultural Sample Survey, 2012/2013. Volume I: Report on "Area and Production of Crops, Addis Ababa, Ethiopia.

Donmez E, Sears JP, Shroyer and GM Paulsen (2001) Genetic gain in yield attributes ofwinter wheat in the Great Plains. *Crop Sci*., **41**: 1412-1419.

Duvick DN (2005) The contribution of breeding to yield advances in maize pp. 83-145. *In:* Sparks DN (ed.), *Adv.Agron*.86.

Evans LT and Fischer RA (1999) Yield potential: its definition, measurement, and significance. *Crop Sci.* **39**:1544-1551.

Faria LC, Melo PGS, Pereira HS, Peloso MJD, Bras AJBP, Moreira JAA, de Carvalho HWL, Melo LC(2013). Genetic progress during 22 years of improvement of carioca-type common bean in Brazil.*Journal of field Crops Research*,**142**: 68-74.

Fekadu W, Zeleke H, Ayana A(2011)Genetic improvement in grain yield potential and associated traits of food barley (*Hordeum vulgare* L.) in Ethiopia.*Ethiop .J. Appl. Sci*.**2**(2):43 -60.

Gaur PM, Gowda CLL, Knights EJ, Warkentin TO, Acikgoz N, Yadav SS and Kumar J (2007) Breeding Achievements. In "*Chickpea Breeding and Management*"; Yadav, S.S.,Redden, B., Chen,W., Sharma, B.(eds.), CABI:Wallingford,UK, pp.391–416.

Kassie M, Shiferaw B, Asfaw S, Abate T, Muricho G, Teklewold H, Eshete M and Assefa K (2009) Current situation and future outlooks of the chickpea sub-sector in Ethiopia. ICRISAT Working Paper, ICRISAT and EIAR, 39 (*Accessed on June 5, 2014*) http://www.icrisat.org/tropicallegumesII/pdf.

Keneni G, Bekele E, Getu E, Imtiaz M, Dagne K and Asefa F (2011) Breeding chickpea (*Cicer arietinum*[Fabaceae]) for better seed quality inadvertently increased susceptibility to adzuki bean beetle(*Callosobruchus chinensis* [Coleoptera: Bruchidae]) *International Journal of Tropical Insect Science*. **31**(4): 249–261.

Khalil IH, Ahmad B, Rahman SU,and Subhan F (2010) Genetic gains for grain yield in two selection phases of a wheat breeding program. *Pak. J. Bot*., **42**(3): 1595-1600.

Ortiz R, Nurminiemi M, Madsen S, RognliOA, and Bjornstad A (2002) Genetic gains in Nordicspring barley breeding over sixty years.*Euphytica*,**126**: 283-289.

9. Genotype x Environment Interaction and Stability Analysis of Chickpea (*C. arietinum* L.) in Ethiopia

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AMMI and GGE models were used to determine the stability and adaptability of seed yield and hundred seed weight of fifteen chickpea genotypes, in RCBD with three replications at three locations (Inewari, Adet, and Sirinka, Ethiopia) during three seasons. The sum square of G x E interaction was partitioned by AMMI model into two significant interaction principal component axes (IPCA).Genotypes based on seed yield Akaki, ICCV 91022, ICCV 91014, and ICCV 92006 best perform at Inewari-2, Adet-2, Inewari-1 and sirinka-2 and Sirinka-1 respectively.GGE biplot depicted the presence of three mega environments among the test environments used for evaluation of genotypes. Inewari-2 and Adet-2 were exceptional environments for seed yield and the rest of the environments cluster together. Besides, hundred seed weight explained PC1 and PCA2 about 59.3 and 40.7%. There was positive correlation among environments except Inewari-3 and Sirinka-3 where ICCV 89303 and ILL 2872 perform well.Pattern analysis has assisted in analyzing the chickpea testing environments leading to the identification of the existence of three and two mega-environment clusters for seed yield and hundred seed weight respectively.

Keywords: Chickpea, G x E interaction, AMMI model, Biplot

Introduction

Chickpea (*Cicer arietinum* L.) with 17-24% protein and 41-50% carbohydrates is one of the most important food crops (Witcombe and Erskine, 1984). Chickpea is an important pulse crop in Ethiopia that contribute more than 1.91% (about 231,298 hectares) and 1.83% (~400,207 tons) of both in area and production among pulses that account for 13.38% (1,616,809 hectares) and 10.6% (~2,316,201 tons) of grain crops in the country (CSA 2011). Ethiopia is the largest producer of chickpea in Africa accounting for about 46% of the continent‘s production during 1994-2006. The country is also the seventh largest producer worldwide and contributes about 2% to the total world chickpea production (Menale *et al*. 2009).

Usually, phenotype of a crop is the value for a given trait at the end of the growing season. The reason is that we are more interested in phenotypes like yield or grain weight at maturity and not, or less, in yield or grain weight at earlier stages. The final state of a trait is the cumulative result of a number of causal interactions between the genetic make-up of the plant (the genotype) and the conditions in which the plant is growing (the environment) (Malosetti *et al*. 2013).

In amulti-environment trials (METs), a number of genotypes are evaluated at a number of geographical locations for a number of years in the hope that the pattern of stress that the genotypes experience is representative of the future growing environments (Malosetti *et al*. 2013). While a large number of genotypes are tested over a number of sites and years, it is often difficult to determine the pattern of genotypic responses across environments without the help of graphical display of data (Yan *et al*. 2001).A mega environment is a group of environments or sub-regions in which a single genotype or a group of similar genotypes are specifically adapted and champion in performance (Gauch and Zobel, 1997). Differences in genotype stability and adaptability to environment can be qualitatively assessed using the biplot graphical representation that scatters the genotypes according to their principal component values (Vita *et al*. 2010). The co-sine of angle between a pair of environment vectors approximates correlation between them (Yan and Kang 2003).The position and perpendicular projection of genotypic points onto an environmental vector can be used to identify a genotype or genotypes having specific adaptation in that environment(s) (Yan *et al*. 2000).

The objectives of this study was to assess stability, genotype-by-environment interaction (GEI) pattern of ―multi-environment trials" (METs) of chickpea genotypes growing in vertisol areas of Northern part of Ethiopia and model the data using AMMI and GGE model using breeding view tool.

Materials and methods

Plant materials: In collaboration with the International Center for Agricultural Research in the Dry Areas (ICARDA), the national chickpea research program introduced chickpea germplasms, and these materials were tested on sick plots to screen for wilt/root rot diseases.The screening nurseries and advanced yield trials were conducted at Inewari, North Shoa. A total of 15 desi chickpea genotypes together with two commericial vareties and a farmers' variety were used in this study.

Design and environments: The genotypes were examined in a Randomized Complete Block Design (RCBD) with three replications in three different environments (Inewari, Adet and Sirinka) for three consecutive growing seasons. Each location per a season was considered as a separate environment and the entire combination would make a total of nine test environments. All the genotypes were planted on a broad bed plot of 1.2m x 4m size. The furrow between any two adjacent plots was 40cm wide. Each plot consisted of 4 rows of chickpea plants 30cm apart.Data on seed yield and hundred seed weight were recorded from the two central rows of each plot to avoid boarder effect. The Additive Main Effects and Multiplicative

Interaction (AMMI) and GGE model was used to investigate GEI. Stastical analysis wasperformed by statistical packages Genstat Dicovery Edition 4 and breeding viewsoftware.

Results and Discussion

The Seed yield in the AMMI model, GEI is explained by two axes: principal component 1 (PCA1) and principal component 2 (PCA2) that are highly significant ($P < 0.001$). Genotypes ICCV 9206, ICCV 92032 and ICCV 89223, being closer to the biplot origin, were average in their performances for grain yield and are more stable across environments (Fig.1).The genotypes that are farther along the positive direction of the vector tend to give higher yields, and are better adapted to those environments.Based on grian yield genotypessuch as Akaki, ICCV 91022, ICCV 91014, and ICCV 92006 were best performer at Inewari-2, Adet-2, Inewari-1 and Sirinka-2, and Sirinka-1, respectively.

GGE biplot depicted the presence of three mega environments among the test environments used for evaluation of genotypes (Fig. 2). Inewari-2 and Adet-2 were exceptional environments for chickpea grain yield and the rest of the environments cluster together. One of the test cultivar, Akaki, had best performance at Inewari-2 and ICCV91022 at Adet-2. In the contrary, ICCV91014 had best performance in all environments except at Inewari-2 and Adet-2.

Hundred seed weight explaned PCA1 and PCA2 about 59.3 and 40.7%. There was positive correlation among environments except Inewari-3 and Sirinka-3, where ICCV 89303 and ILL 2872 performed well. Further, GGE biplot analysis showed the two mega environments and their respective best performing genotypes with high hundred seed weight (Fig .4).

In summary, to determine GEI and stability, it is necessary to include more environments to cover wider growing conditions targeting a particular stress, delinating chickpea grown environments into sub-regions is essential. Besides, one has to use more than one charactersof economic importance in addition to grainyield and hundred seed weight in order to classify cultivarsinto specific or wide adaptation.

Table 1. ANOVA table for AMMI model for grain yield of 15 genotypes.

Source	**df**	**SS**	**MS**	**VR**	**F pr**
Genotypes	14	3.904	0.2789*	3.87	<0.001
Environments	8	35.102	4.3877	60.94	<0.001
Interactions	112	8.065	0.0720**		
IPCA1	21	4.552	0.2167*	2808901.30	<0.001
IPCA2	19	3.513	0.1849*	2396223.80	<0.001
Residuals	72	0.000	0.0000		

Table 2. Correlation between environments for grain yield.

Adet- 1	1.0000							
Adet- 2	–0.2119	1.0000						
Adet- 3	0.9414	–0.5006	1.0000					
Inewari -1	0.7306	–0.0766	0.7564	1.0000				
Inewari -2	0.2674	–0.0059	0.1034	–0.4530	1.0000			
Inewari -3	0.9937	–0.3015	0.9727	0.7612	0.2003	1.0000		
Sirinka -1	0.8862	–0.1694	0.8921	0.9629	–0.2075	0.9080	1.0000	
Sirinka -2	0.6254	0.3247	0.5305	0.9178	–0.4095	0.6172	0.8521	1.0000
Sirinka -3	0.5103	0.5160	0.2044	0.0334	0.7238	0.4114	0.1977	0.2582
	Adet- 1	Adet- 2	Adet- 3	Inewari -1	Inewari -2	Inewari -3	Sirinka -1	Sirinka -2

Table 3. Correlation matrix for hundred seed weight.

Adet- 1	1.0000							
Adet- 2	0.9999	1.0000						
Adet- 3	0.9647	0.9671	1.0000					
Inewari -1	0.9233	0.9271	0.9912	1.0000				
Inewari -2	0.9592	0.9620	0.9992	0.9942	1.0000			
Inewari -3	0.8578	0.8611	0.9550	0.9693	0.9522	1.0000		
Sirinka -1	0.9829	0.9846	0.9967	0.9780	0.9946	0.9311	1.0000	
Sirinka -2	0.9741	0.9755	0.9954	0.9766	0.9908	0.9517	0.9959	1.0000
Sirinka -3	0.8779	0.8769	0.8982	0.8660	0.8808	0.9229	0.8960	0.9313
	Adet- 1	Adet- 2	Adet- 3	Inewari -1	Inewari -2	Inewari -3	Sirinka -1	Sirinka -2

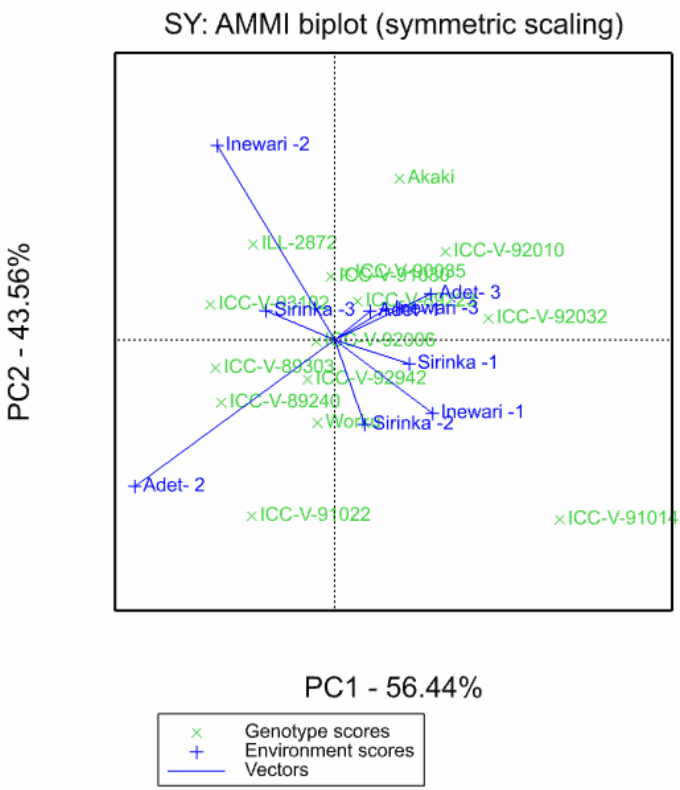

Fig.1: AMMI biplot analysis showing the mega environments and their respective yielding genotypes

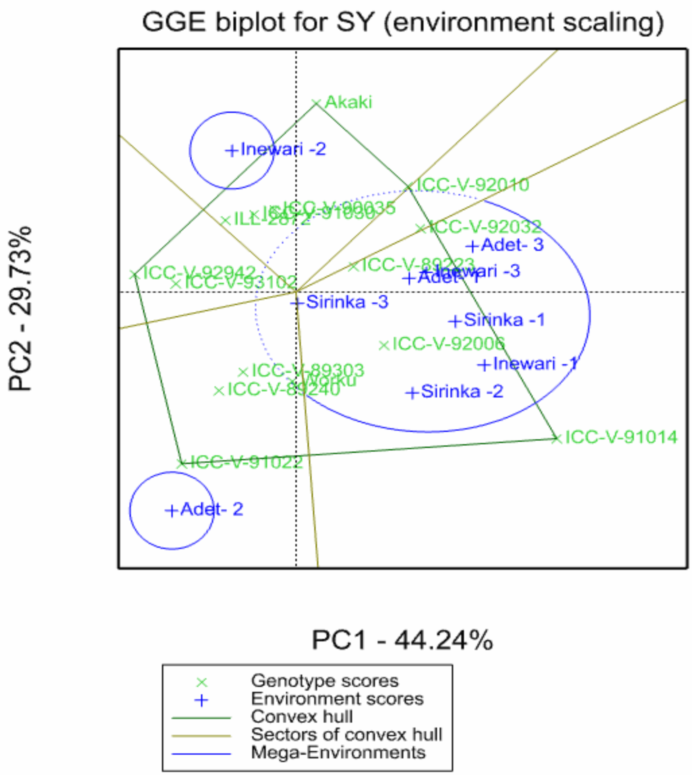

Figure 2: GGE biplot analysis showing the three mega environments and their respective yielding genotypes.

Table 4. ANOVA table for AMMI model for hundred seed weight of 15 genotypes.

Source	df	SS	MS	VR	F pr
Genotypes	14	986.9	70.49	146.62	<0.001
Environments	8	52.9	6.61	13.75	<0.001
Interactions	112	53.8	0.48		
IPCA1	21	31.9	1.52	181120.24	<0.001
IPCA2	19	21.9	1.52	137528.06	<0.001
Residuals	72	0.000	0.0000		

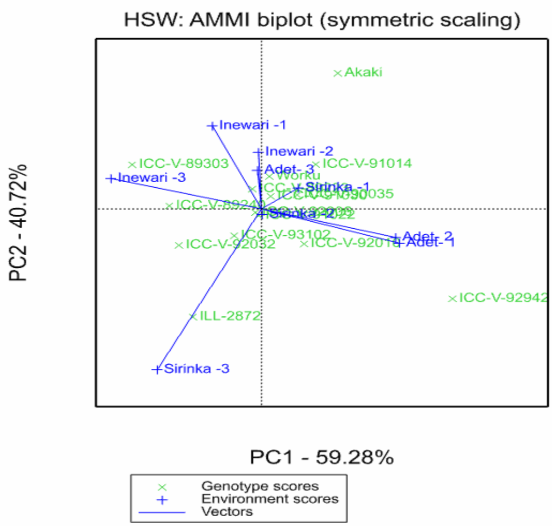

Figure 3: Biplot for PC1 vs PC2 scores obtained from hundred seed weight data of 15 chickpea genotypes across nine environments.

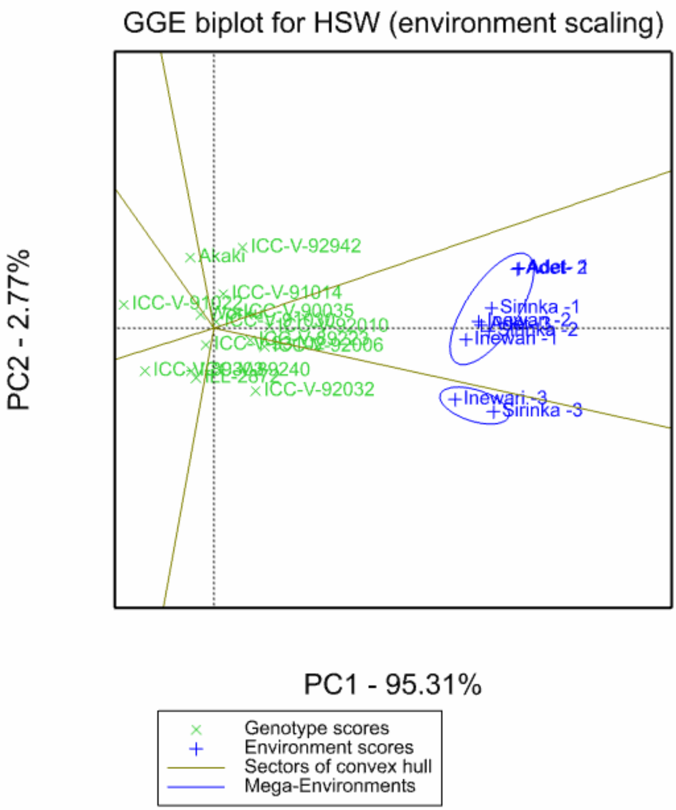

Figure 4**:** GGE biplot analysis showing the two mega environments and their respective high hundred seed weighting genotypes.

Refrences

CSA (Central Statistics Agency) (2012). Agricultural Sample Survey, Area and Production of Major Crops. *Statistical Bulletin*, Addis Ababa, Ethiopia.

Gauch HG, Zobel RW (1997) Identifying mega-environments and targeting genotypes. *Crop Science*, **37**:311-326.

Kassie M, Shiferaw B, Asfaw S, Abate T, Muricho G, Teklewold H, Eshete M and Assefa K (2009) Current situation and future outlooks of the chickpea sub-sector in Ethiopia. ICRISAT Working Paper, ICRISAT & EIAR,39.

Malosetti M, Ribaut JM and van Eeuwijk FA (2013) The statistical analysis of multi-environment data: modeling genotype-by-environment interaction and its genetic basis. *Front. Physiol*. **4**:44.

Vita PD *et al*. (2010) Genetic improvement effects on yield stability in durum wheat genotypes grown in Italy. *Field Crop Res*., **119:68-**77.

Witcombe JR and Erskine W (1984) Genetic resources and their exploitation in chickpea (*Cicer arientinum* L.), faba beans and lentils. The Netherlands and ICARDA.

Yan W and Kang MS (2003) GGE Biplot Analysis: A Graphical Tool for Geneticists, Breeders and Agronomists. CRC Press, Boca Raton, FL.

Yan W *et al*. (2001) Two types of GGE Biplots analyzing multi-environment trial data. *Crop Science,* **41**: 656-663.

Yan W, Hunt LA, Sheng Q and Szlavnics Z (2000) Cultivar evaluation and mega-environment investigation based on the GGE biplot. *Crop Sci*., **40**, 597–605.

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10. The Role of International Research Collaboration in Broadening Genetic Base of Chickpea in Ethiopia: implications on local germplasm use

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In addition to the Ethiopian Biodiversity Institute (EBI), external sources have been playing the major roles in supplying chickpea germplasm resources to the national breeding program. Chickpea research in Ethiopia has got a strong historical attachment with key international partners, particularly ICARDA and ICRISAT. Despite the fact that Ethiopia is the secondary center of diversity for the crop and a large number of chickpea landrace collections are held at the EBI, very limited numbers of local landraces have been utilized in the genetic improvement of chickpea. So far, 24 improved chickpea cultivars have been developed and only the first three oldest varieties: the two Desi types (DZ-10-11 & Dubie) released in 1962 and 1970, respectively, and DZ-10-4 (Kabuli type) released in 1962 were developed from local landraces through selection. Whereas, 21 (~88%) of the developed cultivars are from introduced germplasm or semi-processed advanced breeding lines. This shows that the Ethiopian chickpea breeding sub-program largely reliant on exotic germplasm resources while less attention has been given to local genetic resources. The attributable reasons could be (i) lack of systematically documented information with respect to important merits of local diversities, (ii) problems associated with awareness and attitudes towards the importance of landraces and (iii) lack of proper management and use of chickpea genetic resources in the country. Here we report the status and progress of chickpea genetic resource utilization in Ethiopia in the improvement programs, with a particular focus on local germplasm use.

Keywords: *Cicer arietinum, germplasm, landraces, genetic diversity*

Introduction

The cultivated chickpea (*Cicer arietinum* L.) is a self-pollinated annual grain legume playing an important role in human diet and agricultural eco-systems. Chickpea is one of the major grain legumes with an inimitable sources of dietary protein in the developing world where there is very scarce animal protein or unaffordably expensive otherwise. Besides, it is one of the major crops playing significant roles in maintaining soil fertility through its ability to fix atmospheric nitrogen, and thus improving the N nutrition and yield of subsequent cereals.

Ethiopia is considered as the secondary center of genetic diversity for chickpea (Van der Maesen, 1987; Keneni *et al*., 2011) and the country is the largest chickpea producer in Africa with annual grain production of ~400,000 tons from an area of 231,000 hectares (CSA, 2013), which accounts for more than 46% of the continental production (Kassie *et al*., 2009). Production has been increasing rapidly in the major chickpea growing areas of the central highlands of Ethiopia following the introduction of kabuli chickpeas into the country in the mid 1990s (Shiferaw *et al*., 2007). Besides, combined with the adoption of improved agronomic and management practices, the development of high-yielding and market-preferred cultivars has considerably contributed to the significant increment in chickpea production and productivity in Ethiopia. The crop has also commanded a favorable price in domestic and foreign markets, providing favorable returns on investment for smallholder farmers (Shiferaw *et al*., 2007). Chickpea is an important part of crop rotations along with major cereal crops such as wheat and teff, especially in the *Vertisol* conditions where other food legumes poorly adapted. Currently, chickpea attains the hishest yield (productivity) per unit area (close to 2 t ha^{-1}) among the major food legumes grown in Ethiopia (Table 1). It also contributes more than 17% of the total pulse production in the country. Importance of chickpea in the Ethiopian agricultural sector interms of its area coverage, productivity and volume of production as compared to other major food legumes is summarized in the following table.

Table 1. The current production and productivity of the major food legumes in Ethiopia (Source: CSA, 2014).

.Rank	Crop	Area		Production		Yield*
		ha	%	MT	%	(t ha^{-1})
1	Faba bean	443,108	28.4	838,944	31.4	1.89
2	Beans	323,327	20.7	513,725	19.2	1.59
3	**Chickpeas**	**239,755**	**15.4**	**458,682**	**17.2**	**1.92**
4	Peas	230,667	14.8	342,637	12.8	1.49
5	Grasspeas	136,884	8.8	251,439	9.4	1.84
6	Lentils	98,869	6.3	137,354	5.1	1.39
Pulses total		**1,558,501**	**100.0**	**2,671,853**	**100.0**	**1.64****

**National average of productivity;* ** *Mean yield of the six pulse crops.*

In addition to its domestic importance, Ethiopian chickpe is also gaining a remarkable reputation in the global market. Ethiopia is the largest chickpea producer and exporter in Africa accounting for about 55% of the continent‘s chickpea production, and amongst the top ten global chickpea producing countries – standing 7th in area coverage (240,000 ha), 3rd in terms of productivity (1,913 kg ha^{-1}) and 5th in terms of annual grain production volume (459,000 MT) (Table 2).

Table 2. Wold top ten chickpea producing countries and the position of Ethiopia in the global chickpea production.

Rank	Area (000‘ ha)		Yield (Kg ha^{-1})		Volume (000‘ MT)	
1	India	9,600	Israel	3,559	India	9,880
2	Pakistan	990	China	3,500	Australia	817
3	Australia	574	**Ethiopia**	**1,913**	Pakistan	750
4	Iran	550	Canada	1,864	Myanmar	492
5	Turkey	389	Mexico	1,613	**Ethiopia**	**459**
6	Myanmar	335	USA	1,484	Turkey	450
7	**Ethiopia**	**240**	Myanmar	1,464	Iran	275
8	Mexico	116	Australia	1,397	Mexico	172
9	USA	88	Turkey	1,158	USA	127
10	Canada	72	India	920	Canada	123

Source*: Compiled from FAO (http://faostat.fao.org), accessed on July 27, 2015*

Recent reports, however, indicated that production and productivity of chickpea is stagnating due to various biotic and abiotic stresses (Kassie *et al*. 2009, Keneni *et al*. 2012). Terminal drought, heat and frosts are becoming the major yield-limiting abiotic stresses under the current chickpea production in Ethiopia. The major insect pests of economic importance in chickpea are pod borer (*Helicoverpa armigera*) and cutworms (*Agrostis* spp.) under field conditions, and Adzuki bean beetle (*Callosobruchus chinensis*) under storage conditions. The two pathogens: Ascochyta blight (AB) caused by *Ascochyta rabiei* (Pass.) and Fusarium wilt caused by *Fusarium oxysporum* f. sp. ciceris (Nene and Reddy, 1987; Pande *et al*., 2010) are diseases of major economic importance of chickpea in Ethiopia, among which AB is becoming the major constraints for chickpea production in the country (Ahmed and Ayalew, 2006). Yields of adaptable cultivars are hampered and becoming unstable mainly due to over sensitivity of the dependable cultivars to the aforementioned stress that are exacerbated by climate change.

Chickpea farmers in Ethiopia and elsewhere are demanding stable and high-yielding varieties to improve their food security and soil fertility in the face of climate change. To this end, tolerant to drought and heat (which often co-occur) are primary targets for the current chickpea improvement programs.

The Ethiopia chickpea R&D: key achievements and salient impacts

In the national chickpea improvement history of the country, 24 improved cultivars have been developed and released from the NARS (MoA, 2014). Adoption of these new varieties and their improved agronomic practices is increasing. According to Fikre (2014) (in press), adoption of improved chickpea technology has reached ~30% of the total annual area aloted to chickpea. Remarkable national productivity gain from average productivity of 1.38 t ha^{-1} in 2010 to 1.73 t ha^{-1} in 2014 (CSA, 2010 – 2014) and interestingly, there is an increasing trend of the annual productivity gain over the last decade. Most importantly, substantial wealth creation and improvement in the livelihood (Yirga *et al*. 2010) have been realized in rural chickpea growing communities. In addition, the crop has significantly contributed in the national hard currency revenue generation due to increased Ethiopian chickpea expoert to the world having ~4-6% of the global chickpea market share (Fikre, in press).

Table 3. List of chickpea cultivars developed in the Ethiopian NARS and their corresponding sources (1962 – 2013).

Ser No.	Variety designation	Pedigree	Origin/source	Year of release	Releasing center*	Peculiar breeding merits
			Desi types			
1	DZ-10-11	DZ-10-11	Ethiopia	1962	DZARC	High local use values
2	Dubie	PGRC/	Ethiopia	1970	DZARC	Better local adaptations
3	Mariye	K-850-3/27xF378	ICRISAT	1977	DZARC	Better grain test & use values
4	Worku	ICCL-820104	ICRISAT	1994	DZARC	Better grain yield
5	Akaki	ICCL-820016	ICRISAT	1995	DZARC	Better grain yield
6	Kutaye	ICCV-92033	ICRISAT	2005	SARC	Better yield & seed quality
7	Mastewal	ICCV-92006	ICRISAT	2006	DARC	Better yield & seed quality
8	Fetenech	ICCV-92069	ICRISAT	2006	SARC	Better yield & seed quality
9	Natoli	ICCX-910112-6	ICRISAT	2007	DZARC	Yield, seed quality & RR tolerance
10	Minjar	ICCV-03107	ICRISAT	2010	DZARC	Wilt & AB toleraance
11	Dalota	ICCX-940002	ICRISAT	2013	DZARC	Yield, wilt & AB tolerance
12	Teketay	CJG-74xICCL-83105	ICRISAT	2013	DZARC	Yield, wilt & AB tolerance

*****DZARC = D/ Zeit Agric. Res. Center, SARC = Sirinka Agric. Res. Center, DARC = Debre Birhan Agric. Res. Center.*

Table 3. Continued…

Ser No.	Variety designation	Pedigree	Origin/source	Year of release	Releasing center*	Peculiar breeding merits
			Kabuli types			
13	DZ-10-4	DZ-10-4	Ethiopia	1962	DZARC	High local/traditional use value
14	Arerti	FLIP 89-84c	ICARDA	1991	DZARC	Extensive adaptation, AB resistance & yield
15	Shasho	ICCV-93512	ICRISAT	1991	DZARC	Yield, RR tolerance & adaptation
16	Chefe	ICCV 92318	ICRISAT	2004	DZARC	RR & AB tolerance, yield & adaptation
17	Habru	FLIP 88-42c	ICARDA	2004	DZARC	Earliness, yield, AB & RR tolerance
18	Ejere	FLIP 97-263c	ICARDA	2005	DZARC	Yield, AB tolerance & earliness
19	Teji	FLIP 97-266c	ICARDA	2005	DZARC	Yield, seed quality & RR tolerance
20	Yelibe	ICCV-14808	ICRISAT	2006	SARC	Better yield & seed quality
21	Monino	Acos Dubie	Mexico	2009	DZARC	Seed size, high market value
22	Kasech	FLIP-9531c	ICRISAT	2011	SARC	MS tolerant & seed size
23	Akuri	ICCV-03402	ICRISAT	2011	SARC	MS tolerant & seed size
24	Kobo	ICCV-01308	ICRISAT	2012	SARC	MS tolerant, seed size & yield

**DZARC = D/ Zeit Agric. Res. Center, SARC = Sirinka Agric. Res. Center, DARC = Debre Birhan Agric. Res. Center.*

Although there is a substantial productivity gain of chickpea crop in Ethiopia in an increasing trend, the current national average productivity of the crop is still far below the genetic potential (~5 t ha^{-1}) the crop can offer (Muehlbauer and Tullu, 1997). Improved chickpea varieties in Ethiopia yield ~ 4.5 t /ha under best management (in the fields of model and innovative farmers). The imrovemnt program, however, has limitations in terms of generating diverse breeding material stock through intensive germplasm enhancement and breeding efficiency improvement, and in terms of expanding its capacity towards serving as chickpea genetic resource-base for East and sub-Saharan Africa.

Chickpea genetic resources of Ethiopia: the role of native germplasm in the improvement programs

Crop germplasm collections in Ethiopia are consolidated in the Ethiopian Biodiversity Institute (EBI) using the common conservation strategies: under Genebank (*ex situ*) condition and on-farm (*in situ*) conservation sites (Tanto and Tefera, 2006). EBI is mandated to conservation of genetic resources and associated indigenious knowledge to ensure: i) sustainable use of genetic resources, ii) long-term preservation and maintenance, and iii) provision of germplasm for improvement programs. The EBI is undertaking systematic crop germplasm exploration and collection from all major regions of the country. Up to date, the institute has wealth of ~74,394 accessions of different field crops collected and have been conserved. About 7,745 germplasm accessions of pulse crops have been conserved in the national genebank, of which chickpea accounts for more than 1,213 accesstions (~16%) (Table 4).

Table 4. Status of genetic resource conservation of the major Ethiopian field crops held in the EBI genebank.

Ser No.	Crop Category	Number of Accessions	Remarks
1	Cereals	50,868	
2	Pulses	7,745	Chickpea accounts for more than 1213 accessions
3	Oil crops	7,740	
4	Spices	1,817	
	Total	**68,170**	

Source: *EBI (2014)*

The Ethiopian chickpea landrace collection held at the national gene bank (EBI) has wide coverage and representing almost all geographical regions of Ethiopia (Fig. 1). The two major chickpea producing regions, Amhara and Oromiya, accounts for more than 70% of the entire landrace collections. These genetic resources are national treasures and currently under extensive characterization and evaluation using international descriptor lists to ensure their sustainable utilization.

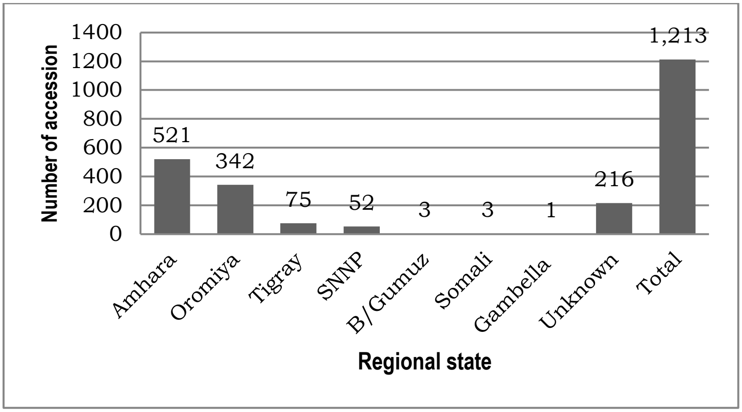

Fig 1: Number and geographyical coverage of Ethiopian chickpea landrace collections conserved in the National Gene Bank (EBI, 2014).

Although fairly a sizable number of chickpea landrace collections are held at the EBI, the majority of these resources have only been used just for the purpose of post graduate studies and there is very limited use in the national improvement (breeding) programs. Recent studies revealed that the Ethiopian chickpea landraces had considerable significance as sources of genotypes with important attributes (Keneni *et al*, in press). It has also been proved by the same authors that Ethiopian chickpea landraces retain untapped wealth of genetic diversity, ascertaining that Ethiopia can serve as chickpea germplasm source and can contribute a lot for future global chickpea research.

Chickpea is known to be grown in Ethiopia since antiquity and the country is considered as the secondary center of chickpea genetic diversity (Van der Maesen, 1987; Keneni *et al*., 2012). Particularly, the country has comparative advantages on the desi type genetic resource basis and the potential genetic diversity hasn't yet been exploited and properly utilized. Chickpea improvement program in Ethiopia thus far is obtaining quite a large number of breeding materials from exotic germplasm sources mainly from international collections following the establishment of research partnership with CGIAR centers (mainly ICRISAT and ICARDA). Accroding to recent reports, more than 10,000 germplasm accessions or semi-processed advanced (pre-breeding) lines have been introduced during the improvement program life span from CGIARS (Fikre, in press). Bejiga and Daba (2006) also indicated that the Ethiopian chickpea breeding program has enormously benefited from the international research partnership though germplasm acquisition. However, local germplasm hasn‘t been exploited in the improvement program and in the past, the Ethiopian chickpea breeding sub-program largely reliant on exotic germplasm resources while less attention was given to the local genetic resources. It seems that a total dependency syndrome has apparently been created in the national breeding programs, and the status of utilizing these exotic breeding materials as important gene sources (as parents) to improve locally adaptable cultivars through targeted hybridization program is still remain behindhand (Table 6).

On the the hand, the bulck of breeding stocks of international chickpea genepool provided from these centers, the majority of which are the domesticated species (*Cicer arietinum*), are lacking the necessary genetic diversity for specific local adaptaions to address the pressing needs of growing conditions of the developing countries (Abbo *et al*, 2003, von Wettberg *et al*, 2016). As a result, the prospect for sustainable genetic gain from the existing germplasm resources is increasingly limited (Warschefsky *et al*. 2014). For instance, between 1991 and 2012 period, a total of 4,348 chickpea breeding nurseries (both *kabuli* and *desi* types) were introduced from ICRISAT (854) and ICARDA (3,494) and the genotypes were mainly tested at Debre Zeit main station (Table 5). The number of genotypes developed into varieties or identified as parental lines for specific gene/trait source is found to be negligible. The anticipated reason for this may be due to the narrow genetic variability of the introduced breeding nursieries. Although the success rate in terms of variety development is low, it is, however, worth to mention that the unique merits of these breeder-ready materials hasn‘t been well studied, and the fate of these massive breeding materials accumulated over years remain undetermined.

Table 5. Role of introduced chickpea germplasm sources in the chickpea improvement (variety development) in Ethiopia (1991 – 2012).

Research period	Germplasm source	Number of breeding materials introduced & tested	Number of cultivars developed	Success (%)
1991-2012	ICRISAT	577 (K*)	3	0.52
		277 (D*)	11	3.97
	ICARDA	3,494 (K)	5	0.14
	Total	**4,348**	**19**	**0.44**

**K = Kabuli types, D = Desi types*

***Source**: Extracted and compiled from field books and data record sheets of the national chickpea breeding program (DZARC, 1991 to 2012).*

Despite the fact that Ethiopia is the secondary center of diversity for the crop, these genetic resources remain underutilized and exploitation of local genetic diversity in the improvement programs has been very limited. This is witnessed by the fact that out of the 24 improved chickpea cultivars developed in the improvement history of the country, only the first three oldest varieties namely, DZ-10-11, Dubie (both *desi* types) and DZ-10-4 (*kabuli* type), which were released between 1962 and 1970 were developed from local landraces through selection (Table 3). Whereas, the remaining 21 (~88%) of the cultivars were developed from introduced germplasm accessions or semi-processed advanced breeding lines. Obviously, this has a critical implication on the use of local chickpea germplasm and exploitation of their adaptable genetic diversity. In terms of germplasm sources, breeding materials from ICRISAT (India) has the largest proportion of 66.7%, ICARDA (Syria) has 16.7% and EBI (Ethiopia) (12.5%).

Full exploitation of local germplasm landraces, which hold long-standing adaptions may therefore, enable breeders to address pressing needs such as increased resilience to drought, heat and cold, reduced dependence on inputs, and resistance to biotic stress. Similarly, new collections of crop wild relatives of chickpea may also augument the initatives.

Table 6. Relative contribution of germplasm sources for chickpea genetic improvement (variety development) in Ethiopia.

Year /period/	Germplasm source	Contribution (%)	Remark
1962 – 1970	Collection	13	
1977 – present	Introduction*	87	
1960s – present	Hybridization	0	

**Introduction mainly includes nursery materials (accessions, lines, segregating populations, etc.)*

Conclusion and Recommendations

Paradigm shift in the national chickpea research strategy: in all so far chickpea research in Ethiopia, considerable investments (in terms of genetic resources and capital) have been made through strong partnering with international research allies (particularly ICRISAT and ICARDA) in the areas of germplasm exchange, knowledge/skill transfer and other capacity building. Out of the 24 improved chickpea cultivars developed in Ethiopia, 21 of them (~88%) were derivatives of introduced germplasm accessions or pre-breeding lines, and only the first three oldest varieties (12%) were developed from local landraces through selection. This shows that the Ethiopian chickpea breeding sub-program largely reliant on exotic germplasm, whereas less attention has been given to the local genetic resources. It is, therefore, high time that the national chickpea improvement program of the future should make a paradiem shift of breeding strategy towards full and systematic exploitation of the untapped local genetic diversity.

The need for initiating extensive hybridization program: It seems that the national chickpea breeding program has followed highly skewed trend towards germplasm importation, and less attention has been given to generation. This trend has created a total dependency on exotic germplasm and the improvement has exclusively been through selection breeding with negligible genetic manipulation. Our breeding experience thus far has indicated that the bulck of breeding materials provided from international stocks are lacking the necessary diversity (both at genetic and phenotypic levels) to address the pressing needs of growing conditions of the developing countries. As a result, the likelihood of getting desirable traits through selection *per sae* will have a diminishing retun on genetic gain. A series of multiple crossing is required in order to bring desirable traits among multiple parents (both from native and exotic sources) supported by advanced breeding techniques such as Marker-assisted breeding. Therefore, the breeding program should initiate an extensive hybridization program and novel genetic manipulation so as to increase the frequency of desirable genes among breeding stocks is increasingly important to bring breakthroughs in chickpea genetic enhancement for the future breeding program.

The next chickpea research frontiers – creating synergy betwwen generation and acquisition: Similar to that of the native germplasm use, exploitation of exotic breeding materials as important gene sources in the cultivar development through hybridization also remain behind. It is also important to note that exotic germplasm has unique merits and can serve as source of complementary genes to deploye superior and specific traits such as seed size in chickpea. Therefore, the future chickpea breeding program should give much greater attention towards establishing novel breeding strategy where both germplasm introduction and generation can co-exist rather than focusing so extensively on acquisition. The desirable relationship between landrace collections and exotic introductions tends to be mutually complementary and need to be synergized towards broadening of genetic base of chickpea breeding in Ethiopia.

Finally, the future research partnership and collaboration on chickpea improvement should also extend to other major producing countries such as Turkey, Canada and Australia which also help in increasing the genetic variability of the crop.

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References

Abbo S, Berger J, and Turner NC (2003) Viewpoint: evolution of cultivated chickpea: four bottlenecks limit diversity and constrain adaptation. *Functional Plant Biology*, **30**, 1081-1087.

Ahmed S. and Ayalew M. (2006) Chickpea, lentil, grass pea, fenugreek and lupin disease research in Ethiopia. Ali K., Keneni G., Ahmed S., Malhautra R., Bainwal S., Makkouk K. And Halila

MH. (eds) (2006). Food and Forage Legumes of Ethiopia: Progress and Prospects. *Proceeding of the workshop on food and forage legumes*. pp. 215.

CSA (Central Statistics Authority) (2010 - 2014) Area and Production of Crops in the Meher Season. *Statistical Bulletin*, Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organisation of the United Nations, Rome) Available online at: http://www.fao.org/statistics/en/

Fikre A (2014) Progresses of chickpea research and development in Ethiopia (in press). A paper presented on the Chickpea International Workshop, 30 Jan - 1 Feb 2014, Debre Zeit, Ethiopia.

Kassie M, Shiferaw B, Asfaw S, Abate T, Muricho G, Teklewold H, Eshete M and Assefa K (2009) Current situation and future outlooks of the chickpea sub-sector in Ethiopia. ICRISAT Working Paper, ICRISAT & EIAR,39.

Keneni G, Bekele E, Imitz M, Ahmed S, Debele T, Assefa F, Getu E, Fikre A and Korbu L. Tapping Genetic Variation in Chickpea (*Cicer arietinum* L.) Landrace Collections to Enhance Productivity and Farming System Sustainability: What does Ethiopia have to offer? (In press) A Paper Presented on the Chickpea International Workshop, 30 Jan - 1 Feb 2014, Debre Zeit, Ethiopia.

Keneni G, Bekele E, Getu E, Imtiaz M, Dagne K and Asefa F (2011) Breeding chickpea (*Cicer arietinum*[Fabaceae]) for better seed quality inadvertently increased susceptibility to adzuki bean beetle(*Callosobruchus chinensis* [Coleoptera: Bruchidae]) *International Journal of Tropical Insect Science*. **31**(4): 249–261.

Muehlbauer FJ and Tullu A (1997). *Cicer arietinum* L: New crop factsheet(http://www.hort.purdue.edu/newcrop/cropfactsheets/chickpea.html#Origin).

Nene YL and Reddy MV (1987) Chickpea Disease and their Control. In: Saxena MC, Singh KB (eds.). The Chickpea. *CAB International, Willingford, UK.*

Pande S., Sharma M., Gaur PM. and Gowda CLL. 2010. Host Plant Resistance to Ascochyta Blight of Chickpea. Information Bulletin No. 82. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Shiferaw B., Jons R., Silim S., Teklewold H. and Gwata E. (2007) Production and Marketing of Kabuli Chickpea Seeds in Ethiopia: Experiences from Ada District. *Project Working Paper 3*. ILRI, Nirobi, Kenya. 48 pp.

Tanto T and Tefera E (2006). Collection, conservation, characterization and sustainable utilization of grain legumes in Ethiopia. In: *Food and Forage Legumes of Ethiopia: Progress and Prospects*, pp. 15-22, (Ali, K., Keneni, G., Ahmed, S., Malhotra, R., Beniwal, S., Makkouk, K. and Halila, M.H., eds). Proceedings of a Workshop on Food and Forage Legumes. 22-26 Sept 2003, Addis Ababa, Ethiopia. ICARDA, Aleppo, Syria.

Van der Maesen LJG (1987). Origin, History and Taxonomy of Chickpea. In: Saxena, M.C. and Singh, K.B. (eds.). The Chickpea. pp. 11-34, *C.A.B International, Wallingford, UK.*

von Wettberg EJ, Chang P, Greenspan A, Moenga S, Alford B, Dacosta-Calheiros E, Abdullah M, Cakmak A, Moriuchi K, Carrasquila-Garcia N, Mamo BE, Singh V, Cordeiro M, Balcha LK *et al* (2016) Ecology and Community Genomics of an Important Crop Wild Relative as a Prelude to Agricultural Innovation. *Nature Communications* (in press).

Warschefsky E, Penmetsa RV, Cook DR and von Wettberg EJ (2014) Back to the wilds: tapping evolutionary adaptations for resilient crops through systematic hybridization with crop wild relatives. *American Journal of Botany* **101**(10): 1791-1800.

12. Participatory evaluation and selection of chickpea varieties at Debre Mawi and Debre Yakob watersheds, Western Amhara Region, Ethiopia

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Chickpea (Cicer arietinum L.) is one of the major pulse crops in Ethiopia and in terms of production it is the second most important legume crop after fababean. The crop is mainly grown on Vertisols that cover 12.3% of Ethiopian land mass. This study was conducted to select adaptable and high yielding chickpea varieties for Debremawi and Debreyakob watersheds in Western Amhara Region with the participation of Farmers' Research Group (FRG) during 2011/12. Four chickpea varieties, namely Monino, Arerti, Shasho and local cultivar were included in the study and varieties were planted on farmer's field of plot size 100m^2. Planting was done using row planting method with a row spacing of 30cm and plant spacing of 10cm. FRG farmers in the two watersheds showed special preference to Shasho and Arerti. The average yield of Shasho and Arerti in these watersheds was 1500 and 1100 kg/ha, respectively. Hence; Shasho and Arerti are recommended for these watersheds for further promotion and scale-up.

Key words: Chickpea, Farmers' Research Group, participatory research

Introduction

Chickpea (*Cicer arietinum* L.) is an annual legume and the only cultivated species within *Cicer* genus. Chickpea provides a cheap, high quality and rich source of protein. It also plays asignificant role in maintaining soil fertility, through biological nitrogen fixation (Kantar *et al*., 2007). The crop is mainly grown on Vertisols that cover 12.3% of Ethiopian land mass. In

Ethiopia, the can grow with altitude range of 1800m to 2300m a.s.l. with annual rain fall of 700mm-1200mm. Chickpea is one of the major pulse crops in Ethiopia and in terms of production it is the second most important legume crop after fababean. According to FAO (2009), it is produced on more than 11 million hectares with over 9.7 million tons annual production worldwide. Chickpea has consistently maintained a significant status, ranking second in area (15.3%) and third in production (14.6%) after dry beans (*Phaseolus vulgaris* L.) and dry peas (*Pisum sativum* L.) (Kantar *et al*., 2007).

Ethiopia is the largest producer of chickpea in Africa and seventh worldwide and contributes about 2% to the total world chickpea production (Kassie *et al*., 2009). Despite its importance, its productivity is very low. The national average yield of chickpea in Ethiopia under farmers‘ condition remains less than 1.5t ha^{-1} (CSA, 2009). On the other hand, the potential of the crop under improved management condition is more than 3t ha^{-1} (Singh 1987; Dadi *et al*., 2005).

In Amhara region, chickpea covers an area of 130,381hectares with annual production estimated to 225,080 tons (CSA, 2013). The major constraints include abiotic and biotic stresses that reduce yield and yield stability. Many chickpea varieties has been released in the country. However; access of these varieties to farmers is at infant stage. The objective of this study was to select adaptable and high yielding varieties based on farmers‘ preference to ensure fast truck scaling up/out of technology for the enhancement of chickpea productivity in the two watersheds.

Materials and methods

Four chickpea varieties, namely Monino, Arerti, Shasho and local cultivar were included in the study in 2011/12 main cropping season. Simple plot of 10m x 10m was used as an experimental design. Spacing between rows and plants was

30cm and 10cm, respectively. The experiment was conducted at Debre-Mawi and Debre-Yakob watersheds in Western Amhara Region, Ethiopia.

Table 1. Biophysical description of the two experimental sites.

Parameter	**Study sites**	
	Debre Mawi	**Debre Yakob**
Total area (ha)	770	325
Altitude (m.a.s.l.)	2127 - 2366	2074 - 2262
Average rainfall (mm/year)	1238	1300
Average temperature (**^{o}c)**	22	20

Results and discussion

Members of FRG farmers in each watershed were involved on evaluation of the performance of the varieties based on their own criteria such as yield performance, seed color, podding potential, pod size, stand vigor and tolerance to major diseases and pest during the demonstration of the varieties at the maturity stage (Table 2). Accordingly, varieties that best fit to their respective locations were identified. At Debre-Mawi watershed, the variety, Shasho, had the highest yield advantage (190.91%) over the local variety (550 kg/ha) followed by Arerti (81.81%) and Monino (18.18%). Similarly, at Debre-Yakob watershed, the highest average grain yield for chickpea was obtained from Shasho followed by Arerti with a yield advantage of 75 and 50% over the local check (800 kg/ha), respectively. Monino was comparatively found inferior to other two varieties (Table 3). From the present study, it is evident that chickpea is well adapted to Westen Amhara Regional State, and it can be produced at larger scale in the two watersheds for the enhancement of productivity to improve the livelihoods of the local community. Acrodingly, the two best performing varieties, Shasho and Arerti, can be recommended for further scaling up/out in the study areas for large scale production.

Table 2. Farmers' selection criteria of chickpea varieties in the two watershed areas during 2011/12.

Variety	Key selection criteria	Rank
Shasho	Vigorous growth, poding potential, large pod size, high tolerance to diseases and better yield potential	1st
Arerti	High pod load, relatively high yield potential	2nd
Monino	Large seed size and good taste but low yield potential	3rd
Local	Inferior in all selection criteria	4th

Table 3. Grain yield and seed size of chickpea varieties at Debre-mawi and Debre-yakob watersheds in 2011/12.

	Debre-Mawi			Debre-Yakob		
Variety	Seed Size	Grain yield (kg/ha)	Rank	Seed size	Grain yield (kg/ha)	Rank
Shasho	Large	1600	1st	Large	1400	1st
Monino	Large	600	3rd	Large	500	3rd
Arerti	Medium	1000	2nd	Medium	1200	2nd
Local	Medium	550	4th	Medium	800	4th

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References

CSA (Central Statistics Agency) (2012) Agricultural Sample Survey, Area and Production of Major Crops. *Statistical Bulletin*, Addis Ababa, Ethiopia.

CSA (2009) Agricultural Sample Survey, Area and Production of Major Crops. *Statistical Bulletin*, Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization) (2009) Crop Production. (Available online at: *http://www.faostat.fao.org*).

Kantar F, Hafeez FY, Shivakumar BG, Sundaram SP, Tejera NA, Aslam A, Bano A and Raja P (2007) Chickpea: *Rhizobium* management and nitrogen fixation. In: *Chickpea Breeding and Management*, pp. 101–142, (Yadav, S.S., Redden, R., Chen, W. and Sharma B, eds.). CAB, Wallingford, UK.

Dadi L *et al*., (2005) Adoption studies on improved chickpea varieties in Ethiopia. EARO, Addis Abeba, Ethiopia and ICRISAT, Patancheru, India.

Kassie M, Shiferaw B, Asfaw S, Abate T, Muricho G, Teklewold H, Eshete M and Assefa K (2009) Current situation and future outlooks of the chickpea sub-sector in Ethiopia. ICRISAT Working Paper, ICRISAT & EIAR,39.

Singh KB (1987) Chickpea breeding. In: *The Chickpea*, pp. 127–162, (Saxena MC and Singh KB, eds.). CAB International, Wallingford, UK.

Chapter III. Crop Management

13. Response of chickpea (*Cicer arietinum* L.) to rates of nitrogen and phosphorus fertilizer at Debre Zeit, Central Ethiopia

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An experiment was conducted in 2012/2013 at Debre Zeit, central Ethiopia, to assess the effect of nitrogen and phosphorus fertilizer rates on yield and yield components of chickpea. Factorial experiment consisting of combinations of four N levels (0, 15, 30 and 45 kg N ha-1), three P levels (0, 20 and 40 kg P ha-1) and two chickpea varieties (Acos dubie and Natoli) were tested in a Randomized Complete Block Design (RCBD) with three replications. As the application rate of N increased, plant height, number of primary and secondary branches per plant, total number pods per plant, biomass yield and grain yield increased significanlty. Similarly, varieties showed significant difference for all agronomic characteristics recorded. Phosphorus application had no significant effect on all of the agronomic traits of chickpea varieties. Based on the present result, the maximum seed yield was obtained due to the highest level of N (45 kg N ha-1) and lowest level of P (0 kg P ha-1) for variety Natoli. Similarly, maximum seed yield was obtained due to the highest level of N and lowest level of P for variety Acos dubie.

Key words: Chickpea, N & P levels, yield and yield components

Introduction

Chickpea (*Cicer arietinum* L.) is one of the major pulse crops of Ethiopia and in terms of production it stands second after faba beans. Besides, being an important source of human food and animal feed, the crop also plays an important role in maintaining of soil fertility, particularly when it grows in rotation with cereals.

Nitrogen deficiency in chickpea before sufficient nitrogen is fixed by symbiosis is common in most soils (Sprent and Minchin, 1983; Abdel-Ghaffar, 1988). Additional nitrogen fertilizer is therefore occasionally added to alleviate the nitrogen stress and optimize yields (Rupela and Dart, 1980).

As a legume, chickpea can obtain a significant portion (4-85%) of N requirement through symbiotic N_2 fixation when grown in association with effective and compatible rhizobium strain (Walley *et al.,* 2005; Chemining and Vessey, 2006). The rest of N is obtained from soil inorganic N, mineralized organic matter, residual N from the previous and/or fertilizer application (Caliskan *et al.,* 2008; Salvagiotti *et al.,* 2008). Walley *et al.* (2005) investigated chickpea response to starter N (0, 15, 30 and 45 kg ha^{-1}) and found that application of 45 kg N ha^{-1} enhanced seed yield by as much as 221 kg ha^{-1} over the control.

Phosphorus is the second most critical plant nutrient overall, but for pulses it assumes primary importance owing to its important role in root proliferation and thereby atmospheric nitrogen assimilation. Phosphorus deficiency in soils is wide spread and most of the pulse crops have shown good response to 20-60 kg P_2O_5 ha^{-1} depending upon nutrient status of soil, cropping system and moisture availability. Idri *et al.* (1989) reported a 59% yield increase when chickpea was fertilized with 26 kg P ha^{-1} and 54% at 35 kg P ha^{-1}. Dubey (1990) found that application of 75 kg P_2O_5 ha^{-1} improved the grain and straw yield of chickpea followed by 50 kg P_2O_5 ha^{-1}.

The effect of N and P fertilizer on the growth and yield of chickpea is well documented in a number of chickpea growing countries. However, there is hardly any evidence in literature in Ethiopia. Most studies on chickpea in Ethiopia have been conducted with no and/or blanket N and P recommendations often on low yielding cultivars. Lately, some chickpea varieties with high potential for seed yields have been released by DZARC. Yet, general characteristics of the genotypes and their response to N and P application has not been determined, despite the fact that N and P nutrition itself having been a common subject for yield improvement. Hence, the objective of this study was to determine the effect of nitrogen and phosphorus rates on the yield and yield components of chickpea varieties.

Materials and methods

The experiment was conducted at Debre Zeit Agricultural Research Center (DZARC) during the 2012/2013 main cropping season. The site is located at 8^0 44‘ N latitude, 38^0 58‘ E longitude, and at an altitude of 1900 masl. The average annual rainfall is 871 mm and has average annual minimum and maximum temperatures of 8.9 and 23.4°C, respectively (FAO-UNDP, 1990). The soil is very fine clay, montmorilloitic, isothermic and classified as Typic Pellusterts (Tamirat, 1991). The physical and chemical properties of the soil are given in Table 1.

Table 1. Some physical and chemical properties of the soil (0-30 cm depth) at the experimental site.

Soil properties	Values
pH (H_2O)1:2.5	7.19
Particle size (%)	
Clay	74
Sand	4
Silt	22
EC	0.06 mS/cm
Total nitrogen	0.08%
CEC	53.4 cmol (+)/kg
Available phosphorus	22.04mg/kg
Organic carbon	1.12%
Exchangeable cations (cmol kg-1)	
Exchangeable Ca	38.09 cmol (+)/kg
Exchangeable Mg	7.18 cmol (+)/kg
Exchangeable Na	0.36 cmol (+)/kg
Exchangeable K	1.55 cmol (+)/kg

Treatments and experimental design: A factorial combination of four rates of nitrogen (0, 15, 30 and 45 kg N ha^{-1}), three rates of phosphorus (0, 20, and 40, kg P ha^{-1}) and two chickpea varieties (Acos dubie and Natoli) were tested in factorial experiment in a Randomized Complete Block Design (RCBD) with three replication. The size of each plot was 1.80 m x 2.40 m (4.32m^2) and the distance between the plots and blocks were kept at 0.6 m and 1 m apart, respectively. Rows were spcaced 30 cm apart, while the spacing between plants was 10 cm. Each plot consisted of 6 rows. The net central unit areas of each plot, which consisted of 4 central rows of 2.4 m long each (2.88 m^2), were used for data collection and measurements.

Treatment application and field activities: All field activities were carried out following the recommended production practices for chickpea. Planting was done on 30

August 2012. All N and P fertilizers treatments were applied at the time of sowing.

Data collection and analysis: The plants were harvested at maturity and yield components, such as plant height, number of primary and secondary branches per plant, number of total pods per plant, number of seeds per pod, 100-seed weight, above ground plant dry biomass yield and seed yield were recorded on 10 randomly taken plants in each central four plot.

Statistical data analysis: Analysis of variances for the data recorded were conducted using the Generalized Linear Model (GLM) of SAS version 9.20 (SAS, 2008) and interpretation was made following the procedure of Gomez and Gomez (1984). Mean separations was done using Least Significance Difference (LSD) test at 5% level of significance.

Results and discussion

Plant height: Analysis of variance showed significant effect of N fertilizer rates on plant height, while P rates did not show significant effect on the trait. On the other hand, highly significant difference was observed between the varieties for the same parameters. Two and three way interaction effect of varieties, N and P rates did not influence plant height significantly.

Increasing N rates increased plant height. Application of 45 kg N ha^{-1} increased plant height by 7.11% compared to control. The increase in plant height in response to the increased N rates indicates maximum vegetative growth of the plants under higher N availability. This result was in line with the findings of Amany (2007) and Caliskan *et al.* (2008) who reported that plant height increased with application of N fertilizer in chickpea and soybean, respectively. The ANOVA table shows a highly significant difference between the two chickpea varieties. The kabuli variety (Acos dubie) was significantly taller than Desi variety (Natoli).

Number of primary & secondary branches per plant: The Analysis of variance indicated that N rate and varieties had highly significant effect on number of both primary and secondary branches per plant. However, P rate and two and three way interactions effects of varieties, N and P rates were not significant for both primary and secondary branches/plant.

Increasing of N fertilizer from 0 to 45 kg N ha^{-1} enhanced the number of primary and secondary branches per plant by 25.56% and 26.12%, respectively. The increase in number of primary and secondary branches per plant in response to the increased N application rate indicates higher vegetative growth of the plants under higher N availability. This could be due to the fact that chickpea produces most of its primary and secondary branches during the early vegetative growth period when there was high soil nitrogen or effective nodules. Amany (2007) and Caliskan *et al*. (2008) reported similar results that the number of primary and secondary branches increased with increase in N rate in chickpea and soybean, respectively.

The mean values for the varieties across all N and P rates indicated higher number of primary and secondary branches for Natoli which was about 29.59% and 48.14% higher than the number of primary and secondary branches of Acos dubie.

Table 2. Some plant characters and important agronomic performances of chickpea varieties as influenced by the main effect of varieties, N and P rates.

Treatments	PHT	NPB/plant	NSB/plant
Variety			
Acos dubie	41.33 [a]	2.26 [b]	3.49 [b]
Natoli	37.68 [b]	3.21 [a]	6.73 [a]
LSD (0.05)	1.25	0.17	0.36
N rates (kg ha^{-1})			
0	38.00[c]	2.33[c]	4.30[c]
15	39.07[bc]	2.58[b]	4.94[b]
30	40.05[ab]	2.90[a]	5.38[ab]
45	40.91[a]	3.14[a]	5.82[a]
LSD (0.05)	1.78	0.24	0.51
P rates (kg ha^{-1})			
0	40.11	2.85	5.31
20	39.49	2.74	5.00
40	38.92	2.62	5.02
LSD (0.05)	NS	NS	NS
CV (%)	6.7	13.3	15.0

Means within a column followed by the same letter are not significantly different at 5% level of significance. NS = non-significant; PHT = Plant height; NPB/plant = number of primary branches per plant; NSB/plant = number of secondary branches per plant.

Number of total pods per plant: Analysis of variance showed significant effect of N fertilizer rates on the number of total pods while P fertilizer rate did not significantly influence the number of total pods. On the other hand, highly significant difference ($P < 0.001$) was observed between the varieties for the same parameters. Two and three way interaction effect of varieties, N and P rates did not influence the number of total pods significantly.

The highest number of total pods per plant was recorded at N rate of 45 kg ha^{-1} but at par with 30 kg N ha^{-1}. Application of 45 kg N ha^{-1} increased the number of pods per plant by about 13.32% compared to control. The increase in number of pods per plant occurs because of the increased leaf area with additional N being associated with more reproductive nodes (Saxena, 1984). A greater leaf area also results in a corresponding increase in assimilate supply which has been reported to determine pod number in field bean (Husain *et al.*, 1988). Corroborating this result, Mckenzie and Hill (1995) and Amany (2007) reported that number of pod per plant increased with increase in N rate in chickpea.

Across all N and P rates, the varieties significantly differed for the number of total pod production in which variety Natoli produced 56% higher number of pod/plant than Acos dubie.

Number of seeds per pod: Analysis of variance for number of seeds per pod indicated no significant effect of the main effects of N and P rates, variety interactions with both N and P rate and N and P interaction effect. However, there was highly significant difference between varieties on the trait.

Non-significant effects of studied treatments on number of seeds per pod might be due to more effects of genetic factors in controlling of this trait than environmental and management factors. This result was in line with the finding of Ali and Raouf (2011) in which nitrogen fertilizer had not significantly influence on the number of seeds per pod.

Pooled over all N and P rates, highly significant difference was observed between varieties for number of seed per pod in which variety Natoli produced 7.08% more number of seed per pod than Acos dubie.

Table 3. Plant characters and important agronomic performances of chickpea varieties as influenced by the main effect of varieties, N and P rates.

Treatments	NP/plant	NS/pod	100 seed weight (g)	AGBY (kg ha^{-1})	Seed yield (kg ha^{-1})
Variety					
Acos dubie	13.34 [b]	1.05 [b]	62.82 [a]	3461 [b]	1728 [b]
Natoli	30.32 [a]	1.13 [a]	29.89 [b]	4258 [a]	2674 [a]
LSD (0.05)	1.29	0.02	0.91	102.3	129.2
N rates (kg ha^{-1})					
0	20.23[c]	1.09	45.78	3713[b]	2058[c]
15	21.49[bc]	1.09	46.96	3754[b]	2127[bc]
30	22.26[ab]	1.09	46.42	3944[a]	2292[ab]
45	23.34[a]	1.08	46.25	4027[a]	2329[a]
LSD (0.05)	1.83	NS	NS	144.7	182.7
P rates (kg ha^{-1})					
0	22.39	1.09	46.56	3857	2298
20	21.77	1.09	46.35	3884	2197
40	21.34	1.08	46.15	3837	2108
LSD (0.05)	NS	NS	NS	NS	NS
CV (%)	12.5	3.25	4.13	5.6	12.4

Means within a column followed by the same letter are not significantly different at 5% level of significance. NS= non-significant; NP/plant = number of pods per plant; NS/pod = number of seeds per pod; AGBY= above ground biomass yield.

Hundered seeds weight: Analysis of variance for 100 seeds weight indicated no significant effect of N and P rates, variety interactions with both N and P rates and N and P interaction effect. However, there was highly significant difference between varieties on the trait.

Non-significant effects of studied treatments on 100 seed weight might be due to more effects of genetic factors in control of this trait than environmental and management factors. In line with this result, Tanaka and Fujita (1979) stated that number of seeds per pod and weight of hundred seeds were strongly controlled genetically in field bean.

Mean 100 seed weight of the varieties averaged over all N and P rates indicated that variety Acos dubie produced significantly heavier seed weight which was about 52.42% higher than the weight of Natoli indicating greater seed weight in the kabuli compared with the desi.

Above ground plant dry biomass yield: the study result indicated a highly significant effect of N rate on the above ground plant dry biomass yield of the crop. There also existed highly significant difference between the varieties for the trait. However, P application rate and two and three way interaction effects of varieties, N and P application rates did not show significant effect on the trait.

The result generally showed an increase in biomass production when N rates increased from the lowest to the highest rate. The highest biomass yield was produced at the rate of 45 kg N ha^{-1} while the lowest was produced at 0 kg N ha^{-1}.

The increase in above ground dry biomass yield at the highest rate of nitrogen might be attributed to the enhanced availability of N for vegetative growth of the plants. This result was in line with that of Yasari and Patwardhan (2006) who reported that nitrogen application had a positive effect on the above ground biomass by increasing conversion of solar radiation to dry matter.

The mean values for the varieties across all N and P rates showed that variety Natoli produced significantly higher above ground dry biomass yield which was about 18.72% higher than the biomass yield for variety Acos dubie, indicating the inherent varietal differences of the varieties in biomass production.

Grain yield: Analysis of variance showed significant effect of N fertilizer rates on seed yield while P fertilizer rate did not significantly influence seed yield. On the other hand, highly significant difference ($P < 0.001$) was observed between the varieties for the same parameters. Two and three way interaction effect of varieties, N and P rates did not influence seed yield significantly.

The mean values for the varieties across all N and P rates indicated higher yield for variety Natoli which was about 35.38% higher than the yield for the variety Acos dubie. This indicates the differences in the genetic background of the two varieties for yield potential.

Application of 45 kg N ha^{-1} increased grain yield by 11.64% compared to the lowest application of N fertilizer (control). High yielding treatment (45 kg ha^{-1}) was a reflection of high supply of nitrogen due to high nitrogen fertilization. This was because experimental soil had low nitrogen content. Saxena (1980) reported a positive response of chickpea to nitrogen fertilization in soils with poor nodulation or low organic matter (Table 1).

The results obtained from this study indicated that use of N fertilization had positive effects on growth indices and, consequently, on yield and its attributes of chickpea. Adding N increased the production of dry matter in plants (Kibe *et al.,* 2006; Salvagiotti *et al.,* 2008; Erman *et al.,* 2011) which can increase the potential of plant to produce more plant height, number of branches, number of pods and number of seeds that ultimately results in high grain and biological yield.

The data presented in Table 3 showed that P application had no significant effects on seed yield of chickpea. The non-responsiveness to freshly applied P is often related to residual P in the soil from previously applied P (Bolland and Jarvis, 1996). In DZARC, soil P (Olson P of 22 mg/kg soil at 0-30 cm) seemed high according to the critical levels suggested by Johansen and Sahrawat (1991). They reported that the response of chickpea to applied P would be likely at topsoil (0-5 cm) Olsen-P levels <2 mg/kg.

In the present study, the experimental soil was high in soil P (22 mg/kg available P) and so was enriched with additional P to support chickpea growth up to maturity had not significant effect. This result was consistent with the results of Enamul (2012) who reported that chickpea poorly responded to applied P to the topsoil and again suggested that P application to topsoil that dries progressively has little or no effect on chickpea DM and P accumulation.

Conclusions

Based on the results of this study it can be concluded that N fertilizer rate markedly affected agronomic performances of chickpea The greater seed yield at high N levels was associated with greater biomass production as it is positively correlated with plant height, number of primary and secondary branches per plant and number of total pod per plant. P application had no effect on growth parameters as well as yield related traits as the soil has adequate level for normal chickpea production. The varieties highly differed in agronomic performance mainly due to the difference to their genetic background. However, similar studies should be conducted by including N rate above 45 kg ha^{-1} and more chickpea varieties at different locations and during different growing seasons with consideration of economic analysis in order to come to a conclusive recommendation.

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References

Abde1-Ghaffar AS (1988) Effect of edaphic factors on biological nitrogen fixation in *Vicia faba* under Egyptian field conditions. PP. 303-319. In: D. P. Beck and L. A. Materon (eds.). Nitrogen Fixation by Legumes in Mediterranean Agriculture. Martinus Nijhoff Publishers, Dordrecht.

Ali, N. and S. S. Raouf. 2011. Phenological and morphological response of chickpea (*Cicer arietinum* L.) to symbiotic and mineral nitrogen fertilization. *Zemdiryste*, *Agri*.2, **98**: 121-130.

Amany, A. B. 2007. Effect of plant density and urea foliar application on yield and yield components of chickpea (*Cicer arietinum* L.). *Res. J. Agri. Bio. Sci.* **3**: 220-223.

Bolland, M. D. A., and R. J. Jarvis. 1996. Effectiveness of different methods of applying superphosphate for lupins grown on sandplain soils. *Aust. J. Exper. Agri.* **36**: 707-715.

Caliskan, S., I. Ozkaya, M. E. Caliscan, and M. Arslan. 2008. The effect of nitrogen and iron fertilization on growth, yield and fertilizer use efficiency of soybean in Mediterranean type soil. *Field Crop Rese.*, **108**: 126-132.

Chemining, G. N., and J. K. Vessey. 2006. The abundance and efficacy of *Rhizobium Leguminosarum* bv. *Viciae* in cultivated soils of eastern Canadian prairie. *Soil Biochem.* **38**: 294-302.

Dubey, S. K. 1990. Res. and Dev. Reporter, **7**: 32-36. In: T. M. Thiyagarajan, M. R. Backiyavathyand P. Savithri., (eds.) in agricultural review of nutrient management for pulse Centre for Soil and Crop Management Studies, Tamil Nadu Agricultural University PP. 40-48.

Enamul, K. 2012. Phosphorus nutrition of chickpea under dry topsoil conditions as in the High Barind Tract of Bangladesh. PhD dissertation.

Erman, M., S. Demir, E. Ocak, S. Tufenkci, F. Oguz and A. Akkopru. 2011. Effects of *Rhizobium*, arbuscular mycorrhiza and whey applications on some properties in chickpea (*Cicer arietinum* L.) under irrigated and rainfed conditions 1-Yield, yield components, nodulation and AMF colonization. *Field Crops Rese.* **122**(1): 14-24.

FAO-UNDP (Food and Agriculture Organization-United Nation Development Program) (1990) Assistance to land use planning project/ MOA LUPRD meteorological data.

Gomez KT & AA Gomez (1984) Statistical Procedures for Agricultural Research, 2nd ed. John Wily & Sons, New York.

Husain MM, Hill GD and Gallagher JN (1988) The response of field beans *(Vicia faba* L.) to irrigation and sowing date. 2. Growth and development in relation to yield. *J. Agri. Sci.* **111**:233-254.

Idri, M., T. Mahmood and K. A. Malik. 1989. Response of field-grown chickpea *(Cicer arietinum* L.) to phosphorus fertilization for yield and nitrogen fixation. *Plant and Soil* **114**(1):135-138.

Johansen, C. and K. L. Sahrawat. 1991. Strategies for maximizing the efficiency of phosphorus utilization in cropping systems involving chickpea and pigeon pea. pp. 227-241. In: Johansen C, KK Lee and KL Sahrawat (eds.) Phosphorus nutrition of grain legumes in the semi-arid tropics. International Crops Research Institute for the Semi-Arid Tropics: Patancheru, Andhra Pradesh, India.

Kibe A. M., S. Singh and N. Karla. 2006. Water-nitrogen relationship for wheat growth and productivity in late sown conditions. *Agri. Water Manag.* **8**(4): 221-228.

McKenzie, B. A., and G. D. Hill. 1995. Growth and yield of two check pea (*Cicer artienum* L.) varieties in Canterbury, New Zealand. *New Zealand of Crop and Horti. Sci.***23**: 467-474.

Rupela, G. P. and P. J. Dart. 1980. Research on symbiotic nitrogen by chickpea at ICRISAT P. 161-167. Proceedings of the International Workshop on Chickpea Improvement, 28 February-2 March 1979: Hyderabad, India.

Salvagiotti, F., K. G. Cassman and J. E. Specht. 2008. Nitrogen uptake, fixation and response to N in soybean: a review. *Field Crop Rese.* **108**: 1-13.

SAS (Statistical Analysis System). 2008. SAS institute version 9.20 Cary, NC, USA.

Saxena, M. C. 1980. Recent advances in chickpea agronomy. pp. 89-96. In: J. M. Green, Y. L. Newne, J. B. Smithson, (eds.) 'Proceedings of the International Workshop on Chickpea Improvement‘. 28 Feb-2 Mar 1979, Hyderabad, India.

(International Crop Research Institute for the Semi-Arid Tropics: Patancheru, Andhra Pradesh, India).

Saxena, M. C. 1984. Agronomic studies on winter chickpeas. pp 88 – 96. In: Proceedings of the International Work shop on Chickpea Improvement, 28 Feb - 2 Mar 1979, ICRISAT Center, India. Patancheru, A. P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sprent, J. J. and F. R. Minchin. 1983. Environmental effects on the physiology of nodulation and nitrogen fixation. pp. 269-317. In: D. G. Jones and D. R. Davies (eds.). Temperate Legumes: Physiology, Genetics and Nodulation. Pitman Books Limited: London.

Tamirat T. 1991. Vertisols of the Central Highlands Evaluation Characterization and Classification. M.Sc. Thesis. Alemaya University of Agriculture, Alemaya, Ethiopia.

Tanaka A and K Fujita. 1979. Growth, photosynthesis and yield components in relation to seed yield of the field bean. *J. Fac. Agric. Hokkaido Univ*. **59**:145-238.

Walley FL, SK Boahen, G Hnatowich and C Stevenson. 2005. Nitrogen and phosphorus fertility management for desi and kabuli chickpea. *Canadian J. Plant Sci.* 85: 73-79.

Yasari E and AM Patwardhan. 2006. Physiological analysis of the growth and development of canola (*Brassica napus* L.) under different chemical fertilizer application. *Asian J. Plant Sci.* 5: 745-752.

14. Response of Kabuli chickpea (*Cicer arietinum* L.) varieties to plant spacing at Debre Zeit, central Ethiopia

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Response of chickpea (Cicer arietinum L.) varieties to plant spacing was assessed at Debre Zeit using a combinations of three kabuli chickpea varieties (Acos dubie, Chefe and Ejeri), three inter-row spacing (20, 30 and 40 cm) and two intra-row spacing (10 and 15 cm) in factorial experiment laid out in RCBD with three replications. As inter and intra-row spacing increased, the number of pods per plant significantly increased, whereas biological and seed yield significantly decreased. Similarly, the main effect of variety on plant height, number of pods per plant and 100 seed weight was significant. Variety Chefe gave the highest number of pods per plant (27.59) whereas Acos dubie gave the highest plant height (41.24 cm) and hundred seed weight (63.54 g). Moreover, the interaction of variety and inter-row spacing were significant on the number of primary and secondary branches plant-1 and harvest index. The highest (2340.33 kg ha-1) seed yield was obtained at 20 cm inter-row spacing whereas 40 cm inter-row spacing gave the lowest (1619 kg ha-1). Similarly, 10 cm intra-row spacing had the higher (2081.65 kg ha-1) seed yield as compared to 15 cm intra-row spacing (1758.32 kg ha-1). From this, it can be preliminary concluded that kabuli chickpea varieties can be planted at inter-row spacing of 20 cm and intra-row spacing of 10 cm in Debre Zeit area to attain maximum yield.

Key words: Chickpea, Kabuli, inter- and intra-row spacing, seed yield

Introduction

Chickpea (*Cicer arietinum* L.) is the most widely grown pulse crops in Ethiopia, where the whole seeds are eaten fresh, roasted, boiled or in other forms. Despite its uses, the productivity of the Ethiopian chickpea, particularly under farmers condition, is low (1.73 t ha^{-1}) (CSA, 2012) as compared to its potential yield under improved management conditions (3.5 t ha^{-1}). A number of limiting factors contribute to this low productivity, but the major constraints are low yield potential of landraces and their susceptibility to biotic and abiotic stresses, and poor cultural practices (Legesse *et al*., 2005). Lack of variety and location specific plant density recommendation is the major limitations of cultural practices for chickpea production in Ethiopia.

Production and productivity of the crop is governed by environmental conditions, genotypic trait and the management of the crop. Appropriate crop density is one of the management activities that improves the performance and productivity of plants. However, plant density of chickpea depends on variety and plant growth habit. Compact, upright-growing plants respond better to increased plant density than the spreading type (Calcagno *et al*., 1988). Ali (1989) compared plant density effect involving two varieties, one desi (BDN 9) and another kabuli (L 550) and concluded that a spacing of 30 cm x 10 cm for desi type and 45 cm x 15 cm for kabuli type was optimum. The optimum plant population depends also on the environmental conditions under which the crop is grown. In India, a population of 33 plants m^{-2} appears to be the best (Singh, 1983). In Canada, yield increment was recorded with an increase in population up to 55 plants m^{-2} (Vanderpuye, 2010).

However, 30 cm inter-row spacing and 10 cm intra-row spacing is used for both kabuli and desi type chickpea in Ethiopia (FDRE, 2010). Thus, there is no site and variety specific recommendation on the plant spacing of chickpea varieties in Ethiopia. In view of the above facts, the present investigation was undertaken. Therefore, the objective of this study was to determine the effect of plant spacing on growth parameters, yield components and yield of kabuli chickpea varieties.

Materials and methods

The experiment was conducted in factorial experiment in RCBD with three replications using factorial combination of three kabuli chickpea varieties, three inter-row spacing (40, 30 and 20 cm) and two intra-row spacing (15 and 10 cm) at Debre-Zeit Agricultural Research Center (DZARC), in 2012/2013 cropping season. The soil of DZARC was very fine clay (Tamirat, 1991). The kabuli chickpea varieties used in the study were Acos dubie, Ejeri and Chefe released in the year of 2009, 2005 and 2004, respectively. Plots having 40, 30 and 20 cm inter-row spacing accommodated 6, 8 and 12 rows, respectively, from which the middle 4, 6 and 10 rows were harvested for data source. Gross plot size was 2.4 m x 3 m (7.2 m^2). Spacing of 0.6 m and 1 m were allocated between plots and blocks, respectively.

Sowing was done on September 4, 2012 by putting two seeds per specified intra row spacing and thin to one plant after germination. Harvesting was took place when the foliage, stem and pods color of plant changed to golden brown and fully dried on January 25, 2013.

Plant height, number of primary and secondary branches per plant and number of pods per plant were recorded on 10 randomly taken plants from each plot. Hundred seed weight was determined by weighing 100 randomly taken seeds from seeds obtained from each plot, whereas biological and seed yield was recorded on plot basis leaving the side rows as non-experimental. Harvest index was computed as the ratio of seed yield to biological yield. Data were analyzed using SAS software Version 9.20 (SAS, 2008) and mean separations were done using Least Significance Difference test at 5% level of significance.

Results and disscussion

The interaction of variety and inter-row spacing had a significant influence ($P < 0.05$) on the number of primary and secondary branches per plant. Variety Chefe at 40 cm inter-row spacing gave the highest number of primary and secondary branches per plant, while variety Acos dubie at 20 cm inter-row spacing gave the lowest number of primary and secondary branches (Table 1).

Table 1. Number of primary and secondary branches per plant and harvest index as affected by the interaction of variety and inter-row spacing.

Variety	Inter-row spacing	Primary branches (No.)	Secondary branches (No.)	Harvest index
Acos dubie	20	2.03[d]	2.88[d]	58.32[ab]
	30	2.35[d]	3.03[d]	58.76[ab]
	40	2.47[cd]	3.40[d]	62.42[a]
Chefe	20	2.92[c]	6.80[c]	63.33[a]
	30	3.93[ab]	9.50[ab]	51.74[cd]
	40	4.30[a]	10.75[a]	48.16[d]
Ejeri	20	2.90[c]	6.27[c]	60.13[ab]
	30	3.57[b]	7.92[bc]	59.91[ab]
	40	4.25[a]	10.73[a]	57.09[bc]
LSD (%)		1.79	1.79	5.38

Means in columns followed by different letters are significantly different at P = 5%.

Number of primary and secondary branches of Chefe and Ejeri decreased with decreased inter-row spacing. However, the number of primary and secondary branches per plant for variety

Acos dubie did not show significant difference with increasing inter-row spacing.

Significant differences on primary and secondary branches were recorded among varieties at all inter-row spacing. Variety Acos dubie had significantly less number of primary and secondary branches than the other two varieties at all inter-row spacing but there was no significant difference between varieties Chefe and Ejeri (Table 1). This could be due to the differences in growth habit since varieties Chefe and Ejeri relatively have bushy growth habit while variety Acos dubie has relatively semi erect type of growth habit. The result of study was in line with Rasul *et al*. (2012) who reported the existence of interaction effect of mungbean varieties and inter-row spacing on the number of primary branches per plant.

The interaction of intra-row spacing and variety of chickpea had a significant influence ($P<0.05$) on the number of primary branches per plant. Variety Ejeri at 15 cm intra-row spacing gave the highest number of primary branches while variety Acos dubie at 10 cm intra-row spacing gave the lowest (Table 2).

Table 2. Number of primary branches per plant as affected by the interaction of variety and intra-row spacing.

Intra-row spacing(cm)	Variety		
	Acos dubie	Chefe	Ejeri
10	2.27^{c}	3.60^{ab}	3.20^{b}
15	2.30^{c}	3.83^{a}	3.94^{a}
LSD (5%)		0.60	

Means in rows and columns followed by different letters are significantly different according to LSD test at 5% probability level.

The number of primary branches of variety Ejeri significantly increased with increasing intra-row spacing. The increase in number of branches with increased intra-row spacing for variety Ejeri was similar with the studies done on French bean (*Phaseolus vulgaris* L.) by Mureithi *et al*. (2012). Variety

Acos dubie significantly gave lower number of primary branches plant^{-1} than varieties Ejeri and Chefe at both intra-row spacing (Table 2). However, the intra-row spacing did not affect (P> 0.05) significantly the number of secondary branches per plant and the harvest index.

Analysis of variance on the harvest index indicated that the interaction effect of variety and inter-row spacing were highly significant (P<0.01). The highest and the lowest harvest index were recorded on variety Chefe at 20 and 40 cm inter-row spacing, respectively (Table 1). The increased harvest index of variety Chefe with decreased inter-row spacing was consistent with Mirazaei *et al*. (2010) who reported that chickpeas were most responsive to increased population for harvest index. However, the harvest index of varieties Acos dubie and Ejeri showed non-significant difference due to inter-row spacing.

Significant differences on harvest index among varieties were observed at 30 and 40 cm inter-row spacing but the effect was non-significant at 20 cm inter-row spacing. For instance, Naseri *et al*. (2012) reported significant effect of the interaction of cultivar and plant densities on harvest index of white bean (*Phaseolus vulgaris* L.). However, the effect of intra-row spacing on the harvest index was not significant.

The main effect of variety on plant height was statistically significant (P<0.05) and variety Acos dubie was significantly taller than variety Ejeri (Table 3). The variation in height might be due to genetic characteristics of the varieties. This result is in agreement with Shamsi (2009) and Rasul *et al*. (2012) who reported significant differences among the genotypes of chickpea in plant height.

Plant height was not affected by the main effects (P> 0.05) of inter and intra-row spacing. This might be due to the fact that crop density has often, but not always been associated with increased plant height. Supporting evidence on chickpea was reported by Bahr (2007).

Analysis of variance showed that varieties highly significantly differed ($P<0.01$) in the number of pods per plant. The highest number of pods per plant was recorded on variety Chefe followed by variety Ejeri, while the lowest number of pods per plant was recorded on variety Acos dubie (Table 3). The differences in number of pods might have been caused due to varietal differences. In line with this result, Tripathi *et al.* (2012) reported significant differences among genotypes of chickpea for number of pods per plant.

Table 3. Plant height, number of pods plant^{-1}, biological yield, hundred seed weight and seed yield as affected by the main effects of variety, inter and intra-row spacing.

Treatments	Plant height (cm)	No of pods plant^{-1}	Biological yield (kg ha^{-1})	Hundred seed weight (g)	Seed yield (kg ha^{-1})
Variety					
Acos dubie	41.24^{a}	17.12^{c}	3047.90	63.53^{a}	1821.77
Chefe	39.17^{ab}	27.59^{a}	3454.82	34.08^{c}	1911.50
Ejeri	37.82^{b}	24.88^{b}	3427.93	37.84^{b}	2026.68
LSD (5%)	2.23	1.58	ns	1.42	ns
Inter-row spacing (cm)					
20	39.47	21.33^{b}	3863.23^{a}	44.45	2340.33^{a}
30	38.97	23.89^{a}	3167.55^{b}	45.37	1800.45^{b}
40	39.80	24.38^{a}	2899.88^{b}	45.62	1619.16^{b}
LSD (5%)	ns	1.58	398.51	ns	250.89
Intra-row spacing (cm)					
10	39.61	22.34^{b}	3599.85^{a}	45.08	2081.65^{a}
15	39.21	24.06^{a}	3020.58^{b}	45.22	1758.32^{b}
LSD (5%)	ns	1.29	325.38	ns	204.85

Means in the same column for a factor followed by different letters are significantly different at P= 5%; ns=non-significant

Number of pods per plant was also significantly ($P < 0.05$) affected by inter and intra-row spacing. As inter and intra-row spacing increases, the number of pods per plant increases (Table 3). The highest numbers of pods per plant were recorded in wider inter and intra-row spaced chickpea, which might be due to low competition of plants in the field that facilitated more aeration, greater light interception and more photosynthetic activity per plant. Similarly, Shamsi (2005) reported that the significant increase of number of pods per plant with increasing inter and intra-row spacing of chickpea.

Biological yield was not significant due to the main effects of variety. The decrease in biological yield of variety Acos dubie due to low branching habit might have been compensated by the increase in other parameters such as plant height and stem thickness. This might be the reason for the non-significant difference in biological yield among the varieties. In line with this, Shamsi (2009) reported non-significant differences of the biological yield among varieties of chickpea.

The analysis of variance revealed that the main effect of inter and intra-row spacing on biological yield was highly significant ($P<0.01$). As inter and intra-row spacing increased, the biological yield decreased (Table 3). Increasing spacing in chickpea did not compensate for the decreased number of plants per unit area, while increased plant population per unit area eventually increased the biological yield. This might be the reason for the increase in biomass yield with decreased inter-row spacing. Similar result was obtained by Rasul *et al*. (2012) who reported that narrow inter-row spacing (30 cm) produced the highest biological yield as compared to wider inter-row spacing (45 cm and 60 cm) on mungbean varieties.

The result of the experiment indicated that varieties did differed highly significantly ($P <0.01$) in hundred seed weight. The highest hundred seed weight was recorded for variety Acos dubie followed by variety Ejeri whereas the lowest hundred seed weight was recorded for variety Chefe (Table 3). In line with this, Shamsi (2009) and Tripathi *et al*. (2012) reported significant differences among genotypes of chickpea on hundred seed weight. However, the main effects of inter and intra-row spacing on hundred seed weight was statistically non-significant.

Varieties showed a non-significant effect on the seed yield of chickpea. However, relatively lower yield was recorded for variety Acos dubie as compared to varieties Chefe and Ejeri (Table 3). This might be due to low branching habit and low number of pods per plant for the variety Acos dubie.

The analysis of variance showed that the main effects of inter and intra-row spacing had a highly significant effect ($P<0.01$) on seed yield of kabuli chickpea varieties. The highest average seed yield was recorded in 10 cm intra and 20 cm inter-row spacing while the lowest yield was recorded in 15 cm intra and 40 cm inter-row spacing (Table 3). The seed yield was decreased by 15.5% and 30.8% when inter and intra-row spacing was increased from 10 to 15 cm and 20 to 40 cm, respectively. In line with this result, Bahr (2007) reported that high plant density gave higher seed yield as compared to low plant density in chickpea. The lowest seed yield in wider inter and intra-row spacing might be due to relatively the inefficient utilization of available resources (light, space and nutrients) per unit area as compared to narrow spacing. For instance, Chandrasekaran *et al*. (2010) justified that when soil moisture and nutrients are not limited, higher density is necessary to utilize other growth factors (solar radiation efficiency) of chickpea.

Conclusion

According to this result, it might be concluded that 20 cm inter and 10 cm intra-row spacing is appropriate for maximum seed yield of kabuli chickpea varieties in Debre-Zeit and similar areas in the country. However, the present study needs to be repeated across years and locations to reach a conclusive recommendation by taking the economic aspects, desi type chickpeas, ridge planting and more varieties.

References

Ali M (1989) Consolidated report on Rabi Pulses: Agronomy. Directorate of Pulses Research, ICAR, Kanpur, U.P. India.

Bahr AA (2007) Effect of Plant Density and Urea Foliar Application on Yield and Yield Components of Chickpea**.** *Research Journal of Agriculture and Biological Sciences,* **3**(4): 220-223.

Calcagno FG *et al*. (1988) Effect of plant density on seed yield and its components for ten chickpea genotypes grown in Sicily, Italy. *Chickpea Newsletter,* **18**: 29-31.

Chandrasekaran, B, K Annadurai and E Somasundaram (2010) A Textbook of Agronomy. Published by New Age International (P) Ltd. Publishers, New Delhi, India.

CSA (Central Statistics Agency, 2012) Agricultural Sample Survey. Report on Land Utilization, *Statistical Bulletin* 302. Addis Ababa, Ethiopia: Central Statistics Authority.

FDRE (Federal Democratic Republic of Ethiopia) (2010) Extension Package for Pulse Production and Improved Management Practices. Agricultural Extension Directorate. Amharic version. Addis Ababa, Ethiopia.

Legesse D *et al*. (2005) Adoption Studies on Improved Chickpea Varieties in Ethiopia. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India.

Mirazaei, N, A Gholipouri, A Tobeh, A Asghari, H Mostafaei and S Jamaati-e-Somarin. 2010. Yield and Yield Components of Chickpea Affected by Sowing Date and Planting Density under Dry Conditions. *World Applied Sciences Journal,* **10**(1):64-69.

Mureithi *et al*. (2012) Response of French Bean (*Phaseolus vulgaris* L.) to Intra-row Spacing in Maseno Division, Kenya. *Journal of Applied Sciences,* **12**(1): 96-100.

Naseri, R, Z Karimi and T Emami. 2012. Variability of Grain Yield and Yield Components of White Bean (*Phaseolus vulgaris* L.) Cultivars as Affected by Different Plant Density in Western Iran.

American-Eurasian Journal of Agriculture & Environmental Sciences, **12** (1): 17-22.

Rasul F, MA Cheema, A Sattar, MF Saleem and MA Wahid. 2012. Evaluating the Performance of Three Mungbean Varieties Grown under Varying Inter-row Spacing. *J. Animal & Plant Sciences,* **22**(4): 1030-1035.

SAS (Statistical Analysis System). 2008. SAS institute version 9.20 Cary, NC, USA.

Shamsi, K. 2005. The Effects of Planting Density on Grain Filling, Yield and Yield Components of Three Chickpea (*Cicer arietinum* L.) Varieties in Kermanshah, Iran. *J. Animal and Plant Sciences,* **2**(3): 99-103.

Shamsi, K. 2009. Effect of Sowing Date and Row Spacing on Yield and Yield Components of Chickpea under Rain fed Conditions in Iran. Islamic Azad University, Kermanshah Branch, Iran. Published at www.biosciences. elewa.org on May 8, 2009. *J. Applied Biosciences,* **17**: 941 - 947.

Singh, BP. 1983. Response of Mustard and Chickpea to Moisture in Soil Profile and Plant Population on Ardisols. *Indian Journal of Agricultural Sciences,* **53**: 543-549.

Tamirat T (1991) Vertisols of the Central Highlands Characterization, Classification and Evaluation. M.Sc. Thesis. Alemaya University of Agriculture, Alemaya, Ethiopia.

Tripathi SV *et al*. (2012) Genetic Variability and Inter-relationships of Phenological, Physicochemical and Cooking Quality Traits in Chickpea. ICRISAT, Patancheru, Hyderabad, India.

Vanderpuye, AW. 2010. Canopy Architecture and Plant Density Effect in Short-season Chickpea (*Cicer arietinum* L.). A Thesis submitted to the College of Graduate Studies and Research for the Degree of Doctor of Philosophy, University of Saskatchewan, Saskatoon.

15. Assessment of Water Requirements of Chickpea grown in the Central Vertisol Areas of Ethiopia

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Chickpea production under residual moisture is a common practice in the central highland Vertisol areas of Ethiopia, where the productivity and production of the crops is still blew the expected level. Thus, producing chickpea either under full or supplemental irrigation could help in improving the productivity as well as the total production in this particular area. Determination of the crop water requirement of the crop for this particular growing area is therefore paramount importance for proper planning of chickpea production using supplemental irrigation. In view of this, the crop water requirement of chickpea was estimated using the FAO Crop Wat 8.1 software and long term weather data record where the planting date is simulated to be 24 December. The assessment hasd showed that the net irrigation requirement of the crop is 37.2mm, 114.4mm, 205.2mm, 79.8mm during seedling, vegetative, late (maturity) growth stages of the crop, respectively. The irrigation requirement of the crop for a single growing season as revealed by the program is estimated to be 436.7mm.

Key words: Chickpea, crop water requirement, Vertisols

Introduction

Chickpea (*Cicer arietinum* L.) is an ancient legume crop believed to be originated in southeast Turkey, and the adjoining part of Syria (Sing, 1997; Lev-Yadun *et.al*., 2000). It is the fourth most important food legume with a total annual global production of 9.1 million M tones from 11.2 million ha (FAO, 2009). Besides, being an important source of human and animal food, chickpea also plays an important role in the maintenance of soil fertility, particularly in the dry, rainfed areas (Saxena, 1996; Katerji *et.al*., 2001). In Ethiopia, chickpea is widely grown across the country and serves as a multi-purpose crop. It is one of the major grain legumes with an inimitable sources of dietary protein in the developing world where there is very scarce animal protein or unaffordable expensive otherwise. Ethiopia is considered as one of the secondary centers of genetic diversity for chickpea.

In many regions where food legumes are grown, the climate is characterized by extremely variable and often chronically deficient rainfall. In such environments both agricultural scientists and farmers seek to identify crop and soil management techniques which make the maximum use of this scarce resource (Cooper *et al*., 1998). Major chickpea producing countries (FAO, 2003), where the crop is generally planted after the main rainy season and grown on stored soil moisture, making terminal drought stress a primary constraint to productivity (Serraj *et al*., 2004).

Similarly, despite the huge importance of the crop as dietary item and land improvement, the yield and production of the crops is still blew the expected level in Ethiopia (Kassie *et. al*, 2009). Among other factors, the use of irrigation practices to grow the crop is critically low in the country. Chickpea cultivation is solely dependent on the soil moisture reserve where planting is made late during the recession of the main rainy season to escape the water logging conditions. But, the flowering and pod setting stages appear to be the most sensitive stages to water stress (Nayyar *et al*., 2006). Limited irrigation to adequately meet the crop needs at critical stages of growth and development may be crucial for realization of yield potential of chickpea varieties. Thus, to match, the ever increasing national demand, growing chickpea under irrigation has to be the top and urgent priority agenda.

In any planning attempt for exercising irrigation, determination of crop water requirement of crops is the primary job in the crop production industry. As the information on crop water requirement of chickpea is severely limited, the objective of this current was to estimate the optimum crop water requirement of the crop using a model, CROP WAT model.

The latest version of model, namely CROPWAT v8 includes a simple water balance model that allows the simulation of crop water stress conditions and estimations of yield reductions based on well-established methodologies for determination of evapotranspiration (FAO, 2006) and yield responses to water. This model utilizes soil, crop, and weather databases to simulate multiyear outcomes of climate change scenarios and various crop management strategies. The model also allows the development of recommendations for improved irrigation practices

Materials and Methods

This study was conducted at Debre Zeit Agricultural Research Center, located in central highlands of Ethiopia and situated between 38‘051‘43‘.63” to 39‘004‘58”E and 8‘046‘16.20” to 8‘059‘16.38”N, in the western margin of the great East African Rift Valley. Long term weather record (1973-2007) from Debre Zeit Agricultural Research Center‘s archive for precipitation, relative humidity, windy speed, minimum and maximum temperature were used to estimate the reference evaptranspiration of the study site. The soil physical properties of the study site were determined using the proper lab procedures. The FAO CROP WAT 8.1 program was employed for estimating the daily, monthly and seasonal crop water of the crop. The irrigation scheduling scenario for the crop was also developed based on the program, the FAO CROP WAT 8.1.

Results and discussions

The precipitation deficit during the selected (December 24 as planting date) growth stages for chickpea was comparatively as high as 130 mm, which is more than one third of the crop water requirement of the crop. The least deficit in precipitation during this same period was 120mm (in April). The model also revealed that during the main rainy season, the month of September need to be monitored as it exhibited moderated deficit (22 mm), i.e, proper planning of agronomic practices (particularly planting date) is crucially important.

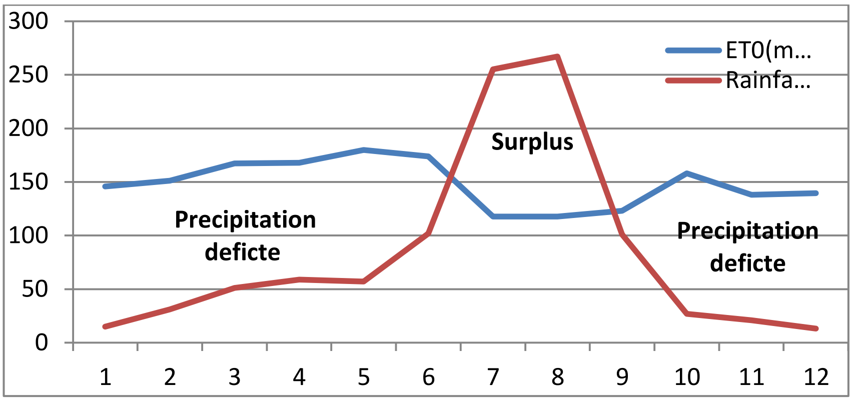

Figure 1: Monthly precipitation vs Reference evapotranspiration

The highest crop water requirement of the crop is at around sixty days after planting (5.6 mm per day) or 56mm per decade (ten days sum). The crop water requirement on basis of stages: the initial stages requires 37.2mm, while the subsequent stages, development, mid and late stages demand 114.4mm, 205.2mm, 79.8mm each respectively (Fig. 2).

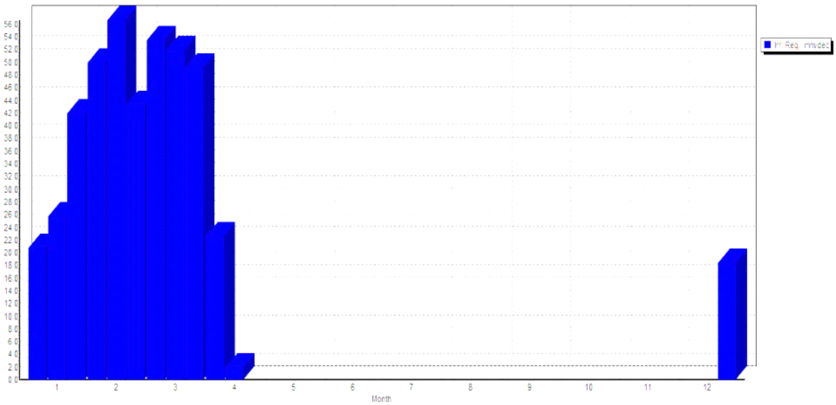

Figure 2: Crop water requirement of chickpea after planting (FAO crop wat model).

If one is to irrigate one hectare of land to grow chickpea, the total irrigation water required would be around 4370 cubic meters of water for a single season. Considering the planting date selected, the frequency of irrigation during initial had to be twice, three times during development, four times at mid stage and three times at late stage.

Once irrigation has started after the soil is irrigated to field capacity in this case, the soil moisture depletion level should be monitored properly. This is because lack of adequate soil moisture in the seedbed is a major hindrance to the establishment of chickpea crop. In addition, inadequate soil moisture can reduce seed germination, slow down seedling growth and diminish yield in rainfed crops. For instance, at the initial stage, the depletion level has to be as low as 40 mm per meter. In other words, after 25 days of the first cycle of irrigation, the soil moisture depletion level reaches 40 mm per meter. This corresponds to the remaining moisture in the soil is nearly 60% of the total available water. Thus, at this stage the next irrigation should be applied (Fig. 3). Similarly, during flowering and grain formation, the soil moisture can be kept at 40 % of the total available moisture.

In an effort to assess the supplementary water need for the rainfed, considering the planting dates: July 1, 15, 30 and August1, 15, and 30, the irrigation requirement varies from 134 to 372 mm in tier respective orders (Table 1). This result may indicate that planting after 30th July should be properly attended if the crop is to grow only under rainfed conditions.

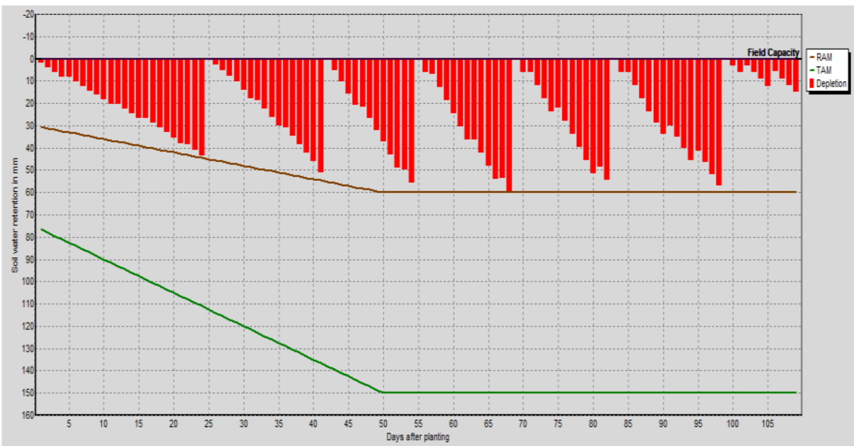

Figure 3: Irrigation scheduling scenarios for chickpea

Table 1. Crop water requirement under different planting.

Planting date	Irrigation requirement (mm)
1-Jul	134
15-Jul	212
30-Jul	282
15-Aug	336
30-Aug	372

Conclusions

The crop water demand of chickpea for a single season, with reasonable full irrigation, can be as high as 437 mm or 4370 cubic meters of water for a hectare. The optimum soil moisture depletion level for the vegetative stages should not exceed 60 % of the total available water and 40% for flowering and grain formation. The model also reveals that irrigating twice to field capacity during vegetative; three to four times during the rest of the stages is optimum. Planting date for the main rainy season should also be monitored with possible care. Under full irrigation scenarios, the agronomic practices (planting dates) and other physiological aspects have to be integrated with either variable, particularly temperature, as some of the growth stages (flowering and grain setting) are sensitive to higher temperature. As this is only preliminary information from the model, field validation of these results should be a follow up work of this study.

References

Cooper P M, GS Campbell, MC Heath, PD Hebblethwaite. 1998. pp. 813-829. In: *World Crops*: Cool Seasons Food Legumes. RJ Summer Field (ed.), Kluwer Academic Publishers.

FAO (Food and Agriculture Organization) (2009) Crop production. Available at: http://www.faostat.fao.org

FAO (Food and Agriculture Organization) (2006) Crop production. Available at: http://www.faostat.fao.org

FAO (Food and Agriculture Organization). 2003. Production Year Book, 2002, Food and Agriculture Organization of the United Nations (FAO). Rome, Italy.

Katerji N, JW van Hoorn, Hamdy A, Mastrorilli M, Oweis T, and Malhotra RS (2001) Response to soil salinity of two chickpea varieties differing in drought tolerance. *Agr. Water Manage*., **50**: 83-96.

Kassie *et al*. (2009) Current situation and future outlooks of the chickpea sub-sector in Ethiopia. ICRISAT and EIAR.

Lev-Yadun S, A Gopher, S Abbo. 2000. The cradle of agriculture. Science, **288**: 1602-1603.

Nayyar H, Singh S, Kaur S, Kumar S, Upadhyaya HD (2006) Differential sensitivity of macrocarpa and microcarpa types of chickpea (*Cicer arietinum* L.) to water stress: association of contrasting stress response with oxidative injury. *J. Integrative Plant Biol*., **48**: 1318-1329.

Saxena NP, Saxena MC, Johansen C, Virmani SM and Harris H (1996) Future research priorities for chickpea in WANA and SAT. pp. 257-263. In: Adaptation of chickpea in West Asia and North Africa region, Saxena NP, MC Saxena, C.Johansen, SM Virmani, and H Harris (eds.), ICARDA, Aleppo, Syria.

Serraj *et al*. (2004) Variation in root traits of chickpea (*Cicer arietinum*) grown under terminal drought. *Field Crops Res*., **88**: 115-127.

Singh, K.B., 1997. Chickpea (*Cicer arietinum* L). *Field Crops Res*., **53**: 161-170.

16. Status and Future Prospects of Chickpea Weed Research in Ethiopia

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Problematic annual broadleaf species in chickpea include those of Amaranthaceae, Brassicacae, Asteraceae, Chenopodiaceae, Fabaceae and Polygonaceae, Rubiaceae, and Solanaceae among other families. Biennial or perennial species of weeds that have been reported to occur include those of the Poaceae, Plantaginaceae, Polygonaceae, Commelinaceae Convolvulaceae, Asteraceae, Cyperaceae and other families. Chickpea is sensitive to early weed competition and is less competitive than other cool season food legumes. Although the crop is traditionally grown on residual soil moisture, weeds competition pose major problem in many situations. Hand weeding is the major weed control method used in chickpea production and is labor intensive and slow compared to other manual weeding operations and is usually delayed until the weeds are tall enough to be firmly held in the hand. Thus, this crop suffers from the adverse effects of early weed interference because of delayed weeding. In general, there is paucity of basic and applied research information which include among others (potential yield loss due to weed interference, critical weed free period requirement, time and frequency of weed removal, cost effective weed management practices that could be applied under small and commercial scale of chickpea production). This paper considers the status of weed management problems in chickpea in Ethiopia and suggests strategies for solving these problems using adaptive research on chemical, non-chemical and integrated control methods.

Key words: chickpea, weed, abundance, frequency

Introduction

Chickpea (*Cicer arietinum* L.) is an annual grain legume crop grown mainly for human consumption. It plays an important role in human nutrition as a source of protein, energy, fiber, vitamins and minerals for large population sectors in the developing world and is considered as healthy food in many developed countries. This crop is widely distributed being grown in over 33 countries in the world in South Asia, West Asia, North and East Africa, Southern Europe, North and South America, and Australia (FAOSTAT, 2012).

Ethiopia is the largest chickpea producer in Africa, with a share of about 39% of total chickpea production of the continent in 2011 (FAOSTAT, 2012). Chickpea production is concentrated in Amhara and Oromia regions, although it is grown in many other parts of Ethiopia as well. The area around Debre Zeit is particularly an area with potential for up-scaling improved chickpea varieties and marketing (Solomon *et al.*, 2010). Chickpea is typically grown on Vertisols, in rotation with wheat and tef using the residual moisture at the end of the rainy season. It is also grown as double crop and this cropping system increases the productivity of scarce land and provides an additional source of income (Kasie *et al.*, 2009). With increased prices for fertilizer, cultivation of chickpea that do not require much fertilizer becomes even more attractive.

Weeds are a serious constraint to increased production and easy harvesting in chickpea. The crop is a poor competitor to weeds because of slow growth rate at early stages of crop growth and establishment (Solh and Pala, 1990). Although chickpeas are traditionally grown on residual soil moisture, weeds competition pose major problem in many situations. Weeds compete with chickpea plants for water, nutrients, sunlight, and space and also harbor insect-pests and diseases. If left uncontrolled, weeds can reduce chickpea yield significantly.

Thus, weed management is crucial in chickpea to realize maximum yields and also to maintain high quality of produce.

Hand weeding is the major weed control method used in chickpea production and is labor intensive and slow compared to other manual weeding operations and is usually delayed until the weeds are tall enough to be firmly held in the hand. Thus, the crop suffers from the adverse effects of early weed interference because of delayed weeding. Efforts towards introducing chemical weed control were not successful due to lack of inexpensive and effective broad-spectrum herbicides for controlling annual grassy and broadleaved weed species.

In general, there is paucity of research information on chickpea weed management in Ethiopia. Nevertheless, the limited studies on improved weed management in the crop stressed practices that benefit small-scale farmers. These were done by improving weed control techniques to match other agricultural operations that are practiced by farmers. The aim of this paper is to give a broad view on the status of chickpea weed management problems in Ethiopia and suggests for solving these problems by using adaptive research on chemical and non-chemical and integrated control methods

The weed flora: weed growth, population density and distributions in chickpea vary from place to place depending upon soil and climatic factors, and farmers' management practices. Chickpea weeds are not only poblems to the chickpea crop, but also they are problems to all crops in the rotation system. The weed species reported to cause major problems in chickpea production are listed in Table 1. Past survey on chickpea weeds indicated that there are about 56 species in 45 genera and 18 plant families (Rezene, 1986; Rezene and Gerba, 2006; Rezene and Kedir, 2008). The problematic annual broadleaf species in chickpea include those of *Amaranthaceae*, *Brassicacae*, *Asteraceae*, *Chenopodiaceae*, *Fabaceae* and *Polygonaceae*, *Rubiaceae*, and *Solanaceae* among other families. Biennial or perennial species of weeds that have been reported to occur include those of the *Plantaginaceae, Poaceae, Polygonaceae*, *Commelinaceae, Convolvulaceae*, *Asteraceae*, *Cyperaceae* and other families.

With this diversity of weed species there is seldom an effective method available that will control all weeds in chickpea. The weed control methods are limited by level of technological advancement, prevailing cropping systems, climatic and soil conditions and by the resource base small-scale farmers.

Table 1. Major weeds of chickpea recorded in Ethiopia (Adapted from Rezene and Kedir 2008).

Family	**Species**	Characteristics[1]			Level of importance[2]
Amaranthaceae	*Amaranthus hybridus*	a	d	rs	xx
Asteraceae	*Bidens pachyloma*	a	d	rs	xx
	Bidens pilosa	a	d	rs	xx
	Cichorium intybus	p	d	rs/rv	xxx
	Galinsoga parviflora	a	d	rs	x
	Guizotia scabra	a	d	rs	xx
	Launea cornuta	p	d	rs/rv	xx
	Parthenium hysterophorus	a	d	rs	xxx
	Sonchus arvensis	p	d	rs/rv	x
	Sonchus oleraceus	a	d	rs	x
	Tagetes minuta	a	d	rs	xx
	Xanthium spinosum	a	d	rs	xx
	Xanthium strumarium	a	d	rs	xx
Brassicaceae	*Brassica napus*	a	d	rs	x
	Raphanus raphanistrum	a	d	rs	xx
Caryophyllaceae	*Cerastium octandrum*	a	d	rs	x
	Corrigiola capensis	a	d	rs	x
	Spergula arvensis	a	d	rs	x
Commelinaceae	*Commelina Africana*	p	m	rs/rv	xx
	Commelina benghalensis	a/p	m	rs/rv	xxx
Convolvulaceae	*Convolvuls arvensis*	p	d	rs/rv	xxx
	Cuscuta campestris				xxx

Table 1. Continued …

Family	Species	Characteristics[1]			Level of importance[2]
Cyperaceae	*Cyperus esculentus*	p	m	rs/rv	xxx
	Cyperus rotundus	p	m	rs/rv	xxx
Leguminosae	*Medicago polymorpha*	a	d	rs	xx
	Scorpiurus muricatus	a	d	rs	xxx
Orobanchaceae	*Orobanche crenata*	a	d	rs	x
	O. minor	a	d	rs	x
Papavaraceae	*Argemone ochroleuca*	a	d	rs	xxx
Plantaginaceae	*Plantago lanceolata*	b	m	rs/rv	xx
Poaceae	*Avena abyssinica*	a	d	rs	xx
	A. fatua	a	d	rs	xx
	Brachiaria eruciformis	a	d	rs	x
	Bromus pectinatus	a	d	rs	x
	Cynodon dactylon	p	m	rs/rv	xx
	Digitaria scalarum	p	m	rs/rv	x
	Eragrostis spp.	a	d	rs	x
	Lolium temulentum	a	d	rs	x
	Phalaris paradoxa	a	d	rs	xx
	Setaria pumila	a	d	rs	xx
	S.vericillata	a	d	rs	xx
	Snowdenia polystachya	a	d	rs	xx
	Sorghum arundinaceum	a/p	m	rs/rv	xxx
Polygonaceae	*Oxygonom sinautum*	a	d	rs	x
	Polygonum aviculare	a	d	rs	xxx
	P. nepalense	a	d	rs	xx
	Rumex abyssinicus	p	d	rs/rv	x
	Rumex bequartii	p	d	rs/rv	xx
Primulaceae	*Anagalis arvensis*	a	d	rs	x
Resedaceae	*Caylusea abyssinica*	a	d	rs	xx
Rubiaceae	*Galium spurium*	a	d	rs	xx
Solanaceae	*Datura stramonium*	a	d	rs	xxx
	Nicandra physalodes	a	d	rs	xx
	Solanum nigrum	a	d	rs	xx
Umbellierae	*Feuniculum vulgare*				xx

[1]Characteristics: a = annual; b = biennial; p = perennial; d =dicot; m = monocot; rs = reproduction by seed; rv = reproduction by vegetative means;
[2] Level of importance: xxx = widely spread; xx = moderately spread; x = localized.

Weed surveys

Major surveys information reported in chickpea include those conducted under distribution and economic importance of

Orobanche Cuscuta spp. in Ethiopia and weed survey in major cool-season food legumes growing areas of west and north shewa. The result of the survey on distribution and economic importance of *Orobanche* and *Cuscuta* spp. in chickpea has been reported in Rezene and Gerba (2006) and Rezene and Kedir (2008).

Weed survey in chickpea growing areas of west and north Shewa zones of Oromiya region: quantitative determinations of weeds in chickpea fields were conducted in 9 and 5 weredas of west and north Shewa zones, respectively, during the period of 2000 – 2001. The frequency, abundance, dominance and species composition of weeds occurring in chickpea fields are presented in Tables 2 and 3 (HARC, 2002).

In west Shewa zone, the frequency and dominance level of individual weed species ranged from 0.48 % to 60.09 % and 0.01% to 8.36 %, respectively. Similarly, the respective order of frequency and dominance level of individual weed species for north Shewa zone of Oromia Region were 12.03% to 86.57 % and 0.49 % to 15.43 % (HARC, 2002).

Only weed species which has frequency and infestation levels greater than 25% and 2.5%, respectively, were considered as major weeds because they constituted more than 30% of the total weed species that infested chickpea fields. In this regard, the most frequent, abundant and dominant weed species for both zones were: *G. scabra, C. octandrum, P. lanceolata, P. paradoxa, P. nepalense, M. polymorpha,* and *Spergula arvensis* (Tables 2 & 3). Similarly, major weeds for west Shewa zone were *Corrigiola capensis, A. fatua, S. pumila* and *Snowdenia polystachya* (Table 2). For north Shewa *Galium spurium, Alchimela sp., Bromus pectinatus, Juncus bufonius, Galinsoga parviflora, Commelina benghalensis,* and *Athraxon quantinanus* were determined as major weed species (Table 3). Forty weed species were identified which belong to 18 plant families. Overall, Poaceae and Asteraceae contributed 9 and 6 species, respectively. All chickpea fields were severely plagued by *'meskel'* flowers (*Bidens pachyloma, B. peristenaria* and *Guizotia scabra*) (HARC, 2002).

Table 2. Major weeds of chickpea recorded in west Shewa zone (2000/2001).

Species	Frequency	Dominance	Abundance
Amaranthus hybridus	1.44	0.03	0.01
Bidens pachyloma	12.98	1.47	0.43
Galinsoga parviflora	13.46	1.91	0.56
Gnaphalium unionis	12.98	1.43	0.42
Guizotia scabra	60.09	5.81	1.70
Launea cornuta	1.92	0.41	0.12
Capsella bursa-pastoris	0.48	0.003	0.001
Raphanus raphanistrum	0.48	0.003	0.001
Cerastium octandrum	31.25	3.45	1.01
Corrigiola capensis	46.63	12.83	3.75
Spergula arvensis	33.65	3.01	0.88
Commelina benghalensis	14.90	1.19	0.35
Cyperus rotundus	2.88	0.27	0.08
Satureya paradoxa	18.26	1.84	0.54
Medicago polymorpha	40.38	3.38	0.99
Oxalis latifolia	11.05	1.30	0.38
Plantago lanceolata	36.0	3.08	0.90
Athraxon quartinianus.	1.92	0.34	0.10
Avena fatua	37.01	3.32	0.97
Bromus pectinatus	17.30	1.23	0.36
Cynodon dactylon	2.40	0.17	0.05
Digitaria scalarum	10.09	1.02	0.30
Eragrostis spp.	2.40	0.17	0.05
Lolium temulentum	5.76	0.41	0.12
Panicum sp.	17.78	2.12	0.62
Phalaris paradoxa	26.44	2.50	0.70
Setaria pumila	35.57	3.59	1.05
Snowdenia polystachya	28.36	4.14	1.20
Polygonum aviculare	13.46	0.99	0.29
Polygonum nepalense	25.0	2.80	0.82
Rumex bequartii	12.98	0.85	0.25
Anagalis arvensis	3.36	0.13	0.04
Caylusea abyssinica	4.32	013	0.04
Galium spurium	4.80	0.34	0.10

Source: (HARC, 2002).

Table 3. Major weeds of chickpea recorded in north Shewa (2000/2001).

Species	Frequency	Dominance	Abundance
Anthemis tigreensis	36.57	4.18	0.93
Bidens pachyloma	12.03	1.03	0.23
Galinsoga parviflora	27.31	2.16	0.48
Gnaphalium unionis	19.44	1.89	0.42
Guizotia scabra	25.46	1.93	0.43
Cerastium octandrum	33.79	3.69	0.82
Corrigiola capensis	21.75	2.20	0.49
Spergula arvensis	25.00	2.43	0.54
Commelina benghalensis	24.53	2.16	0.48
Cyanotis barbata	7.87	0.49	0.11
juncus bufonius	32.40	7.38	1.64
Satureya paradoxa	4.62	0.81	0.18
Medicago polymorpha	86.57	15.43	3.43
Plantago lanceolata	27.31	2.79	0.62
Athraxon quartinianus.	22.22	3.75	0.75
Avena fatua	22.68	1.57	0.35
Bromus pectinatus	34.72	4.41	0.98
Eichinocloa colona	6.01	0.67	0.15
Lolium temulentum	7.40	0.81	0.18
Panicum sp.	12.96	2.83	0.63
Phalaris paradoxa	48.61	10.17	2.26
Setaria pumila	12.96	0.54	0.12
Snowdenia polystachya	15.74	3.28	0.73
Polygonum nepalense	68.98	13.41	2.98
Rumex bequartii	14.35	1.48	0.33
Alchimella sp.	43.98	4.72	1.05
Galium spurium	38.88	4.09	0.91

Source: (HARC 2002).

Crop /weed interference: chickpea competes very poorly with weeds. The crop seems very sensitive to weed competition, like many legume crops, particularly during the early stages of crop growth. If weeds are not controlled early they cause considerable damage to the crop. Yield reductions due to competition from weeds have been shown to occur in chickpea in one local study and many other countries or regions elsewhere (Table 4). Additional losses due to weeds are often seen with reduced harvest efficiency and reduced crop quality

(McKay *et al.,* 2002). Slow emergence, short plant height and late canopy cover of cool season legumes in general, and chickpea specifically, allow weeds to compete effectively against these crops.

Local studies on weed competition in chickpea have been limited and not conclusive. However, substantial reports are available from various investigations carried out elsewhere on the determination of the critical period of weed competition in chickpea.

The critical weed-free period is defined as the period of crop growth during which the crop must be kept weed-free to prevent yield loss due to weed interference (Van Acker *et al.,* 1993). Mohammadi *et al*. (2005) indicated that in two locations in Iran, emergence of chickpea occurred at 5 and 8 days after planting. Weed-removal studies by these researchers indicated that the critical weed-free period was from 48 to 49 days after emergence. A study in Tunisia estimated the critical weed-free period for chickpea at 10 weeks after emergence, for a location with low to medium severity of weed infestation, and 4 weeks for a separate location where the infestation was described as severe. In the Iranian study, the critical weed-free period lasted until the crop was in the early to full flowering stage of growth (Mohammadi *et al.,* 2005). In reality, the critical weed-free period is an estimate and will vary with environment (Table 5).

Table 4. Yield losses due weed competition reported in Ethiopia and some other chickpea producing countries.

Country / Region	**% Yield loss**	**References**
Ethiopia	30.6	Rezene, 1986
India	40 - 94	ICARDA-FSP, 1986; Bhan and Kukula, 1987
Italy	35.0	Calcagno *et al.,* 1987
West Asia	40 - 75	ICARDA-FSP, 1986
North Africa	13 - 98	ICARDA-FSP, 1986

Table 5. Critical period of weed interference in chickpea obtained by various researchers.

Authors	Start of critical period (days after crop emergence)	End of critical period
Mohammadi *et al*. (2005)	17	49
Al-Thahabi *et al*. (1994)	35	49
Ali (1993)	0	56
Bhan and Kukula (1987)	30	60
Ahlawat *et al.* (1981)	28	42
Saxena *et al.* (1976)	30	30
Mean	25	53

Tillage and weed control: the frequency of tillage and weeding operation are the major factors affecting the production and productivity of cool season food legumes in the high lands of Ethiopia. A study on the frequency of tillage and weed control for two cropping seasons (1999-2000) at Akaki and Debre Zeit indicated that there were statistically significant ($P<0.01$) differences between weeding operations but not among frequency of tillage (Table 6). Weeding once increased grain yield of chickpea by 30 and 75% at Akaki and Debre Zeit, respectively, compared to the non-weeded check. The analysis of variance indicated that there was no interaction between the two effects.

Table 6. Effect of tillage and weed control practices on mean seed and total biological yields of chickpea 1999-2000 at Akaki & Debre Zeit.

	Akaki		Debere Zeit	
Factors	Grain yield (kg/ha)	Biomass (kg/ha)	Grain yield (kg/ha)	Biomass (kg/ha)
Tillage(T)				
T_1	2691	6230	1898	4106
T_2	2743	6254	1975	4294
T_3	2653	6165	2024	4014
T_4	2545	5979	1836	4094
T_5	2548	6017	1660	4156
LSD (%)	NS	NS	NS	NS
weeding (T)				
W_1	2653	6165	2653	6165
W_2	2545	5979	2545	5979
F_{test}	**	**	**	**
T x W	NS	NS	NS	NS
CV (%)	24.9	18.9	21.5	15.3

* and ** = Significant at 0.05 and 0.01 probability level, espectively; NS = Not significant. T_1= ?, T_2= ?, T_3= ? T_4= ? and T_5= ?; W_1 = ? and W_2= ?
Source: (Getachew *et al*., 2008)

Chemical control: two chemical weed control trials were conducted at Kulumsa during the year 1969 and 1971. The herbicides tested were: linuron, alachlor and dinoseb amine. Alachlor at 2.4 and linuron at 1.0 kg *a.i.* ha^{-1} were very promising. But, linuron did not persist long to control the late emerging weeds. It is apparent that most effective herbicides do not have very wide-spectrum effect on weed species and the conclusion drawn from this trial was that chemical control in this crop must be followed by supplementary hand weeding even if its initial effect is extremely good (Rezene, 1986).

Since the last seventies more than 35 commercial herbicides were tested on chickpea for weed control and crop tolerance. Several effective herbicides were identified to control broadleaf and grass weeds. Most of these herbicides are soil-acting chemicals applied pre-planting and pre-emergence and prevent the early establishment of seedling from germinating weed seeds. Like most grain legumes, chickpeas are more tolerant to pre-emergent compared to post-emergent herbicides. This explains that why effective post-emergent herbicides are limited particularly, those for broadleaf weeds. Some pre-planting herbicides are also contact weed killers that destroy above ground parts of weeds. The selectivity and efficacy of these soil-acting herbicides is usually limited to specific agro-ecological conditions because of differences in soli type, moisture availability, temperatures and weed flora. Therefore, recommendation differs from one agro-climatic zone to another.

Effective pre-planting and soil incorporated (PPI) herbicides include fluchloralin, oxyfluorfen trifluralin and triallate. Those effective as pre-emergent herbicides are alachlor, dinoseb amine, chlorobromuron, cyanazine, methabenzthiazuron, metribuzin, pronamide, prometryne, and terbutryne. Post-emergent herbicides include: dinoseb acetate, fluazifop-butyl and fenoxprop-ethyl. Post-emergent applications need great care with respect to stage of growth and air temperature to avoid phytotoxicity (Solh and Pala, 1990).

Gap analysis

Hand weeding has remained the most widely used method of weed control in chickpea production and has not seen any modifications over the years. Weed research in chickpea should emphasize on determining the crop growth period when weeds are most injurious and when they are relatively harmless. In this regard, the efficacy of mixed cropping in reducing weed control requirements, weed surveys, interaction effects of cultural practices with weed control methods, studies on economic importance of specific weed problems and the efficacy of chemical control are areas of worth investigation.

It is now recognized that *Orobanche crenata* is likely to constitute a problem in the northern chickpea production areas of the country (Gonder, Gojam, Welo, Tigray and neighboring localities of north and west Shewa). The present awareness of the problem should lead to the formulation of a national and regional programs designed to exploit the genetic possibilities of the host plants and also to improve the understanding of the evolution of the parasite in the environment of the host. The other parasitic weed of a potential threat is also *Cuscuta campastris*.

Proposals for future weed research directions in chickpea production

Weed surveys: weed growth, population density and distributions vary from place to place depending upon soil and climatic factors, and farmers' management practices. Other than the one reported for selective sites in west and north shewa (HARC, 2002) there are no weed inventory data recorded specifically on chickpea production in Ethiopia. Weed surveys on farm and on regional basis are therefore needed to establish efficient weed management and decision making mechanisms and to evaluate weed control measures. Besides, it is useful to record population changes of potentially dangerous weeds on regular basis, to highlight areas where changes in species diversity occur, and to give guidelines for setting up research priorities in weed control.

Determination of critical period of weed control: so far, no single method related to critical period has been fully effective and widely adapted to all environments and situations. Critical period knowledge that increases the capabilities of the farmer is an important consideration in the choice of weed control method. Critical period consideration will also help to set an integrated approach involving chemical, cultural, and mechanical methods that provide an effective weed control system in chickpea.

The critical period of weed control might vary with the environmental conditions, level of weed infestations, composition of weed population, soil moisture, and the fertility level. Due to the lack of relevant information, it is needed to determine the effects of timing of weed removal and duration of weed interference on crop yield in major representative chickpea production areas of Ethiopia using a well adapted or recommended variety for each respective test location with chickpea culture either kept free of weeds for 0, 12, 24, 36, 48 and 60 days after crop emergence (DAE) or weeds were allowed to grow for 0, 12, 24, 36, 48 and 60 DAE.

Breeding for Orobanche resistance: in some parts of northern Ethiopia, notably in south Tigray, south Gonder and south Welo certain legumes, such as faba bean, pea and lentil are susceptible to *Orobanche crenata* and yield loss up to 100% are reported if a susceptible line is grown in a highly infested soil. In the same places this parasite also affects chickpea to some extent. Therefore, it is desirable to screen chickpea accessions against this parasite in fields highly infested by this parasite to confirm the resistance of the lines in the following season. Since most lines could be either tolerant or resistant, the National Breeding Program should monitor the reaction of newly developed lines to *Orobanche crenata* on regular basis to avoid production of susceptible lines. Similar work had been conducted in ICARDA where *Orobanche crenata* is a great menace to most food legumes (Singh, 1987).

Chemical weed control: chemical weed control in chickpea is promising in spite of some technical limitations in its adoption in certain areas. In the Ethiopian case, the present trend indicates that chemical weed control is must for large-scale commercial production of chickpea in the country. Because of the sensitivity of chickpea to herbicides, most effective herbicides pre-sowing and pre-emergence soil acting chemicals and their efficacy is highly dependent on soil type moisture, temperature and weed flora. The effective soil-acting herbicides have limited persistence in the soil and these are only effective at early stages of the crop development. The narrow adaptation of these herbicides and the inconsistency of their effect from season to season are other limitations. Post-emergence herbicides particularly those for broad-leaf weeds are few. The new post-emergent chemicals for grasses seem effective though the choice is limited and thus, there is a need to identify more effective herbicides with broader spectrum of weed control and wide adaptability. An integrated approach involving herbicides and cultural practices to improve crop competitiveness is needed to develop effective and economic control measure. The application of herbicides has to be done with a great care to avoid crop phytotoxicity. Residual effect of herbicides and their effect on biological nitrogen fixation or cereals in rotation following chickpea should be given due attention before selecting a herbicide as a component of weed control package.

Non-technical limitations also constrain use of chemical control in less industrial countries like Ethiopia. Effective herbicides are usually not available locally or not registered in the pesticide registration system. So efforts are needed to acquire a special approval from the National Pesticide Committee to import and get a testing clearance of effective herbicides reported elsewhere.

References

Ahlawat IPS, Singh A, and Safar CS (1981) It pays to control weeds in pulses. *Indian Farming,* **31**: 11–13.

Ali M (1993) Studies on crop-weed competition in chickpea (*Cicer arietinum* L.)/ mustard (*Brassica juncea* (L.) Czern and Coss) intercropping. pp. 18–20. In: *Proceeding 1993 of an Indian Society of Weed Science International Symposium.* Integrated Weed Management for Sustainable Agriculture, Hisar, India,

Al-Thahabi, SA, J.Z. Yasin , B.E. Abu-Irmaileh, N.I. Haddad and M.C. Saxena..(1994. Effect of weed removal on productivity of chickpea (*Cicer arietimum* L.) and lentil (*Lens culinaris* Med.) in a Mediterranean environment. *Journal of Agronomy and Crop Science,* **5**: 333–341.

Bhan, VM and S Kukula. 1987. Weeds and their control in chickpeas. pp. 319–328. In: Saxena, M.C. and Singh, K.B. (eds.). *The Chickpea.* CAB International, Wallingford, UK,

Calcagno F, Gallo G, G Venora & G Restucera (1987) Primi resultati de recherché spermentali sul diserba chimico del cece. In: La cultura Del cece in Italia ENEA, Atti della gronatta tenutasi presso in Centro Recerche Engeria della Casaccia, Roma, Italy.

FAOSTAT (Food and Agricultural Organization Statistical Database). 2012. Crop Production Index. Rome, Italy: FAO.

HARC (Holetta Agricultural Research Center) (2002) Progress Report for the period of 2001/2002. HARC, Holetta.

ICARDA-FSP (International Center for Agricultural Research in the Dry Areas) (1986) Annual Report, Aleppo, Syria.

Kassie M, Shiferaw B, Asfaw S, Abate T, Muricho G, Teklewold H, Eshete M and Assefa K (2009) Current situation and future outlooks of the chickpea sub-sector in Ethiopia. ICRISAT Working Paper, ICRISAT & EIAR,39.

McKay K, Miller P, Jenks B, Riesselman J, Neill K, Buschena D, and Bussan AJ (2002) Growing Chickpea in the Northern Great Plains. North Dakota State University Extension Bulletin A-1236, Fargo, North Dakota.

Mohammadi, G., A. Javanshir, FR Khooie, S.A. Mohammadi and S Zehtab Salmasi. 2005. Citical period of weed interference in chickpea. Weed Research, **45**: 57–63.

Rezene F. 1986. Review of weed science research activities in pulses in Ethiopia. pp 403-426 In: A review of crop protection research in Ethiopia. Tsedeke Abate (ed.). Proceedings of the first Ethiopian crop protection symposium. February 4-7, 1985. Addis Ababa, Ethiopia. IAR, Addis Ababa.

Rezene F. 1998. Review of Broomrapes (*Orobanche* spp.) in Ethiopia. *NVRSRP Newsletter*, **1**:20-22.

Rezene F. 2004. *Orobanche* Research in Ethiopia. pp. 84-88. In: Dahan, R and Mohammed El-Mourid (eds.). Integrated Management of *Orobanche* in food Legumes in the Near East and North Africa. Proceedings of the Expert consultation on IPM for Orobanche in Food Legume Systems in the Near East and North Africa, 7-9 April 2003, Rabat Morocco. ICARDA/INRA/FAO International Center for Agricultural Research in the Dry Areas. ICARDA, Aleppo, Syria, vii+120 pp. ISBN: 92-9127-158-X.

Rezene F and Gerba L (2006) Review of Weed Research in Highland and Lowland Pulses. *In:* Kemal A., Gemechu K., Seid A., R. Malhotra, S. Beniwal, K. Makkouk and M.H. Halila (eds.). Food and forage legumes of Ethiopia: Progress and prospects. *Proceedings of a Workshop on Food and Forage Legumes*. 22-26 Sept 2003, Addis Ababa, Ethiopia. ICARDA, Aleppo, Syria. ISBN 92-9127-185-4. 351p.

Rezene F and Kedir N. 2008. Review of Weed Research in Highland and Lowland Pulses. pp. 133-165. In: Abrham Tadesse (ed.). Increasing Crop Production through Improved Plant Protection – Volume I. Proceedings of the 14th Annual Conference of the Plant Protection Society of Ethiopia (PPSE), 19-22 December 2006, Addis Ababa, Ethiopia. 598 pp.

Saxena *et al*. (1976) Chemical and mechanical control of weeds in gram. *Pantnagar Journal of Research*, **1**:112-116.

Singh, K.B. 1987. Chickpea Breeding. pp. 127-162. *In*: The Chickpea. Saxena, M. C. and K. B Singh (Eds), CAB International: Wallingford, Oxon, OX10 8DE, UK.

Solh, M.B. and M Pala. 1990. Weed control in chickpea. *Options Mediterr. Ser. Semin.*, **9**: 93-99.

Solomon A, Shiferaw B, G. Muricho and F Setotaw. 2010. Socio-economic Assessment of Legume Production, Farmer Technology Choice, Market Linkages, Institutions and Poverty in Rural Ethiopia. Nairobi: ICRISAT.

van Acker, R.C., S.F. Weise and C.J Swanton. 1993. The critical period of weed control in soybeans (Glycine max (L.) Merr.). *Weed Science*, **41**: 194-200.

Vyas, S.C. and L.K Joshi.1975. A new record of parasitic dodder on chickpea. *Current Science*, **44**(19): 701-702.

17. Status of chickpea Insect Pests Management Research In Ethiopia

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Although the insect pests recorded on chickpea are many in number, only the pod borer, Helicoverpa armiger, and cutworm, Agrostis sp. in the field and the Adzuki bean beetle, Callosobruchus chinensis in a store are economically important. Since the mid 2000 researches were carried out on different management methods against these major insect pests. Chickpea accessions were tested for their resistance to pod borer under field condition and was found that except accessions EC583250 and ICC3137, which had pod damage level of 8% and 10%, respectively, the remaining had pod damage level less than 5%. But all the accessions were susceptible to wilt/root rot diseases. In a participatory variety selection (PVS) trials farmers gave more weight for yield and yield related parameters than resistance to insect pests. Insecticide application timing on the basis of phenological stages of the crop did not reduce pod damage by pod borer since the insecticide was not applied at the right phonological stage and as consequence there was no yield advantage due to insecticide spraying. Chickpea accessions were also evaluated for resistance to Adzuki bean beetle and resistant sources, which are small seeded genotypes, were identified. However, their utilization in chickpea breeding might be limited as increasing seed size and grain yield increases the susceptibility of chickpea grain to Adzuki bean beetle. Solar heating of Adzuki bean beetle infested chickpea grain (about 100g) in an obtuse base angle box heater for an hour around midday resulted in complete control of the pest.

Key words: Adzuki bean beetle, chickpea, cutworm, pod borer

Introduction

In Ethiopia, chickpea, *Cicer arietinum* L., is grown under different cropping systems as sole, mixed (with barley, noug), rely (following maize), and double (after barley, tef, field pea or wheat) crop. The soil types on which chickpea is grown also vary from sandy soil to heavy clays soils. Despite these wide ranges of cropping systems and soil types, the crop is attacked only by few insect pests. The pod borer, *Helicoverpa armigera* Hubb., is the single most important field insect pest of chickpea throughout the country. Earlier surveys in major chickpea growing regions of the country have shown that it causes up to 30% pod damage. This damage does not include damages by early instars on leaves, shoots, flower buds and other reproductive organs. Cutworm, *Agrostis sp*. is another field insect pest of chickpea, although currently its importance is limited to the northwestern part of the country. In the central highland regions it has relegated to minor pest status perhaps because of radical changes in chickpea agronomy such as staggered plowing time, clean and fine seedbed preparation and early planting. Termites, *Macrotermes sp*. occasionally damage taproot of standing or cut crop in some localities. The pea aphid, *Acyrthosiphon pisum,* the cowpea aphid, *Aphis crassivora* and unidentified root mealybug also infest chickpea crops. The root mealybug was recorded only around Maksegnit and Abeya valley of the Amhara regional state.

The second workshop on food and forage legume crops research in Ethiopia was held in 2006. Since then insect pest management research works on chickpea were carried but with minimum progress because of the sporadic occurrences of field insect pests, and lack of stable and focused research system. This review paper aims to consolidate results of pest management researches carried out after the second workshop.

Pod borer Management Research

Host plant resistance: chickpea accessions known to have some level of pod borer resistance under Indian condition were introduced from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and evaluated under Debre Ziet condition. The accession reached 50% flowering and maturity at about 42 to 65 and 122 to 130 days, respectively (table 1). Moreover, the number of days from 50% flowering to maturity rang from 57 to 80 days. Even though chickpea is infested by pod borer beginning from seedling stage, it was assumed that the extended time from 50% flowering to maturity provides prolonged feeding period for the insect. In reality, however, there was no apparent correlation between pod damage and days from 50% flowering to maturity.

Chickpea resistance to pod bore is assessed on a 1 to 9 scale, where 1= < 10% pod damage and 9= 100% pod damage and accessions that have less than 10% pod damage are considered as resistant. Thus, except the accession ICC3137 the remaining accessions had pod damage less than 10% and were resistant to pod borer. The other accession that had relatively higher percentage of pod damage was EC583250. However, subsequent evaluations did not yield consistent result because of sporadic incidence of the pest and poor establishment of the crop. Moreover, the accessions were highly susceptible to fusarium wilt/ root rot complex diseases.

The mechanism of chickpea resistance to pod borer has not been studied under Ethiopian condition. However, according to Lateef (1985) compensation for early losses, oviposition preference, larval preference and retention and high level of malic acid content are traits associated with chickpea resistance to pod borer.

Table 1. Reaction of chickpea accession to pod borer attack under Debre Zeit condition

Accessions	Pod damage (%)	Days to 50% flowering	Days to maturity	No. of days*	Wilt/root rot incidence (%)**	Grain yield (g/m^2)
ICC4958	3.8	42	122	80	23.5	450.8
ICC867	3.8	49	122	73	12.4	316.9
ICC5383	4.7	65	122	57	23.5	321.0
ICC10393	3.1	44	122	78	22.0	452.9
ICC1356	3.2	62	122	60	13.9	471.1
ICC16903	2.7	49	122	73	19.6	470.7
ICC637	3.4	56	122	66	24.7	600.8
ICC4533	2.0	42	122	80	12.2	412.4
ICC14402	2.7	49	122	73	21.6	569.0
ICC14831	4.3	65	122	57	25.4	411.4
EC583250	7.9	44	122	78	45.1	88.6
EC583260	-	44	-	-	100.0	-
EC583264	3.2	49	122	73	42.4	271.7
EC583311	3.9	65	130	65	37.8	192.1
EC583318	5.3	65	122	57	36.1	167.2
ICCV07108	3.2	47	122	75	14.0	398.3
ICCV07113	3.6	49	122	73	20.4	497.2
ICCV07106	3.6	42	122	80	21.3	455.3
ICCV07104	2.0	53	122	69	16.0	344.4
ICCV07105	2.4	54	122	68	25.4	465.4
ICCVX960183-4	1.2	62	122	60	10.9	407.3
ICCVX960183-28	1.2	65	122	57	13.9	414.9
ICCVX960183-72	1.7	65	130	65	14.9	500.4
ICCV X 960183-69	0.9	62	130	68	16.1	484.4
ICCVX 960186-1	2.5	62	130	68	20.6	409.0
ICC506	2.7	49	122	73	33.1	372.9
ICCC37	3.2	44	122	78	20.4	515.0
ICCV10	2.3	58	122	64	26.1	411.0
ICC3137	10.2	60	122	62	48.9	132.8
ICC4973	2.9	62	130	68	9.6	473.3
FPLSD (1%)	2.1	-	-	3.0	27.5	241.2

* = number of days from 50% flowering to maturity, **= visual score

Others such as Shahzad *et al*. (2005) indicated that trichome and plant height have negative effect on pod borer infestation. Moreover, Giri *et al*. (1998) stated that seeds in pod borer injured pods have greater amount of trypsin inhibitor and proteinase inhibitor than in the seed of undamaged pods, but pod borer is capable of deactivating these inhibitors.

Assessing farmers' chickpea variety selection criteria: six chickpea varieties which weren‘t grown by farmers before the participatory variety selection (PVS) trial were sown in Minjar-Shenkora, Lume and Gimbichu districts. Each variety was sown on plot of 10m x 10m on each participant farmers‘ field. The varieties were randomized on each of the farmers‘ field so that each farmer‘s field would be considered as randomized complete block. The PVS trial manager farmers were given training on chickpea technologies, production and the PVS trial management prior to launching the trial. At the time of evaluation, in addition to the trial managing farmers a number of other neighboring farmers in the vicinity of each of the PVS trial sites were invited to participate in the evaluation of the varieties at seedling, pod setting, and harvesting stages. The varieties were coded as 1, 2, 3, up to 7 and farmers were informed to walk around the trial plots, make their own evaluation, rank the varieties, and list the selection criteria they used. Data were also collected at each crop stage by breeders, pathologists and entomologists either before farmers began to evaluate or after they finished their evaluation. At maturity, five randomly selected plants per plot in crossed diagonal line were collected and number of *H. armigera* damaged and undamaged pods were counted. From the count data, percent damage was calculated on individual plant basis.

Grain yield and overall stand (uniformity) were common selection criteria to all farmers in all districts (Table 2).

Table 2. Farmers' chickpea variety selection criteria

Selection criteria	Districts and localities			
	Minjar-Shenkora district		Lume district	Gumbichu district
	Ararti Zuria kebele	Zewolde kebele	Ejere kebele	Adadi Gole and Habro-Seftu kebeles
Number of pods	yes	yes	no	no
Seed size	no	yes	no	yes
Early flowering	yes	no	yes	no
Number of branches	yes	yes	yes	no
Plant height (vigor)	no	yes	yes	no
Early maturity	yes	no	yes	no
Adaptation to a soil	no	yes	no	no
Overall stand uniformity	yes	yes	yes	yes
Grain yield	yes	yes	yes	yes
Disease resistance	yes	yes	no	no

In all but Gimbichu district number of branches was the third common selection criterion. Since seeds of the test varieties were dressed with fungicide (Apron star at the rate of 250g/100kg of seed), there was no wilt/root rot diseases incidence in any of the PVS trial plots. Therefore, wilt /root rot diseases resistance was not included in the selection criteria. Although the test varieties are known to possess some level of genetic resistance to wilt/ root rot diseases, the purpose of seed dressing with fungicide was to demonstrate integrated disease management (IDM) practice. However, in Minjar-Shenkora district, where Ascochyta blight (a foliar disease) is economically important, disease resistance was one of farmers' chickpea variety selection criteria. In warmer areas of Minjar-Shenkora district (eg. the Arerti Zuria kebele at an altitude 1700masl or less) the chickpea varieties Shasho, Natoli, and to some extent Teji were hit by Ascochyta blight following small rain shower, which suggests that the varieties should not be promoted in warmer areas. Moreover, compared to Gimbichu district, the length of the rainy season in Minjar-Shenkora and Lume districts is relatively short. Consequently, farmers in these two districts asserted that early flowering and early maturity are important traits of chickpea varieties. Number of pods, seed size and plant height (vigor) were also selection parameters in different localities in each of the three districts.

According to Legese *et al.* (2005) drought tolerance, high yield and early maturity are major traits that the farmers expect from improved chickpea varieties, whereas good food making quality, large seed size, frost tolerance, insect pest tolerance and market demand are less important.

In the PVS trials only pod borer, *H. armigera,* was prevalent in all of the three districts. However, farmers did not recognize early instars of pod borer and their damage symptoms (browsing, nibbling or scraping) during vegetative and flowering stages of the crop. For instance, at Bolo Silasie and Arerti Zuria kebeles of Minjar-Shenkora district at the vegetative stage nearly all sampled chickpea plant exhibited leaves and shoots damaged by pod borer (Table 3). Farmers did not considered damages at the vegetative stage during their evaluation perhaps because of lack of knowledge on the damage done by pod borer at this crop stage.

Table 3. Visual score of damages by *Helicoverpa armigera* at vegetative stage of different chickpea varieties in Minjar-Shenkora district.

Variety	Visual Score*	
	Bolo Silasie	Ararti Zuria
Ararti	3	4
Ejere	3	3
Habru	1	3
Natoli	2	3
Shasho	2	4
Teji	2	4
Local	2	-

** 0= No damage (browse) symptom, 1= ≤ 1% leaf damage symptom and no last instar larvae on each sampled plant, 2= 2-15% leaf damage symptom and at least one early instar per sample plant, 3= 16-20 % leaf damage and at least one third instar larva on each sample plant, 4= ≥ 20% browsed leaves and late instars, and 5= sign of pod damage.*

In Gimbichu district, other than pod borer the chickpea at one of the trial sites was completely ravaged by porcupine and humans for green seed consumption (Table 4). Farmers associated the human consumption/ preference and the porcupine damage to large seed size, sweet test, and low malic acid content of the improved varieties. Percent damaged pod per plant due to pod borer was lowest (0-7%) in Gimbichu district (Table 4). This low pod damage might be ascribed to the cold temperature of Gimbichu district, which limits the activity of the insect pest. Farmers in this area do not use insecticide to control pod bore on chickpea.

Table 4. Degree of chickpea pod damage by *H. armigera* in Gimbichu District

Variety	Adadi Gole)				Habru Softu	
	Farm 1		Farm 2		Farm 1	
	Total number of pods	Pod damage (%)	Total number of pods	Pod damage (%)	Total number of pods	Pod damage (%)
Arerti	48.0	1.42	59.8	5.13	81.6	0.00
Ejere	31.2	0.00	ravaged by porcupine		92.1	1.61
Habru	25.2	5.10	ravaged by porcupine		73.2	2.92
Natoli	27.6	2.71	58.2	7.29	64.5	1.00
Shasho	43.2	4.03	ravaged by porcupine		76.2	0.34
Teji	34.8	2.06	human theft		68.6	1.82

In Minjar-Shenkora district, prevalence of pod borer was relatively more severe than in Gimbichu and Lume districts. Shenkora area is intermediate between low and highland and percent damaged pods per plant varied between 1 and 10% (Table 5). Farmers in Shenkora area sprayed their chickpea with insecticide one time, but they don‘t know the name of the insecticide they sprayed (however, they knew the price was 215Birr/l). The chickpea stand was dense and bumper.

Table 5. Degree of chickpea pod damage by *Helicoverpa armigera* in Shenkora

Variety	Shenkora (Zewolde)			
	Farm 1		Farm 2	
	Total number of pods	Pod damage (%)	Total number of pods	Pod damage (%)
Arerti	40.6	1.04	48.8	10.43
Ejere	47.2	8.42	55.4	8.55
Habru	62.0	3.99	80.4	9.15
Natoli	69.8	3.08	75.2	7.71
Shasho	62.6	3.50	64.2	4.47
Teji	53.6	6.74	46.4	6.81

In Arerti Zuria and Bolo Silasie kebeles of Minjar, *H. armigera* caused 8 to 25% and 9 to 20% pod damage, respectively (Table 6). There was also incidence of Aschocyta blight particularly in Arerti Zuria, which might have reduced the damage done by the pod borer.

Table 6. Degree of chickpea pod damage by *H. armigera* in Minjar district

Variety	Minjar (Arerti Zuria)				Minjar (Bolo Silasie)			
	Farm 1		Farm 2		Farm 1		Farm 2	
	Total number of pods	Pod damage (%)	Total number of pods	Pod damage (%)	Total number of pods	Pod damage (%)	Total number of pods	Pod damage (%)
Arerti	70.6	17.73	53.2	17.08	46	20.15	24.6	17.96
Ejere	34.8	15.11	47.8	15.03	23.4	12.43	30.8	8.78
Habru	30.8	8.06	55.4	15.37	26	16.7	25	14.64
Natoli	27.2	19.9	34	10.2	27.8	11.12	33.4	11.68
Shasho	52.2	22.77	60.8	25.28	30.6	16	29.2	13.4
Teji	29.2	12.9	50.4	20.6	26.8	13.32	20.2	19.88

Farmers in these kebeles said that they had sprayed chickpea with insecticide, but the magnitude of pod damage suggests that farmers have not used an effective insecticide or they might have sprayed at a wrong time. At maturity stage of the crop, most farmers were aware of damages done by pod borer, but still they did not include insect resistance in their variety selection criteria. Even though farmers are familiar with chickpea insect pest problem, 84% of them do not apply any insect control measure on this crop (Mekasha and Geletu, 1999). In eastern Ethiopia sorghum farmers favor yield and stalk height over pest resistance (Tadele, 2004). The exact reason why farmers did not consider reaction of the test varieties to insect attack in their selection criteria requires further investigation.

In conclusion during variety selection farmers give more weight for yield and yield related parameters than for the reaction of the improved varieties to diseases and insect pests. It means that farmers might not be aware of the benefits derived from pest resistant varieties. Moreover, host resistance to a particular pest is an integral part of crop management. Therefore, training farmers on pest biology in relation to crop phenology, the economics of pest management using resistant varieties and other methods, and the safe use and disposal of pesticides would be required as a package in extending improved chickpea varieties to farmers.

Time of insecticide application: chickpea growers in Ethiopia do not scout their chickpea for pod borer or other insect pests. Consequently, those farmers who apply insecticides spray on late instars, which are resistant to insecticides. As a result, farmers complain about the poor efficiency of insecticides they used, which necessitated the determination of critical time of insecticide application that minimizes losses caused by pod borer.

In 2010/11 season, the data on egg and larval number per plant were very irregular (most values were zero) and were omitted from the analysis. At Debre Zeit, there was no significant difference ($p > 0.05$) among the different treatment combination in reducing pod damage, or increasing grain yield (Table 7).

Table 7. The effect of time of insecticide application on pod damage and yield of chickpea (2010/11)

Variety	Crop stage	Number of pods per plant		Pod damage (%)		Grain yield (g/plot)	
		Debre Zeit	Akaki	Debre Zeit	Akaki	Debre Zeit	Akaki
Akaki	first branch appeared	22.00	25.40	3.94	4.00	444.33	497.00
	flower bud initiation	18.33	32.05	3.94	3.03	495.00	549.33
	beginning of flowering	26.33	24.82	6.28	3.91	496.00	660.67
	50% flowering	22.00	28.10	6.24	4.47	550.00	641.33
	at two weeks interval	19.00	19.43	7.65	6.98	453.67	303.33
	unsprayed check	21.00	27.72	6.31	4.17	608.00	456.33
Habru	first branch appeared	24.00	27.78	4.01	3.21	591.00	381.33
	flower bud initiation	19.33	25.08	5.29	4.53	415.33	402.67
	beginning of flowering	19.67	24.78	7.76	3.45	424.00	390.33
	50% flowering	19.67	17.15	5.38	5.03	291.67	404.67
	at two weeks interval	27.00	16.53	13.67	6.39	464.33	220.67
	unsprayed check	23.33	19.43	8.92	7.88	338.00	361.33
	LSD (5%)			NS	2.86	NS	215.93

It was found that seven out of 12 treatments had only one damaged pod per plant and three treatments had only two damaged pods per plant. The pod damage pattern was similar at Akaki, but when pod damage values were converted to percentage, the figures were inflated and were significantly different ($p < 0.05$). Since damaged pods per plant were at most two, the yield difference at Akaki is attributable to some other factors such as waterlogged condition and differences in weed density, which was not removed on time. At Minjar, variety Akaki was wiped out by Ascochyta blight (*Ascochyta rabiei*) and data on Habru was not collected because the plots were not randomized.

The outcome of the 2011/12 season was similar to the 2010/11 season (Table 8), although the percentage of pod damage was slightly less than the preceding season. However, it is worthy to mention that at both locations treatments were not applied at the right phenological stage and at Akaki data were not collected properly due to vehicle problem. Besides due to the confounded incidence of diseases such as Aschocyta blight in Minjar district – the results of the experiment were not conclusive.

Table 8. Effect of time of insecticide application on pod damage and yield of chickpea (2011/12)

Variety	Crop stage	Pods per plant		Pod damage (%)		Grain yield (g/plot)	
		Debre Zeit	Akaki	Debre Zeit	Akaki	Debre Zeit	Akaki
Akaki	first branch appeared	27.65	38.05	3.33	3.33	1737.33	1164.67
	flower bud initiation	27.18	45.82	3.20	2.11	1646.00	1309.33
	beginning of flowering	22.78	38.38	2.47	2.69	1219.67	1530.33
	50% flowering	22.53	44.80	5.42	2.19	1155.33	1039.33
	at two weeks interval	27.25	38.25	4.09	2.61	1156.33	1610.33
	unsprayed check	28.23	38.03	4.45	2.82	1620.00	1232.33
Habru	first branch appeared	27.77	41.35	6.07	3.03	3095.67	2223.67
	flower bud initiation	26.25	38.05	6.84	2.04	2695.67	2509.00
	beginning of flowering	33.27	39.17	4.65	2.10	3251.67	2320.67
	50% flowering	28.08	38.22	5.88	1.70	3125.33	2241.67
	at two weeks interval	29.13	38.20	6.31	2.56	2660.67	2246.33
	unsprayed check	27.95	39.87	6.25	3.54	1940.00	2250.33
LSD (5%)				NS	NS	1100.63	506.54

Aphid infestation and viral diseases

The question ―do aphids infest chickpea?" is frequently raised by extension agents, breeders and agronomists, which primarily stems from the physical absences of aphids that feed on chickpea. In many chickpea growing countries including Ethiopia the pea aphid, *Acyrthosiphon pisum* and the cowpea aphid, *Aphis craccivora* are known to infest chickpea. These aphid species do not cause economical damage directly. Rather they cause significant indirect damage through vectoring many of the viral diseases of chickpea. For instance, according to Berhanu *et al*. (2005) the incidence of viral disease in Gondar and Gojam areas of the Amhara region and Bale zone of Oromia region was 12.3 and 1.9%, respectively. The major viral diseases reported by these workers were the Luteovirus (which includes bean leaf roll virus (BLRV), beet western yellows virus (BWYV) and chickpea chlorotic stunt virus (CpCSV)), Faba bean necrotic yellows virus (FBNYV), pea seed-borne mosaic virus (PSbMV) and alfalfa mosaic virus (AMV). The luteovirus and FBNYV are transmitted by aphids in persistent manner, while the PSbMV and AMV are transmitted by seed and aphids in non-persistent manner. Abraham *et al*. (2006) reported that the CpCSV is transmitted only by *A. craccivora* in persistent manner. However, earlier Tadesse *et al*. (1999) and later Berhanu *et al*. (2005) indicated that they never found aphids on chickpea during their survey time. The cowpea aphid colonizes the collar region, but the pea aphid colonizes the crown (own observation). For instance, in 2008 cropping season following the unseasonable rain there was heavy pea aphid infestation on chickpea at Debre Zeit (Fig 1). At the beginning of the infestation there was an average of 6.7 (range 2.8 to 13.2) pea aphids per plant. The aphids did not proliferate as they do on other crops such as field pea and lentil. The aphids may also simply probe and left the plant. Therefore, appropriate sampling method (eg. beating on boards for pea aphid) must be followed to determine the presence or absence of aphids.

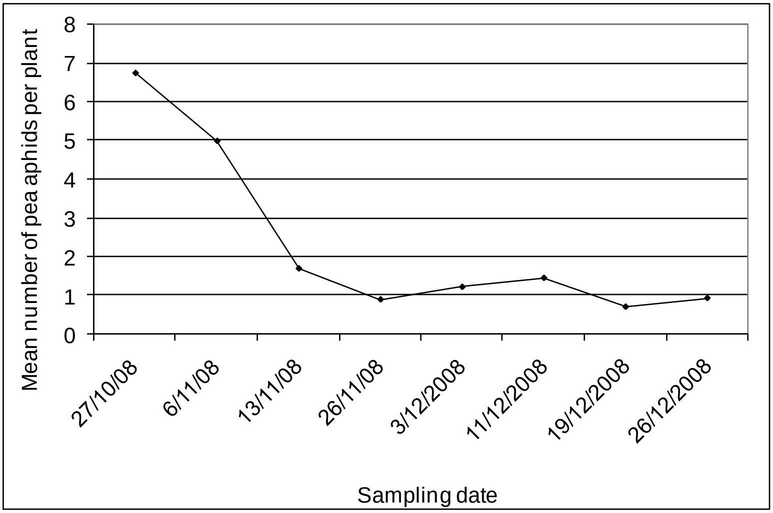

Figure 1. Pea aphid, *A. pisum* incidence on chickpea at Debre Zeit.

Adzuki bean beetle (*Callosobruchus chinensis*)

Biology of C. chinensis: biology of *C. chinensis* (Debre Zeit strain) was studied on chickpea by Rahel (2008) under ambient temperature at Debre Zeit. The life-history traits statistics are indicated in table 9. *C. chinensis* starts egg laying on the first day of emergence and continued for at most five days. The mean number of eggs laid per female during the first, second, third, fourth and fifth day was 19.9, 23.1, 10.4, 5.2 and 1.6, respectively. Although there was considerable variation among individual in the total number of eggs laid, a female on average lays about 60 eggs within five days. Similarly, the mean number of eggs laid per female per day was 12.

Table 9: Life history traits statistics of *C. chinensis* (Rahel, 2008).

Parameter	Average	Range
Eggs per female (total)	60	29-80
Eggs per female per day	12	up to 30
Oviposition period (days)	5	
Incubation period (days)	5	4-6
Egg hatchability (%)	70	36-92
Larval development period (days from oviposition)	10	6-14
Number of instars	4	
Pupal period (days)	6	
Development period (days)	23	22-27
Adult lifespan (days)		
Male		7.8
Female		7.6

Eggs required 4 to 6 days to hatch. Egg hatchability varied between 36 and 92% and decreased as the age of the female increased (Fig 2).

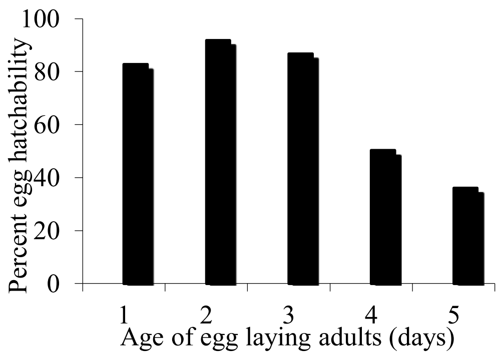

Figure 2. The relationship between age of female and egg hatchability in *C. chinensis* (*Source*: Rahel, 2008)

On the bases of head capsule width *C. chinensis* has four larval instars. The first, second, third and four larval instars have an average of O.12mm, O.24mm, O.34mm and O.55mm, respectively, head capsule width. The larval stadium between the first and second instar was 4 days, second and third instar 3 days and third and fourth instar was 4 days. On the other hand, the pupal stage lasts for about six days.

The mean developmental period of *C. chinensis* was 23 days. The proportion (as percentage of total number of laid eggs) of adults emergence ranged from 41 to 89%. As in the case of the number of eggs laid and egg hatchability, adult emergence decreased as the age of the female increased (Fig. 3). The major shortcoming of the study was that the type of chickpea variety used is not known. Different varieties of chickpea had different impact on the biology of Adzuki bean beetle.

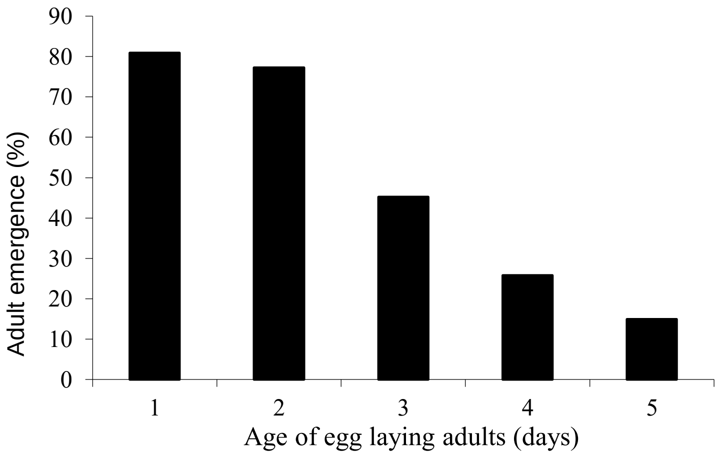

Figure 3: Rate of adult emergence as influenced by the age of egg laying adult of *C. chinensis* (source: Rahel, 2008)

Host plant resistance: Gemechu *et al*. (2011a) studied the response of Ethiopian and introduced chickpea genotypes to

Adzuki bean beetle attack. The Ethiopian chickpea genotypes were obtained from Institute of Biodiversity Conservation collections from Arsi, south and north Gondar, east and west Gojam, west Harargie, north and west Shewa, south Wollo, and Tigray. Apart from the variation among genotypes, the response to this pest infestation was affected by location (Ambo, Debre Zeit, and Holeta). The tested genotypes differentially affected the insect‘s biological performance (Table 10).

Table 10. Effect of chickpea genotypes on the performance of Adzuki bean beetle (values in range, from Gemechu *et al*., 2011a).

Parameter	First generation	Second generation
Number of eggs per female	22-51	-
Days to adult emergence	31-33	33-35
Number of adults emerged	104-222	455-1136
Seed weight loss (g)	2-13	9-20

Accessions ACC41320, 41289, 41291, 41134, 41315, 207658, 41103, 41168, 41142, 41174, 41029, 41207, 209087, and 231327 were reported as relatively resistant to Adzuki bean beetle. Moreover, the Ethiopian chickpea accessions were relatively more resistant to the insect than the introduced (improved) genotypes (Gemechu *et al*., 2011b, c). However, these workers have not identified the mode of resistance in the genotypes to the Adzuki bean beetle.

With the exception of total seed weight loss, other parameters such as number of eggs per female, days to adult emergence, number of adults emerged and adult recovery were affected by location, although these responses are believed to be static across locations (Becker and Leon, 1988). Consequently, for most parameters there were interaction between location and genotypes in their response to Adzuki bean beetle infestation and on the bases of these interactions Gemechu and his colleagues suggested replicate trials over locations or location specific breeding programs. However, these authors had not answered the questions, since seeds are dormant, to what extent do biochemical and physiological changes occur in a dormant seeds? Were the environmental factors in each test location- Ambo, Debre Zeit and Holeta – sufficiently distinct to induce differential biochemical and physiological changes in the tested genotypes? Therefore, the observed location by genotype interaction is more likely to be error than fact.

The improved chickpea varieties were more susceptible to Adzuki bean beetle than the local landraces (Gemechu *et al.,* 2011b) and this was a result of the stable population of landraces and intensive selection for traits other than resistance to insects in improved varieties. For instance, the breeding program focused more on improving grain yield and seed size, though the genetic gain in seed size was more progressive than for grain yield. However, seed size increment was negatively correlated with susceptibility to Adzuki bean beetle and as a consequence, as seed size increased, eggs laid, adults emerged and grain weight loss also increased (Gemechu *et al.,* 2011c). In these improved varieties the premature larvae emerged from the seed instead of the adult beetle. Gemechu and his colleagues speculated that large egg loads on thin seed coat, soft cotyledon and the presence of toxic substance in the seed coat as possible cause of larval expulsion from seeds. However, Adzuki bean beetles are know to lay egg on smooth and curvature surfaces (the jar used for the study has such character) and their larvae have about three pairs of spines that help them attach themselves on the eggshell. These factors were not considered by these authors during experimentation.

Heat treatment: heat as means of Adzuki bean beetle control in stored chickpea was assessed by Rahel *et al*. (2008). The source of heat was an electric solar simulator hanged at a height of 60cm above the ground to simulate solar heat around noon. The exposure times in minutes were 0, 20, 30, 40, 50, 60, 70, 80 and 90. The exposure time and the inter-grain temperature were linearly related. Therefore, exposing chickpea seeds for 20, 30, and 40 minutes increased the inter-grain temperature from an average of 28°C to 49.6, 52.9 and 55.1°C, respectively. This amount of heat not only caused significant adult mortality (87 to 95%), but it also reduced the number of eggs laid by females that survived the heat. Moreover, exposing chickpea seed for 60 or more minutes completely killed the beetles before laying eggs.

Hatchability of Adzuki bean beetle eggs was reduced to 33 and 10% when heated for 20 and 30 minutes, respectively, while 80% of the control (unheated) eggs hatched. Eggs completely failed to hatch when chickpea seeds were heated for 40 or more minutes. In addition, chickpea seeds assumed to contain different larval instars (I to IV) and pupal stages were also exposed to heat. Generally, the survival rate of the different life-stages of Adzuki bean beetle decreased as time of exposure to heat increased from 20 to 50 minutes. However, beyond 50 minutes exposure time, none of the life-stages survived the heat treatment. Application of heat treatment up to 90 minutes does not affect the moisture content and germination rate of chickpea seeds, as 96% or more of heat treated seeds germinated.

The major limitation of the study was that the amount of grain used for a particular treatment was about 100g and this small quantity of grain does not give adult beetles a chance to move to the cooler part of stored grain. Besides eggs hatched in heat treated chickpeas were not adjusted for the natural un-hatchability (as only 80% of the untreated eggs were hatched).

Future research direction

Despite the many years of research efforts, a full package of pod borer management has not been developed. On the other hand, those farmers who control pod borer use only insecticides and some of these insecticides such as endosulfan have been band from use in some countries. Therefore, future research efforts should be geared towards:

- Screening chickpea genotypes for pod borer resistance. Host plant resistance to insect pests is relative and selecting relatively less susceptible genotypes should continue.
- Assessing the effect of changing cropping system on the incidence of chickpea insect pests. For instance, do tomatoes and cottons grown in the Rift Valley contribute to pod bore problem in chickpea during the main season?
- Developing sampling method for pod borer.
- Evaluating safe and effective insecticides.
- Integrating proven insect pest control tactics.

References

Abraham AD, W Menzel, DE Lesemann, M Varrelmann, and HJ Vetten. 2006. Chickpea chlorotic stunt virus: anew polerovirus infecting cool-season food legumes in Ethiopia, *Virology*, **96**: 437-446.

Becker HC and J Leon. 1988. Stability analysis in plant breeding. *Plant Breeding*, **101**:1-23

Berhanu B, Kumari SG, Kemal A, Abdulrazak Y, Makkouk KM, Mandefro A, Melkamu A, Gelelbelu G and Dereje H (2005) Survey of viruses affecting legume crops in the Amhara and Oromia Regions of Ethiopia. *Phytopathol. Mediterr*,**44**: 235–246.

Gemechu K, Endashaw B, Emana G, M.Imtiaz, Kifle D and Fassile A. 2011a. Characterization of Ethiopian Chickpea (*Cicer aritinum* L) germplasm accessions for response to infestation by Adzuki bean beetle (*Callosobruchus chinensis*L) I. Performance evaluation. *Ethiop. J. Agric. Sci.*, **21**:41-65.

Gemechu K, Endashaw B, Emana G, Imtiaz M, Kifle D and Fassile A (2011b) Characterization of Ethiopian Chickpea (*Cicer aritinum* L) germplasm accessions for response to infestation by Adzuki

bean beetle (*Callosobruchus chinensis*L) II. Phenotypic diversity. *Ethiop. J. Agric. Sci.* **21**:66-83.
Gemechu K, Endashaw B, Imtiaz M, Emana G, Kifle D and Fassile A (2011c) Breeding chickpea (*C. arietinum* [Fabaceae]) for better seed quality inadvertently increased susceptibility to Adzuki bean beetle (*Callosobruchus chinensis* [Coleoptera: Bruchidae]). *International Journal of Tropical Insect Science,* **31**:249-261.
Giri *et al*. (1998) Chickpea defensive proteinase inhibitors can be inactivated by pod borer gut proteinases. *Plant Physiol*.**116**: 393-401.
Lateef SS. 1985. Gram pod borer (*Heliothis armigera*) (Hub) resistance in chickpea. *Agric. Ecosys. Environ*., **14**:95-102.
Legesse D, Senait R, Asnake F and Demissie M (2005) Adoption of chickpea varieties in the central highlands of Ethiopia. *Research Report No.62*. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.
Mekasha C and Geletu B (1999) Farmers‘ perception of the importance and management of chickpea insect pests in Ethiopia. *Nile Valley and Red Sea Regional Program (NVRSRP) Newsletter* **2**, 35-37.
Rahel T, Mekasha C and Ferdu A (2008) Effect of heating on bean bruchid, *Challosobruchus chinensis* L. (Coleoptera: Bruchidae) on chickpea. *Pest Mgt. J. Eth.* **12**:67-76.
Rahel T (2008) Study on the Effect of Solar Heating on *Callosobruchus Chinensis* L. (Coleoptera: Bruchidae) on Chickpea. MSc Thesis, Debub University, Ethiopia.
Shahzad K., AIqbal, SK Khalil and S Khattak.2005. Response of different chickpea, *Cicer arietinum* genotypes to the infestation of pod borer, *Helicoverpa armigera* with relation to trichomes. *Research Journal of Agri. and Biological Sciences,* **1**: 120-124.
Tadele T (2004) Farmers‘ perceptions of sorghum stem-borer and farm management practices in eastern Ethiopia. *Inter. Journal of Pest Management*, **50**, 35-40.
Tadesse *et al*. (1999) Survey for chickpea and lentil virus disease in Ethiopia. *Phytopathol. Mediterr*., **38**: 149-158.

18. Efficacy of Parthenium, *Parthenium hysterophorus* in controlling *Callosobruchus chinensis* in stored chickpea

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This study was undertaken to investigate the effectiveness of Parthenium hysterophorus in controlling Callosobruchus chinensis under laboratory condition. Leaf, inflorescence and stem powders were prepared separately and tested each at four doses i.e. 1%, 2%, 3% and 4% per 50g whole chickpea seeds. The assessment periods were 24, 48, 72 and 96 h. The test insects were reared in glass jar. Pirimiphos-methyl and untreated check were used for comparison. The experiment was arranged in a completely randomized design in three replications. Except stem powder at 1% and 2%, the other treatments caused significant mortality on C. chinensis 24h after application. The highest dose 4% inflorescence, leaf and stem powder caused 76.7, 73.3 and 56.7% mortality. Similarly, the number of F_1 progenies that emerged from Parthenium treated chickpea were significantly less than those emerged from untreated chickpea seeds. However, inhibition of the F_1 progenies emergence by all Parthenium powders was significantly lower than Pirimiphos-methyl that resulted in 100% inhibition. Among the Parthenium parts, leaf powder significantly inhibited adult emergence (83.3%), followed by inflorescence and stem powder (52.8%). Consequently, weight losses in Parthenium treated chickpea were much less than the untreated chickpea. Thus, this resul suggests that Parthenium can used to protect chickpea in storage.

Key words: Botanical control, Parthenium, *C. chinensis*, sesquiterpene lactone

Introduction

Ethiopia is the leading country in Africa for chickpea production, with a share of about 37% in area and 48% in production (http://www.investinethiopia.net browsed on 20 October, 2014). According to CSA (2014) pulses are the second major food crops after cereals both in terms of the area they occupy and volume of production. Moreover, the pulses are excellent sources of proteins and minerals, having two or more times higher than the amounts found in most cereals (Bhalla *et al.*, 2008). For instance, chickpea contains 38-59% carbohydrates and 25.3-28.9% proteins (Shukla *et al.*, 2007). Furthermore, they play a vital economic role which is related with their capacity to fix atmospheric nitrogen, thereby reducing agricultural cost through a reduction of fertilizer use and decreasing environmental contamination and enrich the soil fertility (Omeozor, 2005).

Callosobruchus chinensis L., which is commonly known as Adzuki bean beetle or pulse beetle, attacks all pulses, but beans and chickpea are significantly affected not only in terms of quantitaty and qualitaty, but also these grains lose their germinating capacity completely as well (Ahmed and Din, 2009; Kumar *et al.*, 2009; Righi-Assia *et al.*, 2010).

Efficient control of stored grain pests has long been the aim of entomologists throughout the World and synthetic chemical pesticides have been used for many years to control stored grain pests (Salem *et al.*, 2007). Even currently, pest control measures in storage rely on the use of synthetic insecticides and fumigants, which is the quickest and surest method of pest control (Shaheen and Khaliq, 2005). However, the persistent use of these insecticides in granaries of small-scale farmers has led to a number of problems, such as killing of non-target species, user hazards, toxic residues in food, development of insecticide resistance in the treated pest, increased cost of application and the destruction of the balance of the ecosystem (Shaheen and Khaliq, 2005; Boateng and Kusi, 2008).

Historical usage of nicotine and pyrethrum has encouraged scientists to focus their attention on alkaloids, flavonoids, terpenoids and other secondary compounds to be used as pest control agents (Rajapakse and Ratnasekera, 2008**)** and are working for the development and establishment of plant based pesticide, usually called as phytopesticide, botanical pesticide, biopesticide or natural pesticides (Verma *et al*., 2006; Tariq *et al*., 2010).

The search for alternative insect pest control methods and materials which are relatively cheaper and less harmful to the user and the environment has therefore become essential (Bekele *et al.,* 1996*;* Rahman and Talukder, 2006; Ani, 2010). Sidewise, over 200 plant species have been reported to have insecticidal properties capable of controlling insects (Obeng-Ofori, 1997). Thus, plant materials with insecticidal properties are one of the most important locally available, biodegradable and inexpensive methods for the biological control of pests providing small-scale farmers with locally available, biodegradable and inexpensive method for the control of pests of stored products.

Parthenium, *Parthenium hysterophorus* L. is an exotic invasive annual weed believed to be introduced to Ethiopia in 1970s and has currently spread to the most part of the country (Taye, 2002).According to Datta and Saxena (2001) all parts of Parthenium including trichomes and pollen contain toxins called sesquiterpene lactones. The major component of these toxins being parthenin and other phenolic acids of caffeic acid, vanillic acid, anisic acid, chlorogenic acid, parahydroxy benzoic acid and p-anisic acid (Kumar *et al*., 2011).

Materials and Methods

Adults of *C. chinensis* L. were cultured at Addis Ababa University, Faculty of Life Science, Insect Science Insectary at the temperature of 30±2 ^{o}C and relative humidity of 65±5 % (Ahmed and Din, 2009). Chickpea seeds (Kabuli type) were kept in an oven at 60 ^{0}C for 4 h to disinfest the seeds from any prior infestation before using them as a substrate for insect rearing (Bekele, 2002). To obtain newly emerged beetles of the same age, 25 pairs of unsexed adult of *C. chinensis* were placed in three 1-litre volume glass jars containing 250g of chickpea seeds each. The jars were covered with nylon mesh to allow ventilation and were held in place with rubber bands to prevent the escape of beetles. The parent bruchids were allowed 6 days in the jars for mating and oviposition and were removed from the jar. Seeds with eggs were kept under laboratory condition until the emergence of F_1 progeny. The insects emerged after four weeks were used in the entire experiments.

Parthenium leaves, succulent stem and inflorescence used for the study were collected from the road-side around Bishoftu town and the identity of the plant was confirmed at the herbarium of Life Science Faculty, Addis Ababa University.

To obtain the fine powder, a significant amount of each plant parts were dried in the open air for as long as one month. After being dried well, the plant parts were crushed to fine powder using mortar and pestle. The resulting powder was passed through a 25-mesh diameter sieve to obtain a fine and uniform dust. The test materials were admixed thoroughly and gently in plastic containers by manual agitation until the materials were evenly distributed among the grains and ensure a homogeneous admixture. The powders were applied at the rates of 1%, 2%, 3% and 4%/ 50 g of grains following the procedure by Ahmed and Din (2009).

Toxicity Assessment bioassay: about 50 g of fresh, intact and disinfested chickpea seeds were weighed and placed in 1L-volume glass jars and were treated with 1%, 2%, 3% and 4% of dried and ground leaf, inflorescence and stem powder of Parthenium. Pirimiphos methyl at the rate of 0.125 g/ 50 g grain dust was also applied as a standard check. In addition, untreated grains were included as a control. After treatment of the seeds, 10 unsexed adult beteels of 0 to 2 days-old were introduced to the treated and untreated seeds in the glass jars. The jars were covered with nylon mesh and held in place with rubber bands. Insects in each jar were sieved and counted after the 2nd, 3rd, 4th and 5th days of introduction and dead bruchids were discarded while alive insects were introduced back to their respective jars. The experiment was designed in a completely randomized design (CRD) in three replications.

Percentage insect mortality was calculated using Abbott formula (Abbott, 1925) cited in Bekele *et al*. (1996) as follows:

$Corrected mortality(\%) = \left(1 - \frac{N_t}{N_c}\right) * 100$, where: N_t= number of insects in treated jars, N_c= number of insects in control jars.

F_1 progeny assessment bioassay: the treated jars were kept for additional five days of oviposition time after mortality assessment. All alive and dead insects were sieved and discarded after ten days of introduction. Insects were counted as dead when they failed to move any part of their body after prodding with fine brush bristle. The treated and control grains were then kept until emergence of F_1 progeny. Then, the number of F_1 progeny produced by the *C. chinensis* was counted. Counting was stopped after 31 days from the days of introduction to avoid overlapping of generation. Percentage reduction in adult emergence or inhibition rate (% IR) was calculated using Tapondjou *et al*. (2002) method as follows:

$Inhibition rate(IR) = \frac{C_n - T_n}{C_n} * 100$, where C_n is the number of newly emerged insects in the untreated (control) jar and T_n is the number of insects in the treated jar.

Weight loss assessment assay: damage assessments were carried out by counting treated and untreated grains. Samples of 100 seeds were taken from treated and untreated grains and the number of damaged (grains with characteristics hole) and undamaged grains were counted and weighed. Percent weight loss of the seeds were calculated using the method adapted by Dawit and Bekele (2010).

$WeightLoss(\%) = \frac{[(U_a * N) - (U + D)] * 100}{U_a + N}$, where U= weight of undamaged fraction in the sample; N= total number of grains in the sample; U_a= average weight of one undamaged grain and D = weight of damaged fraction in the sample. The assessment was carried three times for each treatment.

Germination test assay: for seed germination test, 100-seed samples were taken at random from each replication of all the treatments and pirimiphos-methyl treated seeds. The seeds were placed in Petri dishes containing moistened filter paper (Whatman No. 1) and arranged in a CRD in three replications. Healthy untreated seeds were used as a control. The number of emerged seedlings from each Petri dish were counted and recorded after 7 days. The percent germination was computed according to Ogendo *et al*. (2004) as follows:

$ViabilityIndex(\%) = \frac{NG}{TG} * 100$, where NG = number of seeds germinated and TG = total number of seeds tested in each dish.

Results

Mortality of *C. chinensis* caused by stem powder at 1% and 2% was not statistically significant 24h after treatment application, whereas all the other powder treatments caused significantly ($P<0.05$) high mortality within the same period of exposure time. It was observed that toxicity of the Parthenium increased with increase in dosage and exposure time. Besides, inflorescence powder caused the highest mortality followed by leaf powder and the stem powder, which suggests that the concentration of the toxic element responsible for the mortality of the beetle is uniform through the plant.

All the Pathenium powders significantly ($P<0.05$) reduced the number of F_1 progenies emerged compared with the untreated chickpea seeds. However, the number of F_1 progenies that emerged from Parthenium treated chickpea was significantly ($P<0.05$) greater ower than F1 progenies from Pirimiphos-methyl treated chikpea, which cause 100% inhibition. The highest percent inhibition in adult emergence was observed on leaf powder treated Chickpea seeds (83.33%), where as the lowest was observed in stem powder (52.78%). The Parthenium powder admixtures reduced significantly ($P<0.05$) weight loss of chickpea seed compared with the untreated check. The highest percentage of grain weight loss was recorded on untreated chickpea and was followed by stem powder treatment at 1%. On the other hand, there was no weight loss on grains treated with Pirimiphos-methyl.

Treating chickpea seed with Parthenium had no any effect on seed germination. The highest germination (96.7%) was recorded on chickpea seeds treated with *P. hysterophorus* stem powder at the rate of 2%/ 50 g of grain and the least (86.7%) on inflorescence powder at 4%/50g of grain.

The results of the present laboratory study demonstrated that different parts of Parthenium had mortality effect on *C.*

chinensis. Also it was observed that mortality of adult bruchids was directly related to application dosages and the time of exposure i.e. high dosage and longer exposure periods were required to achieve appreciable control of *C. chinensis*. A dose-dependent toxicity effects on a range of species have been reported by many workers (Pandey, 1994; Paudel *et al.,* 2009). Kumar *et al*. (2011) has also illustrated that diethyl ether Parthenium leaf extract was most effective in repelling as well as reducing fecundity and causing egg mortality in *Aedes aegypti.* The benzene extracts has comparable effect as the diethyl ether extract.

Furthermore, Wabale and Kharde (2010) reported that an extract of Parthenium damages the life cycle of sugar cane woolly aphid (*Ceratovacuna Lanigera* Zehntner.). Similarly, Roth *et al.* (2008) confirmed that the water extract of Parthenium tremendously reduced the number of *Lipaphis erysimi,* one of the most important pests of *Brassica juncea*, may be due to the effect of phenolic acids.

Conclusions and Recommendation

Parthenium hysterophorus parts had showed insecticidal property against *Callosobruchus chinensis*. However, the distributions of the secondary metabolite vary on its different parts. Inflorescence powder was found to be the more toxic followed by leaf and the least was stem powder at their highest doses and longer exposure time. Thus, after 96h post treatment inflorescence, leaf and stem powders at 4%/50g grain caused 76.7, 73.3 and 56.7% mortality, which shows that the more the exposure period, the more effect on the target insect. Based on the result obtained, it was possible to conclude that all parts of *Pathenium* contain toxic secondary metabolite that distributed unevenly and act against *C. chinensis*. Thus, the use of *Parthenium* part‘s powder needs to be encouraged for use at household level and further work need to be done on other parameters. Besides, the following points of recommendation may be indicated from the current study:

- The potential use of *P. hysterophorus* parts powder for protection of legumes in the lab was promising. However, further work should be made in practical storage situations for related pests and legumes.
- Even though the powders were effective in controlling the pest, further investigation should be done on the quality of agricultural products treated (for example, color, flavor and odor etc.).
- Much work needs to be done to develop effective formulations, by isolating parthenin and its derivates which can be commercialized as biopesticide.
- Furthermore, studies should be conducted on possibility to combine *Parthenium* part‘s powder with other pest management techniques.

References

Ahmed, S. and Din, N. 2009. Leaf Powders of basil (*Ocimum basilicum* L.), lantana (*Lantana camara* L.) and gardenia (*Gardenia jasminoides* Ellis) affect biology of *Callosobruchus chinensis* L. (Coleoptera Bruchidae). *Pak. Entomol*. **31**: 5-9.

Ani, D. 2010. Screening of some Biopesticides for the control of *Callosobruchus chinensis* in Stored Black Beans (*Vigna mungo*) in Imo State. *J. Amer. Sci.* **6**:186-188.

Bekele J, AJ., Ofori, D.O. and Hassanali, A. 1996. Evaluation of *Ocimum suave* (Willd) as a source of repellents, toxicants and protectants in storage against three stored product insect pests. *Inter. J. Pest Mgt.* **42**: 139-142.

Bekele , J. 2002. Evaluation of the toxicity potential of *Milletia feruuginea* (Hochest) Baker against *Sitiphilus zeamais* (Motsch.). *Inter. J. Pest Mgt*. **48**:29-32.

Bhalla, S., Gupta, K., Lal, B. and Kupar, M. 2008. Efficacy of various non-chemicals methods against pulse beetle, *Callosobruchus maculatus* (Fab). *Diver. Cro. Prot*. **41**:12-15.

Boateng, B. and Kusi, F. 2008. Toxicity of *Jatropha* Seed Oil to *Callosobruchus maculates* (Coleoptera: Bruchidae) and its Parasitoid, *Dinarmus basali* (Hymenoptera: Pteromalidae). *J. Appl. Sci. Res.* **4**: 945-951.

CSA (Central Statistical Authority). 2014. Crop Production Forecast Sample Survey, 2013/14 (2006 E.C.). *Stat. Bull*., P.12.

Datta, S. and Saxena, D. 2001. Pesticidal properties of parthenin from *Parthenium hysterophorus* andrelated compounds. *Pest Manag. Sci*. **57**: 95-101.

Dawit K & Bekele J. 2010. Evaluation of Orange Peel *Citrus Sinensis* (L) as a Source of Repellent,Toxicant and Protectant against *Zabrotes subfasciatus* (Coleoptera: Bruchidae). MEJS, **2**: 61-75.

Kumar *et al*. (2009) Use of essential oil from *Mentha arvensis* L. to control storage moulds and insects in stored chickpea. *J. Sci. Food Agric.* **89**: 2643–2649.

Kumar S, Singh A, Nair G, Batra S, Seth A,Wahab N, and Warikoo, R (2011) Impact of *Parthenium hysterophorus* leaf extracts on the fecundity, fertility and behavioural response of *Aedes aegypti* L. *Parasitol. Res.* DOI 10.1007/s00436-010-2126-1.

Obeng-Ofori D. 1997. Survey of indigenous plants as sources of feeding deterrents repellents, toxicants, and protectants in storage against stored product pest. NARP CSIR. Accra, Ghana, pp.6.

Ogendo, J., Deng, A., Belmain, S., Walker, D. and Musandu, A. 2004. Effect of insecticidal plant materials, *Lactana camara* L. and *Tephrosia vogelii* Hook, on the quality parameters of stored maize grains. *J. Food Technol. Afri*. **9**:29-36.

Omeozor, O. 2005. Effect of the Infestation of *Callosobruchus maculatus* (Fab.) on the weight loss of stored cowpea (*Vigna unguiculata* (L.) Walp). *J.Appl. Sci. Environ Mgt.* **9**:169-172.

Pandey DK (1994) Inhibition of salvinia (*Salvinia molesta* Mitchell) by Parthenium (*Parthenium hysterophorus* L.). I. Effect of leaf residue and allelochemicals. *J. Chem. Ecol.,* **20**: 3111-3122.

Paudel,V. Gupta, V. and Agarwal, V. 2009. Effect of fiffusates of *Parthenium hysterophorous* L. on seed germination of *Raphanus sativus* L. *Scient. World.* **7**: 29-32.

Rahman, A. and Talukder, F. 2006. Bioefficacy of some plant derivatives that protect grain against the pulse beetle, *Callosobruchus maculatus*. *J. Ins. Sci*. **6**:1-10.

Righi-Assia, A., Khelil, M., Medjdoub-Bensaad, F. and Righi, K. 2010. Efficacy of oils and powders of some medicinal plants in biological control of the pea weevil (*Callosobruchus chinensis* L.) *Afr. J. Agri. Res.* **5**: 1474-1481.

Roth, I., Wiesner, M., Blievernicht, A., Buettner, C., Tessema, T., Goswami, A., Mewis,I. and Christian. 2008. Insecticidal Effects of *Parthenium hysterophorus* Extracts Rich Terpenoids and Phenolic Acids. [Abstract].

Salem, S. Abou-Ela, M., Matter and El-Kholy, M. 2007. Entomocidal effect of *Brassica napus* extracts on two store pests, *Sitophilus oryzae* (L.) and *Rhyzopertha dominica* (Fab.) (Coleoptera). *J. Appl. Sci. Res.*, **3**:317-322.

Shaheen and Khaliq .2005. Management of pulse beetle, C*allosobruchus chinensis* L. (Coleoptera: Bruchidae) in stored chickpea using red soil powder, ashes, and turpentine oil. *Pak. Entomol*. **27**: 19-24.

Shukla R, Srivastava B, Kumar R, and Dubey N (2007) Potential of some botanical powders in reducing infestation of chickpea by *C. chinensis* L. (Coleoptera: Bruchidae). *J.Agric. Technol.* **3**:11-19.

Tapondjou, L., Adlerb, C., Boudaa, H. and Fontemc, D. 2002. Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post-harvest grain protectants against six-stored product beetles. *J. Stored Prod. Res*. **38**: 395-402.

Tariq, M., Naqvi, S., Choudhary, M. and Abbas, A. 2010. Importance and Implementation of essential oil of Pakistanian *Acorus calamus* (L), as a biopesticide. *Pak. J. Bot*., **42**: 2043-2050.

Taye T (2002) Investigation of pathogens for biological control of Parthenium (*Parthenium hysterophorus* L.) in Ethiopia. Doctoral Thesis. Humboldt University of Berlin, Germany, pp. 152.

Verma, P., Subburaju and Balakrishnan, N. 2006. Larvicidal activity of *Artemisia nilagirica* (Clarke) Pamp. and *Ocimum sanctum* Linn. – A preliminary study. *J. Nat. Remed.* **6**: 157-161.

Wabale, A. and Kharde, M. 2010. Bioefficacy of Plant Extracts against Sugarcane Woolly Aphid (*Ceratovacuna lanigera* Zehntner.) *Asian J. Exp. Biol. Sci*. **1**:592-595.

Chapter IV. Gender, Socioeconomics & Research Extension

19. Gender in chickpea research and development of Ethiopia: achievements, challenges and future direction

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The role of women in chickpea production and marketing is identified as differently between male headed household and female headed household provided that the household resource base and other factors. Both husband (men) and the wives (women) involve in land preparation, planting, weeding, fertilizer application, irrigation, harvesting, transporting and threshing. However, women play a great role in weeding, harvesting, transporting and threshing. Even though women also involve in marketing of agricultural products, they may not equally make a decision to sell and control the income generated from the sale. As available information indicates, from the total households 10% of women headed households benefited from improved chickpea technologies and they are more than 50% among the total women headed household. Women farmers also engaged in chickpea production for seed under informal seed production system. Women in most instances face limited resources, and other social, and institutional challenges to adopt chickpea technologies. As seen from labor availability, cost of external input, soil fertility, land shortage, nutrition and climate risk and change, it is strategic to address women farmers through model innovative value chain improvement programs.

Key words: Gender, chickpea technologies**,** women-headed households

Introduction

Women traditionally have played, and remain to play an important role in agricultural production in developing countries including Ethiopia. They produce between 60 to 80% of the food in most developing countries and half of the world‘s food production (Ashby *et al.*, 2008). According to the Food and Agricultural Organization (FAO) estimates women are the mainstay of small scale agriculture and make up on average 43% of the agricultural labour force globally and in developing countries (FAO, 2011).

Despite women play an important role in agriculture, particularly in Africa, this role often goes unrecognized due to perception bias (Cohen and Lemma, 2011). The absence of recognition of the role of women due to perception bias in agriculture constitutes a serious problem that tends the agricultural services are needed is biased toward men, too (EEA/EEPRI, 2006). Along with the perception bias towards men, the existence of little research on gender roles which often obscures intra-household gender relations and roles crucial factors in determining access to, and control over, livelihood opportunities (Grace, 2004).

Women and men farmers have different characteristic in terms of access to and control over, livelihood opportunities. Besides, women face more severe constraints than men in access to productive resources on account of this, in part agricultural sector in developing countries is underperforming (FAO, 2011). Gender specific constraints that women face in agricultural sector includes inadequate access to and control over land, poorer quality and insecure tenure, low level of utilization of seeds, fertilizers, pest control measures, less education and less access to extension services, low level of production assets and livestock ownership. These constraints have a direct effect on women‘s agricultural technology adoption as readily as men do. As per World Bank observation, women are underperformer in agricultural production on account of rapid advances in agricultural technology have often bypassed women farmers and reduce their productivity (World Bank, 1994).

Likewise, in other developing countries, agricultural sector in Ethiopia is characterized by male dominated research and development system due to the fact that perception bias, scanty information on intra-household gender relation, rules and decision making patterns on access to and control over productive resource and technology adoption. As Cohen and Lemma, (2011) informed the perception bias is a serious problem in Ethiopia despite the enactment of gender equality policies. This is surprisingly true in the country where about half of the population (49.5%) is women and one-fourth of (26%) of the Ethiopian households are headed by women of which, more than 80% of them live in rural areas (CSA, 2012).

Since 1993, the government of Ethiopia has assured women of equal right with men in every sphere through the Constitution of Ethiopia, adopted in 1995, and affirmed its commitment to the equitable development of women through National Policy on Women (NPW), drafted in 1993. Besides, in consequence of women equality international frameworks and development goals (MDG3) at large and the enactment of women's policy and commitments at various level, empowerment of women through development interventions and improved agricultural technologies has been started to consider as an essential ingredient for poverty reduction and development effectiveness from recent years. This is, hence, in Ethiopia, the issue of women in the agricultural sector in general and that of in the research system in particular has been increasingly gained greater attention.

On account of this, a large number of women farmers, both women headed and married women growingly participated in the research for development and benefited from the research outcomes. Among the efforts of the research system to benefit women, delivering the improved chickpea technologies to the farmers, including women through a full package of chickpea technology utilization and innovative approach by Zeit Agricultural Research Center (DZARC), through international collaboration with ICRISAT and ICARDA can be mentioned. Through this improved chickpea varieties of Kabuli and Desi with their proper agronomic practices have been demonstrated to the farmers and chickpea seed production by farmers was also promoted as one of the options to fulfilling the national seed demand along with technology promotion and dissemination.

The aim of this paper is, therefore, to highlight achievements, challenges and future prospects of gender in chickpea research and development with a focus of the interventions by DZARC, in collaboration with ICRISAT and ICARDA.

Methodology and approach

The study made use of cases of women farmers and seed producing cooperatives to assess the achievement and challenges of gender aspect in chickpea production and marketing. The case studies were compiled using checklist at the field with selected women and men farmers through direct consultation and observation. The cases were taken purposively from Ada‘a and Akaki taking into account concentrated efforts made at the areas by DZARC, and availability of seed producing cooperatives. The paper is also made use of secondary information from both published and unpublished sources.

Results and discussion

Gender aspect of chickpea production and marketing

Gender division of labor in chickpea production and marketing: gender division of labor is often described as the way work is divided between men and women according to their gender roles and determined by the society's norms and values that prescribe the way agricultural tasks and responsibilities assigned to men, women, boys and girls. For instance, preparing land is men's responsibility, while weeding is women's responsibility. However, women have often been described as playing a ‗triple role' such as productive role, reproductive roles and community management. Moreover, this division of labor can vary considerably depending on the geographical area, culture and time, technical change and other factors.

Women and girls play an important, largely unpaid, role in generating family income. A study in Ethiopia identified as women involve in numerous agricultural tasks including weeding, harvesting, preparing storage containers, managing all aspects of home gardens and poultry raising, transporting farm inputs to the field, and procuring water for household use and some on-farm uses (EEA/EEPRI, 2006). Another source similarly confirmed that in rural Ethiopia, women are intimately involved in all aspects of agricultural production, marketing, food procurement, and household nutrition, but certain tasks are considered culturally inappropriate for women, notably plowing, even though female household heads often do their own plowing (Cohen and Lemma, 2011).

In the study areas, men and women involve in Chickpea production, but women are mainly responsible in weeding, harvesting, threshing, transporting, storing and processing (Figure 1). Similarly a study by Solomon *et al.* (2010) in east and southwest Shewa zone land preparation, planting, fertilizer application and irrigation are often done by men, whereas women play a great role in weeding, harvesting, transporting and threshing.

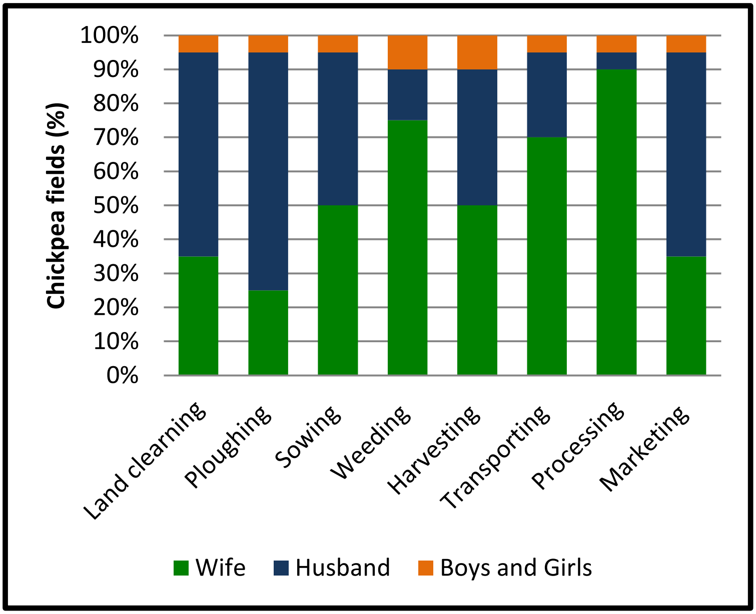

Fig.1: Percentage gender division of labor in chickpea production and marketing (Source: Own case analysis, 2013/14).

However, as per the same source, in most systems, women provide labor for the various tasks related to production, but may or may not control the process of decision-making, particularly over the disposal of produce. Regarding marketing of chickpea, men and women appear to make decisions on the sale of chickpea. The findings of the case analysis of the present study similarly indicated that married women in male headed household have less control over the disposal of the produce. However, there are also households where the husband is inactive to control the farm activity and the disposal of the produce. In this type of household, women become the head of the household to manage the farm activities and control the process of decision making.

In the case of the Female Headed Household (FHH) where the husband passed away or absent due to some reason, the role of boys and girls is considerable as seen from male headed household. Relatively, the boys are more powerful as compared to the girls in making household decisions. Nevertheless, along with increasing expansion of education and youth migration to urban centers, children‘s labor contribution is becoming very scarce in the study areas. This perhaps significantly affects more those female headed households with limited resources.

Women work load and time allocation: the labor contribution of women in rural part of Ethiopia is often valued from the dimension of productive activities from which goods and income are generated. However, women involve in multiple roles in their lives, such as reproductive activities that is maintenance and caring of family, survival of human life (cooking, child bearing, etc.) and community management role, for example, provision and maintenance of scarce resources (road construction, community leadership, water harvesting).

Even though the time allocation studies are scant in Ethiopia, available information has estimated that rural women work in Ethiopia for about 13-17 hours per day with some variability of responsibility from place to place and season to season. The following table presents that the daily activity profile of women in Denkaka, one of the kebeles (lowest administrative unit) of Ada‘a district in East Showa zone. It clearly indicates the total time allocation for different activities during pick chickpea production season. Typical women in the Denkaka kebele spent her significant portion of her workday in production support and household maintenance. Women allocated on average for about 8 hours and 5 hours daily for household maintenance and support during chickpea farming, respectively.

Table 1: Daily activity profile of women during chickpea production season.

Time	Activities
5:00 am	Waking up time
5:30-7:00 am	Breakfast preparation
7:00-7:30 am	Breakfast time
7:00-8:00 am	Milking cows/taking cattle to grazing land/ cleaning cattle pen
8:00-11:00 am	House cleaning/ lunch preparation
11:00-11:30 am	Brining the lunch to the chickpea farm/lunch time
11:30-4:00 pm	Working in chickpea farm field
4:00-4:30 pm	Coming home
4:30- 5:30 pm	Going to grinding mill
5:30-7:00 pm	Dinner preparation
7:00-8:00 pm	Milking cows/ feeding cattle
8:00-10:00 pm	Dinner time/coffee ceremony/ next day preparation for food
10:00-5:00 am	Bed time

Source: Own case analysis, 2014

Achievements and challenges of gender in chickpea technology dissemination

Women participation and representation in chickpea technology dissemination: for recent years, however, women have been increasingly benefited from research outcomes on account of the steps by the research system to improve access to and control over, agricultural technologies to women farmers. Among those who get improved technology directly from the research system, about close to 30% are FHHs, which is regardless of married women indirectly benefited. Women farmers have been benefited from research outcomes to improve the productivity of chickpea among the crop technologies as well.

Research to improve the productivity of chickpea has been conducted for more than 30 years, mainly at Debre Zeit Agricultural Research Center (DZARC) (Shiferaw and Teklewold, 2007). Several new Desi and Kabuli type chickpea varieties have been developed through collaborative research programs involving ICRISAT and ICARDA (Shiferaw *et al*. 2007). Improved chickpea varieties have been demonstrated and initial chickpea seed have also been delivered to the farmers, participating women through a full package technology utilization and innovative approach. The package approach includes using appropriate farm size (1/4 ha), multi stakeholders involvement approach (Innovation Plate), revolving seed loan, clustering of farm fields, timely and iterated training on agronomic practice, support, monitoring and evaluation, input supply and market options, field days, strengthening seed producing cooperatives, and gender. The issues of gender have been well addressed while selecting beneficiaries and training on agronomic practice and quality seed production. Among those who benefited from improved chickpea varieties nationally, 10% are FHHs. This means that more than 50% FHH have been addressed from the total FHHs in chickpea growing areas (Asnake, *et al*. 2012).

Enhancing women to chickpea seed producers: the case of multifaceted role of Denkaka Megertu Farmers' Cooperative: under informal seed production system, there are 8 cooperatives in East Shewa engaging in seed production of different crops including chickpea. The broad objective of the cooperative is to solve limited access of improved seed through creating farmer gate seed access and enhanced farmers to farmers informal seed exchange system. Women involved actively in these seed producing cooperatives. These cooperatives constituted of 4 to 12 % of women farmers.

Denkaka Megertu seed producing cooperative is one of these seed producing cooperatives. The cooperative was established in 2010 and has 95 members (6 women). The cooperative has a multifaceted role, such as, provision of seed to the farmers, training in quality seed production, market for the product, monitoring, support and evaluation. Because of the efforts made to benefit the farmers, including women through the scheme of informal seed production, the members of the cooperative are benefited in many aspects and the intervention creates subsequent demand for new technology.

Reaching specific women's needs: women farmers do have specific needs for improved technologies given that access and ownership of resources particularly land and labor. These constraints related to access and ownership of resources has direct effect on women‘s agricultural technology adoption. Hence provide that different needs, concerns and capabilities, important to focus the demand side helps to prioritize the agricultural technologies that rural women and men want. In this regard, through chickpea promotion and demonstration efforts, women‘s specific needs were acknowledge by DZARC.

Box 1: Create demand for modern mechanized technologies

Case: W/ro Tsehaye Negash

- W/ro Tsehaye Negash is a residence of Denkaka Kebele in Ada'a District of East Showa zone. She is 39 years old widow and a mother of four. Her husband passed away six years ago. Since then she has been fully engaged in farming to support her family. She is now a model farmer, though she is a widow who cannot read and write. Her two boys have helped her on farming after school and the rest two lived at other place for work.
- It was six years earlier that she introduced with improved chickpea varieties such as Arerti and Natoli by Debre Zeit Agricultural Research Center (DZARC). She was provided with training on full package of producing both varieties by DZARC. She discontinued of using Natoli chickpea variety on account of its low productive and marketable.
- She said, Arerti is very productive and grown two years rotation after tef and wheat for improving soil fertility. On average she obtained beyond 40 quintal per ha and has good market value. She learned how to systematically plan to grow chickpea on two hectares of farmland from a total of seven hectares, of which four hectares are renting in. She knew that some farmers can grow up to 48 to 52 quintals of chickpea per hectares. Two quintals chickpea is used from the produce for home consumption.
- W/ro Tsehaye is a member of seed producing cooperative. Afterwards of being the member of the cooperative, she does not face shortage of seed. The cooperative also served her searching of the market for the produce with 300 to 400 Ethiopian Birr additional gains per quintal over selling of grain though there is marketing seasonality.
- W/ro Tsehaye has cherished as one of the model farmers because of her dedication and using different crop technologies including chickpea and knowledge on improved practices. She is now well-regarded women widow by the community as she is able to change her and her family life. She built a house in the town. Finally she informed her wish to have pre and post-harvest mechanized technologies to expand her farm.

Box 2: Women can be good farm manager

Case: W/ro Habu Tesema

- W/ro Habu Tesema is a married woman living in the Denkaka Keble of Ada‘a district. She is 32 years old and a mother of three, one leaved her for work. Though she is a married woman, she is responsible for all farming activities.
- W/ro Habu has 3 hectares of land. She produced improved chickpea for seed purpose and the local one as well (desi chickpea); however, the productivity of improved chickpea is four times that of the local one. After using improved crop varieties, she can be able to rent in an additional 1-2 ha of farmland per crop season and hired additional labor. She is very successful farm manager. She informed that growing chickpea based on rotating with other crops helps to improve soil fertility. However, the benefit may not be valued while producing cereals.
- W/ro Habu is a member of Denkaka Megertu Seed Producing Cooperative. The cooperative has helped her in many aspects such as provision of training on how to produce quality seed in collaborative with Debre Zeit Agricultural Research Center, District Agriculture Office, SG 2000, IPMS of ILRI. The cooperative has distributed basic seed and sometimes pre-basic seed. During farming, the cooperative made adequate follow up to inspect the quality. W/ro Habu noticed that -I have adequate knowledge and skill on how to produce quality seed.”
- However, she informed that she face a pest problem and limited access to appropriate chemical for controlling. The other challenges are low price for grain and lack of appropriate machine to clean the seed for better quality.

Box 3: Men witnessing women‘s capability in Technology validation, multiplication and dissemination

Case: Ato Alemu Tesema

- Ato Alemu Tesema is a farmer in Denkaka kebele of Ada‘a district and chairperson of Denkaka Megertu Seed Producing Cooperative.
- The cooperative mainly engaged in serving the members as a seed source and marketing of the produce with 10% service charge per quintal of seed. The cooperative organized a training program for its member on how to produce a quality seed and other agronomic practices with the support of government and non-government organizations. Sometimes when the members face shortage of seed, the cooperative deliver the seed through a credit scheme repaid in kind with no interest rate. Not only the members that the cooperative help, but also other non-member farmers as well to access improved seed.
- Of 97 members, six of them are women farmers. Ato Alemu ensured that ―There are also women members in our cooperative who perform better than that of men members.” Among other factors, the members are decided based on their willingness, better resource and performance to produce a quality seed. That is the way the number of women farmers‘ small in number as compared to the counterpart men members in the cooperative.
- The members on account of the efforts made have gained knowledge and skill on how to produce quality seed. The livelihood of the members has improved. As a seed producing cooperative, we do have a future plan to deliver seed of improved crops and grains, including chickpea throughout the country and even to the export market. As challenges, we face seed cleaning and other machines for better quality, storehouse, office, lack of good weather road, and market.

Box 4: Labor is a pressing need for women farmers in and around urban centers

Case: W/ro Elifnesh Bermeche

- W/ro Elifnesh Bermeche is a 63 years of married woman. Although her husband lives with her, she is the one who run and control farming activities.
- She cultivates improved crop varieties including chickpea. She says, labor is very limited resource for production. Labor can be hired either annually and based on farm size. She has two annual agricultural workers. Annually, she made a payment based on agreement; 5 qt. of any crop per year or he/she has given a quqarter of a hectare to produce whatever he likes. During the pick season, for instance harvesting, she will pay up to 400 ETB per quqarter of a hectare
- Most of the time, the agricultural workers during a pick harvest time have been coming from Gonder area, and some from Wollo, Jiru, Selale, Fiche areas. She says, the climatic change along with shortage of labor is increasingly challenging the crop production in general and that of chickpea in particular.

Box 5: Test new chickpea crops with women farmers

Case: W/ro Temegnush Dhabi

- W/ro Temegnush Dhabi, a widow, has been farming for 26 years in East Shewa, central Ethiopia. Growing new chickpea varieties with researchers from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Ethiopian Institute of Agricultural Research (EIAR) has led to a dramatic increase in her yields.
- ‗I would never have thought chickpeas could bring me such high returns,' said Temegnush. ‗From 1.5 hectares I harvested 42 bags [about four tones] of grain.' She has turned part of her house into a store, where she sells her grain
- Temegnush said: ‗the high yields and market value of the chickpea last season meant I could buy a second pair of oxen.' She adds that she can now send all her six children to school. 'I'm no longer seen as a poor widow but a successful farmer'. The project involves working with local partners. Tsigeredaa Negesu is the local government extension worker who has been supporting Temegnush to boost her production and improve farm practices. In addition, EIAR has been helping train farmers to become seed producers of these high-yielding varieties.

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Aba Samuel Monastery: *"Aba Samuel Andnet Gedam"* is one of the monasteries under the authority of Ethiopian Orthodox Church. It is located for about 34 km from Addis Ababa near by the former Akaki Beseka town, now under the Akaki Kaliti sub city. Under the monastery, there are 10 women monks living together under the Ethiopian Orthodox religious order for prayer and contemplation. In addition to this, there is also an obligation to work productive activities and to care the poor and needy. This is called obligation of monasticism. Most of the monks in the monastery have an obligation to support themselves and others. During their daily life, they are ordered to attend communal worship if she is an individual monk, engaged in hard manual work like agriculture, and private prayer and spiritual study. Accordingly, the monks in ―Aba Samuel Monastery" have engaged in small scale garmenting to produce clothes for spiritual purpose and agriculture activities like cultivation of crops and keeping livestock.

Major challenges

The below mentioned were the major challenges that the farmers frequently reported in ranking order. Perhaps, each of the following factors affect both men and women farmers, but women farmers are more constricted than men farmers because of so many gender related factors to mention women have not adequate resource at the household to hire labour, adopt new technology, adapt risk and climate change, purchase adequate processing equipment for best quality and premium price, and limited capability to buy important pesticides and other inputs.

- Absence of labour for agricultural work and change of role in the family,
- Lack of adequate labour and time saving pre and post-harvest technologies,
- Climate change and risk (rainfall), tends to challenge more women farmers,
- Poor marketing system and price instability,
- Pest (cut worms) and inaccessibility of proper pesticide by farmers,
- Limited effort on research and development of chickpea recipes and nutrition

Box 6: Chickpea seed multiplication

Case: Emahoy Mebatsion

- Emahoy Mebatsion is a woman monk who is a member of Monastery named ―*Aba Samuel Andnet Gedam*".
- Emahoy Mebatsion said that ―it was before three years that they have received improved crop varieties such as tef, wheat, lentil and chickpea from DZARC." We do not have our own farm land in the monastery to cultivate. However, we have rented in from the farmers who are living near by the monastery.
- Emahoy Mebatsion noticed that all the monks, and the spiritual students are involved in different activities of cultivation mainly weeding, harvesting, threshing and storing. Plowing is mostly done by hiring labor outside the monastery. The cost of labor is 400 to 500 Ethiopian Birr per month. We are exemplary to the surrounding farmers on producing quality seed.
- From the sale of our agricultural produce we brought up eight orphan children and cover living expense of six spiritual students. The orphans are attending their education in the nearby primary school.

Lessons and future direction

Involving women in the chickpea technology dissemination program have brought significant change on the livelihood of women farmers. Intra-household gender relation and role of the rule and decision making on the whole of farm and household management and adoption of new technology is also partly changed due to introduction of new technologies. Due to the interventions, the role of women has been changing into chickpea seed grower which induces better livelihood impact. As part, it was recognized in the study area the introduction of improved and adoption of chickpea technology to women farmers to promote the role of women farmers in commercialization. Other than this, it is realized that growing chickpea has relative advantage for women over growing other crops. In case of the study site, women farmers have preferred chickpea, lentil, tef and wheat in ascending order. This is largely because of low cost production to cultivate chickpea as compared to other crops. This is the fundamental issue that makes chickpea is more responsive to women farmers provided that their resource base and limited ability to afford the production cost. The following are major benefit that the women farmers got form the intervention.

- ***Productivity and income***: women have been be able to increase productivity (12 qt to 40 qt per ha) and earn more income for the household so that rent in additional farm land (expansion of farmland), achieved food and nutrition security, engaged in commercial farming;
- ***Asset building***: women have been able to build asset both in physical and live assets, and furnish the house with quality stuff. Investment in children: Cover school fees for children. Extra labor: Hire extra labor for farming, especially during plowing, trashing and harvesting. Source of seed: women play key roles in chickpea seed production and serve as a source within informal seed system. Further emphasis should be given to scale up best practices to reach a larger number of women farmers for better impact through improved chickpea technologies;
- ***Crop calendar***: women have a systematic crop calendar to improve soil fertility based crop rotation. Planning and implementation of interventions should take the resource base, available time and specific needs and problems of women into account; Understanding of the time use of different household members is very essential and helpful to plan field visits, demonstrations, trainings, field days etc.
- ***Demand for new technologies***: demand is created for advanced labor and time saving technologies. Research and development should give greater attention for labor and time

saving pre and post-harvest mechanized technologies. Attention should be given for chickpea recipes and nutrition aspects specific to women and youth. Address the youth through innovative approaches in value chain development to create better employment opportunities in pre-urban and urban areas.

- ***Knowledge and skill***: efforts have been so far enhance women's knowledge and skill to produce quality seed. Quality is the driver of better price in chickpea farming. Hence, mechanism should be devised to maintain better quality and premium price for seed producing farmers including women. Iterative training, close monitoring and support for women farmers is also needed on seed production and processing for steady progress.

References

Ashby *et al*. (2008) Investing in Women as Drivers of Agricultural Growth. The World Development Report

Asnake F, Million E, Tebkew D, Sherif A, and Sitotaw F (2010) Best Production management practices and application in chickpea

CSA (Central Statistical Agency) and ICF International). 2012. Ethiopia Demographic and Health Survey 2011. Addis Ababa, Ethiopia and Calverton, Maryland, USA: *Central Statistical Agency and ICF International.*

Cohen, M.J. and Lemma, M. 2011. Agricultural Extension Services and Gender Equality. An Institutional Analysis of Four Districts in Ethiopia. International Food Policy Research Institute (IFPRI), Ethiopia Strategy Support Program II (ESSP II). ESSP II Working Paper 28, August 2011.

EEA/EEPRI (Ethiopian Economic Association/Ethiopian Economic Policy Research Institute). 2006. Evaluation of the Ethiopian Agricultural Extension with Particular Emphasis on the Participatory Demonstration and Training Extension System (PADETES)." EEA/EEPRI, Addis Ababa.

FAO (Food and Agriculture). 2011. Gender in Agriculture: Sourcebook. TheWorld Bank, Food and Agriculture

Organization, and International Fund for Agricultural Development.
Grace, J. 2004. Gender Roles in Agriculture. Case studies of five villages in northern Afghanistan. The Afghanistan Research and Evaluation Unit (AREU). European Commission (EC).
Shiferaw B, and Teklewold H. 2007. Structure and functioning of chickpea markets in Ethiopia: Evidence based on analyses of value chains linking smallholders and markets. Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project Working Paper 6. ILRI (International Livestock Research Institute), Nairobi, Kenya. 63 pp.
Shiferaw B, Jones R, Silim S, Teklewold H and Gwata E. 2007. Analysis of production costs, market opportunities and competitiveness of Desi and Kabuli chickpeas in Ethiopia. IPMS Working Paper 3. ILRI, Addis Ababa, Ethiopia. 48 pp.
Solomon Asfaw, Bekele Shiferaw, Franklin Simtowe, F. Muricho1, G. and Setotaw Ferede. 2010. Socio-economic Assessment of Legume Production, Farmer Technology Choice, Market Linkages, Institutions and Poverty in Rural Ethiopia. Report on joint intervention by ICRISAT, CIMMYT, and (EIAR), July 2010.
World Bank. 1994. Rural Women in the Sahel and their Access to Agricultural Extension: Overview of Five Country Studies. Washington, D.C.

20. Review of Chickpea Research Extension in Ethiopia

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Since the introduction of the technology transfer model, the Research and Development arena in Ethiopia has seen a number of shifts. Over the years the research and development system has been testing, adapting and adopting a number of concepts and procedures to make the extension approach more relevant, effective and efficient. Knowledge management can play a pivotal role in enhancing agricultural productivity and addressing the problem of food security. If properly managed, it enables appropriate knowledge and information to reach knowledge intermediaries and smallholder farmers in a timely manner. Such delivery of knowledge and information undoubtedly minimizes the risk and uncertainty that smallholder farmers face from production to marketing of their produce. But, to effectively engage in agricultural knowledge management, adequate mechanisms are needed for generating, capturing and disseminating knowledge and information through the use of effective processes and institutional arrangements. A shift is needed to a multidisciplinary based approach together with a change from top-down extension model to a participatory approach to technology assessment and adoption. This paper presents the review of the conventional or public extension approach, its strengths and constraints and provides suggestions of an innovative best fit solution in chickpea research extension.

Key words: Knowledge management, innovation, dissemination

Introduction

Ethiopia is one of the largest countries in Africa, both in terms of land area (1.14 million square Kms.) and human population estimated at 82 million (CSA,2010). Agriculture is the basis of the Ethiopian economy. It accounts for 40 percent of the GDP, 90 percent of the export revenue and 85 percent of the labor force (FDRE, 2010).

Ethiopian agriculture is virtually small scale, subsistence oriented and mainly dependent on rainfall. About 90 percent of the country‘s agricultural output is generated by subsistence farmers who use traditional tools and farming practices (MoFED, 2008; Dercon *et al*., 2009). Low productivity characterizes the Ethiopian agriculture. The average yield for various crops including chickpea is less than two tons per hectare (Byerlee *et al*., 2007; Dercon *et al*., 2009). The yields of various crops under farmers‘ management are still far lower than what can be obtained under research managed plots. The potential yield of improved varieties of chickpea can reach up to 5.2 t/ha on research managed fields. This is clear indication of the gap which exists between researchers and farmers. The absence of effective linkage between agricultural research and extension system has repeatedly been reported as one of the major reasons for the low productivity of the Ethiopian agriculture. There had been no forum where this linkage problem had not been raised. As a result, it has ever become a concern among policy makers, researchers, development workers and funding organizations (Belay 2002; FDRE, 1999).

Evolution of Agricultural Extension in Ethiopia

Efforts of the Ethiopian government in promoting agricultural development dated back to the 1980s. Later on the establishment of the Ministry of Agriculture (MoA) in 1908 (Belay K (2002) marked the beginning of the activities to modernize Ethiopian agriculture, yet the information that indicates its performance was scarce. The beginning of formal agricultural extension services were linked with the establishment of agricultural institutions in the late 1940s and early 1950s, particularly with the then Alemaya College of Agriculture and Mechanical Arts (1953), now Haramaya

University following the land grant college model of the United States of America where agricultural training, research and extension were fully integrated under one institution (Ayele *et al*., 2003; Gebrekidan *et al.,* 2004).

The responsibility for coordinating the national extension service, which was based at the then college of Agriculture, was later transferred to the MoA in 1963. Since then the Ethiopian agricultural extension has evolved significantly and passed through different political and government episodes as well as policy frameworks that strongly influenced its activities and roles.

The Imperial Period (Pre-1974): During this regime, the country has passed through three successive five year plan periods from 1957-1974. The first five year plan (1957- 1962) put heavy emphasis on a program of rapid industrialization and building of the country's infrastructure. However, the agricultural sector received less priority (Rahmeto, 2004). According to Rahmeto (2004) it was believed, that though without solid evidence, that growth in food production had kept slightly above population growth and was expected to do the same in the plan period without much support. In spite of that, some two or three years later after the launching of the first five year plan, Ethiopia has become a net food importer for the first time in its modern history amounting to 45,000 tons in 1959/60 to meet the growing food demand (Dejene, 1990).

The Second Five Year Plan (1963-1967), continues to favor the process of agricultural modernization. Agriculture once again received less investment when compared to other sectors, but in relative terms, somehow better than the first five year plan. Of the total investment allotted to agriculture in the plan period, the peasant sector received only 10%, commercial agriculture 53% and manpower the rest.

In these two five year plan periods a community development that comprises rural artisan, infrastructure and social welfare activities was adopted as an integrated rural development strategy. However, due to lack of finance and absence of commitment on the part of the government agencies, it was difficult to sustain these development programs (Admassie, 1995). The imperial regime‘s first two five year plans heavily favored large-scale commercial farms for augmenting agricultural production for export in line with the modernization drive that gained currency at the time. Increase in production was expected to be achieved through accelerated investment in large-scale farms pursuant to the dominant line of thinking of the imperial government (EEA, 2004/05). Foreign assistance agencies, particularly the World Bank (IBRD) and the American organizations, advised Ethiopia to give high priority to the agricultural sector and recommended the package approach concentrating on the more promising regions. This idea was also supported by FAO (Nekby 1971). It strongly influenced the third Five Year Plan (1968-1973), which was to a great extent the work of international experts (Stahl 1973). In line with the recommendations, the regime underwent a policy shift, emphasizing the modernization of smallholder agriculture during the third five year plan (1968-1973).

The plan exhibited a marked departure from the previous ones. It recognized the importance of the agricultural sector, and charted out a relatively clear and well articulated agricultural development strategy. The plan argued that ―modernization of peasant subsistence agriculture in all areas of the country simultaneously is hardly feasible". Accordingly, package projects were established in high potential geographical areas (Dejene, 1990). The package approaches have two variants, namely the Comprehensive (CPP) and the Minimum package (MPP)programs focusing on improving agricultural production on farms of individual households and organized groups, respectively, were introduced in some parts of the country.

The first package approach was the comprehensive packages program (1967-1975) which was introduced through bilateral and multilateral assistance. Accordingly, the Chilalo Agricultural Development Unit (CADU) was established in 1967 as the first comprehensive package project with the support of the Swedish International Development Agency (SIDA). The package includes agricultural technology development, dissemination of research results, provision of agricultural inputs, credit and marketing services as well as improvement of infrastructure, vocational education and a promotion of cooperative societies (Stahl, 1974). Agricultural extension service was established to communicate the information from the project to the peasants. New agricultural techniques (mainly fertilizer application) were demonstrated by the extension agents on model farmers‛ plot.

The second and third comprehensive package projects were Wolaita Agricultural Development Unit and Ada District Development Unit established in Wolaita and Ada respectively. The main objectives of the programs comprised: peasants‛ easy access to modern inputs, promotion of better farming practices and farm implements, organize farmers into cooperatives, better access to credit and marketing facilities, expand extension services , building of infrastructure (feeder roads, water points) and environment protection schemes (Rahmeto,2004). The success of the comprehensive packaged program, however, was limited because of its high requirements in terms of modern agricultural inputs and skilled manpower, unfavorable land tenure, and poor infrastructural and market development. Moreover, the comprehensive package projects were found too costly to be replicated in other parts of the country (EEA, 2004/05). As a result, the minimum package programs (MPPs) were initiated in 1970. The MPPs were based upon the concept of concentrating only on few minimum package innovations that were developed and tested on CCPs. Although the MPP I

(1971-1974) concept worked well, it was mainly focused on crop improvement paying little attention to the livestock sub sector. Moreover, the MPPI largely focused on wheat, maize, tef, barley and sorghum neglecting the pulses like chickpea and others. Moreover the MPP too did not entail significant progress due to failure in introducing a more dynamic farming system drawing on the experiences of smallholder farmers. At the end of the imperial era, extension services reached only 16% of the farming population (Rahmeto, 2004).

The Socialist Period (1974-1991): The evolution of the socialist regime in Ethiopia was the result of failures of the imperial regime administration. Immediately upon seizing power, the military regime embarked on the socialist path of development that geared Ethiopia‘s economic and political policies and attendant practices to fit to the principles of this doctrine. Socialist production relations thus prevailed in the workings of the agricultural sectors of the economy. The military regime is famed for introducing radical agrarian changes signified by the Land Reform Act, which was expressed in nationalization and equitable distribution of land. Besides, peasant associations were established as the nuclei of grassroots administration that served as means for controlling grassroots and local communities. Other reforms were introduced for effecting changes in the bid for transforming smallholder agriculture included the establishment of collective and state farms and producers‘ cooperatives, which were given privileged access to improved inputs and technical services, irrigation facilities, productive land, and higher farm-gate prices (EEA,2004/05; Brune,1990). Despite the intensification of collectivization and cooperativization as major features of the agricultural sector and new agrarian relations, production declined during most of the years of the military rule. Critics of the agrarian policies of the military regime argued that discrimination by favoring collectivization to the detriment of smallholder production was the major cause of the steady decline in the performance of the sector (Brune, 1990). Although there is no unequivocal documentary evidence that peasant production is superior to collective forms of agriculture, most studies undertaken so far suggest that the smallholder approach has greater potential for Ethiopia‘s agrarian sector than producer cooperatives and state farms. An International Labor Organization (ILO) mission visiting the country in 1982 concluded that smallholders are more successful at absorbing labor, raising yields and increasing income than the producer cooperatives and state farms are. This is underscored by MOA national survey, which shows that productivity in producer cooperatives was lower than the individual farms in almost all parts of the country in the 1983/84 crop year (MOA, 1985). Similarly a SIDA report based on data taken during 1985 in Bale and Arsi sees no advantage for large scale agriculture, concluding that ―the most efficient method of quickly stimulating agricultural production and increasing marketable grain surplus is by encouraging peasant agriculture" (SIDA 1985).

At the termination of the MPPI in 1974, there was a plan to undertake an expansion of MPPI, under MPPII. Nevertheless, the political and institutional instability did not allow the timely implementation (MOA, 1994). In 1978, the socialist government has passed a legislation to organize smallholder farmers into producer and service cooperatives. After an effort to adopt MPPII to the new socio-economic and political system of the country, MPPII was reinitiated in 1981 and implemented from 1981-1984. The program entered into its second phase (MPPII, 1981-84) with 60% of its total financial expenditure from external loans and grants (Codippily, 1985). Influenced by the political philosophy of the socialist-oriented government, the MPPII was over ambitious in both its objectives and geographical coverage. The MPPII was expected to co-ordinate the various government activities like efforts to organize cooperatives, disseminate modern inputs (chemical fertilizers in particular) and to develop rural infrastructure. It covered 13 administrative regions, 80 awrajas and 440 weredas.

The MPPII was not able to meet its stated objectives as a limited number of development agents (DAs) were forced to cover as wide an area as possible without adequate facilities and logistical support. Moreover, DAs were overburdened with different tasks, such as promoting producers' cooperatives and activities like collecting taxes and loan repayment that are contradictory to the basic tenets of extension (MOA, 1984). The MPPII continued to operate until June 1984, later on it was replaced by the new extension approach, Training and Visit (T&V). The T&V extension system was initiated in 1983 as a pilot project by the World Bank. The approach emphasized on the regular visits to contract farmers by DAs, monthly training of DAs by Subject Matter Specialists (SMSs) and contact of SMs with researchers every fortnight and continuous feedback of farmers problems.

In 1986, Peasant Agricultural Development Project (PADEP) was initiated to promote agricultural development in the dominant smallholder sector. The program was seen as happy medium, as its proposed costs lay between those of comprehensive and minimum package projects. PADEP was supposed to differ from previous rural development projects. It attempted to develop appropriate technologies at the zonal level, to strengthen coordination between research and extension activities. It attempted to develop annual plans for different zones, incorporate livestock development in its programs, and provide extension service at local level, taking service cooperatives (about 1250 households) as a unit of extension work. Moreover, PADEP sought to promote smallholder production and resource conservation by forming stronger institutions. PADEP divided the country into eight agro-ecological zones, which were formed on the basis of similarities in natural resources, climatic conditions, cropping patterns and proximity. Nevertheless, important socio-economic criteria were left out in determining the various PADEP zones, as existing administrative boundaries were taken for granted. During this period, priority was given to large scale farms, but this time it is collectivized producer cooperatives and state farms. According to Yeshitla (2006) ―state farms contributed no more than 4% of the total agricultural output, however, they received more than 82% of the total loans distributed to the agricultural sector, and 69% of the government budget spent on agriculture".

Post 1991: After the change of the government in 1991 the profile of the Ethiopian economy has changed. The government has taken successive macroeconomic and sectoral measures such as the liberalization of the economy including structural adjustment measures of exchange rate of the currency and trade reform.EPRDF's agricultural policy commenced with the introduction of the Agricultural Development-Led Industrialization (ADLI) Strategy in the mid-1990s. The main arguments made to justify this as an overarching economic policy were that improving the performance of smallholder agriculture could lead to increase in framers' income, reduction of poverty, and enhancement of production of industrial raw materials including marketable surplus (Desalegn , 2008). The government strongly believes that ADLI is the fastest way to ensure economic development and recovery. However, critics doubt its efficacy by arguing that ADLI tends to disregard labor productivity by focusing on land productivity despite the fact that the main problem of the Ethiopian agriculture is low labor productivity (Birhanu, 2003). Moreover, ADLI allegedly tends to emphasize the supply side with little concern for demand in the face of low purchasing power of the rural people on the one hand and the small size of the urban population on the other. Hence it is questionable that increased production alone could entail higher farmer income in the absence of adequate demand. Moreover, it is claimed that given its fragmented nature and the small size of per capita land holding, peasant agriculture can‘t shoulder the onus of transforming the performance of agriculture in a manner that could enable it to play pivotal roles in boosting Ethiopia‘s development effort as expected. In spite of the aforementioned constraining factors, however, EPRDF‘s rural development Policy and Strategy (FDRE, 2002) reiterated that the country‘s overall development should be centered on the rural areas where smallholder agriculture is predominant. The justification for this is premised on the rationalization that the overwhelming majority of the country‘s population lives in the rural areas that enjoy comparative advantages in abundant land and labor that can be judicially utilized for ensuring economic growth and sustainable development by offsetting the consequences resulting from scarcity of capital. Agricultural extension services have traditionally been financed and provided entirely by the public sector. Hence, the programs share a significant public investment amounting to over 50 million USD/per budget year. According to Quinones M and T Gebre. 1996), the period after the 1990s is characterized as era of institutional pluralism in the history of extension in Ethiopia. Accordingly, the Sasakwa global 2000 (SG 2000) started its program in 1993 on 160 farmers‘ plot wheat and maize Extension- Management Training Plots (EMTPS). It was reported that some maize farmers had harvested 9.4 tons/ha and the average yield of the demonstration and training plots was 5.1tons/ha and 2.8 tons/ha for maize and wheat, respectively. Even though SG 2000 has enabled to increase yield by three fold more than the traditional practices, there is much greater potential than what has been realized through the EMTPs (Abate, 1997, Gebrekidan *et al*., 2004, Quinones and Gebre, 1996). This made the Ethiopian government and politicians to be committed for supporting agricultural extension. The modified T&V extension approach continued until it was replaced by the Participatory Demonstration and Training System (PADETES) as the national agricultural extension system in Ethiopia in 1995. The T&V extension approach was criticized for: being top down, lacking flexibility, giving priority to state and cooperative farmers, being largely donor driven and low participation of farmers among others. PADETES adopted the merits of past extension approaches of that of the T&V and SG 200 experiences. It also involves a package approach geared towards three different agro-ecologies: reliable moisture, moisture stress and nomadic pastoralist areas. As part of the implementing of the extension strategy, the government also launched, the National Extension Implementation Program (NEIP) in 1994/95. The program was launched for assisting resource poor small scale farmers in the improvement of their productivity through dissemination of research generated information and technologies on major food crops such as tef, maize, wheat and sorghum and giving less attention pulse crops like chickpea and others.

PADETES as name implies recognizes participation of end-users. It allows farmers to participate in the evaluation of the supplied technologies. However, their participation is limited on implementing demonstration activities on their own fields unlike the previous approaches that demonstrated technologies in fenced plots owned by the by MoA and which failed to address the demand of end-users. In a nutshell, the entire body of evidence on agricultural extension revealed that its impact on productivity and poverty alleviation is mixed. Although many farmers seem to have adopted the package promoted by the extension system, up to 70% of the farmers who have tried the package have discontinued its use (Bonger et al. 2004; EEA/EEPRI 2006).

Ayele *et al.,*(2004) also reported that the poor extension services were ranked as the major reason for non adoption of the packages. Moreover, the success of the extension services has traditionally been measured in terms of numeric targets for physical inputs instead of emphasizing on the efficiency and profitability of the inputs.

The Extension service is often the most widely distributed among representatives of the government in the rural areas. Hence, we see both ‗push' and ‗pull' factors: the ‗push' is the temptation for other agencies to use extension because it is the widely distributed government apparatus for contact ith rural communities. The ‗pull' is that agents/ DAs are willing to take on other duties, especially input distribution and tax collection because such tasks increase an extension agents' influence over farmers as well as providing opportunities to extract rent which compensate for low salary. The difficulty of tracing the relationship between extension input and its impact is another generic problem.

In 2000, the government of Ethiopia invested in ATVET centers to train DAs charged with carrying out agricultural extension activities with farm households. By the end of 2008, the program had trained 62,764 DAs with 12% of them being female at diploma level (MoARD, 2009). 45,000 are currently on duty. There are about 8489 FTCs established with 2500 of them reported to be functional. One can say DA recruitment and training have largely succeeded in meeting the numeric target. Given that there are approximately 21.8 million adults (age 15-65 years) who are active in agriculture, it can be estimated that at the time the extension system reaches its goal of 60,000 DAs placed in the field will be roughly 1 DA for every 476 farmers. This would then be one of the strongest extension agents: farmers' ratio in the world. However, the quality and the morale of DAs are in question. In most of the cases it is well observed that they lack confidence on the subject matter and they are even led by model farmers. A sober assessment of the development of extension services from the perspective of small –scale farmers shows a rather negative overall picture. Therefore designing a more participatory approach is essential.

Chickpea Research Extension

Chickpea (*Cicer arietinum* L.) is the third most important cool-season food legume crop, next to faba bean and field pea in Ethiopia. There are two commercial classes of chickpea: Desi and Kabuli. The Desi type has a long history of production in the country.

Chickpea covers about 239,512 hectares of land with a national yield of 1.7t/ha (CSA, 2011/12) which is very low when compared to the yield potential on the research plot and that of farmers‘ in the intervention areas. Some farmers in the intervention areas produce up to 5 tones. This is quite a huge gap. It needs to bridge the gap.

Ethiopia has about 76% share of chickpea production in Africa. The national research system has generated 22 varieties through collaborative research work involving ICRISAT and ICARDA. In spite of the availability of several improved chickpea technologies generated by the research system over the last five decades, adoption of these technologies by the small-holder farmers has been very low.

Chickpea extension was started in 1962 with the release of the first chickpea variety named DZ 10-4 from the Ethiopian collection through mass selection. It is small-seeded Kabuli type Chickpea.

Although some dissemination activities were made to the highlands of Ethiopia, because of the farmers‘ preference of the desi type adoption was very minimal. Subsequently many desi varieties have been released from both local and ICRISAT materials without taking into consideration the demand of small scale farmers. Despite the efforts to disseminate these varieties, adoption once again was poor. In 1991 varieties like Arerti and Shasho were released from ICARDA/ICRISAT and ICRISAT materials, respectively. Variety Arerti came with a merit of solving the extremely aggressive disease of ascochyta blight. Even though, there were some dissemination activities here and there adoption was not as expected till 2005. In Ada district farmers were reluctant to adopt the kabuli type chickpea for fear of theft (green pods) by the passers-by unlike farmers in Akaki and Gimbichu. Hence adoption in Ada was insignificant compared to others (table1).

Table 1. Area coverage of chickpea in some selected weredas

Chickpea coverage	Wereda					
	Ada		Akaki		Gimbichu	
	2005/6	2006/7	2005/6	2006/7	2005/6	2006/7
Total Chickpea area in ha	4346	4938	6070	5963	2008	1984
Improved chickpea area (%)	4.2	2.8	85	85	73.7	67.5
Local Chickpea area	95.8	97.2	15	15	26.3	32.5

The conventional approach to agricultural research emphasized developing new technologies mainly through on-station research that were then supposed to reach farmers through the public sector extension system. As a response to this linear top down approach an innovative multi- stakeholder approach in which several parties contribute relevant insights was designed. This was the turning point.

Debre Zeit Agricultural Research Center has spearheaded a shift in approach to agricultural research for development in recent years towards broader partnership in an innovation systems and value chains. Details of the fundamental features of the new extension approach is found in Kebebew *et al*. (2011).
As indicated in table 2 below, regular training of trainers, farmers, research technicians and agricultural experts at various levels, development agents and other stakeholders played an important role in the success of the innovation system. The training was given every year and season in order to create

awareness and understanding, and to share experiences on improved seed production, chickpea husbandry, chickpea seed system and improved seed production, chickpea value chains especially on the marketing aspects and chickpea extension methods and approaches.Accordingly, a total of 11,241 farmers,2,329 development agents, 377 research technicians, 176 researchers,581 experts from the bureau of agriculture at various levels and 1309 experts from unions and other stakeholders were given training on an integrated chickpea technology and production from 2006 to 2013. The participants represent target districts or weredas, Zones and regions in the country.

Table 2. Number of farmers and other stakeholders trained on chickpea technology and production.

Type of trainees	Number of trained personnel								Total
	2006	2007	2008	2009	2010	2011	2012	2013	
Researchers	8	15	12	17	22	27	33	42	176
Research technicians	22	35	45	55	63	73	45	39	377
Farmers	250	470	603	934	1785	2175	2000	3024	11241
Agr. experts	35	41	33	63	88	83	121	117	581
Development agents	120	169	210	336	375	480	354	285	2329
Unions	5	10	15	28	20	13	12	13	116
Community seed producers		2	6	10	12	13	14	12	69
Others	35	63	79	153	263	200	185	215	1193
Total	475	805	1003	1596	2628	3064	2764	3747	16082

The number of farmers participated and the area covered through the chickpea technology scaling up activities and demonstrations from 2011-13 are shown in table 3. In the eight years, the number of framers‘ households directly involved in the scaling up was about 24 thousand. During the same period, the area under improved chickpea was increased tremendously, from just 87.5 ha in 2006 to 6000 ha in 2013.

The figures depicted in table 3 do not include the area covered through farmers‘ own saved seeds in the previous scaling up activities, farmer-to-farmer seed exchange, regular extension activities of the Bureau of Agriculture, and seeds obtained from other sources such as NGOs and other stakeholders involved in agricultural development. Moreover, we observed that duringthe 2011/12 main season about 98 percent of the chickpea area in Minjar wereda is covered by the improved varieties of chickpea, predominantly Arerti.

Table 3. Number of farmers participated, area covered and yield obtained from on-farm demonstration and scaling-up of chickpea from 2006 to 2013

Year	Number of farmers participated	Area covered (ha)	Total grain production (ton)	Average grain yield (ton/ha)
2006	350	87.5	262.5	3.0
2007	610	150	525	3.5
2008	855	213.75	748.125	3.5
2009	1200	300	960	3.2
2010	4750	1187.5	3818.75	3.3
2011	5300	1325	4637.5	3.5
2012	5675	1418.75	4540	3.2
2013	5200	1300	4550	3.5
Total	23930	5982	20,041.875	

Conclusions and the way forward

Overall management and the orientation of the conventional extension system must be driven by the farmers‘ needs and priorities. A farmer-driven orientation ensures that the extension system is serving farmers in their areas of highest need and allows for flexibility at the Regional, Zone, wereda and kebele level. The role of women in the farm household income should also be considered in setting extension priorities and intervention areas. Since most extension programs lack well defined objectives and priorities, it is important to develop a clear and meaningful extension program for the country.

Although the main thrust of the extension program is to advance and transform agriculture, a slight shift in emphasis is needed to link farmers to markets in response to the current realities of global competition. Linking farmers to markets is not a new thrust rather it is an emerging and imperative priority. This new thrust requires specialists in marketing and processing. The need of this kind of information requires support from the extension, which is different from the support of extension services provided in the past. Hence extension needs to shift some of its focus from food security to increasing farm income and rural employment. This shows that extension is back on the agenda and going through major transition which calls for a change in some, if not all, of its goals, direction and expertise.

Indeed, knowledge and information systems need to be recognized as a fourth pillar alongside land, labor and capital. Knowledge is increasingly recognized as more important than physical inputs since the former makes inputs productive and explains why some technologies succeed while others fail, even when they have equal access to a particular technology or applied the same amount of inputs.

The number of Development Agents (DAs) in Ethiopia has expanded rapidly, and at the present time, it exceeds 60,000. Although most DAs have the basic technical expertise and theoretical knowledge, they are deficient in specific skills which farmers demand. Most DAs have inadequate technical and business skills, and lack in entrepreneurial mind-sets. Moreover, DAs carry out the extension program from their own perspective while farmers seek to diversify their farming system within specific agro-ecological areas. In general, due to their age, lack of on-farm experience, and their narrow subject matter focus, most DAs lack the practical, hands-on skills and knowledge to enable them work with farmers effectively. Hence DAs require training in key areas such as intensification and diversification of farming systems, agricultural marketing and communication skills. Agricultural extension must go beyond simple technology transfer between extensionists and farmers. Smallholder farmers must be put in a position to use their own know-how, skills, and organizations to recognize problems, potentials and opportunities independently and respond to them appropriately in order to lay the foundations for a future that will ensure their existence. Smallholder farmers frequently possess comprehensive knowledge and a great deal of experience in dealing with locally available resources and how to use the potential of these resources to ensure their existence. But it must be admitted that indigenous knowledge cannot keep pace with increasing complexity and rapid economic, ecological, political and social change and must therefore be revitalized. Any new problems and opportunities such as climate change, increasing population pressure, or global markets for capital, labor and goods can only be tackled to a limited extent with conventional knowledge and skills.

Therefore, a different understanding of smallholder operations and household planning and management is needed in order to shape smallholder strategies in a way that will ensure their existence. Extension that confronts these challenges must increasingly invest in communication between the actors involved, in intense learning processes, and in extension themes that deal with all the important aspects of smallholder farming. The essential task of extension in this respect is to familiarize smallholder farmers with changes in the ecological, economic, economic and social environment they live in. Important information must be conveyed and interconnections must be demonstrated and made comprehensible. Efforts to this end will make it possible for farmers to recognize problems, risks, potentials and opportunities more rapidly, respond to them appropriately, and develop greater self confidence and self-esteem.

In a nut shell, a collaborative arrangement that brings together several organizations working towards technical and social change or organizations that are involved in generating, diffusing and adapting new knowledge in agriculture is a way out to improve and build the capacity of the conventional extension system. The key to success in testing and promoting agricultural technologies now depends on how we conduct the research. A paradigm shift is needed to employ farmers‛ participatory research. Farmer‛s participatory approach is the process of collaboration that organizes greater technology extension and then adding value to it gives an extra-ordinary access to modify technologies. It relies on farmers‛ experimentation and farmers‛ interaction with important market opinion, backstopping and follow-up research.Scientists need to work jointly with farmers to find ways to manage the resources to improve their profitability, food security and sustainability of the environment.

References

Abate, H. 1997. Review of extension systems applied in Ethiopia with special emphasis to the participatory demonstration and training extension system. Rome: Food and Agricultural Organization of the United Nations

Admassie A (1995) Analysis of production efficiency and the use of modern technology in crop production: a study of smallholders in the central highlands of Ethiopia. PhD dissertation, University of Hohenheim.

Ayele G, Kelemework F and Alemu D. 2004. The provision of Rural services and Agricultural productivity in Ethiopia: a characterization, phse I report of 2020 vision network‛s East Africa Regional project," Assessing the impact of policies for

Rural service provision on Agricultural productivity and Food Security ”EARO/IFPRI, Washington, D.C.
Belay K (2002) Constraints to Extension work in Ethiopia: The Insiders‘ view, *South African Journal of Agricultural Extension*, **31**: 63-79.
Birhanu N (2003) Introduction: development options for Ethiopia: ―Rural, Urban or Balanced?” in Berhanu Nega and Befikadu Degefe(eds.), The Role of urbanization in the Socio-Economic Development process, Addis Ababa: Ethiopian Economic Association/ Ethiopian Economic Policy research Institute.
Bonger T, Ayele G, and T Kuma (2004) Agricultural Extension, Adoption and Diffusion in Ethiopia. Ethiopian Development Research Institute (EDRI) Research Report I, Addis Ababa.
Brune S. 1990. The Agricultural sector: structure, Performance and Issues (1974-1988). In Fantu Cheru and Stefan Brune (eds.), Ethiopia: rural development options, London: Zed Books.
Byerlee et al. (2007) Policies to Promote Cereal Intensification in Ethiopia: A Review of Evidence and Experience‘, IFPRI discussion paper. IFPRI, Washington, USA.
CSA (Central Statistical Agency)2012. Agricultural sample Survey, Area and production of major Crops.
Codippily H. 1985. Ethiopia, International financial Flows 1967-83, World Bank, staff working paper, Washington.
Dejene A. 1990. The Evolution of Rural development Policies. In: Bahru *et al*. (eds.), Ethiopia Rural development options, London: Zed Books.
Dercon S, DO Gilligan, J Hoddinott and T Woldehana.2008. The Impact of Roads and Agricultural Extension on Consumption Growth and Pverty in fifteen Ethiopian villages, IFPRI Discussion paper 00840, Washington DC: International Food Policy research Institute.
Desalegn R. 2008. Ethiopia: agricultural Policy review. In Taye Assefa (ed.), Digest of Ethiopia‘s National policies, Strategies and Programs: Addis Ababa: eclipse Printers.
EEA (Ethiopian Economic Association). 2004/05. Report on the Ethiopian Economy, Vol. IV, Addis Ababa: Rohobot Printers.

EEA/EEPRI (Ethiopian Economic Association/Ethiopian Economic Policy Research Institute). 2006. Evaluation of the Ethiopian Agricultural Extension, with particular Emphasis on the Participatory Demonstration and Training Extension System (PADETES)‘, Ethiopian Economic association/Ethiopian Economic policy Research Institute (EEA/EEPRI). Addis Ababa.

FDRE 2002. FRDE‘s Rural Development policies and Strategies, Addis Ababa

Gebrekidane B, S Debela and I Mohamed. 2004. Development and Application of Agricultural Technology in Ethiopia, discussion paper presented on the occasion of the 50th Anniversary of the establishment of Alemaya University.

Kebebew A, Sherif A, Getachew B, Gizaw M, Hailu T and ME Sorrels. 2011. Quncho: the first popular tef variety in Ethiopia. International Journal of Agricultural Sustainability 9(1):25-34.

MOFED (Ministry of finance and Economic Development) 2008. Plan for accelerated and Sustained Development to End Poverty-PASDEP-2005/06-2009/10, Vol. I, Addis Ababa

MOA (Ministry of Agriculture). 1994. Task force for Assessment of Agricultural Extension System, (Amharic version). Addis Ababa.

MOA (Ministry of Agriculture). 1985. General Agricultural Survey, producers Cooperatives Preliminary Report.

MOARD (Ministry of Agriculture and Rural Development). 2009. Data on ATVET colleges graduates. Addis Ababa, Ethiopia: Department of Agricultural Technical and Vocational Training and Education,

Nekby B. 1971. CADU : An Ethiopian Experience in Developing Peasant Farming, Stockholm, Prisma Publisher.

Quinones M and T Gebre. 1996. An Overview of the Sasakawa-Global 2000 Project in Ethiopia. In: Breth S.A. (eds.), Achieving Greater Impact From research Investment in Africa, proceeding of the workshop-Developing African Agriculture, Addis Ababa.

Rahmeto, D. 2004. The agricultural policies of the Imperial Regime: What lessons can we draw? (Unpublished)

Stahl M. 1973. Contradictions in Agricultural Development, A study of three Minimum Package Projects in Southern Ethiopia, Uppsala, Scandinavian Institute of African Studies, Research Report No. 4.

Stahl M. 1974. Ethiopia, Political Contradictions in Agricultural Development, Uppsala.

Yonas Ketsela (2006). Agricultural Plicies: The Role of the National extension program in addressing the problem of food security. In: Kassahun and Demise Fantahun (eds). Rural Development policies, trends, Changes and continuities, Addis Ababa, Ethiopia.

Chapter V. Seed System

21. The Seed Constraint: New approaches for smallholder agriculture in eastern and southern Africa

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Pilot interventions through the Tropical Legumes II (TL-II) Project have shown promise in making new varieties available to farmers who depend on the farmer seed system. These initiatives which includes community seed schemes, seed recovery and seed bank schemes, seed fairs, contracting schemes, small seed packs, etc being promoted under TL-II, are further developed, and linked to participatory research, where farmers are directly involved in variety selection and testing. R&D agencies linked through TL-II implementation are designing and testing demand-driven seed supply strategies, which provide the necessary incentives for farmers to buy seed from the marketplace. The alternative approaches described above are based on two propositions; that different approaches are required for different crops and that we must lay greater emphasis on stimulating seed demand rather than focusing exclusively on seed supply. This report describes the legume seed dissemination strategies used for chickpea in Ethiopia, and groundnut and pigeonpea in Malawi and Tanzania and other TL-II focus countries. Preliminary research results from TL-II baseline studies in all three countries found that there was very limited awareness about improved legume varieties, and that neither public- nor private-sector interventions to produce and market legume seeds had a successful track record in these countries. To overcome these constraints investments have been made in breeder and foundation seed production, and proceeds from seed sales used to re-capitalize seed revolving funds that are then used to support subsequent seed production cycles.

Key words: Smallholder agriculture, community seed schemes and seed bank

Introduction

As a result of the inadequacy of the currently existing seed supply system for legumes in Eastern and Southern Africa, the rate of adoption of improved chickpea, groundnut, and pigeonpea varieties is very low - generally less that 10% of the planted area. Most farmers rely on own-saved seed and access seed of improved varieties either through informal networks or relief seed. These crops, particularly chickpea and groundnut, have high seeding rates and low seed multiplication ratio making the regular use of fresh seed expensive to farmers, and as a result yield levels of these crops remain low.

The lack of access to seed of improved varieties was particularly identified as a key hurdle to the adoption of legumes as farmers were observed recycling seed for many seasons without experiencing significant yield reductions. A baseline survey was conducted in Tanzania, Malawi and Ethiopia to confirm these hypotheses and to establish a baseline scenario for the project sites. Farmers were asked to provide information on sources of seed for the crops they grew including chickpea, groundnut and pigeonpea.

The survey results from all study countries reveal two main seed supply systems for the three target legumes. They are the informal, which are usually non-market based seed supply systems and the quasi-formal, mainly market-based seed supply systems. The informal seed supply sources included own saved seed; gifts from family and friends; farmer-to-farmer seed exchanges and others (e.g. donations by NGOs, government agencies, farmer groups/cooperatives, research demo plots etc.). Across both the target crops and countries, most smallholder producers got seed from informal sources with the use of own-saved seed being the most important source. The inter-country comparisons reveal differences on the magnitude of importance of the different sources. The relative importance of own saved seed in the supply of seed was highest in Tanzania: chickpea (100%), groundnut (93%) and pigeonpea (86%). In Malawi own-saved seed accounted for 63% of groundnut and 71% of pigeonpea seed supply. The share of own-saved seed in the total supply was about 60% for pigeonpea, indicating the increasing importance of market-based channels with the emergence and diffusion of new varieties. The situation in Ethiopia for chickpea in the surveyed districts was different with 54% of the total seed supply coming from own-saved seed, and many farmers accessing new *kabuli* varieties from market-based channels. In general these findings are consistent with earlier expectation that informal seed sources are the most important sources of legume seeds in the surveyed communities. The importance of quasi-formal or market based channels seems to increase with the availability of new farmer-preferred varieties, which creates incentives for the emergence of markets and trade in the supply of seed of improved varieties. The observed low private sector participation in legume seed systems provides a justification for encouraging public support for legume seed production. The high cost of exclusion (low excludability), renders investments in legume seed systems unprofitable discouraging the private sector from investing in legume seed production.

Bottlenecks which the project component set out to solve

The inability of the system to meet the legume seed needs of smallholder farmers was a result of a number of constraints on which the project was developed.

- The public sector has consistently failed to ensure a consistent supply of good quality source seed (breeder and foundation) to guarantee further multiplication of the improved varieties by others.
- The private sector has shown little interest in venturing into chickpea, groundnut, and pigeonpea seed production

and marketing due to limited profitability especially relative to hybrid maize.

- The majority of farmers simply do not know of the existence of improved varieties with the result that there is no effective demand.
- Most often, seed is produced in high potential areas or areas with infrastructure for storage and processing far away from its area of utilization – leading to high costs of seed.

The lack of awareness of improved legume varieties by farmers is one of the key bottlenecks being addressed by the project. Results from the baseline confirm this hypothesis in that most farmers are unaware of improved legume varieties being promoted. In Ethiopia the improved *kabuli* varieties ‗Areti' and ‗Shasho' are known to 43.9% and 48% of the sample respondents respectively, but only 6.4% knew of the more recently introduced variety ‗Chefe' and 25% were aware of ‗Ejere'. In comparison 98% of the sample knew the local *desi* variety.

In Malawi about 74% of the sampled farmers were aware of at least one pigeonpea variety, but awareness of the improved pigeonpea varieties ICP 9145 and ICEAP 00040 was only 20% and 8% respectively. These findings indicate that after almost a decade since the two improved varieties were released, efforts to create awareness among farmers have been disappointing. The situation for groundnut was not that different with Chalimbana, that was developed and released in the 1960's, being the most widely known variety (84%) followed by CG7 that was developed and released in the early-1990's (53%). More recently developed and released varieties including Nsinjiro Baka, Kakoma and Chitala were even less well-known. The main source of information about varieties of both groundnut and pigeonpea was found to be other farmers.

A related bottleneck being addressed is the low adoption of legume technologies by small holder farmers in the three countries of study. In Ethiopia the proportion of farmers who planted improved chickpea was even lower than those who knew about improved *desi* and *kabuli* types. The demand for new varieties is high but limited by lack of seed, information and land constraints. In Malawi the situation was not that different with only 57% of farmers who knew about local pigeonpea varieties actually growing them. For both local and improved varieties there appears to be some dis-adoption as fewer farmers planted the crop in the 2007/08 season than had planted them before.

The levels of adoption from the baseline are about 10% for improved pigeonpea varieties (ICEAP040 and ICPL9145) and about 30% for improved groundnut varieties. While 84% of the sample farmers are aware of ‗Chalimbana‘, only 69% have ever grown the variety but in the 2007/08 season only 49% actually grew the variety. These results tend to suggest that there are a range of factors influencing the decision of farmers on which crops and varieties to plant, and that this is more than about the availability of information and seed, as these patterns are also observed with local as well as improved varieties.

Econometric results on the adoption potential for improved pigeonpea in Malawi indicate that once all farmers are aware of a variety, 45% can be expected to actually adopt it as compared to the 10% who were found to have adopted improved varieties. The findings suggest that there is potential for increasing the adoption of improved pigeonpea once awareness is increased and seed made available.

Reasons for not planting varieties that were known included lack of seed. In Ethiopia the share of farmers who mentioned seed constraints as a reason for not growing the varieties ranged from about 20% for all of the *kabuli* varieties to about 37% for improved *desi* types. In Malawi about 60% of the farmers reported that they lacked seed for some of the groundnut and pigeonpea varieties they knew but never planted. The second major reason – around 20% of farmers - for non-adoption of groundnut and pigeonpea varieties were low yielding, and related to the seed problem is the lack of cash to buy seed reported by about 10% of the respondents.

Approaches tested to overcome bottlenecks

Two broad models of seed system operate in the formal sector. These include:

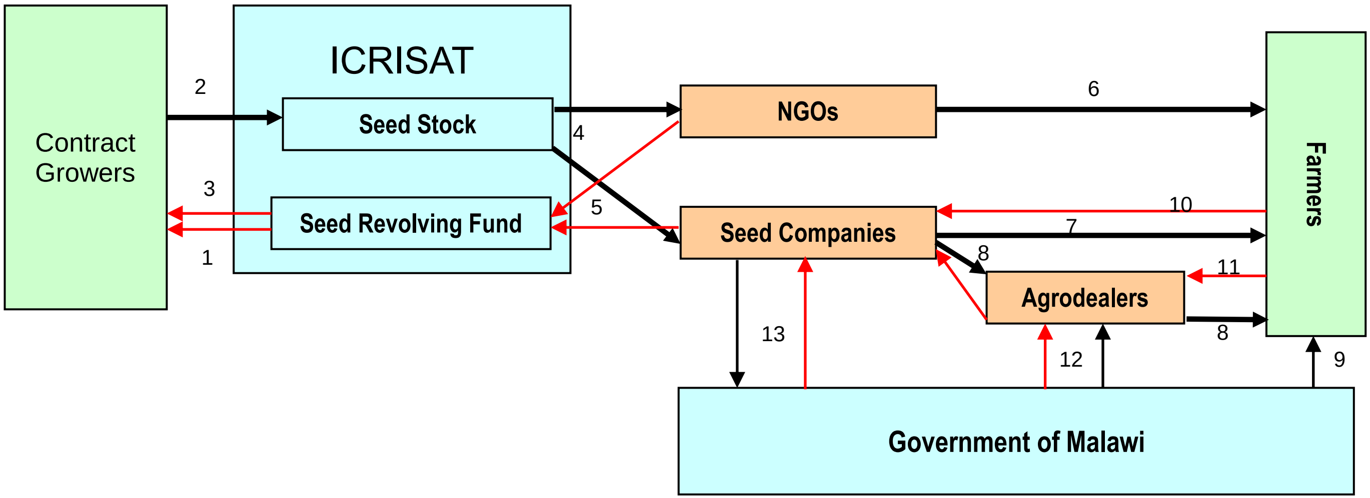
1. State/parastatal Seed Grower Model where researchers provide breeder seed to a parastatal or state agency to multiply on state farms or with contract seed growers,
2. Private Sector Model where researchers provide breeder seed and/or foundation seed to cooperatives and private companies who then undertake certified seed production and marketing.

In eastern and southern Africa neither model has been very effective for the three crops under discussion and the project has utilized a combination of approaches that are described below.

ICRISAT and the national agricultural research systems (NARS) in Ethiopia, Malawi, and Tanzania have been producing high-quality breeder seed of the improved varieties being promoted at their respective research stations using optimum agronomic practices. This seed is then fed into the foundation seed production chain. Project funds are used to purchase breeder seed from the respective research stations, which is then either sold or provided on credit to contract farmers for production of foundation seed. ICRISAT and NARS scientists provide all necessary technical guidance to the contract growers including training courses and regular visits to ensure seed quality. In Malawi a seed revolving fund is then used to purchase seed that has been independently inspected by the national seed service from contract growers and seed loans recovered where this was provided on credit. The seed is then processed, packed and sold to NGO partners running community seed production schemes and in some cases to local seed companies. Proceeds from seed sales are used to replenish the seed revolving fund and a new cycle of seed production undertaken. ICRISAT is working with NARS to establish similar mechanisms with NARS so that funds realized from seed sales can be used for the production of breeder and foundation seed beyond the life of the donor project. The Malawi model is depicted in fig. 1.

The program involves wide-scale promotion of three improved groundnut varieties (CG7 and Nsinjiro in Malawi, and Pendo in Tanzania), two pigeonpea varieties (Kachangu and Mwaiwathu alimi in Malawi Mali and Tumia in Tanzania), and several chickpea varieties in Ethiopia (including Areti, Shasho, Habru, Chefe, Ejere, Teji, Acos dubie, Kutaye and Natoli). Seed marketing is handled by the National Smallholder Farmers' Association of Malawi (NASFAM) in Malawi, by the Agricultural Seed Agency (ASA) and Zenobia Seed Company in Tanzania, and by the Ethiopian Seed Enterprise (ESE) at national and regional level in Ethiopia. These agencies offer smallholder farmers seed production contracts to produce certified seed under joint ICRISAT/NARS supervision, which is then bought back by these agencies. The national seed services of each participating country do independent inspections to assure quality.

Figure 4. Schematic diagram of the Malawi seed revolving fund model



Source: Van den Berg, 2009

To facilitate production, ICRISAT promotes the use of a block system led by agricultural field officers and enumerators to carry out the program of seed production. The agricultural field officers have some formal training in agriculture, but enumerators are elected by their peers because of their status as lead farmers in their respective communities. ICRISAT and NARS train the enumerators (training of trainers) and contract farmers in quality seed production, and additionally train the enumerators to carry out data collection and dissemination of information and program inputs. The farmer field schools extension approach is used for imparting knowledge of the principles and options for improved crop management systems to the farmers.

Community-based seed supply is the major seed source for smallholder farmers in eastern and southern Africa. This sector serves over 90% of the legume seed needs of smallholder farmers. There is, therefore, a lot to gain if strategies to improve the quality of seed coming from this sector were designed and properly implemented. ICRISAT and NARS recognize that assistance is needed to improve the efficiency of the range of investments already being made in NGO seed multiplication schemes. Our intervention is targeted to help NGOs improve seed quality control and develop more efficient seed distribution and marketing practices. Particularly, we undertake to develop a systematic seed production program with NGOs through provision of technical support to undertake:

- Variety evaluation and selection of suitable genotypes (e.g. conduct of participatory varietal selection).
- Maintenance of improved and selected genotypes through appropriate production technologies (e.g. on farm seed production).

- Development of training materials for use in assisting farmers to produce genetically pure seed of cultivars of their choice.

The project focus is resource-poor farmers most of whom cannot afford to buy improved seeds. Farmers are trained how to increase production by using farm-saved seed produced using recommended seed production practices (many farmers access improved seed through NGOs and relief programs but they cannot maintain quality). In addition, our project is also encouraging farmers who like experimentation by training them to first select, and then stabilize varieties they themselves have selected. These farmers - who tend to be the lead farmers in the community - are then encouraged to share seed with other members of the community. This is facilitated through seed fairs organized by the project.

NGOs make huge investments through relief and other seed supply schemes to poor rural communities. Our project is intervening to make these investments more sustainable particularly for self-pollinated crops like chickpea and groundnut. The project has partnered with CARE, the Millennium Village Project, Plan (Malawi), CRS, KIMAS, LVIA, Dutch Connection, DTM (Tanzania), Self-Help Development International (Ethiopia) and follow-up on their huge seed investments, with a simple message – ―for every one kilogram of improved seed received by the farmer, two kilograms should be paid back to the community seed bank for use by other members of the community who did not directly benefit". This simple request is followed up and managed by the community themselves and is resulting in a massive injection of improved seed to the community. The project is addressing five key activities, and the monitoring and evaluation plan for each activity is highlighted below.

a) ***Improving availability of foundation seed***

Area planted for production of foundation seed (FS) of different chickpea, groundnut and pigeonpea varieties per year.

- Quantity of FS produced of each crop and variety per year.
- Irrigation system for breeder seed installed and functioning in each country.

b) ***Designing, testing and implementing seed production programs***

- Area of land planted for production of commercial seed of different varieties for each crop per year.
- Quantity of commercial seed produced of different varieties for each crop per year.
- Number of seed farmers trained in quality seed production methods.
- Extent of participation of the private sector seed producers in seed production.
- Cost-benefit analysis of alternative seed production systems

c) ***Designing, testing and implementing seed marketing and diffusion systems***

- Survey report on constraints to existing seed delivery systems.
- Potential pro-poor seed marketing and diffusion channels identified.
- Cost-benefit analysis of alternative seed packaging and marketing arrangements.
- Number of small seed packs sold through agro dealers and farmer groups.
- Number of farmers (male & female) accessing improved seed.

d) ***Enhanced local capacity to produce deliver, store and market seed***

- Number of short courses on seed production.
- Number of short courses on seed delivery.
- Number of participants in seed training courses.
- Manuals prepared on seed related issues.
- Trial seed packs available at local agro-dealer and retail outlets.
- Evidence of involvement of graduate students to build capacity.

e) ***Enhanced local level awareness of available varieties***

- Number of farmers participating in PVS and demo trials.
- Number of farmer field days organized per year.
- Number of farmers participating in farmer field days for each crop per year.
- Number of small packs of seed distributed during farmer field days.
- Number of seed awareness material (leaflets) printed and distributed to farmers.
- Media (radio, newspaper) coverage to enhance awareness.

Results and lessons from TL–II and previous other ICRISAT initiatives

The project in ESA is addressing issues surrounding production, distribution, marketing and awareness of improved seeds of groundnut, pigeonpea and chickpea in three countries – Ethiopia, Malawi and Tanzania.

Seed Supply and Delivery Strategies*: *A Three-pronged Approach

We are using three alternative approaches, depending on the area and ―target" community:

Contract seed production

In this approach, smallholder farmers take up seed production as a farm business. Researchers working with NGOs and other development partners help organize smallholder farmers into viable seed production groups. These can be farmer clubs in specific villages, farmer field schools or registered farmer associations. The farmers are then trained on procedures for production of good quality seed, and successful famers are linked to organizations interested in seed (seed companies, cooperatives, and commodity companies interested in seed of particular varieties or government initiatives). They then produce a specified class of seed of new improved varieties for the organization/company, which provides logistical support – including further training and credit for inputs. ICRISAT and partners are promoting and have executed this type of arrangement with good success in several countries including Zimbabwe, Zambia, Tanzania, Malawi, Mozambique etc (Monyo *et al.* 2004). Farmers are normally paid 30-50% more for seed production as compared to grain prices.

Strategy

- The program involves promotion of wide scale adoption of new varieties with a regional market. This was initiated in earlier efforts through the Sorghum and Millet Improvement Network for Southern Africa executed from Zimbabwe. The strategy involved Zimbabwe, Mozambique, and Zambia - one variety each of groundnut, sorghum, pearl millet and cowpea.
- ICRISAT used a block system led by local supervisors and enumerators to carry out the program of seed production. The local supervisors have some formal training in

agriculture, whereas the enumerators are elected by farmers on the condition that they are lead farmers. ICRISAT trains the enumerators and the farmers on procedures for quality seed production, and additionally trains the enumerators to carry out data collection and how to disseminate information and program inputs.

- ICRISAT also uses the farmer field schools extension approach for imparting knowledge of the principles and options for improved crop management systems to the farmers.

Achievements

- This project proved that smallholder farmers are committed and can grow seed as a commercial crop. The farmers wanted to maintain the links with the commercial seed company so much they were willing to sell some of their harvest as seed even during the worst seasons of drought (eg 2001/2002 season in Zimbabwe). This shows that smallholder farmer/ private sector partnerships are feasible if based on mutual trust.
- Smallholder farmers were capacitated to produce good quality seed and within four years of the program no single in the program was disqualified for reasons of not following the recommended seed production techniques.
- The methodology and strategy have been tested and refined in Zimbabwe but have since spread to other SADC countries with minimal adjustments.

Reasons for success and lessons

- The scheme is profit motivated. Farmers look at seed production as an enterprise.

- Capacity in seed production in the rural smallholder sector has been developed and opportunity provided for linking smallholder farmers with a private sector seed company
- The program is availing seed of improved OPVs to smallholder farmers in the dry SAT zones which would have otherwise not been available.
- Farmers in the Semi-Arid Tropics are very vulnerable to drought effects and this causes them remain food insecure. This has resulted in non-delivery of seed in preference for keeping it as food in seasons of severe drought. It is important that seed production areas are carefully selected to minimize risk of failure.

Examples under model I

Zimbabwe: The private sector have highlighted the difficulties of producing good quality seed of sorghum or pearl millet because of problems of bird damage if one attempts to provide these crops in isolated blocks. Small-scale farmers in the sorghum and millet growing areas own small plots, which do not provide for adequate isolation distances for seed production. Though individual farmers own small plots, due to the necessity to separate grazing areas from cropping areas, farms are organized into blocks. This arrangement provided for the opportunity to test the feasibility of producing seed for commercial sale in communal areas utilizing the idea of block farming. For this concept to work the community must agree to participate and grow only the identified variety of the selected seed crop. Small-scale farmers in two pilot districts in Zimbabwe have successfully used this concept to produce sorghum and pearl millet seed of designated varieties for the private sector seed companies. (Monyo *et al*. 2003).

Tanzania: the Christian Council of Tanzania (CCT), and the Diocese of Central Tanganyika (DCT) mobilized groups of farmers and assisted them to register as Seed Associations. DCT operates only in Dodoma region but CCT operates nation-wide where they have facilitated registration of 11 farmer seed associations. The CCT concept is to support these associations to produce improved seed of open pollinated varieties (sorghum, pearl millet and maize) for commercial sale (Mwaisela, 1999, Mwaisela, 2000). These associations are reliant upon the communities for which they are located for their seed market and mostly on the contacts of their affiliated churches to find seed markets for them to sell their seed produce. A certain amount of money is retained through by CCT to ensure that the farmers continue to be supplied with fresh source of foundation seed. This model has been in operation since 1995. ICRISAT through the SMIP project started working with CCT during the 1998/99 seasons to provide technical assistance and identify associations, which can serve as successful case study for the purpose of improving the operations of others and or scaling up.

Nambia: The Northern Namibia Farmer Seed Growers Coop (NNFSGC) is another example of ICRISAT technical assistance in establishing viable seed delivery systems to small-scale farmers. Initially the founding members comprising 50 small-scale farmers were trained on aspects of good quality seed production through a training module organized by ICRISAT-Bulawayo and FAO-Namibia in 1994. It took four years for this group of farmers to develop into full-fledged registered Seed Coop – with capacity to produce adequate pearl millet seed for the needs of Namibia. (Lechner *et al.*1996).

Small seed packs

This is through selling seed in small packs, 500 g to 5 kg, instead of the usual 25 kg. ICRISAT and partners has demonstrated that farmers who cannot afford the large packs eagerly buy the smaller quantities, paying the full cost, without subsidy. ICRISAT working with private sector partners in different countries have demonstrated that over 80% of the seed distributed in rural remote areas through the small seed pack program was purchased, helping to spread new varieties in drought-prone –pilot” areas. The private sector – especially emerging small seed companies, retailers and agro-dealers have taken full advantage of this. As a result, TL-II partners in participating countries were able to distribute over 1 million small seed packs to smallholder farmers through seed retail outlets during 2012/13 season (Table 1).

Table 1. Amount of small seed packs distributed during 2012- 2013 crop season in TL-II target countries.

	Number of small seed packs per crop						
Country	Chickpea	Groundnut	Commonbean	Soybean	Pigeon pea	Cowpea	**Total**
India	1,237	4,375	0	0	2,574	0	**8,186**
Bangladesh	90	290	0	0	0	0	**380**
Ethiopia	424	0	5,075	0	0	0	**5,499**
Uganda	0	NA	NA	0	40	0	**40**
Tanzania	45	0	3,045	0	1,825	0	**4,915**
Kenya	3,568	0	50,500	13,566	0	0	**67,634**
Mozambique	0	NA	0	23,899	0	4,600	**28,499**
Nigeria	0	1,500	0	81,000	0	63,000	**145,500**
Niger	0	NA	0	0	0	63,000	**63,000**
Malawi	0	839,500	0	0	NA	0	**839,500**
Mali	0	5,290	0	0	0	15,000	**20,290**
Total	**5,364**	**850,955**	**58,620**	**118,465**	**4,439**	**145,600**	**1,183,443**

Seed production & distribution through primary schools

Primary schools in rural areas multiply seed of improved varieties, with technical and logistical support from ICRISAT, government agencies (Department of Research and Training, Department of Crop Development, Local Government), and other partners. The schools then distribute this seed to nearby communities, ensuring that smallholder farmers have access to affordable, high-quality seed within a convenient distance from their homesteads.

Rural primary schools were identified in two drought-prone districts (Dodoma and Singida) in Tanzania. Each selected school had over 500 students, and served 500-700 families, so there is a substantial demand for seed. Agriculture is part of the curriculum, and trained teachers are already in place. The schools are already engaged in agriculture, mainly cereals (sorghum, millet, maize), legumes (groundnut, cowpea) and vegetables some of which are used to feed students. The children are from farming families, and benefit directly from practical experience in seed production. Adequate land is available to ensure proper isolation distances where needed.

Strategy

- The selected schools are within 15-20 km of each other, so that each area has its own –seed production and distribution center”, and farmers can get seed without having to travel long distances.
- The government assigned Ward Education Officers (WEOs) to supervise project implementation. Each WEO supervised seed production in ten schools.

- ICRISAT provided each school with enough breeder/foundation seed to plant 1 hectare of seed crop. The crop/variety was carefully selected for adaptability to local conditions.
- Training programs were conducted for one teacher per school, plus all supervising WEOs, covering seed production techniques, crop management, quality control, certification standards, and storage methods. Project partners (ICRISAT, DRD, Participating NGOs) provided funding and resource persons for the training; logistics were organized by the schools and the local community.
- Throughout the crop season, ICRISAT, government researchers, the local resident NGO (DCT), monitored crop management, pest control etc, providing advice on quality control.
- The village government and community elders through the Ministry of Local Government, ensured the program was successful by minimizing cross-contamination from other fields; and by organizing seed distribution after the harvest.
- Crops/varieties – sorghum (Pato), in different areas. pearl millet (Okoa), sesame (Ziada 94), groundnut (Pendo), pigeon peas (Mali) and maize (Kilima) were targeted.

Achievements

- The program was launched as a pilot scheme with 50 schools in one district but within 4 years expanded to cover 250 schools in eight drought prone districts of Tanzania.
- The range of crops has expanded; initially only sorghum and pearl millet seed were multiplied but the range of crops expanded to include sorghum, pearl millet, pigeonpea, sesame, groundnut and maize.

- Each school supplies approximately 0.5tons of high-quality seed to the surrounding community every year, at affordable prices. As a result, the area under improved varieties in these target districts increased 5-6 fold.
- This initiative was implemented under a SADC regional program executed project and following the success in Tanzania, similar initiatives were started in Malawi through NGOs.

Why did the program succeed?

Partnership: the program was led by the communities themselves. ICRISAT, government research and extension staff, and NGOs provided support (Monyo and Mgonja 2004). Two key government departments – the ministry of education and Local Government (the district administration) – were closely involved, ensuring that monitoring, logistics, coordination, and other issues (eg, certification, sale permits) were smooth.

Ownership: the community had a clear sense of ―ownership" of the project. It was being implemented at community level, with benefits targeted at the community. So there was enormous popular support, mobilized by village leaders. For example, farmers with plots adjacent to the school‘s seed plot agreed to plant different crops to minimize cross-contamination and ensure genetic purity of the seed being multiplied for the crops that required isolation.

Promotion: field days were held at the schools, to demonstrate the benefits of the project. Over 1000 farmers from ―target communities" on the average attended these field days: as well as farmers from nearby areas, from other districts in Tanzania, even from other countries. The visitors included representatives from the national programs and Seed Services Units from Botswana, Malawi, Mozambique, South Africa and Zambia. As a result, awareness spread rapidly. So, did interest from other communities in implementing similar schemes. Schools-based seed projects are being implemented in Malawi, in partnership with World Vision

International. The Mozambique government also expressed interest with a wider range of crops.

Seed production through community seed schemes

Community-based seed bulking: community-based seed production seeks to involve small-scale individual farmers, farmer groups, NGOs and governmental organizations in forming small but effective seed multiplication units with the objective of supplying quality seeds for farmers' own use and for sale to other farmers. Activities include the selection of farmers or farmer groups to be involved in seed bulking and training on seed multiplication techniques and marketing. The Seeds Technical Services Unit and other CGIAR institutions based at Chitedze Agricultural Research Station - Lilongwe provides all the required training and foundation seed to the community-based seed farmers.

Community-based grain banks: this is a system where the grains produced locally are stored and distributed to participating farmers as seed at planting time. Farmers manage community grain banks, with supervision from CBOs and local NGOs. If run properly, they alleviate shortages of seed and ensure timeliness of seed supply to rural farmers. They can also act as a safety bank for seed, especially in times of drought. The success and sustainability of these grain banks is of paramount importance for local seed security.

Seed recovery and banking program: in this system, farmers are facilitated to prepare a list of crops and varieties they require. The crops are procured from local seed merchants (local seed markets) and kept in a central store (seed bank) at village level. These are then distributed to farmers at planting time. After harvest, farmers return twice the amount of grain or seed given.

Village committees manage the seed recovery and banking with the assistance of location extension staff from the Ministry of Agriculture and local CBOs and NGOs. These CBOs and NGOs usually give the communities initial funds for seed procurement. Each seed bank is run at village level. The village committees monitor the crop in the field and establish and manage the seed banks. Sub-locational committees monitor the village committees and provide a forum for sharing experiences.

Seed fairs: seed fair is a market where households purchase seed through a voucher system. It is organized on a specific day at a specific location, announced in advanced. The routine way of conducting seed fair has been in disaster-hit areas and using vouchers to target households, as an agricultural recovery mechanism. At the seed fair, vulnerable households are provided with vouchers worth specific cash value to purchase seed and tools from registered sellers in the community. Seed fairs aim to:

- Create awareness of alternative seed sources and varieties.
- Enable disaster-affected farmers to access crop/varieties in quantities of their choice.
- Strengthen and stimulate linkages and information sharing among farmers.

After a disaster or displacement, farmers often lack access to seed. The common assumption is that seed is not available within the community. The approach recognizes that farmer seed systems are robust and resilient, and even provide seed in emergency situations. This approach to seed aid focuses on farmer seed system and involves farmers in the procurement.

Seed fairs have been conducted where a need for seed aid has been identified as appropriate when populations are displaced, and/or do not have their own seed stocks. Seed purchase through seed fairs and vouchers can be used when:

- Farmers have suffered total crop loss as a result of conflict or natural disaster.

- Farmers were displaced due to conflict and were not able to harvest their crops.
- Farmers were unable to sow their crops due to an emergency-related disruption.
- Farmers‘ seed stocks were stolen as a result of rebel attacks.
- Internally displaced persons are returning to their homes or refugees are settling on land allocated to them.

The decision to conduct a seed and cultural fair should be based on proper assessment of the disaster-affected location, including the need for seed, availability of seed in the area, and overall security in the area. Seed fairs should utilize farmer seed systems because they offer the following advantages:

- Farmers access seed of their preferred crops and varieties
- Seed quality is left to the judgment of farmers.
- Local crop production is supported.
- Fairs can be planned and implemented in short period of time
- Communities are actively involved in planning and implementation.

They serve the needs of large numbers of families who find it difficult to access seed; the approach can be modified to suit the level of seed insecurity.

In short, seed fairs allow beneficiaries to access seeds and varieties that are locally available, of their preference, and meet their immediate needs (CRS *et al*. 2002).

Skills and knowledge enhancement: one of pillars of expanding and sustaining the outcomes/outputs of the Tropical Legumes Project is to build skills and knowledge of partners/actors along the seed value chain of various grain legumes. Table 2 illustrates the number of seed value chain actors and other partners trained between 2012 and 2013.

Table 2. Training of farmers and extension staff by region (2012/13)

Region	**Number of farmers & extension staff trained**		
	Farmers	Extension staff	**Total**
Eastern & Southern Africa	9,530	4,257	13,787
Western and Central Africa	6,800	418	7,218
South Asia	10,073	2,891	12,964
Total	**26,403**	**7,566**	**33,969**

Awareness creation: training modules, manuals, leaflets/flyers and information bulletins were produced. For instance, a training manual for chickpea production in Kiswahili language has been developed and was used for training in Kenya and Tanzania. A total of 8,000 leaflets with information on groundnut seed production (6,000 in Uganda, 2,000 in Malawi) were distributed. About 2507 bean seed production/business manuals in four languages (Amharic, Oromifa, Swahili and Luganda) were produced and shared with partners in Ethiopia, Kenya, Tanzania and Uganda respectively. Mass communication was also used to disseminate knowledge about new varieties and their seed source through several radio and TV programs and through publication of news articles on local newspapers. Over 21,000 legume seed producers (11,990 in Tanzania, 5,535 in Uganda, 2,300 in Ethiopia, 1,381 in Kenya, 677 in Malawi and 657 in Mozambique) participated in a total of 116 farmer field days and 27 farmers' fairs held at on-farm and on-station trial sites. Strategies that create variety awareness were implemented in Malawi (involving partnerships with agro-processors and traders), Tanzania (involving Dodoma transport and Kilimo markets), Ethiopia (awareness created by farmer cooperatives) and Uganda (in partnership with seed companies). Several production guides and technical manuals were developed for all mandated crops. Several field days and farmers‘ fairs were organized and quite alarge number of users in partner countries was participated. In India and Bangladesh 3,106 farmers (2,365 men & 741 women) were trained on salient features of chickpea varieties, seed production and post-harvest technologies. Further, 135,000 farmers supported through TL-II participated in farm fairs organized by UAS-Dharwad and UAS-Raichur (In India).

Achievements & lessons from Tropical Legumes–II Project

Impressive seed production/supply levels were recorded in phase II. Most crops have surpassed the targeted milestones (based on already executed two year period of the project). For instance, quantities of chickpea seed produced (111,553 MT) surpassed the milestone (11,645 MT) by more than 900% (Table 3).

Table 3. Seed production (tons) across target countries, by crop and phase

Crop	**Phase I (2007-2010)**	**Phase II (2011-2013)**	**Total**
Chickpea	82,381	111,553	193,934
Common bean	9,030	18,451	27,481
Cowpea	604	1,445	2,049
Groundnut	11,977	15,685	27,662
Pigeon pea	921	3,644	4,565
Soybean	1,171	1,720	2,891
Total	**106,084**	**152,498**	**258,582**

Table 4. Crop specific lessons

Chickpea	Groundnut	Common bean
Smallscale farmers require complementary functional seed and product markets if sustainable seed production is to be achieved.	Sustained seed support is essential for large area coverage by FPVs and resultant enhanced productivity in groundnut	Farmers are willing to use new varieties once they are convinced the variety will meet their requirements.
Selection of a given chickpea variety by farmers is largely influenced by the market superiority of that variety.	Project interventions focusing on affordable seed production and delivery systems have a better chance of surviving beyond the lifespan of the project.	Identification of effective partners that share the same vision and interests is important for popularization of new technologies.
Participatory variety selection enhances cost effective testing and increases chances of varietal adoption.	Business-oriented smallholder farmers performed better in seed production, storage & dissemination than food security-oriented farmers.	Remedial training of farmers after some years is essential for enhanced technical capacity.
Strong policy support encourages several private seed companies, and is also crucial for quick dissemination of proven technologies.	Limited access to good land and farm equipment are the major challenges facing women farmers.	Seed loan and small seed packs approaches have proved efficient for variety promotion and dissemination especially for poor farmers and women (e. g. Kenya).
Market pull is the major key driver for success in Ethiopia that resulted in enhanced stakeholder participation and government's policy support.	The project involves many sites. Focusing on one key region per county will be the most effective in terms of resource use and sustainability. Successful interventions can be replicated in other regions.	Use of small packs started as a joint public –private initiative but with progress vision of empowering private sector to sustain and expand the approach.

Table 4. Continued…

Chickpea	Groundnut	Common bean
Poor product standardization and market unpredictability affects seed sector growth in ESA.		A multi-crop approach is important to expanding seed systems for crops of low commercial seed interest.
Farmers‘ awareness and availability of the seed are the key factors in technology dissemination		Decentralized bean seed production and use of small seed packs have improved seed supply capacity (e. g. Ethiopia)
PVS, field days, demonstrations and seed fairs wer very effective in awareness creation, fast adoption and dissemination of new technologies		Farmers‘ awareness on bean production and productivity improved - triggering increase in interest of individual farmers, private farms and farmers groups to venture in bean farming as a business.
		Strong partnerships cemented through formation of innovation platforms resulted in more effective and efficient bean seed system
		The sensitization of famers on the type and kinds of varieties enables the creation of market for seed companies especially for the new varieties.

Next steps

In all three countries of eastern and southern Africa where the project has been working, significant investments have been made particularly by non-governmental organizations in the promotion and dissemination of improved legume seeds. By partnering with these organizations the project has been able to leverage extra resources towards achieving the ambitious targets set for groundnut, pigeonpea and chickpea seed systems in ESA. The project should strive to engage with policy makers at both national and regional level to develop a coherent policy for open-pollinated crops – including legumes – so that investments made by the private sector maximize the benefits from investments in legume breeding.

The project has made progress in developing a sustainable system for the production of source seed by establishing seed revolving funds that overcome some of the bottlenecks faced by the NARS that are dependent on government treasuries for support. However, these mechanisms need to be properly established and managed as businesses if they are to be sustained beyond the life of the project. Source seed production should be open to other parties and not handled exclusively by the seed revolving fund, and there needs to be flexibility to allow for different models to evolve, co-exist and even replace this model as the seed system develops.

In the next phase much greater attention needs to be given towards establishing functioning legume value-chains and stimulating seed demand rather than focusing so extensively on seed supply. Support to entrepreneurs will probably best be provided through business development service providers that are becoming increasingly important, and offer services on a full-cost recovery basis.

References

CRS (2002) Seed vouchers and fairs: a manual for seed-based agricultural recovery in Africa. Catholic Relief Services developed in collaboration with International Crops Research Institute for the Semi-Arid Tropics and Overseas Development Institute, Nairobi, Kenya.

Monyo ES, Rohrbach DD and Mgonja MA (2004) New partnerships to strengthen seed systems in Southern Africa: Innovative community/commercial seed supply models. In *Successful Community-Based Seed Production Strategies*. Mexico, D.F., CIMMYT. **ISBN**: 970-648-115-X.

Monyo ES and Mgonja MA (2004) A community based seed production system—Schools for seed in Tanzania. In *Successful Community-Based Seed Production Strategies*. Mexico, D.F., CIMMYT. **ISBN**: 970-648-115-X.

Setimela PS, Monyo ES and Bänziger M (eds) (2004) Successful Community-Based Seed Production Strategies. Mexico, D.F., CIMMYT. **ISBN**: 970-648-115-X.

22. Whither the Chickpea Seed System?

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Chickpea (Cicer arietinum L.) is the second most important legume crop in terms of area and third in terms of production globally. Chickpea also holds a good share of international pulse market. However, the legume seed industry in general and that of chickpea in particular is least developed in many developing countries; and neither the public sector nor the private sector provides farmers with adequate quantity of chickpea seed of new varieties. Therefore most chickpea seed used is produced in the informal sector. The paper apart from strengthening the formal sector, advocates forpromoting innovative farmer-based small-scale seed enterprises as alternative options to address the delivery of chickpea varieties and seeds through the participation of farmers and/or communities.

Introduction

Chickpea [*Cicer arietinum* (L.)] is an ancient crop grown across five continents i.e. Asia, Africa, Americas, Australia and Europe. It is grown in more than 50 countries with 90% area in Asia, 4.7% in Africa, 3.1% in Oceania, 1.6% in Americas and 0.5% in Europe (Gaur *et. al*., 2012). South Asia contributes over 75% of world‘s chickpea production. India is the largest chickpea producing and consuming country in the world and accounts for over 67% of global chickpea production, followed byAustralia (6%), Pakistan (5%), Turkey (5%) and Myanmar (4%).The other traditional major chickpea producing countries include Ethiopia, Iran and Morocco and new emerging producers like Canada and Mexico.

The global area and production of chickpea has increased by around 18% and 36%, respectively during the last 10 years. According to FAO (Food and Agriculture Organization), the global chickpea production was 11.6 million metric tonnes in 2011 from 13.2 million ha area with average productivity of 880 kg/ha (Garzon, 2013). This increase in production was primarily due to increase in acreage (18%) and productivity per unit area (15.4%).

Chickpea plays an important role in the farming systems as source of food for human consumption, feed for livestock and break crops for rotation. It is a cheap source of protein for resource poor farmers supplementing the cereal-based diets particularly in rural areas. Chickpea like any other legumes is also important break crops and grown as rotation crops in predominantly crop (cereals)-livestock production systems. It also improves soil physical properties and maintains soil fertility by fixing atmospheric nitrogen.

In general despite its economic importance, relatively little attention has been given to agricultural research, crop improvement and seed supply of food legumes in general and chickpea in particular compared to cereals which are considered ‗strategic' food crops. Moreover, research in legumes is relatively new compared to cereals both at IARCs and NARS (Aw-Hassan *et al*., 2003). Even where national and international research centers have made some significant progress in developing new chickpea varieties, the availability of, access to and use of quality seed remain a major challenge certainly in many developing countries. In the CWANA region, where cereal seed industry often operate reasonably well, there is lack of formal seed system (public or private) that provide farmers with quality seed of improved varieties. Many countries fail to exploit the investments made in agricultural research of cool season food legumes because of low adoption and diffusion of improved varieties resulting from lack of appropriate production technology and weak seed systems. Chickpea does not escape this reality and at present, the majority of seed comes from own saved seed or through local exchange and trading among communities whereas the seed from commercial sources is very minimal.

Status of seed industry

The status of national seed systems in the developing world are the manifestation of the politico-socio-economic development path followed by each country. Thus, the national seed systems reveal variation in terms of policy, regulatory and institutional arrangements. The level of seed sector development can be broadly classified into three categories: (i) developing seed industries; (ii) intermediate seed industries; and (iii) least developed seed industries. The first group although deficient in certain aspects has a relatively functioning infrastructure with some pronouncements of national seed policy and regulatory frameworks, independent variety release and seed certification agencies and some private sector participation (e.g. India, Pakistan, Turkey). In the second group, most countries lack clear seed policy and regulatory frameworks, lack independent or have weak variety release and certification agencies, and most seed activities are handled by public sector where efforts to reform and/or diversify the seed sector is rather limited (e.g. Ethiopia, Iran). The third group is characterized by countries where the seed sector is organized on ad hoc basis by agricultural research or departments within the Ministry of Agriculture. Such countries not only lack effective policy and regulatory frameworks, but institutions and infrastructure to support the development of an effective seed sector.

The chickpea seed system

National seed systems can be grouped into two broad categories: formal seed sector and informal seed sector. The formal and informal seed sectors co-exist, but the partition between formal and informal is imprecise and depends on the level of agricultural development (commercial vs subsistence), agro-ecology (favorable vs marginal areas), crops (cross-pollinated vs self-pollinated) and type of seeds (hybrids and OPPs). Formal seed systems are deliberately constructed, involving a chain of activities leading to clear products – certified seeds of verified varieties (Louwaars, 1994). The formal sector comprises variety development, evaluation, release; and its commercialization through large-scale certified seed production and marketing to farmers.

In commercial agriculture, the formal sector is predominant and characterized by use of certified seed of known varietal purity and identity and physical, physiological and health quality. Farmers are accustomed to use of inputs including repeated and regular purchase of certified seed with main objective of maximizing crop production. Major chickpea producing countries such as Australia and Canada has a well-developed chickpea seed sector because of its market-oriented and export-led production with strong public-private partnership where both the government and the private sector are funding the agricultural research and variety development and commercialization.

In major chickpea producing developing countries subsistence agriculture is practiced where farmers produce for consumption and there is little surplus for market. There is lack of integration between agricultural research and transfer of technology, and farmers generally depend on seed from the informal sector.

Performance of chickpea seed system

The performance of seed sector can be measured by many factors including the existence of enabling policy and regulatory environments; institutional and organizational configuration for seed delivery; and the technical performance in terms of the quantity and quality of seed delivered at the right place, at the right time and at an affordable price fulfilling the ‗effective' demand of farming communities. The varietal replacement and seed replacement are useful indicators on the availability of, access to and use of quality seed of farmer and consumer preferred and well adapted improved varieties. Varietal replacement refers to the rate at which new varieties are introduced and adopted by farmers. It shows the degree of client-orientation and effectiveness of the breeding program in generating improved varieties. However, the availability of recommended varieties alone would not imply performance, if they were not available at the farm level and grown by farmers. The weighted average (WA) 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). The lower the weighted average age figure the higher is the varietal replacement rate showing availability of newer varieties on the hands of farmers. Therefore, it is important to know the number of released varieties, the number of years since their release and the proportion of area covered to make an accurate estimate.

On the other hand, seed replacement rate refers to change of seed of an existing commercial variety which a farmer is already growing due to several reasons. The general ‗rule of thumb‘ for certified seed replacement, is every year for hybrids, two to three years for open pollinated crops and four to five years for self-pollinated crops such as chickpea. It is expected that from a total ‗potential‘ seed demand required for planting chickpea area in any given year, at least 25% of seed should come from the formal sector. In reality, such seed replacement rate is rarely achieved because farmers tend to save and use own seed even if they continue growing improved varieties. Understanding farmer‘s seed commercial behavior and varietal perception would help in assessing ‗effective‘ seed demand and production planning (Dawit and Bishaw, 2014a & b).

Some of the highlights of chickpea seed system is presented and discussed in the following sections.

India: In India, traditionally the northern states used to cultivate legumes – specifically chickpea – and this area was most productive with assured irrigation. However, as wheat and rice emerged as food security crops, wheat replaced chickpea in northern India reducing the cultivated area from 5 million ha to less than 1 million ha. Hence, chickpea cultivation shifted from north India to central and south India which increased from 2.4 million ha to 4.5 million ha. However, this new area is mainly rainfed and farmers cultivate chickpea under low input conditions.

India is a major producer and consumer of chickpea worldwide. An average of 8.2 million ha is cultivated annually with estimated average production of 7,241,720 MT and productivity of 0.8785 MT ha^{-1}. Madhya Pradesh, Chhatisgarh, Rajasthan, Uttar Pradesh and Maharashtra are major chickpea growing areas. It is also grown in Andhra Pradesh, Assam, Bihar, Gujrat, Haryana, Himachal Pradesh, Karnataka, Nagaland, Orissa, Punjab, Tamil Nadu and West Bengal.

From 2008-13, the formal sector provides on average 20% of potential seed requirement which appears to be a remarkable achievement (Table 1). However, there is huge disparity of quality seed supply in the different chickpea growing states (Table 2). The seed replacement rates vary from the highest of 75% in Andhra Pradesh to the lowest of 9% in Madhya Pradesh. Karnataka, Gujarat and Maharashtra followed by 30, 25 and 19% seed replacement rates, respectively. However, the major chickpea producing states such as Madhya Pradesh (36% area and 40% production) and Rajasthan (14% area and production) has a seed replacement rate of only 9 and 12%, respectively.

Table 1. Chickpea area, potential seed requirement and certified seed supply in India.

Measurment	Year					
	2008	2009	2010	2011	2012	2013
Area ('000 ha)	7540	7890	7369	9190	8320	8700
Potential seed demand ('000 MT @ 100 kg)	558.5	591.8	552.7	689.3	624.0	625.5
Certified seed supplied ('000 MT)	111.8	118.4	113.8	137.9	124.8	130.5
Seed renewal rate (%)	20.01	20.0	20.6	20.0	20.0	20.9

Note: *Chickpea area is from FAOSTAT*

This seed requirement is being met mostly by the central and state government agencies as private sector is not involved in chickpea seed delivery. There is, therefore, need for synergy between the public and the private sectors. The private is required to be involved in the overall national objective of providing quality seeds including those of high volume low value crops to the farmers at affordable prices.

The involvement of the private sector is being facilitated under the National Seed Plan of the Government of India, in the following manner:

- Arrangements between Seeds Corporations and Seed Industry for the benefit of the farmers. Modalities and exact nature of cooperation will have to be worked out by the Seeds Corporations with the support of the State Governments.
- Trilateral Agreements between seed industry, State Agriculture Universities and State Seed Corporations for development, production and distribution of seeds of new varieties.

- Incentives to private sectors for production of low value high volume seeds including provision of incentives for bankable schemes.

Table 2. Chickpea area and potential seed requirement and quality seed supplied in major growing states in 2013 crop season.

State	**Area** ('000 ha)	**Potential seed required** ('000 tons)	**Certified seed supplied** ('000 tons)	**Seed replacement rate** (%)
Andhra Pradesh	630	47.25	35.44	75
Gujarat	615	49.12	12.28	25
Karnataka	605	45.37	13.61	30
Madhya Pradesh	2,430	182.25	16.40	9
Maharashtra	1,353	101.48	19.28	19
Uttar Pradesh	505	37.88	5.68	15
Rajasthan	1,231	92.33	11.08	12
India	**7,369**	**552.68**	**113.77***	**20**

Source: *Area and Seed replacement rate from DAC, MoA, GoI*

Within the National Seed Plan, it is envisaged that 40% of the total seed requirement to be met by the Central Seed Producing agencies, another 40% by the State Seed Producing agencies and the remaining 20% is to be met by the private sector. However, this ambitious plan is yet to be realized at grass root levels.

Iran: Iran is one of the major chickpea producers in west Asia. According to FAO, average chickpea area and production was 524,425 ha and 239,055 tons, respectively with average productivity of less than half a ton (0.45 ton per ha^{-1}). Apart for dry beans, there is no organized formal seed supply for legumes including chickpea. Although eight chickpea varieties have been released, the majority of farmers are using a popular local landrace known as Bivanij (Mobasser, personal communication). All chickpea producers are dependent on informal sector for their seed.

Table 3. Chickpea area, potential seed requirement and certified seed supply in Iran

Measurment	**Year**				
	2008	**2009**	**2010**	**2011**	**2012**
Area ('000 ha)	426.3	560.2	508.3	562.4	565.0
Potential seed demand ('000 MT @ 100 kg)	42.63	56.02	50.83	56.24	65.50
Actual seed supplied ('000MT)					
Seed renewal rate (%)					

Note*: Data on chickpea certified seed production and supply does not exist.*

Ethiopia: Ethiopia is the largest chickpea producer in Africa accounting for about 46% of the continent‘s production. Chickpea is the second most important legume crop after faba bean in the country. During 2008-12, the average chickpea area was 223,834 ha with average production and productivity, respectively of 409,773 tons and 1.712 t ha-[1]. It contributes about 16% of the total pulse production.

In Ethiopia, the formal sector supplies less than 2% of the chickpea seed requirement, and mostly provided by the Ethiopian Seed Enterprise (ESE). The Ethiopian Institute of Agricultural Research (EIAR) produces and supplies basic seed; and ESE produces and distributes certified seed based on the official demand projection of the regional bureaus of agriculture. The informal seed systems (self-saved seed or farmer-to-farmer seed exchange) accounts for over 95% of the seed used by smallholder farmers.

Apart from efforts of ESE, the EIAR is involved in pre-extension and demonstration of food legumes assisted by successive on-going projects such as the Tropical Legumes implemented by ICRISAT and supported by BMGF. While the adoption and diffusion of improved varieties appeared substantial, the approach did not put in place a sustainable chickpea seed system other than project based activities across the country.

Table 4. Chickpea area, potential seed requirement and certified seed supply in Ethiopia

Measurment	**Year**					
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Area ('000 ha)	226.78	213.19	208.40	231.30	239.51	?
Potential seed demand ('000 MT @ 100 kg)	22.79	21.32	20.84	23.13	23.95	?
Actual seed demand ('000 MT)	16.96	23.98	18.16	14.97	17.39	17.39
Actual certified seed distributed (MT)	280	290	659	492	435	4354
Seed renewal rate (%)	1.2	1.4	3.2	2.1	1.8	

Turkey: Chickpea is a major legume crop grown in Turkey. However, its production fluctuates influenced by unstable the government policy. In the 1980s, Fallow Replacement Project played an important role in introducing and expanding legume production in the farming systems. The credit and subsidy for seed led to peak production of chickpea and lentil in 1988. In early 1990s, the removal of subsidy led to continuous decline in production threatening export market. In 1997, the Legume Exporters Union established a research and development fund imposing levy on export to promote food legume production. In

1998, the Exporters Union Seed and Research Company (ITAS) was established to transfer legume technology (varieties and seeds).

From 2008-12, the average chickpea area was 450,000 ha and production of 526,740 tonnes with a productivity of 1.174 t ha^{-1}. Chickpea area appeared to show some steady decline, although there is steady increase in terms of production. However, the formal seed supply remains low at less than 5% seed replacement rate.

Table 5. Chickpea area, potential seed requirement and certified seed supply in Turkey.

Measurment	**Year**					
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Area ('000 ha)	486.2	454.9	446.2	446.4	416.3	423.6
Potential seed demand ('000 t @ 100 kg)	48.62	45.59	44.62	44.64	41.62	42.36
Certified seed supplied (tons)	127	459	253	309	1239	1609
Seed renewal rate (%)	0.26	1.01	0.57	0.69	2.98	3.80

Dynamics of chickpea seed system

Bishaw *et al*. (2008) highlighted the status of the seed system of cool season food legumes including chickpea in developed and developing countries. Cool season food legumes such as chickpea have been introduced in the farming systems of developed countries as part of agricultural diversification program to support farmers previously dependent on cereal production and export. In developed countries, for example in Australia, Canada, France, Germany and United Kingdom there is strong public-private sector partnership supporting the legume seed industry (Gareau *et al*., 2000). The presence of market-oriented and/or export-led commercial agriculture remains the major driving force for the development of vertically organized and sustainable legume seed industry. As a result agricultural research, variety development, seed production and marketing and grain processing and marketing are well integrated along the grain legume value chain for the benefit of all stakeholders i.e. the government, farmer growers, industrial processors and exporters (Bishaw *et al*., 2008).

In many developing countries, by contrast, legume production including chickpea is practiced as subsistence and mostly produced by smallscale farmers under rainfed conditions mostly for home consumption with little surplus for market. Empirical evidence and practical experience shows that the legume seed sector in general and that of chickpea in particular remain weak in many developing countries. A simple review of the chickpea seed sector from selected countries above clearly demonstrates the predominant role of public sector institutions in agricultural research, variety development and seed supply and the complete absence of the private sector. The public sector remains inefficient and ineffective in chickpea seed delivery in almost all developing countries.

Search for sustainable chickpea seed delivery

In developing countries where privatization of the seed industry has made big strides there is no better record in legume seed provision through the formal channels. The question remains ‗why the formal sector not had been able to make progress in the legume seed sector'? and ‗what are possible approaches to develop a more sustainable legume seed system? There is no mystery and the answer lie in a myriad of policy, regulatory, institutional and technical constraints that hindered the development of robust legume seed industry across the developing countries (Bishaw *et al*, 2008). The bottom line is that the chickpea sector does not get the attention it deserves in the farming systemin in terms of public or private investments. Governments has an obligation to address key policy challenges to ensure that investments made in agricultural research to generate new improved food legume varieties and associated technologies eventually reach farmers and realize the impacts on food and nutritional security and livelihoods of rural population. Supporting an integrated seed supply system, recognizing and exploiting the synergy of both the formal and informal approaches are key for establishing a sustainable seed system (Louwaars and De Boef, 2011).

Understanding the chickpea seed market

There are few reports on legume seed systems in many developing countries; and these reports are also descriptive rather than analytical where a critical review and in-depth analysis of seed value chain is required using a standard set of criteria. A seed value-chain analysis to understand the functioning of chickpea seed system can provide useful guidance to identify critical gaps and recommend possible options to formulate technical, institutional and policy options to address country specific issues for strengthening the seed sector.

It is not clear whether it is lack of seed or demand for seed is a critical constrainteven in the presence of legume varieties and associated technologies. Therefore, case studies need to be conducted on the efficiency of seed production and marketing in countries where the public sector remains to dominate the legume seed sector to identify critical bottlenecks for improvement. This will be augmented by understanding the role of informal sector to design alternative seed production and marketing units which ensures their sustainability.

Strengthening the formal seed supply

The success of legume seed industry in developed countries has often resulted from integration of agricultural research, production technology, input supply, market support, and extension information. Byerlee and White (2000) indicated that the success and rapid expansion in soybean production has been attributed to investments in research, mounting wide-scale extension programs, supporting producer prices and encouraging the industry to develop processing plants and export markets. They suggested that similar efforts are needed for food legumes in developing countries.

The unique advantages of legumes (chickpea) in farming systems in providing food and nutritional security, enhancing soil fertility and health and as cash crops for domestic and export markets need to be widely demonstrated to farmer and policy makers to promote and support production. Reforming the public sector and encouraging participation of private sector is one of the effective strategies for ensuring the availability of and access to chickpea seed through the formal sector.

Promoting farmer-based smallscale seed enterprises

In the immediate future, the public sector remain inefficient in producing sufficient quantities of quality seeds of high volume crops like chickpea to meet the demands of the farmers. On the other hand, there is no private sector to take up the role and fill the gap as it is selective in its business strategy and is profit-oriented and therefore focuses mainly on low volume high value cash crops and hybrids. In view of the above scenario, neither the public sector nor the private sector is able to provide farmers with adequate quantity of chickpea seed of new varieties. To date, in almost all developing countries most of chickpea seed used by farmers is produced in the informal sector. Therefore, mobilizing and engaging farmers in seed production and marketing and promoting farmer based small scale enterprises is an alternative of the day. After all, the present day formal sector emerged as small family or farmer enterprise progressively transited to highly integrated and vertically organized formal system over time.

Sahlu *et al.* (2008) defined ‗farmer-based seed production as any form of seed production and supply conducted with or by farmers, with great variation in scope and ownership'. They can be broadly categorized into community seed production and distribution of local landraces or farmers' varieties as part of genetic resources conservation; participatory crop improvement linked to local seed production and distribution by farmers, on-farm seed production and distribution of improved varieties as part of popularization and dissemination to enhance adoption and diffusion; contractual seed production with small-scale farmers for formal commercial sector or emergency seed distribution; or business-oriented local seed production and marketing by farmers. Currently, there are many variants of farmer or community based seed production of different sizes and shapes being implemented in many parts of developing countries. The ambiguity of names used are misleading and at times confusing because clarity on the role of implementing agencies and farmers' ownership of the enterprises is often lacking. Most of these initiatives are project-centered with little attention to fundamental issues of enterprise profitability and long-term sustainability.

Kugbei and Bishaw (2002) described different forms of small-scale enterprises which canpotentially produce and market seed in a profitable and sustainable manner. In the context of seed delivery,a small-scale enterprise is a business that is owned and managed by either one person orfew people, who are engaged not only in production, but marketing of seed as well. At thecommunity level, these may be individual farmers, group of farmers, traders or merchants, cooperatives, farmers' organizations or associations. Louwaars and de Boef (2011) indicated that local seed businesses emerge at different levels of proficiency, sitting at the intersection between advanced informal and emerging formal.

Bishaw and van Gastel (2007) emphasized profitability and sustainability as core values of any farmer-based small-scale seed enterprises; and elaborated the key steps for its establishment and operationalization. Srinivas *et al* (2010) has demonstrated the technical capacity in terms of the quantity and quality of seed produced and financial performance in terms of enterprise profitability and sustainability, if they are properly organized and supported. Small-scale enterprises have obvious advantages over large-scale commercial seed organizations in serving the needs of small farmers in geographically scattered locations who demand small quantities of seed of diverse crops and varieties. There are several advantages for organizing local seed enterprises: farmer participation and ownership (empowerment); decentralized production (less transaction costs), appropriate technology (mobile cleaners, treaters), relevant quality (e.g. quality declared seed), market driven (focus on local demand), and business orientation (profitability). However, establishing and operating farmer-based seed enterprises is not an easy ride where appropriate criteria need to be developed, critical steps followed and adequate support provided. Khanal (2013) shed some new lights on issue of sustainability of community seed production such as economic, environmental, and social in the analytical framework.

Steps for establishing small-scale seed enterprises

Most initiatives involving farmers is often top-down, based on the assumptions of formal institutions and seldom demand driven and consultative. For successful establishment of farmer-based small-scale seed enterprises a number of steps to be followed are given below (Bishaw and van Gastel, 2008).

- ***Seed system analysis to understand the seed market***: the seed system analysis should be conducted before establishing the enterprises, to assess whether there is a seed demand or ‗seed gap' al local level. A simple feasibility study would also be useful to see the profitability of small-scale seed businesses if established.
- ***Stakeholder's consultation***: stakeholder's supporting local seed business should be identified and consulted by presenting the seed system analysis to gauge their interest and determine their roles and responsibilities in establishing and operationalizing of the small-scale seed enterprises.
- ***Identifying target areas***: Local seed business should target areas where (a) farmers are lacking access to improved crop varieties and seeds due to non-functional formal sector, (b) less favorable, remote and isolated areas with limited infrastructure, and (c) resource-poor small-scale farmers with limited opportunities.
- ***Identifying and selecting farmers***: participating farmers must be interested and committed in setting up seed business; and must have reputation in the community, experience in farming and seed production, relatively better land holdings, possession of key facilities, entrepreneurial skills and financial resources.
- ***Forming seed producer groups***: farmers should take full responsibility for forming the group and take ownership and elect their own leaders whereas partners would facilitate, provide guidance and advice. Farmer participation and empowerment are key elements of the program.
- ***Selecting seed production sites***: the land selected must be suitable for quality seed production: better/fertile soils, reliable rainfall (or irrigation), free of or low incidence of diseases, pests and parasitic weeds, proximity and accessibility to main roads/facilities.

- ***Preparing a business plan***: develop business plan that serves as a guide to the enterprise products (crops, varieties), potential markets, costs, sales and profits. It also includes risk assessments and details of ownership, management, legal structure, staff, equipment, and the budget.
- ***Producing and marketing seed***: all seed production and marketing operations are carried out by the members of the FBSE. Promotional efforts and marketing are prerequisite to ensure success.
- ***Quality assurance***: ensure that all seed production, processing and storage follows a ‗good practice' to produce quality seed and possibly meet certain agreed standards such as Quality Declared Seed (QDS).
- ***Managing the enterprise***: farmers should take full responsibility and assign people managing the day to day activities of the enterprise.

Key elements for success of small-scale seed enterprises

Several authors described the requirements for the successful development of farmer-based smallscale seed enterprises (Kugbei and Bishaw, 2002; Bishaw and van Gastel, 2008; Neate and Guei, 2010; Khanal, 2013). Establishing and nourishing small-scale seed enterprises for chickpea seed delivery should require the following key issues:

Enabling policy and regulatory environment: currently, most of the seed used for planting in developing countries comes from the informal sector. Despite this fundamental fact few countries have recognized and elaborated the importance of informal sector in their national seed policy and strengthening it as complimentary approach to formal sector. The Ethiopian national seed policy is probably the first with explicit statement of the role of informal sector in its nationals seed supply

(Bishaw *et al*, 2008). There are restrictive legislations and bureaucratic mindset which equates seed from the informal sector with ‗inferior quality' and argue that any farmer-based seed production should be ‗qualified' within the norms and standards of formal sector or otherwise not used as seed. This is even true in circumstances where there is no formal seed production from either the public sector or the private sector. Several authors long argued for a policy environment which should recognize the complimentary roles of formal and informal sector and devise a strategy to equally support both systems and create space for strengthening the informal sector (Alemkinders and Louwaars, 2002; Bishaw, 2004; Louwaars and de Boef, 2012; Thijssen *et al*, 2008). Such policy support would enable the establishment and operationalization of alternative chickpea seed delivery systems from the grassroots levels and nurture its growth.

Development of realistic business plans: poor management and inadequate initial planning are often major causes of business failure (Bishaw and van Gastel, 2008). The most important step in the establishment of the seed enterprise is the preparation of a realistic business plan. Each seed enterprise prepares and adopts a business plan which is the road map for the entire business. It describes in detail all aspects of the business, including physical, human and financial resources. A feasibility analysis of the small-scale seed enterprise will also shed some light on the success of the business.

Existence of regular demand and market for quality seed: farm-saved seed is the major competitor of any seed purchased from external sources, formal or informal sector. Regular choices for source seed are influenced by search for new varieties, lack of capacity to produce quality seed on farm or trust of the quality of seed on the market,seed prices, output prices, etc. Farmer seed enterprises should consistently produce better quality seed than farm-saved seed and provide additional services such as inoculants and treatments for chickpea. Quality Declared Seed could be used as an alternative to centralised certification providing producers more responsibility for the seed quality.

Field days can help create awareness and demand for new varieties and quality seed and branding the products would help promote the seed market among farming communities. Linkages should be created with extension services and development agencies in informing farmers on the availability of varieties and seeds. Apart from field days, weekly village markets, public meetings or ceremonies should be adopted within their rural setup.

Availability and access to improved varieties & technologies: NARS made substantial investments in generating new improved varieties and technologies. However, farmers are the final decision makers whether to adopt or not to adopt the new technologies. Therefore development of farmer and consumer preferred and well adapted varieties and associated production technologies are the prerequisites for the success of the seed sector. For example, in India‘s rainfed rice fallow lands grain yield, early maturity and disease resistance were the most preferred traits by farmers, but selection of chickpea genotypes over time and location, indicated a preference for diverse improved varieties (Ghosh *et al*, 2014).

It is anticipated that small-scale seed enterprises should have unfettered access to source (basic or foundation) seed of improved varieties from public agricultural research systems. Access to seed of new varieties would give the enterprises a competitive edge and create demand instead of already existing commercial varieties where farmers continue to use farm save seed. Given the time lag between variety release and availability of seed in farmers‘ fields, NARS should make sufficient effort in early generation seed production and equally distributingto all existing enterprises.

Entrepreneurship, technical skills and capacity: within communities there are resourceful farmers which are open to ideas, keen to innovate, ready to collaborate and take leadership to coordinate, above all willing to take risks to engage in seed business. Seed business is unique by its very nature and requires successful management of physical, financial and human resources to provide farmers with the quality and quantity of seed at the right time and place and at prices they are willing to pay. Therefore farmer entrepreneurs should receive adequate training in technical skills of quality seed production, processing and storage and managerial skills to run the seed business including financial management. It was found that better governance and leadership of community seed production has positive impact both on economic return and seed sales by the group (Khanal, 2013). Equally important is that also all staff of relevant stakeholders acquires the required knowledge and skills to provide the necessary support.

Access to financial resources for capital & operations: access to financial resources is crucial both for capital and operational costs. Farmer-based small-scale seed enterprises require finances for purchase of capital items such as farm machinery for seed production, cleaning and treating equipment to improve seed quality and adequate seed storage facilities. Operational costs are required for seed production, processing, marketing, etc. Farmers need access to low interest rate rural credit facilities for seed business and should receive incentives similar to other enterprises.

Enterprise ownership and profitability: farmers should be encouraged to take ownership of the seed enterprises, to commit resources, and to take responsibility for managing it. Farmer groups should be initially trained and encouraged to operate the enterprises independently. The sustainability of enterprises can only be assured if farmers have sufficient incentives and make profit to continue with seed business. The ultimate aim is to support the establishment of small, sustainable, and profitable seed companies that will provide quality seed of a range of crops and varieties to farming communities.

Monitoring and evaluation: the success of VBSEs depends on farmers‘ willingness to acquire the skills and knowledge necessary to own and manage the seed production and marketing enterprises. To measure their progress and to critically analyze the constraints, it is important to develop performance indicators. Lessons learned can be used to develop alternative strategies that take into account local conditions.

Support and linkages with stakeholders

The formal and informal sectors co-exist and are not mutually exclusive. Understanding their strengths and weaknesses and linking them would provide opportunities for improving the effectiveness and efficiency of both systems (Alemkinders and Louwaars, 2002). Access to business skills, financial services, quality control, and source seed, and benefit sharing among members are important institutional issues for sustainability of enterprises (Khanal, 2013). Key aspects of partner support are described below and shown in Fig 1 (Bishaw and Niane, in press):

- ***Sourcing seed and other inputs***: Partners help the enterprises to source early generation seed of the varieties most adapted to their areas from conventional or participatory breeding programs. Similarly, partners may assist the enterprises to source the inputs (such as fertilizers and pesticides) required for quality seed production.
- ***Producing seed***: Partners provide training, guidance and assistance, to ensure that enterprise members have the skills and knowledge necessary to produce seed that meets quality standards.

- ***Processing and storing seed***: VBSEs assisted to ensure that they are able to acquire simple low-cost mobile cleaner and treater prototypes. Partners will also help enterprises build appropriate central seed storage facilities.
- ***Ensuring seed quality***: Partners will train farmer members to carry out field inspections and simple seed quality tests or through provision of services by the formal sector.
- ***Marketing seed***: The marketing strategy includes promotional activities through on-farm demonstrations of new varieties, organizing field days for neighboring farmers, branding and market information provided through extensions services, and NGOs.
- ***Accessing credit***: VBSEs need access to credit for purchasing field equipment, inputs (e.g. source seed, fertilizers and pesticides) and seed-handling equipment (e.g. cleaning, treatment, and packaging).
- ***Building capacity***: Training will be implemented to build, step-by-step, farmers' technical (planting, harvesting, cleaning, treatment, testing and storage), financial and enterprise management skills (day-to-day operation of seed enterprises, record keeping, developing business plans).
- ***Establishing network of seed enterprises***: Local seed enterprises are assisted to establish a network to link with input providers, facilitate information exchange and sharing experiences.
- ***Linking with local agro-industries***: Linkages between grain producers and local agro-processing industries stimulates the use of better technology, creating demand for the use of quality seed.

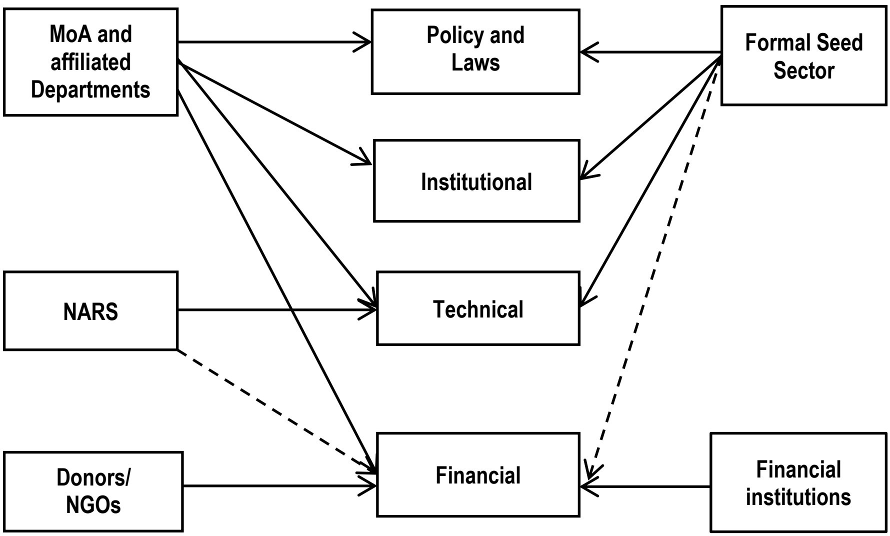

Figure 1: Key stakeholders supporting local seed enterprises (Source: Bishaw and Niane, in press).

Conclusion

To date, there is no well-functioning seed system for food legumes in general and chickpea in particular. Neither the public sector nor the private sector has been able to provide farmers with sufficient quantity of seed of adequate quality. Cognizant of the limited role of organized chickpea seed sector, efforts should be made to mobilize and organize alternative seed delivery systems to fill the gap. In search for establishing a profitable and sustainable farmer-based small-scale seed enterprises, three important pillars, technical, institutional and economics need to be coupled and strengthened. Every effort should be made so that the critical steps for formation, key elements for success and required linkages and support are adequately addressed.

On the other hand, there is also a limited knowledge on the extent of adoption of improved varieties and demand for seed at the farm level. Despite huge investments in technology transfer of chickpea in some major growing countries, we have yet to see a sustainable chickpea seed system established other than chickpea seed production and distribution with farmers. It is important to undertake the seed value chain analysis to understand the overall policy, regulatory, institutional and technical constraints and develop policy recommendations to address the critical gaps in the chickpea seed system. This could help in strengthening the organized formal sector to play its role.

References

Almekinders, CJM and Louwaars NP (2002) The Importance of the Farmers' Seed Systems in a Functional National Seed Sector, *Journal of New Seeds*, **4**:1-2, 15-33.

Bishaw Z and Niane AA (in press) Is farmer-based seed enterprise profitable and sustainable? Experiences of VBSEs from Afghanistan. *In* Proceedings of the workshop on Community Seed Production, Addis Ababa, Ethiopia. ICRISAT, Patancheru, India.

Bishaw Z and van Gastel AJG (2008) ICARDA‘s approach in seed delivery for less favorable areas through village-based seed enterprises: conceptual and organizational issues. *Journal of New Seeds,* **9**(1): 68-88.

Bishaw Z, van Gastel AJG and Gregg BR (2008) Sustainable Seed Production of Cool Season Food Legumes in CWANA Region, 231-257 pp. *In* Proceedings of the Fourth International Food Legumes Research Conference (IFLRC-IV), October 18–22, 2005, New Delhi, India (ed. Kharkwal, M. C.). ISGPB, New Delhi, India.

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

Byerlee D and White R (2000) Agricultural systems intensification and diversification through food legumes: technological and policy options. p. 31-46. *In* Knight R (ed.) Linking Research and

Marketing Opportunities for Pulses in the 21st Century. *Proc. Third Int. Food Legumes Research Conf*., 22-26 September 1997, Adelaide, South Australia. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Gareau RM, Muel F and Lovett JV (2000) Trends in support for research and development of cool season food legumes in the developed countries. pp. 59-66. *In* Knight R (ed.). Linking Research and Marketing Opportunities for Pulses in the 21st Century. *Proc. Third Int. Food Legumes Research Conf*., 22-26 September 1997, Adelaide, South Australia. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Garzón JM (2013) The Production of Chickpea in Argentina: Current Status and Perspectives. Jornada de Actualización Técnica del Grupo CREA Córdoba Norte, Laguna Larga, Córdoba (Argentina), April 2013.

Gaur PM, Jukanti AK, Srinivasanand S and Gowda CLL (2012) Chickpea *(Cicer arietinum L.)*. In: Breeding of Field Crops. *Agrobios* (India), Jodhpur ,India, 165-189 pp.

Ghosh *et al* (2014) Participatory varietal selection of chickpea in rainfed rice fallow lands of Chhattisgarh and Madhya Pradesh in India for sustainable crop production. *International Journal for Plant Production*, **8**(2): 243-254.

FAO (2007) Promoting the Growth and Development of Smallholder Seed Enterprises for Food Security Crops: Case studies from Brazil, Côte d'Ivoire and India. FAO Plant Production and Protection Paper 201. FAO, Rome, Italy.

Khanal NP (2013) Sustainability of Community-Based Rice Seed Production: A Case Study in the Tarai Region of Nepal. PhD thesis, Hiroshima University, Hiroshima, Japan.

Kugbei S and Bishaw Z (2002) Policy measures for stimulating indigenous seed enterprises. *Journal of New Seeds*, **4**(1/2) 47-63.

Louwaars NP and de Boef WS (2012) Integrated seed sector development in Africa: a conceptual framework for creating coherence between practices, programs and policies. *Journal of Crop Improvement*, **26**:39-59.

Neate PJH and Guei RG (2010) Promoting the Growth and Development of Smallholder Seed Enterprises for Food Security Crops. FAO, Rome Italy.

Srinivas T, Bishaw Z, Rizvi J, Niane AA, Manan AR and Amegbeto K (2010) ICARDA's Approach in Seed Delivery: Technical Performance and Sustainability of Village-Based Seed Enterprises in Afghanistan. *Journal of New Seeds*: **11**(2): 138-163

Thijssen MH, Bishaw Z, Beshir A and de Boef WS (2008) (eds.) Farmers, seeds and varieties: supporting informal seed supply in Ethiopia, Wageningen International, Wageningen, the Netherlands. 348 pp

Sahlu Y, Simane B and Bishaw Z (2008) The farmer-based seed production and marketing scheme: lessons learnt, 33-46. *In* Thijssen MH, Bishaw Z, Beshir A and de Boef WS (eds.) Farmers, seeds and varieties: supporting informal seed supply in Ethiopia, Wageningen International, Wageningen, the Netherlands.

23. The chickpea seed system and marketing in Ethiopia: challenges and opportunities

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Seeds of improved chickpea varieties have resulted in yield increase of three to four folds over local varieties; thus, investing on improved seed is a critical step and catalyst for agricultural transformation. Over 24 chickpea varieties have been released in Ethiopia since 1962. Despite the availability of a number of dependable cultivars, the adoption level of these verities and use of improved seeds thus far have been very limited. As a result, there is huge gap between the national average productivity and the productivity levels attained by some innovative model farmers. The majority of smallholder farmers who grow chickpea as major crop have limited access to improved seed and many of the released varieties with superior traits have not yet been widely disseminated. This is mainly due to limited involvement from the public and private seed sectors in the production and supply of improved seeds. The main actors in the formal seed system are the existing parasternal seed enterprise at the federal level - the Ethiopian Seed Enterprise (ESE) and the regional seed enterprises who have played dominant role in promoting improved crop technologies. Overall, the performance of the formal sector is very poor in terms of supplying improved chickpea seeds, and the informal sector remains the dominant and almost the sole supplier of improved chickpea seeds. The current finding suggests that the informal sector need to be further strengthened, through (i) increasing the involvement of the public/ parastatal enterprises in the production and marketing of chickpea seeds, (ii) strengthening community-based seed production by organizing farmers for collective action, (iii) focusing on the promotion of market-preferred chickpea seed classes (types, seed size & color) (iv) synergizing the co-existence of the two seed systems and maximize their interactional benefits in the Ethiopian seed systems.

Key words: Improved seed, demand vs supply, seed systems, Ethiopia

Introduction

The primary role that agriculture plays in Ethiopian socio-economic and political stability makes measures of agricultural productions extremely sensitive. Cognizant of this problem, the Ethiopian Government has launched the so called ‗Agricultural Development Led Industrialization' strategy since 2006, which gives high recognition and focus to commercialization including working towards doubling of the agricultural products through intensification of resource utilization and improvement of technical efficiency of smallholder farmers.

There is tremendous achievement in developing crop technologies that can boost productivity and production of crops in the country. There is, however, limited progress in placing those technologies at farmers' field and registering significant progress. Seed is a key input for improving crop production and productivity. Increasing the quality of seeds can increase the yield potential of the crop by significant folds and thus, is one of the most economical and efficient inputs to agricultural development. In the current Ethiopian crop production, seed is serves as vehicle for promotion of improved crop technologies.

Chickpea is becoming one of the major income security and export earning crop in the farming systems of Ethiopia. This crop has considerably shown significant economic benefits to small-scale farmers because of its relatively higher productivity and market values as compared to high input demanding other field crops. As a result, it has received due emphasis in promotion of agricultural production in Ethiopia. However, supply of improved seeds in the required volume and quality of this crop in the country is identified as one of the major bottlenecks of increasing productivity and production. Except very few farming communities with closest proximity to research centers, the majority of smallscale farmers usually do not have access to appropriate technologies mainly due to weak seed production, distribution, and marketing chain in the country.

The low adoption rate of chickpea in the country is mainly the result of limited supply of improved varieties and lack of extension services impeding the knowledge of smallholder on proven production practices and benefits of diversification. The other constraint is related to lack of market-led demand creation, particularly the price instability that led to weakened trust between the producer side and the market side following declining market returns.

So far, about 26 improved chickpea varieties have been developed and released in Ethiopia since 1972 but mny of the popular varieties don‘t fully possess the ideal combination of high yielding, marketable traits, and wide scope adaptation. Despite the availability of a number of dependable cultivars, the adoption level of these verities and use of improved seeds thus far have been very limited. As a result, there is huge gap between the national average productivity and the productivity levels attained by some innovative model farmers. The majority of smallholder farmers who grow chickpea as major crop have limited access to improved seed and many of the released varieties with superior traits have not yet been widely disseminated. This is mainly due to limited involvement from the public and private seed sectors in the production and supply of improved seeds. Coverage of improved seeds is growing from time to time and currently is about 25% of the annual chickpea production. But, potentially it can reach up to 70-75% considering 25-30% coverage will be maintained for landrace germplasm conservation system. This means that, though it has shown an increasing trend, the majority of Ethiopian smallholder farmers are still relay on genetically low yielding local cultivars.

Overview of the Ethiopian seed system: general outlooks

In the current Ethiopian context, the lack of access to seed of improved varieties was particularly identified as a key hurdle to the adoption of pulse crops as farmers were observed recycling seed for many seasons without getting significant yield increase. The national seed systems can be grouped into two broad categories: the formal and informal seed sectors. In Ethiopia, the formal and informal sectors co-exist and the partition between the two is imprecise and depends mainly on the type of the crop (cross- vs self-pollinated) and type of seeds (hybrids and OPVs) (Bishaw *et al*., 2008). The general overview of the Ethiopian seed systems are briefly described in the succeeding sections.

Formal Seed System: historically, the Ethiopian formal seed sector came into picture with the establishment of agriculture-affiliated higher learning institutes (HLIs) such as Ambo Agricultural School in the late 1930s, Jimma Agricultural and Technical School in 1942, and the then Alemaya College of Agriculture in 1954. Meanwhile, the sector became to some extent operational following the establishment of the then Institute of Agricultural Research (IAR) – now the Ethiopian Institute of Agricultural Research (EIAR) in 1966 (Bishaw *et al*., 2008). In the course of these periods, the system has evolved in various aspects, and has increased its operational capacity with the establishment of the first public seed enterprise, Ethiopian Seed Enterprise (ESE).

Nowadays, the sector has involved other key players engaged in cultivar development (such as the RARIs, and additional HLIs who at the same time engaged in variety release, production and maintenance foundation (mainly breeder and pre-basic) seeds. Mass-production of basic and certified seeds is theoretically the mandate of the parastatal and private seed companies (ESE, OSE, ASE, SSE, etc.). The formal seed systems are intentionally constructed, involving a chain of activities leading to clear, quality and traceable products called –certified seeds” of verified varieties (Louwaars, 1994). The formal sector comprises variety development, evaluation, release; and its commercialization through large-scale certified seed production and marketing to farmers. In commercial agriculture, the formal sector is predominant and characterized by use of certified seed of known varietal purity and identity and physical, physiological and health quality. Farmers are accustomed to use of inputs including repeated and regular purchase of certified seed with main objective of maximizing crop yield and profitability. Major chickpea producing countries such as Australia and Canada has a well-developed chickpea seed sector because of its market-oriented and export-led production with strong public-private partnership where both the government and the private sector are funding the agricultural research and variety development and commercialization.

Informal Seed System: the formal system is supplying not more than 20% of the demanded seeds in a season. The bulk of the informal seed system is often considered as farmer-saved seeds, and the informal and intermediary systems taking the lion share of supplying improved seeds to farmers. The major actors in this system are individual farmers (through farmer-to farmer seed exchange) and farmers' organizations, cooperative associations, and unions involved in seed production. The intermediary system comprises community-based seed production, non-governmental organizations affiliated to agricultural input supply, humanitarian emergency seeds, local seed business and informal interventions of the public sectors. The formal system also include, mixed public-private seed sectors, entirely public or fully commercial seed sectors including federal , regional and international companies involved in seed production and marketing in Ethiopia.

Farmer-to-farmer seed exchange: farmer – farmer seed exchange is the major informal system playing unsubstituted role in the expansion and supply of chickpea technologies throughout the chickpea growing areas. Farmers preserve seeds not only for their own but also for exchange with other producers at planting time based on whether the new cultivars have better merit. Seeds are exchanged home to home or in the market in kind or using monetary values, and this system ensures long-term preservation of a given crop variety under the community as well as country levels.

Co-existence of both systems: integration for synergized seed system in Ethiopia: the unique feature of the Ethiopian seed system is that the two major seed systems are co-existing and operating simultaneously. Yet, the informal and intermediary systems are taking the lion‛s share of supplying improved seeds to farmers. The role of farmers‛ cooperatives and unions in seed multiplication and distribution is increasing from time to time. They are already engaged in seed production, cleaning and trading of non- inspected seed of self-pollinated crop varieties with technical support from bureaus of agriculture (BoA) at district (woreda) level. In addition, they are sporadically producing seeds by contracting individual farmers and seed producers. This system has also helped in enhancing seed production capacity of the formal sector.

Furthermore, the chronic shortage of seed supply coupled with poor access to improved chickpea seed has generated the development of an alternative and innovative seed production and delivery system termed as the ―community-based seed multiplication and marketing" (CBSM). CBSM operates neither purely as commercial seed business nor as traditional way of farmer-managed – it occupies the space between the traditional and the commercial seed production systems. The CBSM responds to the immediate demands of the resource poor farmers and is of particular importance with regard to improving the availability of seeds in time and space, and reducing cost of seed by avoiding some of the transaction costs. Thus, a well functioning CBSM scheme can be considered as a complementary to the formal seed sector.

The farmer-based seed production is an arrangement in which the public seed enterprises and the NARS provide a startup (foundation) seeds either to individual farmers or group of farmers organized into crop-based specialized clusters. These enterprises also offer the basic training on the principles of seed production. The training includes among others the basic principles of seed production, field/site selection, and how to establish farm-clustering. Eventually, the enterprises will purchase the seeds after harvest with the addition of 15% premium on the market prices.

Stimulated by the fast agricultural development growth over the last ten years, demand for improved seed is increasing rapidly from time to time in the country. The overall annual average seed requirement for cereals, pulses and oil crops is estimated to be over 400,000 tons (Thijssen *et al.*, 2008). However; the average yearly supply of improved seed doesn‘t exceed 20,000 tons since the establishment of ESE. In the recent years, following the establishment of several private and public seed enterprises by the regional governments increased the number of actors involved in the seed sector. The Ethiopian government took the initiatives of organizing and bringing together those actors and combining their efforts to increase improved seed supply in the country.

As a result of shift in seed multiplication strategy, production and supply of improved seeds particularly that of hybrid maize and wheat was considerably improved since the last five years (Abebe and Lijalem, 2011). Determination of farmers seed demand followed by demand-oriented seed multiplication and supply is one of the strategies undertaken. Besides, increasing the number of actors involved in the seed businesses is another key initiative of the government in support of the seed system. Among others, establishment of regional public seed enterprises and offering special supports to the private seed sector can be mentioned as typical examples. As a result, for the last seven years both the seed demand and supply of improved varieties were very much improved (Figure 1).

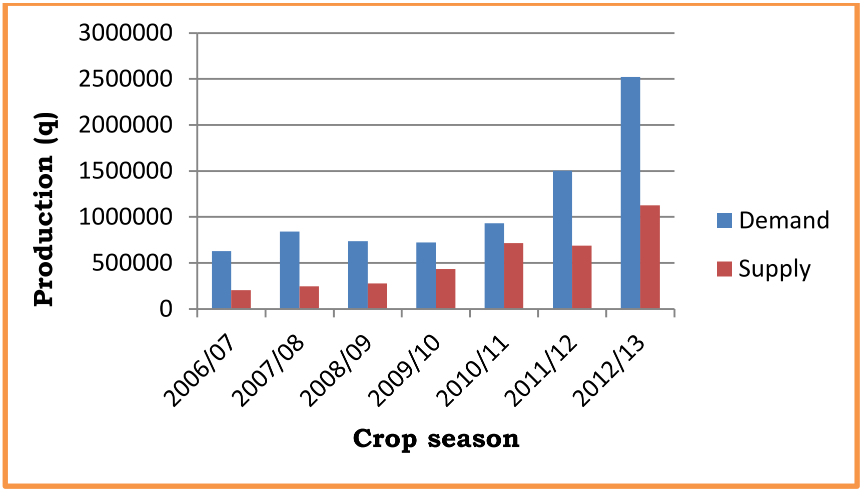

Fig. 1: Demand and supply trends of major (self-pollinated) crops.

Chickpea seed supply and distribution

Chickpea plays an important role in the Ethiopian farming systems as source of food for human consumption and feed for livestock. It is a cheap source of protein for resource poor farmers supplementing the cereal-based diets particularly in rural areas. Chickpea like any other legumes is also important break crops and grown as rotation crop in predominantly cereals-livestock production systems. It also improves soil physical properties and maintains soil fertility by fixing atmospheric nitrogen particularly under vertisol crop production systems.

Despite its economic importance, relatively little attention has been given to seed supply of food legumes in general and chickpea in particular compared to cereals which are considered ‗strategic' food crops. Moreover, research in legumes is relatively new compared to cereals both at IARCs and NARS (Aw-Hassan *et al*., 2003). Even where national and international research centers have made some significant progress in developing new chickpea varieties, the availability of, access to and use of quality seed remain a major challenge certainly in many developing countries.

Seed supply: in Ethiopia, the formal sector supplies about 2% seed requirements of the major cool season food legumes such as chickpea, and that amount is mostly provided by the ESE (Bishaw *et al* 2008). The NARS (EIAR and RARIs) produces and supplies basic seed; and ESE produces and distributes certified seed based on the official demand projection of the regional bureaus of agriculture. The informal seed systems (self-saved seed or farmer-to-farmer seed exchange) accounts for over 95% of the chickpea seed used by smallholder farmers.

In many developing countries like Ethiopia, legume production including chickpea is practiced as subsistence and mostly produced by small-scale farmers under rainfed conditions mostly for home consumption with little surplus for market. Empirical evidence and practical experience shows that the legume seed sector in general and that of chickpea in particular remain weak in many developing countries. A simple review of the chickpea seed sector in the country clearly demonstrates the predominant role of public sector institutions in agricultural research, variety development and seed supply and the complete absence of the private sector. The public sector remains inefficient and ineffective in chickpea seed delivery.

In commercial agriculture, the formal sector is predominant and characterized by use of certified seed of known varietal purity and identity and physical, physiological and health quality. Farmers are accustomed to use of inputs including repeated and regular purchase of certified seed with main objective of maximizing crop production. Major chickpea producing countries such as Australia and Canada has a well-developed chickpea seed sector because of its market-oriented and export-led production with strong public-private partnership where both the government and the private sector are funding the agricultural research and variety development and commercialization.

In major chickpea producing developing countries subsistence agriculture is practiced where farmers produce for consumption and there is little surplus for market. There is lack of integration between research and transfer of technology, and farmers generally depend on seed from the informal sector.

Despite numerous efforts have been made in promoting and distribution of improved chickpea varieties in major growing areas, the adoption rate was found to be limited, especially for market-preferred *kabuli* types. For example, in Ada'a district farmers were reluctant to adopt the kabuli types in fear of theft problem for green pods and market issues unlike farmers in Akaki and Gimbichu. Hence, adoption in Ada was insignificant compared to others (Table 1). However, since 1991 varieties like Arerti and Shasho were released with their unique merits of solving the extremely aggressive diseases scu as ascochyta blight, which somehow has improved the demand for improved chickpea technologies in the areas.

Table 1. Proportion of improved chickpea varieties in some selected districts of East Shoa Zone

Chickpea area coverage	District					
	Ada		Akaki		Gimbichu	
	2005/6	2006/7	2005/6	2006/7	2005/6	2006/7
Area under chickpea (ha)	4346	4938	6070	5963	2008	1984
Improved chickpea (%)	4.2	2.8	85	85	73.7	67.5
Local chickpea (%)	95.8	97.2	15	15	26.3	32.5

Coverage of improved seeds is generally growing in some specific areas from time to time and currently is about 25% of the annual chickpea production. But, potentially it can reach up to 70-75% considering 25-30% coverage will be maintained for landrace germplasm conservation system. This means that, though it has shown an increasing trend, the majority of Ethiopian smallholder farmers are still relay on genetically low yielding local cultivars.

Seed distribution (marketing): though, there is somehow formal institutional setup for seed distribution and marketing, its operational administration is usually run by an ad hoc National Seed Production and Distribution Committee (Dawit,. *et al*. 2010) together with the Agricultural Inputs Directorate and the Animal and Plant Health Regulatory Directorate of the Ministry of Agriculture.

Under the current seed system, the marketing of seed is coordinated by both the federal Ministry of Agriculture (MoA) and regional bureaus of agriculture (BoA) and it is made mainly through cooperatives. The only exceptions to this set up is the case of Pioneer Hi-Bred, SEDCO and other private seed companies who use their own strategies of parental seed maintenance and marketing channels for certified seeds. Mostly the seeds that are available are for major grains like maize and wheat. These public seed enterprises dominantly get the seed through contractual arrangement with both public and private seed producers. The seed quality control under the current institutional setup is the responsibility of the Animal and Plant Health Regulatory Directorate (APHRD) of the federal MoA and the responsible organs of the respective regional BoA.

Seed demand and supply: matches and mismatches

Analyzing the demand, supply and distribution of seed during 2007/08 – 2011/12 in the country one can easily note the mismatch between the planned and what actually supplied. The trend in seed supply fall behind the demand and what is supplied every year is in short almost by half to what is demanded. However, the last three years trend showed that the supply and distribution of seeds were very much improved. This increase in supply side associated with the crash seed multiplication program that has been implemented by the government of Ethiopia since 2009.

The data indicated in the figure below shows problems asscociated with poor demand assessment methods, which is also reflected by a considerable amount of seed leftovers each year. The other reason for the leftover of seed (hybrid maize variety, BH-660 for instance) was attributed due to late on-set of of the rain in the season that forced farmers to shift to early maturing crop varieties (Fig. 2).

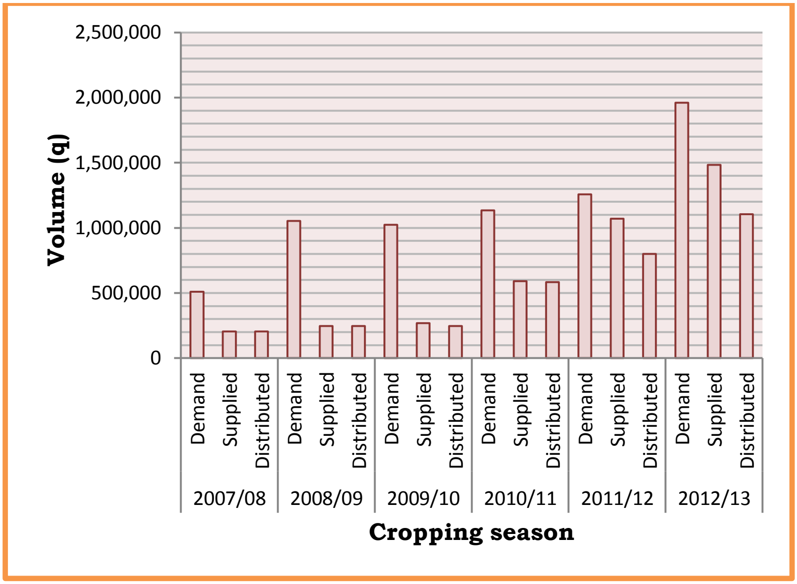

Fig. 2. Demand and supply of certified seeds of major crops between 2007/08 and 2012/13 cropping seasons.

Some of the critical weaknesses of seed supply and distribution process in the country are: i) lack of competitive seed distribution system among seed producers, ii) low accountability and traceability for seed quality deterioration, iii) long distribution chain and lack of credit facilities.

Pre-extension demonstration activities promoted by the NARS have been a key incentive for all three clusters to engage in the production of seed for a wide range of crops and varieties. The most successful example in this regard is the nation-wide pre-extension and pre-scaling-up activities initiated by the NARS in promoting shelfed varieties, which has generated considerable demand accross growing areas of the country. This in turn has created good opportunity for different actors of the seed sector. Furthermore, it also ignited the emergence of more than eight officially licensed primary cooperatives since the last five years, and these coops are engaged in improved chickpea seed production of different varieties based on farmers demand (Table 2). These actors will continue playing the major role in supplying the majority of chickpea seeds demanded in years to come in the entire growing areas of the country.

The role of major actors in the chickpea seed supply chain

The formal seed system is called formal because it is government supported system and several public institutions are involved on it. The major actors of the formal system are: National Agricultural Research System (NARS), Ministry of Agriculture (MoA) ESE and private seed companies specializing on specific crops like Pioneer Hi-bred. Recently, regional seed enterprises (RSE) were also established as public seed enterprises (such as Oromiya Seed Enterprise-OSE, Amhara Seed Enterprise-ASE and Southern Region Seed Enterprise-SRSE) and entered into the formal system. All actors have inter-dependent roles in the system and inefficiency of one actor will automatically affect negatively the performances of the rest of the actors. NARS (EIAR & RARIs) is responsible for variety development and supply of initial seed, and ESE and RSEs are playing key roles in mass production of improved seeds. MoA is also involved in variety release, multiplication, certification and distribution of seeds in the country. Private seed growers and other farmer institutions such as unions and cooperatives are also playing key roles in multiplication, certification and distribution of different classes of seeds. Legal institutions such as variety release procedures, intellectual property rights, certification programs, seed standards, contract laws, and law enforcement are also an important component of the formal seed system of any country.

Moreover, research centers, universities, NGO, private (pioneer Hi-bred, SEDCO), seed dealers (special for vegetable seeds) participate in seed distribution in the regions. They mainly deal in filling agro-ecologies, crops and varieties gap unaddressed by the public seed enterprises. Majority of the farmers purchase seeds on cash basis, while few farmers (~10%) may purchase seed on credit basis with 25-50% down payment or without down payment. The cooperative union collects the money from sales of seeds and deposit to Bank to settle the credit of BoA.Within the context of the national seed system, the federal seed supply and distribution system follows procedure that includes (i) allocation of produced seed by region level, ii) appropriation of produced seed by zone and district level, (ii) engagement of cooperative unions and primary cooperatives in the distribution, and (iii) price setting and sales to farmers. Regional Bureau of agriculture (RBoA) proportionally allocates the produced seeds for Zone Office of Agriculture based on their demand. Then each Zone agricultural office appropriates the allocated improved seeds for their respective districts and authorizes Cooperative Unions to purchase the seeds. The cooperative union supply improved seeds to primary cooperatives by adding cost of transportation and administration costs.

Early generation seed multiplication and supply

The National Agricultural Research System (NARS) is given the responsibility to produce and supply early generation seeds (EGS) of chickpea varieties that are released by the federal public research system. According to the seed production plan, different EGS classes (breeder, pre-basic and basic seeds) were produced in the respective research centers based on the competency and agro-ecological suitability. Most of the national crop improvement programs are coordinated by the federal research centers under EIAR and each program has the responsibility to produce EGS. The Technology Multiplication and Seed Research Directorate (TMSRD) of EIAR is coordinating multiplication of EGS and other research technologies such as livestock and fishery, bio-fertilizers, tissue culture planting materials and farm mechanization prototypes. In addition, the directorate also engages in research activities to generate basic informations towards addressing seed-related problems and enhance tchnological innovation systems in the country.

Annually, about 35,927 tons of seed (at the seed rate of 150 kg ha^{-1}) would be required to cover the estimated area under chickpea production. However, certified seed production of chickpea is negligible; and only 286.2 tons of seed was produced by the formal sector in 2013/14 crop season. This accounts for less than 1% compared to the 25% annual certified seed replacement rate for self-pollinated crops such as chickpea. As a result, alternative efforts are being made under the project in promoting and popularization of chickpea through pre-extension demonstration and technology scaling-up and on-farm seed production working directly with farmers. An acclerated seed multiplication scheme for chickpea is envisaged in implmenting the project including both formal and informal sectors (Fig. 3).

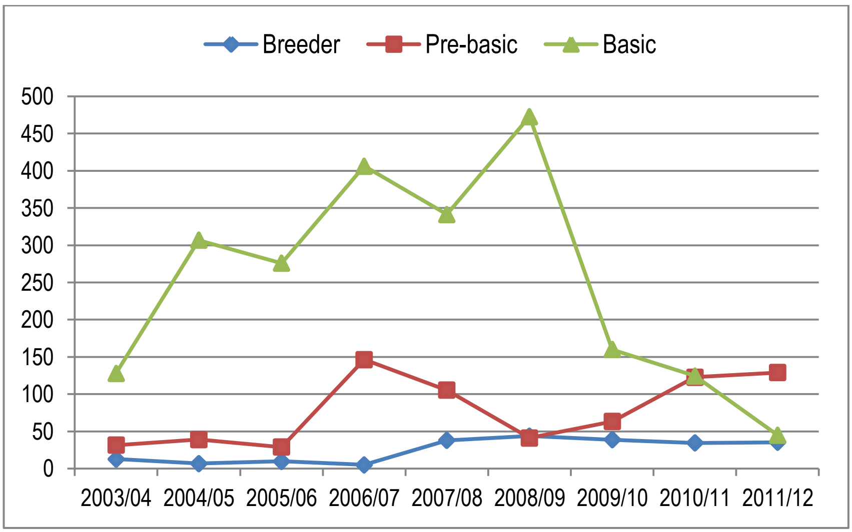

Fig. 3: Volume of early generation chickpea seeds (EGS) supplied by EIAR during the last decade (2003/04 to 2011/12)

Many chickpea varieties have been developed in the NARS, of which only few of them have been picked up by end users. The future research intervention should therefore, give high emphasis towards addressing demand dinamizm in the context of increasing effects of climate change and population growth.

Availability of EGS is one of the major limiting factors in the formal sector, and the NARS has recently been embarked on EGS multiplication using both rainfed (main growing seasons) and supplemental irrigation in the off-seasons. It is also the duty of the NARS to continuously carry out variety maintenance of commercial varieties, breeder and pre-basic seed production thereby to provide sufficient amount of basic seeds to public and private producers for mass production of certified seeds that eventually be distributed to farmers. In addition to their own farms, some research centers (such as Debre Zeit and Holetta) have initiated early generation seed production on farmers‘ fields by organizing seed producing farmer groups. The research centers provide initial seeds (mostly breeder seeds) and technical support to the groups to produce pre-basic/basic seeds which will eventually be purchased back to the respective centers and distributed for next stage of multiplication to large-scale certified seed producers at federal and regional levels. The seed price is determined as per the contractual agreement based on premium price over the previaling grain prices.

In addition to the NARS, some international seed companies have also been involved in providing EGS in Ethiopia. Small-scale local seed companies are generally operating with limited capital and usually don‘t have production and processing facilities, and thus rely on public institutions for EGS supply. Apparently, there is somewhow a similar trend in many other developing countries of the world. In India, for instance, companies may produce their own source seeds of public varieties, or may acquire it from public universities, research institutes or state seed corporations MoA-India, 2012). In Latin America, there are a number of examples of government research services that provide source seed of public varieties to private seed producers. In Brazil, the national research institute (EMBRAPA) provides source seed for hybrids and open-pollinated maize varieties to a group of smallscale private seed companies and co-operatives (Lopez-Pereira and Filippello, 1995). In Argentina, the national research institute (INTA) provides source seeds to a co-operative (PRODUSEM) involved in seed production and marketing (Jacobs and Gutierrez, 1986). The National Research Institute of El Salvador (CENTA) provides source seeds of hybrid maize to private seed companies and co-operatives (Choto *et al*., 1996). In Ghana, the crops research institute is responsible for plant breeding, and an organization called Grains and Legumes Development Board produces source seeds (EGS) and provide to small commercial seed producers (Bockari-Kugbei, 1994).

Large-scale certified seed production

Currently, the federal and regional public seed enterprises (ESE, ASE, OSE, SSE) are the major actors involved in production and supply of certified seeds of chickpea and other field crops. Given the current interest in export market for legumes, there would be an increasing demand for seed of these crop varieties which would stimulate the development of chickpea seed sector.The major bottleneck is consistent flow of breeder, pre-basic and basic seed to ensure supply of certified seed due to inconsistent demand from formal sector. A public-private partnership will be forged to encourage both the public and private sector to play an important role in chickpea seed production and supply. It‘s been found useful to work with private companies engaged on seed (Amuari Seed Production PLC, Yimam Tessema SC, etc). In addition there are licensed farmer seed producer‘s associations (Utuba Jirena, Memhir Ager, Megertu Denkaka, Biftu, Ude, Giche Garababo, Chala, Hundaf Hatau) and farmer cooperatives involved in seed production and local seed business (LSB) entities established and supported by the Integrated Seed Systems Development of the Dutch project and AGRA project. In addition, CGIARs (ICARDA, CIMMYT and ICRISAT) and NGOs (ISSD and

AGRA) are providing targeted technical support in seed production and training in seed business and on advocacy for access to capital and credit services to develop these seed producer associations into private seed enterprises to operate seed business on their own right. Most of the public and private sector enteprsies (to a limited extent including farmer seed producer assocations) do not have enough land to produce certified seed in the quantities needed and are thus producing seed on contract with farmers making them (farmers) double beneficiaries in terms of access to seed and financial rewards as seed growers.

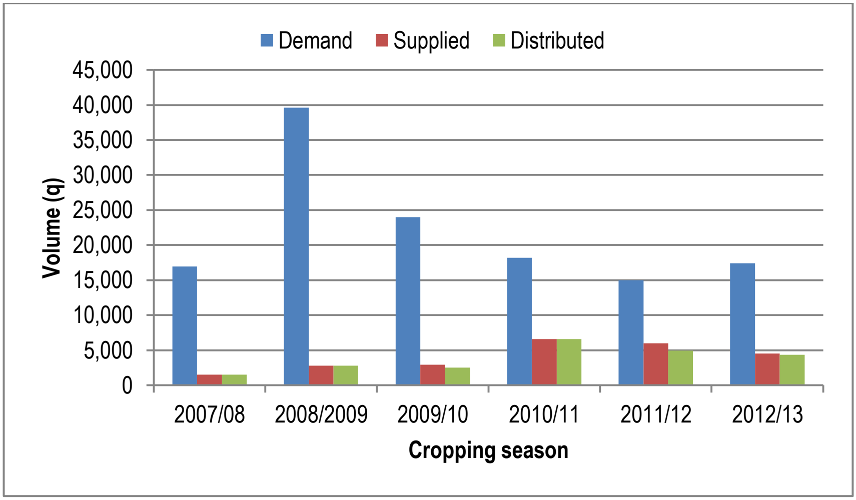

Fig. 4: Chickpea certified seed demand, supply and distribution over the last six years (2007/08-2012/13)

Farmer-based seed production

Currently there are local seed producer groups operating within primary cooperatives and farmer's unions at peasant associations and district levels. Chickpea seed production is undertaken in cluster farms and training is provided to farmers in quality seed production for local sale or exchange and in business skills. These farmer seed producer groups are to district Bureau of Agriculture for techncial support to produce quality seed and to regional public or private seed enterprsies for seed marketing. More importantly in collaboration with regional bureau of agriculture from the existing farmers‘ seed producers some groups are developed into seed producer‘s groups through provision of facilities (mobile seed cleaners, etc) to promote local seed enterprises.

The Ethiopian seed policy recognizes the roles of both the formal and informal seed production particularly ‗quality declared seed‘. The certified seed production by formal sector follows a generation system (breeder, pre-basic, basic and certified seed) where field and seed standards are defined by the Ethiopian seed regulations; and these standards will be adhered to and formal inspection and seed testing will be conducted by the regional seed certification agencies established in different regions. The informal sector farmer-based seed production adopts a ‗quality declared seed‘ approach where producers follow minimum standards outlined in FAO guidelines; and the quality is monitored partly (10%) by official authority and the remaining responsibility is given to the seed producers (90%). Farmer-based seed production are initiated using basic/certified seed from the formal sector with existing unlicensed farmer groups or by organizing and clustering farmers to produce ‗Quality Declared Seed‘ in different regions.

Pre-extension demonstration activities promoted by the NARS have been a key incentive for all three clusters to engage in the production of seed for a wide range of crops and varieties. The most successful example in this regard is the nation-wide pre-extension and pre-scaling up activities of NARS in promoting the new teff variety Kuncho, which has generated considerable demand all across teff-growing areas of the country. This in turn has created a good opportunity for different actors to

The major actors of the informal systems are: About eight officially licensed primary cooperatives emerged since the last five years, and these coops are engaged in improved chickpea seed production of different varieties based on farmers demand (Table 1). These actors will continue playing the major role in supplying the majority of chickpea seeds demanded in years to come.

Table 2. Chickpea seed producing primary cooperatives (Coops) and their existing capacity

Ser No.	Name of Coop	Number of member farmers	Target variety/improved/	Area covered (ha)	Volume of seeds produced (t)	Self-owned seed used (t)	Total volume of seed (t)
1	Megertu Denkaka	95	Arerti, Habru, Natoli	24	96	980	1076
2	Hundaf Haata'u	154	Arerti, Natoli, Teji	35	120	320	440
3	Lemelem Chefe	28	Arerti, Natoli, Teji	7	24.5	450	474.5
4	Hawi Boru	28	Arerti, Natoli, Teji	7	25	380	405
5	Biftu	64	Arerti, Habru, Shasho	16	64	670	734
6	Challa	64	Arerti, Habru, Shasho	16	66	650	716
7	Ude	48	Arerti, Natoli, Teji	12	48	895	943
8	Memihir Ager	44	Arerti	11	44	240	284
Total		**525**	**5**	**128**	**487.5**	**4585**	**5072.5**

Source: *Best Production Management Practices and Application in Chickpea, USAID/Ethiopia, June 2012.*

Seed demand assessment approaches in Ethiopia

Seed system development can be viewed as a dynamic process of matching the supply to the changing demand for seeds. Farmers generally demand seed from the formal seed sources mainly for three reasons: seed replacement, variety change and for emergency response. The approaches and procedures of seed demand assessment in Ethiopia are guided by the overall seed system prevailing in the country along with the key factors involved in the system. The demand for the seeds of the different crop varieties is currently assessed following bottom up approach starting from *Kebele* (peasant association) level towards the national level (Teshome and Dawit, 2012).

Seed demand assessment is usually carried out a season before the actual production season so as to avail seeds of demanded varieties during that season. In Ethiopia, seed demand assessment is undertaken by employing the following procedures: i) collecting demand from individual farmers at *Kebele* level by the development agents (DAs), ii) conducting trend analysis from the past year‘s demand data, and iii) Estimation of hectares of land to be coverd by improved seeds and working out the amount of seed required to cover the area.

Opportunities and future prospects: specific to chickpea seed system in Ethiopia

- The National Improvement Program is making marvelous progress which resulted in the development of best-bit improved chickpea technologies fitting to various agro-ecologies and production systems.
- A continuous increasing of national productivity of the crop and proving the superiority of the improved chickpea production technologies at farmers‘ fields.
- Exceptionally chickpea is fitting to double cropping, crop rotation and irrigation.

- This is a time where cereal-cereal monoculture in some potential production areas is already considered a national threat (at technical and policy levels)
- There is an increased level of awareness among the farming communities and a fertile understanding has already been established as a result of nation-wide promotion and scaling up of high value chickpea technologies already underway farmers, which in turn paved the way for the easy transfer and better adoption of production technologies in the future.
- High and increasing acceptance of improved chickpea seeds (technologies) both in local as well as export markets.

Conclusion and Recommendations

Currently, the chickpea formal seed sector has been supplying very limited portion of seed demand as compared to the informal sector that fulfills the huge seed gap. Thus, the informal system should get due attention and need to be supported through the decentralized farmer/village-based seed production and marketing. Co-existence of the different seed systems should be embraced, not only because they mutually benefit from each other but also from the fact that farmers and their communities cannot depend on one system per se. All systems need to be strengthened and empowered through technical back-ups and quality control of seed production, processing, packaging and marketing. So far, about 18 farmers' seed producer associations involved in chickpea seed production has legally established in the country. On the other hand, the chickpea seed system is constrained by low involvement of the public and private sectors. Thereofre, due attention need to be given to bring community based seed production in to picture by encouraging engagement of innovative farmers into seed production and marketing. This approach is being scaled up to the various chickpea growing areas to make seeds available at farmers' vicinity.

Furthermore, the NARS should implement decentralized initial (breeder) seed production and enhancing production of pre-basic and basic seed classes in the research fields, and expansion under seed producing groups of farmers. It is also critically important to create an effective partnership and linkage between private seed enterprises and seed producer farmer groups towards the production of certified and quakity declared seeds (QDS). Most importantly, seed producing farmers‘ cooperatives should be empowered so that they can advance their current status towards commercial orientation and recognize seed as very favorable business venture.

References

Abebe A and Lijalem K (2011) Recent Development in Seed Systems of Ethiopia. In: Improving Farmers‘ Access to Seed. *Empowering Farmers' Innovation Series*,1(1):13-30.

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 im-provement 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.

Bishaw Z, Sahlu Yand Semane B (2008) The Staus of Ethiopian Seed Industry. In: Thijssen MH, Bishaw Z, Beshir A and de Boef WS (2008) (eds.) *Farmers, seeds and varieties: supporting informal seed supply in Ethiopia*. Wageningen International, Wageningen, the Netherlands, pp.23-32.

Bockari-Kugbei S (1994) The Role of Small-Scale Enterprises in African Seed Industries. Unpublished PhD Thesis, University of Reading.

Choto C, Sain G and Montenegro T (1996) Oferta y Demanda de Semilla Mejorada de Maiz en El Salvador. San Jose, Costa Rica: CIMMYT Programa Regional de Maiz.

Dawit A, Shahidur R, and Rob T (2010) Seed system potential in Ethiopia: Constraints and opportunities for enhancing the seed sector. International Food Policy Research Institute, Washington DC. 62pp.

Jacobs E and Gutierrez M (1986) La Industria de Semillas en La Argentina. Buenos Aires: Centro de Investigaciones Sobre El Estado y la Administracion.

Lopez-Pereira M and Filippello M (1995) Emerging Roles of the Public and Private Sectors of Maize Industries in the Developing World. CIMMYT Economics Working Paper 95-01, Mexico D.F: CIMMYT

Louwaars N (1994) Seed supply systems in the tropics: International course on seed production and seed technology. Wageningen, The Netherlands: International Agriculture Centre.

MoA-India (Ministry of Agriculture of India) (2012) Seed Sector in India. Seeds Division. Department of Agriculture & Cooperation. New Delhi, India. Available at http://seednet.gov.in/ (accessed in October, 2012).

Teshome L, and Dawit A (2012) Approaches and Procedures of Seed Demand Assessment in the Formal Seed Sector. In: Adefris Teklewold, Dawit Alemu, Shiratori Kiyoshi, Abebe Kirub eds. Seed Demand: Assessment Practices, Challenges, and Options. *Empowering Farmers' Innovation* Series, 5, EIAR, Addis Ababa, Ethiopia

Thijssen MH, Bishaw Z, Beshir A and de Boef WS (2008) (eds.) Farmers, seeds and varieties: supporting informal seed supply in Ethiopia. Wageningen International, Wageningen, the Netherlands. 348.

24. Community-based seed system in chickpea: prospects and challenges

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Abstract

The agricultural sector in Ethiopia is largely characterized by smallscale subsistence farming and low productivity. Low productivity is partly due to the limited use of improved seed varieties and associated technologies. The annual potential seed requirement in Ethiopia is estimated to be more than 700, 000 tons, but the formal supply couldn't exceed 20, to thirty thousand tons, of which 80-90% comes from the Ethiopian Seed Enterprise (ESE), representing only 3-6 percent of farmers' actual seed requirement. The supply side is highly skewed to maize and wheat neglecting other major crops like chickpea. The major limitations in chickpea seed system include lack of farmers' preferred varieties, limited capacity of the public seed enterprises and little involvement of the private sector in the seed business. The present seed demand estimation method used by the Inputs Marketing Department of the Ministry of Agriculture is no more than expert estimate. Prospective users particularly were not consulted during the planning phase. The existing market is also supply oriented than demand driven. For small holder farmers, the major constraints are high seed prices and late delivery, exacerbated by poor rural infrastructure making it hard to reach farmers in the rural isolated villages. Access to and use of seeds is critical factors for the ability of smallholder farmers to increase agricultural production and productivity, ensuring food security and improving livelihoods. This paper will try to present the strengths, weaknesses, opportunities and challenges of the CBS system in chickpea based on practical experiences in East Shewa Zone.

***Key words**: Seed, Community Based Seed System, market*

Introduction

The Ethiopian agriculture is characterized by subsistence farming and smallland holdings. Per capita landholdings are smaller in high potential areas inhabited by the majority of framers than in the areas of low potential. The national average landholding for grain crops (cereals, pulses and oil seeds) is only 0.89 ha (CSA, 2012). In Ethiopia, the formal seed production is dated back to the establishment of Jimma Agricultural College (1942) and the then Alemaya Agricultural College (now Haramaya University) and its satellite station of the then DebreZeit Agricultural Experiment Station (now DebreZeit Agricultural Research Center). However, the Ethiopian seed program was very much ad hoc and seed distribution was uncoordinated until the late 1970s. In 1976, the National Seed Council (NSC) was setup to formulate recommendations for organized seed production and supply of released varieties from the national researchsystem. This led to the establishment of the Ethiopian Seed Enterprise (ESE) in 1979 and institutionalized seed production, processing and distribution and quality control of cereals, legumes and oil crops. The Ethiopian Institute of Agricultural Research (EIAR), Higher Learning Institutions (HLIs), the Ministry of Agriculture (MoA) and state farms continued seed production to meet the national demand.Chickpea (*Cicer aritetrium* L.) is the second most important cool-season food legumes, next to faba bean in Ethiopia. The country is the largest chickpea producer in Africa accounting for about 46% of the continent‘s production.There are two commercial classes of chickpea: the desi and the kabuli types. The kabuli type is a recent introduction, while the desi type has a long history of production in the country.

Chickpea covers about 239,512 hectares of land with a national yield of 1.7t/ha (CSA, 2012) which is very low as compared to the yield potential attained in the research plots and some technology adoper farmers‘ field, leaving huge gap in terms of reaching the attainable productivity level.Government, private and commercial seed companies in developing countries able to supply not more than 20% of seed of most food crops (Grossman *et al*. 1991; Cromwell and Wiggins, 1993; Almekinders *et al*. 1994). Such institutions typically produce certified seed in centralized facilities. This figure is even lower for self-pollinated (such as chickpea, common bean), vegetatively propagated crops (e.g. potatoes, sweet potatoes and cassava, and crops having limited seed demand such as forage crops and open pollinated maize cultivars). Crops in these three categories bring little profit to seed companies for several reasons: uncertain and fluctuating demand caused by competition from farm-saved seedsand low multiplication rates (the case of grain legumes), and transportation/ storage difficulties (root and tuber crops) and strong regional or local preferences.

Designing an alternative seed production system, therefore,need to be considered as priority area of intervention towards addressing seed supply bottleneck.The use of improved seeds is at low level (5% of the cultivated area). According to the report on seed marketing study conducted in November 2000 commissioned by the ESE indicated that the potential size of the certified seed market in the county ranges from 75000-100,000 tons/year. On the other hand, the supply is about 20,000 tons (Yonas et al 2008). This huge gap between demand and supply is an indicator that the formal seed sector has limitations in ensureing farmers‘ easy access forimproved seeds.. About 60-70% of seed used by the Ethiopian smallholder farmers is from own farm-saved, while the remaining 20-30% is borrowed or purchased locally (Yonas *et al*., 2008).The share of improved seed is only 10%,and the seed supply market in Ethiopia is dominated by two crops: wheat and hybrid maize making (90% of improved seed supply). Ethiopia is known for its agro-ecological and biological diversity and Ethiopian farmers have a long tradition of settled agriculture, contributing to the evolution and maintenance of the country‘s rich agro-biodiversity.The national seed systems can be grouped into two broad categories: formal seed sector and informal seed sector, and there is co-existance of both systems in the Ethiopian contextThe informal seed system is well-embedded into the agricultural production system of the country. Farmers have been usingthe informal system for centuries: the improvement of farmers saved seeds, farmer-to-farmer seed exchange and farmer managed seed production. The seed production and distribution chain in the informal seed system is not bureaucratic, is short and simple, involving very low transaction costs.Although the formal seed sector was established some five decades back, it still remains limited to a few major crop varieties developed by the agricultural research system. The private sector‘s participation in the seed industry is negligible and limited to hybrid maize. As a result the informal seed sector remains the major supplier of seed of improved and local varieties for many crops grown by smallscale farmers (e.g. chickpea, lentil and tef).

Table 1. Seed Supply ShortfallsSeed Supply shortfalls (2010/11)

Crop	Estimates of quantity demanded (qts)	Quantity Supplied (qts)	Supply as percentage of demand
Barley	9289	2636.7	28.4
Tef	10206.2	2516.6	24.7
F.Bean	3538.1	216.9	6.1
Chickpea	1821.8	447.2	24.5

Table 2: Area covered (_000 ha) by the informal seed sector (2005/06-2009/10).

Crop	2005/06	2006/07	2007/08	2008/09	2009/10
Cereals	7,636.9	8,127.7	8,309.9	8,333.1	7,660.6
Pulses	1,283.6	1,373.9	1,509.4	1,568.5	1,358.4
Oil crops	790.5	736.8	702.5	851.8	706.4
Vegetables	116.3	94.6	118.0	159.6	122.8
Root crops	167.2	186.8	180.6	143.4	183.3
Total	**9,994.5**	**10,519.9**	**10,820.5**	**10,913**	**10,031.4**

Source: CSA, 2005 – 2010

Table 3. Area covered by improved seeds in ha (2005-2010)

Crop	2005/06	2006/07	2007/08	2008/09	2009/10
Cereals	429,536	335,369	412,629	430,937	322,819
Pulses	5,224	5,025	6,309	14,918	12,912
Oil crops	1,833	4,056	2,273	2,328	9,139
Vegetaables	779	559	501	1,899	2,788
Root crops	813	2,114	2,251	799	3,721
Total	**438,185**	**347,123**	**423,963**	**450,881**	**351,379**

Source: CSA, 2005 – 2010

Table 4: Comparison of area coverage (‗000 ha)by the formal and informal seed sector in Ethiopia (2005/06-2009/10).

Sector	2005/06	2006/07	2007/08	2008/09	2009/10
Informal (I)	9,994.5	10,519.9	10,820.5	10,913.0	10,031.4
Formal (F)	429.5	335.4	412.6	430.9	322.8
% I	95.7	96.8	96.2	96.05	96.78
% F	4.3	3.2	3.8	3.95	3.22

The government of Ethiopia is committing necessary resources and technical support to the formal system to tackle the problem associated with seed shortage. Despite the all-round support provided by the government, the formal seed systems could not meet the improved seed demand by the farming community. On the hand, the informal seed system operating with a limited support from the government covers over 90% of the entire seed supply by smallholder farmers. As depicted in Table 4 above the informal seed system covers only 3.2 - 4.35%of the national seed demand,.

Community-based Seed System (CBSS)

The term ―community-based seed production and marketing" implies farmers' ownership of the enterprise, and their responsibility for independently operating it with commercial intent or seed as business. But, in this context, it is used more loosely to describe any form of seed production and supply conducted by group of farmers with great difference in scope and ownership. However, in the Ethiopian context, several approaches are used by the stakeholders involving farmers in local seed production.

In Ethiopia, local seed production ‗projects‘ can be categorized into three class: (1) seed production using contract growers, (2) seed exchange schemes, and (3) farmers‘ seed enterprises (FSE). In the same vein, Yonas *et al*. (2008) categorized local level seed production as: local landrace seed production, landrace improvement, research – based seed production and dissemination to popularize released varieties, contractual seed production by the formal sector and the establishment of local business-oriented seed enterprises. These names are often misleading and lack clarity.

Many of the improved varieties released for production are not known by the majority of smallscale farmers and seed production in the formal sector is restricted to few crop varieties. Moreover, public supported commercial seed enterprises couldn‘t provide attractive options for smallscale chickpea farmers. One of the major reasons for the low adoption of modern varieties by smallscale farmers in developing countries is the incapability of the highly centralized formal seed production system to meet their complex and diverse seed requirements.

The existence of huge seed supply gap as well as uneven access to scarcely available improved chickpea seed has created the development of an alternative and innovative seed production and delivery systems that responds to the immediate demand of the resource poor farmers. Community-based seed production, which operates neither purely as commercial seed business nor as farmer managed ones, has been playing an important role in seed production and supply.. Thus, it occupies the space between traditional and commercial seed production. In this regard, well functioning community-based seed production scheme can be considered as a complementary to the formal seed sector (public or private). In recent years, there have been proliferations of NGOs and research support to local level seed production and dissemination schemes. These activities have a wide range of objectives other than supply of improved seed of modern varieties such as preserving genetic diversity, improving seed availability (time, place, and quantity) and reducing the cost of seed and dependence on external sources.

Under the umbrella of Tropical Legume II (TL-II) project (supported by the Bill and Melinda Gates Foundation through ICRISAT), the DebreZeit Agricultural Research Center designed an innovative approach of the decentralized seed production and delivery system to stimulate and sustain an active engagement of diverse partners. The major stakeholders and ctors include: research centers, regional, zonal and wereda/distric level agricultural offices, district administration offices, farmers, public or parastatal seed enterprises, different organizations affiliated to the community-based seed enterprises (ISSD and others), farmers' cooperative unions and NGOs.

Innovative approaches in community-based seed production

- ***Creation of partnership***: The Partnership was based on shared vision and clearly defined responsibilities and tasks among each of the stakeholders. All stakeholders were involved starting from the planning stage throughout the final implementation. However, the collaboration roles for the partnerships and the regular dailyfollow-ups and supervision of the planned activities are vested upon zonal/wereda agricultural offices and the research centers.
- ***Multiplication and supply of foundation seeds***: Once the farmer preferred varieties are identified from earlier demonstrations, promotion, participatory variety selection(PVS) results, the foundation seed of those varieties will be multiplied and distributed.
- ***Provision of revolving seed loan***: Participating farmers are given the initial planting seeds as loans to be paid back in equivalent amount in kind after harvesting. This model has demonstrated that the secheme is instrumental in addressing the long-standing seed problems of the resource poor farmers.

Moreover, this revolving seed scheme provided confidence and guarantee to farmers against uncertainties (such as doubts about the performance of the technology/variety or crop failures due tounexpected calamities, etc.).

- ***Clustering of adjacent seed fields***: this is mainly useful to minimize contamination and to ensure that the final harvest can again be used as seeds. This also involves provision of regular training and other technical backstoppings to stakeholders on chickpea technology, seed production and value chain.
- ***Orgnaizing field days***: field days were organized every year at national, regional, zonal and wereda levels. These field days were organized by community seed producers and research centers in collaboration with different agricultural offices of the respective community.
- ***Provision of inputs and marketing options***: In this set farmers' cooperatives and their unions played a vital role in the provision of required inputs(fertilizers, pesticides, etc.) and market information and purchase of produce from individual farmers.

Salient features of the success

- Modest variety popularization efforts were made through development of promotional materials and demonstration activities of new varieties.
- The intervention has demonstrated out of the box thinking and practiceby the research program. The research moved a step forward in creating a platform to facilitate for the interactive dialogues
- Availing initial planting materials of needed varieties in the hands of smallscale farmers.
- Presence and engagement of multi-stakeholders working for farmers interests at grass root level.
- Joint reflection and review forums held in each target locations, varieties required, roles and performance of stakeholders as well as challenges discussed and addressed.

- The scheme has created continuous capacity development programs to enhance knowledge and skills in production and distribution of quality seeds.

Features of the Ethiopian chickpea seed system

Ethiopian farmers rely largely on home-saved chickpea seeds, which is actually grain saved from the previous harvest because of the self pollinating nature of the crop. East Shewa zone is not an exception. However, the degree of reliance on own stocks varies significantly across and within the regions of the country and is influenced by the season, household characteristics such as wealth status, and the level of production relative to household usage. Commercial sources (local markets) were second in importance to farmer saved seeds. Farmers commonly give each other gifts of seed, exchange of seed in kind and few seed purchases from farmer seed ―experts" (farmers known in their village for maintain good quality seeds). Farmers also use certified varieties of chickpea that are also disseminated through the research and extension system.

CBSEs involved in chickpea seed systems

There are about nine CBSEs in East Shewa and one in North Shewa (Amhara) located in Gimbichu (2), Ada (4), Lume (2) and Minjar (1) districts initiated by the DZARC in collaboration with the respective districts' Bureau of Agriculture (BoA). Farmers involved in Farmers' Research Group (FRG) and Participatory Variety selection (PVS) with DZARC formed the group, intended to multiply seeds of improved varieties of chickpea, lentil and tef. The groups involved both male and female farmers,all of whom had worked closely with researchers in a participatory research projects. These helped in making the group somehow distinctive and enhance its achievements. A participatory approach was used in training and in all aspects of developing the farmers‘ seed enterprises. The role of the researches was to facilitate the learning process and to support and encourage farmers‘ decision–making, problem solving, and empowerment processes. Producers made all the decisions, including the identification of which variety seed to be multiplied. Topics like disease and pest identification and management, agronomic practices for seed production, post harvest handling of seed, testing germination, marketing, costing, book keeping and group dynamics were covered during the training. To avoid the creation of a dependency mentality, seeds were provided on a revolving or cost sharing basis between farmers and the research center. No form of financial assistance was provided because of the absence of suitable NGO partners who could administer the loans. Researchers visited the groups at the end of each cropping season to monitor and plan activities and discuss problems. Extension agents from the BoA visited the groups more frequently, particularly during field operations, to offer technical advice and collect data.

The CBSE differed with respect to resources such as education, access to land and labor, prior training, group cohesion and business experience and mode of organizing production. For example, the dynamism of the groups in selling and promoting their seed may be attributed to the higher educational levels of its members and stronger group cohesion fostered through training.

Production is organized on individual basis since motivation mechanism is lacking on communal work and land rental costs were high. Members of the CBSEs planted seed on individually owned land. Farmers who have adjacent fields clustered their fields of seed production to avoid physical mixture and for ease of management. There are up to 20 clustered farmers in one CBSE clusterdepending on the land size of the members. A committee of members conducted inspections of individual fields to check for off-types and diseases. Growers were expected to return all seed produced to the respective CBSE for storage and marketing after proper baggaging and labeling. In most of the cases, group members exclusively provided labor for all activities.

Production and seed quality: the productivity and production of all the enterprises was encouraging over the last three years. However, there is variation among the enterprises (Table 5). All producers sowed a larger total amount of ‗Arerti' variety compared to Habru, Shasho and other chickpea varieties. Arerti has gained popularity because of its local market preference, yield advantage per unit area and ascochyta blight resistance. Fluctuations from season to season in the amount of seed sown by all groups depend on the anticipated market demand.

Table 5: Initial seed distribution to CBSEs (2011-2013/14)

Name of CBSE	Amount of seed supplied (tons)	Area covered (ha)	Number of farmers benefited
Hawi Boru	25	208	833
Biftu	30	250	1,000
Chala	25	208	833
Lemlem	20	167	667
Megertu	27	225	900
Hundumaf haata'uu	32	267	1,067
Ude	20	167	667
Giche G.	15	125	500
Memihir hager	42	350	1,400
Total	**236**	**1,967**	**7,867**

There are factors that may account for the less number of seed growers:(a) high disease and insect pest incidences (root rot, wilt and bollworm, (b) adverse climatic conditions (drought and heavy rains), (c) poor cultural practices (poor land preparations, late planting, and poor drainage), (d) poor soils and/or soil fertility, (e) lack of access to resources such as land and oxen. Although little can be done about unfavorable climatic conditions, appropriate interventions and criteria for selecting producers can alleviate the remaining production constraints. High seed losses caused by diseases suggest that, in the absence of fungicides, to achieve economic returns, CBSEs should limit multiplication to the resistant varieties and maintain good crop husbandry. Other suggestions for increasing seed production include targeting farmers with sufficient resources to higher labor and purchase oxen to alleviate labor problems, renting of land specifically for seed production, practice crop rotation and use of fertilizers or other soil amendments (e.g. green manures). Poor cultural practices suggest the need for closer supervision of field activities by technical support staffs.

Seed sale and promotion: nearly, all seed produced by CBSEs were sold in the local markets, within 3-6 months after harvest for 1200-1400 Birr/100kg. These prices are up to 30-40% greater than the local price for grain at planting time. CBSEs sometimes produce seed on a contractual basis for public seed enterprises (e.g. ESE, OSE etc.). But, Theseenterprises usually fail to collect the seeds multiplied on farmers‘ fields. One of the reasons for the failurity of the enterprises is related to their respective pricing policy. The pricing policy of the enterprises most often failed to respond to the ever-changing local market prices. The price offered to farmers couldn‘t attract farmers engaged in seed production. As a result, most farmers that signed the contractual agreement to sell back the produce to the enterprises default the agreement. The seeds are either sold as grain in the local market or collected by other users/ traders, which are able to offer a better and competitive price.

Table 6: Seeds sold to different organizations across years

Year	Seeds Sold (tons)	Number of farmers/users benefited
2010	550	4,583
2011	650	5,146
2012	755	8,750
2013	1,050	8,750
Total	**3005**	**24,770**

Impact of the seed enterprises: the impact of the seed enterprises can be assessed at two levels; among the producers and the wider farming community. Seed production had a positive impact on the producers in the areas of financial improvement and empowerment. The earnings by the seed producer farmers during 2011 – 2013/14 surpassed income earnings from the traditional income earning activities such as the sale of grain and other food crops. The seed sale earns about 1400 Birr/100kg of chickpea seed on the average. This is about 30-40% greater than the grain selling price at the time of planting. Moreover farmers can easily access seeds at their farm gate on time with little or no transaction costs. This in turn enhances the up-take of the improved chickpea varieties.

Challenges

- ***Lack of market intelligence***: questionable accuracy and relevance on an ―official demand estimates" given farmer expectation. Effective seed demand assessment mechanisms and farmers involvement during the planning phase is found to be very crucial.
- ***Inaccessible credit***: collateral requirements for seed business are high, especially when compared to strategic

sector like cut flowers. Availing credit for the seed business can enhance the availability of and access to seeds which provide farmers with adequate crop genetic diversity. Such support may also increase the effectiveness of the formal system, thereby leads to adequately addressing farmers seed requirement.

- ***Partners' Commitment***: there was no enforcement/incentive mechanism to ensure commitment among partners.
- ***Seed quality regulation***: no regulatory mechanisms in place for quality assurance. It is important that the quality assurance is strengthened so as to enforce the seed laws and prevent malpractices which could have serious repercussions for the agricultural sector.
- ***Staff turn-over***: Frequent transfer and work load of the extension staff has been observed in many of the intervention areas.
- ***Inofrmation transfer/exchange***: There was poor information sharing traditions and gaps, and no measn of networking farmers so that they can exchange information

Conclusions

The East Shoa case demonstrated that smallscale farmers can produce good quality chickpea seeds if they get proper training and motivation. Moreover, the capacity of these farmers may also be limited due to lack of basic resources (such as land, labor andcapital). Large-scale farmers may be more capable of achieving modest production levels and may be better placed to establish commercial contracts. Farmers'-based seed enterprises may, therefore, not be applicable to all crops, and it is more appropriate for crops that are receiveing low priority from the formal seed sector.

Depending on various social (level of trust between people, history of working together in groups), financial, and resource considerations, either individual or groups of farmers can be involved in semi-specialized seed production. Smallholders' production and motivation to produce are influenced by the mode of organizing seed growers (individual versus communal) and arrangement for remunerating individual growers. An arrangement that allows individual production and collective harvest and post-harvest handling may be optimal from the production side, but mayn't be suitable for some farmers due to various socio-economic reasons.Women seed producers may face specific constraints because of their limited access to basic resources (land, labor and capital) and difficulties in controlling their own resources.

Several case studies are indicating that regular training on various aspects of seed production, improved agronomic practices, seed processing and packaging,business managementand marketing skills are critically important for successful local seed enterprise development.

As the chickpea case clearly shows that, although local demands for seeds of new improved varieties initiallycreated by specialized producers, maintaing long-term demand for good quality seed for certain commodities in a sustainable manner remains a challenge. To achieve both objectives, farmer-based seed enterprises must devise proactive marketing and promotion strategies targeting larger markets to ensure long-term business success.. For some crops, such as, chickpea, seed producers may face difficulties in selling seed at premimum prices to cover production costs. The probale reasons are: first, farmers especially in non-intervention areas may not easily distinguish between a seed and grain. Secondly, they may not be aware of the importance of quality seed, and thus are unconvinced to pay the premium.

With regard to policy issues, authorities who have national mandates should designate a new class of seed with less stringent quality parameters in order to encourage the growing decentralized seed production system.The ―truthfully labeled” designation could be proposed as an optionto the existing system of centralized public certification. (Tripp and van der Burg, 1997). It is, however, important to develop enforcement mechanisms under the self-assessed quality delared testimonial seed system.Alternatively, independent certification at a decentralized level can be explored. Such a system might operate either by involving individuals 9possibly extension agents) who have been trained by the public certification agency in field inspections for artisanal quality seed, or by shifting responsibility for quality control to an autonomous or local level public institution.

In general, scaling-up or promotion of farmer-led seed production schemesmay be challenging and no single best approach or model exists for its success. Some of the key elements for successful development of farmer-based seed enterprises include: (1) a range of superior varietiesfulfilling the interests of farmers need to be regularly available, (2) strong support at early satge of the intervention to enhance seed production capacity of farmers and small enterprise development, (3) establish a sustainable source seed supplyand (4) a working/ applicable but flexible seed quality control system will be good option.

References

Almekinders C, Louwaars NP and de Bruijin GH (1994) Local seed systems and their importance for an improved seed supply in developing countries.*Euphytica*,**78**: 207-216.

CSA (Central Statistical Authority,2005 – 2010), Annual Agricultural sample survey, Addis Ababa, Ethiopia.

CSA (Central Statistical Authority, 2012), Annual Agricultural sample survey, Addis Ababa, Ethiopia.

Cromwell E and Wiggins (1993)Sowing beyond the State: NGOs and Seed Supply in Developing Countries. London: ODI.

Tripp R. and van der Burg W (1997)The conduct and reform of seed quality control". In:Tripp R (ed.) New Seed and old Laws: regulatory reform and diversification of National seed Systems. London: *Intermediate Technology Publications*.

Sahlu Y Semane B and Bishaw Z (2008)The farmer based seed production and marketing scheme: Lessons learnt. In: ThijssenMH,Bishaw Z, Beshir A and de BoefWS (eds). Farmers seeds and varieties: Supporting informal seed supply in Ethiopia.Wageningen International, The Netherlands.

25. **Effect of Hydro- and osmo- priming on seed quality of chickpea (*Cicer arietinum* L.)**

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Three seed priming media (H2O, 0.5% KH2PO4 and unprimed control), and six chickpea varieties (DZ-10-4, Arerti, Habru, DZ-10-11, Akaki, and Natoli) were arranged in CRD with four replications. The laboratory and lath house results revealed significant differences for all quality parameters, except vigor index 11, among different priming treatments and variety in seed germination, all seed vigor tests and seedling emergence index. The interactions of the main effect were, significant for all the quality parameters excluding seedling vigor index 11, seedling shoot and root length, and seedling dry weight. Moreover, significant correlations were observed between emergence index and vigor parameters such as speed of germination, root length and electrical conductivity of seed leachate. From the present investigation, it can be concluded that seed priming is a viable and sound technology to enhance seed quality. Therefore, water priming did enhance germination percentage and seedling vigor index 1 of all varieties except DZ-10-4 and Habru; speed of germination of Arerti and DZ-10-11 over the control. However, osmo-priming did improve seedling vigor index1 of DZ-10-11 which couldn't be improved by eater priming over the control. Though electrical conductivity of DZ-10-11 was improved by hydro-priming, improvement made by osmo-priming was even better than water priming as compared to control. Therefore, from the present study, it can be concluded that hydro-priming can set up economical benefit of chickpea growing farmers.

Key words: *Cicer arietinum*, seed priming, seedling vigor, electrical conductivity

Introduction

Chickpea is one of the cool season food legume crops of Ethiopia which is mainly grown in the central, northern and eastern highland areas of the country where the mean annual rainfall and altitude, respectively range from 700-2000mm and 1400 – 2300 m.a.s.l (Geletu, 1994). The area under chickpea was about 213,187 ha with a total production of 284,639.8 tons and an average yield of 1.34 t/ha (CSA, 2010). The two chickpea clases, namely desi and kabuli are cultivated in Ethiopia, but the desi type is widely grown in Ethiopia since antiquity. The majority of chickpea production is used for domestic consumption in different forms: green vegetable, roasted (fried), boiled, and dry vegetable. Chickpea can also improve the soil fertility through biological nitrogen fixation and intercropped with cereals. The biotic and abiotic factors are affecting chickpea production (Geletu and Yadeta, 2002). The major abiotic stresses are drought, heat and cold; drought being the major limiting factor. Unpredictable and erratic rainfall, poor soils, low quality seed and limited availability of labor or draft power all contribute to a situation in which good crop establishment is often the exception rather than the rule (Harris, 1996). One way of improving productivity of chickpea in drought prone area is seed priming. The improvement of seed quality by physiological treatments is a simple, easy, and impressive approach to enhance seed performance and agricultural production (Basu, 1994). Heydecker *et al* (1973) acknowledged the use of the term, ―priming of seeds" to describe a pre-sowing seed treatment to enhance germination and increase seedling emergence uniformly under adverse environmental conditions. Priming is a procedure that partially hydrates seed, followed by drying of seed, so that germination processes begin, but radical emergence does not occur. It involves soaking of seeds in water or osmotic solution. The present investigation was initiated with the objective to determine the effectiveness of seed priming treatments and variety on seed quality of chickpea varieties.

Materials and methods

The experiment was carried out in the Debre Zeit Agricultural Research Center during 2010-2011 main cropping seasons. Seeds of six chickpea varieties (three *'desi*' and three *_kabuli*' types) were obtained from the national chickpea improvement program of the Debre Zeit Agricultural Research Center (DZARC) were used (Table 1).

Table 1. Description of chickpea varieties used in the study.

Ser no.	Variety (D=desi, K=kabuli)	Year of Release	Seed color
1	DZ-10- 4(K)	1974	White
2	Arerti (K)	1999	White
3	Habru (K)	2004	White
4	DZ-10-11(D)	1974	Light brown
5	Akaki (D)	1995	Golden
6	Natoli (D)	2007	Light golden

Source: MoAD, 2008; Menali *et al*., 2009

The two priming treatments namely Water and 0.5% KH2PO4 were applied for eight hours. In addition, in one sample, no treatment was applied. The primed treatments were prepared in distilled water. Factorial arrangement comprising six chickpea varieties and three priming treatments (water, 0.5% KH2PO4 and untreated control) laied down in complete randomized design (CRD) with four replications in laboratory and lath house.

Data collection: the standard germination as per ISTA 2004, speed of germination (Maguire index 1962), seedling shoot and root length (Fiala 1987), seedling dry weight (ISTA 2004), seedling vigor index 1 (Islam *et al*, 2009), seedling vigor index 11 (Fiala, 1987), emergence index (Yang *et al* 2005) and conductivity test (Wang *et al*., 2004) were determined.

Data analysis: the collected data were subjected to statistical analysis as per SAS 2001. The mean seperations were carried out using least significant differences (LSD) at 0.05% level of probability. Linear correlations between emergence index and other seed vigor tests were calculated using SAS computer software.

Results and discussion

In the present study, we found that seeds of chickpea varieties showed different responces to the priming media. Analysis of variance revealed that these seed invigoration techniques had influenced seed quality significantly. The effects of priming treatments on percentage of standard germination, speed of germination, electrical conductivity, seedling vigor index 11, emergence index, shoot length, seedling dry weight and seedling vigor index 1 were significantly different. All these parameters showed significant differences over varieties at $P < 0.01$. There were also significant differences in the interaction of priming treatment and variety for all parameters ($P < 0.01$). There were also significant differences in the interaction of priming treatment and variety for all parameters ($P < 0.01$). In contrast, vigor index 11, shoot length, root length and seedling dry weight were not affected by interactions of priming treatment and the variety.

Standard germination (%): Significant differences among varieties were obtained for standard germination percentage across the priming treatments (Table 2). Comparing the varieties, the lowest and the highest germination percentage under laboratory condition were recorded for DZ-10-4 and

Arerti, respectively. Nascimento (2003) has reported that the response of seeds to priming found to be dependent on the duration of the osmotic (priming) treatment, seed maturity, variety and environmental conditions. Higher germination percentage was found for water treatment as also reported by Harris *et al* (1999) and Nascimento (2005) that primed seeds had higher germination percentage compared to unprimed seeds.

Table 2. Interaction effect of priming media by chickpea varieties on standard germination (%).

Variety	**Priming media**			**Mean**
	Control (untreated)	Distilled water (H_2O)	KH_2PO_4 (0.5%)	
DZ-10-4	84fg	75h	69i	76
Arerti	98ab	100a	99a	99
Habru	94cd	86f	82g	87
DZ-10-11	91de	96bc	90e	92
Akaki	95c	92de	91de	93
Natoli	94cd	91de	90e	92
Mean	93	90	86	90
	Variety	Priming	V x P	
LSD (5%)	**1.86**	**1.32**	**3.22**	
CV (%)		**2.53**		

Speed of germination: Significant differences of treatments and interaction were found among the varieties for speed of germination at $P<0.01$. Water treatment had effectively increased the speed of germination over the control and the osmo-priming. However, osmo-priming was not significantly effective in increasing the speed of germination over the control (Table 3). The variety x priming treatment on the speed of germination was significant at $P<0.01$. Improvement in the speed of germination of seeds of chickpea varieties subject to hydropriming is in conformity with results reported by Mohammadi (2009) in soybean. Faster germination rate after priming could be due to increased rate of cell division in the root tips of seedlings from primed seeds as reported in wheat (Bose and mishra, 1992).

Table 3. Interaction effect of priming media by chickpea varieties on the speed of germination.

Variety	Priming media: Control (untreated)	Distilled water (H_2O)	KH_2PO_4 (0.5%)	Mean
DZ-10-4	23.03cdef	24.09c	20.00gh	22.37
Arerti	23.47cd	27.84a	24.65bc	25.32
Habru	20.84fg	21.07efg	18.92ghi	20.27
DZ-10-11	23.26cde	24.61bc	26.86ab	24.91
Akaki	21.20defg	19.96gh	19.20ghi	20.10
Natoli	16.09j	17.99hij	16.93ij	17.00
Mean	21.32	22.59	21.09	21.66
	Variety	Priming	V x P	
LSD (5%)	**1.38**	**0.976**	**2.391**	
CV (%)		**7.78**		

Means with the same letter along the column are not significantly different from each other at p<0.05 and figures not sharing the same letters along the same column are differ significantly at p < 0.05 or p < 0.01.

Seedling vigor index I (SVI): larger seedling vigor index I was recorded for variety Arerti as compared to the rest the varieties tested. Water priming priming medium had produced the highest seedling vigor index 1 followed by 0.5% KH2PO4 (Table 4). The minimum seedling vigor index 1 was in control where non primed seeds were used. There was significant difference in variety x priming medium interaction for seedling vigor index I at P<0.01. When the seeds were water treated all the varieties performed effectively for seedling vigor index I over the control except DZ -10-4 and Natoli. At the same time, these treatments have improved shoot and root lengths. Similar results were reported by Thakare et al (2011) and Umair et al (2010) that both hydropriming and osmopriming of 0.6% KH2PO4 had improved vogor index I of mungbean.

Table 4. Interaction effect of priming media by variety on seedling vigour index I.

Variety	Priming media: Control (Untreated)	Distilled water	KH2PO4 (0.5%)	Mean
DZ-10-4	2683.70abcd	2551.19bcde	2400.81ef	2545.23
Arerti	2488.69cde	2731.40ab	2809.68a	2676.59
Habru	1871.31h	2076.93gh	1995.07h	1981.1
DZ-10-11	2240.36fg	2792.82a	2735.04ab	2589.23
Akaki	2458.29def	2697.89abc	2652.48abcd	2602.89
Natoli	1995.80h	2076.88gh	2093.04gh	2055.24
Mean	2289.69	2487.85	2447.69	2408.41
	Variety	Priming	V x P	
LSD (5%)	131.56	93.027	227.87	
CV (%)		6.67		

Means with the same letter along the column are not significantly different from each other at p<0.05and figures not sharing the same letters along the same column are differ significantly at p<0.05 or p<0.01.

Seedling vigor index II (SVII): The analysis of variance revealed significant differences in seedling vigor indexII due to variety effect (P<0.01) and priming treatment effect (0.05), but there was no significant difference for variety x priming treatment interaction (Table 2). Natoli had the highest seedling vigor index II followed by Arerti. KH2Po4 (0.5%) was the most effective treatment in increasing seedling vigor index II over the control. Both KH2PO4 (0.05%) and distilled water treatments significantly increased seedling vigor index II by 21% and 15%, respectively (Table 5). This is with close agreement with Dornbo's (2002) work who concluded that seedling dry weight represents a logical and relevant estimate of seed vigor. In the present study, it was the seedling dry weight that brought enhancement in the vigor index II.

Table 5. Interaction effects of priming media on chickpea varieties on the vigour index II.

Variety	**Priming media**			**Mean**
	Control (untreated)	Distilled water	KH_2PO_4 (0.5%)	
DZ-10-4	1.183hi	1.435ghi	1.455ghi	1.358ab
Arerti	3.268bc	3.830b	3.698b	3.599d
Habru	1.598fgh	2.345def	2.278def	2.074c
DZ-10-11	0.815i	1.340ghi	1.263ghi	1.139a
Akaki	1.995efg	2.493de	2.798cd	2.429c
Natoli	4.875a	3.543bc	4.623a	4.347e
Mean	2.289c	2.498bc	2.686b	2.491
	Variety (V)	**Priming (P)**	**V x P**	
LSD (5%)	**0.44**	**0.31**	**0.76**	
CV (%)		**21.55**		

Shoot and root lengths and seedling dry weight: the varieties showed significant differences for shoot and root lengths as well as for seedling dry weight at $P<0.01$. However, interaction between variety x priming were not significant for these traits (Table 6). Feaster seed germination resulted in greater shoot and root lengths as well as higher seedling dry weight accumulation for seeds treated with 0.5% KH2PO4 and water (Table 7). Similar results were reported by Umair *et al* (2010) on mungbean. The increase in seedling vigor may be due to enhanced oxygen uptake and the efficiency of mobilizing nutrients from the cotyledons to the embryonic axis (Kathiresan et al, 1984) and decreased catalase and peroxidase levels in pea seedlings (Srivastava and Dwivedi, 1998). Root and shoot lengths are the most important parameters because roots are in a direct contact with soil to absorb water and shoot supply it to the rest of the plant (Thakare *et al*, 2011).

Table 6. ANOVA for electrical conductivity, emergence index, shoot & root lengths, seedling dry weight.

Source of variation	df	Mean squares				
		Electrical emergence	Shoot length (cm)	Root length (cm)	Seedling dry weight (g)	Conduct ivity index
Variety	5	4988.607**	32.716**	113.315**	20.836**	0.095**
Priming	2	3603.446**	16.503**	7.341**	36.955**	0.00057**
V x P	10	393.202**	5.2197**	0.863ns	1.870ns	0.00010ns
Error	54	24.307	1.013	0.849	2.7097	0.0000953
CV (%)		7.268	11.815	10.948	8.894	15.968

Electrical conductivity test: a highly significant difference ($P<0.01$) in electrical conductivity was observed among the varieties tested as a result of seed treatments (Table 6). The primed chickpea seeds with water and 0.5% KH2PO4 had the potential to reduce seed leachates in all varieties. The lowest electrical conductivity was recorded for variety Arerti, where as Natoli had shown the highest electrical conductivity readng. Electrical conductivity was decreased with both hydro and osmo priming treatments as compared to the control.

Table 7. Effect of varieties and priming treatments on shoot length, root length and seedling dry weight.

Variety	Seedling vigour parameters		
	Shoot length (cm)	Root length (cm)	Seedling dry weight (g)
DZ-10-4	13.0708a	20.5867a	0.0181d
Arerti	7.3517b	19.6858a	0.0364b
Habru	5.5292d	17.3142b	0.0242c
DZ-10-11	10.1067b	17.9975b	0.0191cd
Akaki	9.5025b	17.935b	0.0263c
Natoli	4.9458d	17.5283b	0.2427a
CV (%)	10.948	8.894	15.968

Priming treatment by variety interaction was highly significant for the electrical conductivity at $P<0.01$ (Table 8). When seeds primed with water all varieties exhibited a decrease in electrical conductivity over the control and the degree of reduction in the seed electrical conductivity was the highest (54%) for variety Arerti and the lowest (9%) for variety Natoli (Table 8). Prediction of seedling performance in relation to electrical conductivity test is based on nutrient leaching from damaged seeds (McDonald, 1975). The lower electrical conductivity of seed leachates treated seeds may be due to beneficial effect of priming in strengthening the cell membrane integrity and permeability (Kurdikeri, 1991). According to kausar *et al* (2009), seed priming presumably allowed some repairs of damage to membrane caused by deterioration.

Table 8. Interaction effect of priming media by varieties on the electrical conductivity ($\mu scm^{-1}g^{-1}$).

Variety	Priming media: Control (untreated)	Distilled water	KH_2PO_4 (0.5%)	Mean
DZ-10-4	115.86a	64.70e	90.86c	90.47d
Arerti	58.79ef	27.28h	43.79g	43.29a
Habru	59.70ef	42.84g	54.61f	52.38b
DZ-10-11	65.10e	54.77f	46.24g	55.37b
Akaki	89.45c	60.94ef	74.17d	74.85c
Natoli	88.95c	80.55d	102.43b	90.64d
Mean	79.64c	55.18a	68.68b	63.27
	Variety (V)	Priming (P)	V x P	
LSD (5%)	**4.035**	**2.853**	**6.989**	
CV (%)			**7.27**	

Emergence Index (EI): effect of variety revealed significant difference for emergence index at P<0.01(Table 6). When averaged across the priming treatments DZ-10-4 and DZ-10-11 showed the lowest and the highest emergence index respectively (Table 9). There was an increase in emergence index by 8% for hydro-priming as compared to the control. Water treatment was better than both osmo-priming and the control. Several reports also indicated that seed priming by soaking in water for 10 hours followed by serface drying advanced seedling emergence from the soil by 12 hours (Brar and Stewart, 1994; Harris, 1996).

Analysis of variance indicated that interaction of variety x priming medium was significantly different for emergence index (P<0.01). Upon priming seeds with water, only Arerti and DZ-10-11showed significant increase in the emergence index over the control by 24% and 20% respectively (Table 9). According to Taylor *et al* (1998) the physiological basis for increasing seedling emergence of primed seeds might be due to early DNA replication, increased RNA and protein synthesis, greater ATP availability, faster embryo growth, repair of deteriorated seed parts, reduced leakage of metabolites and leaching out of germination inhibitors from the seeds.

Table 9. Interaction effect of priming media and variety on the EI.

Variety	Priming media			Mean
	Control (untreated)	Distilled water	KH_2PO_4 (0.5%)	
DZ-10-4	6.41ij	5.94ij	5.18j	5.84e
Arerti	8.59fgh	10.61abc	9.43cdef	9.37b
Habru	8.38efg	9.12def	7.30ihg	8.27c
DZ-10-11	9.66bcde	11.61a	10.82abc	10.70a
Akaki	10.89ab	10.25abcd	6.35ij	9.16b
Natoli	8.38efg	8.21fgh	6.78hi	7.79d
Mean	8.63b	9.29a	7.64c	8.52
	Variety (V)	Priming (P)	V x P	
LSD (5%)	**0.824**	**0.583**	**1.427**	
CV (%)		**11.81**		

Correlation between EI and other vigor tests: linear correlation analysis between emergence index and other vigor parameters showed that significant associations were observed between emergence index and other vigor parameters. There was positive and significant correlation (r = 0.60) between standard germination and emergence index (Table 10). A significant correlation between seedling emergence index and other vigor tests was reported by Kausar *et al* (2009). In general, correlation comparison results showed that primed seeds with high rate of germination also resulted in high emergence index while a negative relationship was demonstrated by root length and electrical conductivity.

Table 10. Linear correlation coefficient (r) between EI & vigour parameters tested in the lab at 5% and 1% level of significance.

	SGP	SG	VI	VII	SL	RL	DW	EC	EI
SGP	1.00								
SG	0.26**	1.00							
VI	0.22	0.59**	1.00						
VII	0.35**	-0.32	-0.15	1.00					
SL	-0.43**	0.39**	0.70**	-0.55	1.00				
RL	-0.22	0.28*	0.59**	0.01	0.48**	1.00			
DW	0.08	-0.57**	-0.43**	0.69**	-0.53**	-0.15	1.00		
EC	-0.43**	-0.53**	-0.23*	0.01	0.16	-0.08	0.39	1.00	
EI	0.60**	0.40**	0.20	-0.04	-0.15	-0.25*	-0.14	-0.50**	1.00

, = designated significant difference at P<0.05 and P<0.01, respectively. SGP = Standard Germination Percentage, SG = Speed of Germination, VI = Vigor Index I, VII = Vigor Index II, SL = Shoot Length (cm), RL = Root Length (cm), DW = Seedling Dry Weight (g), EL = Emergence Index, EC = Electrical Conductivity EI= Emergence Index*

Conclusions

Analysis of variance showed that significant differences were observed due to priming treatments and varieties in all measured parameters lath house conditions. There were also significant differences in the interactions of main effect for all the quality parameters except seedling vigor index II, root length and seedling dry weight. Results indicated that hydro-priming prior to planting had potentials to enhance seed vigor of chickpea in terms of speed of germination, vigor index, electrical conductivity and subsequent seedling emergence.

Encouraging results were obtained due to priming and variety interactions for speed of germination, seedling vigor index and electrical conductivity. The correlation analysis showed that there is significant relationship between emergence index and vigor parameters such as speed of germination, root length and electrical conductivity.

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References

Afzal, I S . M . A . Basra and A, Iqbal (2005). The effects of seed soaking with plant growth regulators on seedling vigor of wheat under salinity stress. *Journal of stress physiology and Biochemistry*, **1**(1): 6-14.

Basu RN (1994) An appraisal of research on wet and dry physiological seed treatments and their application with special reference to tropical and subtropical countries. *Seed Science and Technology*, **22**: 107-126.

Bejiga G and Anbessa Y (2002). Evaluation of Ethiopian chickpea land races for tolerance to drought. *Genetic Resources and Crop Evaluation*, **49**:557-564.

Bose B and Mishra T (1992) Response of wheat seed to presowing seed treatment with Mg (NO3)2. *Annals of Agricultural research*, **5**:11-16.

Brar GS and Stewart BA (1994) Germination under controlled temperature emergence of 13 sorghum varieties. *Crop science*, **34**:1336-1340.

CSA (Central statistical Agency) (2010) Agricultural sample survey 2009/2010; Report on area and production of crops, *Statistical Bulletin* 446. Addid Ababa, Ethiopia.

Dornbos DL (2002) Seed Vigor. In: Seed quality, Basic mechanisms Agricultural implications. Basra AS (Ed.), CBS Publishers, New Delhi, India, 45-80.

Fiala F (1987) Hand book of vigor test methods. ISTA Publications.

Harris D (1996) The effects of manure, genotype, seed priming, depth and date of sowing on the emergence and early growth of

Sorghum bicolor (L. Moench) in semi-arid Botswana. *Soil and Tillage Research*, **40**: 73-88.

Harris D, Joshi A, Khan PA, Gothkar P and Sodhi PS (1999) On farm seed priming in semiarid agriculture. Development and evaluation in maize, rice and chickpea in India using participatory methods. *Experimen. Agricul.* **35**:15-29.

Heydecker W, Higgins J and Gulliver RJ (1973) Accelerated germination by osmotic seed treatment. *Nature*, **246**:42-44.

Islam AK, Anuar N and Yaakob Z (2009) Effect of genotypes and presowing treatments on seed germination behavior of Jatropha. *Asian Journal of Plant Science*s, **8**:433-439.

ISTA (International Seed Testing Association) (2004) International rules for seed testing. Edition 2004, Bassersdorf, Switzerland.

Karta KK (2009) Seed vigor studies in Vetches (*Vicia dasycarpa* and *V. sativa* L.) from high lands of Ethiopia. MSc thesis presented to School of Graduate Studies, Haramaya University, Haramaya, Ethiopia.

Kathiresan K, Kalyani V, Gnanarethium JL, Kalyani KV, and Gnanarethium JL (1984) Effects of the seed treatments on field emergence, early growth and some physiological processes of sunflower (*Helianthus annus* L.). *Field crops Research*, **9**:255-259.

Kausar MT, Mahmood SM, Basra A and Arshad M (2009) Invigoration of low vogor sunflower hybrids by seed priming. *International journal of Agricultural Biology*, **11**:521- 528.

Kurdikeri MB (1991) Studies on seed quality in hybrid maize (*Zea mays* L.) PhD Thesis presented to the University of Agricultural sciences, Bangalore, Karnataka, India.

Maguire JD (1962) Speed of germination – aid in selection and evaluation for seedling emergence and vigor. *Crop Science*, 2: 176-177.

McDonald MB (1975) A review and evaluation of seed vigor tests. *Proceeding of Association of Official Seed Analysists*, **65**:109-139.

Mohammadi GR (2009) The effect of seed priming on plant traits of late spring seeded Soybean (*Glycine max* L.) *Europian Journal of Agriculture and Environmental Science*, **5**: 322-326.

Nascimento WM (2003) Muskmelon seed germination and seedling development in response to seed priming. *Scientia Agricola*, **60** (1): 71-75.
Nascimento WM (2005) Vegetable seed priming to improve germination at low temperatur. *Horticultura Brasileira*, **23**:211-214.
Ros CR, Bell W and White PF (1997) Effects of seed, Phosphorus and soil phosphorus application in early growth of rice-based cropping system. *Soil and Tillage Research*.
SAS Institute Inc. (2001) Statistical Analysis Systems, Version 9.1., North Carolina, USA.
Srivastava MK and modulates glutathione metabolism in pea seedlings. *Journal of Plant Physiology*, **153**:404-409.
Taylor AG, Allen PS and Misra MK (1998) Seed Enhancements. *Seed Science Research*, **8**:245-256.
Thakare N Pati and Malpathak N (2011) Performance of chickpea under influence of Gibberellic acid and oxygenate peptone during germination. *Advances in Bioscience & Biotechnology*, (**2**):40-45.
Umair M, Ali S, Bashir K and Hussein S (2010) Evaluation of different seed priming techniques in mungbean (*Vigna radiate* L.). *Soil and Environment*, **29**(2):181-186.
Wang YR, Nan ZB and Liu YL (2004) Vigor tests used to rank and predict field emergence in four forage species. *Crop Science*, **44**: 535-541.
Yang Q, Ye WX, Deng H, Cao, Zhang Y and Xu K (2005) Seed germination eco-physiology of Mikania micrantha HB. K. *Botanical Bulletin of Academy of science*, **46**:293-299.