Research on food legumes at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), with special reference to chickpea

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Abstract

ICRISAT is designated as a world centre for improving two cereal crops (sorghum and pearl millet) and three food legumes (chickpea, pigeonpea and groundnut). The objectives of research on and breeding of the food legumes fall into six principal categories: (1) to strengthen national and regional programmes; (ii) to develop productive genotypes with stable yields of seeds of acceptable quality; (iii) to furnish parental lines, segregating populations, and advanced breeding material to national programmes; (iv) to arrange exchanges of germplasm; (v) to disseminate information; and (vi) to train personnel. Substantial progress has been made during the last decade towards fulfilling these objectives. Examples of achievements to date are described and plans for the future are presented.

Introduction

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is one of the 13 International Agricultural Research Centres in a worldwide research network devoted to increasing food production in the developing countries. The aim of ICRISAT is to improve the yield, stability, and quality of five crops which are basic to life in the semi-arid tropics (SAT), and to develop farming systems that will make better use of human resources and animal power, and of the limited water available to farmers in the region.

The SAT cover nearly 20×10^6 km^2 of 50 nations on five continents. More than 700 million people live in this region and depend for their food on the outputs from small farms. ICRISAT's research involves two major cereals, sorghum and pearl millet, and three food legumes, chickpea, pigeonpea (*Cajanus cajan*), and groundnut (*Arachis hypogaea*). Farmers in the SAT produce more than 90% of the world's chickpea, 96% of the pigeonpea, and 67% of the groundnut. Seeds of chickpea and pigeonpea are rich in protein and form an important part of the diet of millions of people. Groundnut seeds, with 25% protein and 50% oil, are both a food crop and one of the world's major sources of edible oil.

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The objectives of the food legume improvement work at ICRISAT are: (i) to strengthen regional and national research programmes; (ii) to develop high yielding genotypes with stable performance and acceptable seed quality; (iii) to furnish parental lines, segregating populations, and advanced breeding material to national programmes; (iv) to arrange and encourage the exchange of germplasm; (v) to develop new research techniques; and (vi) to disseminate new information and train personnel in research and technical skills.

Chickpea improvement

In terms of harvested area chickpea is the third most important food legume in the world after dry bean (*Phaseolus* spp.) and pea (*Pisum sativum*). It is cultivated on almost 10×10^6 ha and in more than 30 countries (FAO, 1984), but is especially important in India, Pakistan, several countries in West Asia, Ethiopia, and in Mexico. Although currently available cultivars have the potential to yield around 4000 kg ha^{-1}, the world average yield is only 663 kg ha^{-1} (FAO, 1984).

The first international effort to improve the chickpea crop was in 1962 when the Regional Pulse Improvement Project (RPIP) began in India and Iran. The project was funded jointly by the USA Department of Agriculture and by the United States Agency for International Development (see pp. 3—6, this Volume). The main emphasis was on the collection and distribution of germplasm and on research in breeding, agronomy, and related subjects.

The chickpea improvement work at ICRISAT began in 1973. Later, in 1978, the Boards of Governors of ICARDA and ICRISAT agreed to coordinate their efforts; ICRISAT appointed a chickpea breeder and a pathologist to work at ICARDA (see pp. 25—37, this Volume).

Chickpea is a short-statured, self-pollinated annual capable of growing with minimal rainfall, either on residual soil moisture or with irrigation. There are two main types: kabuli, which have relatively smooth, large, cream-coloured seeds, and desi, with yellow-to-black seeds, which are usually smaller and have a rougher surface than kabuli seeds. Kabuli types are most often grown as a summer crop in West Asia, the Mediterranean region and in the Americas, while the desi types are usually a winter crop in the more tropical areas. In the work at ICRISAT, the major emphasis is on desi types.

The work began at Hyderabad (17° N) but, later, a cooperative centre was established at Hisar (29° N) in northern India. The soil used for chickpea cultivation at Hyderabad is a black Vertisol with good water retention capacity. The crop is sown after the monsoon rains have ended (annual average rainfall 760 mm) and grows on residual moisture. The soil at Hisar is an Entisol; the total annual rainfall there averages about 450 mm and presowing irrigation is generally necessary. The work on short-duration desi and kabuli types (specifically adapted to India and Pakistan) is conducted at Hyderabad; that on medium and long-duration desi and kabuli types is based at Hisar.

Germplasm

ICRISAT collects, maintains, and distributes germplasm of each of its five "mandate" crops. By the end of 1985, the Genetic Resources Unit (GRU) had collected 14362 accessions of chickpea from 41 countries. ICRISAT distributes the germplasm freely on request. During 1985, for example, the GRU supplied 4756 samples to workers in 15 countries.

Disease research

Among root diseases, fusarium wilt (*Fusarium oxysporum*) and dry root rot (*Rhizoctonia bataticola*) are the most common when chickpea is grown as a rainfed crop in semi-arid areas. Collar rot (*Sclerotium rolfsii*), wet and black root rots (*Rhizoctonia solani*; *Fusarium solani*), and root rot (*Meloidogyne* spp.) are common in irrigated areas. The foliar diseases, ascochyta blight (*Ascochyta rabiei*), botrytis grey mould (*Botrytis cinerea*), and rust (*Uromyces ciceris-arietini*) have been reported from many countries. The viral disease, stunt, is also common and can be serious if the primary source of inoculum (Pea Leaf Roll Virus) is present and if aphid vectors (e.g. *Aphis craccivora*) are common.

ICRISAT pathologists have developed efficient techniques to screen for resistance to fusarium wilt, to several root rots, and to botrytis grey mould. In cooperation with ICARDA, a screening procedure for ascochyta blight resistance has been developed and standardized. Sources of resistance to most major diseases are now available and many have been used in international and national breeding programmes.

Pest research

ICRISAT has extensively surveyed the insect pest problems on chickpea. The surveys show that *Heliothis* spp. are the dominant pests in almost all areas. *Heliothis* causes an estimated annual loss of 500 000 t of chickpea seed in India alone. The leaf miner (*Liriomyza cicerina*) is also troublesome throughout the Mediterranean region. Although losses caused by insect pests do not usually exceed 20%, more than 90% pod damage has been recorded in some farmers' fields in India.

Pest management research on chickpea at ICRISAT has been concentrated on host plant resistance to *H. armigera* (and on *L. cicerina* at ICARDA). Open field screening of the germplasm (14 000 accessions) identified a few genotypes with appreciable resistance to this pest. Crosses were made to increase the degree of resistance to *H. armigera* and to combine this with resistance to fusarium wilt. The resistance to *H. armigera* was found to be additive, so that the accumulation of resistance has been possible, and progenies with resistance to both the insect and wilt have now been selected and are at an advanced stage of testing.

Agronomy research

Irrigation. Timely irrigation can double chickpea yields to 3 t ha^{-1} on Vertisols of good water holding capacity at ICRISAT Center in peninsular India. However, irrigation seldom gives a significant response in north India. The moisture status of surface soil strongly influences the nitrogen fixation potential of chickpea, particularly in the crop establishment phase.

Drought tolerance. Genotypes have been identified that will give better yields than others under drought conditions.

Iron deficiency. Iron deficiency can be a major limitation to growth and seed yield of chickpea on alkaline soils. This problem can be solved by using tolerant genotypes or by foliar sprays with $FeSO_4$.

Biological nitrogen fixation. Efficient strains of *Rhizobium* have been identified and methods for producing *Rhizobium* inoculum in small units have been developed. Positive responses to *Rhizobium* inoculation have been obtained in soils where chickpea had not been planted before, and where chickpea follows rice in the rotation. One of the ICRISAT strains of *Rhizobium*, IC 76, has been recommended for use in India.

Breeding

The major breeding activity is to identify stable and high yielding genotypes of desi chickpea; only limited work is done on kabuli types.

Parental lines for crossing are selected on the basis of information provided by germplasm botanists, pathologists, entomologists, physiologists, microbiologists, and biochemists. Many cross combinations have been made and large numbers of segregating populations have been grown. Breeding materials for priority areas are screened for their reaction to biotic and abiotic stress factors, for adaptation to early plantings at lower latitudes or late planting at higher latitudes, and to winter planting in the Mediterranean region. We freely share the breeding material with our cooperators.

Some significant contributions

Some of the breeding material from ICRISAT and from the ICRISAT/ICARDA joint program has been released or is being considered for release. Examples are shown in Table 1.

Ten-year plan

For the future, ICRISAT will concentrate on the development of short-duration desi types suited to conditions represented by peninsular India; of

Table 1. Selected examples of chickpea breeding lines released from ICRISAT.

Line	Country of release	Principal reasons for release
S-1 (ICCL 81248)	Bangladesh	Yield
ICCC 13	Nepal	Yield
JG-62 x Radhey and 850-3/27 x F378	Ethiopia	Yield
ICCV 1	Gujarat (India)	Yield
ICCC 32	Central India	Kabuli type, wilt resistance, yield
ICCL 83110	Kenya	Yield and wilt resistance
ILC 72, –200, –2548, –2555	Spain	Yield and ascochyta blight resistance
ILC 195, –482, –484	Morocco	Yield and ascochyta blight resistance
ILC 195, –482	Turkey	Yield and ascochyta blight resistance
ILC 3279	Syria and Cyprus	Yield and ascochyta blight resistance

kabuli types suited to southwest Asia and North Africa; of long-duration desi and kabuli types suited to northern India; and of desi types for Pakistan, Nepal, Bangladesh, Burma, Iran, and Ethiopia.

Priority will be given to the respective needs of India, Pakistan, Nepal, Bangladesh, Burma, West Asia, and the Mediterranean region (including North Africa). A chickpea breeder is now based in Pakistan to breed cultivars for resistance to ascochyta blight, which has devastated the crop in that country in recent years.

Groundnut (peanut) improvement

Groundnut crops are now grown throughout the tropical and warm temperate regions. Approximately 80% of world production comes from developing countries and more than 60% of the total is produced in the seasonally dry, rainfed areas of the SAT. Yields in the SAT are small, around 800–900 kg ha^{-1}, compared to those of approximately 2500 kg ha^{-1} in developed countries.

ICRISAT has a large ongoing breeding programme. Over the past decade, the success rate in crossing has been increased from less than 15% to 60% in the field, and to more than 70% in the glasshouse. Field and laboratory techniques have been developed to screen for reactions to diseases such as rust (*Puccinia arachidis*), late leaf spot (*Phaeoisariopsis personata*), bud necrosis (Tomato Spotted Wilt Virus) and to *Aspergillus flavus*, the fungus that produces aflatoxin. Several viruses have been identified and characterized. Sources of resistance to pests such as thrips (*Frankliniella schultzei*) and jassids (*Empoasca kerri*) have also been identified. Drought tolerant genotypes have been found. It has been possible to cross leaf spot-resistant wild diploid *Arachis* sp. with the cultivated tetraploid groundnut, and to restore fertility to the sterile triploids by treating them with colchicine. Large yielding, early maturing lines have been developed and made available to national programs. The cultivar ICGS 11 has recently been released to farmers in India.

Pigeonpea improvement

Traditional forms of pigeonpea are basically perennial shrubs with woody stems and primary branches and are partially cross-pollinated. However, pigeonpea can be grown as an annual crop if circumstances demand. When planted at ICRISAT Center soon after the longest day, the time to maturity of different cultivars ranges from 4 to 10 months and their height varies from <1 to >2 m. The average seed yield in farmers' fields is around 650 kg ha^{-1}, but yields larger than 4000 kg ha^{-1} have been obtained when the crop is well managed.

Pigeonpea is a valuable food in the Indian subcontinent and in eastern and southern Africa and Central America. Green seeds and tender pods are used as a vegetable; dhal (decorticated and split seeds) is used in soups or eaten with rice; and ripe seed may be germinated and eaten as sprouts. The perennial forage crop can be used for animal feed, and the dried stems and branches for fuel, thatching, and making both baskets and grain stores. The yields of fuel wood can be ≥ 6 t ha^{-1} depending upon crop duration.

Traditional, long-duration pigeonpea are normally intercropped with a short-duration cereal. In contrast, short-duration pigeonpea, which can mature within 4 months, can be grown in pure stands. Some recently identified genotypes regularly yield more than 3 t ha^{-1} from one harvest, or even more from multiple harvests of the same crop. Their short duration allows them to fit into non-conventional rotations, such as with wheat in northern India or with rice in tropical regions. In Australia, such cultivars have been developed for mechanized cultivation under rainfed conditions. There is now increasing interest in short-duration pigeonpea in areas where medium- and long-duration types have been the ones traditionally grown.

The selection and development of vegetable pigeonpea, for the Caribbean, eastern Africa, and for parts of India, has led to the production of promising

material for use in these areas. Identification of male-sterile lines and the development of high yielding hybrids has opened up new avenues for exploiting the crop. Lines resistant to wilt (*Fusarium udum*), to sterility mosaic virus, and to phytophthora blight (*Phytophthora drechsleri* f. sp. *cajani*), and less susceptible to *H. armigera*, are being crossed with potentially high yielding types in order to stabilize yields.

Some of the lines developed at ICRISAT have been released or are being considered for release by national programmes; for example, ICPL 87, ICPL 151, and ICP 8863 in India; ICP 7035 in Fiji, and cv. Hunt in Australia.

Asian Grain Legume Program

ICRISAT has consolidated and extended its contacts throughout Asia by forming an Asian Grain Legume Program (AGLP) — dealing with chickpea, pigeonpea, and groundnut and which began in January 1986. The aim is to provide the Asian researcher and farmer with the chance to obtain the best material and technology available for each crop.

This Program will ensure close contacts between ICRISAT scientists and their colleagues in Bangladesh, Burma, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand. ICRISAT will continue the policy of making germplasm, elite breeding material, trials, and information freely available to all scientists.

Training

ICRISAT Training Programs cater to the needs of cooperators and scientists from the national programmes. In-Service participants receive training in the conduct of field trials and in research management. In-Service Fellows receive specialized training in research methods. Research Scholars are students who undertake their course work at a University and their research at ICRISAT Center under the guidance of an academic supervisor and ICRISAT scientist, respectively. Post-doctoral Fellows work on projects related to ongoing research at ICRISAT Center. By the end of 1985, 126 participants from 28 countries, 125 participants from 34 countries, and 220 participants from 39 countries had passed through the chickpea, pigeonpea and groundnut Training Programs, respectively.

Bibliography

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