International Efforts on Improvement of Chickpea and Pigeonpea

W.D. DAR, J. KUMAR, K.B. SAXENA, H.D.UPADHYAYA and J.H .CROUCH

International Crop Research Institute for Semi Arid Tropics, Patancheru

CHICKPEA PROGRAMME

ICRISAT holds in trust the world's largest collection of germplasm for chickpea. These are stored in short and long-term cold stores. The germplasm is shared with interested researchers globally. The world germplasm collection of chickpea at Patancheru consists of 17,115 accessions of cultivated species from 44 countries and 135 accessions of 18 (8 annual and 10 perennial) wild *Cicer* species. Of these, 12,962 accessions of cultivated species were obtained from donations by 18 countries and the remaining 4,153 accessions from 65 collection missions in 15 countries. In the case of wild species, 60 of the 135 wild *Cicer* accessions were assembled by donations from six countries and the remaining accessions were obtained through five collection missions in Afghanistan, Turkey, Syria, and Pakistan. Collection missions for cultivated species were undertaken in many countries. The largest number of collecting missions (39) was undertaken in India resulting in the collection of 2,092 accessions. India (6,932 accessions, 40.5%) and Iran (4,856 accessions, 28.4%) have provided the largest proportion of the ICRISAT collection. For safety purposes, ICRISAT has deposited duplicate samples of 4,566 accessions in the genebank of ICARDA, and ICRISAT genebank holds duplicate samples of ICARDA's 5,914 accessions.

The accessions of wild and cultivated species have been characterized for a complete set of morphological descriptors. These accessions contain very useful diversity that can be utilized in the improvement of chickpea. Evaluation of wild species have resulted in identification of genes for resistance for *Botrytis* gray mold in *C. judaicum* and *C. pinnatifidum*, and for *Ascochyta* blight in *C. judaicum* and *C. reticulatum*. These resources are maintained in the genebank in the long-term (9,053 cultivated and 25 wild) and medium-term (all accessions) storage facilities. The accessions from this genebank are distributed to scientists from different countries on request. In last 25 years (1974-1999) we have distributed 110,740 samples to the scientists in 84 countries beside 159,399 samples to the scientists in ICRISAT for use in various studies. Several germplasm lines have performed well in the evaluations in different countries of world and 15 such lines have been released as cultivars in 13

Souvenir, National Symposium on Pulses for Sustainable Agriculture and Nutritional Security, 17-19 April, 2001

countries.

At ICRISAT a core collection of chickpea has been developed by using data of 13 quantitative traits. The traits used were days to 50% flowering, plant height (cm), plant width (cm), days to maturity, number of basal and apical primary branches, number of basal and apical secondary and tertiary branches, number of pods per plant, seeds per pod, seed yield (kg ha^{-1}), and 100-seed weight (g). The range-standardized data was used for clustering. From each cluster about 10% accessions were randomly selected and a core subset consisting of 1956 accessions was developed. The co-adapted gene complexes controlling the quantitative traits were properly and adequately sampled. Using the evaluation data on the chickpea core subset we have developed a 'mini-core subset' which is about 1% of entire collection, yet adequately represents the core subset and in turn the entire collection. This approach will provide a point of entry and working collection to chickpea scientists to tackle diseases, pests, and other problems. It can be extensively examined for economic traits to generate information on genetic variability in chickpea and possible relationships among traits.

The genetic enhancement of these crops is undertaken in collaboration with NARS and with advanced research institutions. Significant contributions from these research collaborations include extension or adaptation of these crops.

Development of short-duration germplasm e.g. ICCV 2, ICCC 37, ICCV 10 and KAK 2 have helped realize higher yields in short-duration environments. The short duration cultivars effectively escape end-of-season drought.

Early-maturing high-yielding cultivars are needed by farmers to grow in the areas where season length is of limited duration. A total of 13 new early-maturing chickpea lines have been identified. Some of these lines (ICCs 10629, 10981, and 14648) matured in 94-99 days and yielded more than 4.0 t ha^{-1}. Studies indicate a high degree of divergence among the sources of early-maturity and with ICC 5810, the known source of early-maturity.

Seed size is an important trait in Kabuli chickpeas and bold-seeded types gain premium prices in the market. We have identified 15 bold-seeded Kabuli germplasm lines. Some of these lines (ICCs 14199, 14190, 7344, 12498, and 11303) have up to 55 g 100-seed weight compared to 16 g of the control cultivars L 550 and ICCV 2. Studies on diversity indicated high divergence among these lines and with L 550 and ICCV 2.

There has recently been an increased emphasis at ICRISAT on strategic and basic work, as there has been limited continuity of such work in the national programs. A number of screening techniques have been developed that are routinely and fruitfully used by NARS to screen for resistance. A number of research papers have been published to disseminate basic and applied research that has benefited the improvement of the crops worldwide. At ICRISAT we have identified as many as 15 new genes of agronomic importance in chickpea. The first ever intra-specific genome map was developed through a collaboration between ICRISAT and Washington State University. Such developments will magnify the power of plant breeding and lead to better and more productive varieties.

PIGEONPEA PROGRAMME

The world collection of pigeonpea at present consists of 13,015 accessions of this species and its wild relatives from 72 countries. It is a continuing process and ICRISAT scientists in collaboration with various institutions embark on systematic germplasm assembly from time to time. The collection includes different categories of germplasm such as landraces, established cultivars, breeding stocks with specific characters, gene pools, etc.

A viable mechanism for exchanging germplasm and breeding material among member countries was put in place. The ICRISAT gene bank provided 3,498 pigeonpea germplasm samples to the project countries during April 1995 to September 1999. In addition, the member countries received more than 7,117 pigeonpea samples of early and advanced generation breeding lines, and other genetic stocks.

Yield losses due to *Fusarium* wilt in India during the 1977/78 season cost the country an estimated US$ 36.4 million in foregone production. ICRISAT's first major impact in pigeonpea was to help bring wilt under control for millions of smallholders across India. Since the poorest farmers cultivated the most susceptible, long-duration plant types, targeting wilt resistance was a way to deliver research benefits to the most needy smallholders. The largest impact was generated by the line ICP 8863, released in 1986 as 'Maruthi' and it was an immediate success. Its adoption in the northern part of Karnataka state, the primary target zone, increased from 5% in 1987 to almost 60% by 1992/93. Gains included a stabilization of small-holders production, major expansion of crop area, and increased smallholder incomes. In on-farm trials, Maruthi's wilt resistance conferred an impressive 57% advantage in yield performance. Failing smallholder enterprises became profitable once again, as unit costs of production fell by 42%, or US$ 1200 per ton. The net present value of benefits from the research effort have been estimated at US$ 62 million to date, representing an internal rate of return of 65% on the original research investment. This is a classic example of the benefits of partnership, as the exhaustive multilocational testing that was needed to identify Maruthi would not have been possible without a carefully-planned program of collaboration between the Indian Council of Agricultural Research (ICAR) and ICRISAT.

In collaboration with ICAR, ICRISAT developed an unique short-duration (4 month) variety ICPL 87. Farmers were quick to adopt variety ICPL 87, released as 'Pragati' in central India in 1986. Immediately it became popular in the drier regions of Maharashtra and Karnataka, and now covers over 150,000 ha in these states. In a detailed impact study Bantilan and Parthasarathy (1998) found that the variety / management package resulted in an average 93% yield increase over the systems it replaced. Another major reason for adoption was that it enabled double cropping: the pigeonpea matured early enough so that farmers could still sow their staple post-rainy crops of sorghum, chickpea, and wheat. The bottom-line benefit to the overall enterprise was a 30% increase in net farm income. Ryan (1998) estimated that the net present value of the investment is 1978 terms was US$ 117 million, generating an internal rate of return of more than 27%.

A major contribution of ICRISAT was to challenge the assumption that hybrid systems were not achievable for food legumes and the world's first pigeonpea hybrid variety, ICPH 8, released in 1991. By challenging conventional wisdom, ICRISAT has opened up a whole new vista for pigeonpea improvement. The first major impact was on partnerships, as the creation of a hybrid pigeonpea technology stimulated excitement among partner institutions. The hybrid technology was shared with ICAR and a number of public and private seed companies in India and a few additional hybrids were developed. The hybrids demonstrated a consistent grain yield advantage of 25-35% over non-hybrid varieties of similar plant type and duration.

The availability of food in Yemen became a serious problem when more than three million migrant workers returned home during the Gulf war crisis. To increase local production of protein rich food for human beings and fodder for animals, the introduction of pigeonpea (a new crop for this region) was attempted through farmers' participatory approach. The pigeonpea trials conducted in Yemen for the first time were highly successful. Medium-duration varieties produced crop yields of 1 t ha^{-1} without any input of fertilizer, irrigation or insecticide. ICP 8094 produced good seed yield and in addition was the most productive for green fodder and fuel wood. Overall pigeonpea provided several opportunities for the dry area of Yemen.

In Sri Lanka pigeonpea was promoted to produce split peas in the southern, central and western provinces as the main legume crop of the dry areas. Short-duration pigeonpeas have also recorded very high (2-3 t ha^{-1}) yield in paddy-fallows and this provides a good option for crop diversification in the island country.

ICRISAT and China have recently started exploiting alternate uses of

pigeonpea; these include soil conservation and fodder for cattle and goats. In the last two years, significant progress has been made in identifying promising lines for these purposes. In southern China, where soil erosion is a serious problem and afforestation using perennial trees takes 10-15 years, pigeonpea has succeeded in covering barren ground within one year. In addition, it is enriching soil by adding organic matter and providing valuable fuel wood (about 10-12 t ha^{-1}). This production system is rapidly spreading in Yunnan and Guangxi provinces. Also some lines capable of producing 30-40 t ha^{-1} green fodder have been identified and farmers find it a useful crop for grazing purposes.

After South Asia, Eastern and Southern Africa is the second largest pigeonpea growing area in the world, accounting for an estimated 12% of global pigeonpea production. The importance of pigeonpea is expected to grow considerably in the region as structural adjustment of agricultural subsidies in raising fertilizer prices are forcing farmers to increase their cropping of less-fertilizer-dependent crops like pigeonpea. Also this crop has unique characteristics that could help many African countries tackle pressing agricultural and energy problems, such as under nutrition, land degradation, and fuel-wood shortages. According to the United Nations Children's Fund (UNICEF), an estimated 30% of children under the age of 5 in sub-Saharan Africa are underweight mainly due to deficiency of energy and nutrients. Pigeonpea is rich in minerals, vitamins, fats, and protein, which make it an ideal supplement to traditional cereal-, banana- or tuber-based diets that are generally protein-deficient. Pigeonpea in the past has received very low priority from research agencies in Africa until ICRISAT unlocked its rich potential. In 1992, the African Development Bank launched the Pigeonpea Improvement Project since there was a pressing need to develop new technologies to increase pigeonpea productivity and utilization in the region. ICRISAT was chosen as its coordinator as the institute had already gained worldwide recognition for pigeonpea research. The project set specific targets and worked in 10 countries: Kenya, Malawi, Mozambique, Namibia, Sudan, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe. In Eastern and Southern Africa, yields of traditional pigeonpea varieties are depressingly low (300 – 500 kg ha^{-1}). And because most of these varieties require about 6-10 months to mature, they are faced with a host of problems such as mid-season and or terminal drought, diseases, and insect pests. ICRISAT has developed a wide spectrum of improved varieties; some of them escape drought by maturing early (about 3 months). Many are resistant to the major diseases in the region: *Fusarium* wilt and *Cercospora* leaf spot. The new varieties can provide a good harvest even in drought years when traditional landraces fail. And in good years, they can double or even triple landrace yields.

So far, as many as 21 improved high-yielding lines have been developed for specific agro-ecological zones. Among these, KAT 60/8, ICPL 87091 and ICP 9145 have been released. In addition, at least six varieties are being grown in these countries even though they have not yet been officially released. Pigeonpea is highly sensitive to changes in daylength and temperature. A long-term study on the effect of temperature and daylength on pigeonpea phenology and performance has been carried out by ICRISAT along the "Kenya Transect". This transect is a belt of research sites on the equator covering areas from sea level to altitudes of over 2000 m which provides a range of temperatures and constant daylength. The transect studies are helping researchers not only to match varieties with environments, but also to create new niches for pigeonpea and develop widely adapted varieties. The project scientists are now seeking ways to transfer these new technologies to farmers. Farmer-participatory testing will help refine the technologies, pinpoint and eliminate adoption constraints.

ICRISAT has recently initiated research links with USDA for exploring the possibility of cultivating pigeonpea for fodder purpose in the Southern Great Plains. Lines which can germinate at low temperatures have been identified and their field evaluation will follow soon.

In India the present production of 2.5 million t is insufficient to meet the domestic needs and a considerable amount of pigeonpea is imported every year. In 1995-1996 India imported 82,000 t, while in 1996-97 it rose to 132,000 t. India's pigeonpea deficit is projected to continue to grow (Jaeger 1998) and the estimates for the 1998-1999 season are as high as 200,000 t. The entire pigeonpea cultivation in Myanmar is export oriented and it has registered over 300% growth in pigeonpea area from 62,010 ha in 1970 to 265,500 ha in 1998. In 1999, Africa exported more than 60,000 t of pigeonpea to India.

The demographic change in Europe and the USA is creating a demand for immigrants' traditional foods in their new homes. The large Indian and Afro-Caribbean communities in North America offer new potential markets. The potential of canned or frozen green peas is also high. From Dominican Republic, about 80% of the annual harvest is exported. The growing pigeonpea export market has led to increase in pigeonpea area in Dominican Republic from about 7,000 ha in 1970 to 23,000 ha in 1998. The principle importer and consumer in Europe is the United Kingdom, owing to its large population of people of Indian and Caribbean descent. Recent market research in Europe indicated a significant niche market for high quality pigeonpea grain.

MOLECULAR BREEDING OF CHICKPEA AND PIGEONPEA

In the application of molecular approaches high priority is being accorded to molecular breeding of chickpea and pigeonpea. In chickpea major emphasis is given to mapping resistance to diseases such as *Fusarium* wilt, *Botrytis* gray mold, *Ascochyta* blight, drought tolerance and resistance to pests such as *Helicoverpa* pod borer. Similarly in pigeonpea mapping of *Fusarium* resistance and fertility restorer genes for F1 hybrid variety seed production systems is in progress. Emphasis is also being placed on molecular diversity analysis in both crops with particular emphasis on the use of DNA markers to study gene flow in pigeonpea germplasm.