A chapter from

Adaptation of Chickpea in the West Asia and North Africa Region

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1996

5.6. Genetic Improvement and Agronomic Management of Chickpea with Emphasis on the Mediterranean Region

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Chickpea-growing areas can be demarcated into five major eco-geographic regions: South Asia, Mediterranean region, East Africa, Latin America, and Oceania. Long-term data (FAO 1971, 1981, 1992) show a decrease in world chickpea area, a marginal increase in production, and a reasonable increase (35.3%) in productivity from 517 kg ha^{-1} in 1951 to 710 kg ha^{-1} in 1991, at an average rate of increase of 4.8 kg ha^{-1} per year.

The decrease in area seems to be the result of yield instability due to biotic and abiotic stresses, low yield potential of cultivars, and lack of cultivars responsive to applied inputs. Another reason for the decrease is the greater competitiveness and availability of high-yielding, input-responsive, and disease-resistant cultivars of cereal crops.

Although the development of chickpea genotypes with high and stable yields has been a major breeding objective for many years, it has resulted in only limited gains. Landraces continue to dominate in farmers' fields, even though they have low yield potentials and are susceptible to various biotic and abiotic stresses. Traditional agronomic management practices do not favor high yields. The current status of genetic improvement and agronomic management practices in chickpea is reviewed in this section and future strategies to increase and stabilize chickpea yield with emphasis on the WANA region are recommended.

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Genetic Improvement

Selection in germplasm has been a common approach for identifying promising chickpea cultivars. It has been mostly effective because of the general and specific adaptation of the landraces to local conditions. Hybridization and selection are now focusing on combining desirable traits from different landraces or source populations (Singh 1987). Many chickpea cultivars have been released using these procedures (Singh 1987; Smithson et al. 1985).

In cereals, a change in plant type—from tall and lodging to stiff-strawed, semidwarf, and non-lodging type— for greater responsiveness to irrigation and fertilizer has increased yields substantially. Ideotypes for obtaining high yield have also been proposed in chickpea but have not been developed to any significant extent. Developing resistance to biotic and abiotic stresses has been the major objective of crop improvement programs.

Biotic Stresses

Diseases

The chickpea diseases and screening procedures have been described in detail by Beniwal et al. (Section 5.3). They are considered here for genetic and management improvement.

Fusarium wilt and black root rot

Reliable screening techniques are available for fusarium wilt (*Fusarium oxysporum*) and several sources of resistance have been identified (Nene and Haware 1980; Nene et al. 1981; Nene and Reddy 1987; Jimenez-Diaz et al. 1993). Five sources —ICC 10803, ICC 11550, ICC 11551, ICC 11322, and ICC 11323— have proved to be durable and have retained their resistance under high levels of pressure (Nene and Haware 1980). Three kabuli lines, FLIP 82-78C, FLIP 84-43C, and FLIP 84-130C, developed at ICARDA were also found resistant to fusarium wilt at Cordoba in Spain. Combined but moderate levels of resistance to fusarium wilt and root rot (*Rhizoctonia bataticola*) have been identified in ICC 12237 and ICC 12269 (Nene 1988). At ICRISAT Asia Center (IAC), India, over 100 out of some 12 000 germplasm accessions screened have been identified as resistant (Pundir et al. 1988). Chickpea cultivars developed by ICRISAT jointly with various NARS and released for general cultivation are listed in Table 5.6.1. Hybridization and selection using pedigree, modified bulk pedigree, or backcross methods have been successful in enhancing resistance to these two diseases.

Inheritance studies show that resistance to fusarium wilt is oligogenic. Two recessive genes, and in one case a partially dominant gene, conditioning late wilting of chickpea (Singh et al. 1987) have been recognized. The combination of any two confers complete resistance. Resistance to race 1 of fusarium wilt disease is controlled by at least 2 loci (Kumar and Haware 1982; Sindhu et al. 1983; Upadhayaya et al. 1983a and b; Singh et al. 1987, and Singh et al. 1990b). Recessive alleles at each locus separately result in conditioning late wilting and together confer an almost complete resistance.

Table 5.6.1. Releases of chickpea genotypes developed by ICRISAT in collaboration with national programs.

Country	Cultivars released	Year of release	Specific features
Ethiopia	Mariyo (Sel. from 850-3/27 × F 378)	1988	Large seeds
India	ICCC 4 (ICCV 1)	1983	Released in Gujarat
	RSG 44 (Sel. from ICC 12366)	1984	Short-duration, released in Rajasthan
	Anupam (Sel. from ICC 14302)	1984	Released in Uttar Pradesh
	GNG 149 (Sel. from L 550 × L 2)	1985	Released in Rajasthan
	Swetha (ICCV 2)	1989	Short-duration, wilt resistant
	ICCV 2	1991	Released in Maharashtra
	Kranthi (ICCC 37)	1989	High-yielding, short-duration, wilt-resistant, released in Andhra Pradesh
	Bharathi (ICCV 10)	1992	Short- to medium-duration, wilt-resistant, released for central and southern India
Kenya	ICCL 83110	1986	
Myanmar	Schwe Kyehman (Sel. from K 850 × F 378)	1986	Large seeds
	Yezin 1 (ICC 552)	1986	High-yielding
Nepal	Sita (ICCV 1)	1987	High-yielding
	Radha (ICC 6098)	1988	Short-duration, wilt-resistant
	Kosheli (ICCV 6)	1990	Wilt-resistant, kabuli
	Kalika (ICCL 82108)	1990	Wilt-resistant, desi
USA	Aztec (ICC 8521)	Mid 1980s	

In spite of the occurrence of physiological races (Haware and Nene 1982) and differences between early and late wilting, many genotypes with durable resistance have been developed and released for cultivation (Kumar et al. 1985; Buddenhaggen and Richards 1988). Avrodhi, BG 246, ICCC 32, and ICCC 42 were found resistant at several locations in India. A few national agricultural research systems (NARS) have developed and released several resistant cultivars, including WR 315 and CPS 1 by the Indian NARS, Amdoun 1 by the Tunisian NARS, and Surutato 77, Sonora 80, and Santa Domingo by the Mexican NARS. The University of California has released two cultivars UC 15 and UC 27. Some countries including Spain have developed improved sources of resistance to fusarium wilt and released them for commercial exploitation.

Ascochyta blight

Ascochyta blight (*Ascochyta rabiei*) is a major constraint in the Mediterranean region, Pakistan, and northwestern India, and sometimes causes total crop failure. Progress made in breeding for ascochyta blight resistance from 1930 to 1984 has been summarized by Singh (1987). Genetic improvement of resistance was initiated around 1940. Selections made in germplasm resulted in the release of several cultivars, including F 8, VIR 32, ILC 72, ILC 195, ILC 202, ILC 482, and ILC 3279. Hybridization and selection work which began in the 1940s produced several cultivars in Pakistan (C 12/34, C 727, C 44) and India (C 235, G 543). The extensive resistance breeding work undertaken in the ICARDA/ICRISAT chickpea project over the past 10 years has helped identify and develop several blight-resistant, high-yielding kabuli cultivars for the Mediterranean region (Table 5.6.2).

Resistance to ascochyta blight seems to be governed by a single recessive or a single dominant gene (Singh and Reddy 1983, 1989, 1991).

Cultivars at different locations have been found to react differently to blight; there appear to be 13 races of blight in chickpea (Reddy et al. 1992). New races have emerged and resulted in the breakdown of sources that were earlier resistant in many countries. A recent example is the breakdown of resistance in ILC 482 in Syria (K.B. Singh, unpublished data). Strategies for incorporating durable resistance should, therefore, be adopted through pyramiding of genes from sources resistant to different physiological races.

Nematodes

Several nematodes—cyst (*Heterodera* spp), root-knot (*Meloidogyne* spp), and root-lesion (*Pratylenchus* spp)—have been reported from several countries. Root-knot nematodes are the most widespread and damaging plant-parasitic nematodes. Among them, *M. incognita*, *M. javanica*, and to some extent *M. arenaria*, are important in South Asia and *M. artiella* is important in the Mediterranean region. Spring-sown chickpea is more susceptible to *M. artiella* than winter-sown chickpea. However, nematode problems are mostly of localized significance. Field techniques for nematode screening need to be simplified. A pot-culture technique for screening resistance to cyst nematode has been developed at ICARDA (Di Vito et al. 1988). Efforts to identify resistance to root-knot (Sandhu et al. 1981) and cyst nematodes (Di Vito et al. 1988) in cultivated species have not been rewarding. But sources of resistance to cyst nematode have been identified in wild *Cicer* species (Singh et al. 1989a). Most of the resistant sources to cyst nematode are found in *C. bijugum* and *C. pinnatifidum*.

Insect Pests

Insect pests on chickpea and screening methods have been described by Weigand (Section 5.4). Leafminer (*Liriomyza cicerina*) and pod

Table 5.6.2. **Chickpea cultivars developed by ICARDA and released by national programs.**

Country	Cultivars released	Year of release	Specific features
Algeria	ILC 482	1988	High-yielding, blight-resistant
	ILC 3279	1988	Tall, blight-resistant
	FLIP 84-79C	1991	Cold- and blight-resistant
	FLIP 84-92C	1991	Blight-resistant
China	ILC 202	1988	High-yielding, for Ginghai province
	ILC 411	1988	High-yielding, for Ginghai province
	FLIP 81-71C	1993	High-yielding
	FLIP 81-40C	1993	High-yielding
Cyprus	Yialousa (ILC 3279)	1984	Tall, blight-resistant
	Kyrenia (ILC 464)	1987	Large seeds
Egypt	ILC 195	1993	Blight- and wilt resistant
Ethiopia	DZ 10-16-2	1994	For mid-altitude areas, high-yielding, tolerant of wilt/rust
France	TS1009 (ILC 482)	1988	Blight-resistant
	TS1502 (FLIP 81-293C)	1988	Blight-resistant
	Roye Rene (FLIP 84-188C)	1992	Cold- and blight resistant
Iraq	Rafidain (ILC 482)	1991	Blight-resistant, high-yielding
	Dijla (ILC 3279)	1991	Tall, blight-resistant
Italy	Califfo (ILC 72)	1987	Tall, blight-resistant
	Sultano (ILC 3279)	1987	Tall, blight-resistant
Jordan	Jubeiha 2 (ILC 482)	1990	High-yielding, blight-resistant
	Jubeiha 3 (ILC 3279)	1990	High-yielding, blight resistant
Lebanon	Janta 2 (ILC 482)	1989	High-yielding, wide adaptation
	FLIP 85-5C	1993	Blight-resistant
Libya	ILC 484	1993	Blight-resistant, high-yielding
Morocco	ILC 195	1987	Tall, blight-resistant
	ILC 482	1987	High-yielding, blight-resistant
	Rizki (FLIP 83-48C)	1992	Large seed, blight-resistant
	Douyet (FLIP 84-92C)	1992	Large seed, blight-resistant
Oman	ILC 237	1988	High-yielding, irrigated conditions

Continued

Table 5.6.2. *Continued.*

Country	Cultivars released	Year of release	Specific features
Pakistan	Noor 91 (FLIP 81-293C)	1992	High-yielding, blight-resistant
Portugal	Elmo (ILC 5566)	1989	Blight-resistant
	Elvar (FLIP 85-17C)	1989	Blight-resistant
Spain	Fardan (ILC 72)	1985	Tall, blight-resistant
	Zegri (ILC 200)	1985	Medium height, blight-resistant
	Almena (ILC 2548)	1985	Tall, blight-resistant
	Alcazaba (ILC 2555)	1985	Tall, blight-resistant
	Atalaya (ILC 200)	1985	Medium height, blight-resistant
Sudan	Shendi (ILC 1335)	1987	High-yielding, irrigated conditions
	Jeb el Mara 1 (ILC 915)	1994	High-yielding, irrigated conditions
Syria	Ghab 1 (ILC 482)	1986	High-yielding, blight-resistant
	Ghab 2 (ILC 3279)	1986	Tall, blight-resistant
	Ghab 3 (FLIP 82-150C)	1991	High-yielding, cold- and blight-resistant
Tunisia	Chetoui (ILC 3279)	1986	Tall, blight-resistant
	Kassab (FLIP 83-46C)	1986	Large seeds, blight-resistant
	Amdoun 1 (Be-sel-81-48)	1986	Large seeds, wilt-resistant
	FLIP 84-79C	1991	Blight- and cold-resistant
	FLIP 84-92C	1991	Large seed, blight-resistant
Turkey	ILC 195	1986	Tall, blight-resistant
	Guney Sarisi 482	1986	High-yielding, blight-resistant
	Damla (FLIP 85-7C)	1994	For cultivation in Transitional Zone, blight-resistant
	Tasova 89 (FLIP 85-135C)	1990	Blight-resistant
	Akcin (87AK71115)	1991	Tall, blight-resistant
	Aydin 92 (FLIP 82-259C)	1992	Large seed, blight-resistant
	Menemen 92 (FLIP 85-14C)	1992	Large seed, blight-resistant
	Izmir 92 (FLIP 85-60C)	1992	Large seed, blight-resistant
	Aziziye (FLIP 84-15C)	1994	Blight-resistant, for cultivation in Erzurum region
USA	Sanford (Surutato × FLIP 85-58C)	1994	Blight-resistant
	Dwelley (Surutato × FLIP 85-58C)	1994	Blight-resistant

borers (*Helicoverpa* spp) cause most damage in Mediterranean environments, whereas pod borers are the most important insect pests in the semi-arid environments. Among storage insects, bruchid (*Callosobruchus* spp) infestation is widespread.

Pod borer

Since 1976, more than 14 000 chickpea germplasm accessions and breeding lines have been screened for resistance to pod borer (*H. armigera*) under open field conditions at ICRISAT. Some of the selections, ICC 506, ICCV 7, ICC 6663, ICC 10817, ICCL 86012, ICCL 86013, ICC 4935-E 2793, ICCX 730041-8-1-B-BP, PDE 2, and PDE 5, showed good level of resistance to pod borer across the different agroecological zones of India (Lateef and Sachan 1990). A major limitation in genetic improvement of pod borer resistance is the lack of effective screening methods. However, repeated cycles of selection for low damage under field conditions over different generations have been effective in identifying genotypes that are less susceptible (Lateef and Sachan 1990).

Resistance to pod borer damage seems to be governed by additive gene action (Gowda et al. 1985). A pedigree method of breeding for developing high-yielding resistant genotypes is followed at ICRISAT. An integrated approach, involving nonpreference (antibiosis), and early-podding genotypes (increasing podding duration) could help the plants to escape from *Helicoverpa* damage (Singh et al. 1992). Nonpreference (antibiosis), perhaps mediated by malic acid exudation from stem and leaf surfaces, is most likely to be quantitatively inherited, and can be increased through recurrent selection.

Leafminer

Screening of 6800 kabuli chickpea germplasm lines for leafminer resistance under natural field infestation at ICARDA, revealed that only 31 lines were tolerant. Of these, only four, ILC 726, ILC 1776, ILC 3350, and ILC 5901, were promising resistance sources. Most of the leafminer-resistant genotypes have smaller leaflets and seed. The most tolerant genotype, ILC 5901, has characteristic multipinnate leaves. The breeding program for leafminer resistance at ICARDA has made limited progress as it lacks efficient screening techniques. A negative selection for leafminer tolerance is being followed and elite breeding material developed at ICARDA are being screened.

Abiotic Stresses

Drought

Terminal drought is the most important abiotic stress (Saxena et al. 1993). In the Mediterranean region, it is frequently associated with heat stress (Wery et al. 1993). Two common strategies are followed for the genetic management of drought: development of short-duration cultivars to escape drought, and genetic enhancement of drought resistance. Development of the short-duration kabuli cultivar ICCV 2, and desi cultivars such as ICCV 88201 and ICCV 88202, are good examples of the first approach (Kumar et al. 1985). Of the two components of drought resistance, yield potential and drought escape (Silim and Saxena 1993a and b), the latter may have a limited impact on rainfed yield in winter-sown chickpea in WANA as the early-formed flowers may not set pods at extremely cold temperatures. Five kabuli cultivars, Krasnokutskyi (K) 195, Jubilant, K 123, K 28, and Volgagrad 10 have been found tolerant of drought and heat at Kroshy Kut Research Station Saratov, Russia (Nadazda, personal communication).

Using a field-screening technique, a short-duration drought-resistant germplasm (ICC 4958) has been identified (Saxena 1987c), and is being used in genetic enhancement of drought resistance at

ICRISAT (ICRISAT 1989). At ICARDA, FLIP 87-59C has been identified in the same way and is being used in the breeding program (ICARDA 1994).

In addition to the field-screening techniques described by Johansen et al. (Section 5.3), a technique involving late spring (mid- to late-Mar) sowings in Mediterranean-type environments has been evaluated at ICARDA to screen chickpea for drought and high temperature stress (ICARDA 1992). It has been effective in identifying some promising drought-resistant genotypes. Saxena et al. (1993) have established several criteria for identifying drought-resistant genotypes, e.g., empirical methods, yield-based criteria (Saxena 1987c), morphophenological traits such as early maturity, early growth vigor, rapid ground cover, relatively large seed size, and large root biomass associated with drought-tolerance sources. Integrating these with a visual rating for yield in defined drought environments will help to make rapid progress in genetic enhancement of drought resistance in chickpea.

Cold

Cold stress occurs at various crop growth stages—emergence, seedling, vegetative, or flowering—depending upon the ecoregion and sowing time. Extremely cold temperatures coinciding with the flowering stage cause failure of pod setting (Saxena and Johansen 1990). Tolerance for freezing cold at vegetative stages is an essential component of winter chickpea technology that has been introduced in WANA (Singh et al. 1989c). Research on the mechanisms of cold tolerance is in progress in Italy and France (Wery 1990; Malhotra and Saxena 1993).

Sources resistant to cold have been identified (Singh et al. 1989c; Singh et al. 1990a; Wery et al. 1992) and used in genetic enhancement programs (ICARDA 1993) and for studies on the inheritance of cold tolerance (Malhotra and Singh 1990, 1991a). Some of the cold-tolerance sources in cultivated species include ILC 794, ILC 1071, ILC 1251, ILC 1256, ILC 1444, ILC 1455, ILC 1464, ILC 1875, ILC 3465, ILC 3598, ILC 3746, ILC 3791, ILC 3857, ILC 3861, FLIP 82-85C, FLIP 82-131C, FLIP 84-112C, FLIP 85-4C, FLIP 85-49C, and FLIP 85-81C (Singh et al. 1989c).

The level of cold tolerance was found to be higher in wild *Cicer* species than in cultivated species (Singh et al. 1990a). Cold tolerance is governed by both additive and nonadditive gene effects, with preponderance of additive gene action (Malhotra and Singh 1990). Also, additive × additive and dominance × dominance interaction with duplicate epistasis have been reported (Malhotra and Singh 1991a). Selection for cold tolerance is more effective after a few generations of selfing, when dominance and epistatic effects are reduced.

Responsiveness to Inputs

Fertilizer

In general, responses to fertilizers inputs are minimal, possibly because the chickpea crop has been developed under low-input conditions (Smithson et al. 1985). Genotypic differences in response to phosphatic fertilizers have been reported (ICARDA 1991), but there are no published reports on breeding for P responsiveness in chickpea.

Irrigation

In recent years, chickpea has been introduced as an irrigated crop in many countries. It is grown exclusively with irrigation in Egypt and Sudan. In other countries such as India, Iran, Pakistan, Mexico, Syria, and USA, small areas are grown with supplemental irrigation and genotypic differences in irrigation response have been observed. The yield of winter-sown rainfed chickpea in the Mediterranean environments could be increased by more than 50% by using irrigation-responsive genotypes and applying 100 mm of supplemental irrigation (ICARDA 1989). One of the cultivars responsive to irrigation, ILC 237, has been released in Oman. Other cultivars identified as irrigation-responsive include, ILC 104, ILC 202, ILC 482, FLIP 83-69C, FLIP 83-71C, and FLIP 84-116C (ICARDA 1989).

Exploitation of Wild *Cicer* Species

More than 200 accessions of eight annual wild *Cicer* species were evaluated for resistance to ascochyta blight, fusarium wilt, leafminer, cyst nematode, and seed beetle and to cold (ICARDA 1990). Resistance to seed beetle and cyst nematode was found only in the wild species (Singh et al. 1989a, b). In general, the degree of resistance to most of the stresses was greater in wild than in cultivated species. Many accessions have combined resistance to four or even five stresses. Therefore, genes for resistance in blocks for several stresses could be transferred to cultivated species.

Crosses of *C. echinospermum* and *C. reticulatum* with cultivated species were made by Ladizinsky and Adler (1976) and Singh and Ocampo (1993). Recently, crosses have also been reported between cultivated species and *C. bijugum*, *C. judaicum*, and *C. pinnatifidum* (Verma et al. 1990). Work on interspecific hybridization has been initiated to transfer the genes for resistance to cyst nematode from *C. reticulatum*, and for cold tolerance from *C. echinospermum* and *C. reticulatum* (ICARDA 1994).

Biotechnology and Chickpea Improvement

Cellular and molecular biology (CMB) techniques, e.g., restriction fragment length polymorphism (RFLP), promise to be useful in genetic enhancement of resistance. Some progress has been made in DNA fingerprinting of *A. rabiei* isolates and also of improved cultivars (ICARDA 1993). Gene transfer using nonradioactive probes, for oligonucleotide fingerprinting, is currently being explored jointly by ICARDA and the University of Frankfurt, Germany. Application of CMB techniques to improve resistance to drought and other stresses in chickpea needs to be explored. Utilization of gene coding for the production of insect toxin found in the spores of *Bacillus thuringiensis* (Bt) could be important for enhancing tolerance for *H. armigera*. Highly virulent strains of *Agrobacterium tumefaciens* have been identified (Weigand and Saxena 1989). These could eventually be used as vectors for transferring Bt through a nontissue-culture technique.

International Testing Program

International testing networks (ITN), for the desi type (ICRISAT, since 1975) and kabuli type (ICARDA, since 1978) of chickpea have been very useful for genetic improvement work. Various types of nurseries, including segregating populations, improved stocks with different genetic backgrounds, elite improved high-yielding lines, and sources of resistance to various biotic and abiotic stresses are developed and shared with ITN members for evaluation. These networks have been effective in the development and dissemination of high-yielding germplasm tolerant/resistant to various stresses, and of improved technology.

Several kabuli and desi chickpea cultivars have been released through these joint efforts by NARS in many countries (Tables 5.6.1 and 5.6.2) (ICARDA 1994). Some of these are also used as parents in crop improvement programs. Several agronomic trials have recently been conducted through ITN in WANA. Through these trials, scientists have been successful in identifying the most important agronomic constraints and suitable agronomic management practices, such as appropriate date of sowing, plant geometry, herbicide, orobanche (parasitic weed) control, and rhizobial inoculation requirements. These nurseries were also useful in identifying G × E interactions (Multize et al. 1987; Malhotra and Singh 1991b) and key testing sites.

Crop Improvement: Current Status

At least 159 cultivars—102 desi, 51 kabuli, and six unclassified—have been released in 20 countries up to 1983 (Singh 1987). More than 100 of these were selections made in local or introduced germplasm, and 50 through directed crop improvement efforts. Up to 1989, more than 80 disease-resistant cultivars have been released (Singh and Reddy 1991). Some of the cultivars released using the materials supplied through ITN are listed in Tables 5.6.1 and 5.6.2.

Agronomy and Management

Chickpea in WANA is grown primarily in areas with annual rainfall between 350 and 550 mm. It is traditionally a spring-sown crop (from late Feb to early Jun) grown on soil moisture stored during the winter months. Large areas continue to be spring-sown. Winter chickpea technology for WANA (Singh 1990), in which sowing is advanced from spring to early winter, has demonstrated that an integrated agronomic management practice results in large increases in seed yield. Components of winter chickpea technology are discussed below.

Sowing Date

Spring-sown chickpea suffers from temporal and spatial variability in rainfall (Saxena 1990; Pala and Mazid 1992). Advancing the sowing date from spring to early winter in lowlands, or from spring to late winter in highlands results in rapid canopy development, a large shoot mass which supports high yield, and an increase in water-use efficiency (Saxena 1987a and b; Pala and Mazid 1992). As winter-sown chickpea crops are taller (40 cm height) than those of spring (25–39 cm) in WANA, they are suitable for mechanical harvesting. Direct drilling—which allows better utilization of surface soil moisture and early crop establishment (about 2 weeks) than with other sowing methods—enables earlier sowing of spring chickpea (late Feb to early Mar).

Sowing Methods

In environments favorable for chickpea cultivation in WANA, seeds are generally broadcast evenly on flat seed-beds, both for winter and spring sowings. They are then covered either by a duck-foot cultivator or a mold-board plow. Alternatively, the field is first ridged using a one-set duckfoot cultivator, with about 45 cm between the ridges. Seeds are then broadcast and ridges are bisected by another pass with the duck-foot cultivator. In all cases, seed depth varies from shallow (5 cm) to deep (15-17 cm) (Harris and Pala 1987; Saxena 1987a). In some cases seeds are hand-sown behind the duck-foot cultivator with an inter-row spacing of 40–45 cm, which results in early emergence and better crop development. Drilling seeds with a single pass planter with 40-cm row spacing (developed at ICARDA by mounting the seed and fertilizer boxes on a cereal drill with a duck-foot cultivator) resulted in better early crop development and substantial yield increases over the traditional broadcast method in on-farm trials conducted in Syria (Pala and Mazid 1992). Drills designed for cereals are generally satisfactory for sowing chickpea, with minor modifications (Papendick et al. 1988).

Weed Control

Weeds cause 40–94% seed yield losses in chickpea in South Asia, 40-75% in West Asia, 13–98% in North Africa, and around 35% in

Italy (Solh and Pala 1990). Although early weeding before the crop canopy covers the ground is most useful, limitations due to non-availability and high cost of labor often prevent the adoption of this method, particularly in WANA. Weeds are a more serious problem in winter-sown than spring-sown chickpea. Through ITN, effective chemical weed control measures have been identified. Preemergence application of herbicides such as terbutryne (2.5 to 3.0 kg a.i. kg^{-1}), chlorbromuron (1.5 to 2.5 kg a.i. ha^{-1}), methabenzthiazuron (3.0 kg a.i. ha^{-1}), or cyanazine (0.5 to 1.0 kg a.i. ha^{-1}) either alone or in combination with pronamide (0.5 kg a.i. ha^{-1}) have been effective for large-scale weed control. On-farm evaluation in northern Syria demonstrated yield increases of 17–105% with better weed control in chickpea, the effect being greater in the winter-sown crop (ICARDA 1986).

Mechanical weed control would encourage the expansion of chickpea area and production. Many farmers in WANA, especially in Algeria and Morocco, control weeds by inter-row cultivation, where the rows are usually wider than the row spacing recommended for maximum yield in a weed-free situation. The potential of inter-row cultivation for weed control of winter-sown chickpea has also been demonstrated in Syria (Pala 1991).

Mechanization of Harvesting

In contrast to fully mechanized cereal crop cultivation, lack of mechanization is a major constraint to the expansion of chickpea area in many countries (Buddenhaggen 1990; Oram and Belaid 1990; Osman et al. 1990). Mechanized harvesting of chickpea presents fewer problems than for other legumes because of the availability of tall cultivars, which permits the use of traditional cereal grain combines with some minor adjustments (Saxena et al. 1987). The introduction of winter sowing in lowlands and early spring sowing in highlands will improve plant vigor and yield and promote mechanical harvesting.

Yield losses due to mechanical harvesting using a plot combine for end winter- (early spring-) sown chickpea were 29% in ILC 482, a cultivar of conventional plant height, compared with no seed yield loss in ILC 3279, a tall cultivar (Saxena et al. 1987).

Mechanical harvesting of winter-sown ILC 482 (40 cm plant height) and ILC 3279 (60 cm), and a spring-sown Syrian local cultivar (25 cm), with a swath mower, caused 6 to 48% loss in grain yield. The highest yield losses were recorded in the local cultivar. Modified cereal combine harvesters could not be used to harvest the local cultivar due to its short plant height. The loss in seed yield due to combine harvesting was 18% in ILC 3279 and 26% in ILC 482. ILC 3279, because of its height, was the only cultivar where mechanical harvesting was found to be economical.

Fallow Replacement

Currently around 20 million ha of land are under fallow in WANA, contributing to a low cropping intensity (Pala 1992). However, recent data have shown that fallow-cereal rotations in the region do not store water as efficiently as was earlier believed. In the Anatolian plateau of Turkey, with relatively mild evaporative conditions in the spring and summer, low fallow efficiencies were reported by Durutan et al. (1989). In the lowlands of the region, low fallow efficiency was reported in areas with less than 300 mm annual rainfall, probably because rain water is unlikely to penetrate below 70 to 90 cm into soil profile; this was aggravated by improper traditional cultural practices. At a dry site in northern Syria with long-term mean annual rainfall of 280 mm, Harris (1989) found that by the beginning of the cereal season, less than 10% of the rain received during the fallow season remained in the soil profile, implying a very low efficiency.

Chickpea and other food legumes can replace inefficient fallow lands, improve crop water-use efficiency, and contribute to both improved productivity and sustainability of the system. Karaca et al. (1991) reported that wheat had a higher water-use efficiency when grown after chickpea than after fallow in the Central Anatolian Plateau of Turkey.

Due to marked increases in human populations and small ruminants, continuous cropping of cereals is becoming more frequent in WANA. However, monocropping is increasingly being recognized as an unsustainable system (Karaca et al. 1991; Harris 1990). The introduction of legumes to interrupt monocropping could improve productivity, as reported by several researchers (Saxena 1988; Harris 1990), not only because of reduced depletion of soil nitrogen, but also due to other associated beneficial effects.

Future Needs

- Enhanced resistance to ascochyta blight and cold for winter sowing and increased drought resistance for spring sowing are required.
- New, cheap, and effective herbicides need to be identified.
- Where water is available, scope for supplemental irrigation for greater and efficient use of irrigation water should be explored.
- Unavailability of seed of improved cultivars in adequate quantity is a major limitation, that could be removed through policy decisions such as seed multiplication by the private and public sector and attractive prices for improved seed.
- A large yield gap exists, ranging from 50–80% between research stations and farmers' fields (Saxena 1990), which could be bridged through demonstrations of improved technologies.
- There is a shortage of trained researchers in chickpea improvement programs and a lack of multidisciplinary teams among NARS in WANA. Human resource development, specifically for chickpea improvement, should receive priority attention.
- In the past, chickpea was used in South Asia both as food and feed but later became exclusively a human food because of its high prices. It is unlikely that its price will fall to the extent that it can be used again for feed, except as an ingredient in poultry feed. But if productivity increases substantially through the adoption of winter chickpea technology, the crop could be grown for cattle feed, especially in the Mediterranean areas of Europe.

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