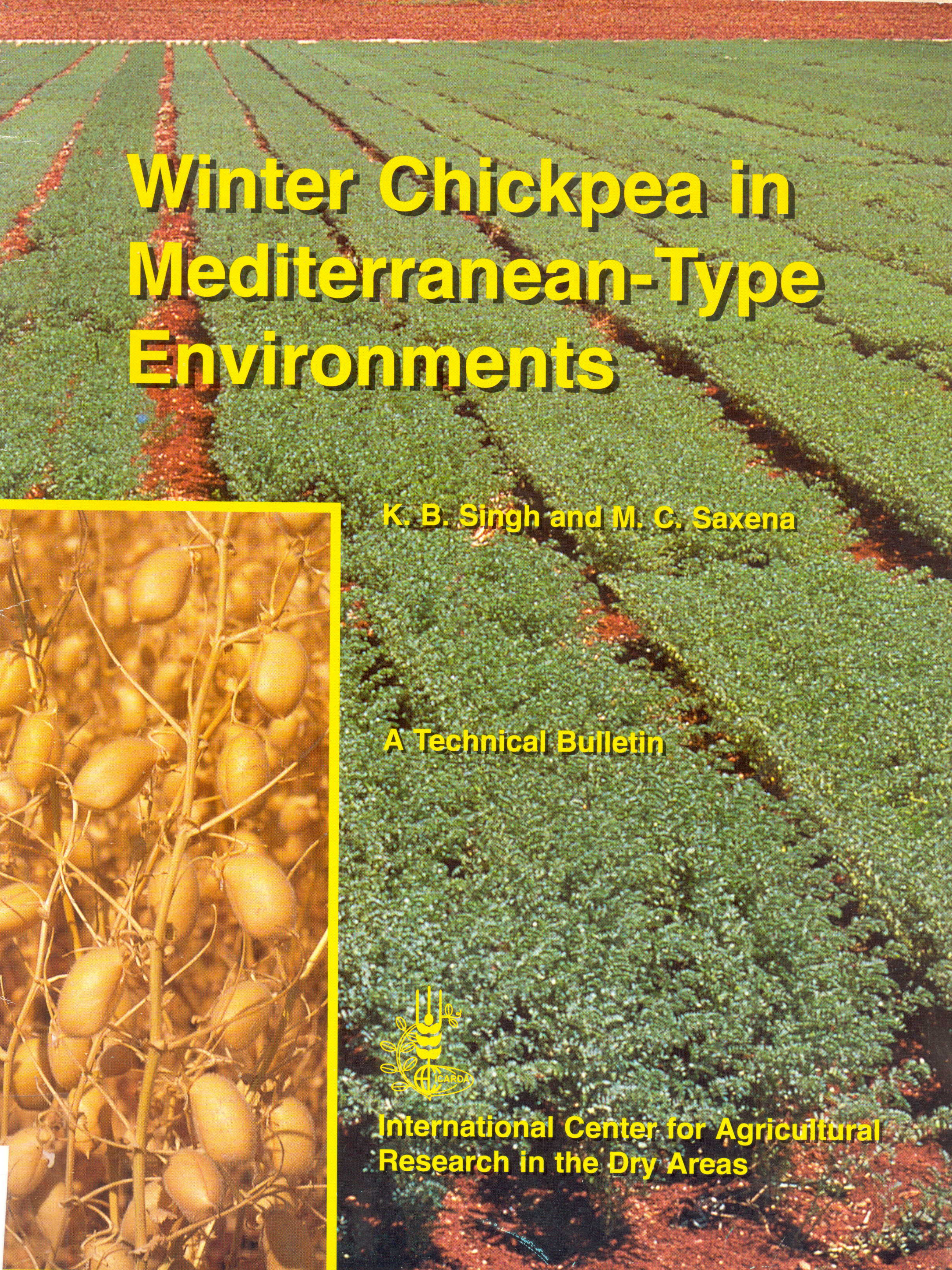

Winter Chickpea in Mediterranean-Type Environments

K. B. Singh and M. C. Saxena

A Technical Bulletin

International Center for Agricultural Research in the Dry Areas

About ICARDA

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 16 centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work.

The CGIAR seeks to enhance and sustain food production and, at the same time, improve socioeconomic conditions of people, through strengthening national research systems in developing countries.

ICARDA's mission is to improve the welfare of people through agricultural research and training in the dry areas in the poorer regions of the developing world, by increasing the production, productivity and nutritional quality of food to higher sustainable levels, while preserving or improving the resource base. ICARDA meets this challenge through research, training, and dissemination of information in a mature partnership with the national agricultural research and development systems.

The Center has a world responsibility for the improvement of barley, lentil, and faba bean, and a regional responsibility in West Asia and North Africa for the improvement of wheat, chickpea, forage and pasture—with emphasis on rangeland improvement and small ruminant management and nutrition—and of the farming systems associated with these crops.

Much of ICARDA's research is carried out on a 948-hectare farm at its headquarters at Tel Hadya, about 35 km southwest of Aleppo. ICARDA also manages other sites where it tests material under a variety of agroecological conditions in Syria and Lebanon. However, the full scope of ICARDA's activities can be appreciated only when account is taken of the cooperative research carried out with many countries in West Asia and North Africa.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs is offered extending from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and specialized information services.

Winter Chickpea in Mediterranean-Type Environments

K.B. Singh
Principal Chickpea Breeder (Consultant)

M.C. Saxena
Research Coordinator

A Technical Bulletin

International Center for Agricultural Research in the Dry Areas
P.O. Box 5466, Aleppo, Syria
1996

Citation: Singh, K.B. and M.C. Saxena. 1996. Winter chickpea in mediterranean-type environments. A Technical Bulletin. ICARDA, Aleppo, Syria, Vii+39 pp.

AGROVOC descriptors: Chickpea, *C. arietinum*, plant breeding, diseases, insects, nematodes, cold, drought, agronomy, physiology, microbiology, farming systems and socioeconomic descriptors.

ISBN: 92-9127-039-3

Editing and production: S.Varma, Guy Manners and Mike Robbins

ICARDA
P.O. Box 5466, Aleppo, Syria
Phone: (963-21) 213477/225112/221512/225012
Fax: (963-21) 213490/225105/219390/551860
Telex: 331208/331206 ICARDA SY
E-mail: ICARDA @ CGNET.COM

Contents

Foreword

Pulses, or food grain legumes, are a major source of protein for the poor in many parts of the world. They are equally important to vegetarians worldwide. Being able to fix atmospheric nitrogen, these legumes play an important role in farming systems, where they are used in rotations to help replenish nitrogen in the soil, and interrupt continuous cycles of cereal cropping which have adverse effects on production. However, because of their low and unstable yields, food legumes are losing ground to more profitable crops. Their role in farming systems is therefore diminishing, and this affects the sustainability of production. Reduced availability of these legumes has a direct effect on the nutrition and health of the poor.

In West Asia and North Africa (WANA), food legumes have always occupied a key position in crop rotations. With an increase in area under irrigation, and lack of mechanization of harvest, food legumes are being relegated to marginal land. In fact, food-legume production has remained nearly static in the past three decades except in Turkey, where much of the production increase has come from an expansion of the cropped area.

In WANA, chickpea is the most important food-legume crop. As with other food legumes, its area and production have increased only marginally, and yields are low and unstable. Some of the major reasons for low and unstable production of chickpea in WANA are: the practice of spring sowing; low-yielding and disease-susceptible cultivars; lack of response to agronomic inputs, and the absence of mechanization. ICARDA, in cooperation with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the National Agricultural Research Systems of WANA, has developed a winter chickpea technology, removing most of the bottlenecks in the production sequence. If the technology is adopted on a wide scale, it will not only make the WANA region self-sufficient in chickpea production, but will also create a surplus for export.

The research on winter chickpea technology began in 1974. The team that developed it included a breeder, an agronomist, a physiologist, a microbiologist, a pathologist, an entomologist, a virologist, a nematologist, a food nutritionist, a systems agronomist, a socioeconomist, a seed technologist and a farm machinery engineer. The technology has reached all WANA countries, and gone beyond the region to Europe, the Americas and Australia. It is poised to cover two million hectares in WANA, with an additional annual income of one billion US dollars to farmers. We place this technology in the hands of WANA farmers in the hope that it will help them enhance their farm income.

For the benefit of researchers, this research report provides a full account of the winter chickpea technology and its potential.

Prof. Dr Adel El-Beltagy
Director General

Acknowledgements

We owe a great deal to NARS scientists of the WANA region who evaluated the improved germplasm and technology for winter chickpea and recommended its adoption in 15 countries. Consequently, thousands of farmers are adopting winter sowing, making this technology economically viable.

Thanks are due to all those scientists at ICARDA who worked as a team to develop the winter chickpea technology. It would be difficult to thank each one of them individually, but we thank the team collectively; it included a breeder, genetic resources specialist, food nutritionist, agronomist, physiologist, microbiologist, soil physicist, pathologist, entomologist, nematologist, virologist, molecular biologist, systems agronomist, socioeconomist, farm machinery engineer and international trial scientist.

We sincerely thank Mr Samir Hajjar, Research Assistant, for technical assistance. Thanks are also due to all the support staff who executed the trials on winter sowing, in particular Messrs Gaby Khalaf and Nabil Trabulsi and Ms Siham Kabbabeh.

We thank Dr S. Varma, Head of ICARDA's Communication, Documentation and Information Services, and Messrs G. Manners and M. Robbins, Science Editors, for their help in editing and publishing this bulletin.

Introduction

Chickpea (*Cicer arietinum* L.) is the second most important pulse crop in the world and is grown in at least 33 countries in South Asia, the West Asia-North Africa (WANA) region, East Africa, southern Europe, South America and Australia. It accounts for 14.8% (10.2 million hectares) of the area and 13.4% (7.9 million tonnes) of world pulse production (FAO 1994).

There are two types of chickpea: desi, with small, dark brown seed and kabuli, with large beige seed (Fig. 1). The desi type is primarily grown in South Asia. The kabuli type predominates in WANA, where the total chickpea area is about 2.7 million ha, but fluctuates widely depending upon the actual seasonal rainfall. For example, in the last 20 years, the area sown to chickpea in Syria has ranged from 17,000 ha in 1979 (a dry year) to 94,000 ha in 1983 (a wet year).

In Mediterranean environments, i.e. dry climates with winter rainfall, chickpea is traditionally sown in spring. The crop therefore encounters heat and drought stress towards maturity; this results in low and variable yields and discourages farmers from investing inputs in its production.

Since chickpea production in most WANA countries falls short of the demand, the deficit is met by imports—using precious foreign exchange. The average annual import in WANA during 1980–87 was 80,868 tonnes costing US$ 47 million (Oram and Belaid 1990). Moreover, while population growth in WANA has continued unabated, chickpea production has remained static since the mid-1960s. As a result, per-capita availability of this important commodity has been declining.

In the cereal-dominated diets of the people in WANA, chickpea plays a vital role by pro-

Figure 1. Two types of chickpea are grown in the world: desi type (left) and kabuli type (right).

Figure 2. Wheat-chickpea is one of the common rotations in WANA.

viding high-quality protein, particularly for vegetarians and those who cannot afford meat. The crop is also used as livestock feed. It has a significant role in farming systems—particularly as a substitute for fallow in cereal-growing areas, where it contributes to the sustainability of production and reduces the need for nitrogen fertilizer by fixing atmospheric nitrogen (Fig. 2).

With the establishment of the International Center for Agricultural Research in the Dry Areas (ICARDA) in 1977, a joint project was started with the International Crops Research Institute for the Semi-Arid Tropics (ICRSAT) to enhance the productivity and yield stability of chickpea in WANA. Work under this project at the main research station of ICARDA at Tel Hadya, near Aleppo, Syria soon established that winter sowing could yield over 100% more than spring sowing (Saxena 1984). Weighed against spring sowing, winter sowing provides higher and more stable productivity, better water-use efficiency, the possibility of mechanized harvesting, increased biological nitrogen fixation and better residual effect on a subsequent cereal crop. Since winter sowing benefits fully from the rainfall during the season, it can be extended to areas which are too dry for spring sowing of chickpea.

In spite of the yield advantage of winter sowing, farmers in WANA continue to sow their chickpea in spring, although other cool-season legumes, such as lentil (*Lens culinaris* Medik.) and faba bean (*Vicia faba* L.), are sown in winter. Investigations at ICARDA revealed that chickpea sown during winter in the region faced the risk of heavy to total yield loss due to two factors. The first was ascochyta blight (caused by *Ascochyta rabiei* (Pass.) Lab.) in seasons favoring disease development and spread.

The second factor was cold stress in seasons with severe winters. To deal with both of these, a multidisciplinary team of researchers from ICARDA, ICRISAT and national programs was set up to develop a production technology that would ensure full realization of the benefits of winter sowing of chickpea in mediterranean environments.

History of Winter Chickpea Development

The first crop of winter chickpea grown

The Arid Lands Agricultural Development Program (the forerunner of ICARDA) grew an observation nursery of 192 chickpea lines at Kfardan in the Beka'a Valley of Lebanon during 1974/75. Temperatures dropped gradually as the winter set in. Sub-zero temperatures and snowfall were recorded on several days. The lowest temperature was –12°C. All lines survived the winter, indicating that chickpea can tolerate the cold winter of the region. Although different results were found later, this finding provided enough impetus for the pursuit of research on winter chickpea.

Ascochyta blight: the first reason why farmers sow chickpea in spring?

An advanced yield trial, comprising 25 lines, was sown during winter and spring of 1976/77 at the University of Aleppo Farm, Muslimieh, Syria. All but two of the winter-sown lines were killed by ascochyta blight (Fig. 3) in contrast to a much higher rate of survival of the spring-sown lines. This pointed to the possible reason why farmers did not grow chickpea during winter.

Figure 3. Winter-sown chickpea, with most plots killed by ascochyta blight.

Response to advancing sowing date

Eight genotypes were sown on five dates in the 1977/78 season at Tel Hadya covering a wide range from early winter to spring. Seedling establishment in the last date of planting (26 March) was extremely poor, and the crop failed. The yield performance of the crop from the first four dates is shown in Table 1. Yield decreased as the date of sowing was delayed from December to March. Averaged over all genotypes, the yield from spring planting (6 March) was about 38% of that obtained from the winter planting (4 December) (Saxena 1980). The weather conditions were such that ascochyta blight did not develop in the winter-sown crop.

Table 1. Effect of planting date on the grain yield (kg/ha) of eight genotypes of chickpea at Tel Hadya, Syria, 1977/78.

Genotype	4 Dec	29 Dec	2 Feb	6 Mar	Mean
NEC-30	1820	1662	1639	787	1477
NEC-144	1409	1576	1031	572	1147
NEC-266	1468	1576	1294	954	1323
NEC-239	1954	1900	1531	809	1548
NEC-1540	1907	1868	1618	768	1541
NEC-1656	2142	1918	1542	741	1586
NEC-2305	1744	1487	1241	698	1292
Syrian local	1689	1804	1422	955	1467
LSD (0.05)		438.8			215.6
Mean	1767	1724	1415	666	
CV (%)		18.5			

Source: Saxena (1980).

Figure 4. A comparison of winter (right) and spring (left) chickpea.

Yield increase of winter over spring sowing

A single advanced yield trial and several preliminary yield trials were also grown during both winter and spring of 1977/78 at Tel Hadya. The crop was protected from ascochyta blight by spraying with fungicide. Yield increases of up to 100% were recorded by winter sowing over spring sowing, indicating the potential of winter sowing (Table 2; Fig. 4).

Table 2. Mean yield (kg/ha) of entries in advanced yield trial at Tel Hadya, Syria, during winter (W) and spring (S), 1977/78.

Entry	W	S	Entry	W	S
ILC 4	1568	1007	NEC 1088	1574	981
ILC 23	1729	988	NEC 1091	1638	1204
ILC 51	1755	1201	NEC 1127-1	1729	1183
ILC 52	1541	1098	NEC 1127-2	1601	964
ILC 205	1090	860	NEC 1130	1437	968
ILC 237	1740	1044	NEC 1148	1503	1127
ILC 262	1856	1233	NEC 1163	1564	1066
ILC 263	1737	1231	NEC 1209	1640	1140
ILC 432	1683	850	NEC 1405	1642	1045
ILC 480	1699	953	NEC 1473	1479	1187
ILC 493	1722	1146	NEC 1691	1582	1005
ILC 571	1544	1008	NEC 1711	1457	1108
ILC 610	1564	918	NEC 1906	1589	1163
ILC 897	1646	1144	NEC 1962	1592	985
ILC 1028	1472	1142	NEC 1963	1769	1106
ILC 1919	1374	912	NEC 2305	1479	975
ILC 1921	1814	989	NEC 2315	1114	765
ILC 1929	1642	1027			
Mean				1578	1050
LSD (0.05)				284.7	274.4
CV (%)				12.9	18.7

Cold susceptibility: the second reason why farmers sow chickpea in spring

As we have seen, the study at Kfardan during 1974/75 showed that chickpea lines survived the cold winter when it set in gradually. However, a more detailed study at Tel Hadya during 1981/82 showed that many lines were killed—and others severely damaged—when temperatures dropped abruptly during winter (Table 3; Fig. 5) (Singh et al. 1993b). The 1981/82 season was one of the coldest on record. This showed that lines would need cold tolerance for winter sowing. Subsequent research showed that all landraces originating in the Mediterranean region were highly susceptible to cold, further indicating why chickpea was not sown during winter.

Table 3. Groupings of 96 genotypes according to cold-tolerance ratings (CT) on first sowing date and mean seed yield in kg/ha (YLD) of all entries in each group on all nine sowing dates.

Group		G1	G2	G3	G4	G5	G6	G7	G8
Cold rating		9.0	8.0–8.9	7.0–7.9	6.0–6.9	5.0–5.9	4.0–4.9	3.0–3.9	2.0–2.9
No. of entries		16	10	15	18	18	12	6	1
Date 1	CT	9.0	8.4	7.2	6.3	5.3	4.4	3.3	2.7
	YLD	0	215	1021	1675	2416	2375	3911	2467
Date 2	CT	8.5	7.5	6.4	5.4	4.8	3.7	3.1	2.3
	YLD	132	504	1222	2028	2205	2487	2846	2593
Date 3	CT	7.4	5.4	4.7	4.4	3.6	2.3	2.3	2.0
	YLD	421	1199	1800	2576	2324	2386	2670	2044
Date 4	CT	5.4	3.5	3.2	2.4	1.9	1.5	1.3	1.3
	YLD	888	1399	1868	2294	2087	1939	2220	2348
Date 5	CT	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	YLD	1150	1322	1920	1946	1607	1806	1904	1867
Date 6†	YLD	1142	1394	1652	1753	1328	1265	1356	1452
Date 7†	YLD	705	971	1425	1410	1199	1030	1258	1000
Date 8†	YLD	856	979	1165	1261	963	995	1115	1081
Date 9†	YLD	890	959	1334	1228	894	902	1023	1111

† There was no cold damage, hence CT is not given.
Source: Singh et al. (1993b).

Figure 5. Most winter-sown plots killed by cold.

International yield trials initiated

Early screening of chickpea lines at ICARDA resulted in the identification of some lines which were resistant to ascochyta blight. Using this material, a 10-entry trial was distributed to cooperators in 1979 for planting in winter 1979/80. The results from nine locations are shown in Table 4. Trial mean yields in the order of 3000 kg/ha were recorded in Algeria, Lebanon and Morocco, indicating a very high yield potential from winter sowing in these countries (Hawtin and Singh 1984).

Table 4. Yield (kg/ha) of entries in the Chickpea International Yield Trial, winter 1979/80.

Line	Lebanon	Syria			Jordan	Algeria	Morocco	Cyprus	Greece	Mean
ILC	Terbol	Tel Hadya	Gelline	Lattakia	Univ.	Khroub				
184	3342	362	1743	2476	1071	3578	3583	303	2503	2107
190	2738	231	1350	2964	1381	3987	3000	379	2471	2056
195	2362	1607	1884	2571	1113	2977	3000	319	2440	2030
202	2094	1313	1626	2321	1106	2992	3042	326	1820	1849
215	2552	178	1375	1481	1268	2609	3062	401	1755	1631
249	2769	125	1414	2690	1401	4286	3917	500	2206	2145
482	3352	1894	2163	2810	1440	3469	3275	483	2646	2392
1929	3672	0	1308	0	1141	281	1521	460	2031	1488
3279	3279	1796	1735	1750	1060	3094	3417	288	1797	2101
Check	2734	131	1451	1333	1298	2010	3500	346	1719	1614
Mean	2959	873	1605	2040	1328	2928	3132	380	2139	1941
CV (%)	30.3	13.2	13.0	5.7	15.1	28.0	21.2			
LSD (0.05)	1538.0	168.6	259.0	111.2	642.7	154.8	656.7			

Source: Hawtin and Singh (1984).

The first set of on-farm trials sown

Eighteen on-farm trials were conducted jointly with the Syrian Directorate of Agriculture and Scientific Research using three resistant cultivars sown in winter and one Syrian landrace sown in both winter and spring (Fig. 6). The mean yield of ILC 482, the most resistant cultivar, sown during winter was 113% higher than that of Syrian landrace sown in spring (Table 5).

Figure 6. Farmers examining performance of winter chickpea.

Table 5. Seed yield (kg/ha) of cultivars sown during winter and spring in farmers' fields and experiment stations in Syria, 1979/80.

Location	Winter ILC 482	Spring Syrian landrace	Location	Winter ILC 482	Spring Syrian landrace
Izraa	1666	793	Derkak	712	5
Gelline	1076	666	Ebben	1039	791
Hama	3427	3190	Kawkaba	1576	1674
A village in Hama	1831	816	Mohambel	1781	264
Homs	2833	1555	Maaret Masrin	1417	1173
A village in Homs	2222	1389	Breda	2481	104
Boustan El-Basha	1667	0	Jindiress	2464	0
Afes	836	401	Kafr-Antoon	1357	1658
Atareb	2110	477	Tel Hadya	1971	605
Mean				1839	865

Source: Hawtin and Singh (1984).

Weeds, a major yield reducer during winter

Research conducted at ICARDA and on farmers' fields indicated that winter-sown crop could become heavily infested with weeds because the weeds germinate along with the chickpea. In contrast, many of the weeds are killed during the land preparation for spring sowing (Fig. 7). Saxena (1984) reported a 42% reduction in yield of winter chickpea due to weeds. An international weed-control trial was, therefore, initiated in the 1979/80 season, which led to the identification of suitable herbicides for the control of weeds in different countries of WANA.

Figure 7. Part of the advantages of winter chickpea can be robbed by weeds, if they are not controlled.

Figure 8. Chickpea field seriously damaged by cyst nematode.

Nematode, a great threat to chickpea

Chickpea sown in Idleb during winter 1982/83 in fields heavily infested by cyst nematode (*Heterodera ciceri* Volvas, Greco & Di Vito) produced little (Fig. 8). Spring chickpea suffered a similar fate. This emphasized the fact that chickpea should not be sown in fields known to be infested with nematodes.

Winter chickpea as a drought escape

During the 1983/84 season, rainfall at Tel Hadya was much below average (230 *vs* 330 mm long-term average). Spring-sown chickpeas either failed completely or produced too little even to meet the cost of harvesting; the winter-sown crop, however, gave reasonable yields (Fig. 9). There were similar conditions during the 1988/89 season. Many entries sown in spring produced no yield, whereas three lines sown in winter produced nearly 1000 kg/ha (Table 6).

Increased water-use efficiency (WUE) of winter chickpea

Keatinge and Cooper (1983) compared the crop growth and WUE of winter- and spring-sown chickpeas. They concluded that WUE increased by more than 100% in the winter-sown crop over the spring-sown one (Table 7). Earlier development of green area with winter-sown chickpea also effectively reduces losses from evaporation. Almost the same amount of water is lost in this way as was lost from the bare soil awaiting spring sowing. However, with winter sowing, the crop is at a late vegetative stage during this period so WUE is higher in practice.

Figure 9. Winter chickpea can escape drought and produce reasonable yield.

First cultivar released for winter sowing

Cyprus, participating in the international chickpea testing program, was the first country to release a winter-sown cultivar—ILC 3279, under the name "Yialousa", in 1984 (ICARDA 1986) (Fig. 10). Although Cyprus has a small area under chickpea, almost all this area is now sown during winter (A. Hadjichristodulou, Head, Crop Division, Agriculture Research Institute, Nicosia, pers. comm.). Since then, several national programs have released cultivars for winter sowing. ILC 482 has been released in nine countries under different names (Singh et al. 1992).

Table 6. Seed yield (kg/ha) of spring- and winter-sown chickpea entries in an advanced yield trial in the drought-affected season of 1988/89 (seasonal rainfall 234 mm).

Entry	Winter	Spring	Entry	Winter	Spring
FLIP 86-88C	410	0	FLIP 87-8C	679	537
FLIP 86-90C	577	46	FLIP 87-14C	651	40
FLIP 86-91C	592	24	FLIP 87-16C	483	33
FLIP 86-93C	540	8	FLIP 87-54C	738	178
FLIP 86-94C	443	67	FLIP 87-71C	499	21
FLIP 86-96C	605	119	FLIP 87-79C	848	21
FLIP 86-110C	625	40	FLIP 87-81C	491	66
FLIP 87-1C	485	132	FLIP 87-82C	497	87
FLIP 87-2C	566	186	FLIP 87-83C	777	80
FLIP 87-3C	576	0	FLIP 87-86C	387	262
FLIP 87-5C	986	419	ILC 482	965	328
FLIP 87-7C	1003	591	ILC 1929	521	238
Mean				623	147
CV (%)				38.604	61.488
LSD (0.05)				497.327	186.623

Table 7. Crop productivity, yield components and water-use efficiency of winter- and spring-planted chickpeas at Tel Hadya.

Season	Maximum above-ground dry matter (t/ha)	Water-use efficiency ($kg\ ha^{-1}\ mm^{-1}$)		No. pods/plant	Empty pods (%)	100-seed weight (g)	Seed yield (t/ha)
		Dry matter†	Seed				
Winter	3.42	11.0	6.7	27.6±0.59	4.6±1.09	27.0±0.37	2.09±0.022
Spring	1.84	6.2	2.7	17.1±2.09	17.5±1.18	23.2±0.50	0.80±0.116

† Estimate from best fit polynominal regression equations.
Source: Keatinge and Cooper (1983).

Breakdown of ascochyta blight resistance in cultivars

The cultivar ILC 482, which showed good tolerance to ascochyta blight when released, became susceptible to this disease in Morocco during 1989/90 and in Syria during 1992/93. The breakdown of resistance of a cultivar to a disease is common in all crops, because of the appearance of new races (or pathotypes) of the pathogen. In chickpea, Reddy and Kabbabeh (1984a) identified six races of *Ascochyta rabiei* in Syria. In another study, Reddy et al. (1992) identified 13 races from WANA. Furthermore, the perfect stage of ascochyta has been found at Tel Hadya (Fig. 11) (Haware 1987). The perfect (or sexual) stage can lead to hybridization of races and the emergence of new races. These developments suggest the need for using a large number of cultivars in each country, preferably with resistance to ascochyta blight conferred by diverse genes. This approach will protect the crop from total failure due to breakdown of resistance in one cultivar.

Figure 10. Cyprus released the first cultivar, Yialousa (ILC 3279), for winter sowing in 1984.

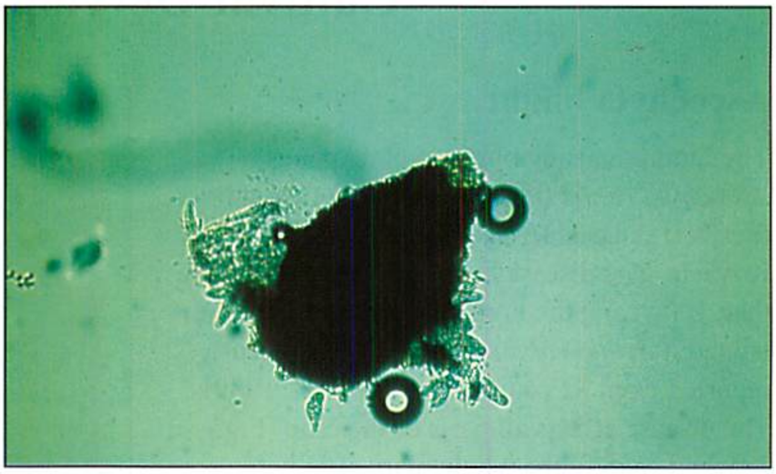

Figure 11. Perfect stage of the ascochyta blight pathogen, responsible for the development of new races causing breakdown of resistance.

Little scope for autumn sowing

The possibility of autumn sowing of chickpea was investigated at Tel Hadya. Twelve lines having resistance and/or tolerance to both ascochyta blight and cold were sown during autumn (1 October), winter (1 December) and spring (1 March) for two years, 1989/90 and 1990/91. A severe spell of cold occurred suddenly on 17 March 1990, with temperature falling to –8.9°C—all the autumn-sown entries in this trial were killed.

In 1990/91, the autumn-sown crop grew well until early April, when it was severely infested with *Orobanche* spp. Chickpea lines available to date are apparently not suitable for autumn sowing because of their susceptibility to cold and *Orobanche* (ICARDA 1991) (Fig. 12).

Figure 12. Orobanche *infestation can limit autumn sowing.*

Cultivar Development

Ascochyta blight

The fungus causing blight in chickpea is *Ascochyta rabiei* (Pass.) Lab. and its sexual (perfect) stage is *Mycosphaerella rabiei* (Pass.) Kovach. The disease has been known for more than 100 years; the French researcher Passerini named it *Zythia rabiei* in 1867. It has been reported from 32 countries (Nene et al. 1989). The disease affects all parts of the crop (Fig. 13), and can kill the whole plant. The book, *Ascochyta Blight and Winter Sowing of Chickpeas*, covers this disease in detail (Saxena and Singh 1984) and only a few relevant points are discussed here.

Figure 13. Ascochyta blight affects all chickpea plant parts.

Yield loss

Losses caused by this disease can be up to 100% (Nene and Reddy 1987). At ICARDA, a study was conducted to examine the ascochyta blight severity and yield loss for three years, during 1982/83 to 1985/86. The average yields of 19 resistant and moderately resistant lines over the three seasons were almost the same under diseased and disease-free conditions (2.3 t/ha) (Table 8), whereas the susceptible cultivar ILC 1929 showed 99% yield loss under diseased conditions (Reddy and Singh 1990a). In another experiment, the yield loss in resistant cultivars due to ascochyta blight was up to 9%, in tolerant cultivars up to 16%, in susceptible cultivars up to 81%, and in highly susceptible cultivars up to 98% (Reddy and Singh 1990b).

How does blight start?

The sources of disease are infected crop debris, infected seed and dissemination of ascospore-bearing debris by wind. The disease begins from one plant and the infection starts in the adjoining plants, making a small circle. In seasons favoring disease development and spread, the circle could enlarge and cover the whole field or even many fields in the vicinity—thus creating an epidemic (Fig. 14 and 15).

Table 8. Average yield (t/ha) of some ascochyta-blight resistant chickpea germplasm lines in comparison with susceptible cultivar ILC 1929 under blight-free and blight-inoculated conditions, ICARDA, Tel Hadya, Syria.

Season	Blight-free		Blight-inoculated	
	Resistant (range)	Susceptible (range)	Resistant	Susceptible
1982/83	2.5† (1.7-2.3)	2.5	2.2 (1.5-2.7)	0
1983/84	2.1‡ (1.2-3.0)	2.8	1.9 (1.4-2.6)	0
1985/86	2.5† (1.8-3.2)	2.5	2.7 (1.8-3.2)	0.08
Average	2.3	2.6	2.3	0.03

† 19 resistant lines and one susceptible line were tested.
‡ 17 resistant lines and one susceptible line were tested.
Source: Reddy and Singh (1990a).

Screening technique

Prior to 1978, screening for ascochyta blight resistance was done opportunistically in so-called hot spots, where disease used to develop in epidemic form once every 5–10 years. However, this resulted in limited progress (Singh 1993a).

At ICARDA, a simple and reliable screening technique for evaluating a large amount of germplasm and breeding material was developed in the late 1970s (Singh et al. 1981). This technique includes:

Figure 14. Blight infection starts in a small circular patch.

(a) sowing of susceptible-cum-indicator rows at an interval of 2, 4 or 10 test rows and round the test plot;
(b) inoculation of the entire material with (i) ascochyta blight diseased chickpea debris collected in the previous season and stored in a dry place, and (ii) spraying spore suspension prepared from the prevalent races of the area;
(c) creation of high humidity (>60%) by sprinkler or mist irrigation;
(d) evaluation of germplasm accessions and breeding material after the death of the susceptible check from the disease; and,
(e) reconfirmation of resistance in the following season.

This technique has been used successfully at ICARDA for 16 years. Because of the simplicity and reliability of the technique, it has been adopted throughout the Mediterranean region, South Asia and North America.

Availability of this screening technique opened up the opportunity for a planned breeding program in chickpea for ascochyta blight resistance (Fig. 16 and 17).

Rating scale

The material is scored on a 1–9 scale where

1 = immune reaction: no visible lesions on stems or leaves;

2 = highly resistant: no lesions on stems but lesions on leaves, with few pycnidia;

3 = resistant: 5% of stems, leaves and pods infected and stems broken, stem lesions ≤5mm long, with few pycnidia;

4 = moderately resistant: 15% of stems, leaves and pods infected and stems broken, stem lesions 5 mm long, with few pycnidia;

5 = tolerant: 40% of stems, leaves and pods infested and stems broken, stem lesions >5mm long, with more pycnidia;

6 = moderately susceptible: 50% of stems, leaves and pods infected and stems broken, stem lesions >5 mm, with more pycnidia;

7 = susceptible: 75% stems, leaves and pods infected and stems broken, stem lesions >5 mm, with more pycnidia;

8 = highly susceptible: 100% of stems, leaves and pods infected and stems broken, stem lesion >5 mm, with more pycnidia;

9 = very highly susceptible: all plants killed.

Figure 15. Entire field killed by blight.

Figure 16. Use of sprinkler irrigation to create blight epidemic.

Identification of resistant sources

The progress in breeding blight-resistant cultivars was hampered by the absence of dependable resistant sources. Therefore, an effort was made to screen the world germplasm collection against known races of *A. rabiei* in Syria and Lebanon. A total of 19,343 germplasm accessions of chickpea (12,749 desi and 6594 kabuli types) were evaluated for resistance to six races (from Lebanon and Syria) of the blight fungus at Tel Hadya, between 1979 and 1991 (Fig. 18). Germplasm accessions were sown in the field during the winter and inoculated by scattering blight-infected chickpea debris and spraying a spore suspension of a mixture of the six races of *A. rabiei*. In greenhouse evaluations, germplasm accessions were grown in pots, inoculated by spraying the spore suspension of a composite of the six races and kept in plastic moist chambers for one week (Singh and Reddy 1993). The following kabuli and desi lines were resistant/moderately resistant (Singh et al. 1981; Reddy and Singh 1984; Singh and Reddy 1993).

Figure 17. A view of the screening technique of blight.

Kabuli lines: ILC 72, ILC 191, ILC 200, ILC 2506, ILC 2956, ILC 3279, ILC 3856, ILC 4421, ILC 4884, ILC 4976, ILC 5586, ILC 5894, ILC 5928, ILC 6482, ILC 7795 and ILC 8068.

Desi lines: ICC 76, ICC 2270, ICC 2342, ICC 3912, ICC 3919, ICC 3991, ICC 4030, ICC 4045, ICC 4188, ICC 4475, ICC 4616, ICC 6328, ICC 11932, ICC 12004, ICC 13292, ICC 13508, ICC 13555, ICC 13729 and ICC 14903.

Genetic studies

Singh and Reddy (1991) reviewed the work on genetics of resistance to diseases. Inheritance of resistance to ascochyta blight has been reported to be mostly monogenic. Either a single dominant or recessive gene confers the resistance. A single dominant gene conferred resistance in ILC 72, ILC 183, ILC 200 and ICC 4935, and a single recessive gene controlled resistance in ILC 191 (Singh and Reddy 1983). In their later study, Singh and Reddy (1989) identified a single dominant gene conferring resistance in ILC 202, ILC 2956 and ILC 3279. However, Malik (1990) inferred from his data that polygenes control inheritance of resistance to ascochyta blight.

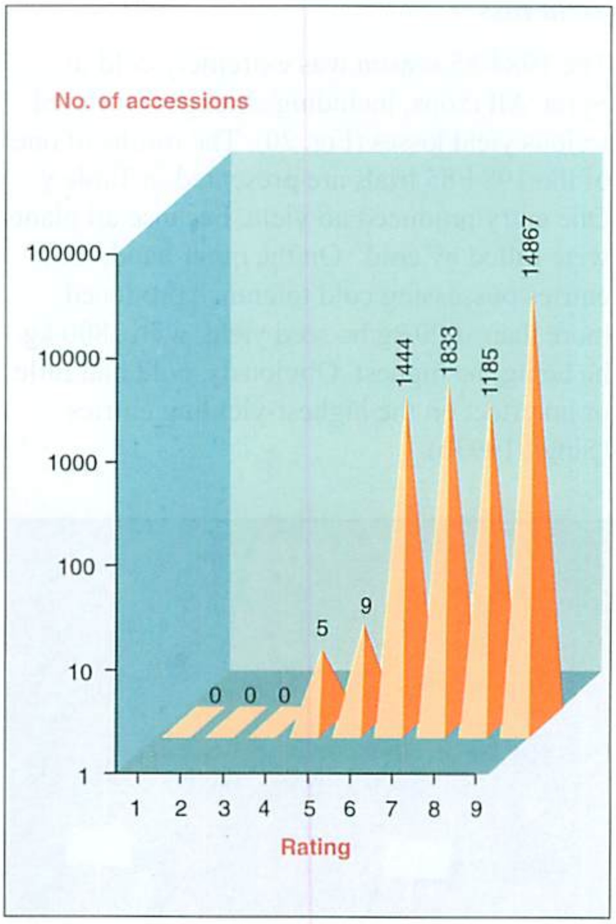

Figure 18. Reaction of chickpea germplasm accessions to ascochyta blight at Tel Hadya between 1979 and 1991 (Source: Singh and Reddy 1993).

Cold

Figure 19. A chickpea field covered with snow.

Temperature is an important climatic factor which determines the geographical distribution of crop plants and affects their growth, development and productivity. It is well known that plants are usually able to tolerate a range of temperature above and below that optimum for growth and development. Optimal temperatures for the cool-season food legumes range between 10 and 30°C (Saxena 1979). Temperatures outside the optimum range cause stress (Fig. 19).

Yield loss

The 1984/85 season was extremely cold in Syria. All crops, including chickpea, suffered serious yield losses (Fig. 20). The results of one of the 1984/85 trials are presented in Table 9. One entry produced no yield, because all plants were killed by cold. On the other hand, nine entries possessing cold tolerance produced more than 1000 kg/ha seed yield, with 1800 kg/ha being the highest. Obviously, cold had little or no effect on the highest-yielding entries (Singh 1993b).

Table 9. Seed yield of chickpea entries as affected by cold at Tel Hadya, Syria, 1984/85.

Entry	Yield (kg/ha)	Cold rating†	Entry	Yield (kg/ha)	Cold rating†
FLIP 84-67C	858	I	FLIP 84-78C	42	S
FLIP 84-68C	1042	I	FLIP 84-79C	1783	T
FLIP 84-69C	1200	T	FLIP 84-80C	975	I
FLIP 84-70C	1683	T	FLIP 84-81C	1292	T
FLIP 84-71C	1800	T	FLIP 84-82C	400	S
FLIP 84-72C	802	I	FLIP 84-83C	1092	I
FLIP 84-73C	1208	T	FLIP 84-84C	0	S
FLIP 84-74C	1142	I	ILC 482	425	S
FLIP 84-75C	467	S	ILC 3279	992	I
FLIP 84-76C	883	I	ILC 1929	475	S
FLIP 84-77C	708	I			
Mean				964	
CV (%)				26.25	
LSD (0.05)				541.62	

† T = tolerant; I = intermediate; S = susceptible.

Figure 20. A resistant line (right) unaffected by cold, compared with a susceptible line killed by cold.

How much cold could chickpea tolerate?

In low-elevation areas (<1000 masl) of WANA with a typical Mediterranean climate, the air temperature can fall to –10°C for several nights during winter (Smith and Hazel 1981). Therefore, a cold tolerance of this level is necessary for winter sowing; ICARDA and other institutions in WANA are investigating this aspect further.

Screening technique

A field screening technique for the evaluation of germplasm accessions for cold tolerance, including a rating scale, was developed (Singh et al. 1989, 1995). The main elements of this technique are:

(1) sowing of germplasm and breeding material in early October, two months earlier than the normal winter sowing, along with a susceptible check as every tenth row;
(2) raising the material to late vegetative stage with supplemental irrigation before the onset of severe winter in late December;
(3) evaluating the material on a 1–9 rating scale after the susceptible check is killed by cold; and,
(4) confirming the tolerance for at least one more season.

Figure 21. Germplasm screening where most lines have been killed by cold.

This technique permitted the evaluation and development of germplasm capable of tolerating cold to –10° C without snow cover and up to 60 days a year at late vegetative stage—conditions which occasionally occur at low to medium altitude in Mediterranean environments (Fig. 21).

Rating scale

A 9-point scale is adopted. The scale is described as follows:

1 = no visible symptoms of damage;
2 = highly tolerant, up to 10% of leaflets show withering and drying, no plants killed;
3 = tolerant, 11–20% of leaflets show withering and up to 20% of branches show withering and drying, no plants killed;
4 = moderately tolerant, 21–40% and up to 20% of branches show withering and drying, no plants killed;
5 = intermediate, 41–60% leaflets and 21–40% of branches show withering and drying, up to 5% of plants killed;
6 = moderately susceptible, 61–80% leaflets and 41–60% of branches show withering and drying, 6–25% of plants killed;
7 = susceptible, 81–99% leaflets and 61–80% of branches show withering and drying, 26–50% of plants killed;
8 = highly susceptible, 100% of leaflets and 81–99% of branches show withering and drying, 51–99% of plants killed; and,
9 = all plants killed.

The evaluation is done after the susceptible check shows 100% mortality. In seasons when the susceptible check is not killed, such screening would be ineffective.

Identification of tolerant sources

Studies were conducted to evaluate 10,554 lines (8417 kabuli and 2137 desi) for cold tolerance from 1981/82 to 1991/92 at

ICARDA sites at Tel Hadya and Breda in Syria (Fig. 22). Correlation studies on 2970 lines indicated that all cold-tolerant lines had prostrate growth habit during the winter months and that all early-flowering lines were susceptible to cold. No association between cold tolerance and anthocyanin pigmentation on the stem was observed. Older plants were more susceptible to cold than younger plants. None of the desi lines was tolerant to cold. Resistant kabuli lines were: ILC 3287, ILC 5638, ILC 5663, ILC 5667, ILC 5951, ILC 5953, ILC 8262, ILC 8568 and ILC 8617.

Evaluation of annual wild *Cicer* species revealed a higher level of cold tolerance. Four lines of *C. reticulatum* were crossed with 10 lines of the cultigen during 1989. Using off-season advancement, 11 lines have been developed with slightly higher levels of tolerance than the best chickpea cultigen; these are: FLIP 93-252C, FLIP 93-253C, FLIP 93-254C, FLIP 93-255C, FLIP 93-256C, FLIP 93-257C, FLIP 93-258C, FLIP 93-259C, FLIP 93-260C, FLIP 93-261C and FLIP 93-262C.

In addition, a large number of tolerant lines have been bred through hybridization.

Genetic studies

The study on inheritance of tolerance to cold suggested that this character is governed by both additive and non-additive gene effects with a preponderance of additive gene effects. Cold tolerance was dominant over susceptibility and was controlled by at least five sets of genes. Its heritability in the narrow sense was 87.9% (Malhotra and Singh 1990). In another study, Malhotra and Singh (1991) confirmed the previous finding of the importance of both additive and non-additive gene effects. They found the presence of genic interactions, as well as additive and dominance gene effects through the generation mean analysis. Among the interactions, additive x additive and dominance x dominance with duplicate epistasis were present. Selection for cold tolerance would be more effective if non-additive effects were reduced after a few generations of selfing.

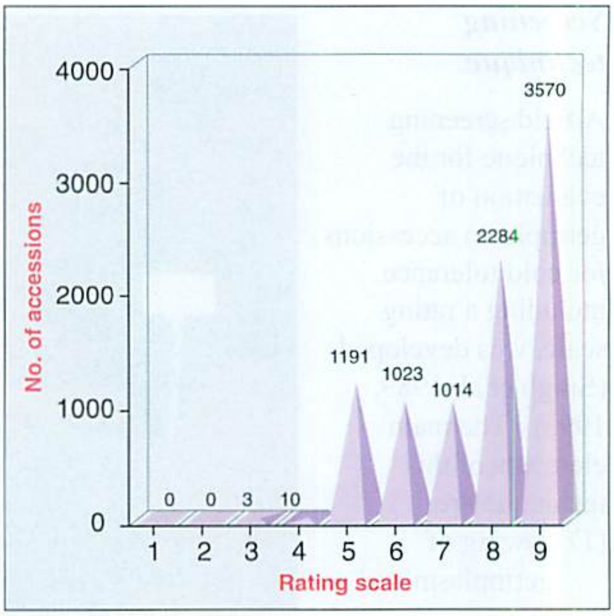

Figure 22. Reaction of chickpea germplasm accessions to cold at Tel Hadya, between 1981/82 and 1991/92 (Singh et al. 1991).

Breeding for combined resistance to ascochyta blight and cold

The program for breeding combined resistance in chickpea began in 1978. The breeding technique used then has undergone many changes. The current scheme is illustrated in Figure 23 (Singh 1993b). This scheme involves the off-season advancement of generations at Terbol, Lebanon (altitude 890 masl), where three generations (F_1, F_3 and F_6) are raised. This reduces the period of cultivar development from eight to four years. Selections for cold tolerance and ascochyta blight resistance are made in the same season. The breeding nursery is sown during early November, one month before the normal recommended time for winter sowing. This provides an opportunity for plants to grow to mid-vegetative stage during the cold period from mid-December to February, when the winter-sown chickpea is normally at seedling stage. Negative selection is practised in F_2 and F_4 generations, where susceptible plants are uprooted. Both generations are grown by bulk method. In F_5 generation, where progeny rows are grown, progenies are evaluated for cold tolerance and susceptible ones are discarded.

In early March, the breeding nursery is inoculated with the debris of chickpea plants infected with ascochyta blight. This is followed by spore suspension sprays prepared from the mixture of six races of *A. rabiei* multiplied in the laboratory. The number of sprays varies from 4 to 10 depending upon the weather. The material is screened at two stages, late vegetative stage (late April) and podding (late May). Resistant plants in F_2 and F_4 generations and progenies in F_5 generation are selected.

Selection for yield, seed characters, maturity and plant height is practised in F_5. Bulking of the promising and uniform progenies is usually done in F_5 generation. The seed of the bulked lines is grown in the off-season for purification and increase. From this stage onwards, replicated yield evaluations begin.

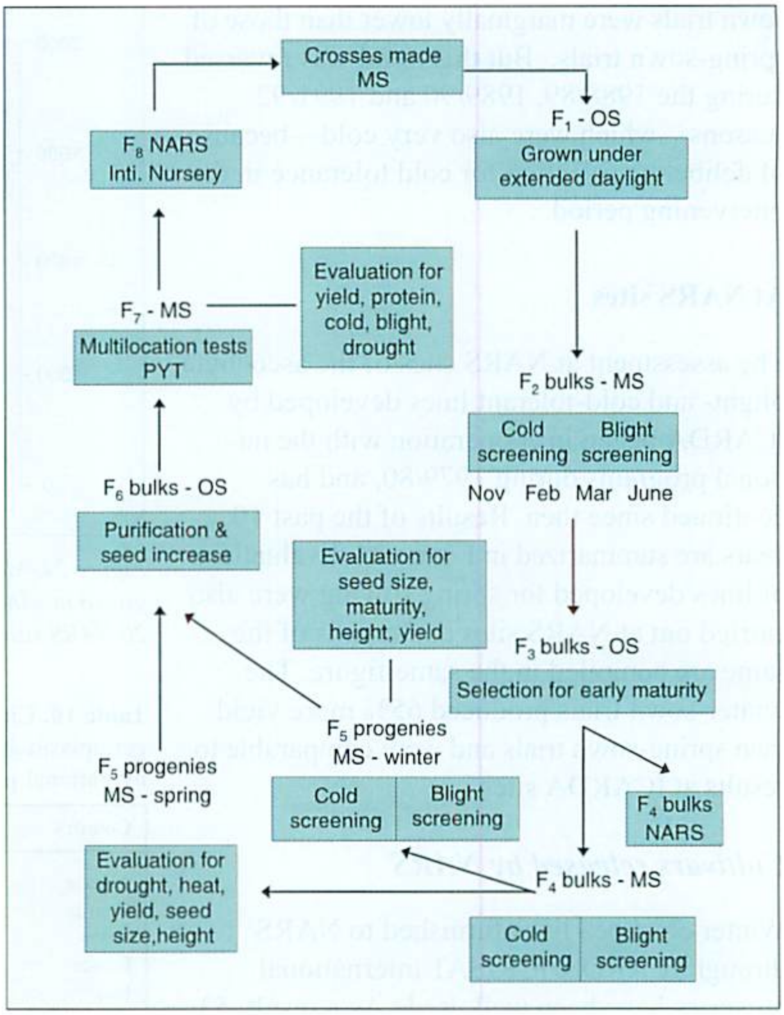

Figure 23. Breeding scheme for ICARDA/ICRISAT kabuli chickpea for development of cold, ascochyta blight and drought (MS = main season; OS = off-season).

Thus, it takes four years from crossing to cultivar development. Following this and earlier breeding schemes, over 2000 lines have been bred.

Yield testing of newly-bred lines

At ICARDA sites

A comparison of spring versus winter sowing has been made over 10 years (1983/84 to 1992/93) at three sites (Tel Hadya, Jindiress and Terbol), using common breeding lines (testing between 72 and 486 lines). The winters of 1984/85, 1988/89, 1989/90 and 1991/92 were colder than normal and the springs of 1983/84, 1988/89, 1989/90, 1990/91 and 1992/93 (especially at Tel Hadya) were drier than normal.

Winter-sown trials on average produced 1674 kg/ha, whereas spring-sown trials produced 1032 kg/ha, giving a yield advantage of 62.2% or 642 kg/ha (Fig. 24). The yield differences between winter and spring were larger during drier seasons. During an abnormally cold year (1984/85), yields of winter-sown trials were marginally lower than those of spring-sown trials. But this trend was reversed during the 1988/89, 1989/90 and 1991/92 seasons—which were also very cold—because of deliberate selection for cold tolerance in the intervening period.

At NARS sites

The assessment at NARS sites of the ascochyta blight- and cold-tolerant lines developed by ICARDA began in cooperation with the national programs during 1979/80, and has continued since then. Results of the past 10 years are summarized in Figure 24. Evaluations of lines developed for spring sowing were also carried out at NARS sites and results of the same are compiled in the same figure. The winter-sown trials produced 65% more yield than spring-sown trials and were comparable to results at ICARDA sites.

Cultivars released by NARS

Winter chickpea lines furnished to NARS through ICARDA/ICRISAT international nurseries have been well used. As a result, 53 cultivars have been released in 15 countries between 1984 and 1995 for winter sowing (Table 10). Some of these cultivars have been released for early spring sowing in Turkey.

Reasons for high yield during winter

Reasons for high yields during winter sowing have been investigated and are summarized below.

A. Environmental
  1. Better use of rainfall during the growing season.
  2. Favorable temperature during most of the growing season.

B. Biological
  1. High above-ground biomass yield.
  2. Long reproductive phase.

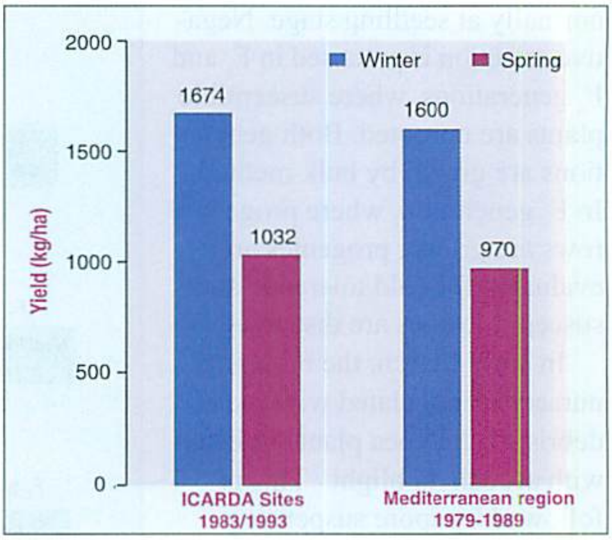

Figure 24. Mean seed yield of several chickpea lines grown in winter and spring at 3 ICARDA sites and over 20 NARS sites in mediterranean environments.

Table 10. Chickpea lines bred using ICARDA germplasm and released as cultivars for winter sowing by national programs.

Country	Cultivar(s) released
Algeria	ILC 482, ILC 3279, FLIP 84-79C, FLIP 84-92C
Cyprus	Yialousa, Kyrenia
Egypt	ILC 195
France	TS1009, TS1502, Roye Rene
Iraq	Rafidain, Dijla
Italy	Califfo, Sultano, Pascia, Otello
Jordan	Jubeiha 2, Jubeiha 3
Lebanon	Janta 2, Baleela
Libya	ILC 484
Morocco	ILC 195, ILC 482, Douyet, Rizki, Farihane, Moubarak, Zahor
Portugal	Elmo, Elvar
Spain	Fardan, Zegri, Almena, Alcazaba, Atalaya, Athenas, Bagda, Kairo
Syria	Ghab 1, Ghab 2, Ghab 3
Tunisia	Chetoui, Kassab, FLIP 84-79C, FLIP 84-92C
Turkey	ILC 195, Guney Sarisi 482, Damla 89, Aziziye, Akcin, Aydin 92, Menemen 92, Izmir 92

Protein content in seed

The protein content in the newly-bred cultivars was regularly monitored (Fig. 25) and results of five years' evaluations are shown in Table 11. The mean protein contents of several hundred breeding lines were 22.40% and 22.84% during the winter and spring seasons, respectively, suggesting no seasonal influence on the protein content in chickpea seed. On an average, protein harvest from a hectare of land was estimated at 463.5 kg/ha from winter-sown compared with 307 kg/ha from spring-sown, giving an increase of 51% in protein content during winter (Table 12) (Singh et al. 1993a).

Figure 25. Protein content of new lines is continually monitored in the laboratory.

Table 11. Mean protein content of entries grown for five years at Tel Hadya, Syria.

Year	No. entries		Protein content (%)	
	Winter	Spring	Winter	Spring
1987/88	120	120	20.94	19.58
1988/89	120	120	22.46	22.27
1989/90	223	225	22.74	26.09
1990/91	286	248	24.42	23.81
1991/92	308	308	21.42	22.20
Mean			22.40	22.84

Table 12. Influence of planting time on yield per hectare, protein content and seed size in kabuli chickpea.

	Tel Hadya		Terbol	
	Winter	Spring	Winter	Spring
Protein content (%)	20.0 ± 0.8	20.9 ± 1.0	19.6 ± 1.0	20.4 ± 1.2
Yield (kg/ha)	2033 ± 344	1142 ± 230	2651 ± 356	1842 ± 209
Mean protein (kg/ha)	406	239	521	375

Source: Singh et al. (1993).

Blight-free seed production

Since seed is a carrier of ascochyta blight disease, it is necessary to produce blight-free seed. Some hints for this are given below:

- Select drier sites
- Follow crop rotation
- Destroy infested chickpea debris by burning or burying
- Treat seed with Tecto (thiabendazole) at 3 g per kg seed or Calixin M (maneb + tridemorph) at 2 g per kg of seed
- Spray with chlorothalonil (3 ml solution per liter of water) or other suitable fungicide at peak flowering.

Technology Development

Fertilizer application

Generally, chickpea does not respond to nitrogen-phosphorus-potassium (NPK) application in moderate- to low-yielding environments, but this may not be so at high-yielding sites. Pala and Mazid (1992) reported significant yield increases with application of 50 kg P_2O_5/ha over no application in a winter-sown chickpea trial (Table 13). Therefore, we suggest that 50 kg P_2O_5/ha be applied to winter-sown chickpea. Furthermore, a basal dose of 20 kg N/ha has been found beneficial. Where there is rotation with crops that have been heavily fertilized, further fertilizer application may not be needed.

Effect of rhizobial inoculation

The amount of biological nitrogen fixation (BNF) during winter and spring sowings has been determined by ICARDA scientists (Fig. 26 and 27) (Saxena 1988; Herridge et al. 1994). The nitrogen fixed ranged between 80 and 120 kg/ha during winter compared with 5–20 kg/ha during spring. Experiments on BNF have also shown that inoculation of seed with *Rhizobium* does not help increase yield in traditional chickpea-growing areas, although Pala and Mazid (1992) did find a response in one out of four years. However, where chickpea crop is being introduced for the first time, inoculation of seed has been useful and is therefore recommended.

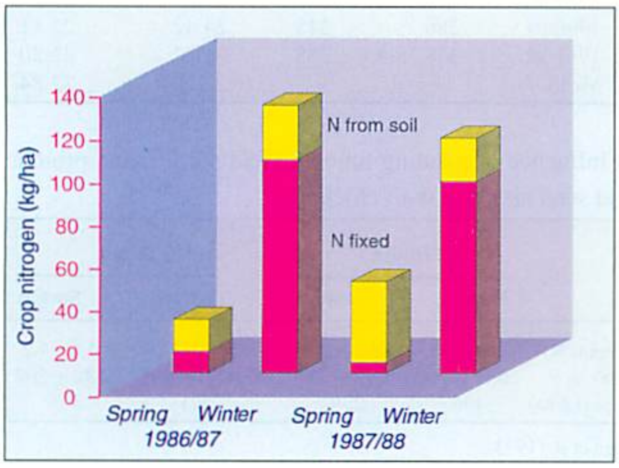

Figure 26. Source of N utilized in spring and winter chickpea (Source: D. Beck, unpublished).

Table 13. The effect of various agronomic factors on chickpea grain yield (t/ha) in northwest Syria, 1985-1989.

Factor	1985/86 (8 sites)	1986/87 (6 sites)	1987/88 (6 sites)	1988/89 (10 sites)
Time of sowing				
Early	1.41**	1.80**	1.52**	0.97**
Late	1.11	1.34	1.00	0.82
Weed control				
Chemical	1.40**	1.50**	1.22**	0.86**
Other†	1.20	1.63	1.29	0.94
P_2O_5 (kg/ha)				
50	1.36**	1.66**	1.31**	0.89
0	1.24	1.47	1.21	0.90
Inoculation				
+	1.33**	1.54	NA	NA
–	1.27	1.59		
Sowing method				
Drilled	NA	1.64**	1.32**	0.94
Broadcast		1.49	1.20	0.85
LSD (0.05)	0.07	0.05	0.05	0.04

*,** Denote significance at $P<0.05$ and $P<0.01$, respectively. NA= not applicable.

† Weedy check in 1985/86 and hand-weeding in the last three seasons.

Source: Pala and Mazid (1992).

Figure 27. Rhizobium *inoculation could be beneficial in fields where chickpea has never been grown.*

Table 14. Mean effects of tillage, row spacing and weed control methods on chickpea seed yield (SYLD), total dry matter (TDM) and weed dry matter (WDM) in t/ha at three locations (Alkamieh, Tel Hadya and Afrin) in Syria, 1989/90 to 1993/94.

Factor	SYLD	TDM	WDM
Tillage			
Deep	1.70	3.90	0.35
Shallow	1.66	3.90	0.35
Row spacing			
35 cm	1.68	3.84	0.33
17.5–52.5 cm pair row	1.70	3.96	0.37
Weed control			
Check	1.53	3.61	0.66
Hand-weeding	1.84	4.21	0.14
Herbicide	1.72	3.90	0.20
Mechanical	1.67	3.87	0.39

Source: Pala (pers. comm.).

Land preparation

Winter chickpea does not require any special land preparation other than that for spring chickpea. The selected fields should be plowed once with mould-board plow followed by harrowing. A field with good drainage should be chosen to avoid waterlogging. The field should also be leveled and free of large stones, to facilitate mechanical harvesting.

Contrary to the common belief that deep tillage produces more yield than shallow tillage, experiments conducted at ICARDA did not show any difference due to depth of tillage (Table 14) (Pala, pers. comm.).

Sowing

Twenty chickpea lines were sown on 22 November, 17 December, 11 January, 15 February and 15 March in 1978/79 at Tel Hadya, Syria. The increase in the mean yield was 69, 128, 193 and 277% when the sowing was advanced from 15 March to 15 February, 11 January, 17 December and 22 November, respectively (Fig. 28) (Saxena 1984). The November-sown trial yielded more than 3000 kg/ha and there was an almost linear decrease in yield as the sowing date was delayed up to 15 March. These results demonstrate the flexibility of the cropping system of rain-fed agriculture in dry areas (Saxena 1990a).

Late November sowing in North Africa and early December sowing in West Asia have been found most appropriate. However, to control weeds, sowing could be delayed until after weed seeds germinate with the first rain and can be destroyed by plowing.

The effect of row spacing on yield was not established in a study spanning five years at three locations (Table 14) (Pala, unpublished data).

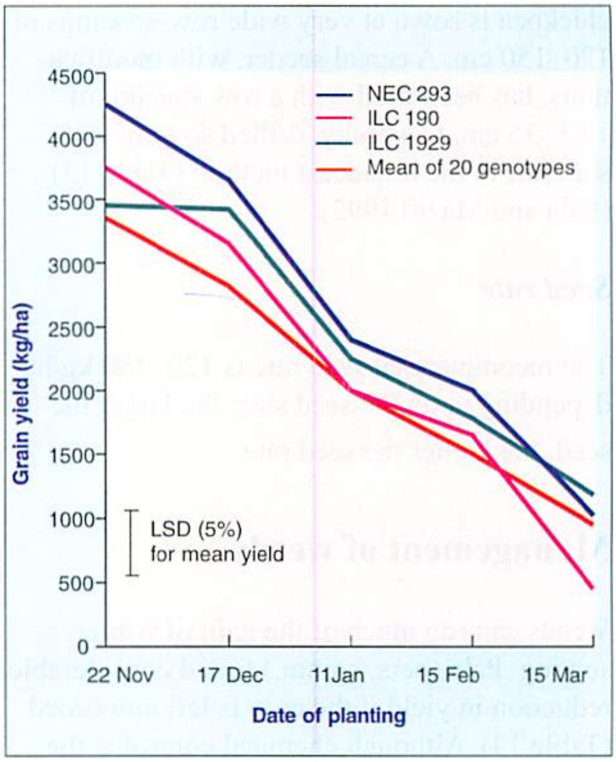

Figure 28. Grain yield of chickpea genotypes as affected by planting date at Tel Hadya, 1978/79 (Source: Saxena 1984).

Plant density

The response of winter- and spring-planted chickpea, raised with supplemental irrigation, to increasing plant density in a fan-type design was studied at Tel Hadya in 1977/78, using genotypes of different growth habit. The yield generally increased as the population level was raised from 4.4 to 71.7 plants/m^2 (Table 15) (Saxena 1980). Therefore, a higher plant density of 40–50 plants/m^2, in contrast to the traditional 33 plants/m^2, is recommended as is a close row-spacing of 17.5–35 cm.

Table 15. Grain yield (kg/ha) of Syrian local and NEC-141 chickpea, grown at Tel Hadya, 1977/78, supplemental irrigation†, as affected by plant population varied in fan-type design.

Plant population (plants/m^2)	Winter		Spring	
	Syrian local	NEC-141	Syrian local	NEC-141
4.4	784	495	629	292
6.3	1051	729	764	311
9.2	1294	840	673	617
13.4	1023	1076	772	758
23.6	1357	1133	991	637
28.4	1721	1616	1295	778
41.3	2535	2143	1158	1020
48.9	2811	2773	1707	1471
71.7	3041	2868	2223	2008

† Crop was irrigated twice in the spring.
Source: Saxena (1980).

Seeding

In West Asia, the broadcast method is generally practised for seeding chickpea. In North Africa, chickpea is sown at very wide row-spacings of 120–150 cm. A cereal seeder, with modifications, has been used with a row spacing of 17.5–35 cm. Generally, drilled sowing was superior to the broadcast method (Table 13) (Pala and Mazid 1992).

Seed rate

The recommended seed rate is 120–180 kg/ha depending upon the seed size; the larger the seed, the higher the seed rate.

Figure 29. Inter-row cultivation could control most of the weeds.

Management of weeds

Weeds can rob much of the gain of winter sowing. Pala (pers. comm.) found considerable reduction in yield if the crop is left unweeded (Table 14). Although chemical control is the best, herbicides are often not available. Therefore, the Farm Resource Management Program scientists of ICARDA investigated alternative methods of control. They found that hand-weeding was the best, followed by herbicide application and mechanical weeding (Table 14; Fig. 29) (Pala, unpublished data). Since labor is expensive, and herbicide is both unavailable and expensive, the best choice is to adopt mechanical weed control.

A mechanical brush was used for inter-row cultivation at the very early growth stage (at the first hand-weeding time) in the 35 cm row-spacing treatment, and a local ducksfoot cultivator was used in the 17.5–52.5 cm pair row planting treatment.

However, if herbicides are available, we suggest that they be applied to each hectare of land as follows:

Pre-sowing:	Gramoxone (paraquat) (3 l)
Post-sowing and pre-emergence:	Terbutrin (terbutryn) (2 kg a.i.) + Pronamide (propyzamide) (0.5 kg a.i.)
Post-emergence:	Fusilade (fluazifop-P) (2 kg a.i.)

The above combination gives the best control of weeds, and some farmers in Mediterranean environments have adopted it. However, if herbicides are not available, then one should adopt the cultural practices suggested below:

(1) sowing after emergence and destruction of weeds;

(2) increased seed rate;

(3) inter-row cultivation.

Management of water

Inadequate soil moisture is one of the main constraints to productivity of chickpea in the rain-fed farming systems of the dry areas of WANA. The response to irrigation at flowering and pod-filling of winter and spring chickpea was investigated from 1983 to 1986 at ICARDA (Saxena et al. 1990).

The yield increase due to supplemental irrigation ranged from 56 to 105%. This study indicated that irrigation is a way of increasing productivity and stability in a mediterranean environment.

In another study at ICARDA during 1985/86, 1986/87 and 1987/88, a set of 24 genotypes was evaluated for response to supplemental irrigation during winter. The rainfall figures during the three years were respectively 316, 358 and 504 mm, and supplemental irrigation was 130, 120 and 80 mm. Irrigation was scheduled based on daily water-balance computations of rainfall and pan-evaporation, and validated by soil moisture measurements with the neutron probe. Mean yields of genotypes tested with and without supplemental irrigation are shown in Figure 30. Supplemental irrigation gave an average of 44% or 916 kg/ha more yield over no irrigation (Malhotra et al. 1996). Response to irrigation showed high genetic variability. Although the above-ground biomass yield with supplemental irrigation (SI) was twice that of rain-fed (R), the harvest index was lower with SI (38%) than with R (46%). Average plant height with SI was greater (58 cm) than that with R (47 cm), but the 100-seed weight was lower with SI (34 g) than with R (37 g) (ICARDA 1989).

Malhotra et al. (1996) have identified a few irrigation-responsive lines—ILC 147, ILC 464, ILC 1272, ILC 3256 and ILC 4291—with yield potential of up to 3900 kg/ha. The yield increases were due to increased above-ground biomass and plant height, and early maturity. This study showed the potential for breeding chickpea with improved response to supplemental irrigation. Supplemental irrigation can also help in maximizing the realization of yield potential in the winter sowing of chickpea in the lowlands of the mediterranean drylands.

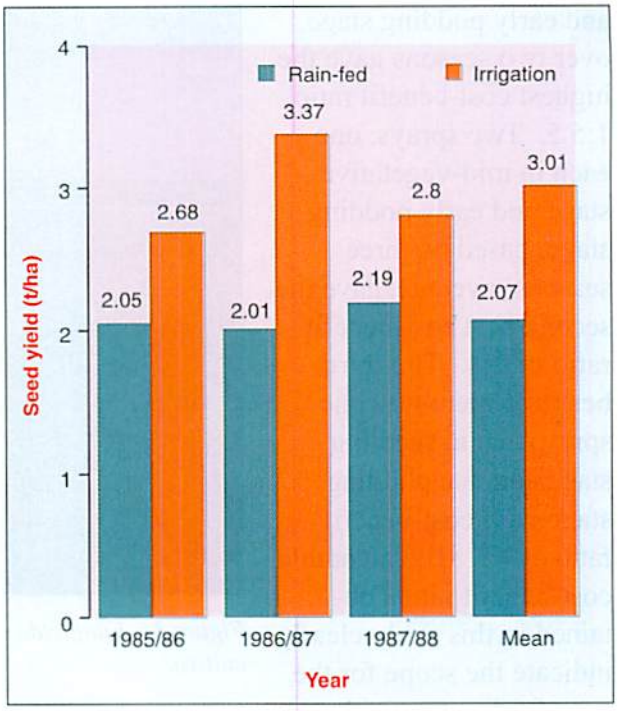

Figure 30. Mean seed yield of 24 chickpea genotypes as affected by supplemental irrigation at Tel Hadya, Syria, 1985/86–1987/88.

Management of ascochyta blight

Ascochyta blight can mainly be managed by resistant cultivars. However, the resistant cultivars can be supplemented by using fungicide and destroying diseased debris of the previous season by burning or burying.

Fungicide regimes

(1) Seed-dressing by Tecto (thiabendazole) at the rate of 3 g per kg seed (Reddy and Kabbabeh 1984b) or Calixin M (maneb + tridemorph) at 2 g per kg of seed (Reddy 1980).

(2) Spraying 1–2 times during flowering and podding with Bravo 500 (chlorothalonil) (3 ml solution per liter of water) (Hanounik 1980). Five hundred liters of water are required to cover one hectare of crop.

Benefit from fungicide spray

The cost-benefit ratio of three highest-yielding treatments over of 2–3 seasons is given in Table 16. One spray each in the seedling stage

Table 16. Cost-benefit ratio of two foliar applications of chlorothalonil (Bravo 500) for control of ascochyta blight in tolerant chickpea cultivar ILC 482, Tel Hadya, Syria, 1982/83 to 1985/86.

Time of spraying	Yield (kg/ha)	Value of additional produce ($)	Cost-benefit ratio
Seedling and early podding	2520	209.0	1:5.5
Mid-vegetative and early podding	2104	159.5	1:4
Seedling and late podding	2254	115.9	1:3
No spray (Control)	1923	-	-

Source: Reddy and Singh (1990b).

and early podding stage, over two seasons gave the highest cost-benefit ratio, 1:5.5. Two sprays, one each in mid-vegetative stage and early podding stage, based on three seasons' average, gave the second best cost-benefit ratio of 1:4. The third best treatment was one spray each in seedling stage and late podding stage with cost-benefit ratio of 1:3. The favorable cost-benefit ratios obtained in this study clearly indicate the scope for the use of foliar fungicides in the management of ascochyta blight (Reddy and Singh 1990c) (Fig. 31).

Figure 31. Fungicide spray is effective in checking blight damage in a tolerant cultivar.

Management of other diseases

Fusarium wilt

Figure 32. A plot infected with fusarium wilt.

Fusarium wilt caused by *Fusarium oxysporum* Schlecht. emend Snyd. & Hans. f.sp. *ciceri* (Padwick) Snyd. & Hans. is not usually a serious disease in the Mediterranean region. In parts of North Africa, however, it can be a serious threat to winter-sown chickpea (Fig. 32).

The best way to control wilt is through the use of resistant cultivars. If the seed is produced in a wilt-infested field it is important to treat the seed with fungicide (Benlate T at 0.15%) before its shipment to other areas (Haware et al. 1978).

Although no chickpea cultivar has been released with combined resistance to ascochyta blight, fusarium wilt and cold, efforts are underway at several research institutions to develop such cultivars. At ICARDA we have identified five lines with a combined resistance to all three stresses: FLIP 90-13C, FLIP 91-178C, FLIP 93-50C, FLIP 93-53C and FLIP 93-98C.

Nematode

Surveys undertaken by ICARDA in cooperation with the national programs in WANA have indicated that cyst nematode (*Heterodera ciceri* Vovlas, Greco & Di Vito), root-knot nematodes (*Meloidogyne* spp.) and root-lesion nematodes (*Pratylenchus* spp.) can cause damage to chickpea (Greco et al. 1992; Di Vito et al. 1994a, b). Unfortunately, there is no economic solution to this problem because soil solarization and nematicides are expensive to use in low-cash crops, such as chickpea. Cultivars with resistance to nematodes may be developed, but it will be many years before they can be given to farmers. Three- to four-course rotations are the only means of avoiding the build-up of nematodes in the soil (Saxena et al. 1992) (Fig. 33).

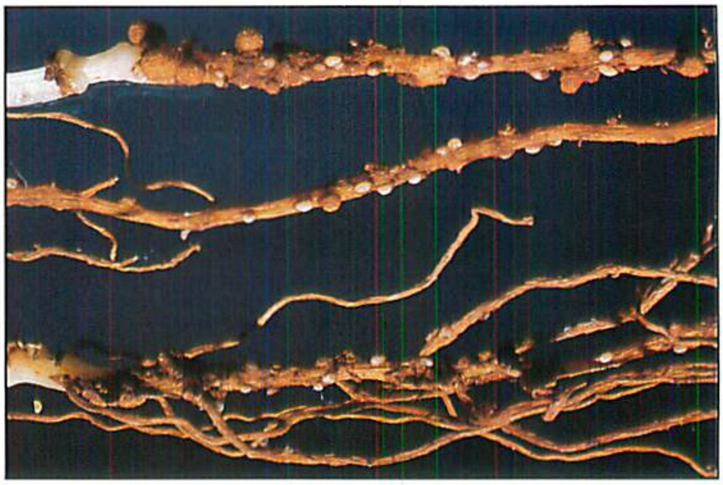

Figure 33. Cyst nematode, if present in a field, is a threat to chickpea.

Virus

A number of viruses are known to attack chickpea, but fortunately none of them are serious in WANA. This is probably why only limited research has been done on chickpea viruses at ICARDA (Makkouk et al. 1993). However, some of the viruses such as stunt virus could become a serious menace in the future (Fig. 34), so there is a need for vigilance.

Figure 34. A plant infected by stunt virus.

Orobanche

The parasitic weed *Orobanche* is a serious problem in other cool-season food legumes (faba bean, lentil and pea), but not with spring-sown chickpea. *Orobanche* has been seen occasionally in fields of winter-sown chickpea, but it is not a threat unless the crop is sown in fields known to be heavily infested. However, there are fields in North Africa which are heavily infested, and all such fields should be avoided for sowing winter chickpea.

Management of cold

Cold can be mainly managed through tolerant cultivars, and ICARDA has already bred cultivars with tolerance to cold as well as to ascochyta blight.

Tolerant cultivars can be supported by delayed sowing—during later December or early January—in West Asia and high altitude, or by deeper sowing ($\geq$ 10 cm) with increased plant populations ($\geq$ 45 plants/m^2).

Management of insect pests

Leaf miner and pod borer

Leaf miner, *Liriomyza cicerina* Rond., is the most serious insect pest of chickpea in WANA (Fig. 35). Losses due to this insect sometimes exceed 20% (Reed et al. 1987). Pod borers (*Heliothis* spp. and *Helicoverpa* spp., especially *Helic. armigera* (Hb.)), (Fig. 36), also damage chickpea in parts of WANA. Although many insecticides are known to control these insects, large-scale insecticide usage is lacking in WANA. Resistant cultivars have not yet been developed.

Therefore, we suggest that insectide be used to control these pests. Insecticide spray could easily increase yield by about 20% (Table 17). Although no threshold has been worked out, it is advisable to spray insecticide when yields are expected to exceed one tonne per hectare.

For controlling leaf miner and pod borer, insecticides such as methamidophos, methidathion, fenitrothion and Fenopropathin-Sumithion at 1 cm^3/L of water should be sprayed. Four hundred liters of solution are required to cover one hectare of crop. One to two sprays are needed, depending on the level of infestation.

Storage pests

The most important storage pests are species of *Callosobruchus*, of which *C. chinensis* (L.) is dominant (Weigand and Tahhan 1990). A detailed survey revealed that infections range from 0 to 79% in Syria. Treatment with olive oil and salt showed 90% effectiveness during four months of storage. This practice can be adopted to protect seed from insect damage.

Mechanical harvesting

One of the most important advantages of winter chickpea is that the crop can be har-

Figure 35. Leaf miner can reduce chickpea yield by up to 20%.

Figure 36. Pod borer can be an occasional threat to chickpea in WANA.

Table 17. Yield increase from insecticide use on winter- and spring-sown chickpeas, and pod damage by *Heliothis* spp. and *Helicoverpa* spp. in samples from unprotected plots at ICARDA, Tel Hadya, Syria, 1979–84.

Season	Winter			Spring		
	No. trials	Yield increase (%)	Pods damaged (%)	No. trials	Yield increase (%)	Pods damaged (%)
1979/80	2	22.5	5.2	2	20.8	2.7
1980/81	2	17.3	10.0	2	22.1	1.1
1981/82	0	–	–	2	31.5	4.3
1982/83	1	20.9	4.0	1	18.9	2.4
1983/84	1	19.0	7.1	1	20.8	3.1

Source: Reed et al. (1987).

vested by cereal combine (Saxena et al. 1987) (Fig. 37). Table 18 presents the result of a mechanical harvesting trial at ICARDA. The harvest loss due to combine harvest in a short-statured cultivar was 28.9% compared with none in a tall cultivar.

Figure 37. Winter chickpea can be easily harvested by a Combine.

In another study at ICARDA, besides losses due to threshing and shattering, broken grains and unthreshed pods were recorded along with whole grain (Table 19). If the machine is not properly adjusted, the losses could be substantial. The percentage of broken seeds and unthreshed pods was higher in large-seeded cultivars (Haffar et al. 1991).

A demonstration trial was conducted jointly by the Government Organization of Agricultural Mechanization, Syria and ICARDA during 1989/90. The results suggest that plant height is important: the taller the plant, the lesser the harvest loss. The swath mower, which cuts the plants close to the soil surface and leaves them to be dried and collected later, caused 6–48% loss in grain yield, depending upon the height of the cultivar; the loss was highest in the local cultivar (Table 20). The cereal combine harvester could not harvest the local cultivar due to its short stature. The grain harvest loss in Ghab 1 (short plants) and Ghab 2 (tall plants) was 26 and 18%, respectively (Pala, unpublished data).

Table 18. Seed yield of a conventional (ILC 482) and a tall (ILC 3279) kabuli chickpea cultivar as affected by method of harvesting at Al-Bawabeya, northern Syria, 1985.

CV	Plant ht (cm)	Seed yield (kg/ha) Hand harvest	Seed yield (kg/ha) Harvest with Hege combine	Loss in mechanical harvest (%)
ILC 482	30	1370 ± 37	975 ± 42	28.9
ILC 3279	50	877± 56	931 ± 35	0.0

Source: Saxena et al. (1987).

Table 19. The overall mean of all treatments and control per variety (kg/ha) for all the experimental parameters in a harvesting experiment conducted at Tel Hadya, 1986.

Variety†	Total weight	Whole grain	Broken grain	Unthreshed pods
		Treatment		
ILC 482	2257.6 a	2103.2 a	45.2 a	63.0 a
ILC 3279	1716.9 b	1625.2 b	33.8 b	23.2 b
		Control		
ILC 482	2512.9 a	2378.6 a	2.6 a	15.4 a
ILC 3279	1862.7 b	1732.1 b	1.5 a	6.8 b

†Means in a column with a common letter are not significantly different at 95% confidence level using the t-test for mean comparison.

Source: Haffar et al. (1991).

Table 20. Grain yield of chickpea under different harvesting methods at Kamishly, Syria, 1989/90.

Harvest method	Cv	TDM (kg/ha)	Grain (kg/ha)	Grain loss (% of hand)
Hand	Ghab 1	3477	1547	-
	Ghab 2	3511	1142	-
	Local	2183	640	-
Swath-mover	Ghab 1	3197	1451	6
	Ghab 2	2564	916	20
	Local	1237	334	48
Combine	Ghab 1	-	1139	26
	Ghab 2	-	942	18
	Local	-	-	-

Source: Pala (unpublished data).

The adjustments in the cereal combine for chickpea harvest are as follows:

Drum type:	as for cereal
Drum speed:	550–600 rpm
Concave type:	as for cereal
Concave opening:	2 x seed diameter
Shaker:	Standard
Sieves:	According to seed size
Wind:	Stronger than required for cereal

With the above modifications, the cereal combine has been used for large-scale harvesting of chickpea (Saxena et al. 1987).

Taller plants will have less harvest grain loss. Hand-harvesting has nominal to no grain loss, but machine harvest will have some loss which growers will have to accept. Although economic studies have not yet been made, machine-harvesting is estimated to be a lot cheaper and faster than hand-harvesting.

Potential of Winter Chickpea

Winter chickpea has a great future in the Mediterranean region for seven good reasons—and these are shown diagrammatically in Figure 38 (Singh 1990). They are: high yield; better water-use efficiency; mechanization of operations; high protein harvest; escape from drought; increased nitrogen fixation; and fallow replacement. Although all seven reasons are significant, substantially higher seed yield and mechanical harvesting are extremely important. These advantages have made winter chickpea a potentially important food crop in the Mediterranean basin.

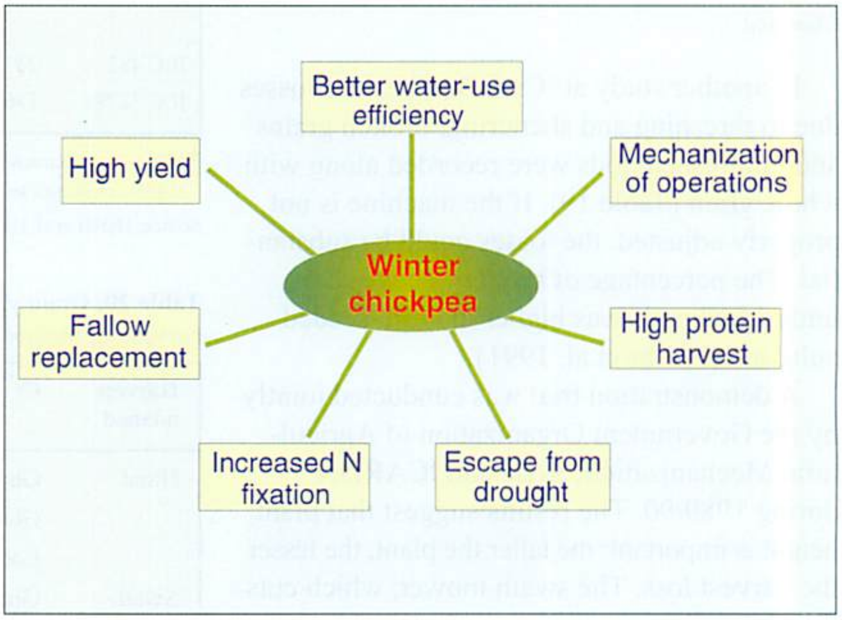

Figure 38. Seven reasons to grow winter chickpea.

Yield potential

The highest yields obtained from winter chickpea at ICARDA and NARS sites are shown in Figure 39. At ICARDA sites, yields of winter chickpea ranged from 2.5 t/ha in a dry season to 4.5 t/ha in a wet season. But yields at NARS sites were much higher, ranging from a minimum of 4 t/ha to a maximum of more than 8 t/ha.

Economics of winter chickpea

As a part of a farm survey, an economic analysis was conducted in 1986/87 of chickpea production by nine farmers in Syria who had planted chickpea during winter and spring on plots of more than one hectare. The economic returns are shown in Figure 40 (ICARDA 1988). The winter-sown crop gave twice as much return as the spring-sown crop. Both Ghab 1 and Ghab 2 were equally profitable, because Ghab 1 produced more seed yield and Ghab 2 more straw yield.

Lessons learned from adoption studies

Socio-economic surveys on adoption of winter chickpea in Syria and Morocco have indicated that farmers appreciated the yield advantage of winter sowing and the possibility of mechanized harvesting. However, increased weed infestation and the comparatively smaller seeds of winter cultivars are considered as limitations in some countries. Government support in providing winter chickpea seeds, herbicides and a more efficient marketing organization would benefit small-holder farmers. These conclusions may apply in other countries as well. Over the past five years, the number of farmers who adopted winter chickpea technology package after one year of use has more than doubled—from 20 % in the first year to 50–60% in the second year (ICARDA 1993) (Fig. 41).

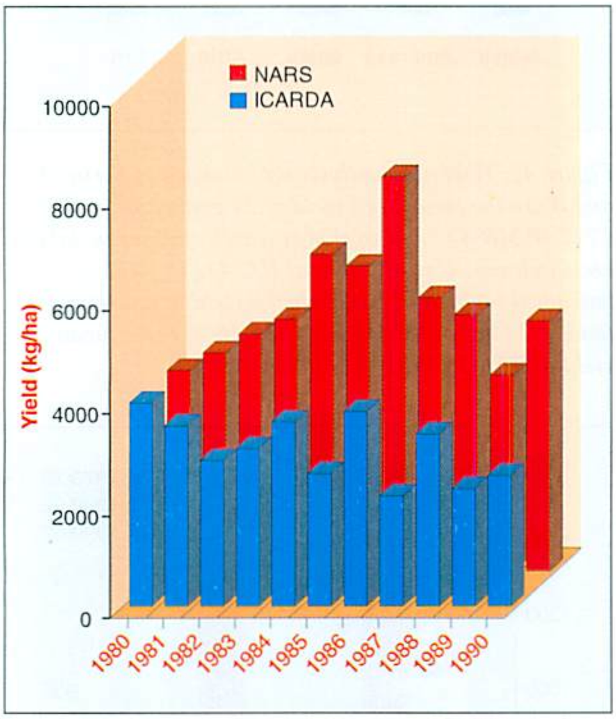

Figure 39. The highest yield recorded at ICARDA and NARS sites indicating the potential yield of winter-sown chickpea.

Tutwiler et al. (1994) and Tutwiler (1995) studied the constraints to winter chickpea adoption in Morocco and Syria. The principal constraints in Morocco were small seeds and poor marketing, although weed control and susceptibility to ascochyta blight were also problems. In parts of Syria where adverse climatic conditions frequently occur, the farmers adopt a risk-avoidance practice of deciding to plant chickpea in spring only when adequate rainfall has occurred in the preceding months.

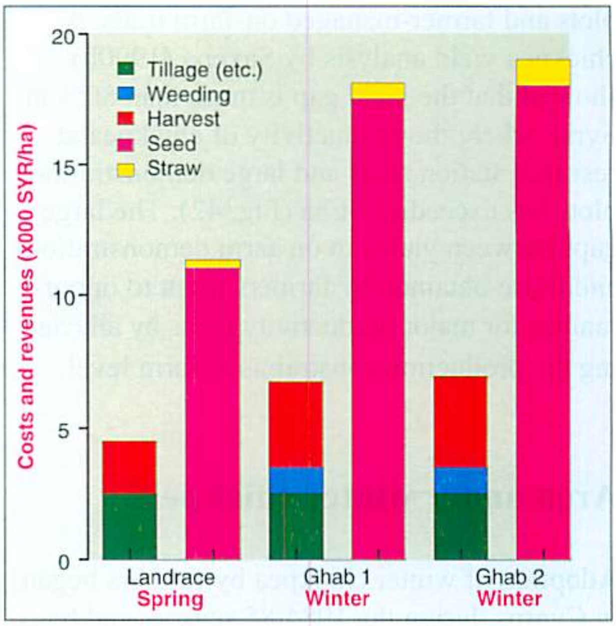

Figure 40. Chickpea cultivars sown in winter double the profit to Syrian farmers (ICARDA 1988).

This practice prevents them from easily accepting winter sowing. A major extension effort would be necessary to make them realize the potential advantage of winter sowing under such conditions.

Yield gap analysis

The global productivity of chickpea, at 0.7 t/ha, continues to be low—and far below the levels realized at research stations, demonstration

Figure 41. A technician interviewing a farmer regarding adoption of winter chickpea.

plots and farmer-managed on-farm trials. A chickpea yield analysis by Saxena (1990b) showed that the yield gap is more than 80% in Syria, where the productivity of chickpea at research station trials and large demonstration plots has exceeded 4 t/ha (Fig. 42). The large gaps between yields in on-farm demonstrations and those obtained by farmers point to opportunities for major productivity gains by alleviating the production constraints at farm level.

Area under winter chickpea

Adoption of winter chickpea by farmers began in Cyprus during the 1984/85 season, and by 1990/91 nearly all the spring chickpea area was replaced by winter chickpea. All eastern Mediterranean countries, including those in West Asia, North Africa and southern Europe, have introduced winter sowing. The concept has also reached Mediterranean environments elsewhere. California (USA), which grew chickpea during spring, has now introduced winter sowing in the Central Valley. Nearly all the chickpea area in the Mediterranean environment of Australia is now sown in winter. Chile has also introduced winter sowing of chickpea.

In general, the area under winter chickpea is increasing. The area under spring chickpea in Mediterranean environments is now estimated at 1.5 million hectares (Fig. 43). It is expected that the adoption rate will increase faster in future because of greater availability of seed. In view of the substantial increase in yield by winter sowing over spring sowing, it is expected that at least one million hectares of area under spring chickpea will be replaced by winter chickpea in due time.

Approximately 20 million hectares is thought to be fallow each year in the wheat-based farming systems of West Asia (Pala 1992). The practice was believed to conserve moisture for the succeeding wheat crop, but a recent study has shown that keeping the land

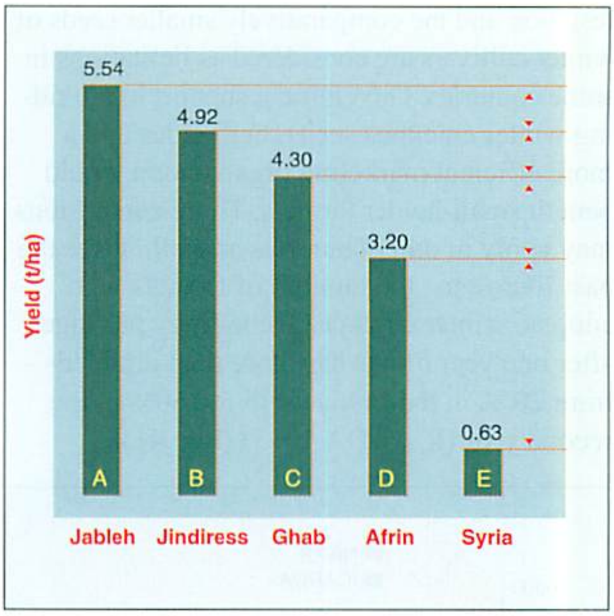

Figure 42. Yield gap analysis for chickpea in Syria: A and B are the mean seed yield of 24 genotypes in the CIYT-W-MR-87 yield trial at research stations of Jableh and Jindiress; C is the yield of ILC 482 in yield maximization plot (2 ha); D is the yield in a farmer's field (1.24 ha) of ILC 482 in 1985/86; E is the mean yield in Syria in 1985–87 (Saxena 1990b).

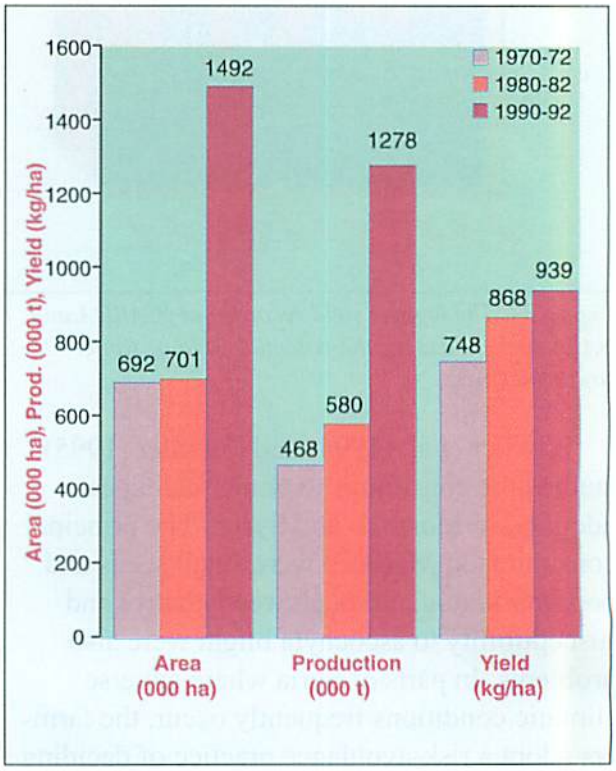

Figure 43. Area, production and yield of chickpea in Mediterranean environments.

fallow in the Anatolian Plateau of Turkey does not store water as efficiently as was thought.

Due to accelerated increase in human and small ruminant populations, continuous cropping of cereal is becoming more popular in WANA. But it is unsustainable. Introduction of legumes to interrupt monocropping could improve productivity by reducing soil nitrogen depletion and by checking insect, disease and weed build-up. Chickpea can replace fallow on some lands, and contribute to both improved productivity and sustainability of the system.

Karaca et al. (1991) reported that wheat grown after chickpea had a higher water-use efficiency than wheat after fallow in the Central Anatolian Plateau. The process of fallow replacement was first initiated in Turkey with spring sowing of chickpea. Here, we suggest that 5% of fallow land, or approximately one million hectares, be brought under winter chickpea. The region would then not only become self-sufficient in chickpea production, but also become an exporter. In Syria, the Department of Agriculture and ICARDA together have introduced winter sowing for fallow replacement in the northeast of the country.

Impact of winter chickpea

The potential economic impact of winter chickpea in Mediterranean environments has been roughly estimated (Table 21). When winter chickpea is fully adopted in Mediterranean environments, it may cover an area of 2 million hectares with an additional annual income of US$ one billion.

Sustainable production system

Chickpea is generally grown by small-holder farmers and consumed by the poor, so winter chickpea technology is benefitting these two groups.

Since winter chickpea increases seed and biomass yields by 50–100%, it generates additional work to handle the extra produce. Large-scale farmers are using herbicides and hired labor to control weeds. In contrast, small-holders use family labor to weed winter chickpea fields. The weeds are invariably fed to cattle. The extra labor provides additional employment for women.

Studies at ICARDA have shown that 80–120 kg/ha of atmospheric nitrogen is fixed by winter-sown chickpea compared with 15–35 kg by spring-sown chickpea. Thus, winter chickpea meets over 90% of its nitrogen requirement through symbiosis, and takes up less soil nitrogen than spring-sown chickpea. The residual effect of winter chickpea on a subsequent cereal crop is demonstrably better than that of spring chickpea.

The newly-bred winter chickpeas resist not only blight disease and severe cold during winter, but also drought in the spring. These characteristics promise sustainable increases in chickpea production in the long term.

Table 21. Impact of winter chickpea in Mediterranean environments.

Expected area to be brought under winter chickpea	
Replacement of two-thirds of area under spring chickpea	1,000,000 ha
Replacement of fallow	1,000,000 ha
Total	2,000,000 ha
Additional annual production of chickpea due to adoption of winter chickpea (0.5) t/ha and replacement of fallow (1.5) t/ha	2,000,000 t
Additional income due to adoption of winter chickpea at a price of US$ 500/t	1,000,000,000 US$

Practical Problems in Adoption of Winter Chickpea

The question often raised is why, despite the substantial gain in yield from winter chickpea obtained by researchers, the rate of adoption by farmers is slow. Some of the reasons are discussed here (Singh 1990).

First, there is a need to publicize the advantages of winter chickpea through information media (radio, television and newspapers). Planting large-scale demonstration plots and organizing field days with the help of extension agents are other important means of informing farmers. In-country training courses on winter chickpea for extension workers and progressive farmers are also beneficial.

Second, seed availability is a major constraint to a speedy spread of the technology. An all-out effort should be made to increase and distribute good-quality seeds. Farmers should be made aware that their own seed for spring sowing is no good for winter sowing.

Third, weeds rob the majority of the advantages of winter sowing if allowed to grow unchecked. ICARDA has identified some chemicals (for example Igran (terbutrin) at 2.5 kg a.i./ha plus Pronamide (propyzamide) 0.800 kg a.i./ha) which provide effective control if sprayed after sowing and before emergence. But these herbicides are not available in most countries.

Fourth, if the winter chickpea is to be introduced in new areas, seed inoculation with *Rhizobium* is required. This will need the establishment of an inoculum-production system.

Fifth, there is the parasitic flowering plant *Orobanche*, which is a common parasite of winter legumes and must be monitored. Research conducted at ICARDA indicates that chickpea is more tolerant to *Orobanche* than other winter-sown food legumes.

Sixth, cultural operations such as land preparation, sowing and harvesting of chickpea may overlap with wheat and other crops which are traditionally winter-sown. This should not be a major constraint, because the area under chickpea is only about 5% that of wheat.

Seventh, some people worry that if there is a large-scale adoption of winter chickpea and the production rises substantially, there may be a surplus. This is a theoretical question, and if it does happen chickpea can be fed to cattle—as is common in South Asia and Australia.

Future Perspectives

Research

Winter chickpea technology is new, and there are several areas where improvements are needed. Also, second-generation problems have been observed which call for additional research.

Breeding

- Because of the breakdown of resistance to ascochyta blight, we must develop cultivars with durable resistance. Use of molecular markers may be helpful here. Additionally, NARS should rely on more than one cultivar to ensure that some lines, at least, will be resistant when a new pathotype becomes dominant in an area.
- There is still a need for further increase in the seed size in winter-chickpea cultivars.
- There is a need for higher levels of cold

tolerance in the existing lines if we are to introduce winter sowing in the high-altitude areas of WANA. Genes for cold tolerance can be transferred from wild *Cicer* species. Here one should try to cross the cultigen with *C. bijugum*, which has the best resistance to cold. The interspecific hybridization would be facilitated through the use of embryo/ovule-rescue technique.

- Efforts should be directed to develop irrigation-responsive lines combining resistance to major stresses with high yields, giving greater overall economies of production and making the crop more profitable.
- Efforts should be increased to develop lines with winter vigor and ability to flower and pod at low temperature.
- Recently identified drought-tolerant genotypes should be utilized to develop lines combining resistance to blight, cold and drought to help stabilize the yield of winter-sown chickpea.
- High-yielding lines derived from the interspecific hybridization program should be utilized in the breeding program to further upgrade the genetic potential of cultivars for winter sowing.
- ICARDA has evaluated 6400 germplasm accessions for 29 descriptors during winter. Identified elite lines should be used effectively in the breeding program for the development of high-yielding cultivars (Singh et al. 1991).

Agronomy and physiology

- As new cultivars are developed, suitable agronomic practices also need to be developed. This requires increased research effort on plant population, plant geometry and supplemental irrigation.
- Additional research is needed on effective weed control through herbicides, mechanical methods or a combination of both. Herbicides are needed for post-emergence application, as this will make their use easier for farmers.
- The mechanism of cold tolerance needs to be better understood so that we can tackle this stress more effectively.
- The mechanism of drought escape in the winter-sown crop needs investigation so that we can take full advantage of this phenomenon in future cultivar development.
- Laboratory screening techniques for cold and drought tolerance can help in discarding susceptible material quickly and reducing costs.

Plant protection

- Screening techniques for both leaf miner and pod borer need refinement if we are to make progress in breeding for resistance.
- Thresholds for chemical spray against diseases or insects need to be worked out. Chemical spray can be beneficial under high-yield conditions. Safe chemicals and integrated pest management need study.
- Identification and mapping of races of the ascochyta blight pathogen in WANA could make breeding for resistance more effective.
- There is a need to continually monitor virus, nematode and *Orobanche* problems.

Other matters

- Socio-economic studies should continue in more countries to increase the understanding of the problems and prospects of winter chickpea.
- Attention should be given to fallow replacement by legumes, especially chickpea.
- Efforts should be made to introduce chickpea into drier areas. Along with this effort, production of *Rhizobium* inoculum should be considered.

Extension

The Ministry of Agriculture in different countries can encourage farmers to adopt winter chickpea cultivation on a large scale in the following ways.

- Disseminating information on winter sowing through news media (newspapers, radio and television) and by distribution of special pamphlets on the topic.
- Conducting demonstration trials on farmers' fields with winter chickpea and organizing field days.
- Organizing short training courses for extension workers to equip them with information on winter chickpea.
- Producing and distributing the seeds of improved cultivars among growers.
- Arranging timely availability of inputs (fertilizer, seed, herbicide, pesticide) to farmers.
- Providing price incentives to chickpea growers.

Summary

West Asia and North Africa is a region with winter rainfall, where chickpea is grown on about 1.5 million hectares mostly by small-holder farmers. In contrast to other cool-season legumes, the crop is traditionally spring-sown and encounters heat and drought stresses towards maturity, which result in low and variable yields. ICARDA-ICRISAT joint research has led to the conclusion that spring, as opposed to winter, sowing was traditionally practised by farmers in the region to avoid the risk of crop failure from disease (ascochyta blight caused by *Ascochyta rabiei* (Pass.) Lab.) and cold.

Multidisciplinary research, started jointly by ICARDA and ICRISAT in 1977, developed a package of improved technology that made possible the winter sowing of chickpea. It consists of sowing of ascochyta blight-resistant and cold-tolerant cultivars in early winter and controlling weeds in an integrated manner. Development of this technology required intensive research efforts. First, it was necessary to devise effective field screening techniques and evaluate a large number of germplasm lines to identify sources of resistance to ascochyta blight and cold. They were then used in breeding to develop lines for release as cultivars.

The winter crop, in contrast to the spring crop, enables matching of various stages of crop growth with optimum environmental conditions, prolongs the period of yield build-up, increases yield, ensures better use of available water, enables the crop to meet over 90% of its nitrogen requirements through symbiosis and results in taller plants which can be harvested by a Combine.

On-farm evaluations, done jointly with NARS in WANA, showed that winter sowing can give more than 60% yield increases over the traditional spring sowing. Fifteen national programs, working jointly with ICARDA, have now released 53 cultivars for winter sowing in the Mediterranean region.

Socio-economic surveys in Syria and Morocco have shown that small-holder farmers see the value of this technology. Its adoption by them would be faster if governments provided seed of winter-chickpea cultivars, herbicides and a more efficient marketing system.

However, adoption of winter chickpea began in 1988 on 1300 ha and there has been a linear increase since then. This should have brought additional income of several million dollars to WANA farmers. Outside WANA, other countries with a Mediterranean environment are adopting the new cultivars and the

recommended management packages. There is the prospect of bringing nearly 2 million hectares under winter chickpea—which could give an additional US$ 1 billion annual income for farmers in the next 10 years.

Adoption of winter chickpea will contribute to increased and sustainable chickpea production in the farming systems of small-holder farmers, generate more employment for the rural poor, and improve nutritional standards of the poor in general by increasing the availability of protein in WANA.

References

Di Vito, M., N. Greco, H.M. Halila, L. Mabsoute, M. Labdi, S.P.S. Beniwal, M.C. Saxena, K.B. Singh and M.B. Solh. 1994a. Nematodes of cool-season food legumes in North Africa. *Nematologia Mediterranea* 22: 3–10.

Di Vito, M., N. Greco, G. Oreste, M.C. Saxena, K.B. Singh and I. Kusmenoglu. 1994b. Plant parasitic nematodes of legumes in Turkey. *Nematologia Mediterranea* 22: 245–251.

FAO. 1994. Production Yearbook, volume 47. Rome, Italy.

Greco, N., M. Di Vito and M.C. Saxena. 1992. Plant parasitic nematodes of cool season food legumes in Syria. *Nematologia Mediterranea* 20: 37–46.

Haffar, I., K.B. Singh and W. Birbari. 1991. Assessment of chickpea (*Cicer arietinum*) grain quality and losses in direct combine harvesting. *Transactions of the ASAE* 34: 9–13.

Hanounik, S. 1980. Influence of host genotype and chemical treatment on severity of ascochyta blight of chickpea. *International Chickpea Newsletter* 2: 13.

Haware, M.P. 1987. Occurrence of perfect state of *Ascochyta rabiei*. *International Chickpea Newsletter* 17: 27–28.

Haware, M.P., Y.L. Nene and R. Rajeswary. 1978. Eradication of *Fusarium oxysporum* f. sp. *ciceri* transmitted in chickpea seed. *Phytopathology* 68: 1364–1368.

Hawtin, G.C. and K.B. Singh. 1984. Prospects and potential of winter sowing of chickpeas in the Mediterranean region. Pages 7–16 *in* M.C. Saxena and K.B. Singh (ed.) Ascochyta Blight and Winter Sowing of Chickpeas. Martinus Nijhoff/Dr W. Junk, The Hague, The Netherlands.

Herridge, D.F., O.P. Rupela, R. Serraj and D.P. Beck. 1994. Screening techniques and improved biological N_2 fixation in cool season food legumes. Pages 472–492 *in* F.J. Muehlbauer and W.J. Kaiser (ed.) Expanding the Production and Yield of Cool Season Food Legumes. Kluwer Academic, Dordrecht, The Netherlands.

ICARDA. 1986. Annual Report 1985. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

ICARDA. 1988. Annual Report 1987. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

ICARDA. 1989. Legume Program Annual Report for 1988. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

ICARDA. 1991. Legume Program Annual Report for 1990. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

ICARDA. 1993. Annual Report 1992. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

Karaca, M., M. Guler, N. Durutan, K. Meyveci, M. Avci, H. Eyuoglu and A. Avci. 1991. Effect of rotation systems on wheat yield and water-use efficiency in dryland areas of Central Anatolia. *In* H.C. Harris, P.J.M. Cooper and M. Pala (ed.) Proceedings of International Workshop on Soil and Crop Management Practices for Improved Water Use Efficiencies in Rainfed Areas. MAFRA/ ICARDA/CIMMYT, 15–19 May 1989, Ankara, Turkey.

Keatinge, J.D.H. and P.J.M. Cooper. 1983. Kabuli chickpea as a winter-sown crop in northern Syria: moisture relations and crop productivity. *Journal of Agricultural Science, Cambridge* 100: 667–680.

Makkouk, K.M., L. Bos, N.M. Horn and B. Srinivasa Rao. 1993. Screening for virus resistance in cool-season food legumes. Pages 179–192 *in* K.B. Singh and M.C. Saxena (ed.) Breeding for Stress Tolerance in Cool-Season Food Legumes. John Wiley & Sons, Chichester, UK.

Malhotra, R.S. and K.B. Singh. 1990. The inheritance of cold tolerance in chickpea. *Journal of Genetics and Breeding* 44: 227–230.

Malhotra, R.S. and K.B. Singh. 1991. Gene action for cold tolerance in chickpea. *Theoretical and Applied Genetics* 82: 598–601.

Malhotra, R.S., K.B. Singh and M.C. Saxena. in press. Effect of irrigation on winter-sown chickpeas in a mediterranean environment. *Journal of Agronomy and Crop Science* (in press).

Malik, B.A. 1990. Genetics of resistance to *Ascochyta rabiei* in chickpea (*Cicer arietinum* L.). PhD Thesis, Quaid-I-Azam University, Islamabad, Pakistan.

Nene, Y.L. and M.V. Reddy. 1987. Chickpea diseases and their control. Pages 233–270 *in* M.C. Saxena and K.B. Singh (ed.) The Chickpea. CAB International, Wallingford, UK.

Nene, Y.L., V.K. Sheila and S.B. Sharma. 1989. A world list of chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanus cajan* (L.) Millsp.) pathogens. Legume Pathology Progress Report 7. ICRISAT, Patancheru, India.

Oram, P. and A. Belaid. 1990. Legumes in Farming Systems. ICARDA, Aleppo, Syria.

Pala, M. 1992. Sustainability of fallow replacement. Paper presented at the Seminar on National Resources and Environmental Management in Dry Areas sponsored by EDI/World Bank in collaboration with ICARDA and AOAD, 16–27 February 1992, Aleppo, Syria.

Pala, M. and Mazid, A. 1992. On-farm assessment of improved crop production practices in northwest Syria. I. Chickpea. *Experimental Agriculture* 28: 175–184.

Reddy, M.V. 1980. Calixin M - An effective fungicide for eradication of *Ascochyta rabiei* in chickpea seed. *International Chickpea Newsletter* 3: 12.

Reddy, M.V. and S. Kabbabeh. 1984a. Pathogenic variability and race establishment in *Ascochyta rabiei* in Syria and Lebanon. *Plant Disease* 69: 177.

Reddy, M.V. and S. Kabbabeh. 1984b. Eradication of *Ascochyta rabiei* from chickpea seed with Thiabendazole. *International Chickpea Newsletter* 10: 17–18.

Reddy, M.V. and K.B. Singh. 1984. Evaluation of a world collection of chickpea germplasm accessions for resistance to ascochyta blight. *Plant Disease* 68: 900–901.

Reddy, M.V. and K.B. Singh. 1990a. Relationship between ascochyta blight severity and yield loss in chickpea and identification of resistant lines. *Phytopathologia Mediterranea* 29: 32–38.

Reddy, M.V. and K.B. Singh. 1990b. Relationship between temperature, relative humidity and Ascochyta blight development in winter-sown chickpea in Syria. *Phytopathologia Mediterranea 29: 159-162.*

Reddy, M.V. and K.B. Singh. 1990c. Management of ascochyta blight of chickpea through integration of host plant tolerance and foliar spraying of chlorothalonil *Indian*

Journal of Plant Protection 18: 65–69.
Reddy, M.V., K.B. Singh and R.S. Malhotra. 1992. Multilocation evaluation of chickpea germplasm and breeding lines for resistance to ascochyta blight. *Phytopathologia Mediterranea* 31: 59–66.
Reed, W., C. Cardona, S. Sithanantham and S. Lateef. 1987. Chickpea insect pests and their control. Pages 283–318 *in* M.C. Saxena and K.B. Singh (ed.) The Chickpea. CAB International, Wallingford, UK.
Saxena, M.C. 1979. Some agronomic and physiological aspects of the important food legume crops in West-Asia. Pages 155–165 *in* G.C. Hawtin and G.J. Chancellor (ed.) Food Legume Improvement and Development. ICARDA, Aleppo, Syria.
Saxena, M.C. 1980. Recent advances in chickpea agronomy. Pages 89–96 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb to 2 Mar 1979, Hyderabad, A.P., India. ICRISAT, Patancheru, India.
Saxena, M.C. 1984. Agronomic studies on winter chickpeas. Pages 123–139 *in* M.C. Saxena and K.B. Singh (ed.) Ascochyta Blight and Winter Sowing of Chickpeas. Martinus Nijhoff/Dr W. Junk, The Hague, The Netherlands.
Saxena, M.C. 1988. Food legumes in the mediterranean type environment. Pages 11–23 *in* D.P. Beck and L.A. Materon (ed.) Nitrogen Fixation by Legumes in Mediterranean Agriculture. Martinus Nijhoff, Dordrecht, The Netherlands.
Saxena, M.C. 1990a. Status of chickpea in the Mediterranean basin. Pages 17–24 *in* M.C. Saxena, J.I. Cubero and J. Wery (ed.) Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries. *Options Mediterraneennes, Serie A: Seminaires Mediterraneens*, No. 9. CIHEAM, Zaragoza, Spain.
Saxena, M.C. 1990b. Problems and potential of chickpea production in the nineties. Pages 13–25 *in* H.A. van Rheenen and M.C. Saxena (ed.) Chickpea in the Nineties. ICRISAT, Patancheru, India.
Saxena, M.C. and K.B. Singh (ed.). 1984. Ascochyta blight and winter sowing of chickpeas. Martinus Nijhoff/Dr W. Junk, The Hague, The Netherlands.
Saxena, M.C., J. Diekmann, W. Erskine and K.B. Singh. 1987. Mechanization of harvest in lentil and chickpea in semi-arid areas. Pages 211–228 *in* Proceedings of the IAMFE/ICARDA Conference on Mechanization of Field Experiments in Semi-Arid Areas, 23–27 May 1987, Aleppo, Syria. ICARDA, Aleppo, Syria.
Saxena, M.C., S.N. Silim and K.B. Singh. 1990. Effect of supplementary irrigation during reproductive growth on winter and spring chickpea (*Cicer arietinum* L.) in a mediterranean environment. *Journal of Agricultural Science, Cambridge* 114: 285–193.
Saxena, M.C., N. Greco and M. Di Vito. 1992. Control of *Heterodera ciceri* by crop rotation. *Nematologia Mediterranea* 20: 75–78.
Singh, K.B. 1990. Winter chickpea: problems and potential in the Mediterranean region. Pages 25–34 *in* M.C. Saxena, J.I. Cubero and J. Wery (ed.) Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries. *Options Mediterraneennes, Serie A: Seminaires Mediterraneens*, No. 9. CIHEAM, Zaragoza, Spain.
Singh, K.B. 1993a. Experiences, difficulties and prospects of disease resistance breeding in chickpea. Pages 241–248 *in* Th. Jacobs and J.E. Parlevliet (ed.) Durability of Disease Resistance. Kluwer Academic, Dordrecht, The Netherlands. IAC, Wageningen, The Netherlands.
Singh, K.B. 1993b. Problems and prospects of stress resistance breeding in chickpea. Pages 17–35 *in* K.B. Singh and M.C. Saxena (ed.)

Breeding for Stress Tolerance in Cool-Season Food Legumes. John Wiley & Sons, Chichester, UK.
Singh, K.B. and M.V. Reddy. 1983. Inheritance of resistance to ascochyta blight in chickpeas. *Crop Science* 23: 9–10.
Singh, K.B. and M.V. Reddy. 1989. Genetics of resistance to ascochyta blight in chickpea. *Crop Science* 29: 657–659.
Singh, K.B. and M.V. Reddy. 1991. Advances in disease resistance breeding in chickpea. *Advances in Agronomy* 45: 191–222.
Singh, K.B. and M.V. Reddy. 1993. Resistance to six races of *Ascochyta rabiei* in the world germplasm collection of chickpea. *Crop Science* 33: 186–189.
Singh, K.B., G.C. Hawtin, Y.L. Nene and M.V. Reddy. 1981. Resistance in chickpeas to *Ascochyta rabiei*. *Plant Disease* 65: 586–587.
Singh, K.B., R.S. Malhotra and M.C. Saxena. 1989. Chickpea evaluation for cold tolerance under field conditions. *Crop Science* 29: 282–285.
Singh, K.B., L. Holly and G. Bejiga. 1991. A Catalog of Kabuli Chickpea Germplasm: An Evaluation Report of Winter Sown Kabuli Chickpea, Land Races, Breeding Lines and Wild *Cicer* Species. ICARDA, Aleppo, Syria.
Singh, K.B., R.S. Malhotra and M.C. Saxena. 1992. Registration of "ILC 482" chickpea. *Crop Science* 32: 826.
Singh, K.B., G. Bejiga and R.S. Malhotra. 1993a. Genotype-environment interaction for protein content in chickpea. *Journal of Science and Food Agriculture* 63: 87–90.
Singh, K.B., R.S. Malhotra and M.C. Saxena. 1993b. Relationship between cold severity and yield loss in chickpea. *Journal of Agronomy & Crop Science* 170: 121–127.
Singh, K.B., R.S. Malhotra and M.C. Saxena. 1995. Additional sources of tolerance to cold in cultivated and wild *Cicer* species. *Crop Science* 35: 1491–1497.
Smith, R.C.G. and H.C. Hazel. 1981. Environmental resources and restraints to agricultural production in the mediterranean-type environment. Pages 31–57 *in* J. Monteith and C. Webb (ed.) Soil Water and Nitrogen in Mediterranean-type Environments. Martinus Nijhoff/Dr Junk, The Hague, The Netherlands.
Tutwiler, R.N. 1995. The great chickpea challenge: introducing winter sowing in the Mediterranean region. ICARDA Social Science Paper No. 4 (ICARDA, Aleppo, Syria).
Tutwiler, R.N., M. Amine, M.B. Solh, S.P.S. Beniwal and M.H. Halila. 1994. Approaches to overcoming constraints to winter chickpea adoption in Morocco, Syria and Tunisia. Pages 899-910 *in* F.J. Muehlbauer and W.J. Kaiser (ed.) Expanding the Production and Yield of Cool Season Food Legumes. Kluwer Academic, Dordrecht, The Netherlands.
Weigand, S. and O. Tahhan. 1990. Chickpea insect pests in the Mediterrranean zones and new approaches to their management. Pages 169–175 *in* H.A. van Rheenen and M.C. Saxena (ed.) Chickpea in the Nineties. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India.

ICARDA-032/1000/Sep 1996