Superiority of Winter Sowing over Traditional Spring Sowing of Chickpea in the Mediterranean Region

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ABSTRACT

Chickpea (*Cicer arietinum* L.), when traditionally grown as a spring-sown crop in the Mediterranean region, often suffers from heat and moisture stress, resulting in low and unstable yields. In contrast, sowing the crop in winter with cultivars tolerant to cold and to ascochyta blight [caused by *Phoma rabiei* (Pass.) Khune & J.N. Kapoor; syn. *Ascochyta rabiei* (Pass.) Lab.] minimizes the effects of terminal heat and drought stress and increases and stabilizes productivity. Therefore, a study was conducted with the objective of assessing the comparative seed yield advantage of winter over spring sowing in Mediterranean environments. Nineteen to 23 ascochyta blight-resistant and cold-tolerant breeding lines were compared in winter and spring sowing for 10 yr (1983-1993) at three locations in Syria and Lebanon. The set of lines used in this study differed each year. Averaged over 10 yr, winter-sown chickpea produced 70% (692 kg ha^{-1}) more seed yield than the spring-sown crop. The longer growing period of winter-sown chickpea resulted in higher biomass production, which contributed mainly toward increased seed yield. The yield potential of lines sown during winter was approximately 4000 kg ha^{-1}, and yields were more stable than in the spring-sown crop. The correlation between seasonal rainfall and seed yield was positive and significant in both seasons. In 1988-1989, when the Tel Hadya site experienced severe drought, the spring-sown crop resulted in virtually no seed yield, whereas the winter-sown crop produced an average yield of 542 kg ha^{-1} by a partial escape of the severe drought. Winter-sown plants were taller than those in the spring sowing, permitting harvesting by combines. Because of these advantages, winter sowing of chickpea is gaining popularity in the Mediterranean region.

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IN LOW-ELEVATION AREAS around the Mediterranean Sea, chickpea is traditionally sown in spring, near the end of the rainy season. During this time, the chickpea crop suffers from terminal abiotic stresses caused by rising temperature and depleted soil moisture as the season advances toward maturity. Studies conducted at ICARDA revealed that the winter-sown crop is prone to damage by ascochyta blight and cold, both of which can be avoided by spring sowing (Hawtin and Singh, 1984). Thus, lack of blight- and cold-tolerant cultivars for winter sowing has been the major reason for growing spring-sown chickpea.

Reddy and Singh (1990) studied the relationship between ascochyta blight severity and yield loss in winter-sown chickpea for 3 yr at ICARDA, Syria. They found less than 10% yield loss in disease-resistant lines, compared with a loss of more than 80% in susceptible ones. In two separate studies, conducted at ICARDA during 1981-1982 and 1989-1990 seasons, Singh et al. (1993) found that the lines lacking cold tolerance were killed and the lines tolerating cold yielded up to 4 Mg ha^{-1}.

Because of the importance of ascochyta blight resistance and cold tolerance, ICARDA scientists evaluated a large number of germplasm accessions for these two stresses. Of 19 343 accessions evaluated for their reaction to six races of ascochyta blight available at ICARDA, only 14 lines were resistant (Singh and Reddy, 1993). Of 3200 lines evaluated for cold tolerance, only 21 tolerant lines were identified (Singh et al., 1989). However, none of the 14 ascochyta blight-resistant lines was tolerant to cold; likewise, none of the 21 cold-tolerant lines was resistant to ascochyta blight.

Singh and Hawtin (1979) reported that winter-sown chickpea gave higher seed yield than the traditional spring-sown chickpea. Saxena (1980) studied the effect of successive delay in date of sowing from autumn, through winter, to spring; and reported a linear reduction in the yield as sowing was delayed. Hawtin and Singh (1984) reported that winter-sown chickpea could yield over 3000 kg ha^{-1} under rainfed conditions when seasonal precipitation is around 350 mm and that chickpea could be grown successfully even with as little as 250 mm rainfall if the rainfall is well distributed. Many of these early yield comparisons were based on 1-yr results and were made in seasons when environmental conditions were not conducive for the development of ascochyta blight and the winter was mild (Hawtin and Singh, 1984). High temporal variability in weather conditions around the Mediterranean Sea was reported by Smith and Harris (1981). Our objective in this study was to assess the comparative seed yield advantage of winter sowing of chickpea over spring sowing for a longer period using new breeding lines with superior cold tolerance and ascochyta blight resistance.

MATERIALS AND METHODS

Nineteen to 23 newly bred ascochyta blight-tolerant and cold-tolerant chickpea lines were evaluated each year. They were sown both in winter and spring, over a period of 10 yr (1983–1984 to 1992–1993) at two locations in Syria (Tel Hadya, 36°01′ N, 36°56′ E, elevation 284 m; and Jindiress, 36°23′ N, 36°41′ E, elevation 365 m) and one in Lebanon (Terbol, 33°49′ N, 35°59′ E, elevation 890 m). All three locations have a Mediterranean climate with cold, wet winters and warm, dry summers (Smith and Harris, 1981). Each year, new lines from the breeding program were included in the yield trial; hence, the entries differed from year to year. However, as the entries tested were similar for both winter and spring sowing at all locations in a particular year, the comparison between winter and spring could be made. Each year, new lines from the breeding program were included in the yield trial; hence, the entries differed from year to year.

Trials were sown between 20 November and 5 December (winter crop) and in early March (spring crop). Sowing during the first 2 yr was in 30-cm rows; in the subsequent 8 yr, row spacing was increased to 45 cm. A population of 330 000 plants ha^{-1} was maintained in four-row plots 4 m long. These plots were contiguous without any space between two plots. A randomized complete block design with two replications was used for each trial. Plots were fertilized with 50 kg P_2O_5 ha^{-1} as triple superphosphate. Weeds were controlled by hand weeding in the first 2 yr and by preemergence application of terbutryne (2-*tert*-butylamino-4-ethylamino-6-methylthio-1, 3,5-triazine) and pronamide [3,5-dichloro-*N*-(1,1-dimethy-propynyl)benzamide] in the remaining 8 yr in the winter-sown crop. The spring-sown crop was hand-weeded in all years. No insecticide or fungicide was used to control insect pests and diseases. The winter-sown crop matured by late May to early June at Tel Hadya, early June at Jindiress, and mid to late June at Terbol. The spring-sown crop matured by mid-June, late June, and early July at these sites, respectively.

Days to 50% flowering (i.e., when 50% of the plants in the plot had at least one flower), plant height (cm), days to maturity (all plants dried) in the field, yield of aboveground biomass (total dry matter of straw and seed) (kg ha^{-1}) in threshing floor, seed yield (kg ha^{-1}) and 100-seed weight (g) in the seed laboratory were recorded. The harvest index was computed as the ratio of seed yield to total aboveground biomass. As two border rows were grown on both sides of the experiment area and no space was left between two plots, all four rows of the plot were harvested, leaving 0.25 cm on both ends. Thus, yield estimates of biomass and seed were based on a harvested area of 4.2 m^2 in the first 2 yr and 6.3 m^2 in the remaining 8 yr.

Analysis of variance was performed on data from all three locations and two sowing dates for each year. Data were analyzed for correlations and stepwise regressions using SAS (SAS Inst., 1990). Correlations between various traits were evaluated and stepwise regression analysis was performed to determine the contribution of each trait toward seed yield in winter- and spring-sown crops.

Data on rainfall and minimum and maximum temperatures were collected from the permanent weather stations at ICARDA research stations of Tel Hadya, Jindiress, and Terbol. The experiment area was generally within 100 m from weather stations.

RESULTS

There were large year-to-year variations in the total seasonal rainfall at all locations, which is typical of the dry areas around the Mediterranean Sea (Fig. 1). The 10-yr average rainfall was highest at Terbol (559 mm), followed by Jindiress (451 mm) and Tel Hadya (321 mm). Most of the rainfall at these locations was received during December to March (Fig. 2), when evapotranspiration rates were low, and little rain was received during the spring months. Rainfall was less than the long-term average during the 1983–1984, 1988–1989, and 1989–1990 cropping seasons at Tel Hadya. This resulted in drought, and crop yield was severely reduced. The rainfall at Jindiress and Terbol in the 1988–1989 and 1989–1990 cropping seasons was also less than the long-term average (Fig. 1), but the effect on yield was not severe because of overall higher rainfall at these locations.

Seasonal temperatures, on average, were lowest at Terbol, followed by Tel Hadya and Jindiress (Fig. 2). Snow fell during most winters at Terbol, but was rare at Tel Hadya and Jindiress. Although not shown in Fig. 2, soil temperatures were favorable for root growth of winter-sown chickpea during most of December to February, but low ambient temperatures during these months permitted only limited vegetative growth. As the temperature rose in March, the subsequent period of March to May had an ideal combination of temperature and moisture availability for rapid vegetative and reproductive crop growth. The winter-sown crop thus could make use of the ideal temperature and moisture regimes in this period because plants had already developed a good vegetative frame by the time these favorable growth conditions occurred. This also resulted in a prolonged reproductive period of the crop. In contrast, the spring-sown crop had a shorter span of its growth period coinciding with the favorable environment and its reproductive phase was exposed to higher than optimal temperatures.

The analyses of variance (ANOVA) combined over two sowing dates and three locations were made for each of the 10 yr. However, only data for seed yield are presented in Table 1. In most years, the main effects of sowing dates, genotypes, and their interactions were

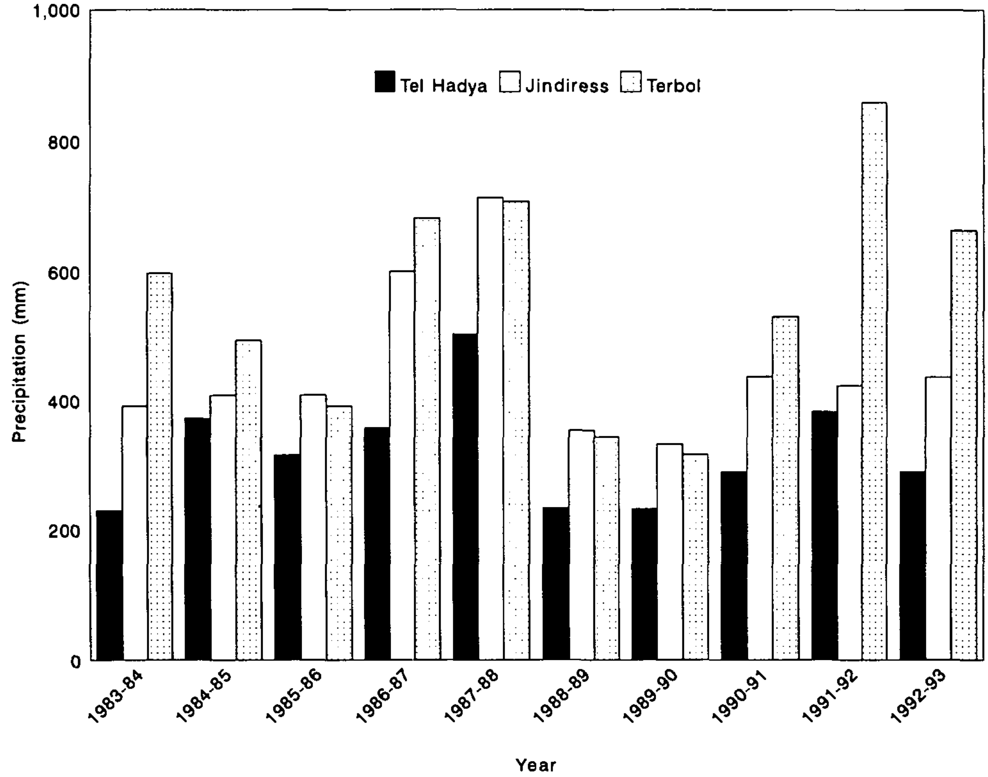

Fig. 1. Total annual precipitation for three locations in Syria and Lebanon over 10 yr.

significant. The significance of genotype × sowing date interactions in most of the years indicated the variable response of different genotypes to dates of sowing. Since different genotypes were used in different years and our aim was to assess the overall performance of genotypes in two sowing dates (winter and spring), genotype × sowing date and genotype × location × sowing date interaction effects were not given much weight in the present study. Seed yields were highest at the wettest location, Terbol, and lowest at the driest location, Tel Hadya and were generally higher in the winter-sown than in the spring-sown crop (Table 2). The mean seed yield across locations and years for the winter sowing was 1686 kg ha^{-1}, compared with the spring sowing yield of 994 kg ha^{-1} (Table 2); a 692 kg ha^{-1} or 70% increase. The coefficient of variation for the 10-yr yield average over locations was 15.7% for the winter-sown crop, compared with 22.3% for the spring-sown crop.

The correlation coefficient between winter and spring seed yields was 0.584 (significant at P = 0.001). Seed yields in winter and spring had correlation coefficients of 0.429 (significant at P = 0.018) and 0.464 (significant at P = 0.010), respectively, with total rainfall; −0.396 (P = 0.030) and −0.232 (P = 0.218) with mean minimum temperature and −0.411 and −0.424 (P = 0.020) with mean maximum temperature.

The stepwise regression of seed yield of the winter-sown crop on monthly total rainfall during the cropping season accounted for 27.8% of variability. January and May rainfall contributed, respectively, 15.4 and 12.4% to variability in seed yield. On the other hand, 41.5 and 8.1% variations in seed yield of the spring-sown crop were due to the rainfall in February and June, respectively. Similarly, the stepwise regression of seed yield using mean minimum monthly temperatures revealed that maximum contribution to the variation in the seed yield of the winter-sown crop was 23.0 and 7.6%, which was due to variation in the mean minimum temperature in May and January, respectively. The maximum contribution toward the variation in seed yield of the spring-sown crop, amounting to 14.0%, was caused by variation in the minimum temperature in the month of March. The stepwise regression of seed yield using mean maximum monthly temperatures revealed that mean maximum temperature during May was responsible for the highest (40.2%) variation in the seed yield of the winter-sown crop. The next highest contribution (4.7%) was that of mean maximum temperature in June. In the case of the spring-sown crop, the mean maximum temperature in May also caused widest variation in seed yield, but the value was smaller (23.2%) than for the winter-sown crop. Mean maximum temperature of March appeared to be the second largest contributor (7.9%) to the variation in the seed yield of the spring-sown crop.

The stepwise regression analysis using all the variables in the winter-sown crop revealed that the mean maximum temperature in May contributed maximum variation (R^2 = 40.1%) in seed yield, followed by the rainfall in January (R^2 = 5%). In the case of spring-sown chickpea, however, variations in seed yield of 41.5, 8.6, and 5.1% were due to the rainfall in February, the rainfall in June, and the maximum temperature in May, respectively.

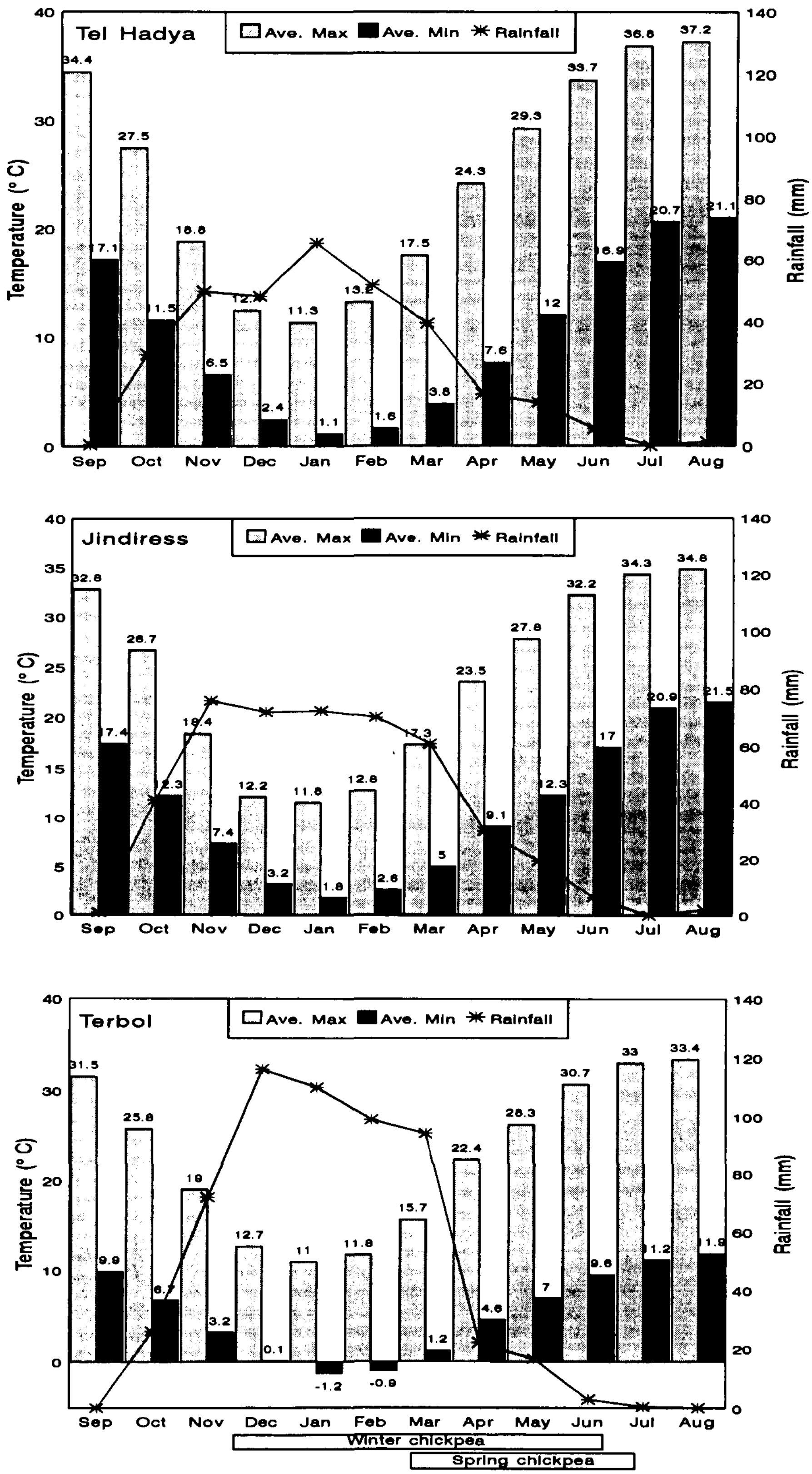

Fig. 2. Mean monthly precipitation and mean monthly maximum and minimum temperatures for three locations in Syria and Lebanon over 10 yr.

Table 1. Combined analysis of variance for chickpea seed yield at three locations in Syria and Lebanon (Tel Hadya, Jindiress, and Terbol) for 10 growing seasons.

		Mean square ($\times 10^4$)‡									
Source of variance	df†	1983–1984	1984–1985	1985–1986	1986–1987	1987–1988	1988–1989	1989–1990	1990–1991	1991–1992	1992–1993
Reps within locations and sowing dates	6	38.5	36.1	4.9	30.4	24.7	6.7	8.0	11.9	85.2	45.4
Location (L)	2	3424.6	2009.8	510.6	200.0	567.6	1878.9	1154.1	6381.3	338.5	694.5
Sowing date (S)	1	7142.2**	4.4	7755.4**	3121.2**	4333.3**	3787.8**	1406.1**	5907.7**	583.3**	6172.7**
L × S	2	169.3	61.1	1459.3	3.8	8.1	124.2	488.2	2245.8	483.0	411.4
Genotype (G)	22	26.0**	40.1**	13.0**	6.2**	25.8**	10.6**	13.4**	32.1**	15.5**	38.4**
G × L	44	8.7	9.7	5.0	8.3**	4.8	3.7**	5.9**	7.2**	12.3**	26.5**
G × S	22	11.6	37.9**	15.3**	9.5**	10.4*	5.8**	16.4**	14.1**	12.2**	20.7**
G × L × S	44	7.7	14.5**	5.9	6.5**	5.5	3.8**	4.4**	11.4**	7.9**	9.7
Residual error	132	9.3	6.6	4.9	2.9	5.8	1.3	2.2	3.3	4.3	8.8
Total	275										

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

† Genotypes during 1983–1984 and 1984–1985 were 21 and 19, respectively, and thus degrees of freedom of various sources of variation, including genotypes, were different from the ones listed above.

‡ Actual values = value shown $\times 10^4$.

The mean values across years for days to 50% flowering, days to maturity, plant height, biomass, harvest index, 100-seed weight (seed size), and seed yield are given in Table 3. The winter-sown crop achieved 50% flowering in 136 d, whereas it was reduced to 66 d when spring-sown. Sowing chickpea in winter resulted in 70% increase in biomass production and 8% increase in harvest index over spring sowing. Plant height of winter-sown chickpea was 47 cm, compared with 36 cm when spring-sown. Seed weight was influenced little by the time of sowing.

Results of the stepwise regression of seed yield using biomass, days to flowering, days to maturity, plant height, 100-seed weight, and harvest index as independent variables are given in Table 4. Both in winter and spring, biomass and harvest index were closely associated with seed yield. The 100-seed weight, plant height, and days to flowering, did not contribute to yield in any year or sowing date; however, days to maturity seemed to have contributed to yield in the winter-sown crop in 1983–1984. Therefore, biomass and harvest index during both winter and spring sowing proved to be the most important selection criteria to increase yield of chickpea in the Mediterranean region. Of the two components, biomass was more important for the winter-sown crop, and harvest index for the spring-sown crop.

DISCUSSION

This study has shown that seed yields can be increased by 70% by sowing chickpea in early winter than in spring. These gains in yield are an important consideration for increased chickpea production in the Mediterranean region. Some of the highest-yielding lines had seed yields as high as 4000 kg ha^{-1}, albeit on small plots. This shows the potential of chickpea when sown in winter. Our results are in conformity with those of Hawtin and Singh (1984), with a major difference. Hawtin and Singh's conclusions were based on 1 yr of data, whereas our results are based on data over 10 yr. Substantially higher yields in the winter-sown crop over the traditional spring-sown chickpea appear to be the result of increased total biomass produced from a longer period of vegetative growth, while retaining nearly the same harvest index as that of spring chickpea. A longer vegetative period in the winter sowing results in a larger vegetative frame and increased capture of photosynthetically active radiation (PAR), which in turn results in increased total biomass production. This observation is supported by the stepwise regression analysis of the present study, which revealed the importance of biomass and harvest index in determining seed yield in chickpea. This has also been

Table 2. Mean (± standard error) for chickpea seed yield of winter and spring-sown crops grown at three locations in Syria and Lebanon for 10 growing seasons.

	Seed yield										
Sowing date	1983–1984	1984–1985	1985–1986	1986–1987	1987–1988	1988–1989	1989–1990	1990–1991	1991–1992	1992–1993	Mean
	kg ha^{-1}										
Tel Hadya, Syria											
Winter	1027 ± 281	1118 ± 205	1660 ± 201	1626 ± 244	2009 ± 212	542 ± 114	478 ± 106	595 ± 76	2028 ± 250	2057 ± 372	1314
Spring	290 ± 129	1338 ± 166	1519 ± 131	963 ± 136	1184 ± 184	29 ± 47	338 ± 70	249 ± 99	1236 ± 132	723 ± 123	787
Jindiress, Syria											
Winter	2510 ± 502	1032 ± 289	2315 ± 347	1716 ± 212	1738 ± 388	1277 ± 140	873 ± 251	1556 ± 271	1764 ± 214	1906 ± 334	1669
Spring	1294 ± 203	1030 ± 152	796 ± 105	999 ± 131	909 ± 129	545 ± 100	639 ± 88	1192 ± 137	1870 ± 174	1411 ± 126	1068
Terbol, Lebanon											
Winter	2153 ± 355	2071 ± 279	2740 ± 208	1395 ± 99	1463 ± 295	1652 ± 104	1606 ± 162	3115 ± 279	2108 ± 260	2443 ± 314	2075
Spring	913 ± 21	1936 ± 377	1219 ± 247	758 ± 162	739 ± 118	675 ± 158	626 ± 145	1048 ± 109	1923 ± 189	1436 ± 388	1127
Mean											
Winter	1897	1407	2238	1579	1737	1157	986	1755	1967	2136	1686
Spring	832	1435	1178	907	944	416	534	830	1676	1190	994

Table 3. Mean values for various traits in chickpea, with percent of increase of the winter-sown crop over the spring-sown crop for three locations in Syria and Lebanon.

Location and variable	SYLD†	BYLD	DFLR	DMAT	PLHT	100SW	HI
	kg ha^{-1}		d		cm	g	%
Tel Hadya, Syria							
Winter	1314	3459	127	171	41	34	39
Spring	787	2141	68	105	32	32	32
% change	67	62	87	63	28	6	21
Jindiress, Syria							
Winter	1669	4296	138	187	47	33	40
Spring	1068	2594	70	109	33	32	41
% change	56	66	97	72	42	3	−2
Terbol, Lebanon							
Winter	2075	4991	143	193	53	37	43
Spring	1127	2744	59	101	43	34	41
% change	84	82	142	91	23	8	5

† SYLD, seed yield; BYLD, biomass yield; DFLR, days to flowering; DMAT, days to maturity; PLHT, plant height; 100SW, 100-seed weight; HI, harvest index.

reported by Saxena et al. (1990) and Singh et al. (1990). Thus, the higher the biomass yield and harvest index, the higher the seed yield. As the reproductive phase of the winter-sown crop is initiated in a more favorable thermal and moisture regime than the spring-sown crop (Saxena, 1987), a larger vegetative frame of the winter-sown crop then supports proportionally larger reproductive sinks and adequate dry-matter partitioning. Also, the reproductive phase of winter chickpea is longer than spring chickpea, contributing to higher seed yield.

The advantage of winter sowing can be lost if the environmental conditions become unfavorable at critical phases. Although the probability of a winter-sown crop facing drought during the early reproductive growth is not as high as that of a spring-sown crop, it occasionally occurs (Smith and Harris, 1981) in the Mediterranean lowlands. This explains the higher correlations between yields of winter-sown chickpea and total monthly rainfall in January and May than for the spring-sown crop. It also explains why the coefficient of variation in the yield of the winter-sown crop is lower ($\approx$15.7%) than that of the spring-sown crop ($\approx$22.3%).

The yield of the winter-sown crop is more sensitive to the mean minimum temperature in May (which corresponds to the rapid grain-filling stage). Therefore, the advantage of winter sowing can be lost when a late cold period occurs as happened in 1984–1985. In the breeding strategy used at ICARDA, emphasis is placed not only on enhanced cold tolerance at the early vegetative stage of the crop growth, but also during the reproductive phase. Wild *Cicer* species are currently being used (ICARDA, 1995) to further enhance cold tolerance and to encourage onset of flowering and pod setting at lower temperatures.

The advantage of winter sowing over spring sowing is more conspicuous in years when the seasonal rainfall is less than optimum (350 mm) for the spring-sown crop. This may be because the winter-sown crop is able to use moisture received from rain and plants are able to increase the proportion of transpiration over evaporation in the total consumptive use of water. This cannot be done by the spring-sown crop because plants essentially grow on stored soil moisture (Keatinge and Cooper,

Table 4. Summary of stepwise regression of chickpea seed yield by season, combined over three locations in Syria and Lebanon (Tel Hadya, Jindiress, and Terbol) for 10 growing seasons.

Variable	1983–1984	1984–1985	1985–1986	1986–1987	1987–1988	1988–1989	1989–1990	1990–1991	1991–1992	1992–1993
	Partial R^2									
	%									
Winter										
Biomass	16.3	92.9	34.0	56.6	48.9	49.6	57.0	22.7	66.5	64.2
Harvest index	21.3	6.1	65.3	39.6	40.1	46.1	37.2	74.8	32.8	35.4
Plant height	–	–	–	0.8	1.7	–	–	–	0.2	–
Days to maturity	57.3	–	–	–	–	–	1.5	–	0.1	–
Days to flowering	–	–	0.2	–	1.6	–	–	–	–	–
100-seed weight	–	0.2	–	–	–	–	–	–	0.1	–
Overall model	94.9	99.1	99.4	97.1	92.3	95.7	95.8	97.6	99.7	99.6
Spring										
Biomass	38.9	51.1	7.4	73.4	43.6	4.3	15.0	14.7	34.8	58.1
Harvest index	51.4	48.1	90.1	18.0	55.5	92.1	84.3	81.1	63.5	38.5
Plant height	0.9	–	0.4	–	–	–	–	–	0.2	–
Days to maturity	–	–	–	–	–	0.5	–	–	–	–
Days to flowering	2.1	–	1.1	–	–	–	–	–	–	–
100-seed weight	–	–	–	1.3	–	–	–	0.6	–	–
Overall model	93.3	99.2	98.9	92.6	99.1	97.0	99.3	96.4	98.5	96.6

1983). Because of increased water use efficiency of the winter-sown crop, chickpea production can be extended to areas that are too dry to produce a spring crop.

The productivity of spring-sown chickpea is more dependent on the total seasonal precipitation than is that of winter-sown chickpea. Farmers in the dryland areas of West Asia and North Africa plant their spring crop only when adequate rainfall is received. Since the rainfall is highly variable in the West Asia-North Africa (WANA) region, there are large year-to-year fluctuations in the total areas sown to chickpea, with consequent fluctuations in total production. Introduction of winter sowing can lead to a more stable production of chickpea.

Another agronomic advantage of winter-sown chickpea is increased plant height. The mean height of the winter-sown crop was 47 cm, compared with 36 cm for the spring-sown crop. The winter-sown crop can, therefore, be directly harvested by combines normally used for winter cereals. In contrast, because of its short stature, the spring-sown crop can be harvested only by hand labor, at increasing costs. Reduced harvest costs further increase the profitability of the winter-sown crop (ICARDA, 1987).

Besides substantially higher seed yield, reduced crop failure due to drought, and higher profitability, there is another advantage of winter sowing: i.e., improved biological N_2 fixation. A larger proportion of total N harvested is derived from symbiotic N_2 fixation in winter-sown chickpea than in the spring-sown crop. The biological N_2 fixation by winter-sown chickpea has been found to be 80 to 120 kg N ha^{-1}, compared with 25 to 40 kg N ha^{-1} by spring-sown chickpea (Saxena, 1988; Herridge et al., 1994). Thus, winter chickpea encourages the inflow of combined N in the farming system in dry areas. This would increase sustainability of production in the cereal-dominated farming systems in dry areas of West Asia and North Africa.

Winter sowing is spreading in the Mediterranean region of West Asia and North Africa, as well as in southern Europe, and a large number of cultivars have been released (ICARDA, 1995). Availability of blight- and cold-tolerant cultivars, along with improved seed production, suitable weed control measures and extension education support, would lead to accelerated adoption of winter chickpea, with a positive impact on the sustainability of the production system, protein availability, and rural income in dry areas of WANA.

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