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# Comparison of the Performance of Autumn and Spring Sowing of Chickpeas in a Temperate Region

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**Abstract:** The effects of autumn and spring sowing on chickpea yield were investigated by examining yield components in a 2-year (2000-2001 and 2001-2002 growing seasons) field experiment in a temperate region, in north-west Turkey. Twenty-one chickpea genotypes (2 registered varieties of winter type for the Mediterranean region and 19 breeding lines) were evaluated in 2 sowing seasons (autumn and spring). Autumn-sown crops were subjected to –2.1 °C and snow cover twice (2 and 4 days) in the first year and –7.6 °C and snow cover 3 times (8, 14 and 6 days) in the second year. All genotypes were resistant to cold at the seedling stage, but 2 lines (FLIP 98-33C and FLIP 98-86C) were affected by a late cold spell at the late vegetative stage and their yields were reduced in the 2000-2001 season. Environmental conditions were favourable for *Ascochyta* blight infestation, but there was no incidence of blight in either year or at any sowing time. The longer growing period of autumn-sown chickpeas affected positively characters contributing to yield such as plant height, branches per plant, pods per plant, pod bearing shoot length and 100-seed weight, which in turn contributed to increased seed yield. Averaged over the 2 years, the autumn-sown crop produced 102% (1642 kg ha$^{-1}$) more seed yield than the spring-sown crop. Stepwise regression of seed yield with characters contributing to yield were not consistent and estimated less than half of the whole effects. However, days to maturity, 100 seed weight and days to flowering were important for autumn sowing and days to flowering, 100-seed weight, plant height and days to maturity were important for the spring-sown crops.

**Key Words:** *Cicer arietinum*, autumn sowing, spring sowing, temperate region

## Ilıman Şartlarda Nohutun Kışlık Ekiminin Yazlık Ekime Göre Performansı

**Özet:** Ilıman iklim koşullarında, kışlık ve yazlık ekimlerinin nohut bitkisine etkisi, verim ve verim karakterleriyle birlikte Kuzeybatı Türkiye'de iki yıllık tarla çalışmasında (2000-2001 ve 2001-2002 yetiştirme yılı) araştırılmıştır. İkisi Akdeniz bölgesinde kışlık ekim için tescil edilmiş ve 19 ıslah hattından oluşan 21 farklı nohut genotipi kış ve yaz ekimlerinde ayrı ayrı denenmiştir. Kışlık ekilen bitkiler birinci yıl -2.1 °C sıcaklık ve iki kez (2 ve 4) gün kar örtüsü altında, ikinci yıl -7.6 °C sıcaklık ve 3 kez (8, 14 ve 6 gün) kar örtüsü altında kalmıştır. Fide döneminde bütün genotipler soğuğa dayanıklılık göstermiş, fakat iki hat FLIP 98-33C ve FLIP 98-36C, 2000-2001 yılında bitkilerin son vegetatif dönemlerinde gelen soğuktan etkilenmiş ve verimleri düşmüştür. Ortam koşulları *Ascochyta* gelişimine uygun olmasına karşın, her iki yıl ve ekim zamanında antraknoz hastalığına rastlanmamıştır. Kışlık ekimlerde uzun yetişme süresi; bitki boyu, bitkide dal sayısı, bitkide bakla sayısı, bakla tutan dal uzunluğu ve 100 tane ağırlığını artırmış ve sonuçta tane verimi daha yüksek gerçekleşmiştir. İki yıl ortalaması olarak kışlık ekimlerde, yazlık ekimlere göre % 102 (1642 kg ha$^{-1}$) verim artışı tespit edilmiştir. Tane verimi ile verim öğeleri arasında yapılan stepwise regresyonu tutarlı bulunmamış ve toplam etkinin yarısından azını tahmin edebilmiştir. Bununla birlikte kışlık ekimlerde; hasada kadar geçen süre, 100 tane ağırlığı ve çiçeklenmeye kadar geçen süre, yazlık ekimlerde; çiçeklenmeye kadar geçen süre, 100 tane ağırlığı, bitki boyu ve hasada kadar geçen sürenin tane verimine etkisi önemli bulunmuştur.

**Anahtar Sözcükler:** *Cicer arietinum*, kışlık ekim, yazlık ekim, ılıman bölge

## Introduction

The chickpea is an important pulse crop in the developing world. About 92% of the sowing area and 88% of the production takes place in developing countries (FAO, 2001). Due to its high protein content, the chickpea is used as a major protein source in most of these countries. For a wide range of agro-ecological environments, it is also an alternative legume crop for increasing the diversification of cropping systems. Its low fertiliser requirements, increasing soil nitrogen content in rotations and sufficient yield in marginal lands are considerable benefits.

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Traditionally, the chickpea is sown in spring in order to avoid *Ascochyta* blight (*Ascochyta rabiei* Pass) and frost, both in Mediterranean and temperate regions. It has been well documented that if the chickpea is sown in autumn, higher yield can be obtained than with traditional spring sowing in Mediterranean and dry regions. Calcagno et al. (1987) reported a 60% yield increase in autumn sowing over spring sowing. Singh et al. (1997) reported that winter-sown chickpea produced seed yield as 70% higher than spring-sown crop in Syria. Iliadis (2001) calculated 23-188% more seed for winter over spring sowing in Greece. In most of these studies the high yield potential of winter crop has been attributed to the extended growing period and favourable rainfall during winter and early spring. Low winter temperatures restrict the seedling growth of the chickpea; however, it enters a phase of rapid growth when temperatures increase in spring, the time when the soil allows spring sowing (Siddique et al., 1999; O'Toole et al., 2001). Rapid leaf area development allows greater photosynthesis under favourable conditions and it partitions into seed yield (Leport et al. 1999). Increased biomass yield, contributed by plant height, increased branches and pods per plant, was positively correlated with seed yield (Singh et al., 1990).

Genetic improvement of resistance to blight and cold has been extensively studied by national and international breeding programmes, and high yielding, blight-resistant cultivars have been developed for the Mediterranean region (Singh, 1997). Most experiments on chickpea adaptation to autumn sowing have also been performed in winter-dominated rainfall Mediterranean-type environments. The temperature in temperate regions is lover than in the Mediterranean region and rainfall is rather balanced during the vegetation period. However, chickpea yields were lower in the countries in temperate regions (FAO, 2001). Thus, there is also a need for definition of the optimal time of sowing in such different environments. Cold tolerance is an important prerequisite for sowing the chickpea in autumn in temperate regions and there is a wide genetic variation among genotypes (Singh et al., 1995). In the present study, the potential advantages of autumn sowing were studied with 21 chickpea genotypes in a temperate region, compared with traditional spring sowing.

## Materials and Methods

Nineteen chickpea breeding lines obtained from the ICARDA/ICRISAT collection and 2 registered cultivars for winter sowing in the Mediterranean region were evaluated over 2 consecutive cropping years (2000-2001 and 2001-2002), as a winter and spring crop. An experiment was conducted in fields in Sakarya, north-west of Turkey (lat. 41° 02'N, long. 30°18'E, altitude 50 m). The cultivars and lines were selected from our previous experiments and they were both early and late and small and large seeded types. All are considered suitable for winter sowing, with tolerance to *Ascochyta* blight and cold.

The soil was clay-loam Vertisol. The soil characteristics for the winter crop were pH 7.69, organic matter 3.08%, available $P_2O_5$ 257.2 kg $ha^{-1}$ and available $K_2O$ 487.8 kg $ha^{-1}$. For the site selected for the spring crop, the soil had pH 7.81, organic matter 2.64%, available P205 229.5 kg $ha^{-1}$ and available K20 189.7 kg $ha^{-1}$.

Trials were sown on November 15 in the first year and November 10 in the second year as a winter crop; and on February 10 in the first year and February 13 in the second year as a spring crop (normal practice in the region). Seeds were dressed with the fungicide pentakol (Hektas, Turkey) before sowing to prevent seedling loss. Each plot consisted of 4 rows 4 m long, 30 cm apart, with an intra-row distance of 10 cm. Plots were contiguous without any space between any 2. A randomised complete block design with 3 replications was used for each separate trial. Winter crops were not fertilised due to the sufficient soil fertility. Spring crops were fertilised with 20 kg $ha^{-1}$ nitrogen in the form of urea at sowing. Seeds were not inoculated with *Rhizobium* because previous observations indicated that indigenous *Rhizobium* effectively nodulated the crop. Several plants from the buffer rows were removed before flowering to confirm whether nodulation had occurred. Weeds were controlled by hand weeding. No insecticide or fungicide was used to control insect pests or diseases.

The winter-sown crop matured by early July and the spring-sown crop by mid July, 1 week or 10 days later. The following observations were recorded: date of flowering when 50% of the plants in the plot had at least one flower and date of maturity when the plants had dried and were ready for harvest. Plant height (cm), pod bearing shoot length (cm), number of branches and number of pods per plant were measured on each of 10 plants, and from these measurements plant height, pod bearing shoot length, the number of branches and pods per plant were calculated. Seed yields were obtained from all 4 rows of the plot, leaving 25 cm on both ends and the amount was calculated as kilograms per hectare. 100-seed weight (g) was determined from the seeds of plots yield as the mean of 4 replications in each plot. Cold and *Ascochyta* blight tolerance were scored according to Singh et al. (1981; 1995).

Analysis of variance was performed on data from 2 sowing dates, combined over the years, using MSTAT C. Significant results were subjected to a Tukey's HSD means comparison procedure. Correlations between various traits were evaluated and stepwise regression analysis was performed to determine the contribution of each trait toward seed yield in autumn- and spring-sown crops using the SAS statistical program.

The climatic conditions that prevailed during the 2 years of the experiment varied considerably, mainly in terms of rainfall (Table 1). The cultivation year 2001-2002 was very wet; 1 week after sowing until February it was continuously rainy or snowing and this caused water lodging even though the experimental site was in an upland area, and resulted in partial seedling loss. No germination failure was observed in either of the experiments.

## Results

The autumn-sown crop emerged at the end of December and stayed to the end of February at the seedling stage and then started to grow again. The spring-sown crop emerged in mid March from cool soil and continued to grow for almost one month later than the autumn-sown crop. Plots were checked when the germination occurred in all plots and there was no germination failure in either sowing. At least 90% of germinations were successful.

The cold tolerance of cultivars was scored during the vegetation period. Autumn-sown crops were subjected to –2.1 °C and snow cover twice (2 and 4 days) in the first year and –7.6 °C (Table 1) and snow cover three times (8, 14 and 6 days) in the second year. No cultivars or lines were affected by cold during winter at the seedling stage but in the first year, during late vegetative growth in April, FLIP 98-33C and FLIP 98-86C were affected by a late cold spell. No total plant death occurred but shoot tips were damaged and their yields significantly reduced compared to the second year of the experiment. Environmental conditions were quite favourable for *Ascochyta* blight infestation, but there was no blight incidence in either year or sowing time.

In the first year, autumn-sown crops flowered on April 28. In the second year, flowering was delayed 1 week. For spring-sown crops in both years, all cultivars started to flower after May 20. Flowering initiation of the genotypes sown in autumn shifted earlier than the ones

Table 1. Monthly rainfall and temperature during the cultivation periods of experiments for autumn and spring sowing of chickpea in north-west Turkey.

| Years | Months | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
| 2000-2001 | | | | | | | | | |
| Averaged (°C) | 16.3 | 11.3 | 11.3 | 2.6 | 6.8 | 8.5 | 15.8 | 17.6 | 21.1 |
| Maximum (°C) | 26.0 | 28.6 | 19.8 | 21.2 | 21.2 | 31.9 | 27.7 | 31.5 | 36.6 |
| Minimum (°C) | 3.9 | 1.7 | -2.1 | -1.3 | -1.0 | 0.0 | 2.7 | 6.8 | 11.2 |
| Rainfall (mm) | 138.4 | 27.3 | 54.3 | 23.1 | 87.1 | 47.8 | 87.9 | 50.3 | 29.9 |
| 2001-2002 | | | | | | | | | |
| Averaged (°C) | 16.0 | 11.6 | 6.2 | 3.5 | 9.7 | 12.2 | 12.5 | 17.0 | 22.4 |
| Maximum (°C) | 29.4 | 25.0 | 17.2 | 18.7 | 23.0 | 29.5 | 26.4 | 31.0 | 38.3 |
| Minimum (°C) | 3.2 | 0.7 | -0.3 | -7.6 | -1.2 | 2.0 | 0.9 | 8.0 | 11.8 |
| Rainfall (mm) | 23.9 | 140.6 | 252.2 | 95.2 | 25.4 | 42.8 | 74.1 | 29.9 | 75.4 |

sown in spring by 16-22 days in the first year and, by 9-15 days in the second year. The time of plant maturity for harvest was on average 7 days earlier with autumn sowing for all genotypes in both years of the experiment. Rainfall late in the season resulted in a flush of new flowers and leaves, which caused uneven ripening in autumn sowing. However, the earlier cultivars Güney Sarısı (ILC 482), FLIP 82-150C and FLIP 97-63C were not affected by late rainfall and matured about 10 days earlier than the spring-sown crop. Nevertheless, the prolonged period of flowering and growth due to autumn sowing had a significant influence on the productivity of the genotypes. All the genotypes sown in autumn in both years of the experiment gave substantially higher yields than with spring sowing.

All the characters were affected by the experimental factors (genotypes, sowing time and their interactions), but the main effect was found to be sowing time. The significance of genotype x sowing time interactions in both years indicated the different responses of genotypes to sowing time. Seed yields were higher in the autumn-sown crop than in the spring-sown crop. The mean seed yield of winter sowing was 3227 kg ha$^{-1}$, compared with the spring sowing yield of 1600 kg ha$^{-1}$ (Table 2); a 1642 kg ha$^{-1}$ or 102% increase. For the highest yielding cultivar the yield gain over spring sowing was a 2277 kg ha$^{-1}$ or 120% increase. Stepwise regression of the autumn-sown crop showed that monthly total rainfall and monthly mean maximum temperature during the cropping season accounted for 14.6% and 12% of variability, respectively. In the case of the spring-sown crop, variations in seed yield of 22.6% and 24.7% were due to the total monthly rainfall and mean maximum temperature, respectively.

Table 2. Seed yields (kg ha$^{-1}$) of 21 chickpea genotypes for autumn and spring sowing in north-west Turkey (Sakarya) for 2 growing seasons.

| Genotypes | Winter Crop | | | Spring Crop | | |
|---|---|---|---|---|---|---|
| | 2000-2001 | 2001-2002 | Mean | 2000-2001 | 2001-2002 | Mean |
| FLIP 97-25C | 3423 | 3093 | 3258 | 1510 | 1627 | 1568 |
| FLIP 97-26C | 2810 | 3403 | 3106 | 1290 | 1343 | 1317 |
| FLIP 97-73C | 2857 | 3223 | 3040 | 1643 | 1580 | 1612 |
| FLIP 97-75C | 3303 | 3980 | 3642 | 1170 | 1450 | 1310 |
| FLIP 97-85C | 3517 | 3003 | 3260 | 837 | 1573 | 1205 |
| FLIP 97-114C | 3617 | 3513 | 3565 | 1567 | 1667 | 1662 |
| FLIP 98-32C | 2767 | 2357 | 2562 | 1580 | 1687 | 1633 |
| FLIP 98-33C | 1733 | 2770 | 2302 | 1587 | 1533 | 1560 |
| FLIP 98-36C | 4823 | 3540 | 4182 | 1923 | 1887 | 1905 |
| FLIP 98-40C | 2110 | 1733 | 1922 | 1277 | 1283 | 1280 |
| FLIP 98-55C | 2307 | 3313 | 2810 | 1587 | 1587 | 1587 |
| FLIP 98-74C | 3580 | 3873 | 3727 | 1827 | 1857 | 1842 |
| FLIP 98-82C | 3950 | 3090 | 3520 | 1930 | 2060 | 1997 |
| FLIP 98-86C | 1970 | 3517 | 2738 | 1673 | 1673 | 1673 |
| FLIP 98-107C | 3750 | 3833 | 3792 | 1717 | 1800 | 1758 |
| FLIP 98-109C | 2770 | 3917 | 3343 | 1607 | 1573 | 1590 |
| FLIP 98-119C | 3610 | 3420 | 3515 | 1593 | 1683 | 1638 |
| FLIP 98-126C | 3373 | 2713 | 3043 | 1767 | 2337 | 2052 |
| FLIP 82-150C | 3517 | 3673 | 3595 | 1433 | 1287 | 1610 |
| Güney Sarısı | 4633 | 3513 | 4073 | 1857 | 1890 | 1870 |
| Menemen 92 | 3103 | 2437 | 2770 | 770 | 1140 | 955 |
| Mean | 3215 | 3238 | 3227 | 1535 | 1667 | 1600 |
| m.s.d. | 585 | 692 | 571 | 272 | 295 | 283 |

m.s.d. minimum significant difference

Winter sowing increased plant height; it exceeded 100 cm (mean 91.6 cm) in the first year, but all plants were lodged as a result of rainfall during the pod-filling stage. In the second year of the experiment, plant heights were decreased (Table 3), but Güney Sarısı, FLIP 82-150C and FLIP 97-73C were lodged for the same reason. For spring sowing, average plant heights were 56 and 61 cm in 2000-2001 and 2001-2002 seasons respectively and lodging did not occur. However, compared to the spring crop, increased plant height in the winter crop was positively correlated with seed yields (r = 0.679**). Pod bearing shoot length was significantly greater in autumn sowing than in spring sowing.

Branch number per plant and pods per plant were most influenced by sowing times and years (Table 3). The main reason for the year difference was the water-lodging effects in 2001-2002 for the winter crop. The relatively decreased plant number in plots encouraged branching and pods per plant. For spring crops the mean branch number and pods per plants were not significantly different between years. Nevertheless, the extended duration in vegetative and reproductive growth in winter crop increased branching and pod setting in both years (Table 3) and those characters were positively correlated with seed yields (r = 519**, r = 625** respectively) and each other (r = 676**).

There were at least 10 cultivars with a 100-seed mass of 40 g or over and some of them were higher than 45 g, such as FLIP 97-75C, FLIP 97-114C. Autumn sowing increased the mean 100-seed mass by an average of 10% over spring sowing (Table 3). Greater 100-seed weight had a yield increasing effect on spring sowing but not autumn sowing.

Stepwise regression of seed yield with characters contributing to yield was not consistent and estimated less than half of the whole effects (Table 4). However, days to maturity, 100-seed weight and days to flowering were important for the autumn sowing; days to flowering, 100-seed weight, plant height and days to maturity were important for the spring-sown crops.

## Discussion

The superiority of the autumn-sown crops is mainly due to the matching crop phenology with the availability of optimum temperature and moisture regimes (Table 1). The winter crop started to the race at seedling stage but spring sowing plants from dry seed. The autumn-sown chickpea genotypes were at their mid-vegetative stages while the spring-sown seeds were emerging from the soil. After a long wait at the seedling stage, winter-sown crops quickly started to develop photosynthetic surfaces, a larger crop canopy, and more branches and reproductive nodes in favourable temperature on a very moist soil over a longer duration. On the other hand, for the spring-sown crop, plants produced lover plant heights and fewer branches and reproductive nodes, causing a yield decrease. Previous researchers reported that temperatures below the optimum delayed the emergence and sometimes caused poor crop stand in the chickpea (Auld et al., 1988; Ozdemir, 1996; O'Toole et al., 2001). However, there was no germination failure in the present experiment.

The 2001-2002 growing season represented average winter characters in a coastal temperate region in Turkey. Improved cultivars as those in the present experiment

Table 3. Mean (± standard error) for various traits of autumn-sown and spring-sown crops for 2 growing seasons in north-west Turkey (Sakarya).

| Seasons | Variables | | | | | |
|---|---|---|---|---|---|---|
| | Days to flowering | Days to maturity | Plant height (cm) | Branches Plant$^{-1}$ | Pods Plant$^{-1}$ | 100-Seed Weight (g) |
| Autumn | | | | | | |
| 2000-2001 | 164 (0.35) | 231 (0.38) | 91.6 (0.72) | 8.6 (0.23) | 26.9 (1.09) | 39 (0.65) |
| 2001-2002 | 181 (0.25) | 234 (0.33) | 74.0 (0.94) | 12.1(0.43) | 44.0 (0.94) | 38 (0.51) |
| Spring | | | | | | |
| 2000-2001 | 94 (0.16) | 156 (0.17) | 56.3 (0.65) | 6.9 (0.16) | 17.7 (0.50) | 34 (0.65) |
| 2001-2002 | 98 (0.13) | 153 (0.18) | 61.1 (0.77) | 7.6 (0.32) | 17.0 (0.41) | 36 (0.52) |

Table 4. Results of stepwise regression of chickpea seed yields for autumn- and spring-sown crops for 2 growing seasons in Sakarya, Turkey.

| Variable | Partial $R^2$ (%) | | | |
|---|---|---|---|---|
| | Autumn | | Spring | |
| | 2001 | 2002 | 2001 | 2002 |
| Plant height | - | - | 16.4 | - |
| Pods per plant | - | - | - | - |
| Branches per plant | - | - | - | - |
| Pod bearing shoot length | - | - | - | - |
| Days to flowering | - | 12.4 | - | 37.9 |
| Days to maturity | 14.6 | 30.2 | 7.7 | - |
| 100-seed weight | 24.1 | - | 19.8 | - |
| Overall model | 38.7 | 42.6 | 43.9 | 37.9 |

were resistant to –7.6 °C and 14 days' snow cover at seedling stages, and could be grown in temperate regions to exploit the yield advantage, as in the Mediterranean region. The influence of temperature on growth and development varies according to genotype and stage of growth. The results confirmed that the seedling stage was more tolerant to cold than later vegetative or reproductive growth in the chickpea (Singh et al., 1995; Srinivasan et al., 1998; O'Toole et al., 2001).

Genotype-environment interactions have been shown to be high for the chickpea, and yields vary considerably between seasons and locations, depending on the weather conditions (Singh and Bejiga, 1990; Ozdemir et al., 1999). Seed yield variations between years and sowing times were consistent with previous findings. Singh et al. (1997) reported that winter-sown chickpeas produced 70% more seed than spring-sown ones in Syria. Iliadis (2001) calculated 23-188% more seed for winter crops over spring crops in Greece. The great yield difference between years was explained mainly by the variation in rainfall over the year in the experiments. In the current experiment, mean yield gain over the spring crop was 102% and did not vary much between the years. This was because rainfall during reproductive growth did not differ much (Table 1) and mean yields were consistent for both winter- and spring-sown crops. The coefficients of variation (8.98 and 11.68% winter and spring crops respectively) were smaller than previous findings (Singh et al., 1997; Iliadis, 2001). There for low yields in spring sowing in temperate regions cannot be explained by a water deficit, such as in the Mediterranean climate. The effects of temperature on the duration of growth might also have important consequences. The highest seed yield variability corresponded to the maximum mean monthly temperature in the spring-sown crop, likely due to an accelerated maturation process. Temperature increases during May and June restricted adequate vegetative growth, shortened flowering and the seed-filling stage and caused shorter reproductive nodes and reduced seed weight (Table 3). The higher correlations between seed yield with days to flowering (r = 0.817**) and days to maturity (r = 0.820**) confirms the superiority of autumn sowing over spring sowing.

The main breeding strategies for increasing chickpea yield are increasing biomass yield by increasing plant height and branching in winter-dominated rainfall areas in Mediterranean regions (Singh et al., 1990, 1997). In water-restricted conditions, taller plants are desired (Singh et al., 1997), but in temperate regions taller plants increase lodging risks. For the winter crop, plant heights were reduced significantly in the second year but yields were not different. However, compared to the spring crop, increased plant height in the winter crop was positively correlated with seed yields (r = 0.679**). Plant height is necessary for increasing yield but above the optimum there may lead be lodging problems, which make mechanical harvesting difficult.

Branch number per plant and pods per plant were most influenced by sowing times and years (Table 3). The main reason for the year difference was the water-lodging effects in 2001-2002 for the winter crop. Relatively decreased plant numbers in plots encouraged branching and pods per plant and thus compensated for yield loss. O'Toole et al. (2001) suggested that the ability of the chickpea to compensate for poor establishment is limited; however, for autumn sowing there is the possibility of compensation due to extended vegetative and reproductive phases. Extended duration of vegetative and reproductive growth in the winter crop increased branching, reproductive nodes via increased pod bearing shoot length and pod setting in both years (Table 3) and these characters were positively correlated with seed yields (r = 519**, r = 625** respectively) and each other (r = 676**), confirming the importance of adequate vegetative growth. However, a high vegetative frame is not always an indicator of high chickpea yields. Dry matter redistribution is highly variable in different chickpea genotypes (Leport et al., 1999). Even though most of the cultivars have similar vegetative frames, some of them had higher yields than others. High yielding cultivars, FLIP 98-36C and ILC 482, may have a greater ability to forward photosynthesised product into the seeds.

In the chickpea, 100-seed weight is a highly stable character and variation mainly depends on genotype. However, autumn sowing increased the mean 100-seed mass by an average of 10% over spring sowing, possibly due to the moderate temperature regime during the seed-filling stage (Table 3). Such increases in 100-seed mass due to autumn sowing have also been reported by Singh et al. (1997) and due to irrigation by Davies et al. (1999) and Leport et al. (1999).

## Conclusion

A 2-year experiment demonstrated that autumn sowing with cold- and disease-tolerant chickpea cultivars significantly increased yield in a temperate region. In addition to tolerance to cold and biotic disorders, the superiority of autumn sowing could be ensured with upright growing, lodging-resistant cultivars in well-drained soils or upland areas in temperate regions. Large-seeded chickpea types could increase the acceptance of autumn sowing technology by the farmers. Autumn sowing also increased the 100-seed weight substantially over spring sowing.

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