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Effects of sowing date, planting method and cultivar on growth traits, seed yield and yield components of chickpea in dry farming condition

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ABSTRACT

An experiment was carried out to investigate about the influence of sowing date, planting method and cultivar on morphological traits, yield and yield components of chickpea seed. The trial was done in dry farming condition at Faculty of Agriculture, Lorestan University in Khorramabad with average annual precipitation of 482.42 mm in 2006-07 farming year. The experiment was conducted factorially, based on randomized complete block design with three replications and three factors, including sowing date in three levels (December 23, January 23 and February 23), planting method in two levels (row cropping and sow broadcast methods) and cultivar in three levels (Arman, Hashem and Greet local bulk). However, the plant density was constant and was 50 seeds per m^2 in all treatments. The results showed that except the single plant's biological yield and seed number per pod that were affected by triple interaction probability of 1%, all other characteristics such as plant height, pod number per plant, seed yield, biological yield, number of side branches per plant, gain yield of single plant, protein per cent, weight of 100 seeds and harvest index were influenced by triple interactions and became significant in probability of 5%. The highest values for the number of side branches was 7.12 from sowing date of December, sow broadcast method and Arman cultivar for the number of pods per plant was 14.8 from sowing date of December row cropping method and Arman cultivar; for seed yield was 2821.73 kg per hectare from sowing date of January 23, Arman cultivar and row cropping method; for biological yield was 8781.2 kg per hectare from sowing date of January, row cropping method and Arman cultivar; for seed protein percent was 23.86 from sowing date of February, sow broadcast method and Hashem cultivar; and for harvest index was 43.74% from sowing date of January 23, row cropping method and Arman cultivar. A delay in planting declined the seed yield and harvest index in the investigated cultivar. The lowest percentage was achieved for number of side branches per plant (1.25) from planting February, row cropping method and Arman cultivar; biological yield (455.8 kg per hectare) from December planting date, handing planting method and local bulk Greet; seed protein per cent (20.16) from January planting date, row cropping method and Greet local bulk and harvest index (17.44%) from February planting date, handing planting method and Hashem cultivar. It seems that the delay in planting use of unbreeded local bulk will cause the decreasing of protein per cent and the significant difference was in the level of 5% of probability. The results of growth analysis showed that the highest crop growth rate belonged to Arman cultivar (19.10 $W.A^{-1}.T^{-1}$) and January sowing date (13.5 $W.A^{-1}.T^{-1}$) and, row cropping method (14.59 $W. A^{-1}.T^{-1}$). The highest leaf area index was gained from January sowing date (3.2), handing planting method (3.3) and cultivar Arman (3.5). The highest net assimilation rate (9.6 $W.A^{-1}.T^{-1}$) was achieved from January sowing date and row cropping method.

Key words : Chickpea, cultivar, planting method, sowing date, yield components

INTRODUCTION

Legumes are recognized as the second food source of humankind and have considerable agronomic and nutritional characteristics. As the most important protein-

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rich plant source, legumes were planted globally and are acclimatized to different climatic conditions ranging from temperate to warm and from humid to arid. Chickpea as the most important product of leguminous was considered a cheap protein source. It is recognized as a low water consuming plant in semi-arid regions like Mexico and can produce a considerable yield by using just half as much water as wheat. Its production is very cost-effective and helpful to improve poor farmers' economic condition (Begum *et al.*, 1992; Ortega *et al.*, 1996).

Using different sowing dates exposes growth and reproductive stages of the plant to different temperatures, solar radiations and day lengths. Although, an appropriate sowing date for chickpeas has not yet been exactly determined, but, it is very important in plants like chickpea which are usually planted in dry farming condition or are dependant on the reserved soil moisture and are exposed to high temperatures during the growing season.

In early planting, plants grow bigger reproductive organs which will feed bigger reproductive libraries and, allocate adequate dry matter to them and therefore, increase the yield (Mckenzie and Hill, 1995; Singh *et al.*, 1997). High temperature is an important environmental factor which affects growth and development of seeds especially in the stages after pollination. Temperatures higher than the plant's tolerance disturb physiological functions and decrease the length of developmental stages and, therefore, decrease the yield. In legumes, negative effects of high temperatures on plant's yield may be moderated by choosing appropriate sowing dates and avoiding high temperatures at the end of the growing season. In late planting, terminal drought stress and temperature increase, which often reach more than 30°C, have negative effects on seed filling in chickpeas in seed filling stage. Autumnal and expectly cropping help to adaptation the phenology of chickpea with the desired temperature and moisture. Pre-flowering stage is prolonged and the plant has more time for vegetative growth. In these circumstances, vegetative growth starts with a decline in temperature and day length. Furthermore, reproductive stage is also prolonged and finds a more appropriate thermal and humidity condition, compared to spring cropping (Majnon-Hoseini, 1996; Davt, 1997).

Two major growth types in chickpeas include : Kabuli and Desi types. In Kabuli type, seeds are large in size, circular in form, and white or yellow-white in color; seed diameter varies between 6 to 10 mm, weight of 100 seeds varies between 35 to 65 g, and flowers are colourless. In Desi type, seeds are smaller in size, angular in shape, and brown in colour, weight of 100 seeds varies between 13 to 25 g, and flowers are colourful (Rastegar, 1998; Yhannay and Hawthorne, 2003).

Greet local bulk has expanded growth type, high number of pods per plant and high amount of dry matter and is early maturing. This bulk, with its expanded growth type, covers the space between rows more quickly and makes the most of solar radiations. Hashem cultivar has hoisted growth type, does not use the space between rows effectively and is late maturing. Arman cultivar has erect growth type and is appropriate for mechanized harvesting. In 2003, this cultivar was introduced and permitted for autumnal cropping in moderate and semi-tropical regions of the country such as Kermanshah, Ilam, Golestan and Kohkiluye-va-Boyerahmad. In most of the researches done seed yield of this cultivar was higher than other cultivars under study (Fallah *et al.*, 2005). Despite every endeavour to increase the production of chickpeas, the average of production is still very low in some countries such as Iran. While some countries such as the United States of America have increased its production upto 2.5 to 3 t per hectare by using appropriate cultural practice. Australia has also increased its production to 3.4 t per hectare by on time planting and weed control. Because of adapting to a wide range of soil and environmental conditions, chickpeas are very important and further researches must be conducted to find the best agronomic and managing methods to increase the yield in level unit (Hernandez and Hill, 1983).

MATERIALS AND METHODS

A trial was carried out to investigate the effects of sowing date, planting method and cultivars. The trial was done in the research field at the Agricultural College of Lorestan, University in Khorramabad province at longitude 48°22´E, latitude 33°29´N, and altitude of 1125 m, with (long-term) annual precipitation mean of 471.5 mm and (long-term) annual temperature average of 17.07°C and semi-arid climate in 2006-07 farming year. The experiment was conducted in factorial and was based on randomized complete block design with three replications and three factors including sowing date in three levels of December 23, January 23 and February 23; planting method in two levels of row cropping and broadcast cropping methods; and cultivar in three levels of Hashem, Arman and Greet local bulk.

The trial includes three blocks with dimensions 44.5 per 5 and 18 treatments. In each replication, there were nine plots related to broadcast cropping and nine plots related to row cropping that had eight rows per plot. Area of the experimental design was 756 m^2. The farm was tilled by a plough and levelled simultaneously at the beginning of the year. After germination and in growth initial stage thinning was done in all row plots to provide desired space between the plants in the row. Trimming was done sooner in growth initial stages because the plant had week competition with weeds in this stage. Trimming was done several times in subsequent growth stages. Sampling and registering of the studied traits, including the growth indexes, number of leaves per plant and dry weight was done every two weeks during the growth stages. Measurements in harvest time include :

A. *Seed yield :* 1 m^2 of the 4^{th} and 5^{th} rows were harvested after elimination of borderal effects to determine the seed yield in row cropping plots.
B. *Seed protein percentage* : Seed protein percentage was measured by Bradford method.
C. *Number of pods per plant and number of seeds per pod :* A number of plants were chosen from each plot and after elimination of borderal effects number of pods per plant and number of seeds per pod were determined.
D. *1000-seed weight :* A sample was taken from each plot to measure weight of 1000 seeds.
E. *Plant height :* In final harvest 10 plants were chosen randomly from each plot and their height mean was determined.
F. *Yield per plant* : Total yield in each treatment was divided by total number of harvested plant to determine the yield per plant.
G. *Number of branches* : A number of plants were taken in final harvest and the number of branches was determined.
H. *Total dry matter* : A certain part of each plot was harvested and dried by Aven equipments to determine the total dry matter.
I. *Harvest index :* After finding seed yield and biological yield the harvest index was determined by dividing seed yield by biological yield.
J. *Biological yield per plant :* Five plants were chosen randomly from each treatment and their weight was registered to determine the biological yield per plant.

Analysis of variance of all the traits and comparison of means (by Duncan's multiple-range test) and correlation coefficients were carried out by MSTAT-C software and the diagrams were drawn by Microsoft Office Excel 2003.

RESULTS AND DISCUSSION

The number of branches per plant and the number of seeds per pod were influenced by sowing date and cultivar (P=5% and P=1%, respectively) (in probability level of 5 and 1%, respectively) but not by planting method. The number of pods per plant was influenced by sowing date and cultivar (P=1%) but not by planting method. 100-seed weight was influenced just by cultivar (P=1%). Seed and biological yields were affected by sowing date, planting method and cultivar (P=1%). Seed and biological yields per plant were influenced by sowing date and cultivar (P=1%) and by planting method (P=5%). Seed protein percentage and harvest index were influenced just by sowing date and cultivar (P=1%) (Table 1). We interpret double and triple interaction effects because of their significance.

Interaction Effects of Sowing Date and Cultivar

Interaction effect of sowing date and cultivar was significant (P=5%) on plant height, number of branches, 100-seed weight, seed yield per plant and seed protein percentage. Interaction effect of sowing date and cultivar

Table 1. Analysis of the variance of the traits under study (Mean of squares)

Variation source	d. f.	Harvest index	Seed protein percentage	Single-plant seed yield	Single-plant biological yield	Seed yield	Biological yield	1000-seed weight	Seeds/ pod	Pods/ plant	Branches number
Replication	2	10.12^{ns}	934*	0.037^{ns}	0.75^{ns}	92412.30^{ns}	921.34^{ns}	95.22^{ns}	0.035^{ns}	0.675^{ns}	0.027*
Sowing date (A)	2	721.84**	5.04**	0.868**	25.71**	2639933.31**	67.32356**	82.06^{ns}	0.024^{ns}	0.862^{ns}	0.269*
Planting method (B)	1	5/78^{ns}	0.463^{ns}	0.74*	1.06*	788703.45**	63695.21**	145.86	0.002^{ns}	0.445^{ns}	0.001^{ns}
A × B	1	20.48	0.335^{ns}	0.082*	0.146^{ns}	6489.50^{ns}	10096.42*	30^{ns}	0.015^{ns}	0.625^{ns}	0.001^{ns}
Cultivars	2	167.22**	29.06**	3.93**	66.42**	2069333.03**	2249989.19**	22451.16**	1.25**	23.18**	0.61**
A × C	4	290.99**	0.745^{ns}	0.737**	10.16**	730606.21**	15042.13**	161.71^{ns}	0.054*	0.810^{ns}	0.35**
B × C	2	5.36^{ns}	0.330ns	0.66*	0.279^{ns}	225020.2*	11410.65*	101.19^{ns}	0.017^{ns}	0.212^{ns}	0.005^{ns}
A × B × C	4	27.65*	0.709ns	0.312**	1.55**	21563.21^{ns}	7232.71^{ns}	338.52*	0.016^{ns}	0.330^{ns}	0.03^{ns}
Error	34	10.03	0.304	0.017	0.241	50615.75	3064.94	133.56	0.019	0.380	0.057
CV (%)		9.88	2.50	4.65	5.14	15.95	11.72	4.19	9.74	4.73	7.26

*,**Significant at P=0.05 and P=0.01 level, respectively.
NS : Not Signficant.

was also significant (P=1%) on number of pods per branch, number of seeds per pod, seed yield, seed and biological yield per plant and harvest index (Table 1).

Arman cultivar with sowing date of January 23 had the maximum seed yield equal with 2646.83 kg/ha and Greet local bulk with sowing date of February 23 had the minimum seed yield equal with 190.46 kg/ha. Difference in yield mean per hectare was not significant in Arman and Hashem cultivars in sowing dates of December 23 and January 23, while it was significant in sowing date of February 23. It seems that the first factor in declining seed yield is the delay in sowing date of February 23. Low temperature and shorter day length increase the length of vegetative growth stage in different cultivars and, in turn, increase canopy and improve the absorption of photosynthetically active radiation (Pezeshpour and Mosavy, 2005).

Arman cultivar with sowing date of January 23 had the maximum biological yield equal with 7763.3 kg/ha and Greet local bulk with sowing date of February 23 had the minimum biological yield equal with 551.1 kg/ha. There was no significant difference between biological yield of Arman and Hashem cultivars in three different sowing dates and it was Greet local bulk cultivar which made the effect of sowing date and cultivar significant in biological yield.

Arman cultivar with sowing date of January 23 had the maximum harvest index equal with 41.04% and Hashem cultivar with sowing date of February 23 had the minimum harvest index. There was no significant difference in three different sowing dates of Hashem cultivar but other cultivars showed significant interaction effect in three different sowing dates. Harvest index was lower in Greet local bulk and Arman cultivar with sowing date of February 23 which may result from their low adaptation to environmental conditions in this sowing date. The interaction effect of sowing date and cultivar was not significant in the number of branches per plant.

Interaction Effect of Planting Method and Cultivar

Interaction effect of planting method and cultivar was significant (P=5%) in plant height, number of branches, 100-seed weight, seed protein percentage, number of pods per branch, number of seeds per pod, seed yield, biological yield, seed yield per plant, biological yield per plant and harvest index. Seed yield per plant was also influenced by interaction effect of planting method and cultivar (P=1%) (Table 1).

Hashem cultivar with broadcast cropping method had the maximum seed protein percentage equal with 23.14%.

Maximum and minimum 100-seed weights were 315.49 g in Great local bluk with row cropping method and 248.60 g in Hashem cultivar with broadcast cropping method, respectively. The other two cultivars did not show any significant difference in 100-seed weight. Therefore, planting method did not have any effect on 100-seed weight and this significance was the result of different cultivars.

Arman cultivar with sow broadcast method had the maximum number of branches per plant and Greet local bulk with sow broadcast method had the minimum number of branches per plant. Planting method made no significant difference in each cultivar.

Maximum and minimum seed yields per hectare were 2507.06 kg/ha in Arman cultivar with row cropping method and 177.54 kg/ha in Greet local bulk with sow broadcast method, respectively. Arman cultivar with sow broadcast method had a better seed yield per hectare in comparison to sow broadcast method because of having more space growing sooner, and feeding better. This confirms Ehsanzade *et al.* (2006). Greet local bulk had a lower seed yield than two other cultivars in both the planting methods.

Maximum and minimum biological yields per hectare were 7530.2 kg/ha in Arman cultivar with row cropping method and 512.9 kg/ha in Greet local bulk with sow broadcast method, respectively. Hashem and Arman cultivars had significant difference in both the planting methods. As it was mentioned earlier, in row cropping method, the plant benefits from the space between the bushes, captures the soil moisture and nutrient materials more effectively, and in turn, has a better biological yield per hectare.

Greet local bulk with sow broadcast method had the maximum harvest index and Hashem cultivar with sow broadcast method had the minimum harvest index. Hashem cultivar with both the planting methods had a lower harvest index than the other two cultivars with both planting methods. This may be the result of its genetic traits or the decline in leaf area index and growth rate in final stages.

Sowing Date and Planting Method

Effect of sowing date and planting method was significant (P=5%) in seed protein percentage, harvest index, 100-seed weight, number of pods per branch, seed yield, single plant seed yield, biological yield and single plant biological yield. Number of branches, 100-seed weight, plant height and the number of seeds per pod were not influenced by this mutual effect and were insignificant. Number of pods per branch found the maximum of 2.66 in sowing date of January 23 with sow broadcast method and the minimum of 1.63 in sowing date of February 23 with row cropping method. Ehsanzade *et al.* (2006) reported that the number of pods per plant in sow broadcast method was considerable and statistically significant in comparison with linear planting method. This difference seems to be connected with the lack of an appropriate plant and seed bed in sow broadcast method which results in the production of weak plants with lower pod producing power (Ehsanzade *et al.*, 2006).

Studying the effect of sowing date and planting method on mung bean, Faroukh *et al.* (2006) reported that mutual effect of sowing date and planting method on the number of pods in mung bean was significant. Maximum number of pods per branch was in sowing date of third week in July and planting method of furrow cropping with 20 cm space between the furrows. It may be the result of shorter vegetative and longer reproductive growth stage or better aeration in furrow cropping method in comparison with broadcast planting method.

Different sowing dates resulted in different yields in the two cultivars and the local bulk under study but different planting methods made no difference. Reviewing simple effects of sowing date and planting method showed that it was sowing date which made the mutual effect significant. Mean of harvest index was 31.71 and 32.37 in sow broadcast and row cropping method, respectively. The maximum seed yield per hectare was 1762.24 kg/ha in sowing date of January 23 with row cropping method and the minimum seed yield per hectare was 826.24 kg/ha in sowing date of February 23 with sow broadcast method. Difference in the two planting methods was significant just in sowing date of February 23 and was not significant in sowing date of December 23 and January 23. Therefore, lower seed yield in February 23 may be connected with the delay in planting. Delay in planting causes the leaf area index and leaf area continuity to decline in reproductive growth stage and, in turn, decreases the yield. Auld *et al* (1988) reported that a delay of 28 days decreased the seed yield in chickpea to 34%. Keainge and Kooper (1981), studying the effect of sowing date on chickpea, reported that in all areas under study the yield in winter planting was more than two times as high as the yield in spring sowing because of vegetative growth stage prolongation, leaf area index increase, moisture security, appropriate leaf area continuity, and absorption of photosynthetically active radiation in reproductive stage. This confirms the results of the present trial (Keainge and Kooper, 1981; Auld *et al.*, 1988). The maximum and minimum biological yields were 5708.5 kg/ha in sowing date of January and row cropping method and 3917.69 kg/ha in sowing date of October and sow broadcast method, respectively. This may be the result of the fact that plants use the environmental sources most effectively in row cropping. There was a significant difference in biological yield of between sow broadcast and row cropping methods in both October and February but not in January sowing date.

Mutual Effect of Sowing Date, Planting Method and Cultivar

The triple mutual effect of sowing date, planting method and cultivar was significant (P=5%) in height, number of branches, biological yield, seed yield, seed protein percentage, 100-seed weight, number of seeds per pod and harvest index. It was also significant (P=1%) in number of pods per branch, single plant seed yield and single plant biological yield. The maximum and minimum seed yield means per hectare were 2821.73 kg/ha in Arman cultivar with sowing date of January and row cropping method and 158.53 kg/ha in Greet local bulk with sowing date of October and sow broadcast method, respectively. In all three sowing dates, the maximum seed yield was in Arman cultivar with row cropping method. Seed yield was highest in Arman cultivar with sowing date of January because in Arman cultivar the number of pods per plant was greater in sowing date of January and 100-seed weight was more than Hashem cultivar. The maximum and minimum biological yields per hectare were 8781.2 kg/ha in Arman cultivar with sowing date of January and row cropping method and 455.8 kg/ha in Greet local bulk with sowing date of October and sow broadcast method, respectively. The maximum and minimum harvest indexes were 43.77% in Arman cultivar with sowing date of January and row cropping method and 17.44% in Hashem cultivar with sowing date of February and sow broadcast method, respectively. In all three cultivars and in both planting methods harvest index in sowing date of February was lower than other two sowing dates. It seems that Arman cultivar had a better harvest index because of having a faster growth rate, more branches, and using environmental sources more effectively in row cropping method. Sowing date of January is better than October because of its more appropriate temperature condition for vegetative and reproductive stages in the plant and is also better than February because of its longer growth stage.

Number of Leaves/Plant

Process of change in the number of leaves per plant in sowing date of February showed that the maximum number of leaves per plant happened in the interval of 72 days after germination. In first sampling the number of leaves per plant in this sowing date was more than other two sowing dates. This may be the result of better environmental condition. The maximum number of leaves was in the sowing date of January. The maximum number of branches per plant was also in sowing date of January. This may be linked to more appropriate and adaptable environmental condition at the end of vegetative growth stage. Process of change in the number of leaves per plant in sowing date of January showed that the maximum number of leaves per plant happened in the interval of 86 days after germination that is the time in which seed weight per pod had its maximum weight and did not increase afterward. In subsequent stages, the number of leaves per plant declined gradually. Arman cultivar, in all three sowing dates, had a larger leaf area index in comparison with Hashem cultivar and Greet local bulk. In all three sowing dates, leaf area index was larger in row cropping than in sow broadcast method. Growth rate was higher in January in comparison with other two sowing dates. In relay seeding (sowing date of February) growth rate increased in row cropping method. In all three sowing dates, growth rate was higher in Arman cultivar in comparison with Hashem cultivar and Greet local bulk. In dormant seeding (sowing date of January) Arman cultivar had the maximum growth rate of 18.56 g/m^2 per day. In sowing dates of October and February the growth rate in the end of growth stage declined in Hashem cultivar more rapidly than in Arman cultivar.

Effect of Sowing Date, Planting Method and Cultivar on Growth Indexes and their Relation to Seed Yield, Biological Yield and Harvest Index

Plant's growth rate : Plant's growth rate is the most significant term in analyzing growth in plant population which indicates the amount of dry matter accumulation in plant in a specific unit of time and soil.

Process of change in growth rate in sowing dates of October, January and February showed that the maximum growth rate was in the interval of 85 days after germination in January and February and in the interval of 100 days after germination in October sowing date. January, among these three sowing dates, had the maximum growth rate of 13.5 g/m^2 per day (Fig. 1). It seems that the relay in planting decreases net (pure) photosynthesis and, in turn, decreases the production and rate of dry matter accumulation which results in greater seed and biological yield in sowing date of January in comparison with February. Chickpea due to more vegetative growth in sowing date of October in comparison with January was more vulnerable and had a less biological yield (Begum *et al.,* 1992). Sowing date of January had the maximum biological yield of 5154.34 kg/ha and sowing date of October had the minimum biological yield of 4306.74 kg/ha.

Process of change in growth rate in row planting and sow broadcast method showed that

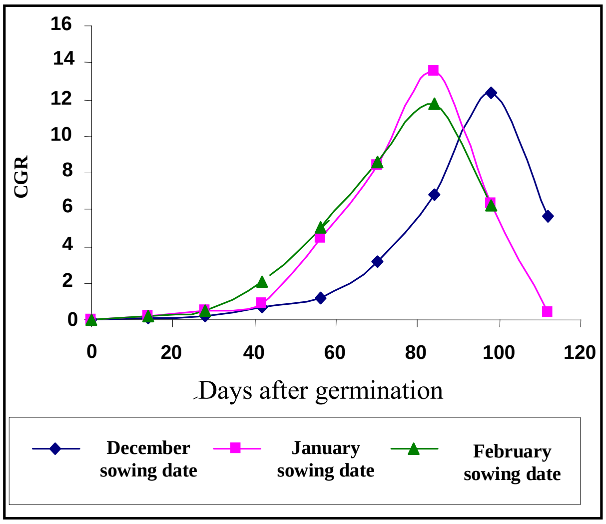

Fig. 1. Process of change in growth rate in sowing dates of October, January and February.

as a result of incomplete canopy growth rate in growth initial stages was low in both planting methods but when the length of the growth period increased a rise was detected in growth rate as leaf area index increased. The maximum growth rate in row cropping and sow broadcast method was 10.94 and 9.99 g/ m^2 per day, respectively (Fig. 2). In row cropping method, the competition between the crops in the field is lower : all plants have equal space in each plot, can capture minerals and assimilates in the soil more effectively, grow sooner in comparison with plants in sow broadcast method and, finally, green covering (canopy) is uniform on the plot and there is less soil moisture loss. Another advantage of row cropping in comparison with sow broadcast is that row cropping is better for cultural practice. The maximum biological yield of 5066.84 kg/ha was in row cropping method and the minimum biological yield of 4379.96 kg/ ha was in sow broadcast method. In all growth stages, plant's growth rate was higher in row cropping method in comparison with sow broadcast method. As a result, biological yield was also higher in row cropping method. Row cropping method had the maximum seed yield of 1531.34 kg/ha and sow broadcast method had the minimum seed yield of 1289.63 kg/ ha. Seemingly, in row cropping method, due to producing more leaf area, the plant absorbs more light, photosynthesizes better and, finally, has a higher growth rate which results in more dry matter production. These results match the results of Ehsanzade *et al.* (2006) who reported that sow broadcast method critically decreased seed germination (growing) percentage in dry-land chickpea even upto 40%. In row cropping method seeds germinated (grew) sooner and plant density in plot was more uniform (Ehsanzade *et al.*, 2006). As a result of these characteristics, the plant starts growth faster, finds a higher leaf area index and, in turn, makes the most of environmental sources to produce yield and yield components. The competition between the plants in the field for light, moisture and nutrient elements in the soil is lower in row cropping in comparison with sow broadcast (Rastegar, 1998).

Process of change in growth rate of the two cultivars and the local bulk is as follows : in the beginning of growth initial stages growth rate was low in both cultivars and in the local bulk. The maximum growth rate of Arman and Hashem cultivars and Greet local bulk was 13.98, 12.28 and 2.41 g/m^2, respectively (Fig. 3). Rhythm of fall in growth rate at the end of growth period in Arman cultivar was faster than Hashem cultivar.

Growth rate rapidly increases with

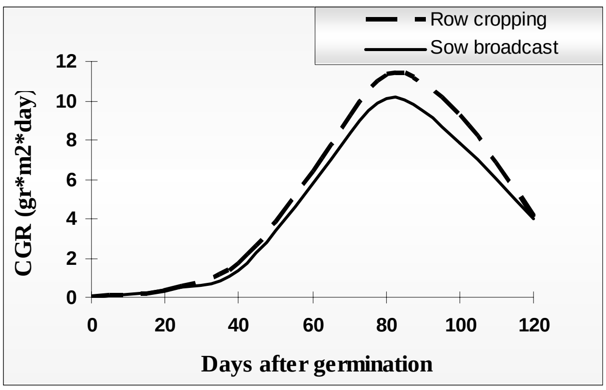

Fig. 2. Process of change in growth rate in hand and row cropping methods.

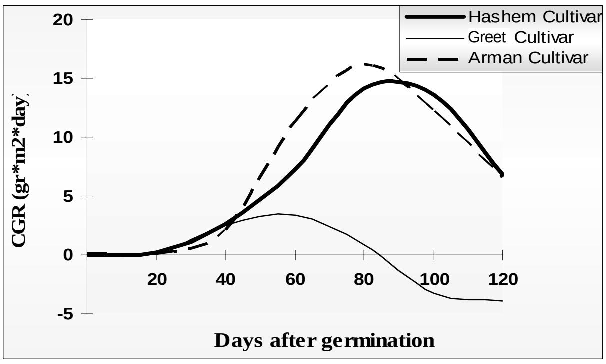

Fig. 3. Process of change in growth rate in Arman and Hashem cultivars and Greet local bulk.

blooming and then starts to decline after 50% pod-set stage and continues to physiological maturity stage. This agrees with the results in this experiment.

The maximum biological yield of 6908.84 kg/ha was in Arman cultivar and the minimum biological yield of 644.39 kg/ha was in Greet local bulk. Because of having larger leaf area index and higher growth rate, Arman cultivar produces a larger green covering (canopy) in the field in comparison with Hashem cultivar. As a result, photosynthesis per green level unit is more in Arman cultivar which by producing assimilate in the source and transmitting it to growth organs results in more growth and bigger libraries and, in turn, greater biological yield in Arman cultivar in comparison with Hashem cultivar. Arman cultivar had the maximum seed yield of 2261.8 kg/ha and Greet local bulk had the minimum seed yield of 206.32 kg/ha. Hashem cultivar, in comparison with other cultivars, blooms and probably because of not providing the need for vernalization and the delay in reproductive stage, seeds later. If the cultivar has the ability to adapt to environmental conditions then it will compensate for the decline in growth stages by increasing the growth rate. One reason of greater yield in Arman cultivar may be its higher capability in transmitting photosynthetic elements to the seeds (Regan *et al.*, 2003). Growth rate and leaf area index were higher in Arman cultivar in comparison with Hashem cultivar and Greet local bulk. As a result, the plant produces more photosynthetic elements in vegetative stage and grows larger libraries which transmit more assimilate towards the source organs and use them to produce more flower and fruit in reproductive stage.

Leaf area index : Leaf area index indicates leaf area ratio to the area on the field occupied by the plant which reaches its maximum value in the middle of growth season and decreases afterward due to death (falling) of old leaves and growth of small young leaves. Process of change in leaf area index in different sowing dates showed that the maximum leaf area index of 3.2 happened 85 days after germination in January sowing date (Fig. 4). Rhythm of rise in leaf area index in growth initial stages was faster in February in comparison with other two sowing dates.

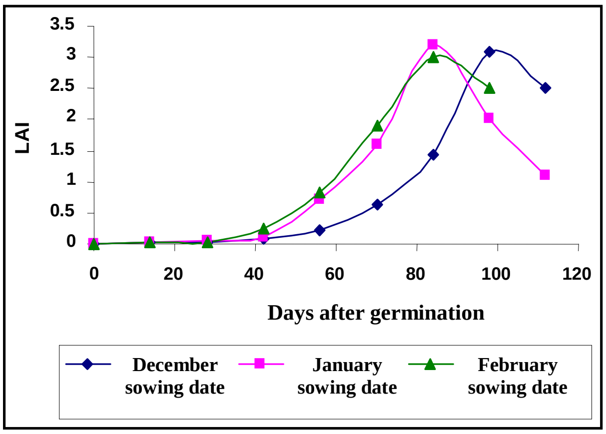

Fig. 4. Process of change in leaf area index in October, January and February sowing dates.

This is related to more appropriate temperature conditions in growth initial stages in February sowing date. Leaf area index curve was influenced by sowing date and reached its maximum value in January sowing date and because of more light absorption in this date the plant had a higher growth rate. The maximum seed and biological value was also in January sowing date. It seems that by early planting the plant has more opportunity to utilize appropriate environmental condition and therefore leaf area index develops sooner and reaches its maximum earlier. As a result, plant's canopy develops more in early planting and, in turn, increases leaf area index in comparison with relay planting (Goldani and Rezvani, 2007).

Process of change in leaf area index in row cropping and sow broadcast methods showed that in all growth stages leaf area index development was higher in row cropping method in comparison with sow broadcast method (Fig. 6). Uniformity percentage of green

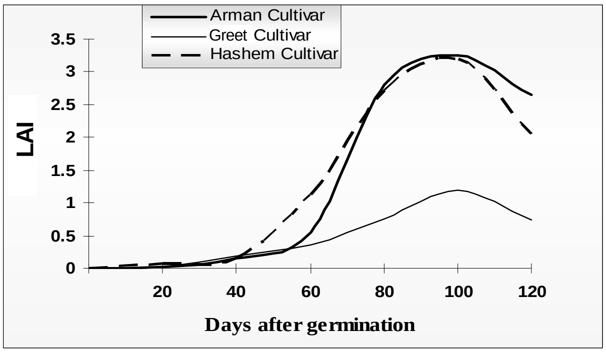

Fig. 5. Process of change in leaf area index in Arman and Hashem cultivars and Greet local bulk.

covering (canopy) in the field was more proportionate in row cropping method in comparison with sow broadcast method. Therefore, in row cropping method, the plant utilizes light, moisture and nutrient elements more effectively and produces a better yield in the area. In row cropping method, due to the uniformity of green covering (canopy) in the field the plant utilizes the environmental sources more effectively and has a greater leaf area index in comparison with sow broadcast method which results in better photosynthesis in the area and therefore increases growth rate and develops seed and biological yield/ha.

Process of change in leaf area index in Arman and Hashem cultivars and Greet local bulk showed that the maximum leaf area index in Arman and Hashem cultivars was 3.06 and 2.99, respectively (Fig. 5). Rhythm of fall in leaf area index at the end of growth stages in Hashem cultivar was faster than Arman cultivar. Because of its divergent growth type, Arman cultivar produces more leaf area and, in turn, by optimal capture of light and better photosynthesis, produces more dry matter. As it is represented in the diagram, leaf area index is the same in the two cultivars and in the local bulk until 60 days after germination but, from the beginning of growth stages different growth traits are detected in the two cultivars and in the local bulk. Arman cultivar, because of its divergent growth type, absorbs more light and has a faster rise in growth rate. On the contrary, Hashem cultivar, because of its standing growth type, absorbs less light and has a slower rise in growth rate. Greet local bulk has a divergent growth type but because of Ascochyta blight disease its growth declines and its leaf area index is less than other two cultivars. Arman cultivar, because of

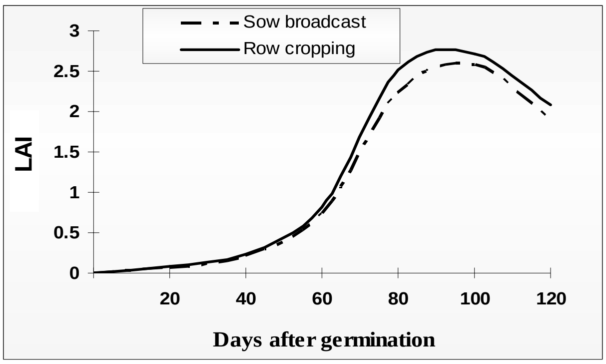

Fig. 6. Process of change in leaf area index in row and sow broadcast methods.

developing its leaf area index sooner and having a better rise in growth rate, produces more dry matter and, finally, has a better seed and biological yield per hectare.

Net assimilation rate : Net assimilation rate is the amount of material formed in leaf area unit per time unit which is an estimation of mean of leaf efficiency in a vegetative population and reaches its maximum value when all the leaves are exposed to complete sun light. Therefore, net assimilation rate decreases as the leaf area increases.

Process of change in net assimilation rate in different sowing dates showed that the maximum net assimilation rate was 9.6 g/m^2 per day in sowing date of January and 14 days after germination. As the number of leaves and therefore their to shadow on each other increased net assimilation rate declined because the leaves completely covered each other. Net assimilation rate in growth initial stages in sowing date of October was less in comparison with other two sowing dates (Fig. 7). It seems that in this sowing date the plant received less light in the beginning of growth stages. In the beginning of growth stage in sowing date of January the plant received more light and its growth rate increased more. Therefore, it utilized environmental sources

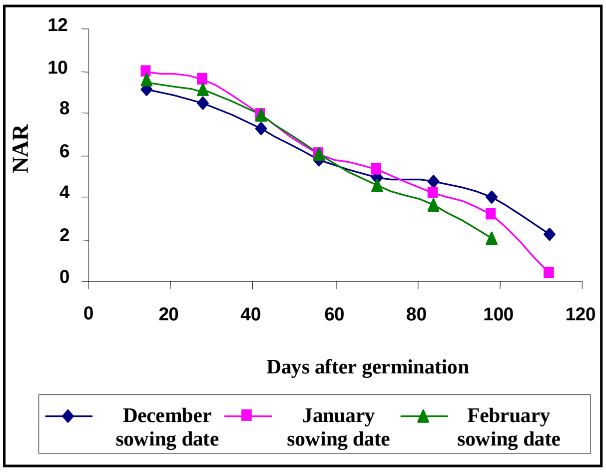

Fig. 7. Process of change in net assimilation rate in October, January and February sowing dates.

in a short time, entered the reproductive growth stage sooner, produced larger reproductive organs and, finally, increased seed and biological yield per hectare in sowing date of January.

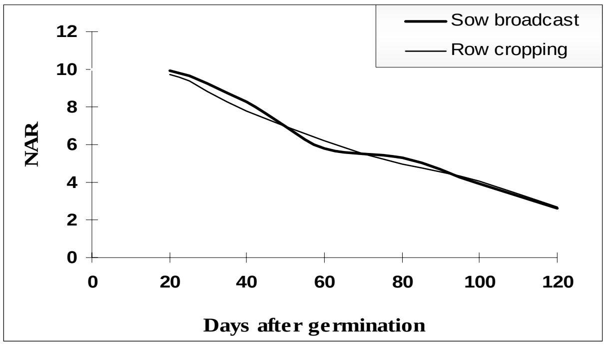

Fig. 8. Process of change in net assimilation rate in row and sow broadcast methods.

Process of change in net assimilation rate in row cropping and sow broadcast method is as follows: rhythm of fall in net assimilation rate in the beginning of growth stages in sow broadcast method is faster (Fig. 8). The reason may be the higher growth rate in the plant due to better light absorption and nutrient uptake in this planting method which, in turn, causes the upper leaves to cast shadow on lower leaves.

In row cropping method due to uniformity of plants in the field and appropriate space during growth stages, the plant grew and developed sooner, leaf area index and growth rate increased and as a result dry matter yield per hectare increased in row cropping method.

Process of change in net assimilation rate in Arman and Hashem cultivars and Greet local bulk showed that the maximum net assimilation rate was in Hashem cultivar. Hashem cultivar, due to its standing growth type, more light passes through the canopy and reaches the lower leaves (Fig. 9). On the contrary, in Arman cultivar and Greet local bulk, having divergent growth type and leaf area index rise in a shorter time after

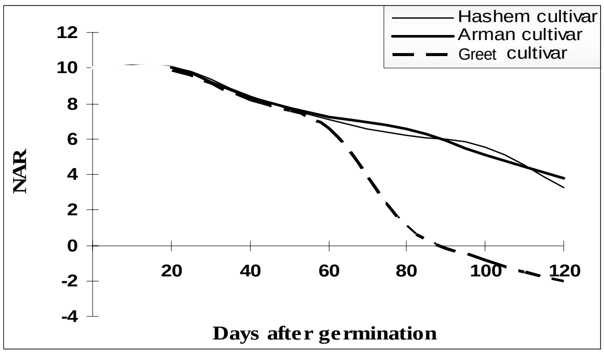

Fig. 9. Process of change in net assimilation rate in Arman and Hashem cultivars and Greet local bulk.

germination, net assimilation rate declines sooner.

As it is shown in the diagram, in Arman cultivar, due to divergent growth type and higher leaf area index, the green organs photosynthesize better and, in turn, grow and develop better. In pod stage dry matter accumulation rate per time unit is higher in Arman cultivar in comparison with Hashem cultivar. Rhythm of fall in net assimilation rate in Hashem cultivar is faster than Arman cultivar. This results from standing growth type in this cultivar. Finally, all these factors result in superiority of Arman cultivar in production of dry matter in comparison with Hashem cultivar.

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