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Chickpea (*Cicer arietinume* L.) yield and Yield Components as affected by Sowing date and Genotype under rainfed Conditions

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ABSTRACT
Chickpea as the second most important legume after soybean is usually cultivated in the spring; however, its plantation in the autumn may also be of economical benefits, especially with respect to the amount of rainfall during the autumn. Interestingly, just now chickpea genome has been sequenced, and hence the production of tolerant genotypes is likely under different conditions including stress. Sowing time and plant genotype are two important parameters affecting chickpea (Cicer arietinum L.) growth and yield. Accordingly, a field experiment was performed in 2008-2009 to evaluate the likeliness of chickpea plantation in the autumn in Aleshtar, Lorestan province, Iran. The experimental treatments of sowing date (autumn and spring) and plant genotype (Azad, Arman, Hashem and Grit) were tested using a factorial arrangement on the basis of a completely randomized block design with four replications. According to the analyses of variance, yield and the entire yield components of chickpea were significantly affected by sowing date; however the effects of genotype were just significant on grain yield and some of the yield components. Interestingly, the autumn planting date showed to be suitable for planting chickpea under such climatic conditions, and the combined effects of autumn planting and Azad cultivar resulted in the highest grain yield (2243.3 kg/ha). However, there are two important points, which must be more investigated regarding chickpea plantation using different sowing times and genotypes. 1. How chickpea can be more acclimated to the cold stress if it is planted in the autumn, and 2) how chickpea can be more tolerant to the drought stress if it is planted in the spring. There are also some conclusions regarding the appropriate planting of chickpea including: 1) if the average temperature is not less than 10^{o}C, chickpea can be cultivated in the autumn and winter as there is usually enough rainfall for plant growth 2) the main parameters, affecting chickpea tolerance to the cold stress, 3) if chickpea is planted during the spring under rainfed conditions, at least one time irrigation at grain filing stage can significantly increase grain yield, and 4) although a few chickpea tolerant genotypes are being planted, the recognition of chickpea genome has made the production of the most ideal genotypes under different conditions likely.
***Key words**: Grain yield, rainfed chickpea (Cicer arietinum L.), sowing time, yield components, plant genotype*

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Abbreviations: T1 and T2: autumn and spring sowing date, respectively. V1, V2, V3 and V4: Azad, Arman, Hashem and Grit genotype, respectively. HI: harvest index

INTRODUCTION

In the rainfed regions of the world, including the western parts of Iran, chickpea (*Cicer arietinum* L.) is a very important yield for the farmers. It is ranked second after soybean (*Glycine max* L.) in the world with respect to its importance as a legume food [1-3]. Interestingly, its genome with a size of 738 Mb and 28269 genes has just now been sequenced. The recognition of genes with different functions makes it likely to improve chickpea performance under different conditions including stress [4]. Chickpea is morphologically high, however genetically is not very diverse [1].

Due to some environmental constraints such as deficient rainfall and cold stress in regions such as Lorestan province, Iran, the cultivation of only a few crop plants such as wheat, barley, chickpea and lentil, is likely. The continuous cropping of a crop yield such as wheat and barley may not be recommendable due to their adverse effects on soil properties; it is also the case for lentil because of its difficult harvesting. Hence, chickpea is rotated with wheat in such regions and accordingly research work has been conducted to find the most optimum conditions for chickpea cultivation. More than 90% of chickpea is planted under rainfed conditions, so drought is among the most important stresses affecting chickpea growth and yield [5, 6]. Accordingly, it can be very interesting and of great practical use to test chickpea plating during the autumn so that the drought issue can be resolved.

In such regions, after harvesting wheat the field remains uncultivated for 6-7 months and during such a time it is possible to increase soil moisture to higher amounts using appropriate practices. Chickpea seeds are then planted and due to the minimal use of chemical fertilizers and herbicides in the region, planting chickpea is considered as an importation step toward a sustainable agriculture. However, to make chickpea yield economically there must be some proper practices, resulting in the optimum amount of yield. Selecting the suitable genotypes and sowing date are among the suitable practices, profoundly affecting chickpea yield.

Drought stress and high temperature during the spring season, especially at the time of pollination, are among the environmental parameters, adversely influencing chickpea growth and yield [7]. By selecting suitable planting times it is likely to avoid the adverse effects of high temperatures on cool adapted legumes [8]. Usually the length of chickpea vegetative and productive growth during the fall is higher than the spring. However, during the fall season, the conditions, with the exception of cold stress, are more suitable for chickpea growth. If the cold stress can be controlled during the autumn, it is likely to produce higher yield amounts related to the spring planting.

In this research work two important experimental factors have been considered on the growth of chickpea including the sowing time and genotypes. Sowing time can influence different climatic parameters, such as temperature, moisture, sunlight, etc. affecting plant growth. Chickpea is usually planted in the spring; however, it can also be interesting to indicate if its plantation during the autumn can also result in reasonable amount of yield. Such a response is also a function of plant genotype. Hence, these two parameters were tested in this experiment hypothesizing that planting chickpea during the autumn can also be likely providing that the tolerant plant genotype is selected and the cold stress can be handled.

MATERIALS AND METHODS

The experiment was performed in the city of Aleshtar, Lorestan province, Iran in 2008-2009. It is located in the northern altitude of 33^{o} and 30' and eastern longitude of 48^{o} and 18', 1171 m above the sea level. The average 35-year rainfall is equal to 528mm with temperatures ranging from -14.6 to 47.4, number of freezing days of 28.5, and the yearly evapotranspiration amount of 1033 mm. The soil texture is a silt loam, with the salinity of 0.4 dS/m, and pH of 7.6.

The experimental treatments of sowing date (autumn, 14/11/2008 and spring 23/2/2009) and genotype (Azad, Arman, Hashem and Grit) were investigated in a factorial arrangement based on a completely randomized block design with four replications. Plots measuring 1.8 x 6 m with six rows, 6 m long and 30 cm apart were used for the experiment. Seeds were planted at a 6.5 cm distance. To make the results applicable to the farmers, the field was prepared according to the farmers in the region. The field was plowed at suitable moisture after the autumn rainfall and was fertilized before using the disk according to the soil analyses at 20 kg/ha nitrogen and 50 kg/ha phosphorous.

Seeds were planted at the favorite density using a furrow with the depth of 5 to 7 cm. The four middle rows were used to determine the amount of grain yield. The harvested plants were air dried in a few days and the biological yield was then determined. To calculate the biological and economical yield the grains were obtained from the straw using a German Winter steiger machine. The weight of 100 grains was determined by randomly selecting the grains using a digital balance. The harvest index was calculated by dividing grain yield by the biological yield multiplied by 100.

To determine the yield components including the number of pod and grain per square meter as well as the weight of 100 grain, a 1m space from each plot was randomly selected. Number of pod per plant was determined by dividing the number of pod by the number of plant per square meter. Data were analyzed using MSTATC and SAS. The coefficients of coloration between the independent and dependent variables determined.

RESULTS

According to the analyses of variance sowing time significantly affected all the experimental parameters. However, the effects of genotype were just significant on the weight of 100 grains, number of pods with one seeds, number of grain per pod, grain yield and harvest index. The interaction of the two factors just significantly affected the number of grain per pod (Table 1).

Autumn sowing time resulted in significantly higher values for all the experimental parameters related to the control treatment. The higher weight of 100 grains was resulted by autumn sowing time (27.4g) significantly different from the spring sowing time (24.8g). The corresponding values for the other parameters were like the following. Number of pod with two seeds 77.57 and 34.4, number of pod with one seed 519.6 and 275.2, number of grain per pod 1.19 and 1.03, number of pod/m^2 669.3 and 339.8, number of pod/plant 19.15 and 12.56, number of grain/m^2 675 and 347, biological yield 3785.9 and 2155.7 kg/ha, grain yield 1819.8 and 797.8 kg/ha and harvest index 49.4 and 36.8%, respectively (Table 2).

Table 1. Analyses of variance presenting the effects of different experimental parameters on chickpea yield and yield components

SOV	d.f.	Weight of 100 grains	Two seed Pod/m^2	One seed Pod/m^2	Grain/pod	Pod/m^2	Pod/plant	Grain/m^2	Biological yield	Grain yield	HI
Rep.	3	4.23 ns	976.61	3240.6	0.014	7434.9	79.32	43214 ns	561808.5	57985.8	22.03
Sowing time (A)	1	52.6 **	15007.7 *	466336.5 **	0.16 **	868562 **	347.42*	860344 **	21262373.2 **	8356485 **	1276.01**
Genotype (B)	3	60.08 **	253.94 ns	40250.9 *	0.061 **	42213.3 ns	53.28 ns	34758 ns	870106.3 ns	463539.9 *	192.2 **
(AxB)	3	4.93 ns	789.78 ns	10480.8 ns	0.49 **	22498.1 ns	26.1 ns	4126 ns	1530518.3 ns	173623.4 ns	49.6ns
Error	2	6.24	1308.7	12022.9	0.009	18620.6	59.8	15899	641943.9	108272.8	70.23
Coefficient of variation		9.56	64.4	27.4	8.5	27	48.4	24.7	26.9	25.14	19.43

SOV: Source of variation, Rep.: replication

ns, *, **: not significant, significant at 5 and 1% level of probability

Table 2. Chickpea yield and yield components as affected by sowing time and plant genotype

	Weight of 100 grains (g)	Two seed Pod/m^2	One seed Pod/m^2	Grain/pod	Pod/m^2	Pod/plant	Grain/m^2	Biological yield (kg/ha)	Grain yield (kg/ha)	HI (%)
					Sowing date					
Autumn	27.4a	77.57a	519.6a	1.19a	669.3a	19.15a	675a	3785.9a	1819.8a	49.4a
Spring	24.8b	34.4b	275.2b	1.03b	339.8b	12.56b	347b	2155.7b	797.8b	36.8b
					Genotype					
Azad	28.6a	47.8a	449a	1.2a	563.7a	17.68a	544.7ab	3325.4a	1561.3a	47.3a
Arman	27.7ab	60a	437a	1.15ab	547.4ab	17.03a	556.7a	3160.2a	1438.07a	46.5ab
Hashem	25.6b	59.5a	294.6b	1.02b	404.2b	12.04a	413.6b	2607.1b	1016.7a	36.7b
Grit	22.4c	57a	415a	1.06b	505.4ab	16.7a	529ab	2790.7b	1219.0a	41.9ab

Plant genotype resulted in the following significant values, the weight of 100 grain (g) for Azad, Arman, Hashem and Grit were equal to 28.6a, 27.7ab, 25.6b and 22.4c, respectively. Number of pod with one seed for different genotypes resulted in the following significantly different values: 449a, 437a, 294.6b and 415a, respectively. Number of grain/pod was equal to 1.2a, 1.15ab, 1.02b and 1.06b, respectively. Grain yield for different genotypes were equal to 1561.3, 1438.07, 1016.7 and 1219.0 (kg/ha), respectively. The differences in plant genotype resulted in the harvest index values (%) of 47.3a, 46.5ab, 36.7b and 41.9ab, respectively (Table 2).

According to the table of interactions (Table 3) the highest weight of 100 grain (g) was related to T1V1 (30.7a), followed by T1V2 (28.1) and T2V2 (27.3). For the number of pod with two seed the highest values were resulted by treatments T1V3 (93), followed by T1V2 (76.5) and T1V1 (73.5). The highest number of pod with one seed were related to T1V1 (601.5), followed by T1V2 (546.5) and T1V4 (489). Number of grain per pod were the highest for T1V1 (1.49), T1V2 (1.18) and T2V2 (1.13). The number of pod/m^2 resulted in the highest values for T1V1 (765.5), T1V2 (724.5) and T1V3 (604.5) (Table 3).

Number of pod/plant was the highest for T1V2 (22.90), followed by T1V1 (20.50) and T1V4 (18.60). Treatment T1V1 (748.5), T1V2 (699) and T1V3 (627) resulted in the highest number of grain/m^2, respectively. The highest biological yield was resulted by T1V1 (4467.8), T1V2 (4200.5) and T1V3 (3508.9 kg/ha). However, treatment T1V1 (2243.3), T1V2 (1967.15) and T1V4 (1541.5 kg/ha) resulted in the highest grain yield. The HI (%) of 51.3, 51.11 and 51.04 were resulted by treatment T1V1, T1V4 and T1V2, respectively (Table 3).

There were high and significant correlation among different yield and yield components with the highest related to the number of grain/m^2 and number of pod/m^2 (0.98**), followed by the number of grain/m^2

and grain yield (0.93**), number of pod/m^2 and biological yield (0.92**), biological and grain yield (0.90**) and number of grain/m^2 and biological yield (0.89**) (Table 4).

Table 3. The interactive effects of sowing time and genotype on chickpea yield and yield components

Interaction effects	Weight of 100 grains (g)	Two seed Pod/m^2	One seed Pod/m^2	Grain/pod	Pod/m^2	Pod/plant	Grain/m^2	Biological yield (kg/ha)	Grain yield (kg/ha)	HI (%)
T1V1	30.7a	73.5ab	601.5a	1.49a	765.5a	20.5ab	748.5a	4467.8a	2243.3a	51.3a
T1V2	28.1ab	76.5ab	546.5a	1.18ab	724.5a	22.9a	699a	4200.5ab	1967.15ab	51.04ab
T1V3	26.5ab	93a	441ab	1.04b	604.5ab	14.5b	627ab	3508.9abc	1527.2abc	44.3ab
T1V4	24.2ab	68ab	489.abc	1.05b	592ab	18.6ab	625.5ab	2966.7bcd	1541.5abc	51.11a
T2V1	26.6ab	22.3b	296.5bc	0.92c	371cd	14.9b	341cd	2183d	879.25bc	43.4ab
T2V2	27.3ab	43.5ab	327.5bc	1.13ab	370.2cd	11.08b	414.5c	2119.7d	909bc	42.06bc
T2V3	24.8ab	26b	148.3cd	0.99c	199.7d	9.5c	200.3d	1705.3d	506.3c	29.04c
T2V4	20.6b	46ab	340.5d	1.07b	418.5bc	14.7b	432.5bc	2614.8cd	896.5bc	38.83abc

T1 and T2: autumn and spring sowing date, respectively. V1, V2, V3 and V4: Azad, Arman, Hashem and Grit genotype, respectively. Values in the same column followed by the same letters are not significantly different. HI: harvest index

Table 4. Coefficients of correlation between different yield and yield components

	Yield	Biological yield	HI	Grain/m^2	Pod/m^2	Grain/pod	Weight of 100 grain
Yield	1						
Biological yield	0.90**	1					
HI	0.58**	0.20 ns	1				
Grain/m^2	0.93**	0.89**	0.48**	1			
Pod/m^2	0.90**	0.92**	0.48**	0.98**	1		
Grain/pod	0.12 ns	0.14ns	0.37*	0.13ns	-0.1ns	1	
Weight of 100 grain	0.53**	0.32ns	0.53*	0.32ns	0.33ns	-0.08ns	1

DISCUSSION

The effects of different sowing date and genotype on the yield and yield components of chickpea were investigated. Some clear and significant differences were resulted, the most interesting of which was the higher significant values for the autumn planting, related to the spring planting. It is because chickpea is usually cultivated in the spring, although it is cold adopted legume, temperatures less than 10^{o}C decreases the amount of yield [9].

Hence, two important points must be more investigated: 1) how chickpea may handle cold stress (temperatures less than 10^{o}C), and 2) how chickpea tolerance can be increased under drought stress. There are two different strategies to increase chickpea tolerance to the drought stress including the production of early maturity and tolerant genotypes. Higher root biomass is a very effective method to tackle the drought stress [10]. It can be achieved be genetically modifying the plant or use of biological fertilization. There are also some other traits, which may be modified in drought tolerant plants including reduced size of leaflets, decreased canopy temperature, efficient use of carbon, drought avoidance by increasing leaf chlorophyll content [8].

Shamsi [11] found that Nov 6th resulted in significantly higher chickpea yield and yield components for Hashem genotype related to the other sowing times (Nov 23rd and Dec 6th). Kobraee et al. [12] also tested three different sowing time (March 6th, 21st and April 4th). They indicated that earlier sowing time resulted in significantly higher yield and yield components. They also found that there were high and significant correlation between chickpea yield and yield components.

Shamsi et al [11] indicated that supplemental irrigation can alleviate the terminal drought stress and significantly increase chickpea yield. Yield and yield components of Arman genotype was significantly higher than Hashem and LC-482 genotype. There were also high and significant correlation between chickpea yield and yield components. They accordingly indicated that pod filling is the most sensitive growth stage to the drought stress and one time irrigation at this stage can effectively alleviate the stress, especially for Arman genotype.

Yagmur and Kaydan [13] indicated that use of irrigation, N fertilization and rhizobium inoculation can be effective treatments to increase chickpea yield under rainfed conditions. Under non-irrigation conditions the effectiveness of N fertilization and rhizobium significantly decreased. Similar results were obtained by Mansourifar et al. [15]. They found significant differences between chickpea genotypes and Bivaniej (drought tolerant) and Hashem were the genotypes with the highest and lowest amounts of grain yield, respectively. Mafakheri et al. [14] also examined the effects of drought stress and genotype on the yield and chlorophyll content of chickpea under rainfed condition. Similarly, Bivaniej genotype was the most tolerant genotype under drought stress and the adverse effects of drought stress on chickpea yield during the reproductive stage was more pronounced that during the vegetative stage. Similar results were obtained by Fang et al. [16].

Although the root properties are among the most important parameters affecting drought tolerance in chickpea, according to Zaman-Allah et al. [17,18] the efficient use of water during the vegetative and reproductive stage may also be very important determining the tolerant chickpea from the sensitive genotypes. In the tolerant chickpea more water was absorbed (less transpiration; decreased stomatal conductance, Reynolds-Henne et al., [19] by plant during the reproductive stage, while in the sensitive chickpea more water was absorbed during the vegetative stage.

Kaur et al. [9] and Turan and Ekmekci [20] indicated that the higher production of superoxide dismutase and H_2O_2 content and the lower production of malondialdehyde and phytic acid were among the most important physiological processes indicating the cold tolerance in the tolerant species. Heidarvand and Maali-Amiri [21] used some proteomic analysis to quickly indicate the response of plant cell to the cold stress with respect to the cellular homeostasis and the response of cellular organelles. Such properties may be useful for the production of cold tolerant species. Turan and Ekmekci [20] also indicated that seed acclimation is a suitable method to increase cold tolerance in chickpea plant.

With respect to the economical importance of chickpea and its sensitivity to the cold stress, Heidarvand et al. [22] tested the response of 10 different chickpea genotypes to the stress under field and growth-chamber conditions. They examined the plants for the amounts of electrolyte leakage as plant response to the cold stress and indicated the most tolerant chickpea genotypes expressing that it is also likely to indicate plant response to the cold stress under controlled conditions. Hence breeding for the cold stress even for chickpea plants, which are grown under drought and heat stress may also be a suitable method to increase chickpea yield under different climactic conditions.

Deokar et al. [3] and Jain and Chattopadhyay [1] indicated the genes, which are up and down regulated during the drought stress. This can be very useful for the production of drought tolerant genotypes. Accordingly, the genes, which make the plant tolerant to stress can influence cellular response and homeostasis, protein production, signaling pathways and gene expression. Soltani and Sinclair [2] simulated chickpea response to the current and future climate (4 ^{o}C increased temperature, 15% decreased rainfall and CO_2 with the concentration of 700μmol mol^{-1}) conditions under drought stress to investigate plant response. Under future climate plant yield increased mainly due to the earlier sowing date (21 days). They found that shorter vegetative and longer productive growth (20%) can significantly increase chickpea yield under both current and future climate.

It is actually a very important point which must be addressed by research; when is the most suitable sowing time for chickpea. A set of experimental parameters must be tested and compared using different sowing times. The most responsive and yielding sowing time can be assumed as the appropriate sowing time. The plant and climate properties are among the most important parameters determining the most optimum sowing time. Interestingly, and accordingly it may be likely to indicate the suitable sowing time with respect to the plant and climate properties using models [23].

Different research work has indicated that chick pea is a suitable choice for planting under rainfed conditions and the related details have been presented by different researchers. Benjamin and Nielsen [24] indicated that chickpea has the ability to change its root distribution under drought stress. Different species including soybean, chickpea and field pea were compared. Drought stress did not affect soybean root distribution as 97% of its roots were distributed on the 0.23 cm soil depth. Under non-stressed conditions, 80% of the pea roots grew on the 0.23 cm soil surface. However, under drought stress just 66% of the pea roots were found in the 0.23 cm depth and the remaining grew into the deeper depth. Field pea and chickpea and soybean resulted in a root surface area to weight ratio (AWR) of 35-40, 40-80 and 3-7 m^2 kg^{-1}, respectively. The extensive rooting growth (higher root surface area) for chickpea indicates its suitability for growth under rainfed conditions.

CONCLUSION

Different sowing date and chickpea genotypes were compared under the rainfed conditions of Aleshtar, Lorestan, Iran. Chickpea usually is planted in the spring; however it can be interesting to determine if it can also be planted in the autumn, providing that the selected chickpea genotype is tolerant to the cold stress or the average temperature is not less than 10 ^{o}C. Some very important and applicable points regarding the increased tolerance of chickpea to the cold and drought stress as the two most important stresses, which adversely affect chickpea growth and yield have been presented. Interestingly chickpea genome has just now been sequenced and hence it is likely to produce more tolerant genotypes under different conditions including stress.

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