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Growth and grain yield of chickpea (*Cicer arietinum*) cultivars as affected by plant densities under the fall dry land farming

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ABSTRACT

A field experiment was carried out during the 2013-2014 growing season in Lorestan Province (Iran) to evaluate the effect of three planting densities (30, 55, and 83 plant.m^{-2}) on growth indices and grain yield of four chickpea cultivars (Azad, Hashem, Arman and ILC482) under the fall dry land farming condition. The experiment design was factorial based on a randomized complete block design (RCBD) in three replications. The growth of pea under different planting densities was evaluated by measuring the growth indices including dry matter accumulation (DMA), crop growth rate (CGR), leaf area index (LAI), and relative growth rate (RGR). Results showed that pod number per plant was affected by plant density and cultivar, where ILC482 had the highest pod per plant. Also, the highest pod per plant was observed in the density of 55 plant.m^{-2} which was 38% and 32% higher than those of 30 and 85 plant.m^{-2} planting densities, respectively. Branch number, plant height, 100-grains weight, grain yield, biological yield, and harvest index were affected significantly by the interaction of cultivar × planting density. ILC482 cultivar had the highest grain yield (2077 kg.ha^{-1}) in the density of 83 plant.m^{-2} which was 25, 59 and 23% more than that of Hashem, Azad and Arman cultivars, respectively. ILC482 cultivar had the highest LAI and CGR during the growing season. Since the highest grain yield was achieved at the highest density, it is required to evaluate the higher densities effect on grain yield of chickpea under dry land farming.

Keywords: Chickpea cultivars, crop growth rate, dry matter, leaf area index, plant population, relative growth, yield, yield component.

بررسی شاخص‌های رشد و خصوصیات عملکردی ارقام نخود (*Cicer arietinum*) در واکنش به تراکم‌های مختلف کاشت در شرایط کشت پاییزه دیم

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چکیده

یک آزمایش مزرعه‌ای در سال زراعی ۹۳-۱۳۹۲ در لرستان اجرا شد تا اثر سه تراکم کاشت (۳۰، ۵۵ و ۸۳ بوته در متر مربع) بر شاخص‌های رشد و عملکرد دانه چهار رقم نخود (آزاد، هاشم، آرمان و ICL482) در شرایط کشت پاییزه و دیم مورد بررسی قرار بگیرد. آزمایش به صورت فاکتوریل بر پایه بلوک‌های کامل تصادفی در سه تکرار انجام شد. رشد ارقام نخود در تراکم‌های مختلف با اندازه‌گیری شاخص‌های تجمع ماده خشک، سرعت رشد گیاه، شاخص سطح برگ و سرعت رشد نسبی بررسی شد. نتایج نشان داد که تعداد غلاف در بوته تحت تأثیر تراکم و رقم قرار گرفت و رقم ICL482 بیشترین تعداد غلاف در بوته را داشت. بیشترین تعداد غلاف در بوته در تراکم ۵۵ بوته در مترمربع مشاهده که از تراکم‌های ۳۰ و ۸۵ بوته در مترمربع به ترتیب ۳۸ و ۳۲ درصد بیشتر بود. تعداد شاخه، ارتفاع بوته، وزن ۱۰۰ دانه، عملکرد دانه، عملکرد بیولوژیکی و شاخص برداشت به صورت معنی‌داری تحت تأثیر اثر متقابل رقم× تراکم بوته قرار گرفتند. رقم ICL482 بیشترین عملکرد دانه (۲۰۷۷ کیلوگرم در هکتار) را در تراکم ۸۳ بوته در مترمربع تولید کرد که از رقم‌های هاشم، آزاد و FILIP9393 به ترتیب ۲۵، ۵۹ و ۲۳ درصد بیشتر بود. رقم ICL482 بیشترین شاخص سطح برگ و سرعت رشد گیاه را در طول فصل رشد دارا بود. از آنجا که بیشترین عملکرد دانه در بالاترین تراکم بدست آمد نیاز است اثر تراکم-های بالاتر بر عملکرد دانه ارقام نخود در شرایط دیم مورد بررسی قرار گیرد.

واژه‌های کلیدی: ارقام نخود، تراکم بوته، سرعت رشد گیاه، سرعت رشد نسبی، شاخص سطح برگ، عملکرد و اجزای عملکرد دانه، ماده خشک.

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Introduction

Pulse crops are the second most important source of human food for their high (18-32%) protein content. The ability of these crops in biological nitrogen fixation, provides a considerable nitrogen source and improves soil fertility (Rahimi *et al.*, 2006).

The cultivation of a large number of crop plants is limited by environmental restrictions in the western Iran, where except some crops such as wheat, barley, chickpea and lentil, other crops is not successfully cultivated. Therefore, chickpea (*Cicer arietinum*) plays an important role in the rotation programs in these areas. Due to agronomical managements, monoculture of wheat and barley is not advisable. Lentil is not cultivated in large scales due to the difficulty in its harvesting. Thus, in the western Iran, especially Lorestan, chickpea is cultivated in rotation with wheat and barley, emphasizing the role of chickpea in the sustainability of agronomical systems in west Iran. About 21% of the chickpea cultivation area belongs to Lurestan which is often cultivated in spring dry land farming systems (Ahmadi, 2015).

Soltani *et al.* (2016) reported that agronomical management is more important than breeding management for improving chickpea grain yield in Iran. In this regard, cultivar and planting densities are important factors affecting the growth and grain yield of chickpea. It has been reported that the density of 28 plant.m^{-2} is the optimum density for chickpea cultivated under irrigated conditions in cold climates (Shams *et al.*, 2005), while 25 plant.m^{-2} has been recorded as a superior density of chickpea in dry land farming systems of northwest of Iran (Ahmadi and Kanooni, 1994). Ahmadian *et al.* (2005) showed that increasing the density of chickpea from 12 to 33 plant.m^{-2} is accompanied with the higher grain yield in a dry land farming system of northeast of Iran. Kanooni and Nematifard (2013) evaluated the grain yield of two chickpea genotypes in 25, 35 and 45 plant.m^{-2} in a dry land farming system in the dry-moderate region. In this research, the chickpea genotypes produced the highest grain yield in the density of 45 plant.m^{-2}. Naseri *et al.* (2011) observed that the density of 20 plant.m^{-2} produces a higher grain yield compared with the density of 40 plant.m^{-2}. Seddique and Sedgeley (1985) revealed that the branch number of chickpea is affected by plant density and, thus, chickpea has a lower branch in high densities. Therefore, it is possible to obtain the maximum grain yield by managing the planting density to increase the main stem number and reducing the branch number per unit area.

Growth analysis is an appropriate way for interpretation of plant response to environmental conditions (Nazeri *et al.*, 2012; Hashemi-Dezfouli *et al.*, 1995; Eskandari, 2009). Torabi *et al.* (2007) concluded that the relative growth rate (RGR) of bean (*Phaseolus vulgaris*) increased by enhancing the plant density. It has been reported that increasing the plant density from 20 to 30 plant.m^{-2} improved crop growth rate (CGR) and RGR of wax bean (*Phaseolus sp*). However, higher density (40 plant.m^{-2}) diminished the recent growth indices (Latifi and Navabpour, 2000). In a dry and warm region a significant difference was observed between the mung bean (*Vigna radiata*) cultivars in terms of growth indices, where NM92 cultivar (which produced the highest grain yield) had the maximum leaf area index (LAI) and CGR (Arian-Nia *et al.*, 2009). Seyed-Sharifi *et al.* (2013), working on the relationship between plant density and chickpea grain yield in the northwest of Iran with annual precipitation of 400mm, reported that the CGR increased when plant density changed from 25 to 45 plant.m^{-2}.

Sabaghpour *et al.* (2007) observed that the fall cultivation of chickpea increased grain yield up to 72%, suggesting the superiority of the fall dry land farming compared to the spring dry land farming of chickpea in terms of grain production and yield sustainability. However, in Lorestan Province, chickpea is often cultivated in the spring cultivation system. On the other hand, plant density has a different effect on the grain yield of chickpea in different climate conditions. Thus, the response of chickpea to plant density in Lorestan needs to be more documented. Therefore, the present research was conducted to evaluate the response of growth and grain yield of chickpea cultivars to different plant densities in the fall dry land farming system.

Materials and Methods

A field experiment was carried out in Khorramabad, Iran (33º29´N, 48º18´E, and altitude 1170 m above sea level) during 2013-14 growing season. The research field is located in a region with the mean annual precipitation of 520 mm. Some physicochemical properties of soil at the experimental site are presented in Table 1. The meteorological data were recorded from the sowing date to the harvest of treatments (Table 2).

According to previous reports (Seyed-Sharifi *et al.*, 2013; Kashfi *et al.*, 2010; Majnoon-Hosseini *et al.*, 2003; Ehsanzadeh *et al.*, 2006), the highest grain yield of chickpea is obtained in the density of 45-48 plant.m^{-2}. Since the highest grain yield in these investigations was recorded in the highest density, the effect of three plant densities of 30, 55, and 80 plant.m^{-2} (two densities more and one density lower than the optimum density of other studies) were evaluated for the growth and grain yield of four chickpea cultivars (Hashem, Azad, Arman, and ILC482). Some characteristics of cultivars are presented in Table 3. The experiment was carried out as a 3×4 factorial based on a randomized complete block design RCBD with three replications.

Table 1. Some physical and chemical properties of soil in the experimental site.

Depth (cm)	Soil texture	P_2O_5 (ppm)	K_2O (ppm)	pH	EC (µS.cm^{-1})	Organic matter (%)
0-30	Clay-Loam	3.0	430	7.2	0.69	1.23

Table 2. Some meteorological properties during 2013-14 growing season in the experimental site

Month	Mean daily temperature (ºC)	Mean relative humidity (%)	Monthly precipitation (mm)
October	19.9	28	0.6
November	12.2	41	26.3
December	8.0	53	58.1
January	7.5	66	20.1
February	7.8	69	57.0
March	12.8	60	36.1
April	15.5	60	101.5
May	20.3	43	39.5
June	26.9	19	0.0
Means	10.9	36.6	28.3

Table 3. Some characteristics of chickpea cultivars used in the experiment.

Cultivar	Introduction year	Specific characteristic
Hashem	1997	Resistant to blight and cold stress
Azad	2008	Resistant to blight and cold stress
ILC482	1990	Resistant to blight and cold stress-Early mature
FLIP 9393	1996	Resistant to blight and cold stress

Grain color of all cultivar was white. Grain size of all cultivar-except Azad with large grain-was medium.

Each subplot was 16.2 m^2 and consisted of 9 rows of 6m length, located 30 cm apart. All plots were fertilized with the same amount of fertilizer. The fertilizers containing N 40 and P2O5 55 $kg.ha^{-1}$ were broadcasted before sowing. Chickpea seeds were sown on the 7th of November in a dry land farming system in the 2013 growing season. The seeds were sown at high density to ensure the adequate emergence. After the seedling establishment, subplots were thinned to 30, 55, and 80 $plants.m^{-2}$ and weeds were removed from the field by hand.

LAI, dry matter accumulation (DMA), crop growth rate (CGR) and RGR were measured for the chickpea growth analysis. All above-ground parts of chickpea were harvested from a 0.1 m^{-2} area from 70 to 166 days after planting in 10 days intervals. Samples were harvested from rows 2 and 8. After sampling, leaf area was measured using LA measuring device (model Delta-T). Then, samples were over dried at 75℃ for 72 hours. All other growing indices were determined using the following equations (Abdolrahmani *et al.*, 2011):

(1) $DM = a+bH+cH^2+dH^3$

(2) $CGR = [(\Delta DM) / (\Delta H)]$

(3) $RGR = [(1/DM) \times (\Delta DM/\Delta AH)]$

Where, DM is the shoot dry weight, H is growth degree (GDD) day and a, b, and c are equation constants; CGR is determined by differentiation of DM equation; and RGR is measured by dividing CGR by DM. The following equation was used for determination of GDD from planting date to each sampling time (Abdolrahmani *et al.*, 2011):

(4) $GDD = [(T_{max} + T_{min}) /2)]-T_b$

In this equation, T_{man} is the highest daily temperature (℃), T_{min} is the lowest daily temperature (℃) and T_b is base temperature which was considered as 5℃ (Shobeiri *et al.*, 2007).

At maturity, an area of 2 m^2 from each plot was harvested and then the branch number per plant, grain number per plant (pod number per plant multiplied by grain number per pod), plant height, biological yield, and harvest index were determined.

The analysis of variance (ANOVA) of the data and the comparison of the means based on Duncan's multiple range test were carried out by MSTATC software. Excel software was used to draw figures.

Results and discussion

The ANOVA data showed that the growth properties included plant height, branch number per plant, and physiological traits of growth were significantly ($P \leq 0.01$) affected by density and cultivar. AS SHOWN IN Table 4, the interaction of density × cultivar has no significant effect on the growth indices. Except for the pod number per plant, other yield properties including 100-grain weight, biological yield, grain yield, and harvest index were significantly affected by density × cultivar interaction (Table 5).

In all chickpea cultivars, LAI was increased from 150 days after planting (DAP) (late vegetative growth and near to flowering stage) and decreased thereafter. The highest LAI was observed in the

ILC482 cultivar. As shown in Fig. 1, Hashem cultivar indicates the lowest LAI. In this connections, the highest difference between the maximum and minimum value of LAI was recorded at late vegetative growth and near to flowering stage, whereas LAI of ICL482 cultivar was 48% more than Hashem cultivar. At the end of growth stage, LAI was decreased in all cultivars and all cultivars had no leaf at harvest time (Fig. 1). At early growth stage, there was a negligible difference among the planting densities in terms of LAI. However, it reached the highest value at the end of the vegetative growth stage (140 DAP). The highest and the lowest LAI were obtained in the density of 83 and 30 plant.m^{-2}, respectively. LAI of 83 plant.m^{-2} was 35% more than that of the planting density of 30 plant.m^{-2}.

As increase in the plant density supplies the adequate leaf area for intercepting higher amount of solar radiation resulting in higher assimilates and, thus, grain production (Ebrahimi *et al.*, 2012). Since the time needed for the chickpea maximum LAI decreased with increasing plant density (Rahimi *et al.*, 2006), the interception of solar radiation is higher at higher plant densities (83 plant.m^{-2}); thus, it has positive effect on photosynthetic potential and the grain yield of chickpea. However, LAI decreased in all cultivars during the late growing season due to the upper leaves shading, which accelerates the leaf senescence (Malek *et al.*, 2012).

DMA followed a sigmoid curve, which was similar in different cultivars and densities. At first, DMA was increased slowly and then followed an upward trend. Chickpea accumulated the highest dry matter 145-150 days after planting (end of vegetative growth and early stage of flowering) and then it was diminished (Fig. 2). The highest DMA was observed in ILC482 cultivar all over the growing period. In the maximum point, Hashem cultivar had the lowest DMA, where its DMA was 33% lower than that of ILC482 cultivar (Fig. 2). Increasing the plant density resulted in higher dry matter production. In all growth stages the plant densities of 83 and 30 plant.m^{-2} produced the highest and lowest dry matter, respectively (Fig. 2), compatible with the finding of Saber-Ali *et al.* (2007) who reported that increasing the plant density, raised the radiation absorption resulting in higher dry matter production.

Chickpea is an indeterminate crop in which the vegetative growth continues at the reproductive stage. Therefore, at the end of the chickpea life cycle, vegetative and reproductive organs compete for assimilates. With the onset of flowering and fruit development, dry weight of vegetative organs diminished probably due to the reduction of leaves and petioles and the movement of storage from stems and pod walls to grain (Tuba-Bicer *et al.* 2004). The plant is devoid of leaves at harvest time, leading to a reduce 20-30% decrease in total dry weight of the plant (Tuba-Bicer *et al.*, 2004).

Table 4. Analysis of variance for plant height, branch per plant and growth indices of chickpea cultivars in different plant density

S.V	df	Relative Growth rate	Crop Growth rate	Dry matter accumulation	Leaf area index	Branch per plant	Plant height
Replication	2	4.25 ns	2.81 ns	661.32 ns	0.317 ns	196**	3.738**
Density (D)	2	4.73**	2.44**	5911.36**	0.911**	1.608**	25.284**
Cultivar (C)	3	9.28**	6.51**	5033.81**	1.33**	0.749**	42.690**
D×C	6	4.50 ns	3.11 ns	1326.91 ns	0.073 ns	2.786**	21.524**
Error	22	2.2	1.38	398.80	0.068	0.243	3.812
CV (%)		15.5	22.41	17.50	18.23	17.92	5.56

** Significant at P≤0.01 and ns: non significantly differences.

Table 5. Analysis of variance for biological yield, grain yield, grain yield component of pea cultivars in different plant density

S.V	df	100-grain weight	Pod/plant	Grain yield	Biological yield	Harvest index
Replication	2	0.228**	92.596**	6153.5**	19947.047^{ns}	21.67**
Density (D)	2	25.024**	1522.652**	382397.15**	6694396.05**	111.260**
Cultivar (C)	3	36.275**	722.944**	1462848.12**	8922508.698**	139.577**
D × C	6	15.877**	26.471^{ns}	377284.88**	1711465.53**	160.656**
Error	22	0.237	49.982	3167.79	11855.86	0.627
C.V (%)		2.03	15.56	4.83	3.36	2.19

** Significant at P≤0.01 and ns: non significantly differences.

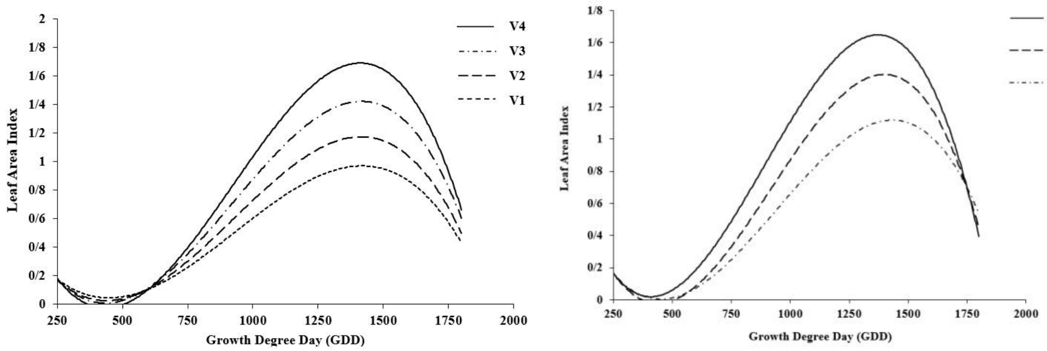

Figure 1. Effects of cultivar and plant density on leaf area index of chickpea under dry land farming. V_1, V_2, V_3 and V_4 are Hashem, Azad, Arman and ILC482 cultivars, D_1, D_2 and D_3 indicate 30, 55 and 83 plant.m^{-2}, respectively.

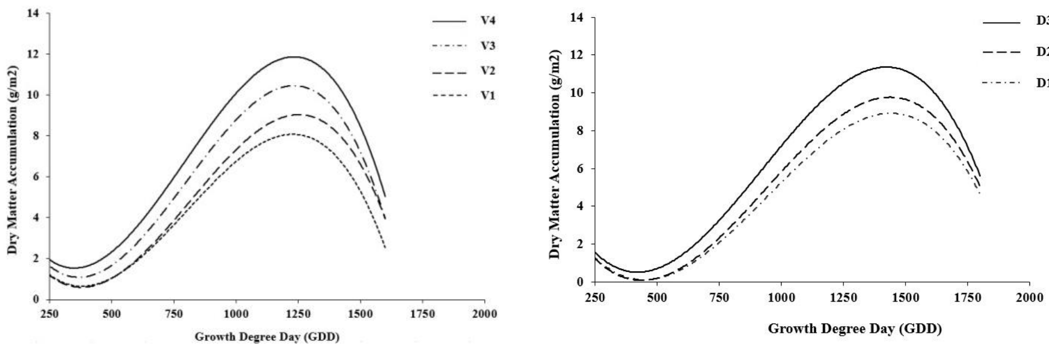

Figure 2. Effect of cultivar and plant density on dry matter accumulation of chickpea under dry land farming. V_1, V_2, V_3 and V_4 are Hashem, Azad, Arman and ILC482 cultivars; D_1, D_2 and D_3 indicate 30, 55 and 83 plant.m^{-2}, respectively.

The results show that the highest crop growth rate (CGR) belonged to ICL482 cultivar, while Hashem had the lowest value of CGR. Crop growth rate of ICL482 was 30% higher than that of Hashem cultivar. However, CGR reduced at the late season due to the leaves shading and the reduction of dry matter production (Fig. 3). In the early stages of measurement, planting densities had a low difference in CGR. However, their difference was increased gradually and reached its peak at 120-130 DAP. It seems that insufficient vegetation resulted in a low crop growth rate of chickpea in the early growth stages. Along with continued growth and increased leaf area, thus, better exploitation of solar radiation, the dry matter production per unit area was increased and a higher CGR was achieved. However, low CGR was observed at the end of chickpea growth stages owing to the allocation of assimilates to grain (Ebrahimi *et al.*, 2012). Furthermore, shading upper organs reduced the photosynthetic potential of lower leaves resulting in the CGR reduction (Seyed-Sharifi *et al.*, 2013).

The RGR of ILC482 cultivar was more than other cultivars during all growth stages, expecting to produce higher dry matter (Fig. 2). However, in all cultivars, RGR had a downward trend and reduced over time (Fig. 4). RGR expresses gross assimilate production per photosynthetically active surface. Therefore, an increase the chickpea growth and shading on photosynthetic surfaces reduced RGR (Bahl, 1980). In this regard the highest RGR was recorded in the lowest plant density (30 plant.m^{-2}). Under the condition of low density, there are fewer leaves, diminishing shading on young leaves and more light penetrates to the lower parts of chickpea canopy.

The number of pod per plant was significantly (P≤0.01) affected by density and cultivar. The results indicated that the maximum pod per plant was achieved at 55 plant.m^{-2} (Table 6). Regarding the pod number per plant, there was no significant difference between 30 and 83 plant.m^{-2} densities. Cultivars showed a significant (P≤0.01) difference in terms of pod number per plants (Table 5). The maximum pod number per plant belonged to ICL482 followed by Arman while Hashem and Azad indicated the lowest pod number per plant (Table 6). Pod number per plant is one of the most important factors affecting the grain yield of chickpea. It has been reported that in chickpea, the highest correlation among grain yield and yield components belongs to the pod number per plant (Filippeti, 1990. This result is in line with the findings of the current research, where the highest pod number per plant was for ICL482 as the superior cultivar in terms of the grain production per unit area (Table 5).

The highest branch per plant belonged to Azad cultivar in the density of 30 plant.m^{-2}. In 55 and 83 plant.m^{-2} densities, branch per plant showed a reduction in Azad cultivar, suggesting the susceptibility of this cultivar to higher densities in terms of branch production. There was no significant difference between Arman and ICL482 cultivars in terms of branch number per plant. Hashem cultivar had the highest plant height in the density of 55 plant.m^{-2}. However, the recent cultivar showed a considerable reduction in plant height (Table7).

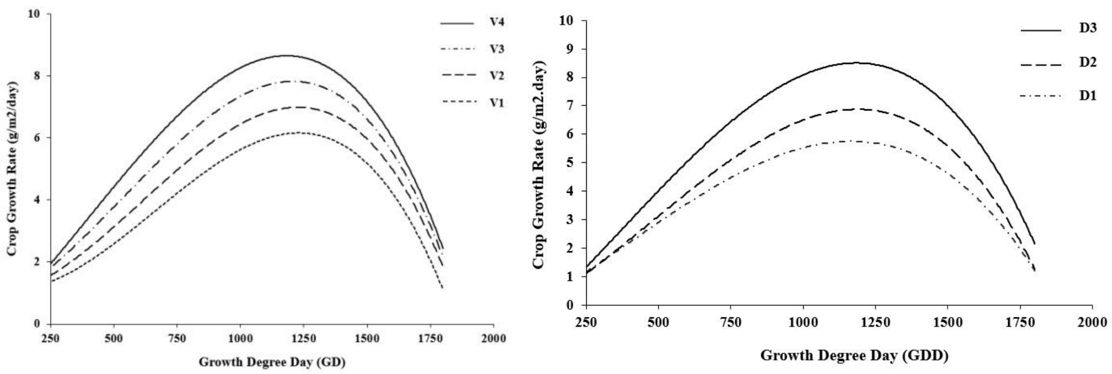

Figure 3. Effects of cultivar and plant density on crop growth rate of chickpea under dry land farming. V_1, V_2, V_3 and V_4 are Hashem, Azad, Arman and ILC482 cultivars; D_1, D_2 and D_3 indicate 30, 55 and 83 plant.m^{-2}, respectively.

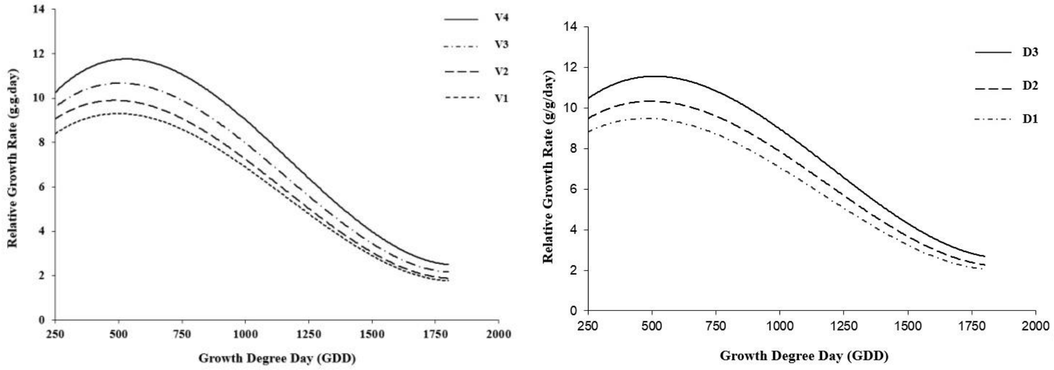

Figure 4. Effect of cultivar and plant density on relative growth rate of chickpea under dry land farming. V_1, V_2, V_3 and V_4 are Hashem, Azad, Arman and ILC482 cultivars; D_1, D_2 and D_3 indicate 30, 55 and 83 plant.m^{-2}, respectively.

Table 6. Effect of cultivar and planting density on pod number/chickpea plant

Treatment		No. Pod/plant
Cultivar	Hashem	23 c
	Azad	19 c
	Arman	30 b
	ILC482	41 a
	Mean	28.3
Density (plant.m^{-2})	30	23 b
	55	37 a
	83	25 b
	Mean	28.3

Different letters indicates significant difference at P≤0.01.

The maximum grain weight was obtained in ICL482 cultivar under the density of 83 plant.m^{-2}. Azad cultivar in the density of 30 plant.m^{-2} produced the smallest grain. Generally, the chickpea cultivars had a larger grain at higher densities (Table 7).

The harvest index of Hashem cultivar in 83 plant.m^{-2} was the lowest. ILC482 cultivar, which produced the highest grain yield, had a low harvest index, suggesting that this cultivar had a high biological yield too (Table 7).

The chickpea cultivars respond differently to planting density in terms of grain yield. The highest grain yield (2077.35 kg.ha^{-1}) belonged to ILC482 in 83 plant.m^{-2} density (Table 7). Results showed that the grain yield of Hashem and Arman increased with enhancing the plant density from 30 to 55 plant.m^{-2}. However, their grain yield reduced in the density of 83 plant.m^{-2}. In ILC482 cultivar, the grain yield increased with enhancing plant density. Hashem cultivar in the density of 55 plant.m^{-2} had the highest plant height (42.7cm). Generally, all cultivars produced their highest plant height in the recent density.

Arman and Azad cultivars produced the highest and lowest biological yield, respectively (Table 7). The biological yield of the fall sown chickpea cultivars in this experiment was higher than that of the spring-sown chickpea in the study of Hamzeie and Seyedi, (2012). This result is consistent with the findings of some other studies (Rezvani-Moghaddam and Sadeghi, 2008; Pezeshkpoor *et al.*, 2005) that report a higher biological yield of the fall sown compared with the spring cultivation. However, the high biological yield in this experiment did not result in higher grain yield (Table 7). The highest grain yield belonged to ICL482 cultivar in which the biological yield was lower than that of Arman and Hashem. Therefore, it can be concluded that the impact of assimilating allocation on the grain yield of chickpea is more than the biological yield.

Table 7. Interaction of cultivar × plant density on growth and yield of chickpea under dryland farming

Cultivar	Density (plant.m^{-2})	Branch per plant	Plant height (cm)	Grain weight (g)	Grain yield (kg.ha^{-1})	Biological yield (Kg. ha^{-1})	Harvest index (%)
Hashem	30	1.7 d	36.3 bc	20.9 e	1220.15c	2486.55 f	49.07 a
	55	3.4 b	42.7 a	24.68 b	1570.82 b	5039.53 a	31.17f
	83	2.37 cd	32.1 d	21.70 de	886.54 d	2366.0 e	37.47 d
Azad	30	4.8 a	33.33 cd	18.97 f	842.45 d	1887.63 g	44.63 c
	55	2.3 cd	33.0 cd	26.10 a	697.38 e	1844.92 g	37.80 d
	83	2.03 cd	32.47 d	22.33 c	540.57 e	1830.58 g	29.53 f
Arman	30	2.7 bc	38.26 b	22.16 c	690.71 d	2395.8 f	28.83 g
	55	2.77 bc	36.33 bc	25.88 ab	1604.24 b	4794.50 a	33.46 e
	83	2.57 bcd	36.4 c	25.96 a	936.63 d	3115.86 d	30.06 fg
ILC482	30	3.23 b	33.33 d	21.89 de	1337.04 c	3692.46 c	36.21 d
	55	2.6 bcd	34.02 cd	24.69 b	1592.17 b	4444.92 b	35.82 de
	83	2.9 bc	33.5 d	27.26 a	2077.35 a	4475.12 b	46.42 b

Different letters in each column indicate significant difference at $P \leq 0.01$.

The interception of solar radiation is of high importance in the pulse crops grain yield (Naseri *et al.*, 2011). Increasing the plant density from 30 to 55 plant.m^{-2} led to a higher solar energy exploitation and, thus, assimilated supply for grain filling. Under the condition of 83 plant.m^{-2}, with the reduction of light penetration into the chickpea canopy, the grain yield potential was also low, leading to a lower pod number induced by lower branch per plant. Moreover, it has been reported that increasing the plant density reduce the activity of buds forming branches of chickpea, resulting in a negative effect on the grain yield (Seddique and Sedgely, 1985). Watt and Singh (1992) showed the reduction in the chickpea pod number per plant with an increase in the plant density. They concluded that the high density diminished the ability of plant for translocation of assimilates from source to sink.

In this experiment, higher branches did not lead to a higher grain yield (Table 7), where Azad cultivar had higher branches but a lower grain yield in 30 plant.m^{-2} compared with ICL482 cultivar. Also, ahigher plant height was expected at higher densities due to the competition for light absorption. However, it seems that an adequate light was available in this experiment and there was no competition for light leading to insignificant variation in plant height (Table 7). In a study, it was reported that the plant height is effective on the grain yield due to its impact on branch and, thus, pod number per plant. However, plant height is a genetic-related traits (Tuba Bicer *el al.*, 2004) which that has little effect on the grain yield of chickpea cultivars in this experiment. In this case, although ILC482 had the highest grain yield, it did not have the highest plant height (Table 7). Vaghar *et al.* (2009) working on the grain yield of three chickpea cultivars in a dry land farming system concluded that Arman cultivar had the highest plant height but not the highest grain yield; consistent with the results of the current experiment.

Chickpea cultivars had larger grains when they produced lower branches (Table 7) which affected their grain yield, especially in the ILC482 cultivar. The high grain yield of the ICL482 cultivar is related to its larger grain and higher pod number per plant compared to other chickpea cultivars (Table 6 and Table 7). Leport *et al.* (2005) reported the effectiveness of pod number on the grain yield of chickpea. Tyahi *et al.* (1982) also stated that the chickpea grain yield is positively correlated with the grain weight and pod number per plant in line with the findings of this experiment. Summerfield and Robert (1986) concluded that lower grain weight leads to the grain yield reduction. Since ICL482 indicated a lower branch but higher pod numbers compared with the other chickpea cultivars, it can be concluded that pods were placed on branches with a high density.

Growth analysis approved the superiority of ICL482 for the grain yield. ICL482 cultivar had the highest LAI during all growth stages (Fig. 1). Azad cultivar had a low ability for the leaf area expansion, which consequently results in a negative effect on the grain production. Having a higher LAI is considered as a factor increasing the crop growth rate (Bullock *et al.*, 1988). CGR is the most suitable index for the growth evaluation and is affected by solar radiation interception, where higher light absorption leads to higher crop growth rate (Sarmad-Nia and Koocheki, 1988). In the wheat dry land farming system (Khorsandi *et al.*, 2013; Davidson and Campbell, 1984) and in chickpea (Kaka cultivar) (Seyed-Sharifi *et al.*, 2013) the higher grain yield was achieved when CGR was high, supporting the findings of this experiment. The results of correlation coefficients showed that LAI and CGR had the higher correlation with a chickpea grain yield (Table 8).

Table 8. Correlation coefficients between grain yield and growth indices of chickpea cultivars under autumn sown dry land farming

Cultivar	Leaf area index	Relative growth rate	Crop growth rate	Dry matter accumulation
Hashem	0.69^{*}	0.38^{ns}	0.59^{*}	0.56^{*}
Azad	0.57^{*}	0.47^{*}	0.65^{*}	0.58^{*}
ILC482	0.73^{**}	0.43^{ns}	0.68^{*}	0.73^{**}
FILIP9393	0.56^{*}	0.31^{ns}	0.60^{*}	0.61^{*}

*, **, ns: Significant at $P \leq 0.05$ and $P \leq 0.01$, and non significantly differences, respectively.

Conclusion

The results of the experiment revealed that in the dry land farming system of chickpea under Khoramabad climate condition, ILC482 cultivar produced a higher grain yield in the density of 83 plant.m^{-2}. The higher pod per plant resulted from the high density of pods on branches, resulted in the higher grain production per unit area by ILC482 cultivar. Since the highest grain yield in this experiment was obtained in the highest plant density, the possibility of increasing the chickpea grain production through higher densities needs to be evaluated further. Overall, the spring cultivation of chickpea in Lorestan region can be superseded by the fall cultivation of ILC482 cultivar.

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