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The Response of Chickpea Cultivars to Field Water Deficit

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Abstract

An experiment was carried out in 2006 to investigate the effects of different irrigation regimes (I_1, I_2, I_3 and I_4 for irrigation after 80, 110, 140 and 170 mm evaporation from class A pan, respectively) on ground cover, yield and yield components of four chickpea cultivars (Arman, ILC and Jam from kabuli type and Pirooz from desi type) in the field. In most stages of crop growth and development, the ground cover of ILC under different irrigation regimes was higher than that of the other cultivars. The ground cover of all chickpea cultivars was reduced, as water deficit severity increased. Grain yield and yield components were significantly affected by irrigation regimes. Mean grains per plant, 1000 grain weight and grain yield per unit area for I4 were significantly lower than those for other irrigation regimes, but these traits did not differ significantly among I_1, I_2 and I_3. Thus, irrigation after 140 mm evaporation from class A pan could be a suitable irrigation regime for chickpea cultivars, when water resources are limited. Grains per plant did not differ significantly among chickpea cultivars. In comparison, the largest and the smallest grains were obtained from ILC and Pirooz, respectively. In general, mean 1000 grain weight of kabuli type cultivars was higher than that of desi type cultivar. The superiority of ILC in ground cover and 1000 grain weight resulted in higher grain yield, compared to other cultivars. However, no significant differences in grain yield of Arman, Jam and Pirooz were observed. Interaction of cultivar × irrigation for ground cover, grain weight and grain yield per unit area was not significant, indicating that ILC was a superior cultivar under both well and limited irrigation conditions.

Keywords: evaporation, grain yield, ground cover, limited irrigation, yield components

Introduction

In many regions where food legumes are grown, the climate is characterized by extremely variable and often chronically deficient rainfall. In such environments both agricultural scientists and farmers seek to identify crop and soil management techniques which make the maximum use of this scarce resource (Cooper et al., 1998).

Major chickpea producing countries include India, Pakistan and Iran (FAO, 2003), where the crop is generally planted after the main rainy season and grown on stored soil moisture, making terminal drought stress a primary constraint to productivity (Serraj et al., 2004). Most chickpea growing areas in Iran have cool and cold semiarid climates with terminal drought stress. Projected global climate change may have major influences on cropping patterns of chickpea in the region (Soltani et al., 2001). In order to ensure a balanced crop growth and development in this region, a comprehensive assessment of the vulnerability of chickpea cropping due to projected climate change is required (Saxena et al., 1996).

In NW Iran, chickpea is sown from mid-March to the end of April and grows mainly on reserve moisture which is progressively depleted with crop growth. The crop experiences drought stress from late vegetative stages until maturity. The intensity of drought stress varies from year to year,depending on the amount and distribution of rainfall and on spring and early summer temperatures. Supplementary irrigations to release the crop from soil moisture stress at critical stages of growth and development have been found to substantially increase chickpea yield (Soltani et al., 2001).

The flowering and pod setting stages appear to be the most sensitive stages to water stress (Nayyar et al., 2006). Limited irrigation to adequately meet the crop needs at critical stages of growth and development may be crucial for realization of yield potential of chickpea varieties. So, the objective of this research was to evaluate the performance of chickpea cultivars under full and limited irrigation conditions in the field, in order to identify suitable cultivar and irrigation regime for this crop, particularly when water resources are limited.

Materials and methods

Four chickpea (*Cicer arietinum* L.) cultivars including Arman, ILC, Jam and Pirooz were obtained from the Agricultural Research Center of Sanandaj and Kermanshah, Iran. Arman, ILC and Jam are kabuli type and Pirooz is a desi type. Seeds were treated with 2 g/kg Mancozeb before experimentation. This research was carried out at the Research Farm of Tabriz University, Tabriz, Iran (latitude

Table 1 Analysis of variance of the effects of different irrigation regimes and cultivars on various traits of chickpea

Source	Degrees of freedom	Ground cover	Grains per plant	1000 grain weight	Biological yield	Harvest index	Grain yield
Replication	2	8.231	14.29	1.89	3750.39	15.78	548.76
Irrigation (A)	3	41.99	30.60*	12.09**	17835.24**	149.71*	10194.4**
Cultivar (B)	3	104.87*	17.31	238.04**	34972.12**	416.34**	8106.26**
A*B	9	7.31	11.10	1.23	5479.85	86.00*	1521.90
Error	30	23.58	7.32	0.66	2980.59	36.96	1122.91
CV (%)		13.55		2.52	26.73	12.34	29.20

*,** Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

38.05⁰N, longitude 46.17⁰E, Altitude 1360m above sea level) in 2006. The climate is characterized by mean annual precipitation of 245.75 mm, mean annual temperature of 10°C, mean annual maximum temperature of 16.6°C and mean annual minimum temperature of 4.2°C.

The experimental design was factorial on the bases of randomized complete block in three replicates. Factors were four chickpea cultivars and four irrigation regimes (I_1, I_2, I_3, I_4 for irrigation after 80, 110, 140 and 170 mm evaporation from class A pan, respectively). Seeds were hand sown on 9 April 2006 in 4 cm depth of soil. Each plot consisted of 6 rows of 5 m length, spaced 25 cm apart, oriented in a north-south direction. Seeding rate was 68 seeds /m2. Plots were fertilized with 30 kg/ha urea and irrigated immediately after sowing, but subsequent irrigations were adjusted according to the treatment. After seedling emergence, plants per unit area were reduced to 50 plants/m2 by thinning. Hand weeding and pesticide application were done as required. Ground cover was measured every week by viewing the canopy through a wooden frame (50 cm × 50 cm), divided into 100 equal sections. The sections were counted when more than half of each filled with chickpea plants. At maturity, ten plants were harvested from each plot to determine above ground biomass (biological yield), grains per plant, 1000 grain weight and harvest index. Finally, plants from 3 m 2 in the middle of each plot were harvested and grains detached from the pods and grain yield per unit area was determined. Analysis of variance appropriate to the experimental design was conducted, using MSTATC software. Means of each trait were compared according to Duncan test at $P \leq 0.05$. Excel software was used to draw figures.

Results and discussion

Regression curves fitted on ground cover data (Figure 1) showed that at the most stages of growth and development, ground cover of ILC under different irrigation regimes was higher than that of other cultivars. Ground cover of all cultivars was reduced, as water deficit severity increased, but this reduction for the desi type cultivar was less than that for the kabuli type cultivars (Figure 1). Maximum ground cover of Arman, Jam, and Pirooz was statistically similar. However, maximum ground cover of ILC was significantly higher than that of other cultivars. ILC also produced the largest grains, followed by Jam, Arman and Pirooz, respectively (Table 2).

The effects of irrigation and cultivar on 1000 grain weight, biological yield, harvest index and grain yield per unit area were significant, while interaction of irrigation × cultivar was only significant for harvest index (Table 1).

Differences in mean 1000 grain weight, grains per plant, biological yield and grain yield per unit area among I_1, I_2 and I_3 were not significant, but these traits for I_4 were significantly lower than those for other irrigation regimes. Harvest index of chickpea plants under I_1, I_2 and I_3 was

Table 2 Comparison of means of different traits for chickpea cultivars and irrigation regimes

Treatment	Ground cover (%)	Grains per plant	1000 grain weight(g)	Biological yield(g/m²)	Harvest index	Grain yield(g/m²)
Irrigation						
I1	38.25a	9.75a	291.06a	234.67a	52.94a	140.60a
I2	34.50a	9.77a	299.15a	226.30a	50.15a	129.04a
I3	34.50a	9.08a	289.97a	206.77a	49.51ab	115.51a
I4	30.67a	6.41b	263.36b	149.10b	44.46b	73.82b
Cultivar						
Arman	29.25b	9.23a	301.48c	235.20a	40.91b	110.48b
ILC	41.08a	10.08a	334.39a	259.94a	49.43a	150.25a
Jam	33.17b	7.25a	320.09b	182.26b	52.75a	110.51b
Pirooz	34.42ab	8.46a	187.57d	139.44b	53.97a	87.73b

Different letters indicating significant difference at $p \leq 0.05$. I1, I2, I3, I4: Irrigation after 80, 110, 140 and 170 mm evaporation from class A pan.

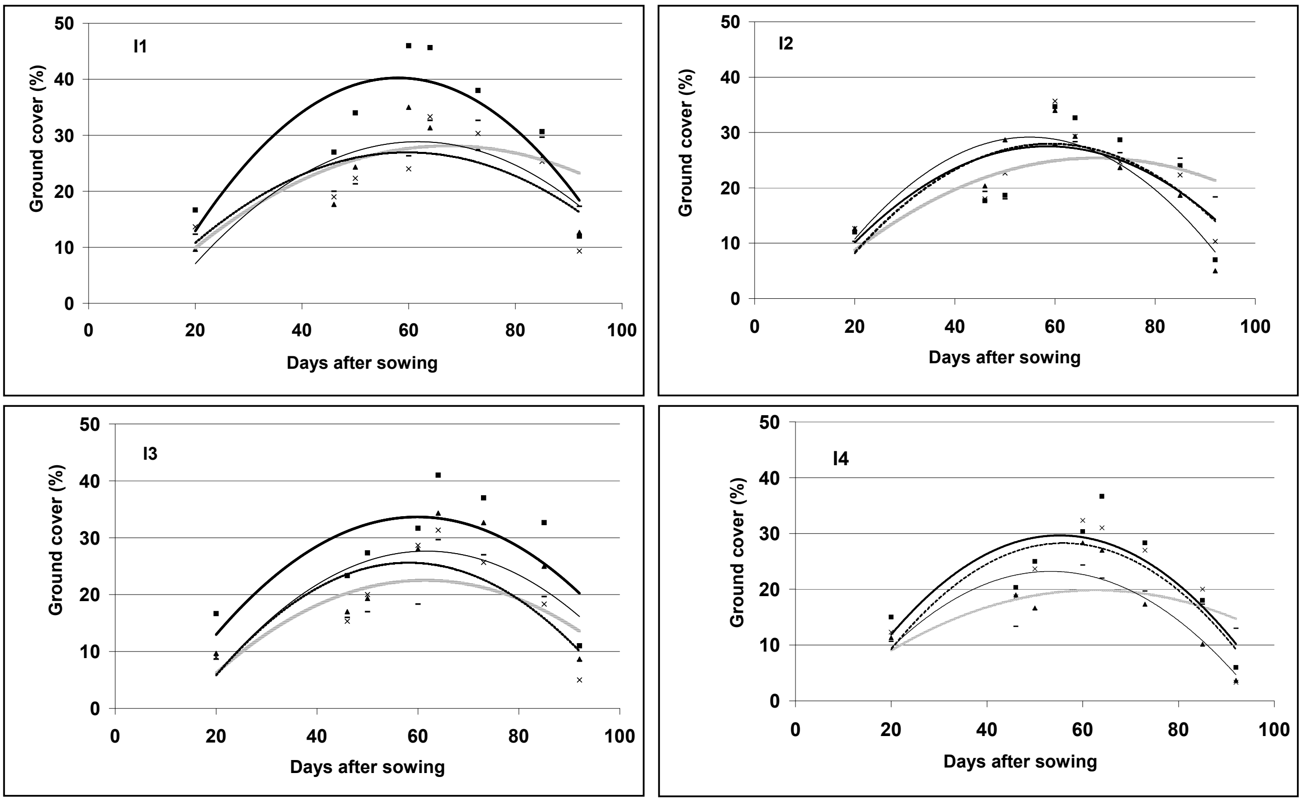

Figure 1 Changes in ground cover percentage at different stages of growth for Arman (-), ILC (▪), Jam (Δ) and Pirooz (×) cultivars under different irrigation regimes (I1, I2, I3 and I4: Irrigation after 80, 110, 140 and 170 mm evaporation from class A pan)

higher than that under I_4, but no significant difference between I_3 and I_4 was observed (Table 2). Biological yield of Jam and Pirooz and harvest index of Arman was significantly lower than those of the other cultivars. In comparison, grain yield per unit area was statistically similar for Arman, Jam and Pirooz. The highest grain yield per unit area was obtained from ILC, which was considerably higher than the other three cultivars (Table 2). Harvest indices of Arman and ILC under severe water deficit (I_4) was significantly lower than that under I_1, but harvest index for Jam and Pirooz did not differ significantly between I_1 and I_4 (Table 2).

A great deal of effort has been made to develop plants that can withstand drought or production systems that avoid water stress (Howell et al., 1998; Edmeades et al., 1999; Norwood, 2001). Resistance to drought stress can also be achieved by matching crop phenology with prevailing rainfall patterns (Edwards et al., 2005). In this research, limited irrigation even after every 140 mm evaporation from class A pan (I_3) prevented significant ground cover and yield loss (Table 2), as compared with well-watering (irrigation after 80 mm evaporation). However, further limitation in irrigation (irrigation after 170 mm evaporation) resulted in significant reductions in mean grain weight, grains per plant, biological yield, harvest index and, consequently, grain yield per unit area (Table 2). Therefore, irrigation after 140 mm evaporation could be a suitable regime for chickpea cultivars, when water resources are limited. In this way, irrigation at the reproductive stages of chickpea plant would also be possible, which could prevent significant yield loss in this crop. Water deficit at reproductive stages of chickpea can abort flowers and pods, thus reducing yield potential (Nayyar et al., 2006).

ILC was a superior cultivar in percentage ground cover at the most stages of growth and development (Figure 1), leading to the production of the largest grains and the highest yield per unit area (Table 2). Although harvest index of Arman, particularly under severe water deficit (I_4), was considerably lower than that of other cultivars (Table 3), but biological yield of that cultivar was significantly higher than that of Jam and Pirooz (Table 2).

As a result of this, grain yield per unit area for Arman, Jam and Pirooz was statistically similar (Table 2). In comparison, the superiority of ILC in ground cover led to the production of higher biological yield, larger grains and slightly more grains per plant, compared to other cultivars (Table 2).

Consequently, grain yield per unit area for ILC was 36%, 36% and 71% higher than that for Arman, Jam and Pirooz, respectively. Yield differences among chickpea cultivars mainly resulted from differences in ground cover and mean 1000 grain weight (Table 2). Thus, grain weight was the most important yield component in determining yield potential of chickpea cultivars in the field.

No significant interactions of cultivar × irrigation for ground cover, 1000 grain weight and grain yield per unit

Table 3 Comparison of means for interaction of cultivar × irrigation on harvest index

I_1				I_2				I_3				I_4			
C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
42.41 c	54.65 ab	59.93 a	54.79 ab	44.61 bc	52.19 abc	45.18 bc	58.62 a	46.74 bc	48.62 abc	52.74 abc	49.94 abc	29.89 d	42.28 c	53.16 abc	52.53 abc

I_1, I_2, I_3, I_4: Irrigation after 80, 110, 140 and 170 mm evaporation from class A pan. C_1, C_2, C_3, C_4: Arman, ILC, Jam and Pirooz cultivars

area (Table 1) suggest that ILC was a superior cultivar under both well and limited irrigation conditions.

Since there is a linear relationship between ground cover and light interception (Burstall and Harris, 1983), grain yield of chickpea was closely related to this growth index. A similar result was reported for faba bean (Nasrullahzadeh et al., 2007). Ground cover also has the practical advantage as a simple, quick and non-destructive measurement, allowing frequent sampling. So, it is a reliable index for estimating yield potential of chickpea and other crops under well and limited irrigation conditions.

Conclusions

When water resources are limited, irrigation of chickpea cultivars after every 140 mm evaporation from a class a pan could be a desirable irrigation regime for obtaining economic crop yield. Percentage ground cover is a reliable index for estimating yield potential of chickpea cultivars in the field. ILC is a high yielding cultivar under both well and limited irrigation conditions.

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