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Grain Yield and Protein of Chickpea (*Cicer arietinum* L.) Cultivars under Gradual Water Deficit Conditions

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ABSTRACT

Chickpea (*Cicer arietinum* L.), an important food legume grown in the arid and semi-arid tropical regions, suffers substantial yields loss due to water deficit at the end of the growing season. The main objective of this study was to investigate the effect of gradual water deficit stress on grain protein and grain yield of desi and kabuli chickpea cultivars. Two field experiments were carried out in 2007 and 2008, to evaluate responses of three chickpea cultivars (Hashem and Arman from kabuli and Pirooz from desi type) under well watering (I_1: 70 mm evaporation from class A pan), gradual water deficit (I_2 and I_3: 70→90→110→130 and 70→100→130 mm evaporation, respectively) and water stress (I_4: 130 mm evaporation). As water deficit increased, percent of grain protein also slightly increased although this increasing was not significant. By applying water deficit, grain and biological yield were decreased. This reduction was significant under gradual water stress (I_2 and I_3) and well watering (I_1), compared with water deficit (I_4). Grain filling period under I_4 was 16 and 9 days shorter than I_1 and gradual water stress treatments (I_2 and I_3), respectively, leading to the most reduction in grain yield. There were no significant differences in grain and biological yield among I_1, I_2 and I_3 irrigation treatments. Progressively increasing irrigation intervals (I_2 and I_3 irrigation treatments) can help the chickpea plants to adopt water stress and prevent significant reductions in grain and biological yield per unit area. Arman is a superior cultivar under both well watering and limited irrigation conditions.

Key words: Biological yield, gradual water deficit, grain yield, grain protein content

INTRODUCTION

In today's world, paralleling to population growth, nutrition problem is also growing increasingly. Especially production of high-range protein foods has been important for the solving nutrition problem. For this reason, it's necessary to grow the most productive and high quality cultivars to the regions and investigation of environmental conditions on the protein quantity.

Drought or water deficit is the most important environmental stress that limits agricultural production and reduced drought regions out-put (Bahavar *et al.*, 2009). Chickpea (*Cicer arietinum* L.) with 17-24% protein (Niari-Khamssi *et al.*, 2010a) is one of the most important legume plants in providing human food. Agriculture is a major user of water resources in many regions of the world. With increasing aridity and a growing population, water will become an even scarcer commodity in the near future (Rahman, 2009). A better understanding of the effects of drought on plants is vital for improved management practices to know the best time for crops irrigation and breeding efforts in agriculture (Rahman, 2009).

Although chickpea is known for its better drought tolerance than most other cool-season legumes, drought does reduce yields and can even lead to total crop failure (Turner *et al.*, 2001). In both Mediterranean and sub-tropical climates, seed filling in chickpea is subject to terminal drought which limits seed yield (Turner *et al.*, 2001). Terminal drought during the reproductive stage is a major constraint to yield of chickpea in many regions of the world (Fang *et al.*, 2009).

Jaimez *et al.* (1999) stated that different irrigation frequencies or different irrigation intervals have beneficial effects on water balance fruit quality and fruit production. Irrigation also plays important role in maintaining sustainable growth of every crop especially it reduces the wilting which causes 60-80% crop loss but sometimes excessive water or frequent flooding for longer periods of time affect the yield of the crop (Gajera *et al.*, 1998).

Grain yield of chickpea is a quantitative character and also affected by many genetic factors as well as environment fluctuations (Muehlbauer and Singh, 1987). One of the early effects of water deficit is a reduction in vegetative growth and in general leaves growth was found to be more sensitive than root growth (Khaled, 2010). The chemical composition of seed, specially the concentration of carbohydrates, amino acids and proteins, has direct bearing on the nutritive value of the crop (Loss *et al.*, 1998). Information on the effect of gradual water deficit on chemical composition of chickpea is limited and not always conclusive. Early maturing chickpea varieties that escape terminal drought have been developed by Kumar and Abbo (2001) but early maturity places a ceiling on the potential yield and limits the crop's ability to exploit extended growing periods.

Regarding of the approach, an interesting method to prove tolerance in the field was described by Salekdeh *et al.* (2009), based on yield qualification in function of the water use and harvest index (Xoconostle-Cazares *et al.*, 2010). Increasing the water deficit adaptation in the chickpea should help to stabilize yields at higher levels of stress. Water limitation in the West and North-West of Iran gradually increase during plant growth and development, particularly under rain-fed conditions (Niari-Khamssi *et al.*, 2010b). Therefore, this study was carried out for the first time to investigate the effects of gradual water deficit on grain protein and grain yield of desi and kabuli type chickpea cultivars.

MATERIALS AND METHODS

Site description: Two field experiments were carried out in 2007 and 2008 at the Research Farm of Kermanshah Islamic Azad University (lat 34°20' N, long 46°20' E, altitude 1351.6 m above sea level). Kermanshah is located in west of Iran and has a mean annual temperature of 13.8°C and annual rainfall of 478 mm. The monthly mean temperature during the first and second year of the experiment were 19.5 and 21.3°C, respectively. Amount of total rainfall during the crop season in 2007 was 243 mm while the amount in 2008 was 153.1 mm. The soil texture of the research area was sandy-loam (Niari-Khamssi *et al.*, 2010b).

Plant materials: There were two kabuli type (Hashem and Arman) and one desi type chickpea cultivars (Pirooz). The chickpea cultivars were obtained from Dry land Agriculture Research Sub-Institute (DARSI), Sararoud, Kermanshah, Iran.

Experimental design: The experiments were arranged as split-plot, based on randomized complete block design in three replications. Irrigation treatments (I_1, I_2, I_3, I_4: 70; $70\rightarrow90\rightarrow110\rightarrow130$; $70\rightarrow100\rightarrow130$ and 130 mm evaporation from class A pan, respectively) and cultivars (Hashem (C_1) and Arman (C_3) from kabuli type and Pirooz (C_2) from desi type cultivars) were assigned in main plots and sub plots, respectively. All plots were irrigated twice after sowing and subsequent irrigations were applied according to the treatments by furrow method (Niari-Khamssi *et al*., 2010a). The plots under I_1 irrigation treatment received adequate water and the water deficit increased progressively with the increasing irrigation intervals based on evaporation amount from the pan. In gradual water deficit treatments (I_2 and I_3), the plants were irrigated after 70 mm evaporation from the pan. The second, third and forth irrigations in I_2 were applied after 90, 110 and 130 mm evaporation, respectively. Irrigations intervals were increased in I_3 so that second and third irrigations were applied after 100 and 130 mm evaporation from the pan, respectively. Fertilizers were applied prior to sowing at the recommended rates of 20 kg ha^{-1} for N as urea. Seeds were pretreated with Mancozeb to minimize the probability of seed- and soil-borne diseases. The seeds were sown in six rows of 6 m length, spaced 25 cm apart (64 seeds per m^2) in the two years in early March. The experiment area was hand weeded. The data were taken from 10 randomly selected plants in each sub plot. At maturity, plants in 1 m^2 of middle part of each plot were hand harvested and oven dried at 80°C for 48 h, then weight by 0.001 g balance. The pods were then removed, threshed and grains detached from the pods and subsequently grain yield per unit area for each treatment at each replicate was determined by Niari-Khamssi *et al*. (2010a, b). Characters evaluated were recorded as grain yield (g m^{-2}), biological yield (g m^{-2}), harvest index (%) and grain protein (%). Grain protein was measured by Kjeldahl method (Maff, 1984).

Statistical analysis: Combined analysis of variance appropriate to the split plot design was carried out using SAS (version 9.1) General Linear Method (GLM) procedure. Years were considered as random effects while irrigation treatments and cultivars were fixed in the model. Duncan multiple range test was used to compare the differences between means of irrigation levels, cultivars and interactions of the two factors at $p<0.05$.

RESULTS AND DISCUSSION

Analysis of variance: Combined analysis of variance of the data (Table 1) showed that the effect of year on any measured traits was not significant. Biological and grain yield were significantly affected by irrigation treatments ($p<0.05$). However, grain protein and harvest index were not significantly different among the irrigation treatments. Cultivar had significant effect only on grain yield ($p<0.05$) while grain protein, biological yield and harvest index were not significantly influenced by cultivar. Interactions of year × irrigation on all the measured traits were not significant while interactions of year × cultivar for biological yield, grain yield and harvest index ($p<0.01$) were significant (Table 1).

Mean comparisons: Effect of increasing irrigation interval on grain protein content was not significant. However, as water limitation increased percent of grain protein content also slightly increased although this increasing was not significant (Table 2). This result may be due to reduction in development period leading to reduction in carbohydrate per protein ratio. Behboudian *et al*. (2001) and Khaled (2010) also reported significant increasing in grain protein under terminal water stress in chickpea and wheat, respectively.

Result showed that grain and biological yield was decreased, as water limitation increased. This reduction was significant under gradual water stress (I_2: 70→90→110→130 and I_3: 70→100→130 mm evaporation from class A pan) and well watering (I_1: 70 mm evaporation from class A pan), compared with water deficit treatments (I_4: 130 mm evaporation from class A pan). There were no

Table 1: Combined analysis of variance of the effects of gradual irrigation levels on various traits of three chickpea cultivars

Source	df	GPC	BY	GY	HI
Year (Y)	1	17.60	99629.0	57478.5	232.06
Rep/Y	4	0.11	157901.5	1266.3	172.66*
Irrigation (I)	3	3.99	513480.6*	56755.0*	18.24
Y×I	3	1.24	66508.1	6002.4	25.07
Ea	12	1.62	91119.0	7124.9	39.19
Cultivar (C)	2	8.05	1939124.0	94483.3*	1737.60
I×C	6	1.83	56901.4	6062.1	88.99
Y×C	2	2.03	2479575.0**	94351.0**	967.20**
Y×I×C	6	1.65	79354.1	5838.1	36.78
Eb	32	1.65	77445.6	6190.7	59.24
CV (%)		1.44	23.62	36.48	23.73

*,** Significant at $p<0.05$ and $p<0.01$, respectively, GPC: Grain protein content; BY: Biological yield; GY: Grain yield; HI: Harvest index

Table 2: Mean comparison of traits for three chickpea varieties under four gradual irrigation levels

Treatment	GPC (%)	BY (g^{-2})	GY (g^{-2})	HI
Irrigation				
I_1	20.52^{a}	994.2^{a}	291.24^{a}	33.28^{a}
I_2	20.81^{a}	760.6^{ab}	200.3^{ab}	33.31^{a}
I_3	21.37^{a}	681.4^{ab}	215.78^{ab}	31.68^{a}
I_4	21.52^{a}	603.3^{b}	156.77^{b}	31.44^{a}
Cultivar				
C_1	21.64^{a}	993.8^{a}	205.26^{b}	23.06^{a}
C_2	20.48^{a}	443.5^{a}	158.81^{b}	39.68^{a}
C_3	21.04^{a}	842.5^{a}	282.99^{a}	34.56^{a}
Year				
2007	19.05^{a}	772.7^{a}	243.94^{a}	34.23^{a}
2008	19.99^{a}	797.1^{a}	187.44^{a}	30.64^{a}

Different letters in each column for each factor indicating significant difference at $p<0.05$. I_1: 70→70; I_2: 70→90→110→130; I_3: 70→100→130, I_4: 130→130, C_1: Hashem, C_2: Pirooz, C_3: Arman, GPC: Grain protein content, BY: Biological yield, GY: Grain yield, HI: Harvest index

significant differences in grain and biological yield among I_1, I_2 and I_3 irrigation treatments. Grain filling period under I_4 was 16 and 9 days shorter than I_1 and gradual water stress treatments (I_2 and I_3), respectively (data not shown), leading to the most reduction in grain yield (Table 2). Mean grain yield under well-watering (I_1) and gradual water deficit (I_2 and I_3) was not statistically significant. However, grain yield per unit area significantly ($p<0.05$) reduced as a result of water deficit (I_4). The present study confirmed previous field studies with chickpea that water deficit reduces grain and biological yield (Behboudian *et al.*, 2001; Bahavar *et al.*, 2009; Niari-Khamssi *et al.*, 2010a).

Mean grain yield per unit area for Pirooz (C_2) was 37 and 78% higher than that for Hashem (C_1) and Arman (C_3), respectively (Table 2). Gradually increasing irrigation intervals improved chickpea resistance to water stress as indicated by non-significant differences in biological and grain yield per unit area under I_1, I_2 and I_3 (Table 2). Significant reduction of these traits under I_4 suggests that chickpea plants cannot adapt to water stress, when it is severe and non-gradual.

Mean value: Grain yield of C_1 in the first year was slightly but not significantly, lower than that of other cultivars. In contrast, grain yield of C_3 in the second year was significantly lower than that

Table 3: Mean values of GP, BY,GY and HI of chickpea cultivars in two years

	Y_1			Y_2		
Traits	C_1	C_2	C_3	C_1	C_2	C_3
BY (g^{-2})	682.80^{b}	725.30^{b}	765.0^{b}	745.60^{ab}	526.70^{c}	780.90^{a}
GY (g^{-2})	197.20^{b}	259.50^{ab}	275.2^{ab}	213.30^{ab}	58.20^{c}	280.80^{a}
HI	28.69^{ab}	35.28^{a}	35.9^{a}	28.41^{ab}	11.03^{c}	35.96^{a}

Different letters in each row for each trait indicating significant difference at $p<0.05$. Y_1: 2007, Y_2: 2008, C_1: Hashem, C_2: Pirooz, C_3: Arman, BY: Biological yield, GY: Grain yield, HI: Harvest index

of C_1 and C_2. C_3 had the highest biological and grain yield in two years while there was no significant difference among three cultivars in first year and between C_1 and C_3 in the second year (Table 3). Chickpea needs the highest water during flowering, podding and grain filling. Therefore terminal water deficit stress is the most important abiotic stress affecting to low productivity in Iran (Niari-Khamssi *et al.*, 2010b). Increasing crop adaptation to water deficit conditions can be the most economic approach to reduce the use of fresh water resources and to improve crop productivity (Xiong *et al.*, 2006).

The adaptation of a crop variety is the ability of that variety to perform and produce to its maximum in a particular environment. Acclimation to water stress may also lead to a decrease in efficacy of the other processes like photosynthesis and growth.

CONCLUSION

The impact of climatic conditions on chickpea development and productivity was not statistically different in the two years. Progressively increasing irrigation intervals can help the chickpea plants to adopt water stress and prevent significant reductions in biological and grain yield per unit area. Arman is a superior cultivar under both well watering and limited irrigation conditions.

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