INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES
IJPAES
Volume-4, Issue-1, Jan-Mar-2014

ISSN 2231-4490
Coden : IJPAES www.ijpaes.com
Received: 09th Jan-2014 *Revised: 15th Jan-2014* *Accepted: 20th Jan-2014*

Research article

CANOPY GROWTH, IRRIGATION WATER USE EFFICIENCY AND RELATIVE WATER CONTENT OF CHICKPEA UNDER ACCLIMATION TO GRADUAL WATER DEFICIT CONDITIONS

Nahid Niari Khamssi[*1], Kazem Ghasemi Golezani[2], Saeed Zehtab[2], Abdollah Najaphy[3]

[1*]Department of Agronomy and Plant Breeding, Faculty of Engineering, Islamic Azad University, Kermanshah Branch, Kermanshah 6715685415, Iran; Tel: +98 831 8324215; Fax: +98 831 8323731
[2]Department of Agronomy and Plant Breeding, Faculty of Agriculture, Tabriz University, Tabriz 5168678531, Iran
[3]Department of Agronomy and Plant Breeding, Campus of Agriculture and Natural Resources, Razi University, Kermanshah 6715685415, Iran

***Corresponding author, e-mail: khamssi@gmail.com**

ABSTRACT: Two field experiments were undertaken in 2007 and 2008 to evaluate the effect of gradual imposition of water deficit stress on percentage ground cover (PGC), irrigation water use efficiency (IWUE), relative water content (RWC), grain yield (YG) and biomass (BM) of three Kabuli and desi chickpea (*Cicer arietinum* L.) cultivars. Both experiments were arranged as split-plot, based on randomized complete block design in three replications. The irrigation treatments [well watered (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 from class A pan, respectively) and water deficit conditions (I_4: 130 mm evaporation from class A pan)] were assigned to main plots and cultivars were allocated to sub plots. PGC, IWUE, BM and YG were decreased as water limitation increased. These reductions were only significant under water deficit (I_4), compared with control (I_1) for PGC, IWUE, BM and YG. IWUE was not significantly different among I_1 (well watered), I_2 and I_3 (gradual water deficit) treatments. Although increasing irrigation intervals from I_1 to I_4 caused a small non significant reduction in RWC, but it reduced IWUE about 29% in I_4 rather than I_1. All characters included in this study (viz., PGC, IWUE, RWC and BM) were significantly correlated with YG. Non significant differences among I_1, I_2 and I_3 treatments for YG and IWUE, suggest that I_3 can be a more appropriate irrigation treatment for chickpea to obtain optimum yield and to save the water (up to 25%).
Key words: Canopy, Irrigation, Chickpea

INTRODUCTION

Based on recent rates of increase, the world population is expected to double from 6 billion in the next 50 years [1]. Proper management of input using modern technology, particularly irrigation water management, is essential to maximize crop production and return for the farmers [2]. Even if rainfall does not change, increased risks for drought will result from an increased atmospheric evaporative demand in a warmer future climate [3]. A well-managed irrigation envisages maximum yields per unit of water applied with a minimum of unavoidable losses while guaranteeing ecological sustainability [4]. Depending on water availability, small amounts of irrigation water applied at strategic periods could achieve substantial increases in yield and water use efficiency of rain-fed crops [5]. Most chickpea growing areas in Iran have cool and cold semi-arid climates with terminal drought stress during pod filling stage [6]. The reduction in the grain yield in chickpea under drought has been reported to be associated with significant decrease in the above ground dry matter or vegetative biomass [7]. Plants adapt to drought environment either through escape, avoidance, or tolerance mechanisms. Increasing crop tolerance to water limitation would be the most economical approach to enhance productivity and reduce agricultural use of fresh water resources. To survive against the stress, plants have involved a number of morphological, physiological and biochemical responses [8]. In Iran, farmers usually are not able to plant chickpea in the beginning of March due to high moisture in field. Therefore, they often have to plant chickpea in end of March [9]. The crop, in particular, is affected by drought stress because of late sowing.

Terminal drought stress is normally accompanied by increasing temperature towards maturity, often to levels, more than 30^{0}C, which may affect pod filling [10]. It is considered essential that to enhance the adaptation of chickpea varieties to drought prone environments via both genetic and agronomic approaches. The adaptation of a crop variety is the ability of that variety to perform and produce to its maximum in a particular environment [11]. High relative water content (RWC), irrigation water use efficiency (IWUE) and percentage ground cover (PGC) are related to water deficit adaptation, and these parameters have also been proposed as more important indicators of water status than the other water potential parameters under water deficit and drought stress conditions. As available water resources become scarcer, more emphasis should be given to efficient use of irrigation water for maximum economic return and water resources sustainability. Water limitation in the West and North-West of Iran gradually increase during plant growth and development, particularly under rain-fed conditions [8]. Therefore, in this study, we focused for the first time on investigating the adaptation of chickpea to gradual water deficit stress by evaluation of canopy growth, relative water content (RWC), irrigation water use efficiency (IWUE) and yield of desi and kabuli type chickpea cultivars.

MATERIALS AND METHODS

Location and Plant material

Two field experiments were carried out at the Research Farm of Islamic Azad University, Kermanshah Branch (latitude 34º20' N, longtitude 46º20' E, altitude 1351.6 m above sea level) during 2007 and 2008. Kermanshah is located in west of Iran and has a mean annual temperature of 13.8ºC and annual rainfall of 478 mm. The monthly rainfall amounts and mean temperature during the crop season in the two years were given in Fig. 1. The soil texture of the experimental area was sandy-loam. Amounts of field capacity (FC), permanent wilting point (PWP), bulk density (BD) and water holding capacity (WHC) in 0-30 cm, where most of the active roots were concentrated [12]. Amount of some measured traits in different depths are presented in Table 1.

Two kabuli type (Hashem (C_1) and Arman (C_3)) and one desi type chickpea cultivars (Pirooz (C_2)) were planted. The chickpea cultivars were obtained from Dry land Agriculture Research Institute (DARI), Sararoud, Kermanshah, Iran

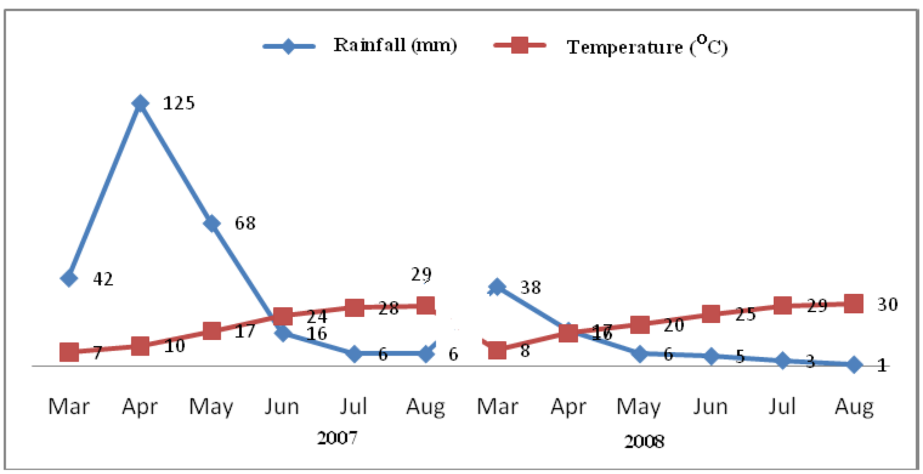

Fig 1. Pattern of monthly rainfall amounts and mean temperatures recorded during the crop season in 2007 and 2008.

Experimental design and irrigation treatments

The experiments were arranged as split-plot, based on randomized complete block design in three replications. The irrigation treatments [well watered (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 from class A pan, respectively) and water deficit conditions (I_4: 130 mm evaporation from class A pan)] were assigned to main plots and cultivars were allocated to sub plots. All plots were irrigated twice after sowing and subsequent irrigations were applied according to the treatments by furrow method. 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 (Table 2).

Fertilizers were applied prior to sowing at the recommended rates of 20 and 30 kg/ha for N as urea and P as TSP, respectively. 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 size of main plots and sub plots were 36 and 12 m^2, respectively. The experimental area was hand weeded.

Measurements

Ground cover was measured using a wooden quadrate frame (50 cm × 50 cm) every week by viewing the canopy from seedling establishment time to seed maturity. The quadrate divided into 100 equal parts. The parts were counted when more than half of each of them filled with crop green area. Water characteristic such as relative water content (RWC) was determined according to Barss and Weatherley [13] using the equation:

$$RWC\ (\%) = [(FW - DW)/ (TW - DW)] \times 100$$

Leaf material was weighed (1 g) to determine fresh weight (FW) and placed in double-distilled water for 24 h at room temperature (about 23^0C) under dim light, and then turgid weight (TW) was recorded. Subsequently, dry weight (DW) was measured after oven drying the samples at 75^0C for 48 h.

The crop evapotranspiration was calculated according to the formula:

$$ET_c = K_c ET_o$$

Where, ET_c is the crop evapotranspiration (mm d^{-1}); K_c the crop coefficient; and ET_o the reference crop evapotranspiration (mm d^{-1}). According to the recommendations of FAO-56 method, under a standard climatic condition, which is defined as a sub-humid climate with average daytime minimum relative humidity (RHmin) of 45% and having calm to moderate wind speeds averaging 2 m s^{-1}, the typical values of K_c for chickpea, $K^*_{c\text{-}ini}$, $K^*_{c\text{-}mid}$ and $K^*_{c\text{-}end}$ are 0.4, 1.0 and 0.35, respectively [14]. Although K_p changes daily, but amount of this parameter at research farm of Kermanshah was estimated 0.88, 0.72 and 0.82 for spring, summer and autumn crops, respectively [15]. Amounts of ET_c for I_1 irrigation treatment are presented in Table 3. Amount of E_p (pan evaporation) for I_1 was 70 and for I_2, I_3 and I_4 were according to Table 2. ET_c amounts for the other irrigation treatments (I_2, I_3 and I_4) are calculated likewise according to table 3. Irrigation water use efficiency (IWUE) was calculated as the ratio of grain yield to the seasonal amount of irrigation water per unit area. A standard irrigation weir was fixed in the entrance of each plot [16]. The flow rate was constant during each irrigation treatment. The formula for calculating IWUE was:

$$IWUE = [YG/(Q \times Tm)] \times 100$$

where, YG, is grain yield (g/m^2); Q, Discharge, liter per second and Tm, is duration of entrance of water to plot from the sown to the harvest. Depth of irrigation in different growth stage of chickpea varied from 4.8 to 11.2 cm. There was no tail water or runoff from the plots. Amounts of irrigation (liters) during growth season for the two years are presented in Table 4. Desi and kabuli type cultivars matured in early July and early August, respectively. At maturity, plants in 1 m^2 of middle part of each sub plot were hand harvested and brought back to the laboratory. 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. Biomass (BM) and grain yield (YG) weight were recorded for each plot in irrigation treatments.

Statistical analyses

Combined analysis of variance appropriate to the split plot design was carried out using SAS software (version 9.1), general linear method (GLM) procedure. Years were considered as random effects, while irrigation treatments and varieties were fixed in the model. Duncan test was used to compare the differences between means of irrigation levels, varieties and interactions of the two factors at $P<0.05$.

Correlation coefficients between traits were calculated by SPSS

RESULTS

Sum of irrigation water amounts (liter) by I_1, I_2, I_3 and I_4 for the three cultivars were 22304, 18058, 16641 and 14571, respectively for the two years (Table 4). Percentage ground cover (PGC) increased with increasing days after emergence (DAE) up to 60 DAE in Hashem and Arman cultivars and 55 DAE in Pirooz in the both years. The reduction of PGC for plants under the fourth irrigation treatment (I_4) started earlier in Pirooz cultivar, compared to the treatment in Hashem and Arman. At most stages of growth in both years, the highest PGC was obtained under I_1, followed by I_2 and I_3, respectively (Fig 2 and Fig 3). These differences were more evident for Pirooz than the two other cultivars. Combined analysis of variance of the data (Table 5) showed that the effect of year on all the measured traits was not significant. PGC, IWUE, YG and BM were significantly affected by irrigation treatments ($P<0.05$). However, RWC was not significantly different among the irrigation treatments. Cultivar had only significant effect on YG, while the other measured traits were not significantly influenced by cultivar. Interactions of year × cultivar for PGC, IWUE, BM and YG were also significant (Table 5).

Table 1. Amount of some measured traits in different depths of the soil

Depth (cm)	*FC*	*BD (gr.cm^{-3})*	*WHC (mm.m^{-1})*	*PWP*
0-30	0.31	1.31	100	0.21
30-60	0.34	1.31	120	0.22
60-90	0.34	1.30	110	0.23

Table 2. The pan evaporation amounts between each irrigation

Irrigation Treatment	Evaporation to 1st Irrigation (mm)	Evaporation to 2nd Irrigation (mm)	Evaporation to 3rd Irrigation (mm)	Evaporation to 4th Irrigation (mm)	All succeeding (mm)
I1	70	70	70	70	70
I2	70	90	110	130	130
I3	70	100	130	130	130
I4	130	130	130	130	130

*I_1, I_2, I_3, I_4: 70**;** 70…90…110…130**;** 70…100…130 and 130 mm evaporation from class A pan, respectively*

Table 3. Amounts of ET_c for I_1 irrigation treatment of Arman (C_3)

Growth stages	Irrigation No.	Kcp (Kc×Kp)	Etc (Kcp×Ep) [mm]
	1	(0.4×0.88) = 0.35	24.6
Vegetative phase	2	(0.5×0.88) = 0.44	30.8
	3	(0.7×0.88) = 0.61	43.1
	4	(1×0.88) = 0.88	61.6
	5	(1×0.88) = 0.88	61.6
Reproductive phase	6	(0.7×0.72) = 0.50	35.2
	7	(0.35 ×0.72) = 0.36	25.2

ET_c: The crop evapotranspiration; K_c:The crop coefficient; K_p: The reference crop coefficient; E_p: The pan evaporation (70 mm)

Table 4. Irrigation amounts during growth season for chickpea cultivars in the two years

Sum of irrigation amounts (liters)													
		C_1				C_2				C_3			
Year	DAE	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
	20	300	202	197	181	200	160	150	95	300	300	250	210
2007	40	900	600	500	499	507	400	390	292	851	842	622	569
	60	1636	1132	900	859	1044	760	709	603	1602	1585	1141	958
	80	390	300	345	400	300	287	240	190	601	545	440	359
Total (liters)		3226	2234	1942	1939	2051	1607	1489	1180	3354	3272	2453	2096
	20	389	320	280	280	269	234	218	199	400	347	290	250
2008	40	1168	966	931	883	900	781	715	590	1250	1100	998	810
	60	2500	2000	1962	1905	1770	1603	1500	1160	2600	2300	2100	1800
	80	989	744	600	521	638	500	496	398	800	750	640	560
Total (liter)		5046	4030	3773	3589	3577	3118	2929	2347	5050	4497	4028	3420

*DAE: days after emergence; I_1, I_2, I_3, I_4: 70**;** 70…90…110…130**;** 70…100…130 and 130 mm evaporation from class A pan, respectively. C_1=Hashem, C_2=Pirooz, C_3=Arman*

PGC, IWUE, BM and YG were decreased as water limitation increased. This reduction was only significant under water deficit (I_4), compared with control (I_1) for PGC, BM and YG. The highest PGC was recorded for I_1 irrigation treatment, but there was no significant difference among I_1, I_2 and I_3. Irrigation water use efficiency ranged from 0.357 to 0.468 g cm^{-3}. The highest IWUE value was obtained at I_2 irrigation treatment, nevertheless no significant difference was observed among I_1, I_2 and I_3. There was significant reduction of IWUE under water deficit (I_4), compared with control (I_1) and gradual water deficit (I_2 and I_3). In contrast, no significant differences in RWC were recorded among irrigation treatments (Table 6). Mean grain yield under well-watered (I_1) and gradual water deficit (I_2 and I_3) treatments was not statistically significant. However, grain yield per unit area significantly reduced as a result of severe water stress. Mean grain yield per unit area for Arman (C_3) was 37% and 78% higher than that for Hashem (C_1) and Pirooz (C_2), respectively (Table 6).

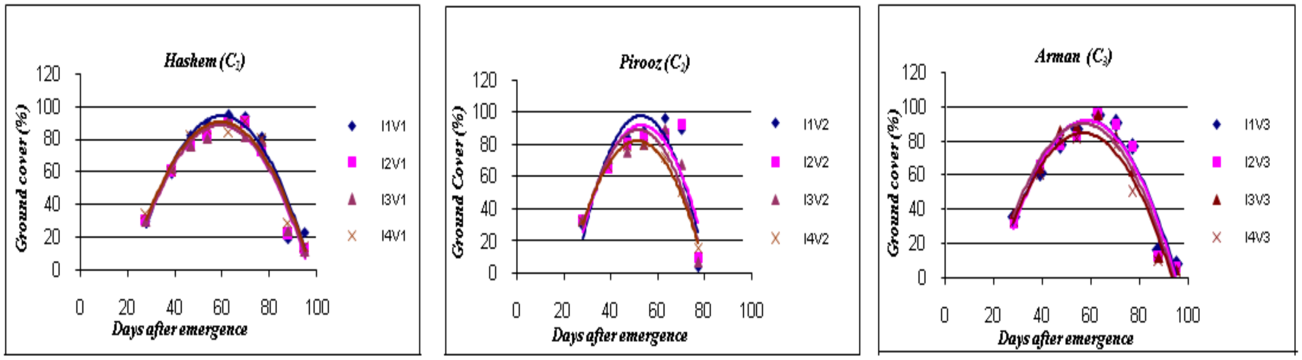

Fig 2. Changes in percentage ground cover of three cultivars under irrigation treatments in 2007

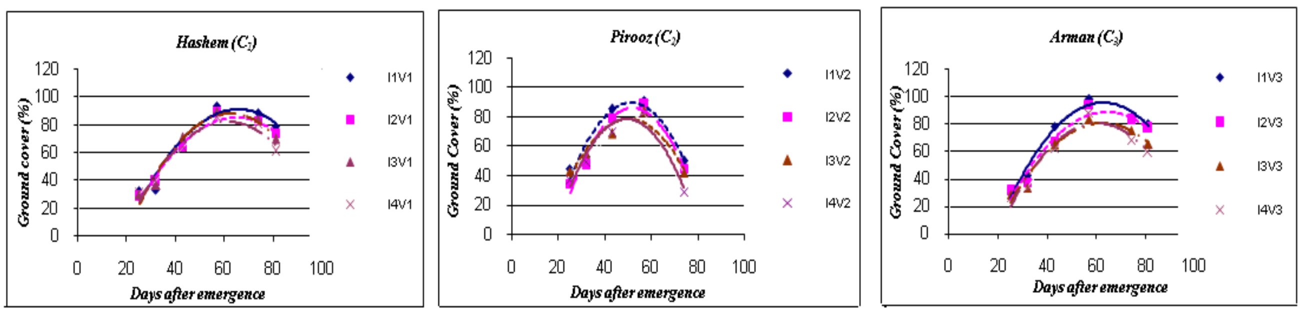

Fig 3. Changes in Percentage ground cover of three cultivars under irrigation treatments in 2008

Table 5. Combined analysis of variance of the effects of gradual irrigation levels on various traits of three chickpea varieties

Source	df	PGC	RWC	IWUE	BM	YG
Year (Y)	1	60.5	426.56	0.008	99629	57478.5
Rep/Y	4	20.69	64.94	0.006	157901.5	1266.3
Irrigation (I)	3	351.4*	121.98	0.076*	513480.6*	56755*
Y×I	3	43.43	107.55	0.023	66508.1	6002.4
Ea	12	67.95	235.54	0.007	91119	7124.9
Cultivar (C)	2	257.2	245.92	0.063	1939124	94483.3*
I×C	6	40.94	54.97	0.019	56901.4	6062.1
Y×C	2	47.54*	63.47	0.06*	2479575**	94351**
Y×I×C	6	44.3	75.42	0.008	79354.1	5838.1
Eb	32	67.51	56.51	0.008	77445.6	6190.7
CV (%)		9.1	11.42	25.06	23.62	36.48

*PGC: Percentage Ground Cover, RWC: Relative Water Content, IWUE: Irrigation Water Use Efficiency, BM: Biomass and YG: Grain Yield. *,** significant at P<0.05 and P<0.01, respectively*

In general, the impact of climatic conditions on chickpea development and productivity was not statistically different in the 2 years (Table 6 and Table 7). The superiority of Arman (Kabuli type) in producing comparatively greater grain yield could be attributed to higher PGC of this cultivar in both years. Arman had the highest PGC in both years and the differences among all cultivars in the first year and between Hashem and Arman in the second year were not statistically significant. The lowest PGC in both years was recorded for Pirooz. Although Arman had the highest IWUE in both years, the differences with Pirooz in the first year and with Hashem in the second year were not statistically significant (Table 7). YG and BM of Hashem in the first year were slightly, but not significantly, lower than that of other cultivars. In contrast, YG and BM of Pirooz in the second year were significantly lower than that of Hashem and Arman. Arman had the highest IWUE, YG and BM in the both years (Table 7). The correlation coefficients among the traits are presented in Table 8. Results revealed that all characters included in this study (viz., PGC, IWUE, RWC and BM) were positively correlated with YG. Correlation between IWUE and PGC in this research was positive and significant (r = 0.655**). PGC was positively correlated with grain yield (r = 0.764**).

Table 6. Mean comparison of traits for three chickpea varieties under four gradual irrigation levels

Treatment	PGC	RWC	IWUE (g/cm^3)	BM (g/m^2)	YG (g/m^2)
Irrigation					
I_1	94.8a	67.77a	0.436a	994.2a	291.24a
I_2	91.4ab	67.23a	0.468a	760.6ab	200.3ab
I_3	90.1ab	67.04a	0.460a	681.4ab	215.78ab
I_4	84.5b	61.91a	0.357b	603.3b	156.77b
Cultivar					
C1	89.9a	67.89a	0.374a	993.8a	205.26b
C2	86.4a	62.13a	0.425a	443.5a	158.81b
C3	92.9a	67.43a	0.478a	842.5a	282.99a
Year					
2007	91.3a	63.39a	0.437a	772.7a	243.94a
2008	88.4a	68.25a	0.416a	797.1a	187.44a

PGC: Percentage Ground Cover, RWC: Relative Water Content, IWUE: Irrigation Water Use Efficiency, BM: Biomass and YG: Grain Yield. Different letters in each column for each factor indicating significant difference at P<0.05.I_1, I_2, I_3, I_4: 70**;** 70…90…110…130**;** 70…100…130 and 130 mm evaporation from class A pan, respectively. C_1=Hashem, C_2=Pirooz, C_3=Arman

Table 7. Mean values of four traits of chickpea cultivars in the two years

Traits	2007			2008		
	C_1	C_2	C_3	C_1	C_2	C_3
PGC	8.1b	4.2b	8.6b	10.2a	3.4c	12.4a
IWUE(g/cm^3)	0.33b	0.48a	0.49a	0.41ab	0.36b	0.57a
YG (g/m^2)	197.2b	259.5ab	275.2ab	213.3ab	58.2c	280.8a
BM(g/m^2)	682.8b	725.3b	765.0b	745.6ab	526.7c	780.9a

IWUE: Irrigation Water Use Efficiency, YG: Grain Yield and BM: Biomass Different letters in each row for each trait indicating significant difference at P<0.05.
C_1=Hashem,C_2=Pirooz,C_3=Arman

Table 8. Correlation coefficients of some traits in chickpea cultivars

	PGC	RWC	IWUE	BM
RWC	0.554			
IWUE	0.655**	0.083		
BM	0.629**	0.682**	0.146	
YG	0.764**	0.565*	0.626**	0.735**

PGC: Percentage Ground Cover, RWC: Relative Water Content, IWUE: Irrigation Water Use Efficiency, BM: Biomass and YG: Grain Yield. *,** significant at P<0.05 and P<0.01, respectively

DISCUSSION

Percentage ground cover for three cultivars under irrigation treatments in both years (Fig 2 and Fig 3), showed that maximum PGC was obtained under well watered treatment (I_1), led to the highest grain yield in this irrigation treatment rather than the other treatments. Husain et al. [17] reported that total dry matter production and seed yield of field bean were strongly correlated with total green area duration (GAD) and post-flowering GAD, respectively. Our results also indicated the effect of irrigation water amount on production and duration of chickpea green cover. In well watered conditions, plants continued to produce more green area. Development of optimal leaf area is important to photosynthesis and grain yield. Water stress primarily reduces leaf growth and in turn leaf area in chickpea and many other plant species [18, 19, 20]. Reduction in plant and leaf growth rates is an early phenomenon that occurs before decreases in leaf water potential can be detected [21]. Gradually increasing irrigation intervals improved chickpea resistance to water stress as indicated by non-significant differences in PGC, IWUE, BM and grain yield per unit area under I_1, I_2 and I_3 (Table 6). The irrigation water amounts in I_2 and I_3 treatments were 19% and 25 % lower than those in I_1, respectively, while there were no significant differences among the three treatments for all of the measured traits.

Significant reduction of the traits under I_4 suggests that chickpea plants cannot adapt to water stress, when it is severe and non-gradual. Inadequate irrigation application results in crop water stress and yield reduction. Excess irrigation application may lead to pollution of water sources due to the loss of plant nutrients through leaching, runoff, and soil erosion. 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 [22]. 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. Although increasing irrigation intervals from I_1 to I_4 caused a small reduction (not significant) in RWC, but it reduced IWUE about 29% in I_4 rather than I_1. According to Anwar et al. [12], low green area index coupled with low stomatal conductance is mainly responsible for low water use from stressed chickpea plants.
Similar relationship was found for Pirooz in the second year, which had the lowest PGC and grain yield (Table 7). Anwar et al. [12] observed that kabui chickpeas produced higher biomass and grain yield. It has been shown that there is a strong positive relationship between PGC and light interception [23]. We found a significant positive correlation between PGC and grain yield (r = 0.764**). On the other hand, percentage ground cover was also positively correlated with IWUE (r = 0.655**). Therefore PGC can be used as a reliable criterion in selection of water stress tolerant chickpea cultivars. Water management through controlling the quantity of irrigation water during vegetative growth and /or reproductive growth deserves attention in high evaporative environments to minimize the reduction of crop growth, yield and achieve higher efficiency in water use [24].

CONCLUSION

Gradually increasing irrigation intervals can help the chickpea plants to adapt water stress and prevent significant reductions in percentage ground cover, irrigation water use efficiency, biomass and grain yield per unit area. Non significant differences among I_1, I_2 and I_3 treatments for grain yield and irrigation water use efficiency, suggest that I_3 can be a more appropriate irrigation treatment for chickpea to obtain optimum yield and to save the water (up to 25%). Percentage ground cover, irrigation water use efficiency and biomass were significantly correlated with grain yield. Ground cover could be as a reliable index for selecting high yielding chickpea cultivars. Arman was a superior cultivar under both well watered and limited irrigation conditions.

ACKNOWLEDGMENTS

The authors thank the Kermanshah Azad University for providing the necessary facilities. We also thank Dr. B. Farhadi and Mr. H. Mirzaei for their helpful suggestions.

REFERENCES

[1] Cohen, J.E. 2003. Human population: the next half century. Science 302 (5648): 1172-1175.
[2] Panda, R.K., Behera, S.K., Kashyap, P.S. 2004. Effective management of irrigation water for maiz under stressed conditions. Agric. Water Manage. 66(3), 181-203.
[3] Bolle, H.J. 2003. Climate, climate variability and impacts in the Mediterranean area: An overview. P. 5-86. In HJ Bolle (ed.) Mediterranean climate: Variability and trends. Springer, Berlin.
[4] Cetin, O., Bilgel, L. 2002. Effects of different irrigation methods on shedding and yield of cotton. Agric. Water Manage. 54, 1-5.
[5] Bouthiba, A., Debaeke, P., Hamoudi, S.A. 2008. Varietal differences in the response of durum wheat to irrigation strategies in a semi-arid region of Algeria. Irrig. Sci. 26, 239-251.
[6] Soltani, A., Khooie, F.R., Ghasemi, K., Moghadam, M. 2001. A simulation study of chickpea crop response to limited irrigation in a semiarid an environment. Agric. Water Manage. 49, 225-237.
[7] Basu, P.S., Ali, M., Chaturvedi, S.K. 2004. Adaptation of photosynthetic Components of chickpea to water stress. International Crop Science Congress, Queensland, Australia.
[8] Niari Khamssi, N., Ghassemi, K., Zehtab, S., Najaphy, A. 2010. Effect of water deficit stress on field performance of chickpea cultivars. Afri. J. Agric. Res. 5(15), 1973-1977.
[9] Sabaghpoure, S.H., Mahmodi, A., Saeed, A., Kamel, M., Malhotra, R.S. 2006. Study on chickpea drought tolerance lines under dryland condition of Iran. Indian J. Crop Sci. 1, 70-73.
[10] Toker, C., Cagirgan, I. 1998. Assessment of response to drought stress of chickpea lines under rainfed conditions. Turk. J. Agric. Forest. 22, 615-621.
[11] Yadav SS, Kumar J, Turner NC 2004. Enhancing adaptation of larg-seeded kabuli chickpea to drought prone environments. Crop Sci 44: 134-139.

[12] Anwar, M.R., Mckenzie, B.A., Hill, G.D. 2003. Water use efficiency and the effect of water deficits on crop growth and yield of Kabuli chickpea in a cool temperature sub-humid climate. J. Agric. Sci. 141, 285-301.
[13] Barrs, H.D., Weatherley, P.E. 1962. A re-examination of the relative turgidity technique for estimating water deficit in leaves. Aust. J. Biol. Sci. 15, 413-428.
[14] Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998. Crop Evapotranspiration, Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage Paper 56. FAO, Food and Agriculture Organization of the United Nations, Rome, Italy, 293 pp.
[15] Ahmadi, M., Farhadi Bansouleh, B., 2012. Spatial and temporal variation of evaporation pan coefficient in Kermanshah province. Nivar Journal, In Persian, Accepted. In Press.
[16] Sree Ramulu, U.S. 2005. Management of water resources in agriculture. New Age International (P) Ltd., Publishers, New Delhi, pp 38-39.
[17] Husain, M.M., Hill, G.D., Gallagher, J.N. 1988. The response of field beans to irrigation and sowing date. II. Growth and development in relation to yield. J. Agric. Sci. Cam. 111, 232-245.
[18] Wullschleger SD, Yin TM, Difazio SP, Gunter LE, Davis MF, Tuskan Ga 2005. Phenotypic variation in growth and biomass distribution for two advanced-generation pedigrees of hybrid poplar. Canad J Forest Res 35: 1779-1789.
[19] Farooq, M., Wahid, A., Kobayashi, N., Fujita, D., Basra, S.M.A. 2009. Plant drought stress: effects, mechanisms and management. Agron. Sustain. Dev. 29, 185-212.
[20] Krouma, A. 2010. Plant water relations and photosynthetic activity in three Tunisian chickpea genotypes subjected to drought. Turk. J. Agric. For. 34, 257-264.
[21] Sanchez, F.J., De Andres, E.F., Tenorio, J.L., Ayerbe, L. 2004. Growth of epicotyls. Turgor maintenance and osmotic adjustment in pea plants subjected to water stress. Field Crop Res. 86, 81-90.
[22] Xiong L, Wang RG, Mao G, Koczan, JM 2006. Identification of drought tolerance determinants by genetic analysis of root response to drought stress and abscisic acid. Plant Physiol 142: 1065-1074.
[23] Burstall, L., Harris, P.M. 1983. The estimation of percentage light interception from leaf area index and percentage ground cover in potatoes. J. Agric. Sci. Camb. 100, 241-244.
[24] Eck HV 1985. Effect of water deficit on yield, yield components and water use efficiency of irrigated corn. Agron. J. 76, 421-428.