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*Full Length Research Paper*

# Drought stress mitigation using supplemental irrigation in rainfed chickpea (*Cicer arietinum* L.) varieties in Kermanshah, Iran

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**An experiment was carried out in 2007 to investigate the effects of different irrigation regimes, and chickpea cultivars on chickpea production in the Agricultural Research Station, College of Agriculture, Islamic Azad University, Kermanshah Branch, Iran. The experimental design was split-plot with three replications. Supplemental irrigation at three levels, that is, control treatment (without irrigation) ($I_0$), one time irrigation at 50% flowering stage ($I_1$) and one time irrigation at pod-filling stage($I_2$), was allocated to main plots and the varieties ILC-482 ($V_1$), Hashem ($V_2$) and Arman ($V_3$) were allotted to sub plots. A significant difference was observed between irrigation treatments in terms of grain yield, plant height, number of axillary branches, distance to the first pod from soil surface, number of grain per plant, number of pod per plant, biological yield, harvest index and 100-grain weight. Such differences were also observed between testing varieties in terms of all traits rather than 100-grain weight. Grain yield was significantly higher for Arman than that of Hashem which was significantly higher than that of ILC-482. Of course, there was no significant difference between Hashem and ILC-482 in terms of grain yield. Arman had the highest values of the number of grain per plant and the highest pod per plant pertained to Arman and Hashem, respectively. High rate of grain yield in irrigation treatment at pod-filling stage was associated with yield components, especially with the number of pod per plant and 100-grain weight. Grain yield was positively correlated with number of pod per plant ($r = 0.654^{**}$), number of grain per plant ($r = 0.902^{**}$) and 100-grain weight ($r = 0.707^{**}$). This research showed that pod-filling is the most sensitive stage to drought stress, and under water limitation conditions, we can considerably increase grain yield at this stage by one time irrigation, especially for Arman cultivar.**

**Key words:** Chickpea, supplemental irrigation, drought stress, grain yield, yield components.

## INTRODUCTION

Having cultured area of 755,000 ha, chickpea possesses a vast part of rain-fed farming area in Iran (FAO, 2004). Application of appropriate methods of irrigation, supplemental irrigation, and water harvesting is among strategies reducing the risk of crop production within arid and semi-arid areas, hence providing relatively permanent yield in these areas. In fact, supplemental irrigation is applicable for those crops capable of producing economic products naturally using rainfall water, therefore, irrigation results in their permanence and yield improvement. In other words, supplemental irrigation is aimed at supplying minimum amount of plants water requirement and compared to full-irrigation during plants growth period, its efficiency has been reported about 60 - 70% in some countries (Perrier and Salkini, 1987). Optimal supplemental irrigation is done in dry-farming regions based on three following basic aspects: (i) Water is utilized only to improve rain-fed crop yield with a normal yield without irrigation; (ii) under rain-fed farming, supplemental irrigation is done when rainfall does not provide enough water to prevent drought stress and (iii) the amount and time of

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**Table 1.** Climatological statistics in Kermanshah region in the farming year of 2006 - 2007.

| Months | Climatological factors | | | | | |
|---|---|---|---|---|---|---|
| | Minimum temperature (°C) | Maximum temperature (°C) | Average temperature (°C) | Mount foresting days | Precipitation (mm) | Average humidity (%) |
| October | 7.1 | 33.5 | 19.9 | 0 | 11.3 | 38 |
| November | -1.9 | 24.6 | 11.3 | 3 | 118.8 | 68 |
| December | -7.1 | 13.7 | 3. 2 | 23 | 25 | 66 |
| January | -10.8 | 11.2 | -0.1 | 27 | 30.3 | 70 |
| February | -8.1 | 15.5 | 14.2 | 16 | 81.3 | 66 |
| March | -3.8 | 19.5 | 7.1 | 18 | 42.6 | 63 |
| April | -2.8 | 23 | 10.5 | 5 | 125.4 | 64 |
| May | 1.2 | 30.7 | 17 | 0 | 68.7 | 59 |
| June | 9.5 | 39.4 | 24.7 | 0 | 6. 2 | 36 |
| July | 12.8 | 40.1 | 28.5 | 0 | 0 | 24 |
| August | 14.9 | 41.2 | 29.5 | 0 | 0 | 22 |
| September | 8.8 | 39.1 | 25.1 | 0 | 0 | 18 |

supplemental irrigation are planned to attain optimum yield with the least amount of water available during grain per pod, number of pod per plant, biological yield, and harvest index. Also, Romteke et al. (1998), Summer-field and Roberts (1986), Singh et al. (1991), and Silim and Saxena (1993) have emphasized on the negative effects of moisture defect on chickpea grain yield and yield components. Dahiya et al. (1993) determined nutritional requirement of 2 chickpea varieties in semi-irrigated conditions and specified that their highest yields were attained using 27 kg ha$^{-1}$ nitrogen and 69 kg ha$^{-1}$ phosphorus and by 2 times irrigation at branching stage and onset of pod formation stage, obtaining the maximum consumption of water with one time irrigation. Krentoz (1987) reported the importance of considering amount of consumed water and plant development in supplemental irrigation. Nelson (2001) and Nagarajan et al. (1999) reported a significant negative effect of drought stress on grain yield and biomass of chick pea and wheat at final growth stages. According to Silim et al. (1993), high percentage of green sheath, especially in critical period of grain-filling reduces evaporation from soil surface, results in the improvement of soil moisture status and an increase in the amount of water available for plants, plus superiority of yield under irrigation conditions. Dahiya et al. (1993) argued that two times of irrigation, at branching and the onset of pod formation stages, entailed the highest yield. Drought stress is among the important challenges in chickpea production in the western part of Iran including Kermanshah province. Objectives of this research were as follows:

(i) To study the effect of drought stress on chick pea grain yield;

sensitive stages of crop growth (Oweis, 1997). Yadav et al. (1994) reported that, supplemental irrigation at the
(ii) To understand the advantage of supplemental irrigation in chickpea production and;
(iii) To select adapted varieties for supplemental irrigation.

## MATERIALS AND METHODS

Present research was carried out in cropping season 2006 - 2007 on Agricultural Research Station, College of Agriculture , Islamic Azad University, Kermanshah Branch, Iran (47°20′ E, 34°20′ N, 1362 m ASL). Annual mean precipitation of this station is 435 mm; based on Koppen's classification, this region has cold, semi-arid climate (Table 1). The soil texture of the test site was clayey-silt, with pH 7.5 (Table 2). The previous crop was wheat. On the basis of soil test, 40 kg ha$^{-1}$ urea fertilizer and 80 kg ha$^{-1}$ di-ammonium phosphate fertilizer were applied on late winter.

Experimental design was split plot with three replications. The major factors of experiment were control treatment (without irrigation) ($I_0$), one-time irrigation at 50% flowering stage ($I_1$) and one time irrigation at pod-filling stage($I_2$); and minor factors were varieties including: ILC-482 ($V_1$), Hashem ($V_2$) and Arman ($V_3$), obtained from Dry land Agricultural Research Sub-Institute, Kermanshah, Iran. Each plot consists of 4 rows 4 m long and 25 cm apart. Planting was done with hand on 5th April, 2006. Before planting, the seeds were treated with Mankuzeb fungicide. For hand planting, in each plots, 4 grooves with 5 cm depth were made with Fuka and seeds density were twice of recommended amount and target density was achieved by thinning plants after seeds germination. For supplemental irrigation at 50% flowering and pod-filling stage, a sample of soil was taken from 0 - 60 cm depth and sent to the laboratory for measuring soil moisture and accordingly, the required amount of water for each treatment to reach to field capacity was calculated and based on required irrigation, was applied using water counter. Laboratory soil water measurements indicated that the limits of field capacity were 16.7 and 17.8% of weight at 50% flowering and pod-filling stages, respectively, and nominal specific mass of soil was 1.32 gcm$^{-3}$. To estimate moisture

**Table 2.** Chemical and physical characteristics of the soil.

| Depth (cm) | pH | EC (mmohs/cm) | %C | %N | P (ppm) | K (ppm) | %Silt | %Clay | %Sand | Texture |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 – 30 | 7.5 | o. 8 | 1.95 | 0.11 | 7 | 300 | 42.6 | 41.41 | 14 | Silty clay |

coefficient (FC) and nominal specific mass (BD), such parameters as soil texture and content of soil organic matter were employed, then the amount of net irrigating water at the stages of 50% flowering and pod-filling were estimated at 134.64 and 146.30, respectively, by using equation of moisture fraction.

$$In = (FC - M) \times BD \times D$$

Where BD, is nominal specific mass gcm-3; D is the depth of root extending (60 cm); M is weight of moisture pre-irrigation; and In is the depth of net irrigation water fraction. Ten plants from each plot were used to specify yield components and plant morphological traits. Grain yield was calculated after eliminating two side rows of each plot and 0.5 m from both ends of central rows. Parameters of rainfall rate and diurnal temperatures were obtained from Meteorology General Office of Kermanshah province .Statistical analysis was performed by MSTATC and SPSS software.

## RESULTS AND DISCUSSION

### Number of axillary branches per plants

A number of axillary branches per chickpea plant was significantly affected by an irrigation factor (Table1). Among various irrigation levels, maximum number of axillary branches per plant pertained to the treatment with on-time irrigation at pod-filling stage was 58.1% higher than the number of axillary branches under or without irrigation conditions. Although there was no significant difference between none-irrigation and one-time irrigation at 50% flowering stage, the treatment with one-time irrigation at 50% flowering stage and the treatment without irrigation were, respectively, ranked after the treatment with one-time irrigation at pod-filling stage in terms of a decrease in number of axillary branches (Table1). Palled et al. (1985) reported that the number of axillary branches per plant increased due to irrigation. Auld et al. (1980) reported that the number of branches per unit area decreases as moisture available at terminative stage reduces. The effect of varieties on number of axillary branches per plant was significant and Arman had the highest number followed by ILC-482 and Hashem. Interaction between irrigation and variety was not significant for the number of axillary branches per plant (Table 1), indicating that tested varieties gave the same responses to irrigation treatments.

### Number of pod per plant

Number of pod per plant was highly significantly influenced by irrigation factor (Table 1). Compared to treatment without irrigation, the treatments with only one-time irrigation at 50% flowering and pod-filling stages had 149.9 and 117.9% increases in the number of pod per plant, respectively (Table 2). Number of pod per plant was highly/significantly affected by variety factor (Table 1). Number of pods per plant was significantly higher for Arman and Hashem than that of variety ILC-482. There was no significant difference between Arman and Hashem in this regard (Table 3). Results of experiment showed that sufficient available water at flowering and pod formation stages increases the number of pods per plant. The existence of significant difference between tested varieties considering the number of pod per plant indicates the effect of genetic background on this trait. For chickpea and Mungbean, Singh et al. (1994) and Pannu and Singh (1993), respectively, reported that among yield components, the number of pod per plant is more sensitive to drought stress.

### Number of grain per plant

Effects of irrigation and variety on the number of grain per plant were highly significant (Table 1) so that the highest number of grain per plant pertained to the treatment with on-time irrigation at pod-filling stage followed by treatment with one-time irrigation at 50% flowering stage and treatment without irrigation. The treatment with one-time irrigation at pod-filling stage had a 188% increase in number of grain per chickpea plant in comparison with the treatment without irrigation (Table 2). There was no significant difference between ILC-482 and Hashem in terms of the number of grain per plant (Table 2). The highest number of which pertained to Arman.

### 100 grains weight

The weight of 100 grains of chickpea was highly/ significantly affected by irrigation (Table 1). Among different irrigation levels, the maximum weight of 100 grains pertained to treatment with one-time irrigation at pod-filling stage while the minimum of it pertained to the treatment without irrigation (Table 2). The significant effect of irrigation on grain weight during varied stages of plant growth, especially at grain-filling stage, has been reported as common by Singh (1995). And Tuba Bicer et al. (2004) reported that chickpea 100 grain weight was affected by irrigation. It appears that moisture defect at

**Table 3.** Analysis of variance of agronomical characteristics.

| SOV | df | Plant height | No. of axillary branch | Distance from first pod to soil surface | No. of pods per plant | No. of grains per plant | Weight of 100 grains | Grain yield | Biological yield | Harvest index |
|---|---|---|---|---|---|---|---|---|---|---|
| Rep | 2 | 83.468 | 0.038 | 0.298 | 6.763 | 2.484 | 13.488 | 559.707 | 99804.167 | 8/417 |
| V | 2 | 197.514** | 2.629** | 45.818** | 104.536** | 71.901** | 10.290** | 685294.374** | 2471394.641** | 434.710 ns |
| Error (a) | 4 | 10.131 | 0.091 | 0.179 | 4.604 | 1.252 | 7.311 | 13260.269 | 22694.694 | 5/649 |
| I | 2 | 339.488** | 6.629** | 76.001** | 28.936** | 100.323** | 154.030** | 919762.907** | 4931525.470** | 17.667** |
| I × V | 4 | 1.377ns | 0.489ns | 0.952ns | 2.662** | 1.521ns | 9.470ns | 53364.402 ns | 189479.580** | 0.540ns |
| Error (b) | 12 | 6.261 | 0.295 | 2.387 | 7.196 | 2.070 | 5.965 | 19625.306 | 27762.785 | 1/179 |
| C.V (%) | - | 7.19 | 17.95 | 10.79 | 25.30 | 14.85 | 9.22 | 15.86 | 6.65 | 3/11 |

NS,* and **: Non-significant at $p < 0.05$, significant at 5 and 1% level of probability, respectively.

the time of pod formation and grain-filling can decrease the rate of photosynthetic products transmission, resulting in grain shriveling. Given that, in this research, supplemental irrigation has been done at pod formation and grain-filling stage, moisture defect has been resolved fairly, therefore, period of grain-filling has lengthened, as a result more photosynthetic products accumulated in grains. So, supplemental irrigation at this stage has resulted in a 137% increase in the weight of 100 grains compared to rain-fed conditions (Table 2). Silim et al. (1993) report is in agreement with findings of this experiment.

## Plant height

The effects of irrigation and variety on plants height was highly significant ($P < 0.01$) (Table 1). One-time irrigation at pod-filling stage caused the highest plant height and rain-fed condition caused the lowest (Table 2). Arman had the highest plant height, and there was no significant difference between Hashem and ILC-482 (Table 2). Hawtin and Singh (1984) suggested that variation in plants height depends on variety, latitude, and date of planting. In fact, water defect at vegetative and generative stages decreased plants height. Results of this experiment for plant height are similar to the results reported by Gupta et al. (1995).

## First pod height from soil surface

The effects of irrigation and variety on height of first pod from soil surface were significant (Table 1).The highest and lowest FPH from soil surface pertained to the treatment with one-time irrigation at pod-filling stage and rain fed treatment, respectively (Table 2). The highest value of FPH and the lowest one pertained to Arman and ILC-482, respectively (Table 2).

## Biological yield

Irrigation has a highly significant effect on biological yield (Table 1). The treatment with one-time irrigation at pod-filling stage had the highest biological yield and rain fed treatment had the lowest (Table 2). Sharp reduction of shoots weight and photosynthetic products due to water limitation has been reported by Singh et al. (1987) and Xia (1997). The effect of variety on biological yield is significant (Table 1). Among tested varieties, Hashem had the highest biological yield followed by Arman and ILC-482 (Table 2). Interaction between irrigation and variety were significant (Table 1) and accordingly, the highest biological yield pertained to the combined treatment of Arman and one-time irrigation at pod-filling stage and the lowest biological yield pertained to the treatment of ILC-482 under rain-fed condition (Table 2).

## Harvest index

Harvest index was significantly affected by irrigation treatments (Table 1). The maximum and minimum harvest indexes pertained to the treatment with one- time irrigation at pod-filling stage and to rain-fed treatment, respectively (Table 2). There was no significant difference between treatment with one-time irrigation at pod-filling stage and rain-fed treatments at 50% flowering stage. Chickpea harvest index was signi-

**Table 4.** Mean comparison of agronomical characteristics.

| Treatments | Means | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plant height (cm) | No. of axillary branch | Distance from first pod to soil surface (cm) | No. of pods per plant | No. of grains per plant | Weight of 100 grains g | Grain yield (kg/h) | Biological yield (kg/h) | Harvest index (%) |
| Irrigation (I) | | | | | | | | | |
| $I_0$ | 28.46C | 2.311B | 11/44C | 7/244B | 7/178B | 22/03C | 551/1C | 1796C | 33/36B |
| $I_1$ | 35.30A | 2.789B | 14/27B | 8/544AB | 8/411B | 27/27B | 900/6B | 2451/4B | 35/26A |
| $I_2$ | 40.71A | 3.978A | 17/26A | 10/790A | 13/480A | 30/20A | 1194/2A | 3274/2A | 36/09A |
| Variety (V) | | | | | | | | | |
| $V_1$ | 31/28B | 2/511C | 12/10C | 4/989C | 7/456B | 26/270A | 667/2B | 1913/1C | 34/48B |
| $V_2$ | 33/06B | 2/978B | 14/26B | 10/181A | 8/744B | 25/571A | 788/5B | 2904/6A | 28/17C |
| $V_3$ | 40/13A | 3/589A | 16/61A | 11/415A | 12/870A | 27/670A | 1194/6A | 2704/3B | 42/05A |
| Irrigation × Variety (I × V) | | | | | | | | | |
| $V1I_0$ | 24/63F | 1/600D | 8/967E | 4/367D | 4/867D | 22/60CD | 400/2F | 1157/4D | 33/19D |
| $V1I_1$ | 31/805D | 2/633C | 12/33CD | 4/300D | 6/767D | 27/75B | 700/4DE | 2027/3C | 34/74CD |
| $V1I_2$ | 37/40BC | 3/300C | 15/00BC | 6/300CD | 10/730BC | 28/63B | 900/3CD | 2555/1B | 35/52C |
| $V2I_0$ | 26/10E | 2/567C | 11/57DE | 8/033BCD | 6/867D | 22/03CD | 564/8EF | 2463/6B | 26/25F |
| $V2I_1$ | 33/77CD | 2/700C | 14/53BC | 10/630ABC | 6/767D | 26/30BC | 750/3DE | 2632/5B | 29/01E |
| $V2I_2$ | 39/30B | 3/667B | 16/67B | 11/870AB | 12/600B | 28/37B | 10/51BC | 3618/6A | 29/25E |
| $V3I_0$ | 34/63CD | 2/767BC | 13/80BCD | 9/333ABCD | 19/800C | 2147D | 700/3BE | 1769/0C | 40/63B |
| $V3I_1$ | 40/33B | 3/033BC | 15/93B | 10/700ABC | 11/700BC | 27/93B | 1251/04B | 2695/9B | 42/02AB |
| $V3I_2$ | 45/43A | 4/967A | 20/10A | 14/200A | 17/100A | 33/60A | 1630/5A | 3648/4A | 43/50A |

In each column, values with similar letter(s) are not significantly different at the 5% level of probability $I_0$, $I_1$ and $I_2$: without irrigation, one-time irrigation at 50% flowering stage and one time irrigation at pod-filling stage, respectively. $V_1$, $V_2$ and $V_3$: ILC-482, Hashem and Arman, respectively.

ficantly affected by variety factor (Table 1). The highest and lowest values of harvest index pertained to Arman and Hashem, respectively (Table 2). Harvest index of Hashem was lower than those of the other two varieties, which is attributed to late maturity and lack of timely formation of flowers, pods, and grains of this variety. Having done an experiment on 25 chickpea genotypes under rain-fed and irrigation conditions in Syria, Singh and Saxena (1991) concluded that grain size, grain yield, biological yield, and harvest index are improved by irrigation, which is in agreement with the result of the present experiment.

## Grain yield

Irrigation effect on chickpea grain yield was significant (Table 1). One-time irrigation at pod-filling stage had the highest grain yield (1194.2 kg $ha^{-1}$), having a 216.7% increase in yield of chickpea grains in comparison with rain-fed condition. Saxena (1980) reported that using supplemental irrigation in order to resolve stress at critical stages of plant growth had significant effect on grain yield increase. Also many researches have emphasized on the effect of water defect on reduction of yield throughout plant growth period, especially at the stages of grain formation and grain-filling (Desclauxs and Roumet, 1996; Meckel et al., 1984; Shaw and Laing, 1996; Specht et al., 1989; Vieira et al., 1991; Xia, 1997). The effect of variety on chickpea grain yield per unit area was completely significant (Table 1). Arman's variety had the highest grain yield (1194.6 kg $ha^{-1}$), which was significantly different from means of grain yield of Hashem (788.5 kg $ha^{-1}$) and ILC-482 (667.2 kg $ha^{-1}$). Literatures indicated that using supplemental irrigation to free the crops from soil moisture stress at critical growth and development stages, would increase chickpea grain yield (Soltani et al., 2001). It appears that water defect at chickpea generative stages prevents yield potential attainment through flowers and pods shedding (Nayyar et al., 2006). Iyadao et al. (1994), Romteke et al. (1998) and Ney et al. (1994) have reported an increase in grain yield due to

**Table 5.** Correlation among traits in chickpea.

| Traits | Plant height | No. of axillary branch | Distance from first pod to soil surface | No. of pods per plant | No. of grains per plant | Weight of 100 grains | Harvest Index | Biological yield | Grain yield |
|---|---|---|---|---|---|---|---|---|---|
| Plant height | 1 | | | | | | | | |
| No. of axillary branch | 0.712** | 1 | | | | | | | |
| Distance from first pod to soil surface | 0.852** | 0.839** | 1 | | | | | | |
| No. of pods per plant | 0.624** | 0.615** | 0.651** | 1 | | | | | |
| No. of grains per plant | 0.803** | 0.812** | 0.837** | 0.558** | 1 | | | | |
| Weight of 100 grains | 0.596** | 0.591** | 0.652** | 0.233 ns | 0.679** | 1 | | | |
| Harvest Index | 0.610** | 0.384** | 0.466** | 0.240 ns | 0.561** | 0.366 ns | 1 | | |
| Biological yield | 0.664** | 0.764** | 0.816** | 0.651** | 0.749** | 0.670** | 0.610 ns | 1 | |
| Grain yield | 0.715** | 0.837** | 0.838** | 0.654** | 0.902** | 0.707** | 0.594** | 0.776** | 1 |

NS and **: Non-significant at $p<0.05$ and significant at 1% level of probability, respectively.

supplemental irrigation for chickpea and green pea, respectively.

## Correlation between grain yield and yield attributes

There was highly significant positive correlations between grain yield and number of pods per plant (r = 0.654**), number of axillary branches (r = 0.837**), plant height (r = 0.715**), number of grain per plant (r = 0.902**), 100 grain weight (r = 0.707**), height of first pod from soil surface (r = 0.837**), harvest index (r = 0.594**) and biological yield (r = 0.776**) (Table 3). These results indicated that tallerplants with higher number of axillary branches, which resulted in production of higher number of pods per plant have higher grain yield, and these traits could be used effectively for screening high yielding genotypes. These results are consistent with the results of many workers on chickpea (Sharma et al., 1990; Filippetti., 1990; Mani and Bahl, 1990; Singh and Saxena, 1991; Silim and Saxena, 1993; Chavan et al., 1994; Kumar et al., 2003; Jeena et al., 2005; Obaidullah et al., 2006).

## Conclusion

Results of this research showed that average of grain yield was 1194.2 kg $ha^{-1}$ for treatment with one-time irrigation at pod-filling stage. Showing a 216.7% increase in comparison with rain-fed treatment (551.1 kg $ha^{-1}$). Arman and Hashem had the highest number of grain per plant and number of pod per plant, respectively. Among yield components, the number of pod per plant and 100 grains weight had the most effect on increasing the grain yield. Given the increase in regional temperature in late season usually associated with rainfall stoppage, it appears that using supplemental irrigation at pod-filling stage strengthens the plants in terms of tolerance, transition and escape from dryness of late growth period, and increases velocity of grain-filling and, ultimately, causes an increase and improvement in stabilizing chickpea yield in unit area, especially for Arman's variety.

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