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Effects of irrigation applied at different growth stages on chickpea yield

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Abstract. This study was conducted over the experimental fields of Erciyes University in 2016 to investigate the effects of irrigations applied at different growth stages on chickpea yields. Experiments were conducted in randomized blocks design with 3 replications. There were 7 irrigation treatments as of I_1: rainfed, I_2: pre-bloom single irrigation, I_3: single irrigation at the beginning of blooming, I_4: single irrigation at 50% pod set, I_5: two irrigations at 50% bloom and 50% pod-set, I_6: two irrigations at pre-bloom and 50% pod-set, I_7: full irrigation. The amount of applied irrigation water varied between 85.6–323 mm. Plant water consumptions varied between 262–569 mm. The greatest yield was obtained from I_4 treatment with 273 kg da^{-1} and the lowest yield was obtained from I_1 treatments with 146 kg da^{-1}. It was concluded for chickpea cultivation under deficit water resources conditions that water deficits may be applied at different growth stages except for 50% pod-set period.

Key words: Chickpea, irrigation, yield, ET.

INTRODUCTION

Chickpea kernels contain more than 20% protein, more than 40% carbohydrate, oils, phosphorus and calcium. Therefore, chickpea has always a great significance in human nutrition. Worldwide chickpea production is used as foodstuff in different fashions. It also a legume and thus able to fixate free atmospheric nitrogen into the soil and therefore it is used as a well intercropping plant (Degirmenci et al., 2009).

Chickpea is the most important legume worldwide and 87% of world production comes from Asia, 4.5% from Africa, 4.1% from America and 0.9% from Europe (FAOSTAT, 2014). It is produced over 14 million hectares and annual world production is around 13.7 million tons. In Turkey, chickpea is produced over 388 thousand hectares and annual production is about 450 thousand tons (FAOSTAT, 2015).

Global warming, climate change and rapid increases in world population exert ever-aggravating pressure on water resources (Yılmaz, 2011). Food demand of increasing population can only be met with the optimum utilization of soil and water resources. Sustainable agriculture primarily depends on proper irrigation practices.

Drought is the greatest limiting factor for agricultural production activities (Kalefetoglu & Ekmekci, 2005). Plants are subjected to various levels of droughts from sowing till the harvest (Gunes et al., 2006). Droughts have two major impacts on agriculture. The first one is insufficient emergence and the second one is the decrease in growth and yields because of water deficits (Saxena et al., 1993).

Chickpea plants are quite resistant to droughts, but do not like humid conditions. They can have quite high yield levels with slight irrigations during the dry periods. Besides a proper field preparation, use of high-yield seeds, fertilization and the other cultural practices, irrigation scheduling and amounting are also quite significant issues in chickpea culture (Yolcu, 2008).

In semi-arid climate zones, chickpea culture is commonly carried out under quite dry conditions because of deficit water resources of these regions. One or two irrigations throughout the growing season will greatly improve yield levels in chickpea and consequently will increase the agricultural income of farmers.

The present study was conducted to investigate the effects of supplementary irrigations performed at different growth stages on yield and plant water consumption of chickpea.

MATERIALS AND METHODS

Experiments were carried out over the experimental fields of Erciyes University Agricultural Research and Training Center in 2016. Experimental site has an altitude of 1,094 m and located at 34°56′ north longitude and 36°59′ east longitude. Some weather data for chickpea growth season of 2016 are presented in Table 1. Total rainfall from seeding (13 April) to harvest (11 August) was 179.4 mm for the growth season.

Table 1. Some weather data for the growth season of 2016

Weather data	Months				
	April	May	June	July	August
T_{mean} (°C)	14.02	14.83	20.41	23.33	25.38
T_{max} (°C)	20.4	26.7	34.6	37	34.8
T_{min} (0°C)	4.5	4.4	7.5	10.8	14.5
Wind speed (m s^{-1})	1.57	1.88	1.75	1.81	1.81
Rainfall (mm)	0	151.8	25.6	2	0
RH_{max} (%)	65.2	80.0	78.2	66.1	62.4
RH_{min} (%)	25.5	34.4	30.8	21.1	19.9

T_{mean}, T_{max} and T_{min}: Daily mean, maximum and minimum temperatures of the related month, respectively; RH_{max} and RH_{min}: Monthly averaged maximum and minimum relative humidity.

Soil samples were collected from 1.2 m soil profile at three points. Texture was found as loamy. Soil pH and salinity were suitable for production (Table 2).

Water samples were taken from a deep well within the experimental site. Irrigation water class was C_1S_1 according to Wilcox (1948) (Table 3). Infiltration tests were performed at three different locations and average infiltration rate was found as 23.3 mm per hour.

Table 2. Some soil properties of the experimental site

Soil property	Soil depth			
	0–30 cm	30–60 cm	60–90 cm	90–120 cm
Texture	Loamy	Loamy	Clay-Loamy	Loamy
Salinity (dS m^{-1})	0.22	0.173	0.258	0.191
pH	8.13	8.17	8.14	8.23
Field capacity (%)	23	26	26	25
Wilting point (%)	10.73	11.38	9.3	9.37
Bulk density (g cm^{-3})	1.27	1.24	1.22	1.28
Organic matter (%)	1.25	1.05	0.69	0.73
Lime (%)	2.54	5.83	3.15	6.2
Nitrogen (kg ha^{-1})	2.15	1.05	0.4	0.4
Phosphorus-P_2O_5 (kg ha^{-1})	20.5	11.5	6.0	2.0
Potassiun-K_2SO_4 (kg ha^{-1})	271.6	376.4	310.1	310.1

Table 3. Some properties of irrigation water

pH	EC (µS)	Na^+ (mg L^{-1})	K^+ (mg L^{-1})	Ca^{+2} (mg L^{-1})	Mg^{+2} (mg L^{-1})	HCO_3^- (mg L^{-1})	CO_3^{-2} (mg L^{-1})	SAR	Class
7.6	242	11.6	4.57	26.4	6.63	12.2	< 1.0	2.86	C_1S_1

Electrical conductivity and pH of irrigation water were 242 mS m^{-1} and 7.6, respectively.

A completely randomized blocks design with three replications was used. Row spacing was 35 cm, on-row plant spacing was 5 cm and each plot (5 x 1.75 m) had 6 rows, sowing was performed manually. Observations and harvests were performed from the inner 4 rows. Two side rows were omitted as to consider the side effects. A spacing of 1.2 m was left between the experimental plots and 2.5 m was left between the blocks to prevent interactions among the treatments.

Drip irrigation system with 16 mm laterals at each plant row was used for irrigation. The dripper discharge rate was 2 L h^{-1} at 4 atm pressure and dripper spacing was 0.25 m. Plant efficient root depth was taken as 60 cm (Allen et al., 1998)

Soil moisture content was determent with TDR probes with 60 cm long and deficit moisture was brought to field capacity in each irrigation.

Irrigation treatments: I_1 – Rainfed; I_2 – Pre-bloom single irrigation; I_3 – Single irrigation at the beginning of blooming; I_4 – Single irrigation at 50% pod set; I_5 – Two irrigations at 50% bloom and 50% pod-set; I_6 – Two irrigations at pre-bloom and 50% pod-set; I_7 – Full irrigation.

Chickpea seeds were planted manually on 13 April, 2016 and they were harvested between July 18, 2016 and August 11, 2016. In June 1, 2016 programmed irrigations were initiated.

Amount of irrigation water to be applied was calculated by using the following Eq. 1:

$$d = \frac{\left(P_{vfc} - P_{vp}\right)}{10} \cdot D \cdot P \tag{1}$$

where d – Amount of water applied, mm; P_{vfc} – volumetric water content at field capacity %; P_{vp} volumetric water content before irrigation %; D – depth of soil to be irrigated, cm, and P – canopy percentage.

Actual plant water consumption (ET) was determined based on James (1993) using water balance Eq. 2:

$$ET = I + R + Cr - Dp - Rf \pm \Delta s \quad (2)$$

ET is plant water consumption (mm); I is irrigation water applied (mm); R is effective rainfall (mm); Cr is capillary rise (mm); Dp is deep percolation (mm); Rf is runoff (mm) and Δs is soil moisture storage difference between the seeding and harvest.

RESULTS AND DISCUSSION

The effects of irrigations performed at different phenological stages on plant water consumption and yield of chickpea plants are provided in Table 4. The amount of irrigation water applied in different treatments varied between 85.6 (I_3) – 323 (I_7) mm. For reliable emergence levels, before the initiation of programmed irrigations, 17 mm water (5 mm on 28 Nisan 2016 and 12 mm on 13 May 2016) was applied to all treatments. Seasonal plant water consumption in I_1, I_2 , I_3, I_4, I_5, I_6 and I_7 treatments were respectively measured as 262, 374, 326, 360, 391, 438 and 569 mm. As compared to dry treatment without any irrigations (I_1), 54.13% decrease was observed in plant water consumption in full irrigation treatment (I_7).

Table 4. Effects of different irrigation water levels on yield and plant water consumption

Treatments	Irrigation (mm)	ET (mm)	Yield (kg da^{-1})
I_1	17	262	146
I_2	142,7	374	157.0
I_3	85,6	326	212.0
I_4	119,7	360	273.1
I_5	164	391	221.7
I_6	199	438	224.7
I_7	323	569	217.7

Different irrigation water treatments had significant effects on yields at $P < 0.05$ significance level. The greatest yield was obtained from I_4 treatments with 273 kg da^{-1} and the lowest yield was obtained from I_1 treatment with 146 kg da^{-1} (Table 5). There were four different statistical groups and the treatments of I_5, I_6 and I_7 were placed in the same group (Table 6). Irrigations significantly increased chickpea yields. Thusly Soltani et al. (2000) carried out a study in Iran and reported chickpea yields as 276.6 kg da^{-1} for full irrigation and 90.9 kg da^{-1} for rainfed treatment. Oweis et al. (2004) carried out a study in West Asia and North Africa and reported chickpea yields as 255 kg da^{-1} for full irrigation and 144 kg da^{-1} for rainfed treatments. Yolcu (2008) investigated the effects of irrigation performed at different growth stages of chickpea under Diyarbakır conditions and reported significant increases in yields with irrigations at pod-set period.

Table 5. Effects of different irrigation water levels on chickpea yield

Sources	SD	Sum of squares	Means square	F
Block	2	197.429	98.715	0.09 ns
Irrigation level	6	33,725.143	5,620.86	5.21*
Error	10	12,944.571	1,078.71	
General	17	46,867.143		

ns – not-significant;
* – significant at 5% level;
** – significant at 1% level.

Table 6. Duncan's test groups for yields (kg da^{-1})

Irrigation treatments	Mean
I_1	146.0 d
I_2	157.0 cd
I_3	212.0 bc
I_4	273.0 a
I_5	221.7 ab
I_6	224.7 ab
I_7	217.7 ab

The relationship between the amount of irrigation water and ET was identified as ET= 0.9896 I – 234.26 and $R^2 = 0.9951$ (Fig. 1).

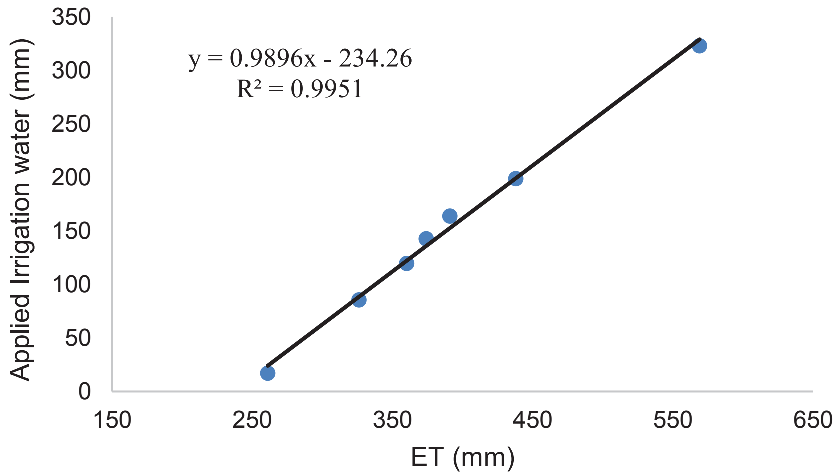

Figure 1. The relationship between amount of irrigation water and ET.

Soil moisture contents at measurement days are presented in Fig. 2 and it was observed that moisture levels were brought to field capacity later on with irrigation.

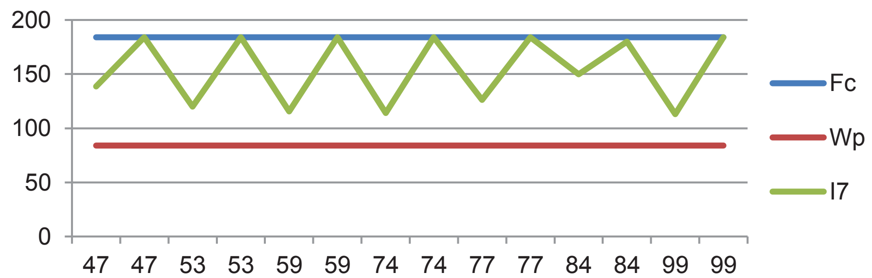

Figure 2. Variation in soil moisture levels.

CONCLUSIONS

In present study, effects of irrigations applied at different growth stages of chickpea on yields were investigated under Kayseri conditions. Results revealed that irrigations at 50% pod-set period improved yield levels of chickpea and single irrigation at 50% pod set had higher yield than full irrigation. Such a case revealed that water deficits can be applied in chickpea culture at proper produces. Therefore, it is recommended that irrigation should be performed at 50% pod-set period of chickpea in places with semi-arid climate conditions and deficit water resources.

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