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Efficiency in Water Use and Yield of Okra (*Abelmoschus esculentum* L.) under Drip Irrigation

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Abstract The objective of this study was to determine the irrigation levels that results in the maximum productivity and efficient use of water for the cultivation of okra. The experiment had six irrigation levels (1.15, 1.00, 0.85, 0.702, 0.55 and 0.40 of crop evapotranspiration (ETc) through drip irrigation system. The experiment was planned in *kharif* season. The experimental design is in randomized block, with four replications. Irrigations were applied to the crop at an alternate day by drip irrigation system, the FAO Penman-Monteith standard method was used to estimate the reference evapotranspiration by using available climatological data. The treatment T_2 i.e. 1.00 ETc of water through drip irrigation system produced maximum yield (160.37 q/ha) and followed by treatment T_3 (0.85 ETc) was 154.35 q/ha. As the yield of treatment T_2 (1.00 ETc) shows maximum yield and at par with the yield of treatment T_3 (0.85 ETc), the treatment T_3 i.e. 0.85 ETc of water through drip irrigation system can be recommended for irrigation of scheduling for okra. It was shown that the total effective rainfall occurred during crop season was 119.00 mm and total depth applied are as 347.44 mm, 301.60 mm, 219 mm, 177 mm, 159 mm to the treatment T_1, T_2, T_3, T_4, T_5 and T_6 respectively. Among the different treatments, treatment T_6 (0.40) ETc of water through drip irrigation system) shows maximum and significantly superior water use efficiency (85.86 kg/ha-mm) over other treatments. This shows that the treatment with the low application of water applied water efficiently. However this may be due to the considerable amount and rainfall received during the period which is 30-40% of total water applied.

Keywords Irrigation level, Yield, Water use efficiency, Okra.

Introduction

India is the topmost country, producing 4.18 million tonnes of okra (*Abelmoschus esculentum* L.) annually, which is around 70% of global okra production. The nutritional value of 100 g of edible portion of okra contains 1.9 g protein, 0.2 g fat, 6.4 g carbohydrate. 0.7 g minerals and 1.2 g fiber (Gopalan et al. 1989). Irrigation scheduling is considered as a vital component of water management to produce higher irrigation efficiency under any irrigation system, as excessive or sub-optimum irrigation both have detrimental effects on productivity parameters of okra (Aiyelaagbe and Ogbonnaya 1996). In almost all regions of the world, water supply is the major con-

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straint to crop production due to water demand for rapid industrialization and high population growth. The further scarcity of irrigation water for crop production should be checked for sustaining the food supply through efficient water conservation and management practices even in high rainfall areas (Panda et al. 2004). Agricultural sector consumes about 83% of water whereas; about 50-70% of water is wasted through conveyance, evaporation, field application and distribution losses in conventional method of irrigation. These losses can be reduced by adopting drip irrigation method with efficient water management practices (Dahiya et al. 2005).

Due to water scarcity problem in this region and we are not able to take higher production of crop in available water. Therefore, deficit water for agriculture has to be utilized in an efficient and rationalized manner. Two issues that need attention are (1) finding a means of lowering the current level of water use by some efficient water use techniques, and (2) promoting economic return to the farmers in an effort to enhance economic incentives. Under such circumstances, it is necessary to study the response of crop to different irrigation levels during crop grown period. Therefore, it was undertaken to study the effect of different levels of irrigation on yield and water use efficiency of okra under drip irrigation system.

Materials and Methods

The experiment was conducted at the Instructional Farm of Department of Irrigation and Drainage Engineering, Dr Annasaheb Shinde College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, India during *kharif* season of period from July 2013 to October 2013. The altitude of the experimental site is 657 m from mean sea level. The latitude and longitude are $19^0 24'$N and $74^0 34'$E respectively.

Treatment details

The experiment was carried out in randomized block design with six treatments of irrigation levels and four replications as below : T_1: 1.15 ETc of water for okra through drip irrigation system, T_2 : 1.00 ETc of water for okra through drip irrigation system. T_3 : 0.85 ETc of water for okra through drip irrigation system, T_4 : 0.70 ETc of water for okra through drip irrigation system, T_5: 0.55 ETc of water for okra through drip irrigation system, T_6 : 0.40 ETc of water for okra through drip irrigation system.

Irrigation scheduling

During the experiment period the irrigation was given to the crop at an alternate day by drip irrigation system. The depth of irrigation water were applied to okra as per the stress levels of different treatments previously decided. The irrigation scheduled was based on the Penman-Monteith method (Allen et al 1998) and it is given by following equation.

$$ET_0 = \frac{0.408\,\Delta\,(R_n - G) + \gamma \left(\frac{900}{T+273}\right) u_2\,(e_s - e_a)}{\Delta + \gamma\,(1+0.34\,u_2)}$$

ET_0 = Reference evapotranspiration (mm day^{-1}), G= Soil heat flux density (MJ M^{-2} day^{-1}), R_n = Net radiation (MJ M^{-2} day^{-1}), T = Mean daily air temperature (^{0}C), γ = Psychometric constant (kPa $^0C^{-1}$), Δ = Slope of saturation vapour pressure function (kPa $^0C^{-1}$) e_s = Saturation vapour pressure at air temperature T (kPa), e_a = Actual vapour pressure at dew point temperature (kPa), U_2 = Average daily wind speed at 2 m height (m sec^{-1}).

The depth of water to be applied for different treatments was calculated on the basis of maximum crop evapotranspiration during the period between two irrigation specified for the treatment and crop coefficients during this period by the equation :

$$Df_i = \sum_{t=si}^{Ei} (ETr_t * Kc_t)$$

Where, Dfi = Depth of full irrigation to be applied during i^{th} irrigation (mm), i = Suffix for irrigation, ETr_t = Reference crop evapotranspiration on t^{th} day (mm), Kc_t = Crop coefficient on t^{th} day, Si = Start day of ith irrigation, Ei = End day of i^{th} irrigation, t = Suffix for day. Reference crop evapotranspiration values were estimated by Penman-Monteith equation.

Crop coefficient (Kc)

The Kc value of any crop depends upon foliage characteristics stage of growth of crop, environment and geographical location. Values are ranging from 0.3 to 1.15 according to crop growth stage (Gadge et al. 2014).

$$KC = -6.688\left(\frac{t}{T}\right)^{3} + 11.421\left(\frac{t}{T}\right)^{2} - 4.9514\left(\frac{t}{T}\right)^{1} + 1.0685$$

Time of operation

The time of operation of drip irrigation system is based on the emission uniformity

$$T = \frac{\text{Amount of water to be applied (lit)}}{\text{Discharge of emitter}\left(\frac{lit}{hr}\right) * \text{No. of emitter}}$$

Where, T = Time of application (hr).

Water use efficiency

The water use efficiency was worked out using following formula :

$$WUE = \frac{yield}{volume\ of\ water}$$

In which, WUE = Water use efficiency (Qt/ha-mm), Y = Total fruit yield (Qt/ha) and, WR = Total amount of water applied in a season (mm).

Results and Discussion

Effect of different irrigation levels on yield of okra

The okra yield for all treatments and replications are given in Table 1. These were analyzed statistically for randomized block design. The yields were statistically significant. It is observed that from Table 1 that the higher yields are observed in treatment T_2 followed by T_3, T_4, T_1, T_6 and T_5 . The treatment T_2 i.e. 1.00 ETc of water through drip irrigation system produced maximum yield (160.37 q/ha) and followed by treatment T_3 i.e. 0.85 ETc of water through drip irrigation system was 154.35 q/ha. The yields of the treatment T_2 is at par with T_3 but significantly superior over other treatments. As the yield of treatment T_2 (1.00 ETc of water through drip irrigation system) shows maximum yield and at par with the yield of treatment T_3 (0.85 ETc of water through drip irrigation system), the treatment T_3 i.e. 0.85 ETc of water through drip irrigation system can be recommended for irrigation of scheduling for okra.

Water requirement for okra crop

Irrigations were scheduled at an alternate day by considering two days cumulative reference crop evapotranspiration over a growth period of okra crop. The number of irrigations and depth of water applied per irrigation for each treatment is given in Table 2. It was

Table 1. The yield of okra (qt/ha) influenced by different irrigation levels.

Treatments	Replication				Mean yield (qt/ha)
	R_1	R_2	R_3	R_4	
T_1	143.33	150.45	150.56	149.50	148.460
T_2	148.25	150.47	170.22	172.55	160.373
T_3	131.55	158.02	173.40	154.44	154.353
T_4	129.33	148.81	157.33	150.45	146.480
T_5	120.45	144.44	148.55	135.55	137.248
T_6	130.22	140.45	144.08	131.33	136.520
				SE	3.40
				CD (5%)	1.18

Table 2. The number of irrigations and depth of water applied per irrigation for each treatment.

Date	Depth of water applied (mm) T_1	T_2	T_3	T_4	T_5	T_6	Effective rainfall (mm)
31/07/2013	11.76	10.23	8.69	7.16	5.63	4.09	-
02/08/2013	6.63	5.76	4.90	4.03	3.17	2.31	7
04/08/2013	9.00	7.83	6.65	5.48	4.30	3.13	4
06/08/2013	8.84	7.69	6.54	5.38	4.23	3.08	-
08/08/2013	7.60	6.61	5.62	4.63	3.64	2.64	-
10/08/2013	6.91	6.01	5.11	4.21	3.31	2.40	-
12/08/2013	6.30	5.48	4.66	3.83	3.01	2.19	-
14/08/2013	5.95	5.18	4.40	3.62	2.85	2.07	-
16/08/2013	5.73	4.98	4.24	3.49	2.74	1.99	6.6
18/08/2013	5.61	4.88	4.15	3.42	2.69	1.95	-
20/08/2013	5.51	4.79	4.07	3.35	2.63	1.92	-
22/08/2013	5.09	4.43	3.76	3.10	2.44	1.77	-
24/08/2013	4.69	4.08	3.47	2.86	2.24	1.63	-
26/08/2013	4.79	4.17	3.54	2.92	2.29	1.67	-
28/08/2013	5.15	4.48	3.81	3.13	2.46	1.79	-
30/08/2013	5.48	4.76	4.05	3.34	2.62	1.91	-
01/09/2013	5.06	4.40	3.74	3.08	2.42	1.76	-
03/09/2013	5.51	4.79	4.07	3.36	2.64	1.92	75
05/09/2013	-	-	-	-	-	-	-
07/09/2013	-	-	-	-	-	-	-
09/09/2013	-	-	-	-	-	-	-
11/09/2013	-	-	-	-	-	-	4
13/09/2013	-	-	-	-	-	-	2
15/09/2013	-	-	-	-	-	-	8
17/09/2013	-	-	-	-	-	-	-
19/09/2013	-	-	-	-	-	-	-
21/09/2013	-	-	-	-	-	-	-
23/09/2013	-	-	-	-	-	-	-
25/09/2013	-	-	-	-	-	-	-
27/09/2013	-	-	-	-	-	-	-
29/09/2013	-	-	-	-	-	-	-
01/10/2013	-	-	-	-	-	-	-
03/10/2013	9.31	-	-	-	-	-	3
05/10/2013	8.67	-	-	-	-	-	-
07/10/2013	9.58	8.33	-	-	-	-	-
09/10/2013	9.65	8.39	-	-	-	-	9
11/10/2013	8.46	7.35	6.25	-	-	-	-
13/10/2013	8.85	7.70	6.54	-	-	-	-
15/10/2013	9.09	7.90	6.72	-	-	-	-
17/10/2013	8.51	7.40	6.29	5.18	-	-	-
19/10/2013	8.72	7.59	6.45	5.31			
21/10/2013	8.13	7.07	6.01	4.95			
23/10/2013	8.23	7.15	6.08	5.01			
25/10/2013	7.78	6.76	5.75	4.73			
27/10/2013	7.39	6.43	5.46	4.50	3.54		
Total	347.44	301.60	259.00	219.00	177.00	159.00	119.00

observed (Table 2) that the total amount of effective rainfall is 119 mm due to rainy season. It was also observed that there is no requirement for giving of water to the crop to all treatments through drip irrigation almost in the month of September 2013. The total depth of irrigation water applied to different treat-

Table 3. Depth of irrigation applied (mm), effective rainfall, total depth of water applied (mm), yield (qt/ha) and WUE (kg/ha-mm) to different treatments during crop period.

Treatments	Depth of irrigation water applied (mm)	Effective rainfall (mm)	Total depth of water applied (mm)	Mean yield (qt/ha)	WUE (kg/ha-mm)
T_1	228	119.00	347	148.460	42.73
T_2	182	119.00	301	160.373	53.17
T_3	140	119.00	259	154.353	43.00
T_4	100	119.00	219	146.480	66.89
T_5	58	119.00	177	137.248	80.73
T_6	20	119.00	159	136.520	85.86
			SE	3.40	1.42
			CD (5%)	10.18	3.27

ments during crop period is presented in Table 3. It was shown (Table 3) that the total effective rainfall occurred during crop season was 119.00 mm and total depth applied are as 347.44 mm, 301.60 mm, 219 mm, 177 mm, 159 mm to the treatment T_1 (1.15 ETc), T_2 (1.00ETc), T_3 (0.85ETc), T_4 (0.70ETc), T_5 (0.55ETc), T_6 (0.40ETc) respectively.

Water use efficiency

The water use efficiency for the okra is the ratio of yield data and total depth of water applied. The water use efficiency for all the treatments were calculated according to the procedure adopted in methodology section. The water use efficiencies for different treatments are presented in Table 3.

Among the different treatments, treatment T_6 (0.40 ETc of water through drip irrigation system) shows maximum and significantly superior water use efficiency (85.86 kg/ha-mm) over other treatments. This shows that the treatment with the low application of water applied water efficiently. However this may be due to the considerable amount and rainfall received during the period which is 30-40% of total water applied.

It reveals that the experiment carried out under drip irrigation system in which on the basis of yield parameter T_2 and T_3 are at par. The maximum yield should be obtain at T_2 treatment which is based on 1.00 ETc and T_3 treatment gives significant yield on the basis of 0.85 ETc. Based on the results of experiment under drip irrigation method, application of water @ 85% of ETc (15% stress) at an alternate day interval is recommended for maximum yield of okra crop and @ 40 % of ETc (60% stress) at an alternate day is recommended for maximum water use efficiency during rainy season.

Conclusion

Based on the results of experiment following conclusions were drawn from study : (1) Under drip irrigation system, the depth of water applied at different irrigation levels ranges from 159 mm to 347 mm and water use efficiency at different irrigation levels ranges from 42.73 kg/ha-mm to 85.86 kg/ha-mm. (2) Application of water through drip irrigation system @ 85% ETc at an alternate day interval is recommended for maximum yield of okra crop and @ 40% of ETc (60% stress) at an alternate day is recommended for maximum water use efficiency during rainy season.

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