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Effect of Drip Irrigation with Saline Water on Yield and Water Use Efficiency of Okra *(Abelmoschus Esculentus* L. *Moench)*

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ABSTRACT

A field experiment was conducted during summer season of 2015 at College of Agricultural Engineering, Bapatla on sandy soil to evaluate the effect of drip irrigation with saline water on yield and water use efficiency of Okra. The experiment was laid out in split plot design with three replications. The four salinity levels *viz,* M1 (freshwater with 0.42 dSm^{-1}), M2 (2 dSm^{-1}), M3 (4 dSm^{-1}) and M4 (6 dSm^{-1}) were considered as main treatments and three irrigation levels viz, S1 (100% CWR) *i.e.* irrigation at 100 percent of crop water requirement, S2 (80% CWR) and S3 (60 % CWR) were considered as sub treatments. The crop water requirement (ET_c) for the Okra crop during summer season was estimated as 460.4 mm. The results shown that freshwater M1S1 (0.42 dSm^{-1} of salinity at 100 % CWR) recorded higher yield (6.35 t ha^{-1}). The 100 percent CWR recorded significantly higher yields in all salinity levels of irrigation. Increased salinity levels caused yield reduction by 7.4 %, 42.0 % and 62.0 % in the treatment irrigated with salinity levels of 2 dSm^{-1}, 4 dSm^{-1} and 6 dSm^{-1} respectively as compared to the yield obtained by irrigation water salinity of 0.42 dSm^{-1}. The treatment M1S3 (0.42 dSm^{-1} of salinity at 60 % CWR) recorded significantly higher WUE as 0.20 t/ha.cm.

Key words : Drip irrigation, Saline water irrigation, Okra crop, Water Use Efficiency.

Water is needed to ensure food security, industrial production and conserve the biodiversity of the ecosystem. Due to burgeoning population and increasing high standard of living, demand of the water in domestic as well as industrial sectors is increasing at a much faster rate. Thus all eyes are on the agricultural sector to release a part of the fresh water for other sectors. Thus, use of saline water and the water that have been used once and have not lost their potential for use in agriculture need to be exploited for crop production (Gupta and Gupta, 2003). But, utilization of saline water for irrigation is associated with salt accumulation in the soil, which has negative impact on plant growth through three major components viz. osmotic, nutritious and toxic stresses.

Saline water irrigation through drip irrigation maintain high soil matric potential in the root zone thus compensate the decrease of osmotic potential and the constant high total water potential can be maintained for the crop growth as its characteristic of low rate and high frequent irrigation applications over a long period of time (Kang,1998). To mitigate the salinity problem to certain extent, the saline water through drip irrigation is considered as an important research subject in this study.

Okra (*Abelmoschus Esculentus L. Moench*) is one of the important vegetable crop commercially grown in India is selected as a crop for this study. Andhra Pradesh is the leading Okra producing state which has production of around 1184.2 thousand tons followed by West Bengal (862.1 thousand tons). Okra also has a good potential as a foreign exchange crop and accounts for 60 % of the export of fresh vegetables from India. Okra is moderately tolerant to salinity (Ali *et al.* 2008). So, an attempt was made to investigate the effect of different salinity levels on yield, yield parameters and water use efficiency.

MATERIAL AND METHODS

The field experiment was conducted at College of Agricultural Engineering, Bapatla during the summer season of 2015. The experimental design was Split plot design having four salinity levels as main treatments and three irrigation levels as sub treatments with three replications. Size of the plot for main treatment, sub treatment and replication is 16 m × 6 m, 5.4 m × 6 m and 1.8 m × 6 m respectively. Irrigation was given to every main treatment from separate tanks to maintain the different salinity level for irrigation. Phosphorous was applied basally at the rate of 24 kg ha^{-1}.

Nitrogen and potassium were applied at the rate of 48 kg ha^{-1} and 24 kg ha^{-1} respectively in four splits as per recommended dose.

Details of treatments:

M - Main treatments (Different levels of salinity)
S - Sub treatments (Different levels of irrigation)
M1S1 - Fresh water at 100 % CWR; M1S2- Fresh water at 80 % CWR
M1S3 - Fresh water at 60 % CWR; M2S1 - Saline water (2 dSm^{-1}) at 100 % CWR
M2S2- Saline water (2 dSm^{-1}) at 80 % CWR; M2S3- Saline water (2 dSm^{-1}) at 60 % CWR
M3S1- Saline water (4 dSm^{-1}) at 100 % CWR; M3S2- Saline water (4 dSm^{-1}) at 80 % CWR
M3S3- Saline water (4 dSm^{-1}) at 80 % CWR; M4S1- Saline water (6 dSm^{-1}) at 100 % CWR
M4S2- Saline water (6 dSm^{-1}) at 80 % CWR; M4S3- Saline water (6 dSm^{-1}) at 60 % CWR

The yields were collected from all pickings with replication wise and summed up for a total yield. The yield parameters such as plant height, root depth, pod weight, pod length and pod size were statistically analyzed using the split plot design. The analysis and interpretation of data were done using the Fisher's method of analysis of variance technique as described by Gomez and Gomez (1984).

Water Use Efficiency

The term water use efficiency denotes the production per unit of water applied. It is expressed as the weight of crop produce per unit depth of water over a unit area, *i.e.*, kg/ha-cm (Michael, 2008).

RESULTS AND DISCUSSION

The treatments irrigated with Saline water level of 2 dSm^{-1}, 4 dSm^{-1} and 6 dSm^{-1} were compared with the treatment irrigated with fresh water (0.42 dSm^{-1}) for its yield and other yield parameters. The treatments irrigated at a level of 80 % CWR and 60 % CWR were compared with the treatment irrigated at a level of 100 % CWR.

Crop Water Requirement:

CROPWAT model was run with the 10 years average meteorological data of Bapatla to estimate the crop water requirement for the Okra crop. The crop water requirement (ET_c) for the whole crop season during summer was estimated as 460.4 mm and stage wise crop water requirement for the Okra was presented in Table 1. Present study was conducted with different levels of salinity of irrigation water during summer season and assumed that there is no rainfall during the crop season. The CROPWAT gives output with the crop water requirement per each decade (ten days) in the crop season from initial stage to late season for the crop duration of 20th January, 2015 to 24th April, 2015.

Crop Yield and Yield Parameters:

The data of the crop yield (Table 2) revealed that the treatment M1 recorded significantly higher yield (5.98 t ha^{-1}), plant height (101.7 cm), root depth (22.9 cm), pod weight (14.7 g), pod length (11.9 cm) and pod size (15.6 mm). Similarly the lower yield was obtained in the treatment M4 (2.25 t ha^{-1}). The plant height (70.6 cm), root depth (18.2 cm), pod weight (8.9 g), pod length (9.4 cm) and pod size (14.2 mm) also recorded for its significantly lower growth performance. Thus the yield and other parameters were reduced with increase in salinity of irrigation water. These results are in accordance with the results reported by Singh *et al*. (1978) as the yield reduction with increase in EC. Muhammad *et al.* (2011) reported that increasing in salinity caused to decrease of plant height, root depth, pod weight and pod length of the Okra.

Among the different levels of irrigation given at 100 % CWR (S1) recorded significantly higher yield as 4.59 t ha^{-1}. The treatment S1 also recorded significantly better performance in yield parameters such as plant height (88.9 cm), pod weight (12.3 g) and pod length (11.1 cm) respectively. The root depth and pod size have no significant difference among the sub treatments. The significantly lower yield (4.05 t ha^{-1}) was obtained in the treatment S3. Hence the yield was decreased with decrease in irrigation quantity. Singh *et al.*(1978) also reported that yield reduction while giving irrigation less than the crop water requirement. The treatment combinations of fresh water irrigation at 100 % of CWR (M1S1) recorded significantly higher yield (6.35 t ha^{-1}) where as the treatment combination M4S3 recorded significantly lower yield as 2.08 t ha^{-1} (Table 2).

Table 1. Crop water requirement (ETc) for the Okra crop during summer season.

S. No.	Month	Decade (10 days) number	Crop stage	Crop coefficient (Kc)	ETc (mm/day)	ETc during decade (mm/dec)
1	January	2nd	Initial	0.70	2.74	2.7
2	January	3rd	Initial	0.70	2.89	31.8
3	February	1st	Development	0.70	3.07	30.7
4	February	2nd	Development	0.78	3.59	35.9
5	February	3rd	Development	0.88	4.31	34.4
6	March	1st	Development	0.98	5.09	50.9
7	March	2nd	Mid	1.03	5.66	56.6
8	March	3rd	Mid	1.03	5.97	65.7
9	April	1st	Late	1.03	6.29	62.9
10	April	2nd	Late	0.98	6.32	63.2
11	April	3rd	Late	0.98	6.41	25.6
Total						406.4

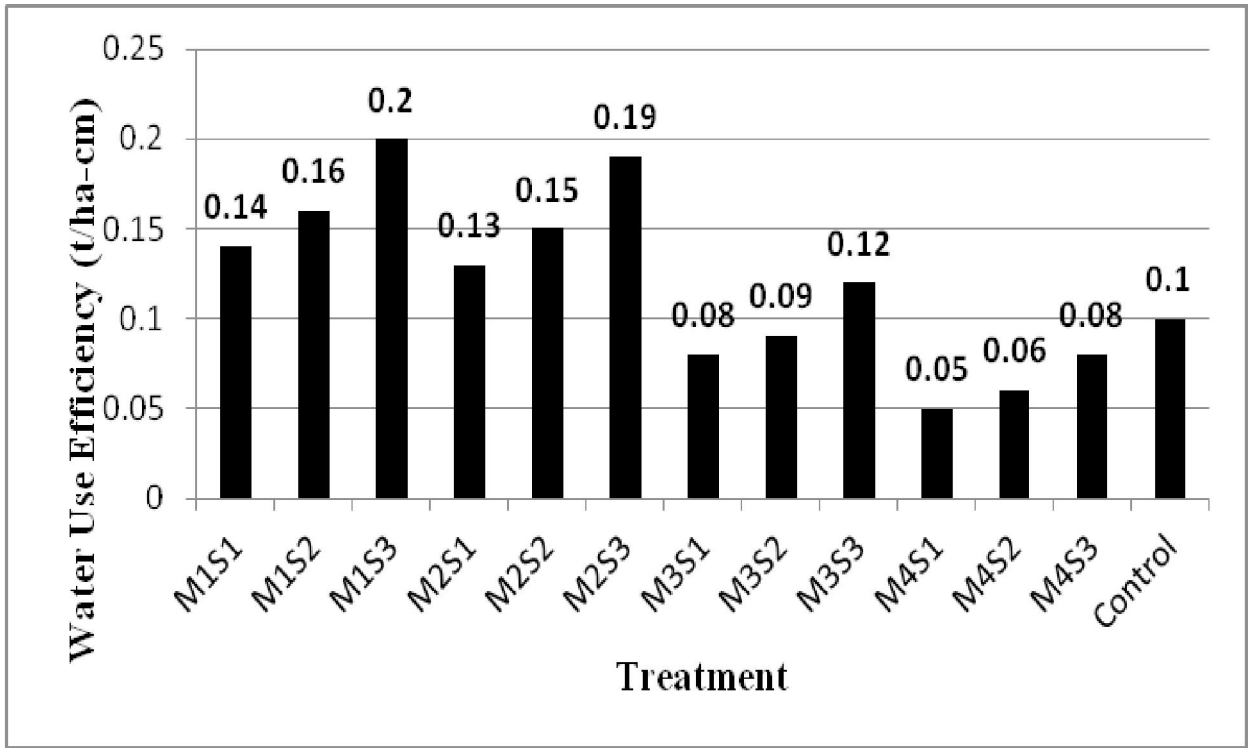

Fig. 1. Effect of saline water irrigation on water use efficiency

Water use efficiency:

The main treatments *i.e* different quality of saline water irrigation, the yields of the sub treatments *i.e* at different levels of irrigations were decreased with the decreasing in the quantity of water application (Table 3). The maximum yield was recorded as 6.355 t ha^{-1} in treatment M1S1 *i.e.* freshwater irrigation through drip system at 100% of CWR followed by M1S2 *i.e.* freshwater irrigation through drip system at 80% of CWR. But considering the applied water, 60% of CWR level of irrigation has high water use efficiency without much difference in yield (5.614 t ha^{-1}) with 50.6 % of water saving compared to control *i.e.* conventional irrigation method. These saved water can use for the irrigation to other fields then

Table 2. Effect of saline water at different levels of irrigation on yield and yield parameters of Okra.

Treatment	Yield (t ha^{-1})	Plant Height (cm)	Root Depth (cm)	Pod Weight (g)	Pod Length (cm)	Pod Size (mm)
Salinity of irrigation water(M)						
M1 (Fresh water)	5.98	101.7	22.9	14.7	11.9	15.6
M2 (2 dSm-1)	5.53	85.6	22.3	13.5	11.5	15.2
M3 (4 dSm-1)	3.44	79	19.6	9.9	9.9	14.7
M4 (6 dSm-1)	2.25	70.6	18.2	8.9	9.4	14.2
S.Em	0.04	0.90	0.22	0.35	0.15	0.15
C.D.(0.05)	0.15	3.11	0.76	1.22	0.53	0.53
Levels of irrigation (S)						
S1(100%)	4.59	88.9	21.1	12.3	11.1	15.1
S2(80%)	4.28	83.3	20.7	11.8	10.6	14.9
S3(60%)	4.05	80.5	20.4	11.2	10.3	14.7
S.Em	0.03	0.74	0.23	0.27	0.14	0.08
C.D.(0.05)	0.08	2.22	NS	0.81	0.43	N.S
Interaction (M×S)						
M1S1	6.35	108.1	23.4	15.2	12.4	15.8
M1S2	5.97	101.1	22.9	14.8	11.9	15.6
M1S3	5.61	95.8	22.3	14	11.5	15.5
M2S1	5.88	90.3	22.6	14.2	11.7	15.5
M2S2	5.49	84.1	22.1	13.7	11.4	15.2
M2S3	5.23	82.4	22.1	12.8	11.2	14.9
M3S1	3.68	83.8	19.7	10.3	10.3	14.8
M3S2	3.42	77.6	19.6	10	9.8	14.7
M3S3	3.21	75.6	19.4	9.5	9.7	14.5
M4S1	2.43	73.4	18.9	9.3	10.0	14.3
M4S2	2.25	70.4	18.1	8.8	9.4	14.2
M4S3	2.08	68.1	17.6	8.5	8.9	14.1
S.Em	0.06	1.48	0.45	0.54	0.28	0.17
C.D.(0.05)	NS	NS	NS	NS	NS	NS

irrigated area can be increased and can get more crop yields These results revealed that the water use efficiency decreases with increase in salinity level of irrigation water and increases with decrease in irrigation quantity. The treatment M1S3 have recorded water use efficiency of 0.20 t/ha.cm with water saving of 50.6% with compared to the control and the treatment M4S1 have recorded for its lowest water use efficiency of 0.05 t/ha.cm with water saving of 17.7% compared to the control. These saved water can use for the irrigation to other fields then irrigated area can be increased and can get more crop yields. Fresh water irrigation treatments recorded the high water use efficiencies and saline water irrigation treatments having less water use efficiency may be due to the plants suffering with more soil moisture stress due to osmotic pressure buildup by the saline water irrigation. It was concluded that irrigation water use efficiency was decreased with increase in salinity and increased with decrease in quantity of water applied respectively. These results are in confirmation with Lei *et al.* (2003) as the water use efficiency increased with decrease in water quantity using saline water.

Based on the study, it was concluded that the increased salinity levels caused yield reduction of 7.4 %, 42.0 % and 62.0 % in the treatment irrigated with irrigation water salinity of 2 dSm^{-1}, 4 dSm^{-1} and 6 dSm^{-1} respectively as compared to the yield

Table 3. Effect of saline water and irrigation levels on water use efficiency.

S.No.	Treatment	Yield (t ha^{-1})	Irrigation water applied (cm)	Water saving (%)	Water use efficiency (t/ha-cm)
1	M1S1	6.355	46.04	17.7	0.14
2	M1S2	5.969	36.83	34.2	0.16
3	M1S3	5.614	27.62	50.6	0.20
4	M2S1	5.880	46.04	17.7	0.13
5	M2S2	5.494	36.83	34.2	0.15
6	M2S3	5.228	27.62	50.6	0.19
7	M3S1	3.683	46.04	17.7	0.08
8	M3S2	3.423	36.83	34.2	0.09
9	M3S3	3.215	27.62	50.6	0.12
10	M4S1	2.428	46.04	17.7	0.05
11	M4S2	2.253	36.83	34.2	0.06
12	M4S3	2.082	27.62	50.6	0.08
13	control	5.407	56.00	—-	0.10

obtained in the plot irrigated with freshwater with salinity of 0.42 dSm^{-1}. Decreased irrigation level with freshwater caused yield reduction of 5.98 % and 11.60 % in the treatment irrigated with irrigation level of 80 % CWR and 60 % CWR respectively as compared to full irrigation (100 % CWR). The treatment M1S3 (freshwater irrigation with 0.42 dSm^{-1} of salinity at 60 % CWR) recorded significantly higher WUE as 0.20 t/ha.cm. It shows that the water use efficiency was increased with decrease in quantity of water applied. Okra crop using saline water for irrigation with 2 dSm^{-1} at 100% of CWR recorded as good crop yield on par with the freshwater irrigation and beyond the 2 dSm^{-1}, increase in the salinity of the irrigation water decreases the crop yield for Okra.

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