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Response of Okra (*Abelmoschus esculentus* L.) to EC and SAR of Irrigation Water

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ABSTRACT

To increase crop production in arid and semi-arid regions are hindered by the shortage of fresh water for irrigation. A pot experiment was conducted to study the combined effect of EC_{iw} and SAR_{iw} on growth, yield and physiological (photosynthesis, transpiration rate, water and osmotic potential (behaviour) of okra. Total nine treatments having different EC_{iw} (2, 4 and 6 dS m^{-1}) and SAR_{iw} [10, 15 and 20 (mmol $L^{-1})^{1/2}$], respectively were applied throughout the growth period of okra. The results revealed that height, fresh and dry weight, fresh pod yield, photosynthesis, transpiration rate and turgor potential were depressed with the increasing levels of EC_{iw} and SAR_{iw}. From the present studies, it could be concluded that except control, the okra plant could tolerate EC_{iw} up to 2 dS m^{-1} and SAR_{iw} up to 20 (mmol $L^{-1})^{1/2}$) on loamy soil. The higher levels of EC_{iw} (> 2.0 dS m^{-1}) were found to be hazardous for okra plants.

Key Words: EC_{iw}; SAR_{iw}; Okra yield; Photosynthesis; Transpiration; Turgor potential

INTRODUCTION

Pakistan is situated in the semi-arid and arid region with scanty rainfall, which necessitates the artificial irrigation for producing good crop yields. In spite of the extensive canal system, the vast areas of the country are not being utilized efficiently due to lack of canal irrigation water. Using water from other sources such as ground water could possibly make up the deficiency of canal irrigation water. According to an estimate about 67.1 millions acre-feet (MAF) ground water is being pumped out to augment canal supplies in the country (Anonymous, 2001). Unfortunately, major portion (50%) of this ground water is unfit for irrigation due to variable amount of sodium and bicarbonate ions (Malik *et al.,* 1984).

Okra (*Abelmoschus esculentus* L.) belongs to family Malvacea, originated in tropical Africa and was grown in Mediterranean region. It is now grown in all parts of the tropics and during summer in the warmer parts of the temperate regions. It is grown from March to June in Pakistan and is very delicious vegetable. The young tender pods of okra are cooked in curries, stewed and used in soup called gumbo soups. When ripe, the black or white-eyed seeds are sometimes roasted and used as substitute for coffee. The stem of plant provides fiber, which is used in the paper industry (Balooch, 1994). The crop has high nutritive value.

It is classified as semi-tolerant vegetable crop (Maas & Holfman, 1977). Minhas and Gupta (1993) reported 90, 75 and 50% reduction in fresh yield of okra, respectively at EC_{iw} 2.1, 3.9 and 6.7 dS m^{-1}. High salt concentration has multiple adverse effects on plant morphology, physiology, metabolism, enzyme activity and crop yield. There are at least three components of salt stress to plants including osmotic effects, nutritional effects and more vague component of toxic effects of specific ions. The ions impose adverse effect on enzyme activity responsible for various metabolic reactions in the cell and plant metabolites and hence on the ultimate yield of the plants (Bernstein & Hayward, 1958).

Sufficient information is not available in the country regarding the effect of EC and SAR of irrigation water on okra in the country. The evidence shows that growth, yield and physiological parameters of okra and other vegetables decreased with an increase in the EC_{iw} and SAR_{iw} (Mangal *et al.,* 1989; Singh, 1998). The present study was thus planned to study the combined effect of EC_{iw} and SAR_{iw} on growth, yield and physiological behaviour of okra on sandy clay loam soil.

MATERIALS AND METHODS

The experiment was conducted in the net-house, Institute of Pure and Applied Biology, Bahauddin Zakariya University, Multan during 2000. Surface soil (0-15 cm) in bulk was collected from the normal field. The soil was air-dried, ground, passed through a 2 mm sieve and thoroughly mixed. The physio-chemical analysis of soil showed that it was loamy in texture (sand 38.36%, silt 46.36% and clay 15.28%) and had EC_e 1.52 dS m^{-1}; CO_3^{2-} nil; HCO_3^- 8.7 $mmol_c$ L^{-1}; Cl^- 3.15 $mmol_c$ L^{-1}; $Ca^{2+} + Mg^{2+}$ 8.3 $mmol_c$ L^{-1}; Na^+ 6.9 $mmol_c$ L^{-1}; SAR 3.39 (mmol $L^{-1})^{1/2}$; organic matter 0.60%. Cemented pots lined with polyethylene sheet were filled with this soil @ 15 kg per pot. Three levels each of EC_{iw} and SAR_{iw} @ 2, 4 and 6 dS m^{-1}; 10, 15 and 20 (mmol $L^{-1})^{1/2}$, respectively were used. The soil and water were analyzed following methods outlined by U.S. Salinity Lab. Staff (1954). Total nine waters having different EC_{iw} and SAR_{iw} combinations including one as a control (best available water at the experimental site: EC_{iw} 0.91 dS m^{-1} and SAR_{iw} 2.15) were investigated and are shown as below:

Treatment	EC_{iw} (dS m^{-1})	SAR_{iw} (mmol $L^{-1})^{1/2}$
T0 (control)	0.91	2.15
T1	2.00	10.00
T2	2.00	15.00
T3	2.00	20.00
T4	4.00	10.00
T5	4.00	15.00
T6	4.00	20.00
T7	6.00	10.00
T8	6.00	15.00
T9	6.00	20.00

The treatments were arranged according to complete randomized design. The pots were irrigated with freshly prepared above mentioned waters by dissolving NaCl, Na_2SO_4, $CaCl_2$. $2H_2O$ and $MgSO_4$. $7H_2O$ salts in tube well water (EC_{iw} 0.91 dS m^{-1} and SAR_{iw} 2.15). The NPK were added @ 0.17, 0.08 and 0.051 g pot^{-1} to each pot at the time of sowing as urea, triple super phosphate (TSP) and sulphate of potash (SOP). Total eighteen irrigations (2 L of each irrigation) of designed waters were applied to the respective columns. The crop was grown up to maturity and the following responses were recorded: Height; Fresh and dry weight of plant; Fresh pod yield; Photosynthetic rate; Transpiration rate; Water potential; Osmotic potential.

Four harvests were taken after a period of 7-day intervals. Total four harvests were taken and average yield of pod per pot was used for statistical analysis. ADC-LAC4 photosynthetic meter measured the photosynthesis and transpiration rate. For this, the pots were kept in the full sunlight. After 70 days of growth, a fully expanded leaf was excised from each plant at 9.00 am and leaf water potential was measured with pressure bomb method. At 9.00 am one fully expanded youngest leaf was excised from each plant for the measurement of osmotic potential. The leaf materials were immediately frozen in ultra low freezer (-85°C). After two weeks the frozen sap was extracted by crushing the leaf material with metal rod. The osmotic potential of the sap was then measured by osmometer (Wescor, 5500 vapor pressure osmometer.

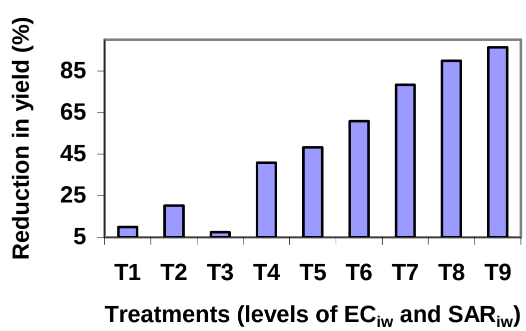
RESULTS AND DISCUSSION

Height of plant. The data (Table I) shows that increasing concentration of EC_{iw} and SAR_{iw} had significant adverse effect on plant height. The maximum height of plant (72.50 cm) was recorded in T1 (EC_{iw} 2.0 dS m^{-1} and SAR_{iw} 10), while minimum was (26.67 cm) in the case of T9 (EC_{iw} 6.0 dS m^{-1} and SAR_{iw} 20). It is interesting to note that height of plant from T1 was higher that that from the control (EC_{iw} 0.91 dS m^{-1} and SAR_{iw} 3.91) but the difference was statistically non-significant at P<0.05. Similarly, the treatment T4 (EC_{iw} 4.0 dS m^{-1} and SAR_{iw} 10) and T5 (EC_{iw} 4.0 dS m^{-1} and SAR_{iw} 15) have statistically non-significant difference with each other, while showed significant difference ($P < 0.05$) with other treatments. Results indicated that at same SAR_{iw}, the reduction in height of plant was more with high EC_{iw} (6.0 dS m^{-1}). For instance, the height was 26.07 cm with EC_{iw} 6.0 dS m^{-1} at SAR_{iw} 20 (mmol $L^{-1})^{1/2}$ than EC_{iw} 2 and 4.0 dS m^{-1}, respectively.

Fresh and dry weight of plant. The treatments (Table I) significantly affected the fresh and dry weight of okra plant over control. Maximum fresh weight was (61.82 g) in the control, whereas minimum (12.99 g) in the case of T9 (EC_{iw} 6.0 dS m^{-1} and SAR_{iw} 20). Results indicated that 15.33, 8.52, 4.61, 27.61, 48.57, 54.17, 70.5, 74.49 and 78.99% reduction in fresh weight of plant was occurred with T1, T2, T3, T4, T5, T6, T7, T8 and T9 over control. The treatments T0, T1 and T3 behaved statistically similarly regarding the fresh weight of plant. Maximum dry weight of plant (13.51 g) was resulted from control, while minimum (2.67 g) from T9. It is evident that at similar EC_{iw} and SAR_{iw}, reduction in dry weight of plant was more than that of fresh weight of plant (Table I). Mangal *et al.* (1989) reported reduction in plant height, number of tillers, and green and dry weight of twelve barley varieties with soil salinity.

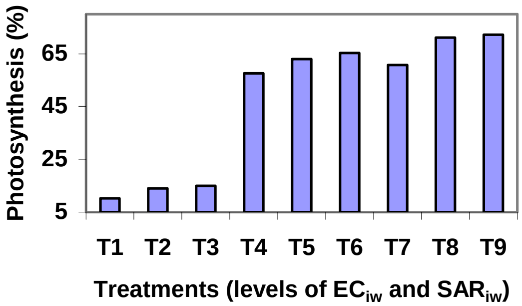
Fresh pod yield. The fresh pod yield was affected significantly with treatments over control (Table I). The highest fresh pod yield of okra (227.80 g) was noted in the T0 (control), whereas lowest (8.55 g) in the case of T9 (EC_{iw} 6.0 dS m^{-1} and SAR_{iw} 20). Results showed that at given SAR_{iw}, the reduction in pod yield was more with EC_{iw} from 2.0 to 6.0 dS m^{-1}. Figure 1 depicts that 20, 50, 75, and 95% reduction in fresh pod yield of okra was noted with T2, T5, T7 and T9, respectively. It is evident (Table I) that the designed okra variety could be grown on loamy soil with 50% yield reduction at EC_{iw} 4.0 dS m^{-1} and SAR_{iw} 15 (mmol $L^{-1})^{1/2}$.

Fig. 1. Percent reduction in yield of fresh pod yield of okra with EC_{iw} and SAR_{iw} over control



Photosynthetic rate (μ mol m^{-2} S^{-1}). Fig. 2 depicts that photosynthetic rate decreased significantly with treatments over control. The photosynthetic rate of leaves decreased with increasing levels of EC and SAR of irrigation water.

Fig. 2. Percent reduction in photosynthetic rate over control as affect with EC_{iw} and SAR_{iw}



Maximum photosynthetic rate (18.80 μ mol m^{-2} S^{-1}) was observed in control (T0), while the minimum (18.80 μ mol m^{-2} S^{-1}) was in the case of T9. The decrease in photosynthetic rate with high EC and SAR of irrigation water might be due to reduced plant growth, which ultimately retarded the physiological and metabolic functions in the cells. Biomass production which is a function of carbon fixation in photosynthesis is determined by the rate of photosynthesis per leaf area and area of leaf surface. This may also be due to reduced leaf area and increased in leaf thickness, thus reducing area for light interception and carbon dioxide fixation (Shazia & Ismail, 1994).

Transpiration rate (mmol m^{-2} S^{-1}). The EC and SAR of irrigation water significantly affected the transpiration rate of the leaves (Table II). The maximum transpiration rate (10.9 mmol m^{-2} S^{-1}) was noted in the control, while minimum was in the case of T9. The treatment T3 (EC_{iw} 2.0 dS m^{-1} and SAR_{iw} 20) and T4 EC_{iw} 4.0 dS m^{-1} and SAR_{iw} 10) have statistically non-significant difference with each other but significantly differ with all other treatments. Results indicated that increasing levels of EC and SAR had significant adverse effect on transpiration rate of leaves due to the closure of stomatal conductance. Gale *et al.* (1967) observed the similar results and reported that due to salinity, the toxic ions (Na^+ and Cl^-) get accumulated on the cuticle and mesophyll cells of the leaves, which closed the stomatal conductance and hence decreased the transpiration rate on onions, beans and cotton plants.

Water, osmotic and turgor potential. The data regarding effect of EC_{iw} and SAR_{iw} on water, osmotic and turgor potential, respectively are presented in Table II. Results indicated that water, osmotic and turgor potential were affected significantly with treatments over control. There was a gradual significant decrease in the leaf water potential from treatment T0 to T9. The lowest water potential (-2.30 MPa) was recorded in T9, whereas lowest (-1.60 MPa) in the case of T0 (control). It is evident that with increasing levels of EC_{iw} and SAR_{iw}, the osmotic potential of leaves decreased significantly. The lowest osmotic potential (-2.42

Table I. Effect of EC_{iw} and SAR_{iw} on growth and yield of okra

S.No.	Treatments		Height (cm)	Fresh weight (g)	Dry weight (g)	Fresh pod yield (g)
	EC_{iw}	SAR_{iw}				
T0	0.91	2.15	70.83a	61.82a	13.51a	227.80a
T1	2.00	10.00	72.50a	52.34ab	9.07bcd	205.13b
T2	2.00	15.00	65.71ab	56.55a	9.94bc	181.71c
T3	2.00	20.00	56.67bc	58.97a	11.28ab	210.69b
T4	4.00	10.00	46.67d	44.75b	8.23cde	134.89d
T5	4.00	15.00	43.67d	31.79c	6.44de	117.95e
T6	4.00	20.00	40.10de	28.33cd	6.07e	89.24f
T7	6.00	10.00	37.51def	18.21de	3.11f	49.28g
T8	6.00	15.00	28.45ef	15.77e	2.90f	23.03h
T9	6.00	20.00	26.07f	12.99e	2.67f	8.55h
	LSD at 5% level of significance		11.19	11.56	2.83	15.31

Mean followed by same letters in columns are non-significant at 5 % level of significance.

Table II. Effect of EC_{iw} and SAR_{iw} on physiological growth parameters of okra

S.No.	Treatments		Transp. rate (mmol m^{-2} s^{-1})	Water pot. (Mpa)	Osmo. pot. (Mpa)	Turg. pot. (Mpa)
	EC_{iw}	SAR_{iw}				
T0	0.91	2.15	10.90a	-1.60a	-2.10a	0.50a
T1	2.00	10.00	8.43b	-1.73ab	-2.15ab	0.42b
T2	2.00	15.00	7.25c	-1.75ab	-2.16ab	0.41b
T3	2.00	20.00	6.50cd	-1.77b	-2.17ab	0.40b
T4	4.00	10.00	6.33cd	-1.93c	-2.29bc	0.36c
T5	4.00	15.00	5.71de	-1.95cd	-2.29bc	0.34d
T6	4.00	20.00	5.15ef	-1.98d	-2.30d	0.32d
T7	6.00	10.00	4.41fg	-2.10c	-2.36e	0.26e
T8	6.00	15.00	3.97gh	-2.20f	-2.40f	0.20f
T9	6.00	20.00	3.40h	-2.30g	-2.42g	0.12g
	LSD at 5% level of significance		0.992	-0.354	-0.284	0.123

Mean followed by same letters in columns are non-significant at 5 % level of significance

MPa) was noted in T9, while the highest value (-2.10 MPa) was in the case of T0. Statistically non-significant difference was noted between T1, T2 and T3. Moreover, the effect of T4 and T5 was statistically similar on the osmotic potential of leaves.

Data (Table II) show that turgor potential of leaves decreased with EC and SAR of irrigation water. The lowest (0.12 MPa) turgor potential was recorded in T9, whereas minimum (0.50 MPa) was in the case of control. It is evident that T1, T2 and T3 have statistically non-significant effect on turgor potential of leaves. Similarly, T5 and T6 are statistically similar with each other but differed significantly with other treatments. Delane *et al*. (1982) observed the similar results and reported that salinity significantly reduced the turgor potential of leaves of okra.

Water salinity and SAR retarded the growth, yield and physiological growth parameters of okra. The effects of these water quality parameters were visible in morphological characters because the treated plants were smaller than the control. Impact became more severe as EC_{iw} and SAR_{iw} levels progressed. Height, fresh and dry matter yield and fresh pod yield were reduced with EC_{iw} and SAR_{iw} than control. Inhibition in growth with high EC_{iw} and SAR_{iw} may be due to reduced cell production, cell enlargement and/or cell wall expansion (Curtis & Lauchli, 1987). Malach *et al*. (1989) applied saline water having EC_{iw} 1.0, 2.0, 4.0, 6.0 and 8.0 dS m^{-1} to onion in a pot. They reported that onion could tolerate EC_{iw} up to 4.0 dS m^{-1}. Mangal *et al*. (1990) reported a significant negative correlation between soil salinity and yield of garlic. Salinity induced water deficit (Pessarakli & Tucker, 1988), which is the main cause of growth inhibition (Mass & Neiman, 1978), ultimately resulted in turgor loss by plants (Delane *et al*., 1982). Loss in cell turgor cause its membrane to become disorganized, so various physiological processes became disturbed. Due to retarded metabolism, biosynthesis of new compounds such as protein is checked. This ultimately leads to the inhibited production of dry matter and yield of plants.

CONCLUSIONS

The fresh pod yield and physiological parameters such as photosynthesis, transpiration rate, water and osmotic potential decreased with EC_{iw} and SAR_{iw}. The treatment comprising EC_{iw} up to 2.0 dS m^{-1} and SAR_{iw} up to 20 proved to the best for producing maximum fresh pod yield of okra.

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