Effect of salinity and drip fertigation on maize (Zea mays) and water use efficiency

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Water is one of the earth's most vital resources and crucial for agriculture and life. Growing population, urbanization and climate change reduce the world's freshwater supply. Food security and environmental sustainability require longterm water shortage solutions because freshwater scarcity negatively impacts agricultural production. In tropical and subtropical ecosystems rapidly depleting freshwater resources for agriculture leads to irrigating the fields with high salt water. Saline water often thought harmful to crops and soil (Hu and Schmidhalter 2002), is now a viable alternative in coastal tropical ecosystems. Saltwater irrigation promotes salinization, which disrupts most plant processes and is a global agricultural concern. Ineffective irrigation techniques can reduce soil matric potential and raise root zone salt concentrations, reducing crop water uptake and salinating the cultivated layer (Chu et al. 2016). To successfully use salt water in agriculture, meticulous planning and management are required.

Unlike other irrigation methods, drip irrigation reduces soil salinity and minimize fertilizer (Yang et al. 2023) while preserving crop yield (Makarana et al. 2019). Conjunctive use of fresh and saline water can also minimize the negative effects of salinity on crops (Murad et al. 2018). Effective nutrient management through well-planned drip fertigation systems enhances water and fertilizer absorption, significantly boosting crop yields while limiting salt impacts. Maize (Zea mays L.), despite its susceptibility to salinity, has emerged as a crucial winter (rabi) season crop in the Krishna delta region due to its profitability and high productivity. In this context, an attempt was made to assess the impact of drip fertigation using saline water on maize and its water use efficiency.

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Present study was carried out during winter (rabi) season of 2022–23 at the Saline Water Scheme, Agricultural College Farm, Acharya N. G. Ranga Agricultural University, Bapatla, Andhra Pradesh to see the effect of salinity and drip fertigation on maize and water use efficiency. Experiment consisted of 8 treatments, viz. T_1 , Irrigation with BAW (Best Available Water) (<1 dS/m); T_2 , Irrigation with 2 dS/m; T_3 , Irrigation with 4 dS/m; T_4 , Irrigation with BAW + Recommended dose of fertilizer (RDF); T_5 , T_2 + RDF; T_6 , T_3 + RDF; T_7 , T_2 + RDF with alternate use of fresh water; and T_8 , T_3 + RDF with alternate use of fresh water in a randomised block design (RBD) with 4 replicates.

The experimental site was sandy loam, uniform in topography, homogeneously fertile, slightly alkaline (7.2), non-saline (0.46 dS/m), low in nitrogen (151 kg/ha), rich in phosphorus (34 kg/ha), and potassium (345 kg/ha). The drip irrigation system had 50 cm-separated 16 mm in line laterals and 2.0 litre/h discharge emitters. To create waters with 2 and 4 dS/m EC, 34 dS/m sea water was diluted with 0.6 dS/m pure water. Using IW/CPE ratio, irrigation was given to all plots. The recommended package and practices of crop products were followed. Plants were selected randomly, and their growth was observed. Attributed yield was recorded at harvest using kernel yield and harvest index, and water use efficiency were calculated. Gross net returns and benefit-cost ratios were calculated using the cost of cultivation. Based on the field data, the data collected for crop growth, yield attributes and yield were statistically analyzed for variance. Isohalines were prepared based on the measured results of EC to represent the salinity measures in each treatment.

Plant height and dry matter accumulation: Significantly, the tallest plants (Table 1) were observed at all the crop growth stages under T₄ treatment. The soil solution's low osmotic potential led to less plant accessible water and salt accumulation in leaf tissue. Reduced synthesis and absorbed supply to growth parts may have affected plant height compared to freshwater fertilized treatments. These findings are in line with the results of Murad et al. (2018).

Table 1 Effect of saline water on plant height and dry matter accumulation of maize under drip fertigation

Treatment		Plant he	ight (cm)		Drymatter accumulation (t/ha)					
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest		
T_1	65.3	164.7	204.0	209.2	1.0	8.4	14.1	15.2		
T_2	61.9	158.8	197.8	201.3	0.9	8.0	13.0	13.9		
T_3	54.9	145.6	185.7	189.6	0.8	7.1	11.9	12.8		
T_4	81.3	210.3	250.4	256.8	1.3	10.3	18.0	19.7		
T_5	76.7	195.4	236.5	241.4	1.2	9.4	16.9	18.1		
T_6	72.4	188.0	228.4	232.5	1.1	8.6	15.6	16.6		
T_7	79.2	203.2	246.6	251.2	1.3	10.0	17.9	19.2		
T_8	77.7	199.9	240.1	245.5	1.2	9.8	17.3	18.6		
SEm±	3.0	7.5	10.5	11.3	0.1	0.4	0.7	0.8		
CD (P=0.05)	8.9	22.1	31.0	33.3	0.1	1.1	2.2	2.2		

Refer to the methodology for treatment details.

The dry matter accumulation (Table 1) recorded in the T_4 treatment was highest at all crop growth stages and recorded lowest in treatment T_3 . Salinity decreases the growth of younger leaves by limiting carbohydrate delivery to growing cells. Due to decreased stomata conductance and photosynthesis rate, photosynthate production, leaf area and dry matter production might decrease (Munns 2002).

Yield attributes and yield: The number of cobs per plant did not differ significantly among all the treatments (Table 2). Leogrande et al. (2016) observed similar non-significant results. The number of kernels/cob of maize changed significantly due to a change in saline water levels. Irrigation with T_4 treatment produced the highest number of kernels/cob (451). Freshwater fertilizer treatments increased kernels/cob. This may be owing to the crop's low root zone salt concentration. These findings were consistent with Li et al. (2018).

Irrigation with T₄ treatment recorded the longest

cobs (17.2 cm), significantly superior to the rest of the treatments. The cob length had decreased to the increase in salinity in irrigation water. Rad *et al.* (2012) also noticed a similar pattern. Alternate freshwater and RDF use across salinity levels significantly increased cob length. The lowered osmotic effect of salt on plants enhanced carbon assimilation, plant growth, dry matter partitioning and cob length. Significantly, the heaviest cobs (164.4 g) were observed by irrigating with T₄ treatment, which was found on par with T₇. The increased weight of cobs with fresh water treatment could be attributed to reduced salt effects, which results in a greater number of kernels/cob and a higher test weight of the kernels, resulting in a higher weight of the cob. The findings are consistent with those of Leogrande *et al.* (2016).

Data on the grain yield of maize revealed that the highest kernel yield (7.38 t/ha) was recorded under T_4 treatment. The kernel yield (%) drop (Table 2) for T_3 treatment was 34.5%, the greatest of any treatment.

Table 2 Effect of saline water on yield attributes, yield and economics of maize under drip fertigation

Treatments	Number of cobs/ plant	Cob length (cm)	Number of kernels/ cob	Cob weight (g)	Kernel yield (t/ha)	Kernel yield % reduction	Stover yield (t/ha)	Harvest index (%)		Net returns (₹/ha)	B:C ratio
T_1	1.0	12.6	350	115.9	5.91	20.0	8.0	42.6	120378	77522	1.8
T_2	0.9	11.7	330	104.8	5.6	24.6	7.5	42.7	112358	69502	1.6
T_3	0.9	10.4	288	92.2	4.8	34.5	6.7	41.8	99127	56271	1.3
T_4	1.1	17.2	451	164.4	7.5	-	9.6	43.6	154406	99650	1.8
T_5	1.1	15.2	424	140.7	6.7	8.5	8.8	42.7	144182	89426	1.6
T_6	1.0	13.6	409	124.5	6.1	17.1	8.3	42.0	131363	76607	1.4
T_7	1.1	16.4	443	151.3	7.2	2.9	9.4	43.2	150017	95261	1.7
T_8	1.0	15.9	433	145.7	6.9	6.5	9.15	43.0	147025	92269	1.8
SEm±	0.1	0.7	18.7	6.0	0.3	-	0.50	1.8	7236.5	7236.5	0.1
CD (P = 0.05)	NS	2.0	55.2	17.6	1.0	-	1.5	NS	21283.1	21283.2	0.4

Refer to the methodology for treatment details.

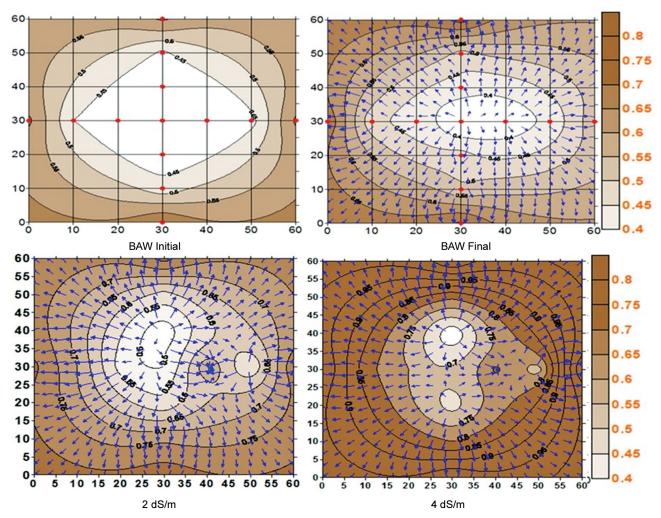


Fig. 1 Isohalines under drip irrigation.

Salt-induced physiological stress reduces kernel storage capacity during filling as reduces endosperm cells and amyloplasts, lowering grain weight and yield. These findings concur with those of Shehzad et al. (2020). Data on the stover yield of maize revealed that the highest stover yield (9.61 t/ha) was registered under irrigation with the T₄ treatment. Salinity significantly reduced the stover yield. Lower stover yields with saline water irrigation may be owing to reduced leaf number and greater root zone salt concentration. The findings were consistent with those of Chamekh et al. (2015). It is evident from the data that the harvest index of maize was not influenced significantly by saline water under drip fertigation. The results follow the findings of Barbosa et al. (2012) who stated that the harvest index is not affected by salinity levels either in continuous saline water or in cyclic usage of saline and fresh water.

Gross returns, net returns and B: C ratio: Significantly, the highest gross returns, net returns and B: C ratio were recorded in T₄ treatment. Irrigation with BAW along with RDF increased economic benefits by increasing kernal and stover yields. The results are consistent with the findings of Feitosa et al. (2016).

Water use efficiency: Significantly, the highest water use efficiency was recorded under T₄ treatment. Increased salinity decreased water consumption efficiency. Saline conditions may reduce rooting depth, reducing crop water intake soil volume. Lower soil volume and osmotic potential limit moisture availability (Katerji et al. 2003). Salt stress disrupts crop nutrition, affecting physiological and metabolic systems and reducing water consumption efficiency.

The isohalines (Fig. 1) imply that BAW and saline water increased soil salinity around irrigation zones. However, salinity intensity varies considerably. The maximum salinity was recorded in irrigation water with 4 dS/m electrical conductivity. EC values started at 0.7 dS/m near the emitters and grew toward the edges. The contrary is true for irrigation, which optimizes water use.

According to the study's findings when saline irrigation water with an EC of 4 dS/m was used without the RDF the growth parameters, yield attributes, yield, and water use efficiency of maize crop were reduced compared to fresh water. However, using saline and fresh water in a cyclic technique with an EC of 2–4 dS/m could produce equivalent results without affecting crop growth, yield and economic returns.

SUMMARY

Climatic variability is immensely pressurised on freshwater availability in arid and semi-arid ecosystems, leading to poor quality water for crop production not becoming uncommon, especially in coastal ecosystems. A field experiment was conducted during winter (rabi) season of 2022-23 at the Saline Water Scheme at Agricultural College Farm, Acharya N. G. Ranga Agricultural University, Bapatla, Andhra Pradesh to assess the impact of saline water on maize growth, yield and water use efficiency under drip fertigation. The experiment consisted 8 treatments laid in randomized block design (RBD) with 4 replications. The utilization of the BAW irrigation method, together with the application of a prescribed quantity of fertilizer, resulted in the highest plant height and dry matter accumulation during all phases of crop growth. These outcomes were comparable to those achieved by using a combination of fresh water and saline water with an electrical conductivity of 2 dS/m. The maximum values for the number of kernels per cob (451), cob length (17.2 cm), cob weight (164.4 g), kernel yield (7.38 t/ha), stover yield (9.61 t/ha) and water use efficiency (18.5 kg/ha mm) of maize were observed under the irrigation treatment T_4 . The parameters exhibited their minimum values when irrigation was conducted using water with a salt level of 4 dS/m and no fertilizers were used. However, there was no statistically significant difference observed in the number of cobs per plant and harvest index of maize when saline water was used in conjunction with drip fertigation. In the context of maize cultivation, employing a cyclic irrigation technique that alternates between salty (EC 2–4 dS/m) and freshwater sources, in conjunction with recommended dose of fertiliser (RDF) has the potential to deliver comparable crop development, productivity, and economic benefits when compared to the use of freshwater sources alone.

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