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Research Article

Effect of Saline Water and Nitrogen Levels on Growth and Yield of Brinjal (*Solanum melongena* L.) Crop under Drip and Flood Irrigation

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ABSTRACT

The study was conducted at the research farm of department of CCSHAU, Hisar to determine the effects of saline water and nitrogen application on yield and growth parameters of brinjal under drip and surface flood irrigation grown on a sandy soil during *Kharif* season of 2019. The treatments consist of two irrigation method (drip and surface flood), three saline water levels (canal water, ECiw- 2.5 and 5.0 dS m^{-1} and three N levels (75, 100 and 125% RDN). Results showed that drip irrigation increased the crop yield, plant height, number of branches per plant, LAI and dry matter accumulation by 19.5, 19.4, 23.4, 8.2 and 17% as compared the surface flooding. Application of saline water of ECiw 2.5 and 5.0 dS m^{-1} through drip system significantly increased the plant height by 20.8%, 37.1% and leaf area index by 20.1%, 29% compared to their respective treatments under surface flooding. All the growth parameters were found highest in the treatment having 125% RDN followed by 100% RDN and 75% RDN. The effect of interaction between irrigation methods and saline water and irrigation methods and nitrogen levels was found significant on fruit yield and plant height. The study concludes that the drip irrigation has a great potential in areas with limited availability of good quality water and slightly saline water through drip system might be used in arid and semi-arid climatic conditions.

Key words: Brinjal yield, drip irrigation, dry matter, leaf area index, saline water

Introduction

In irrigated agriculture, one of the challenging situations throughout world is the decreasing availability of fresh water. In most of the areas, there are considerable sources of saline water, which can be utilized for irrigation purposes with adoption of suitable crops, soil and water management strategies (Mantell *et al.,* 1985; Rhoades *et al*., 1992). Although irrigation with saline water overcomes the shortages of fresh water resources while, the inappropriate use of saline water (such as the use of saline water with excessive salinity and improper irrigation method) may result in salinity stress conditions that lead to the secondary salinization and a series of environmental problems (Kumar *et al.,* 2015; Li *et al.,* 2015). The safe and efficient use of saline water for irrigation requires adoption and implementation of improved water management practices and the choice of the most appropriate irrigation methods

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such as drip or trickle system to prevent the development of excessive salinity in root zone for crop production. Surface flood irrigation is one of the most inefficient ways of water application practiced widely in South Asia that must be replaced with furrow, drip or sub-irrigation systems (Ajula *et al.,* 2007).

Brinjal (*Solanum melongena* L.) is a warm season vegetable crop widely cultivated in the central, southern and south-east Asia and in some African countries. Brinjal is commonly known as eggplant or aubergine belongs to the "Solanaceae" family and genus "solanum". In India, Brinjal is grown in an area of about 0.73 mha with annual production of 12.8 Mt (National Horticulture Board, 2018). The eggplant is usually considered as moderately sensitive to salinity (Maas, 1984), although (Bresler *et al*., 1982) categorized it as sensitive to salinity. Previous literatures have reported that the use of saline water is acceptable for irrigation of moderate and mild salt-tolerant crops (Kang *et al.,* 2010; Amer *et al.,* 2010; Xue *et al.,* 2017). Therefore, to overcome the water scarcity of good quality water in arid and semi-arid areas, drip irrigation offers better opportunities for improving the yield and water use efficiency of saline water over conventional method, especially, for cash crops, i.e., vegetables to meet the crop demands. The present study was carried out to investigate the response of brinjal (*Solanum melongena* L.) crop to different saline water and nitrogen levels through drip and surface flood irrigation methods.

Materials and Methods

Experimental site and treatment details

The experiment was carried out from July–November 2019 at research farm of Department of Soil Science, CCS Haryana Agricultural University, Hisar (latitude 29°09′03.5″ N and longitude 75° 41′20.8″ E). Mean air temperature ranged between 20.7 and 41.2°C and the mean minimum air temperature ranged between 8.8 and 30.3°C during the crop season. The initial basic soil physical and chemical properties of the experimental site are summarized in Table 1. The conventional irrigation method (surface flood irrigation) was compared with the drip irrigation with three different water qualities

Table 1. Initial physico-chemical properties of the experimental site

Properties	Soil depth	
	0-15 cm	15-30 cm
Texture	Sandy	Sandy
Bulk density (Mg m^{-3})	1.51	1.53
pH (1:2)	7.34	7.44
Soil organic carbon (%)	0.28	0.22
Available N (kg ha^{-1})	124.3	119.6
Available P (kg ha^{-1})	30.3	26.5
Available K (kg ha^{-1})	256.2	244.9

- ECiw- 0.46 (canal water), 2.5 dS m^{-1} and 5.0 dS m^{-1} in main plots. Three levels of nitrogen (N) were studied, i.e. 75, 100 and 125% of recommended dose of nitrogen (RDN) as sub plots. The round variety of brinjal used was *Hisar Shyamal.*

Irrigation and nitrogen scheduling

The irrigation was applied on alternate days on the basis of daily crop evapotranspiration (ETc) data under drip and irrigation water of 40 mm was applied fortnightly under surface flood method. During crop establishment, for initial one month, irrigation was applied with canal water; thereafter the water quality treatments were imposed. Before transplanting of the crop full recommended dose of FYM @ 8 kg per plot, phosphorus @ 20 g per plot (50 kg/ha RD) and K @ 10 g per plot (25 kg/ha RD) was applied. In each water quality treatment, three nitrogen fertilizer levels i.e. 75% RDN (75 kg/ha), 100% RDN (100 kg/ha) and 125% RDN (125 kg/ha) were applied. In drip irrigation, the nitrogen fertilizer was applied with irrigation water in 6 equal splits at 15 days internal. In surface flooding method, 1/3 of nitrogen fertilizer was applied before transplanting and remained nitrogen was applied in two equal splits at 30 and 60 days after transplanting.

Plant growth measurements and yield

The fruits were harvested seven times when attained marketable size for vegetable purpose. The total yield of the fruit from each plot was recorded by cumulating the yield per picking and expressed in kg per plot. Plant height was measured on randomly five plants per plot from each replication and labelled for recording of various observations.

Numbers of primary and secondary branches arising from the main stem from all the observation plants were counted manually from the plants after last picking. The dry matter accumulation excluding the weight of the fruits was estimated by obtaining dry weight of leaves, stem and roots after drying at 65°C for 48 hrs. Leaf area was determined using portable leaf area meter (CI-202 Laser area meter) at the end of the experiment. Leaf area index (LAI) was calculated as a ratio between leaf area and ground area.

Statistical analysis

The experiment was conducted in a split plot design with the methods of irrigation and saline water as main treatments and N levels as sub-main treatments with the three replications. The significance of treatment effects was analysed using analysis of variance by split-split plot design using OP Stat software, CCS HAU Hisar.

Results and Discussion

Electrical conductivity (ECe)

The electrical conductivity of the soil increased with increasing saline water levels at 0-15 and 15-30 cm depths. The data in Table 2 showed that saline water irrigation increased the total soluble salt content in soil. The plots irrigated with saline water of EC 2.5 and 5.0 dS m^{-1} showed a significant increase in soil ECe as compared to their initial values. Application of saline water of ECiw= 2.5 and 5.0 dS m^{-1} results in ECe build-up of 3.51 and 5.24 dS m^{-1} at surface layer (0-15 cm depth). However, use of saline water (ECiw= 5.0 dS m^{-1}) through drip irrigation lowered the soluble salt concentration in soil by 34.3% at 0-15 cm and 23.4% at 15-30 cm with mean value of ECe 3.44 and 3.67 dS m^{-1} as compared to the surface flooding. After each irrigation cycle under surface flood method, soil dried out and the salts are concentrated at the surface layer. Alternatively drip system with frequent irrigation maintains optimum moisture in soil which keeps the soluble salts diluted in soil and make potential use of saline or brackish water with minimum soil salinity development (Zaman *et al.,* 2018).Similar results were obtained with ECiw=2.5 dS/m under drip over flood irrigation. Our results were observed in agreement with Huang *et al*. (2011), Malik *et al.* (2015) and Ragab *et al.* (2008) also reported the similar results that the accumulation of salts increased with increased irrigation water salinity due to continuous application of saline water in soil. The salinity of upper soil layer

Table 2. Soil electrical conductivity (ECe) influenced by methods of irrigation, salinity and nitrogen levels

Irrigation methods	ECiw levels (dS/m)	0-15 cm depth 75% RDN	100% RDN	125% RDN	Mean	15-30 cm depth 75% RDN	100% RDN	125% RDN	Mean
Drip irrigation	0.46	0.54	0.40	0.34	0.47	0.66	0.58	0.52	0.59
	2.5	2.14	1.97	1.82	1.98	2.22	2.12	1.99	2.17
	5.0	3.49	3.43	3.40	3.44	3.74	3.67	3.61	3.67
	Mean	2.06	1.93	1.85	1.96	2.21	2.12	2.04	2.13
Surface flood irrigation	0.46	0.47	0.42	0.37	0.42	0.42	0.38	0.31	0.37
	2.5	3.63	3.50	3.41	3.51	3.31	3.20	3.15	3.22
	5.0	5.32	5.24	5.15	5.24	4.93	4.78	4.66	4.79
	Mean	3.14	3.05	2.98	3.06	2.89	2.79	2.71	2.79
CD (p=0.05)		Irrigation method (I)= 0.19 Salinity level (S) = 0.24 Nitrogen level (N) = 0.11 I × S level= 0.33 I × N= NS S × N= NS I × S × N=NS				Irrigation method (I)= 0.20 Salinity level (S) = 0.24 Nitrogen level (N) = 0.10 I × S level= 0.35 I × N= NS S × N= NS I × S × N=NS			

Table 3. Brinjal fruit yield (t ha^{-1}) and dry matter accumulation (%) as influenced by methods of irrigation, salinity and nitrogen levels

Irrigation methods	ECiw levels (dS/m)	Fruit yield (t ha^{-1}) 75% RDN	100% RDN	125% RDN	Mean	Dry matter accumulation (%) 75% RDN	100% RDN	125% RDN	Mean
Drip irrigation	0.46	22.88	24.79	26.98	24.88	54.19	61.96	66.27	60.81
	2.5	20.08	22.42	25.00	22.50	46.51	54.92	59.94	53.79
	5.0	16.42	18.73	21.08	18.74	39.70	46.31	52.14	46.05
	Mean	19.79	21.98	24.35	22.04	46.80	54.40	59.45	53.55
Surface flood irrigation	0.46	19.67	22.33	26.17	22.72	45.34	54.05	60.02	53.14
	2.5	13.75	17.92	22.46	18.04	39.2	47.67	53.74	46.87
	5.0	10.92	14.33	18.54	14.60	29.85	38.43	43.66	37.31
	Mean	14.78	18.19	22.39	18.45	38.13	46.72	52.47	45.77
CD (p=0.05)		Irrigation method (I) = 0.73 Salinity (S) = 0.89 Nitrogen (N) =0.72 I × S = 1.26 I × N = 1.02 S × N= NS I × S × N=NS				Irrigation method (I) = 2.93 Salinity (S) = 3.58 Nitrogen (N)= 4.08 I × S = NS I × N = NS S × N= NS I×S×N=NS			

was greater than the lower layer with traditional method irrigation.

Fruit yield

The data in Table 3 revealed that the fruit yield (t ha^{-1}) varied widely under different treatments of saline water applied through surface flood and drip irrigation methods at different N levels (Table 3). Drip irrigation significantly increased the fruit yield by 19.5% over surface flood method. In drip irrigation, a highest mean value of fruit yield of 24.88 t ha^{-1} was recorded in $S_{0.46}$ followed by 22.5 t ha^{-1} in $S_{2.5}$ and 18.74 t ha"^{1}in $S_{5.0}$ treatments. Application of saline water through conventional method lowered the fruit yield in each treatment with the mean value of 22.72 t ha^{-1} in $S_{0.46}$, 18.04 t ha^{-1} in $S_{2.5}$ and 14.6 t ha^{-1} in S_5. The nitrogen doses also have significant effect on the yield and highest mean value was reported under 125% RDN i.e., 24.35 t ha^{-1} under drip irrigation and 22.39 t ha^{-1} under surface flooding.

The results revealed that application of poor quality water through drip produced 38.8% and 44.4% higher fruit yield in $S_{2.5}$ and $S_{5.0}$ saline water treatments as compared to surface flooding. Thus, the magnitude of increase in yield under drip irrigated plots in comparison to surface flood irrigated plots signifies advantage of drip over conventional method (flooding) with saline irrigation water. Interaction between irrigation and salinity and irrigation and nitrogen showed significant difference on fruit yield. The crop yield decreased with the increasing irrigation water salinity due to accumulation of salts near the root zone and the reduction of magnitude found positively correlated to the concentration of the soluble salts in the soil (Unlukara *et al.*, 2010; Kumar *et al.,* 2017). Jha *et al.* (2017) reported similar results of higher potato tuber yield (33.07 t ha^{-1}) for good quality water and minimum yield of 18.8 t ha^{-1} observed with EC_{iw}- 8 dS m^{-1} under drip as compared to furrow irrigation. Our results were observed in agreement with Kumar *et al.* (2017) reporting highest tomato yield in plots of good quality water with 125% RDN (61.53 Mg ha^{-1}) and lowest yield of 34.68 Mg ha^{-1} in saline water irrigated plots (ECiw- 2.5 dS m^{-1}) under drip irrigation.

Dry matter accumulation (%)

The highest dry matter accumulation of 53.5% was recorded in drip irrigation treatment which was 17% significantly higher than the surface flood

(Table 3). The results revealed that the highest mean value of dry matter content was observed in $S_{0.46}$ (60.83) followed by $S_{2.5}$ (53.77) and $S_{5.0}$ (46.03) under drip irrigation. Total dry matter accumulation significantly reduced with the increasing irrigation water salinity, whereas, through drip system the application of saline water of ECiw-2.5 dS m^{-1} and ECiw-5.0 dS m^{-1} increased the dry matter content by 14.8% ($S_{2.5}$) and 23.4% ($S_{5.0}$) compared to their respective treatments under surface flooding. Dry matter accumulation also increased significantly with the nitrogen doses. Under drip irrigation, dry matter production increased by 22.7%, 16.4% and 13.3% at 75, 100 and 125% RDN compared to respective N levels under surface flooding. Interaction between different treatments was non-significant. For conventional irrigation method, dry matter accumulation also followed the similar trends, dry matter of plants reduced with the higher water salinity and increased with the higher rate of nitrogen application, which confirms the results of Al-Maskri *et al.* (2010). Kadam *et al*. (2007) and Javeed *et al*. (2018) recorded the maximum reduction of the dry matter production in plants subjected to the salinity stress.

Primary branches and secondary branches per plant

The highest mean value of primary and secondary branches per pant was observed under drip irrigation (5.68 and 8.77) as compared to the surface irrigation (4.61 and 7.1) given in Table 4. Among different saline water treatments under drip irrigation, canal water (6.12 and 9.64) reported maximum mean number of primary and secondary branches per plant followed by ECiw-2.5 dS m^{-1} (5.7 and 8.79) and ECiw-5.0 dS m^{-1} (5.21 and 7.88), respectively. Application of saline water through drip increased the number of primary branches by 7.7, 27.5, and 41.6% and secondary branches by 6.9, 31, and 41.2% for canal water, ECiw-2.5 dS m^{-1} and ECiw-5.0 dS m^{-1} in comparison to their respective treatments under surface flooding. Number of primary and secondary branches was significantly higher at 100% RDN (5.82 and 8.98) as compared to 75% RDN (5.07 and 7.78) and it was at par with 125% RDN (6.15 and 9.57) under drip irrigation, similar results were observed in surface flooding. Similar results were reported by Hadole *et al.* (2020) and Sollapur and Hiremath (2017) they reported that higher fertilizer

Table 4. Primary and secondary branches per plant as influenced by methods of irrigation, salinity and nitrogen levels

Irrigation methods	ECiw levels (dS/m)	Primary branches per plant				Secondary branches per plant			
		75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean
Drip irrigation	0.46	5.53	6.27	6.57	6.12	8.67	9.87	10.37	9.64
	2.5	5.07	5.87	6.17	5.70	7.60	9.07	9.70	8.79
	5.0	4.60	5.33	5.70	5.21	7.07	7.93	8.63	7.88
	Mean	5.07	5.82	6.15	5.68	7.78	8.96	9.57	8.77
Surface flood irrigation	0.46	5.00	5.87	6.17	5.68	7.93	9.33	9.80	9.02
	2.5	3.77	4.67	4.97	4.47	5.53	7.07	7.53	6.71
	5.0	3.07	3.80	4.17	3.68	4.53	5.67	6.53	5.58
	Mean	3.95	4.78	5.10	4.61	6.00	7.36	7.95	7.10
CD (p=0.05)		Irrigation method (I)= 0.33 Salinity level (S) = 0.41 Nitrogen level (N) = 0.37 I × S level= 0.58 I × N= NS S × N= NS I × S × N=NS				Irrigation method (I)= 0.36 Salinity level (S) = 0.44 Nitrogen level (N) = 0.63 I × S level= 0.62 I × N= NS S × N= NS I × S × N=NS			

levels recorded significantly higher number of branches per plant in brinjal crop.

Plant height

Different irrigation methods, saline water and nitrogen levels significantly affected the plant height. The highest mean value of plant height was observed under drip irrigation (140.4 cm) over surface flooding (117.6 cm). Plant height was significantly increased under drip irrigation by 19.4% compared to the surface flooding method (Table 5). In drip irrigation treatments, the plant height increased by 7.3, 20.8 and 37.1% for canal water, ECiw-2.5 dS m^{-1} and ECiw-5.0 dS m^{-1} in comparison to their respective treatments under surface flooding. The height of the plant significantly increased with increase in the rate of N upto 125% RDN in all the treatments. Irrigation methods, saline water and nitrogen interaction showed significant effect on the plant height. Irrigation with saline water caused the accumulation of the salts around the root zone which impeded the water and nutrient uptake. Higher concentration of salts in soil solution leads to salinity hazards or salt toxicity in plants, which affects plant growth as well as development processes including seed germination, vegetative growth and fruit set (Sairam and Tyagi, 2004). Soomro *et al.* (2012) in okra and AL-Zubaidi (2018) in brinjal crop reported that with increase in water salinity levels growth of the plant reduced significantly.

Leaf area index (LAI)

There were significant decreases in LAI of plants under higher salinity stress, especially under surface flood irrigation method for $S_{5.0}$ at N_{75} treatment. Similar trend was observed for drip irrigation system, where salinity stress reduced the LAI of plants in $S_{5\cdot 0}$ treatment plots but LAI increased with increase in the N levels. LAI significantly increased by 8.2% under drip irrigation (4.72) over surface flooding (4.36). Highest mean value of LAI was recorded in treatment with canal water (5.65) in drip system followed by the canal water (4.97) under surface flood irrigation (Table5). Application of saline water of ECiw- 2.5 dS m^{-1} and 5.0 dS m^{-1} through drip system increased LAI values by 20.1% ($S_{2.5}$) and 29% ($S_{5.0}$) compared to their respective treatments under surface flooding. Nitrogen doses significantly increased the mean value of LAI i.e. 4.14, 4.77 and 5.24 at 75, 100 and 125% RDN under drip and 3.69,

Table 5. Plant height (cm) and leaf area index (LAI) as influenced by methods of irrigation, salinity and nitrogen levels

Irrigation methods	ECiw levels (dS/m)	Plant height (cm)				LAI			
		75% RDN	100% RDN	125% RDN	Mean	75% RDN	100% RDN	125% RDN	Mean
Drip irrigation	0.46	150.53	156.8	163	156.78	4.7	5.24	5.65	5.20
	2.5	133.67	142	148.8	141.49	4.04	4.66	5.19	4.63
	5.0	115.73	123.07	130.07	122.96	3.69	4.4	4.89	4.33
	Mean	133.31	140.62	147.29	140.41	4.14	4.77	5.24	4.72
Surface flood irrigation	0.46	134.73	148.73	154.73	146.06	4.42	5.01	5.48	4.97
	2.5	101.93	121.73	127.8	117.15	3.59	4.38	4.99	4.32
	5.0	76.93	88.93	103.2	89.69	3.07	3.87	4.43	3.79
	Mean	104.53	119.80	128.58	117.63	3.69	4.42	4.97	4.36
CD (p=0.05)		Irrigation method (I) = 3.71 Salinity (S) = 4.55 Nitrogen (N) = 3.80 I × S = 6.43 I × N = 5.37 S × N= NS I × S × N=NS				Irrigation method (I) = 0.27 Salinity (S) = 0.34 Nitrogen (N) = 0.42 I × S = NS I × N = NS S × N= NS I × S × N=NS			

4.42, 4.97 at 75, 100 and 125% RDN under surface flooding Due to presence of salts in irrigation water resulted in detrimental effects on crops i.e. decreased turgor pressure, degraded cell expansion, thus reducing the growth rate and photosynthesis (Zhai *et al.,* 2015). Interaction between different irrigation methods, saline water and nitrogen levels was reported non-significant on LAI. Similar results were reported earlier by Hebbar *et al.* (2004) on tomato crop where the leaf area index (LAI) and total dry matter (TDM) production were significantly higher in drip irrigation (3.12 and 165.8 g, respectively) over furrow irrigation (2.25 and 140.2 g, respectively).

Conclusion

The findings of the present study indicated that controlled application of poor quality water through drip irrigation decreased the reduction magnitude of fruit yields and growth parameters over the flood irrigation method, leading to more effective utilization of available resources. Therefore, the application of saline water through drip system reduction magnitude of plant height, number of branches per plant, leaf area index and dry matter of the plants was lower than the conventional method. The maximum fruit yield and growth parameters were achieved at 125% RDN as compared to the 100 and 75% RDN.

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