International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 2952-2957

Received: 19-05-2019
Accepted: 21-06-2019

Rajkumar RH
Department of Soil and Water Engineering, CAE, UAS, Raichur, Karnataka, India

Nemichandrappa M
Department of Soil and Water Engineering, CAE, UAS, Raichur, Karnataka, India

Anilkumar T Dandekar
Department of Soil and Water Engineering, CAE, UAS, Raichur, Karnataka, India

Ayyanagowdar MS
Department of Irrigation and Drainage Engineering, CAE, UAS, Raichur, Karnataka, India

Polisgowdar BS
Department of Irrigation and Drainage Engineering, CAE, UAS, Raichur, Karnataka, India

Satyanarayana Rao
Main Agricultural Research Station, UAS, Raichur, Karnataka, India

Vishwanatha J
AICRP on Saline water scheme, A.R.S, Gangavathi, UAS Raichur, Karnataka, India

Correspondence
Rajkumar RH
Department of Soil and Water Engineering, CAE, UAS, Raichur, Karnataka, India

Effect of different irrigation methods and saline water on soil properties in tomato (*Solanum lycopersicum*) crop under vertisols of Tungabhadra project command

Rajkumar RH, Nemichandrappa M, Anilkumar T Dandekar, Ayyanagowdar MS, Polisgowdar BS, Satyanarayana Rao and Vishwanatha J

Abstract

The experiment was conducted at Agricultural Research station, Gangavathi (Karnataka) during 2018-19 and 2019-20 to study the effect of three (Furrow-M_0, Surface drip-M_1 and Subsurface drip-M_2) different irrigation techniques and five (0.65 dS m^{-1}-S_0 normal water, 2 dS m^{-1}-S_1, 3 dS m^{-1}-S_2, 4 dS m^{-1}-S_3 and 5 dS m^{-1}-S_4) different irrigation water salinity levels on soil properties viz., soil pH and soil salinity in tomato (*Solanum lycopersicum*) crop under Vertisols of Tungabhadra Project Command. The soil pH was maximum at the top surface during after harvest in first year and decreased in second year during before sowing under all the treatments. In subsurface drip technique the pH at the 15-30 cm was less as compared to 0-15 cm because of buried drip laterals to a depth of 20 cm. In case of surface drip the top surface (0-15 cm) was having slightly less pH as compared to (15-30 cm) after harvest because of frequent application of water at the top surface through drippers. In case of surface drip, more salt were present at 20 cm distance apart from the dripper at 0-15 and 15-30 cm depths. In case of subsurface drip irrigation, accumulation of salts was more at the soil surface but it was lesser at near and below the buried dripper but increased with distance from the dripper. Due to upward capillary action, more salts accumulated on the top surfaces and at periphery of the water front outside the root zone and less at the root zone of the crop because of continuous salt leaching downwards under subsurface drip. More salt accumulation was observed as salinity level increases. The soil salinity for tomato crop in the active root zone varies within a narrow range. Hence, the salinity was not much affected to the plant roots (20 cm depth). Therefore subsurface drip irrigation can be preferred over furrow irrigation whenever saline water is used under drip irrigation upto a threshold limit of 2 dS m^{-1}.

Keywords: Subsurface drip, surface drip, capillary, salinity

Introduction

The continuous increase in the earth's population requires increasing quantities of water for domestic, industrial and agricultural needs. Water scarcity is becoming one of the major limiting factors to economic development and welfare in most parts of the semi-arid regions of the world. One of the major problems confronting irrigated agriculture nowadays throughout the world is the decreasing availability of fresh water. Saline water irrigation is practiced in several regions of the world (Rhoades *et al.*, 1992), where water scarcity prevents the use of freshwater for irrigation. Poor quality water constitutes 32-84% of ground water surveyed in different parts of India is rated either saline or alkali (Minhas, 1996) [10]. Utilization of saline water for irrigation is associated with salt accumulation in the soil, which might be harmful to plants, and reduces yields. The salt effects on physiological process could be due to lowering of the soil water potential and the toxicity of specific ions. When water resources are limited and the cost of non-saline water becomes prohibitive, crops of moderate to high salt tolerance can be irrigated with saline water especially at later growth stages, provided appropriate irrigation methods and management practices are used. Utilization of saline water for irrigation is associated with salt accumulation in the soil, which might be harmful to plants, and reduces yields. The salt effects on physiological process could be due to lowering of the soil water potential and the toxicity of specific ions. When water resources are limited and the cost of non-saline water becomes prohibitive, crops of moderate to high salt tolerance can be irrigated with saline water especially at later growth stages, provided appropriate irrigation methods and management practices are used. A regular and frequent water supply is only possible with the drip system for crop production. The rooting zone has the lowest possible salinity and the leaching is not needed, except at the harvest and before the next crop is sown (Ragab, 1998). The drip irrigation is efficient for management of both saline and sodic waters.

The surface drip irrigation may results in localized accumulation of salts at the soil surface due to increased evaporation (Ayers and Westcot, 1985) [2]. The salt accumulates on the soil surface before migrate and reach the root zone when surface drip irrigation is used therefore, subsurface drip irrigation (SDI) has been developed to improve salinity management and water use efficiency. The SDI decreases the accumulation of salts at the root zone level of plants, producing an improved yield and fruit quality (Phene *et al.*, 1991 and Oron *et al.*, 1999) [12]. During the last few years, irrigated tomato has been expanding rapidly in the semi-arid part of Karnataka around shallow to deep wells having a salinity of more than 2 dS m^{-1} with normal irrigation methods. This leading to land becomes more prone to the salt affected. Tomato is considered moderately sensitive to salt stress, since it can tolerate an ECe (EC of the saturated soil extract) of about 2.5 dS m^{-1} and fruit yield decrease by 10% with each unit of ECe increasing above the threshold value (Maas, 1986; FAO, 2005). Campos *et al.* (2006) stated that the maximum soil salinity level tolerated by tomato is 2.5 dS m^{-1}, without reduction in the yield. However, there is no much information available on the effect of different irrigation techniques under saline water on soil properties, growth and yield of tomato crop in Vertisols under TBP command area. It is also essential to study solute dynamics under different irrigation techniques using different quality of irrigation water and also to suggest method of irrigation suits under different water salinity levels. Therefore to see the effect of different irrigation methods and use of different saline water levels on soil properties, a study has been conducted.

Material and Methods

Site description

The experiment was carried out at Agricultural Research Station (A.R.S), Gangavathi. The site is located in Koppal district of Karnataka state of India and falls in the Northern Dry Zone viz., Zone-III of agro ecological region 6 in the state. The field's location corresponds to 15^0 27' 22.15" N latitude and 76^0 31' 54.83" E longitudes with elevation of 423.17 m above mean sea level (msl). According to the data at Meteorological Department of the A.R.S, Gangavathi, the mean annual rainfall based on 38 years record (1979-2015) is 530.9 mm (Anon., 2017). Although, monsoonal climate sets in early June, rains during September-October (North-east) are more assured in this region. Normally dry weather prevails over entire summer months with hottest period observed during April-May. During the first year of study period, the total rainfall was 112.1 mm and out of it, 107.9 mm was in the month of May, 2018 and during second season, the total rainfall was only 13.2 mm (3.6 mm in January and 9.6 mm in February month, 2019). The maximum open pan evaporation of 6.0 mm day^{-1} was recorded in the months of March, 2018 and April, 2018 with the minimum evaporation of 0.9 mm day^{-1} in the month of January, 2018. During second year, the maximum open pan evaporation of 6.0 mm day^{-1} was recorded in the month of April, 2018 and the minimum evaporation of 1.0 mm day^{-1} in the month of December, January, February and March, 2019.

The texture of the soil was determined by international pipette method. The soils texture of the study area is classified as clay with 33.6 per cent sand, 22.6 per cent silt and 43.8 per cent clay at 0-30 cm depths, 25.1 per cent sand, 27.6 per cent silt and 47.3 per cent clay at 30-60 cm depths and 17.5 per cent sand, 27.2 per cent and 55.3 per cent clay at 60-90 cm depths. The density of soil was found to be 1.26, 1.25 and 1.23 g cm^{-3} at 0-30, 30-60 and 60-90 cm depths respectively. The irrigation water used for experiment was from irrigation pond water, where water was stored through the field channels of seventeen distributory, left bank canal of TBP command. This water was analyzed for pH and EC and was found to be 7.10 and 0.65 dS m^{-1} respectively.

The three different irrigation techniques and five different saline levels of irrigation water were kept as main and sub treatments respectively. The main treatments were M_0– Furrow irrigation, M_1–surface drip irrigation and M_2– subsurface drip irrigation and sub treatments were S_0–normal (0.65 dS m^{-1}) water, S_1–2 dS m^{-1}, S_2–3 dS m^{-1}, S_3–4 dS m^{-1} and

S_4–5 dS m^{-1}. Four water tanks (2, 3, 4 and 5 dS m^{-1}) of 2000 liter capacity and one tank (normal water i.e. 0.65 dS m^{-1}) with a capacity of 2500 liter were installed on 8.0 (L) x 2.4 (W) m cement concrete platform. The filtered water was connected to five water tanks with separate control valves for filling.

After filling up the tanks, a known quantity of sodium chloride (NaCl) was calculated and added (Soria and Cuartero, 1998) to get desired ECiw of saline water of 2, 3, 4 and 5 dS m^{-1} as per the calculation procedure given by Bibha Rani and Sharma (2015). Every time after adding NaCl to the tanks, the irrigation water was thoroughly mixed. The samples were collected from each tank in capped high density PVC labeled bottles, fortified with 1mL toluene to arrest any biological activity. The samples were analyzed in the laboratory for salinity/sodicity parameters *viz.*, pH, electrical conductivity (EC), cationic concentrations (Ca^{2+}, Mg^{2+} and Na^{+}) and anionic concentrations (Cl^-, SO_4^{2-}, CO_3^{2-} and HCO_3^-) as per standard procedures outlined by Richards (1954). Calcium and magnesium were estimated by Versenate method while sodium and potassium were analyzed by flame photometry. The anions viz., CO_3^{2-} and HCO_3^- were estimated by titration with standard acid. The Cl^- and SO_4^{2-} were estimated by titration with silver nitrate and precipitation as barium sulfate. The values obtained were used to compute for sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) using the equations 1 and 2.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \text{ mmol mL}^{-1} \quad \ldots (1)$$

$$\text{RSC (meq L}^{-1}) = (CO_3^{-2} + HCO_3^-) - (Ca^{+2} + Mg^{+2}) \quad \ldots (2)$$

The Tomato nursery plants were sown with plant to plant and row to row distance of 0.4 and 1.2 m respectively. To meet the nutrient requirement and as per the recommended dose of fertilizer, the nitrogen, phosphorus and potassium at the rate 250:250:250 kg ha^{-1} were supplied from the different fertilizers through manually for furrow irrigated plots and the water soluble fertilizers like Urea, 19:19:19, KNO_3 and $CaNO_3$ were applied in splits through irrigation using fertilizer injection system (Venturi) for drip irrigated treatments at different growth stages. All agronomic practices except method of irrigation and application of fertilizer were kept same in all treatments. Manual weeding was done two times during the crop cycle.

Soil pH

Soil samples to a depth of 0-15 and 15-30 cm were collected using screw auger during initial stage (before transplanting), mid season (60 DAT) and after harvest of the crop and labeled for measuring soil pH. For furrow irrigation technique, soil samples were collected at the ridge near the plant at depth of 15 and 30 cm. Under surface and subsurface drip techniques, soil samples were collected at 15 and 30 cm soil depths near the dripper and buried dripper.

Soil salinity

Soil samples to a depth of 0-15 and 15-30 cm were collected using screw auger during initial stage (before transplanting), mid season and after harvest of the crop and labeled for measuring soil EC. For furrow irrigation technique, soil samples were collected at the ridge near the plant. Under surface and subsurface drip technique, soil samples were collected at 0-15 and 15-30 cm soil depths at near the dripper and buried dripper.

Results and Discussion

Every time after filling up of the water tanks, a known quantity of salt (NaCl) were added to obtain desire level of salinity. After this process, the water samples were collected in capped high density PVC labeled bottles and taken to laboratory to make analysis of pH, ECiw, anions and cations present in the samples. The average data's collected over the growing period was presented in the Table 1. It is observed from the data that, the pH and ECiw were 7.28, 7.24, 7.40, 7.52 and 0.65, 2.10, 3.24, 4.04 and 5.12 dS m^{-1} for S_0, S_1, S_2, S_3 and S_4 respectively. Similarly, the important cations like Ca^{2+} Mg^{2+} and Na^+ for S_0, S_1, S_2, S_3 and S_4 treatments were 1.91, 3.06, 3.93, 5.03 and 6.17 meq L^{-1}, 6.17, 3.65, 4.61, 4.28, 5.46 and 6.48 meq L^{-1} and 6.64, 10.19, 13.92, 19.86 and 24.51 meq l^{-1} respectively. The average SAR and RSC of the applied water were 4.36, 5.44, 7.20, 9.03 and 9.59 $mmol^{1/2}$ $l^{-1/2}$ and nil or zero for all the salinity levels of irrigation water respectively. As the irrigation saline water level increases, the SAR was increased (Singh *et al.*, 2017).

Table 1: Mean chemical composition of applied saline irrigation water

Chemical composition of irrigation water	Water salinity				
	S_0	S_1	S_2	S_3	S_4
pH	7.28	7.24	7.40	7.52	7.50
ECiw (dS m^{-1})	0.65	2.10	3.24	4.04	5.12
Ca^{2+} (meq L^{-1})	1.91	3.06	3.93	5.03	6.17
Mg^{2+} (meq L^{-1})	3.65	4.61	4.28	5.46	6.48
Na^+ (meq L^{-1})	6.64	10.19	13.92	19.86	24.51
Cl^- (meq L^{-1})	2.01	3.06	4.41	4.23	4.78
SO_4^{2-} (meq L^{-1})	0.39	1.65	1.52	1.80	2.53
HCO_3^- (meq L^{-1})	0.039	0.485	0.038	0.043	0.048
CO_3^{2-} (meq L^{-1})	0	0	0	0	0
SAR ($mmol^{1/2}$ $L^{-1/2}$)	4.36	5.44	7.20	9.03	9.59
RSC (meq L^{-1})	Nil	Nil	Nil	Nil	Nil

Note: S_0: Normal water (ECiw=0.65 dS m^{-1}) S_1: ECiw=2.0 dS m^{-1} S_2: ECiw=3.0 dS m^{-1} S_3: ECiw=4.0 dS m^{-1} S_4= ECiw=5.0 dS m^{-1}

Soil pH

To see the effect of soil pH on different irrigation techniques and irrigation saline water levels, soil sample were collected at 0-15 and 15-30 cm depth near the tension meters under fifteen treatments. The soil samples were collected at vertical (Z-axis) depth near the plant during before sowing, mid season and after harvest of the crop under furrow irrigation and same procedure was followed for second year also. Similar procedure was followed for subsurface drip but soil samples taken at the buried dripper location. The data on soil pH during before sowing, mid season and after harvest at different depths (0-15 and 15-30 cm) at near the plant/dripper for the first year are presented in Table 2 and 3.

Before transplanting i.e. before imposition of treatments, at plant/dripper point soil pH varied from 7.52 (M_1S_2) to 8.22 (M_2S_2) and 7.44 (M_1S_2) to 8.25 (M_1S_1) at 0-15 and 15-30 cm depth respectively. At mid season not much variation were observed at plant/dripper point. At plant/dripper, soil pH varied from 7.56 (M_1S_4) to 8.11 (M_2S_1) and 7.82 (M_2S_4) to 8.21 (M_1S_0) at 0-15 and 15-30 cm depth respectively. Irrespective of treatments and soil depths (0-15 and 15-30 cm), soil pH was higher at after harvest compare to respective values during before transplanting and mid season. During after harvest of the crop, at plant/dripper point it varied from 8.48 (M_2S_4) to 9.06 (M_0S_2) and 8.23 (M_1S_2) to 9.02 (M_0S_3) at 0-15 and 15-30 cm depths respectively. It was observed that after harvest, the surface soil pH was more than the subsurface soil pH at almost all the treatment combination.

Before transplanting of second year crop, soil pH at plant/dripper varied from 8.23 (M_2S_0) to 8.76 (M_0S_4) and 8.14 (M_1S_2) to 8.80 (M_0S_3) at 0-15 and 15-30 cm depth respectively. During mid season, at plant/dripper, soil pH varied from 7.91 (M_0S_0) to 8.45 (M_0S_4) and 7.89 (M_1S_4) to 8.39 (M_0S_4) at 0-15 and 15-30 cm depth respectively. Irrespective of treatments and soil depths (0-15 and 15-30 cm), soil pH was higher at after harvest compare to respective values during before transplanting and mid season. During after harvest of the crop, at plant/dripper point it varied from 7.57 (M_2S_3) to 8.85 (M_0S_4) and 8.14 (M_2S_2) to 8.70 (M_0S_4) at 0-15 and 15-30 cm depths respectively. It was observed that after harvest of the crop, the subsurface soil pH was more than the surface soil pH at almost all the treatment combination.

Table 2: Soil pH at different vertical depths in different irrigation techniques and irrigation salinity water treatments during before transplanting, mid season and after harvest of first season crop

Sl. No.	Treatments	Soil pH at plant/dripper location					
		Before transplanting		Mid season		After harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	M_0 S_0	7.66	7.46	7.95	8.15	9.02	8.94
2	M_0 S_1	7.95	7.92	7.89	8.01	8.83	8.61
3	M_0 S_2	7.82	7.59	7.68	8.00	9.06	8.93
4	M_0 S_3	7.94	7.93	7.69	8.11	8.97	9.02
5	M_0 S_4	7.84	7.73	7.66	7.88	9.00	8.72
6	M_1 S_0	7.86	7.65	7.62	8.21	8.50	8.25
7	M_1 S_1	7.89	8.25	7.60	8.04	8.87	8.45
8	M_1 S_2	7.52	7.44	7.64	8.05	8.86	8.23
9	M_1 S_3	7.84	7.94	7.59	8.16	8.83	8.87
10	M_1 S_4	7.54	7.78	7.56	8.00	8.64	8.47
11	M_2 S_0	7.94	7.87	7.91	7.94	8.60	8.72
12	M_2 S_1	8.15	7.93	8.11	8.03	8.61	8.51
13	M_2 S_2	8.22	7.82	7.94	7.98	8.56	8.69
14	M_2 S_3	8.01	7.61	7.80	7.96	8.69	8.66
15	M_2 S_4	8.06	7.76	7.84	7.82	8.48	8.42

Table 3: Soil pH at different vertical depths in different irrigation techniques and irrigation salinity water treatments during before transplanting, mid season and after harvest of first season crop

Sl. No.	Treatments	Soil pH at plant/dripper location					
		Before transplanting		Mid season		After harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	M_0 S_0	8.69	8.70	7.91	8.18	8.02	8.22
2	M_0 S_1	8.60	8.33	8.33	8.13	8.37	8.64
3	M_0 S_2	8.56	8.63	7.73	8.07	8.30	8.28
4	M_0 S_3	8.71	8.80	8.02	8.18	8.38	8.73
5	M_0 S_4	8.76	8.56	8.45	8.39	8.85	8.70
6	M_1 S_0	8.35	8.16	7.95	8.16	8.32	8.44
7	M_1 S_1	8.49	8.26	8.27	8.31	8.30	8.63
8	M_1 S_2	8.55	8.14	8.15	8.11	8.16	8.65
9	M_1 S_3	8.61	8.60	8.15	8.35	8.05	8.23
10	M_1 S_4	8.33	8.40	8.15	7.89	8.31	8.33
11	M_2 S_0	8.23	8.50	8.05	7.95	7.95	8.22
12	M_2 S_1	8.32	8.25	8.06	8.34	7.77	8.34
13	M_2 S_2	8.30	8.43	7.76	8.04	7.83	8.14
14	M_2 S_3	8.42	8.56	8.34	8.45	7.57	8.69
15	M_2 S_4	8.20	8.35	7.93	8.24	8.07	8.32

Soil salinity

To see the effect of soil salinity on different irrigation techniques and irrigation saline water levels, soil sample were collected at 0-15 and 15-30 cm depth. The soil samples were collected at vertical (Z-axis) depth near the plant during before sowing of first year, at mid season and after harvest of the crop under furrow irrigation. Similar procedure was followed for subsurface drip but soil samples taken at the buried dripper location. The data on soil salinity before transplanting, mid season and after harvest of the crop at different depths (0-15 and 15-30 cm) for first and second year are presented in Table 4 and 5.

Table 4: Soil salinity at different vertical depths in different irrigation techniques and irrigation salinity water treatments during before transplanting, mid season and after harvest of first year crop

Sl. No.	Treatments	Soil salinity (dS m^{-1}) at plant/dripper location					
		Before transplanting		Mid season		After harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	M_0 S_0	0.77	0.96	1.08	1.37	1.98	1.70
2	M_0 S_1	0.58	1.26	1.26	1.40	1.50	1.62
3	M_0 S_2	0.67	0.72	2.19	2.34	2.44	2.28
4	M_0 S_3	0.95	1.41	3.16	3.52	3.81	3.50
5	M_0 S_4	0.85	1.17	4.09	5.05	5.15	4.12
6	M_1 S_0	0.64	1.04	0.85	1.21	1.04	1.30
7	M_1 S_1	0.74	0.93	1.25	1.68	1.08	1.62
8	M_1 S_2	0.59	0.82	1.46	1.90	1.47	1.98
9	M_1 S_3	0.82	1.19	1.78	2.13	1.90	2.50
10	M_1 S_4	0.85	1.14	2.19	2.45	2.44	3.01
11	M_2 S_0	0.77	0.88	0.70	0.63	1.05	0.87
12	M_2 S_1	1.02	1.11	1.32	1.20	1.83	1.50
13	M_2 S_2	0.69	0.82	1.60	1.13	2.22	1.72

14	M_2 S_3	0.61	0.72	1.75	1.58	2.68	1.70
15	M_2 S_4	0.99	1.08	2.15	1.80	3.30	2.00

Table 5: Soil salinity at different vertical depths in different irrigation techniques and irrigation salinity water treatments during before transplanting, mid season and after harvest of second year crop

Sl. No.	Treatments	Soil salinity (dS m^{-1}) at plant/dripper location					
		Before transplanting		Mid season		After harvest	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	M_0 S_0	2.15	1.21	1.19	1.45	1.70	1.96
2	M_0 S_1	2.65	1.72	1.38	1.68	2.05	2.18
3	M_0 S_2	3.43	1.98	2.30	2.48	2.39	3.00
4	M_0 S_3	3.40	2.79	2.68	3.49	3.18	3.6
5	M_0 S_4	4.38	3.12	3.21	4.78	4.41	5.27
6	M_1 S_0	2.15	1.34	1.21	1.34	1.48	1.56
7	M_1 S_1	2.30	1.40	1.50	1.89	1.56	1.92
8	M_1 S_2	2.69	1.57	2.01	2.10	2.08	2.95
9	M_1 S_3	3.32	1.89	2.34	2.80	2.50	3.10
10	M_1 S_4	3.44	2.10	2.72	3.22	3.25	3.85
11	M_2 S_0	1.83	1.20	0.99	1.18	1.31	1.72
12	M_2 S_1	2.22	2.16	1.85	2.15	2.40	2.35
13	M_2 S_2	2.58	2.38	2.09	2.10	2.74	2.61
14	M_2 S_3	3.23	3.18	2.69	2.11	3.20	3.10
15	M_2 S_4	3.67	3.30	3.13	2.78	3.49	3.10

Before transplanting *i.e.* before imposition of treatments, at plant/dripper point soil salinity varied from 0.58 (M_0S_1) to 1.02 (M_2S_1) and 0.72 (M_0S_2 and M_2S_3) to 1.41 (M_0S_3) at 0-15 and 15-30 cm depths respectively. Soil EC was slightly more at 15-30 cm compared to surface soil (0-15 cm) across the sampling position and depths. It is only the observation in each plots, since treatment imposition was not there at this time.

During mid season, at plant/dripper point, soil EC varied from 0.70 dS m^{-1} (M_2S_0) to 2.15 dS m^{-1} (M_2S_4), 0.85 dS m^{-1} (M_1S_0) to 2.19 dS m^{-1} (M_1S_4) and 1.08 dS m^{-1} (M_0S_0) to 4.09 dS m^{-1} (M_0S_4) at 0-15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. At 15-30 cm depth, soil EC varied from 0.63 dS m^{-1} (M_2S_0) to 1.80 dS m^{-1} (M_2S_4), 1.21 dS m^{-1} (M_1S_0) to 2.45 dS m^{-1} (M_1S_4) and 1.37 dS m^{-1} (M_0S_0) to 5.05 dS m^{-1} (M_0S_4) in subsurface drip, surface drip and furrow methods of irrigation respectively. Among different treatment combination, M_0S_4 had (4.09 and 5.05 dS m^{-1}) higher soil EC at both depths compared to other treatment combinations. In surface drip and subsurface drip systems lower soil salinity was observed compared to furrow irrigation method at both 0-15 and 15-30 cm depth.

After harvest of the crop, at plant/dripper point, soil EC varied from 1.05 dS m^{-1} (M_2S_0) to 3.30 dS m^{-1} (M_2S_4), 1.04 dS m^{-1} (M_1S_0) to 2.44 dS m^{-1} (M_1S_4) and 1.98 dS m^{-1} (M_0S_0) to 5.15 dS m^{-1} (M_0S_4) at 0-15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. At 15-30 cm depth, soil EC varied from 0.87 dS m^{-1} (M_2S_0) to 2.0 dS m^{-1} (M_2S_4), 1.30 dS m^{-1} (M_1S_0) to 3.01 (M_1S_4) dS m^{-1} and 1.70 (M_0S_0) dS m^{-1} to 4.12 dS m^{-1} (M_0S_4) in subsurface drip, surface drip and furrow methods of irrigation respectively. Among different treatment combination, M_0S_4 had (5.15 and 4.86 dS m^{-1}) higher soil EC at both depths compared to other treatment combinations.

Before transplanting of second year crop at plant/dripper point, soil salinity varied from 1.83 (M_2S_0) to 4.38 (M_0S_4) and 1.20 (M_2S_0) to 3.12 (M_0S_4) at 0-15 and 15-30 cm depth respectively.

During mid season, at plant/dripper point, soil EC varied from 0.99 dS m^{-1} (M_2S_0) to 3.13 dS m^{-1} (M_2S_4), 1.21 dS m^{-1} (M_1S_0) to 2.72 dS m^{-1} (M_1S_4) and 1.19 dS m^{-1} (M_0S_0) to 3.21 dS m^{-1} (M_0S_4) at 0-15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively.. At 15-30 cm depth, soil EC varied from 1.18 dS m^{-1} (M_2S_0) to 2.78 dS m^{-1} (M_2S_4), 1.34 dS m^{-1} (M_1S_0) to 3.22 dS m^{-1} (M_1S_4) and 1.45 dS m^{-1} (M_0S_0) to 4.78 dS m^{-1} (M_0S_4) in subsurface drip, surface drip and furrow methods of irrigation respectively. Among different treatment combination, M_0S_4 had (5.15 and 5.02 dS m^{-1}) higher soil EC at both depths compared to other treatment combinations. In surface drip and subsurface drip systems lower soil salinity was observed compared to furrow irrigation method at both 0-15 and 15-30 cm depth.

After harvest of the crop, at plant/dripper point, soil EC varied from 1.31 dS m^{-1} (M_2S_0) to 3.49 dS m^{-1} (M_2S_4), 1.48 dS m^{-1} (M_1S_0) to 3.25 dS m^{-1} (M_1S_4) and 1.70 dS m^{-1} (M_0S_0) to 4.41 dS m^{-1} (M_0S_4) at 0-15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. At 15-30 cm depth, soil EC varied from 1.72 dS m^{-1} (M_2S_0) to 3.10 dS m^{-1} (M_2S_4), 1.56 dS m^{-1} (M_1S_0) to 3.85 (M_1S_4) dS m^{-1} and 1.96 (M_0S_0) dS m^{-1} to 5.27 dS m^{-1} (M_0S_4) in subsurface drip, surface drip and furrow methods of irrigation respectively. Among different treatment combination, M_0S_4 had (5.27 and 5.01 dS m^{-1}) higher soil EC at both depths compared to other treatment combinations.

From the above results, it was observed that surface drip and subsurface drip pushes salts towards 10 and 20 cm away whereas it is not in the case with furrow irrigation. Salinity increases as distance from the dripper increases (20 cm). Similar results were obtained by Malash *et al.* (2008) [8] and Chen *et al.* (2010). Water has tendency that it moves from wetter surface to drier surface quickly. Hence with continuous moisture present near the dripper under surface and subsurface drip, moisture moved towards the outer periphery. Therefore, salts also push to the outer periphery. Increase in accumulation of salts was observed as the salinity of the irrigation water increases and in subsurface drip irrigation there was less accumulation of salt in the root zone compared to furrow irrigation method. Similar results were obtained by Malash *et al.* (2011) [9]. It was also observed that, the higher soil salinity was observed more after harvest due to lesser moisture at the surface as well as at the bottom.

Conclusion

Salinity increases as distance from the dripper increases (20 cm). Water has tendency that it moves from wetter surface to drier surface quickly. Hence with continuous moisture present near the dripper under surface and subsurface drip, moisture moved towards the outer periphery. Therefore, salts also push to the outer periphery. Increase in accumulation of salts was observed as the salinity of the irrigation water increases and in subsurface drip irrigation there was less accumulation of salt in the root zone compared to furrow irrigation method. It was concluded that whenever there is shortage of fresh water, we can use saline water upto 2 dS m^{-1} with subsurface drip irrigation method without any harmful effect to the tomato crop and soil.

References

1. Anonymous Ann. Rep. (2017-18). Management of salt affected soil and use of saline water in agriculture. Weather data of A.R.S., Gangavathi. 2017, 72.
2. Ayers RS, Westcot DW. Water quality for agriculture. J Irrigation and Drainage. 1985; 2(7):170-174.
3. Bibha Rani, Sharma VK. Standardization of methodology for obtaining the desired salt stress environment for salinity effect observation in rice seedlings. Int. J of Environ. Sci. 2015; 6(2):232-236.
4. Campos, Carlos Alberto Brasiliano, Pedro Dantas Fernandes, Hans Raj Gheyi, Flavio Favaro Blanco, Cira Belem Goncalves *et al*. Yield and fruit quality of industrial tomato under saline irrigation. Scientia Agricola. 2006; 63(2):46-52.
5. Chen, Weiping, Zhenan Hou, Laosheng Wu, Yongchao Liang, Changzhou Wei. Evaluating salinity distribution in soil irrigated with saline water in arid regions of northwest China. Agril. Water Mgmt. 2010; 97(12):1-8.
6. FAO, Field Guide. 20 things to know about the impact of salt water on agricultural land in aceh province. Field Guide on Salinity in Aceh-Draft publication RAP 05. 2005, 1-7.
7. Maas EV. Salt tolerace of plants. Appl. Agric. Res. 1986; 1:12-26.
8. Malash NM, Flowers TJ, Ragab R. Effect of irrigation methods, management and salinity of irrigation water on tomato yield, soil moisture and salinity distribution. Irrigation Sci. 2008; 26(4):13-23.
9. Malash, Nabeel M, Timothy J, Flowers, Ragab Ragab. Plant-water relations, growth and productivity of tomato irrigated by different methods with saline and non-saline water. Irrigation and Drainage. 2011; 60(4):46-53.
10. Minhas PS. Saline water management for irrigation in India. Agril. Water Mgmt. 1996; 30(1):1-24.
11. Oron G, Demalach Y, Gillerman L, David I, Rao VP. Improved saline-water use under subsurface drip irrigation. Agril. Water Mgmt. 1999; 39(1):19-33.
12. Phene CJ, Davis KR, Hutmacher RB, Bar-Yosef B, Meek DW. Effect of high frequency surface and subsurface drip irrigation on root distribution of sweet corn. Irr. Sci. 1991; 12:135-140.
13. Richard LA. Diagnosis and improvement of Saline and Alkali Soils. – Agric. Handbook 60, U.S. Dept. Agric., Washington, D.C, 1954, 160.
14. Rhodes JD, Kandiah A, Mashak AM. The use of saline waters for crop production. Irrigation and Drainage, 1992, 150.
15. Singh VK, Ramprakash, Rajpaul Kumar S, Singh K, Satyavan. Evaluation of groundwater quality for irrigation in Gulha Block of Kaithal District in Haryana. J of Soil Salinity and Water Quality. 2017; 9(2):241-248.
16. Soria T, Cuartero J. Tomato fruit yield and water consumption with salty water irrigation. Acta Horti. 1998; 45(8):15-19.