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Irrigation management strategies for cultivation of beetroot (*Beta vulgaris*) under saline vertisols

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■ **ABSTRACT :** The experiments were conducted with beetroot (*Beta vulgaris*) as test crop in saline vertisols of Tungabhadra Project command area in Northern Karnataka, India during 2007-'08 and 2008-'09 in strip plot design with three soil salinity levels (Electrical conductivity, EC - 1.3, 2.7 and 4.3 dS m^{-1}) in main plots and five drip irrigation levels (Evapotranspiration , ET- 0.6, 0.8, 1.0, 1.2 and 1.4) with three surface irrigation levels (0.8, 1.0 and 1.2 ET) in sub-plots adopting three replications. There was significant difference in tuber yield owing to different irrigation regimes by various levels of drip and surface irrigation methods. The highest tuber yield of 19.43 t ha^{-1} was recorded by drip irrigation at 1.2 ET followed by drip irrigation at 1.4 ET (18.28 t ha^{-1}) as against the lowest tuber yield of 9.98 t ha^{-1} in surface irrigation scheduled at 0.8 ET during 2007-'08. Similarly, the highest tuber yield of 18.91 t ha^{-1} in drip irrigation at 1.2 ET and the least yield of 9.6 t ha^{-1} in the surface irrigation scheduled at 0.8 ET were registered during 2008-'09. The different levels of salinity had marked influence on tuber yield during both the years. Significantly the highest tuber yield of 18.23 t ha^{-1} and the lowest tuber yield of 11.0 t ha^{-1} were recorded, respectively in salinity levels-I and III during 2007-'08. Similarly, during 2008-'09 significantly the maximum tuber yield of 17.89 t ha^{-1} in salinity level-I and the least of 10.5 t ha^{-1} in salinity level-III were observed.

■ **KEY WORDS :** Irrigation, Drip, Surface irrigation, Irrigation levels, Salinity, Saline soil, Beetroot, Vegat

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Population growth and economic development always translate into growing pressure on use of land and water resources especially in agriculture. Though irrigated agriculture, essentially responsible for transforming India from a food deficient to a food surplus country, is under stress due to age-old nemesis of waterlogging and soil salinisation, which have serious socio-economic and environmental implications. With more intensive agriculture, there has been a rising stress on efficient management and utilisation of natural resources.

Strategies involving technological advances inter alia land use planning, land reclamation, conjunctive use of surface and groundwater and encouraging large scale adoption of sprinkler and drip irrigation system, will be required for meeting significantly higher food grain requirements. On the other hand, the dynamic processes of waterlogging, salinisation and sodification in many irrigated command areas of the arid and semi-arid regions render the lands degraded, thereby causing decline in agricultural production.

The salt affected soils of the world amount to be 970 million ha of which 250 million ha are Solanchak and Solonetz soils and approximately 650 million ha are saline and sodic phases and mark present or potential degradation. In general 7 per cent of the total soil surface area of the world is covered by salt affected lands. It is estimated that the world as a whole is loosing at least 3 ha of fertile land every minute due to salinisation/ sodification (Siyal *et al.*, 2002). The salt-affected soils form sizable area in India and according to one estimate an area of 6.73 M ha has been salt-affected in the country (Sharma *et al*., 2006). As per the future projection made on an all India basis, an area of about 13 M ha is likely to be affected by the problems of waterlogging and soil salinity in the irrigation commands of India. Waterlogging, soil salinity and saline groundwater conditions at shallow depth in Haryana are resulting in a potential annual loss of about US $ 37 M at 1998-'99 prices. About 42 per cent increase in area under waterlogging and soil salinity in southwest Punjab occurred over a 4-year period (1997-2001).

Judicious use of irrigation water in avoiding waterlogging and soil salinity is more important to enhance total agricultural production, the area under irrigation and optimum use of water. This can be achieved by adopting advanced methods of irrigation like pressurised irrigation involving piped distribution of water, sprinkler and drip irrigation (Singh, 2001). Hence, the recent advances in irrigation techniques involving efficient use of water through micro irrigation systems hold a key to arrest further increase in salinisation while also can enhance the farm produce. This in turn would improve the employment opportunities and net farm returns and thereby would enhance the standard of living of farmers, improve the rural milieu and result in regional development. The environmental degradation also can be minimised. Drip irrigation which allows application of water to the root zone of crop according to crop water requirements avoids over irrigation of crops and minimises downward percolation of water so that the water table remains deep below the root zone. This leads to the development of favourable conditions of soil moisture content and low salt concentration in the root zone. Frequent irrigation dilutes the salt concentration in the soil; it saves water and enhances yield and quality of produce. Furthermore, use of drip system of irrigating crops was observed to enhance the threshold limits of their salt-tolerance by modifying the patterns of salt distribution and maintenance of constantly higher matric potentials over continuous water supply (Nakayama and Bucks, 1986).

Efforts made to make use of advanced irrigation systems in enhancing yields of various field and vegetable crops in normal soils were found to be more efficient and economic. However, such information under saline vertisols is scanty and more so for vegetable crops. Keeping in view all the above issues, the investigation was undertaken with beetroot (Beta vulgaris) as the test crop to study the effect of different methods and levels of irrigation in saline vertisols.

■ METHODOLOGY

The experiment to find out the effect of different level and methods of irrigation on performance of beetroot was conducted at the salinity block of the Agricultural Research Station (ARS), Gangavathi, which is situated in the north eastern dry zone *i.e.* zone-3 of region–II of Karnataka State, India and the location corresponds to 15°15’40” North latitude and 76°31’ 45” East longitude at an altitude of 419 m above the mean sea level. The site selected for the conduct of experiment was found to have wide range of soil salinity. Soil samples from 0-60 cm depth were taken to classify the experimental site into three salinity (EC, dS m^{-1}, 1: 2.5 soil and water extraction) level blocks and divided accordingly. The soil of the experimental site is clay belonging to Noyyal series.

Weather and climate:

Daily climatological data during the study period were obtained from the meteorological station at the Agricultural Research station, Gangavati. It is seen that during the period of study (2007-’08), the highest maximum temperature of 34.9°C was recorded in the month of April, while the lowest minimum temperature of 15.2°C occurred in the month of March. During 2008-’09, the highest maximum temperature of 40.3°C was recorded in the month of May, while the lowest minimum temperature of 16.8°C was observed in the month of February.

Treatment details :

The treatment consisted of three salinity levels in main plots and eight irrigation regimes in sub-plots as follows. The experiment was laid-out in strip plot design

Main plot: Salinity levels (Three) - S :

S_1 : Salinity level – I (EC = 1.3 dS m^{-1})
S_2 : Salinity level – II (EC = 2.7 dS m^{-1})
S_3 : Salinity level – III (EC = 4.3 dS m^{-1})

Sub plots: Irrigation levels (Eight) - I :

I_1 : Drip irrigation at 0.6 ET
I_2 : Drip irrigation at 0.8 ET
I_3 : Drip irrigation at 1.0 ET
I_4 : Drip irrigation at 1.2 ET
I_5 : Drip irrigation at 1.4 ET
I_6 : Surface irrigation at 0.8 ET
I_7 : Surface irrigation at 1.0 ET
I_8 : Surface irrigation at 1.2 ET

Lay-out of drip irrigation system :

Irrigation water was pumped through 3 hp motor and conveyed to the main line of 75 mm PVC pipes after passing through sand and screen filters. From the main pipes, sub mains of 63 mm PVC pipes were drawn. From the sub main, laterals of 12 mm pipes were installed at an interval of 1.20 m. Each lateral was provided with individual tap control for imposing irrigation. Along the laterals, pressure compensating drippers of 4 Lph, were fixed at a spacing of 60 cm. One lateral was used for four rows of beetroot. Sub mains and laterals were closed at the end with end cap. After installation, trial run was conducted to assess mean dripper discharge and uniformity co-efficient. During the irrigation period an average uniformity co-efficient of 95 per cent was observed. This was taken into account for fixing the irrigation water application time.

Irrigation schedule :

Irrigation was scheduled based on climatological approach. Good quality (EC = 0.34 dS m^{-1} and pH = 7.64) water was used for irrigation. The daily evapotranspiration (ET) rate of beetroot was estimated using the following equation

$$ET = Ep \times Kp \times Kc$$

where,

ET = evapotranspiration, mm
Ep = pan evaporation, mm
Kp = pan co-efficient
Kc = crop co-efficient.

Quantity of water required to be applied per day per plant for 100 per cent ET in case of drip irrigation was computed using the following equation

Q = ET x A x B

where,

Q = quantity of water required per day per plant, L

A = gross area per plant, plant to plant distance x row to row distance, m^2

B = amount of area covered with foliage fraction, (100 per cent Tiwari, *et al.,* 2003).

From the above equation, irrigation water required to meet 100 per cent crop evapotranspiration (ET) was determined, followed by 0.6, 0.8, 1.2 and 1.4 ET values. Accordingly, the irrigation was given every 48 hours. The same quantity of water was applied for all the three salinity levels in both the methods under different levels of irrigation. For drip irrigation, one common irrigation of 60 mm was applied at sowing. Thereafter, irrigation through drip system was given at two days interval based on the estimated ET requirement of the crop. In case of surface irrigation one common irrigation depth of 60 mm at sowing and one life irrigation of 30 mm three days after sowing was applied before imposing the treatments.

■ RESULTS AND DISCUSSION

The results of the present study as well as relevant discussions have been presented under following sub heads:

Water applied :

The total amount of water applied through drip irrigation was maximum in case of 1.4 ET (500.1 mm) followed by 1.2 ET (445.72 mm), 1.0 ET (391.2 mm), 0.8 ET (336.8 mm) and minimum for 0.6 ET (282.3 mm) during 2007-'08 including the effective rainfall of 29.5 mm. Similarly, during 2008-'09 the total amount of water applied through drip irrigation was highest in case of 1.4 ET (557.8 mm) followed by 1.2 ET (492.5 mm), 1.0 ET (427.1 mm), 0.8 ET (361.8 mm) and least for 0.6 ET (296.4 mm) which also included the effective rainfall of 40.3 mm. The total amount of water applied through surface irrigation was maximum in case of 1.2 ET (419.5 mm) followed by 1.0 ET (325.5 mm) and minimum in case of 0.8 ET (305.3 mm) during 2007-'08. Similarly, the amount of water applied through surface irrigation was highest in 1.2 ET (487.3 mm) followed by 1.0 ET (427.3 mm) and lowest for 0.8 ET (374.6) during 2008-'09. All these included the effective rainfall of 95.3, 55.5, and 29.5 mm in 0.8, 1.0 and 1.2 ET in 2007-'08 and 44.6, 37.3 and 37.3 mm under 0.8, 1.0 and 1.2 ET during 2008-'09, respectively.

Biometric parameters :

The plant height, number of leaves, tuber length, tuber girth and tuber fresh weight (Tables 1 to 7) were significantly influenced by both irrigation and salinity levels and there was distinct variation in plant height between the surface and the drip irrigation at 60 DAS and harvest stage except that at 30 DAS (days after sowing) during both the years (2007-08 and 2008-09) of study.

The drip irrigation at 1.2 ET resulted in the highest plant height of 49.9 cm during 2007-08 and 48.5 cm during 2009 over other levels of irrigation experimented. Among the soil salinity levels, the maximum plant height of 48 cm during 2007-'08 and 46.2 cm during 2008-09 was recorded in the salinity level-I. Among the surface irrigation levels too, 1.2 ET produced the tallest plants of 42.2 cm during 2007-08 and

Table 1: Effect of different levels of drip and surface irrigation on plant height at 30 days after sowing (DAS), cm

Irrigation levels	2007-08			Mean	2008-09			Mean
	Salinity levels				Salinity levels			
	S_1	S_2	S_3		S_1	S_2	S_3	
I_1	15.1	14.1	13.0	13.7	14.5	13.5	11.5	13.2
I_2	15.3	14.4	12.3	14.0	14.5	13.9	11.8	13.4
I_3	15.6	14.7	12.5	14.3	15.1	14.3	12.0	13.8
I_4	16.5	14.9	13.3	14.9	15.9	14.2	12.6	14.2
I_5	16.1	14.5	12.7	14.4	15.4	13.9	12.0	13.8
I_6	14.1	13.3	11.2	12.9	13.5	12.9	11.2	12.5
I_7	14.4	13.6	11.6	13.2	13.9	13.2	11.1	12.7
I_8	14.7	13.8	11.7	13.4	14.3	13.2	11.1	12.9
Mean	15.2	14.2	12.2		14.6	13.6	11.7	
C.D.(P=0.05)	S	I	I x S		S	I	I x S	
	0.7	1.5	NS		0.8	1.6	NS	

S - Salinity levels, I - Irrigation levels

Table 2: Effect of different levels of drip and surface irrigation on plant height at 60 DAS, cm

Irrigation levels	2007-08 Salinity levels			Mean	2008-09 Salinity levels			Mean
	S_1	S_2	S_3		S_1	S_2	S_3	
I_1	30.6	29.0	24.9	28.2	30.1	28.4	24.4	27.6
I_2	32.0	30.2	26.0	29.4	31.2	29.4	25.3	28.6
I_3	33.3	31.1	27.0	30.5	32.7	30.4	26.4	29.8
I_4	35.4	33.2	29.1	32.6	34.8	32.5	28.5	32.0
I_5	34.0	31.7	27.6	31.1	33.5	31.0	28.0	30.8
I_6	27.1	25.1	20.9	24.4	23.5	24.5	20.3	23.8
I_7	28.2	26.2	22.0	25.5	27.6	24.7	21.4	24.9
I_8	29.4	27.7	23.7	26.9	28.7	27.5	23.6	26.2
Mean	31.3	29.3	25.2		30.7	28.7	24.7	
C.D.(P=0.05)	S	I	I x S		S	I	I x S	
	1.2	0.9	NS		1.1	0.9	NS	

S - Salinity levels, I - Irrigation levels

Table 3 : Effect of different levels of drip and surface irrigation on plant heigh at harvest, cm

Irrigation levels	2007-08 Salinity levels			Mean	2008-09 Salinity levels			Mean
	S_1	S_2	S_3		S_1	S_2	S_3	
I_1	47.7	45.4	39.3	44.1	45.7	43.5	39.5	42.9
I_2	49.3	47.2	41.3	45.9	47.9	45.9	40.7	44.8
I_3	51.3	48.5	42.7	47.5	48.7	46.7	42.2	45.9
I_4	53.4	51.3	45.1	49.9	51.7	49.6	44.1	48.5
I_5	51.5	49.5	43.5	48.2	49.8	48.7	43.4	47.3
I_6	41.9	40.1	33.7	38.5	40.7	38.1	33.1	37.3
I_7	43.3	41.3	35.2	39.9	41.7	39.5	34.8	38.7
I_8	45.3	43.4	37.9	42.2	43.6	41.8	37.1	40.8
Mean	48.0	45.8	39.8		46.2	44.2	39.4	
C.D.(P=0.05)	S	I	I x S		S	I	I x S	
	0.7	1.9	NS		0.8	0.9	NS	

S - Salinity levels, I - Irrigation levels

Table 4 : Effect of different levels of drip and surface irrigation on number of leaves at 60 DAS

Irrigation levels	2007-08 Salinity levels			Mean	2008-09 Salinity levels			Mean
	S_1	S_2	S_3		S_1	S_2	S_3	
I_1	11.0	10.0	8.0	9.7	10.3	9.5	7.6	9.1
I_2	11.3	10.4	8.4	10.0	10.8	9.8	7.9	9.5
I_3	11.7	10.6	8.8	10.4	11.2	10.1	8.3	9.9
I_4	12.0	11.0	9.2	10.7	11.5	10.5	8.7	10.2
I_5	11.8	10.8	9.0	10.5	11.3	10.2	8.6	10.0
I_6	9.8	8.8	6.8	8.5	9.1	8.1	6.4	7.8
I_7	10.1	9.1	7.1	8.8	9.4	8.5	6.8	8.3
I_8	10.8	9.8	8.0	9.5	10.2	9.3	7.6	9.0
Mean	11.1	10.1	8.2		10.5	9.5	7.7	
C.D.(P=0.05)	S	I	I x S		S	I	I x S	
	0.4	0.5	NS		0.6	0.5	NS	

S - Salinity levels, I - Irrigation levels

Table 5: Effect of different levels of drip and surface irrigation on tuber girth, cm

Irrigation levels	2007-08 Salinity levels			Mean	2008-09 Salinity levels			Mean
	S_1	S_2	S_3		S_1	S_2	S_3	
I_1	9.1	8.3	6.5	8.0	8.8	7.9	6.3	7.7
I_2	10.1	9.6	8.1	9.2	9.7	9.2	7.8	8.9
I_3	11.3	10.3	8.6	10.0	11.0	9.6	8.2	9.6
I_4	13.1	11.2	9.6	11.3	12.7	11.0	9.2	11.0
I_5	12.6	11.0	9.2	10.9	12.3	10.6	8.7	10.5
I_6	7.0	6.0	4.5	5.8	6.8	5.8	4.4	5.7
I_7	7.7	6.8	5.0	6.5	7.5	6.4	4.9	6.3
I_8	8.7	7.1	5.7	7.2	8.5	7.0	5.4	7.0
Mean	10.0	8.8	7.1		9.7	8.4	6.7	
C.D.(P=0.05)	S	I	I x S		S	I	I x S	
	0.2	0.6	NS		0.2	0.6	NS	

S - Salinity levels, I - Irrigation levels

Table 6 : Effect of different levels of drip and surface irrigation on tuber length, cm

Irrigation levels	2007-'08 Salinity levels			Mean	2008-'09 Salinity levels			Mean
	S_1	S_2	S_3		S_1	S_2	S_3	
I_1	8.7	7.7	7.1	7.8	8.2	7.2	6.6	7.4
I_2	10.2	8.8	8.3	9.1	9.7	8.6	7.8	8.7
I_3	10.8	9.7	9.3	9.9	10.3	9.3	8.7	9.4
I_4	12.2	11.1	10.5	11.3	11.8	10.7	10.3	10.9
I_5	12.0	11.0	10.3	11.1	11.5	10.5	10.1	10.7
I_6	7.1	5.8	4.6	5.8	6.7	5.6	4.5	5.6
I_7	7.8	6.4	5.1	6.4	7.5	6.2	5.0	6.2
I_8	8.5	7.1	5.6	7.1	8.2	6.8	5.5	6.8
Mean	9.7	8.5	7.6		9.2	8.1	7.3	
C.D.(P=0.05)	S	I	I x S		S	I	I x S	
	0.2	0.4	NS		0.2	0.4	NS	

S - Salinity levels, I - Irrigation levels

Table 7: Effect of different levels of drip and surface irrigation on fresh weight of tuber, g

Irrigation levels	2007-08 Salinity levels			Mean	2008-09 Salinity levels			Mean
	S_1	S_2	S_3		S_1	S_2	S_3	
I_1	390.4	289.8	164.0	281.4	385.9	285.5	159.7	277.0
I_2	423.5	325.9	197.1	315.5	418.1	321.6	192.7	310.8
I_3	449.8	368.5	236.4	351.5	445.4	364.1	231.9	347.1
I_4	481.7	411.3	289.5	394.2	477.4	406.9	285.1	389.8
I_5	471.0	404.0	280.9	385.3	466.6	399.6	276.5	380.9
I_6	230.4	138.7	62.1	143.7	226.0	134.3	57.8	139.4
I_7	264.4	163.2	97.3	175.0	259.9	158.9	93.1	170.6
I_8	303.8	202.1	118.3	208.1	299.7	197.7	113.9	203.8
Mean	376.9	287.9	180.7		372.4	283.6	176.3	
C.D.(P=0.05)	S	I	I x S		S	I	I x S	
	9.8	21.0	NS		9.84	21.0	NS	

S - Salinity levels, I - Irrigation levels

40.8 cm during 2008-09. The number of leaves was the highest under the drip irrigation at 1.2 ET and it was at par with drip irrigation at 1.4 ET. The salinity level-I recorded the highest number of leaves as compared to the other higher salinity levels. Similarly among the surface irrigation levels, irrigation at 1.2 ET recorded the maximum number of leaves. The drip irrigation at 1.2 ET produced the biggest size tubers (11.3 and 10.9 cm length and 11.3 and 11 cm girth, respectively during 2007-08 and 2008-'09). In the same way, among the surface irrigation schedules, irrigation at 1.2 ET produced the biggest size tubers during both the years. Among the salinity levels, the salinity level-I recorded the largest size tubers (7 and 6.8 cm length and 7.2 and 7 cm girth, respectively) during first and second years. The maximum 394.2 and 389.8 g average fresh weights of tuber were recorded in drip irrigation schedule of 1.2 ET and the salinity level-I produced tubers of the highest average fresh weights of 376.9 and 372.4 g during 2007-08 and 2008-09, respectively. Among the surface irrigation levels, irrigation regime of 1.2 ET recorded tubers of the maximum fresh weights of 208.1 and 203.8 g, respectively during 2007-08 and 2009 over other levels of irrigation.

The crop performed better with respect to vegetative parameters in case of drip irrigation level at 1.2 ET under salinity level-I. The availability of moisture in optimum level and the lowest salinity together might have contributed to effective absorption and utilisation of nutrients and better proliferation of roots resulting in better plant growth. Better soil moisture condition positively contributes for higher solubility and conductivity of nutrients which ultimately results into increased mass flow transport of nutrients (Tisdale and Nelson, 1975). The frequent application of irrigation through drip system at optimum level maintains most of the root zone with well aerated condition and at adequate soil moisture content that does not fluctuate between wet and dry extremes (Patil and Janawade, 1999). The highest plant height and branches per plant in case of egg plant were recorded with drip irrigation at 1.2 ET,while the lowest were observed with surface irrigation at 1.0 ET under salt-affected soils (Manjunath *et al.*, 2004).

Tuber yield :

There was a significant difference in tuber yield (Table 8) owing to different irrigation regimes by various levels of drip and surface irrigation methods and salinity levels. The drip irrigation scheduled at 1.2 ET resulted in the maximum tuber yield of 19.43 and 18.91 t ha^{-1} during 2007-08 and 2008-09, respectively. Among the salinity levels, the highest tuber yields of 18.23 and 17.89 t ha^{-1} were recorded in salinity level-I. Whereas among the surface irrigation levels, irrigation at 1.2 ET recorded the maximum tuber yields of 12.2 and 11.84 t ha^{-1} during 2007-08 and 2008-09, respectively. The tuber yield reduced as the salinity increased. The reduction was to the extent of 12 per cent in salinity level-II and 39.7 per cent in salinity level-III as compared to the tuber yield obtained in salinity level-I during 2007-08 against 12.8 and 41.3 per cent during 2008-09. Among all the irrigation levels under both the drip and the surface irrigation methods, 1.2 ET performed better under all the three salinity levels. The highest tuber yield in case of drip irrigation at 1.2 ET under salinity level-I might be attributed to better performance of all crop growth and yield attributing characters due to lowest salinity, better availability of soil moisture environment and availability of plant nutrients throughout the crop growth period under the drip irrigation system. This is in accordance with the findings of Manjunath *et al.* (2004) who reported that higher egg plant yield was recorded for drip irrigation at 1.2 ET followed by drip irrigation at 1.4 ET under varied salinity levels. There was good correlation between yield in drip (R^2 = 0.9021, 2007-08) and

Table 8: Effect of different levels of drip and surface irrigation on tuber yield, t ha^{-1}

Irrigation levels	2007-08			Mean	2008-09			Mean
	Salinity levels				Salinity levels			
	S_1	S_2	S_3		S_1	S_2	S_3	
I_1	19.02	16.53	11.20	15.58	18.47	15.77	10.42	14.89
I_2	20.25	17.58	12.31	16.71	19.77	17.03	11.70	16.16
I_3	21.47	18.80	13.67	17.98	21.02	18.31	13.12	17.48
I_4	22.69	20.42	15.19	19.43	22.25	19.91	14.56	18.91
I_5	21.79	19.12	13.92	18.28	21.28	18.63	13.39	17.77
I_6	12.79	11.05	6.10	9.98	12.42	10.66	5.73	9.60
I_7	13.83	12.09	7.18	11.04	13.34	11.70	6.82	10.62
I_8	14.76	13.19	8.64	12.20	14.54	12.77	8.22	11.84
Mean	18.23	16.04	11.00		17.89	15.60	10.50	
C.D.(P=0.05)	S	I	I x S		S	I	I x S	
	0.33	0.71	NS		0.4	0.8	NS	

S- Salinity levels, I- Irrigation levels surface irrigation (R^2 = 0.9993, 2007-08) levels. When the relationship between the tuber yield and the salinity levels were considered, there was very high correlation during both the years (R^2 = 0.9508 and 0.9540). With the foregone discussions, it could be concluded that, adoption of drip irrigation for hybrid beetroot at 1.2 ET with recommended dose of fertiliser would be a viable proposition and an ideal practice to achieve greater yield and water saving benefits as compared to surface irrigation under saline vertisols.

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