Saline Water Irrigation and Plant Growth in Vertisol

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Regardless of the source, irrigation waters often contain some dissolved salts, the nature and extent of which determine their suitability for irrigation besides the consideration of other factors like soil characteristics, its drainability and depth, kind of crops to be grown, climatic conditions of the area and management practices to be followed. The underground waters especially in the arid and semi-arid areas are of poor quality and form the only or the major source of irrigation because of scanty, erratic and ill-distributed rainfall. The continuous use of these saline ground waters for irrigation affects the physical and chemical properties of the soil, which in turn result in sub-normal crop performance. In India, out of the total cultivated area of approximately 138 million hectares, 49.5 million hectares are irrigated and of these, 16 million hectares are irrigated from ground water sources and the rest from surface waters (AGARWAL et al. [1]).

Because of the high clay content of predominantly montmorillonitic clay mineral, the vertisol soils are easily amenable to the adverse effects of saline water irrigation. This paper presents the results of the investigations conducted on some important aspects of the use of saline water irrigation in a vertisol soil at Dharwar, Karnataka State, South India (latitude: 15°.21′ N; longitude: 75°.7′E; mean elevation above sea level: 677 m; rainfall: 830 mm; and maximum and minimum temperatures: 37°C and 14°C in April and January). The work reported in the paper was undertaken under the All India Coordinated Project for Research on Use of Saline Water in Agriculture.

Results and discussion

Chemical composition of ground waters

Over 1200 ground water samples were collected and analysed from two districts (Dharwar and Bijapur) of Karnataka State. The mean distribution of various cations and anions in relation to the electrical conductivity in a number of well waters in Bijapur and Dharwar districts is shown in Tables 1. and 2. respectively. Amongst the cations Na is most dominant, while Mg is generally

Table 1

Mean distribution of ions in relation to electrical conductivity in well waters of Bijapur district

Block	EC range mmhos/cm	No. of samples	Na^+	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-	SO_4^{2-}
			me/l					
Indi	<1.0	29	1.9	2.1	2.2	3.4	1.7	1.3
	1.0—2.0	22	5.4	3.9	4.4	5.0	3.9	4.2
	2.0—3.0	18	11.3	7.4	11.2	4.2	7.2	17.0
	3.0—4.0	11	18.2	7.6	13.0	3.3	14.2	23.5
	4.0—5.0	5	31.5	5.7	17.3	4.4	14.6	31.3
	>5.0	7	38.1	9.5	27.8	4.6	32.5	38.7
Sindgai	<1.0	17	2.6	1.8	2.7	5.5	0.9	0.5
	1.0—2.0	30	6.1	2.2	4.0	7.3	1.9	2.9
	2.0—3.0	13	8.6	6.1	8.7	4.3	6.0	14.1
	3.0—4.0	8	15.3	10.7	15.9	5.4	11.2	26.3
	4.0—5.0	—	—	—	—	—	—	—
	>5.0	—	—	—	—	—	—	—
Bijapur	<1.0	39	3.5	3.2	3.6	3.5	2.0	5.1
	1.0—2.0	57	8.4	6.2	6.2	5.8	4.0	8.4
	2.0—3.0	44	15.7	9.2	11.7	7.0	9.6	14.7
	4.0—6.0	12	28.9	14.4	19.6	6.9	16.4	32.5
	>6.0	2	43.5	57.3	44.0	4.0	80.5	57.8
Bagalkot								
	<1.0	43	4.7	2.4	3.4	5.3	4.0	0.8
	1.0—2.0	34	13.3	3.5	4.1	6.9	8.2	2.0
	2.0—3.0	3	13.9	6.9	7.9	8.3	15.4	3.0
	3.0—4.0	1	10.4	2.1	8.5	4.5	18.1	5.4
	4.0—5.0	—	—	—	—	—	—	—
	>5.0	—	—	—	—	—	—	—

present in higher quantities than Ca. These water samples are thus mainly of Na—Mg—Ca cationic type as seen from the mean ionic composition given in Fig. 1. The use of highly saline waters having higher Mg : Ca ratio for irrigation is likely to create adverse effect on the physical properties of the black clay

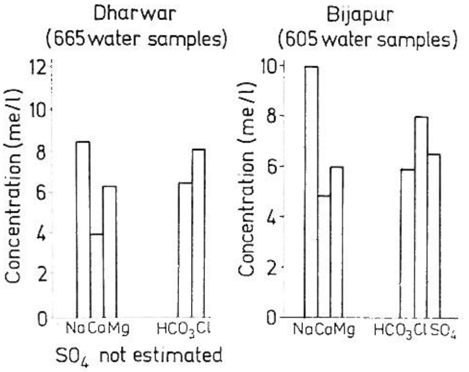

Fig. 1
Ionic composition of underground irrigation waters of Dharwar and Bijapur districts

Table 2

Mean distribution of ions in relation to electrical conductivity in well waters of Dharwar district

EC range mmhos/cm	No. of samples	Na^+	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-
		me/l				
<1.0	174	3.5	3.1	3.4	5.3	3.9
1.0—2.0	163	7.7	3.7	5.1	6.8	6.1
2.0—4.0	62	13.5	6.0	9.5	6.9	13.2
4.0—6.0	28	20.2	9.7	19.1	7.3	22.5
6.0—8.0	15	35.1	8.0	25.4	5.5	32.1
<8.0	8	48.3	9.1	18.9	6.5	45.9

Note: SO_4 was not determined.

soils of montmorillonitic clay mineral and on the growth of crops (YADAV and GIRDHAR [5]). Bicarbonate ions are dominant over Cl ions in the lower salinity range (upto EC 2 mmhos/cm), while Cl ions exceed the content of HCO_3 in the higher EC range. Sulphate ions are also found to increase with increasing salinity of the water. Furthermore, the water samples from Bijapur district having lower rainfall are more saline than those from Dharwar district having higher rainfall, irrespective of the similarity in the lithological formations with which they are in contact (Fig. 2).

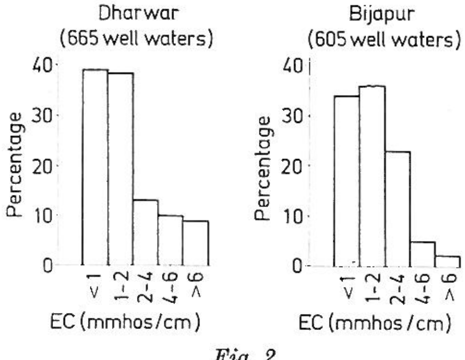

Fig. 2
Percent distribution of well waters in relation to electrical conductivity (EC) values

Effect on soil salinity and crop growth

The continuous use of saline water for irrigation results in the development of soil salinity and ultimately affects the yields of crops. In order to study the effect of saline water irrigation on soil salinity and crop growth, an experiment was conducted in a medium black clay soil (Vertisol) having the characteristics given in Table 3.

The experiment was laid out in the micro-plots (2.5 m × 2.5 m) separated by polythene sheets inserted vertically to 90 cm depth to prevent lateral movement of the applied saline irrigation water from one treatment plot to another.

A rotation of sorghum in *kharif* (rainy season) and wheat in *rabi* (winter season) was followed during the entire period of experimentation. The treatments included seven qualities of irrigation water (EC 0.95, 2, 4, 6, 8, 12 and 16 mmhos/cm). The ratio of Na : Mg : Ca in the artificially prepared irrigation water was kept as 60 : 25 : 15 and Cl : SO_4 : HCO_3 ratio as 2 : 1 : 1, as long as SO_4 did not exceed 30 me/l and HCO_3 not more than 10 me/l. Beyond this, the anions were substituted by Cl.

Table 3

Physical and chemical properties of the soil

Coarse sand	5.8%
Fine sand	14.2%
Silt	28.0%
Clay	51.9%
pH (1 : 2.5 soil water suspension)	7.3
Electrical conductivity (1 : 2.5 soil water suspension)	0.254 mmhos/cm
Cation exchange capacity	57.4 me/100 g
Calcium carbonate	3.0%
Organic carbon	0.83%
Total nitrogen	0.016%

The results of the experiment indicated that the continuous use of saline water irrigation adversely affected the crop yields. The grain yields of sorghum and wheat obtained during the period 1973—74 to 1978—79 are

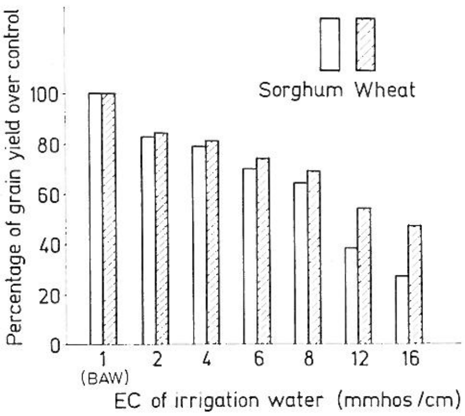

Fig. 3

Performance of sorghum and wheat under saline water irrigation (BAW = best available water)

presented in Table 4. On the whole, a gradual reduction in the grain yield of the crops occurred with an increase in the salinity of irrigation water, though the grain yields did not show any significant reduction even at higher EC values of irrigation waters in the beginning, particularly in the first year. In the sub-

Table 4

Effect of saline water irrigation on the grain yield of sorghum and wheat at Dharwar (t/ha)

Treatment water quality EC×10³	1973	1974	1975	1976	1977	1978	1979
Sorghum							
Control (BAW)	8.10	8.08	8.85	8.81	7.00	6.88	
2	7.41	7.38	7.55	7.52	5.82	5.70	
4	7.47	7.33	7.37	7.28	5.57	5.45	
6	7.27	7.29	6.50	6.31	4.87	4.78	
9	7.51	7.15	5.25	5.06	3.62	4.40	
12	7.72	7.05	3.62	3.41	2.63	2.58	
16	7.43	6.53	1.87	2.12	6.25	1.88	
C. D. at 5%	N. S.	N. S.	—	0.61	0.83	0.32	
Wheat							
Control (BAW)		1.83	3.60	2.83	3.59	3.27	2.33
2		1.67	3.32	2.65	3.22	2.90	1.95
4		1.64	3.07	2.59	2.91	2.67	1.88
6		1.63	2.87	2.51	2.73	2.50	1.73
9		1.60	2.82	2.38	2.47	2.15	1.60
12		1.53	2.65	1.99	2.31	1.57	1.25
16		1.49	2.25	1.14	1.70	1.50	1.10
C. D. at 5%		N. S.	0.21	—	0.40	1.07	0.21

BAW = Best available water

sequent years, however, the decrease in the crop yields with increase in the salinity status of water became very much pronounced. Thus, during 1978—79, the reduction in the yield varied from 17.3 to 73.5 per cent in the case of sorghum and from 16.1 to 52.6 per cent in the case of wheat, when the salinity of the irrigation waters increased from 2 mmhos/cm to 16 mmhos/cm (Fig. 3). The decreasing trend in the yield became distinctly more marked above EC 8 mmhos/cm. It was also noticed that wheat crop is more tolerant to salinity than

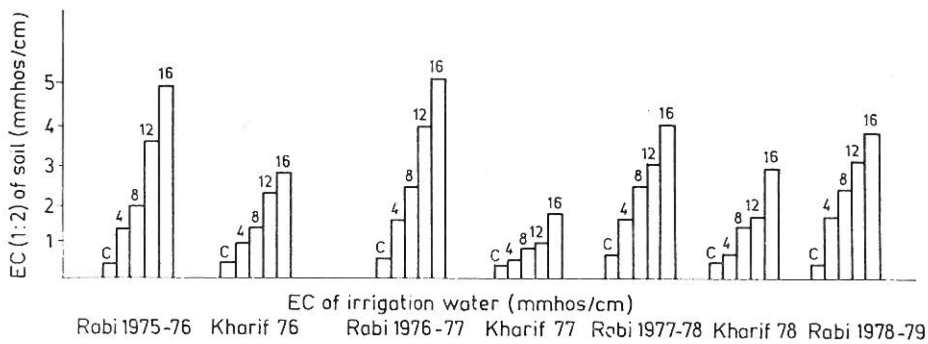

Fig. 4
Salinity status of soil due to irrigation with varying quality waters. After harvest of sorghum and wheat crops

sorghum crop. The salinity level of irrigation waters which could be used for growing wheat and sorghum successfully is around 4 mmhos/cm.

A substantial increase in the development of soil salinity was observed with increase in the salinity of water applied (Fig. 4). The accumulation of salts in the soil was found to be greater after the harvest of *rabi* crop than after *kharif* harvest, chiefly because of larger number of saline water irrigations applied and almost complete absence of leaching of the salts by rain in the winter season. The salts accumulated in the soil during the *rabi* (winter) season, were leached to some extent in the subsequent rainy season, but the magnitude of leaching was relatively less in the local heavy textured soil as compared to what occurs in the light textured soil. According to YADAV [4] greater leaching of salts in the permeable sandy loam soil at Agra, creates favourable conditions for the growth of *kharif* (monsoon) as well as *rabi* (winter) crops.

Salt tolerance according to growth stages

It is known that many crops show considerable variations in their tolerance to salinity at different growth stages. Thus, a study was undertaken to identify the growth stages of the important crops of the region which are relatively more sensitive so that irrigation with saline water could be avoided at such growth stages, if good quality water is also available in the area to some

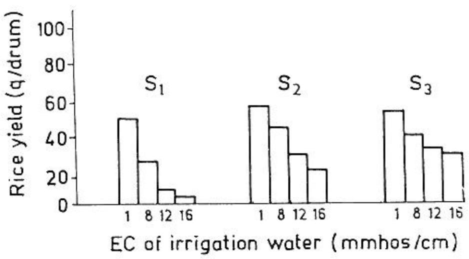

Fig. 5

Effect of saline water irrigation at different growth stages on rice yield. S_1 = Transplanting to tillering; S_2 = Tillering to flowering; S_3 = Flowering to maturity

extent. The experiments involved the use of saline waters of different quality (EC of 0.95, 4, 8, 12 and 16 mmhos/cm) for irrigating crops, namely, rice, wheat, cotton and sorghum at various growth stages. The growth stages of the important crops which have been identified to be relatively more sensitive to saline water irrigation are indicated below:

Crop	*Sensitive stages*
Rice	Transplanting to 50% flowering
Wheat	Germination
Cotton	Germination and early seedling growth
Sorghum	Planting to ear initiation

The pertinent data on the rice yield (unhusked) as influenced by irrigation application of varying quality waters at different growth stages are illustrated in Fig. 5. Application of saline water irrigation after transplanting up to tillering stage brought about maximum reduction in rice yield. The growth stage from flowering to maturity seems to be more tolerant to saline water irrigation. The growth stage of tillering to flowering exhibited an intermediate performance in this respect. This suggests that saline water irrigation should be avoided during transplanting to tillering or even up to flowering stage in the case of rice, if good quality water is available for irrigation during this period.

Varietal differences in salt tolerance

Several varieties of important crops were tested for their tolerance to saline water irrigation of varying EC values, using crops such as sorghum, rice, sunflower, finger millet *(ragi)*, wheat, safflower and bengal gram. The experiments were conducted in the micro-plots and the irrigation waters had EC

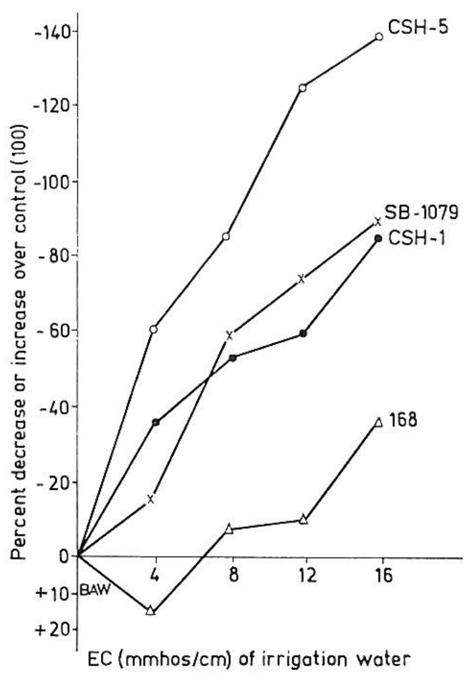

Fig. 6

Effect of saline water irrigation on osmotic pressure of sorghum leaf cell-sap

levels of 0.95, 4, 8 and 12 mmhos/cm. In screening these varieties, largely the Mean Salinity Index (100×mean of yield under the various salinity levels/yield under control) was taken into consideration. Out of several varieties tested under each crop, the following varieties appeared to hold promise with regard to their tolerance to saline water irrigation:

Crop	*Salt tolerant varieties*
Sorghum	CSH-1 and CSH-5
Rice	Getu, SR-26B, MR-18, Bilikagga
Sunflower	Ramson Record, B-Inbred, EC-101494, BSH-1
Ragi	Annapurna, Indaf-7
Wheat	Kharchia-65, UP-301, DWR-137, Bijaga Yellow
Safflower	A-300, CTS-7218

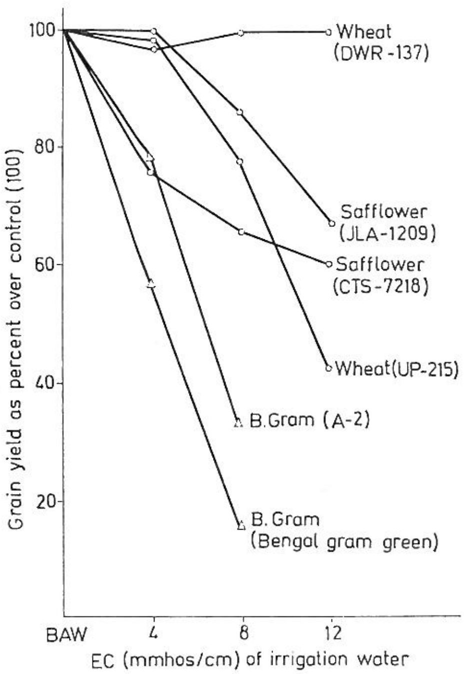

Fig. 7
Relative tolerance of varieties of crops to saline water irrigation

The osmotic pressure of the leaf cell sap at certain growth stages was found to be higher in the case of tolerant varieties than in the sensitive varieties. Thus, CSH-5, a tolerant variety of sorghum, showed higher osmotic pressure in the leaf cell sap than 168, a susceptible variety (Fig. 6.). The relative tolerance of a few varieties of wheat, safflower and bengal gram is presented in in Fig. 7. This brings forth not only the variation in the tolerance among the crops, but also among the varieties of each crop.

Potassium: sodium ratio levels in the leaves of crop plants also show variation in the tolerant and susceptible varieties. This ratio was found to be appreciably high in the tolerant varieties and low in the susceptible ones because of more uptake of Na in the latter. It was observed in case of cotton that the salt tolerant genotypes Varalaxmi and Bhagya had higher K : Na ratio in their leaves than in the susceptible varieties Laxmi and Hampi (Fig. 8.). Occurrence of higher K : Na ratio in the leaves as an index of salt tolerance was also noted in case of wheat by MURTHY et al. [3] in the black clay soil at Dharwad. Similar observations have been made at Karnal (JOSHI et al. [2]). This suggests the need of examining in detail whether increased K fertilization can alleviate the ill-effects of salinity.

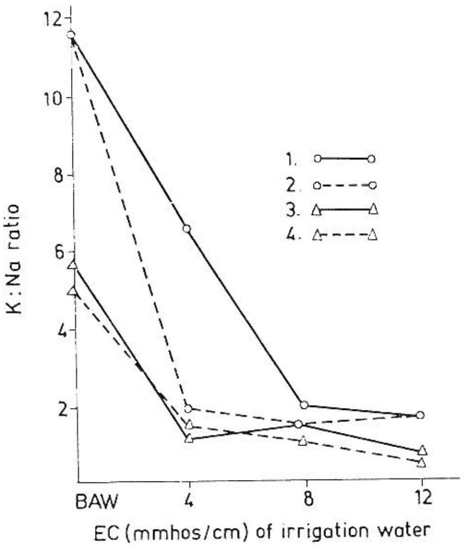

Fig. 8

Effect of saline water irrigation on K : Na ratio in cotton leaves. Cotton varieties: 1. Varalaxmi; 2. Bhagya; 3. Hampi; 4. Laxmi

Summary

The chemical composition of a large number of water samples from the wells in Dharwar and Bijapur districts of Karnataka State, India, revealed that these waters are generally of Na—Mg—Ca cationic type. Amongst the anions the bicarbonate ions dominated in the lower salinity ranges and Cl in the higher salinity ranges. Waters of Bijapur district having lower rainfall showed higher salt concentration than those of Dharwar district which has relatively higher rainfall.

A linear reduction in the grain yield of sorghum and wheat was noticed when the salinity of the applied irrigation water increased from 2 mmhos/cm to 16 mmhos/cm. This was accompanied by a corresponding increase in the accumulation of salts in the soil. The early stages of crop growth appeared to be more sensitive to saline water irrigation than the later stages in most of the crops, namely, rice, wheat, cotton and sorghum. Out of the several varieties tried under each crop, some were identified to be more tolerant to salinity than others. In the tolerant varieties, the mean salinity index, K/Na ratio and the osmotic pressure of the leaf cell sap were higher than those in the susceptible varieties.

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