Effect of Saline and Sodic Water Irrigation on Soil Characteristics and Growth of *Eucalyptus* hybrid

J. S. P. YADAV and O. S. TOMAR

Central Soil Salinity Research Institute, Karnal (India)

Ground water is the main source of irrigation next to surface water in many parts of the world including India. In the arid and semiarid regions the quality of the ground water is often extremely poor and poses a serious problem as no dependable alternative source of good quality water is available for irrigation in most of these areas because of scanty and erratic rainfall. The use of such ground waters for irrigation becomes inevitable for utilizing the land resources for productive purposes in the arid and semiarid areas. The continuous use of these waters is likely to adversely affect the soil properties depending upon the concentration and chemical composition of the salts present in the waters, the texture, organic matter content, calcareousness, clay mineralogy and drainability of the soil, kind of crops and varieties to be grown, management practices adopted and climatic conditions of the area, etc. (SINGH and BHUMBLA [14], YADAV [18], GUPTA and ABICHANDANI [6]).

Besides certain agricultural crops, the raising of tree plantations irrigated with saline ground water for meeting the local demand of fuel, timber etc. and for moderating the ill-effects of prevailing weather conditions is of paramount importance in the maintenance of optimum land use and ecological environment. *Eucalyptus* hybrid, which has a wide adaptability to varied agroclimatic conditions, has a great scope for cultivation in some of the arid and semiarid areas. However, scientific information on the effect of the use of saline irrigation waters on soil properties and the growth behaviour of this forest species is lacking. Hence, the present study was undertaken with *Eucalyptus* hybrid seedlings to examine the effects of irrigation with saline and sodic waters on the soil properties and the role of farmyard manure and gypsum application in alleviating the likely harmful effects.

Materials and methods

The study was conducted at the research farm of the Central Soil Salinity Research Institute, Karnal in big glazed pots (30 cm × 30 cm) in two separate parts, using *Eucalyptus* hybrid seedlings. Nineteen kg of normal well-pulverized soil of a sandy loam texture having pH 8.0 and EC 1.18 mmhos/cm was filled in each pot. In part I of the experiment three irrigation waters of EC 0.4, 5 and 10 mmhos/cm having the chemical composition as given in Table 1, were em-

Table 1

Chemical composition of irrigation waters used in experiments I and II

EC mmhos/cm	RSC me/l	SAR	Ca^{2+}	Mg^{2+}	Na^{+}	HCO_3^-	Cl^-	SO_4^{2-}
			me/l					
I. Experiment								
0.4 (BAW)	—	1.0	1.7	1.8	1.3	4.1	0.4	0.5
5	—	12.8	5.0	10.0	35.0	2.0	40.0	8.0
10	—	18.1	10.0	20.0	70.0	4.0	80.0	16.0
II. Experiment								
0.4 (BAW)	0.6	1.0	1.7	1.8	1.3	4.1	0.4	0.5
2	5	9.5	2.0	3.0	15.0	10.0	7.5	2.5
2	10	15.6	1.0	1.5	17.5	12.5	5.0	2.5
2	15	23.2	0.5	0.8	18.7	16.3	2.0	1.7
4	5	16.0	3.0	5.0	32.0	13.0	23.0	4.0
4	10	22.2	1.5	3.5	35.0	15.0	21.0	4.0
4	15	22.2	1.5	3.5	35.0	20.0	17.5	2.5

BAW = Best available water; RSC = Residual sodium content.

ployed. In half of the pots of each EC water FYM was applied 1 kg per pot at the time of filling the soil, while no FYM was applied in the remaining pots.

In part II of the experiment, irrigation waters of two EC levels (2 and 4 mmhos/cm) and three RSC levels (5, 10 and 15 me/l) besides one control of best available water were used for irrigation. The chemical composition of the irrigation waters used is shown in Table 1. In the case of RSC 10 and 15 me/l, two additional treatments were also included, in which gypsum was added to the soil to reduce RSC from 10 and 15 me/l to 5 me/l to mitigate the adverse effect of RSC on soil properties and plant growth. Gypsum was applied in the soil at the time of each irrigation. Thus, there were 11 treatments in a completely randomized design, comprising of combinations of 2 levels of salinity and 5 levels of RSC in irrigation water and one control.

One four months old *Eucalyptus* hybrid seedling was planted in each pot on July 2, 1977. Care was taken to use seedlings of uniform size in all the pots. A total of 26 irrigations in part I and 29 irrigations in part II were given as and when required during the study period of 17 months. Each irrigation contained 2.5 litres of water excepting the first irrigation of 5 litres. The experimental pots had no provision of drainage and were not allowed to stand in the rain. At the time of termination of the experiment, soil samples were collected to determine the chemical changes that occurred during the experimental period due to irrigation with saline and sodic waters, following the standard procedures.

Results and discussion

Changes in soil properties

The pH of the soil varied from 8.2 to 8.4 under irrigation with best available water (BAW) and from 7.9 to 8.1 under the treatments with saline waters of EC 5 and 10 mmhos/cm. A depression in soil pH noticed in the treatments with

Table 2

Effect of saline water irrigation with FYM application on soil properties (Ionic composition of saturation extract)

Treatments	EC mmhos/cm	pH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{2-}	SAR	Organic matter, %
			me/l								
BAW F_0	2.1	8.4	6.4	9.3	14.0	0.5	3.1	19.6	7.5	5.0	0.74
BAW F_1	3.9	8.2	8.4	15.0	19.7	3.4	2.6	25.5	14.5	5.7	0.91
EC_5 F_0	26.3	8.0	40.6	67.2	356.8	1.1	3.6	338.0	71.3	48.6	0.73
EC_5 F_1	26.8	7.9	42.8	69.1	361.3	7.0	3.2	396.0	73.0	48.3	1.05
EC_{10} F_0	38.5	8.0	64.9	95.9	646.3	1.1	2.8	699.5	107.0	72.1	0.84
EC_{10} F_1	41.9	8.0	68.3	102.6	657.0	8.3	3.8	715.0	119.5	71.1	1.04

high EC irrigation waters can be attributed to the high electrolyte concentration. The EC of the soil varied from 2 to 4 mmhos/cm in the case of BAW, but it increased to 26—28 mmhos/cm and 39—42 mmhos/cm in the case of waters of EC 5 and 10 mmhos/cm (Table 2.). The EC of soil in the case of water of EC 10 mmhos/cm was about 5– 6 times as compared to the EC of the irrigation water, and was, on the whole, about 5 times more than that observed in the case of best available water. It is interesting to observe that the increase in soil salinization in the case of irrigation water of EC 10 mmhos/cm was of a lesser magnitude as compared to that with the water of EC 5 mmhos/cm. It seems that as the salinity in the soil increases, some salts might precipitate resulting in lower values of EC. The SAR values of the soil became $\sim$ 5—6, 48—54, 71—77 with BAW and waters of EC 5 and 10 mmhos/cm, respectively. As compared to SAR of the irrigation waters, the SAR of the soil increased by about 4—5 times. The pH, EC and SAR values of the soils were not affected significantly by the addition of FYM (Table 2).

In the case of sodic waters, it was noticed that pH and SAR values of the soil increased with the increase in RSC values at both levels of EC of the waters used for irrigation, whereas the EC of the soil decreased with the increase in RSC of the irrigation waters. The SAR values of the irrigation waters increased from 9.5 to 23.2 as RSC increased from 5 to 15 me/l. Salinization and alkalization to which the soil has been subjected can, therefore, be ascribed to the combined effect of RSC and SAR. It is also observed (Table 3) that in the treatments where gypsum was applied to reduce the RSC values from 10 and 15 to 5 me/l, the irrigated soils registered low values of pH and SAR, which were on a par with those noticed under the RSC 5 me/l of the same EC of irrigation water.

The effect of irrigation water on soils of the same texture also depends on the climatic conditions of the area (TALATI [15]). Soil salinization decreases in the well drained soils with the annual rainfall (BHUMBLA [3], YADAV [17], LAL and SINGH [8], MANCHANDA and BHANDARI [11]). However, in the present study owing to the exclusion of the leaching effect of rain water, excessive salt accumulation took place in the soil of the pots and thus, the effect of rain is not perceptible here.

Considerable information is available on soil salinization and alkalization under field conditions with respect to agricultural crops. BERNSTEIN [2] stated that for an ideally drained irrigated soil the EC of soil could approximate half the value of EC of irrigation water. YADAV [17], on the basis of the

Table 3

Effect of sodic water irrigation with and without gypsum application on soil properties (Ionic composition of saturation extract)

Irrigation waters		EC mmhos/cm	pH	$Ca^{2+} + Mg^{2+}$	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}	SAR
EC mmhos/cm	RSC			me/l						
2	5	9.3	9.2	8.8	113.8	0.7	12.5	77.0	35.4	54.4
	10	8.6	9.4	6.4	107.5	0.5	14.5	68.5	31.9	60.1
	15	7.4	9.8	3.0	87.0	0.4	28.8	36.0	25.5	71.1
	10→5	9.7	9.2	10.8	121.8	0.7	13.0	59.5	63.0	52.5
	15→5	9.2	9.3	11.6	120.3	0.7	14.8	27.0	96.0	49.9
4	5	18.9	9.0	19.2	245.3	0.9	9.5	222.0	42.8	79.1
	10	19.7	9.3	7.1	280.5	0.8	13.2	235.7	42.1	149.2
	15	17.0	9.6	3.8	242.8	0.7	16.3	205.5	25.6	176.2
	10→5	16.7	9.1	13.2	236.3	0.9	10.0	169.7	78.3	91.9
	15→5	16.3	9.2	15.2	219.5	0.9	9.5	50.2	92.8	79.6
0.4 BAW	0.6	2.7	8.4	13.0	16.5	0.6	5.5	11.0	12.2	6.5

10→5 and 15→5 = RSC of the irrigation water were reduced from 10 and 15 me/l to 5 me/l with the application of gypsum

results of the experiments conducted in the microplots at several places in India, reported that the adverse effect of saline irrigation water on the soil properties is much less in the light textured soils than in the heavy soils. Similar observations were made by SINGH and BHUMBLA [14]. TRIPATHI et al. [16] observed that the continued use of brackish ground waters in the Agra region could not result in harmful accumulation of sodium salts under the good drainage conditions of light textured soils. SAR of soils was found generally less than that of the irrigation waters. JAIN et al. [7] noticed that irrigation with water of EC 4.8 mmhos/cm (SAR 32, RSC 7.4 me/l) did not cause any appreciable accumulation of salts in 0—60 cm depth of a sandy permeable soil in a three-year field experiment.

GUPTA [5] stated that although saline waters of EC less than 2 mmhos/cm and RSC upto 10 me/l could be used continuously for a longer period without adverse effect on the growth of crops like wheat on the light and medium textured, well drained soils, provided SAR was less than 10 or adj. SAR less than 20, yet the use of gypsum was observed to be beneficial in keeping lower SAR values of the soils. The results of a study in microplots at Agra revealed that irrigation with water having RSC as high as 10 me/l continuously for the past six years during the *rabi* season (1972—77) did not cause any appreciable salinization or alkalization in the sandy loam soil [1]. Thus, it would seem logical to conclude that if drainage is no problem and rainfall is appreciable and effective, the salinization and alkalization of the soil as reported here would shift to a much lower degree and may not affect the growth of the forest species adversely.

Plant growth under saline waters

Addition of FYM resulted in significant height increment of *Eucalyptus* seedlings in the case of the best available water (Table 4). In the case of higher salinity waters, the increase in height increment due to FYM addition was much

Table 4

Effect of FYM application on height increment of plants (cm) with irrigation waters of varying salinity

Treatments	Days after transplanting							
	60	120	180	240	300	360	420	480
EC×10³								
BAW (0.4)	42	59	63	76	90	101	111	114
5	29	36	36	40	43	43	43	43
10	19	23	23	23	23	23	23	23
C. D. at 5%	6.7	7.4	7.9	7.9	6.9	6.9	7.3	7.1
FYM								
No FYM	27	35	37	41	47	50	53	54
FYM	33	42	45	51	57	61	64	65
C. D. at 5%	5.5	6.0	6.4	6.5	5.7	5.6	5.9	5.8
EC×FYM	Not significant							

smaller. As the salinity of the waters increased, the EC of the soil also increased (Table 2) and when the accumulation of the salts became excessive, there was no beneficial effect of FYM application. Thus, the height growth of the species was primarily governed by the EC of the soil and the response to FYM application was observed only at the low EC levels. Like the height growth, the beneficial effect of FYM application on diameter increment and dry matter production was noticed only at lower EC of irrigation water, but the data are not given here for the sake of brevity.

Several workers have reported that the addition of manures enhances the suitability of saline waters for irrigation. MALIWAL and PALIWAL [9, 10] observed a beneficial effect of FYM application on wheat and bajra crops only upto a moderate level of salinity and SAR of the irrigation water. Similar results were obtained in the case of maize (PALIWAL and MALIWAL [12]). The grain yields of wheat grown on the poorly drained sandy clay soil irrigated with bicarbonate rich water, were increased by addition of 5 to 20 t/ha of dung (PUNTAMKAR et al. [13]).

Plant growth under sodic waters

The effect of the various treatments of RSC and gypsum application was more distinct in the case of irrigation water of EC 2 mmhos/cm. Since the water of EC 4 mmhos/cm created high salinity in the soil which in turn affected plant growth significantly, the effects of other treatments were not discernible vividly in this case. Further, the adverse effect of high RSC (15 me/l) was perceptible after 300 days of growth (Fig. 1). The beneficial effect of gypsum application in reducing the harmful effect of high RSC was, therefore, noticed only at the later stages of plant growth, particularly at 360 days after transplanting.

Thus, it can, be inferred that certain values of RSC in the irrigation water are not harmful in the early growth stage of *Eucalyptus* hybrid. Irrigation with high RSC waters can, therefore, be done upto a period till the SAR of the soil rises to an injurious level. The response to gypsum application for such a short

period is also not expected. Once the critical limits of SAR of the soil are exceeded due to prolonged use of high RSC water which would have an injurious effect on the height growth of the plants, the response to gypsum application is obvious. The favourable influence of gypsum in counteracting the adverse effect of high SAR of the soil may be due to the improvement in the physicochemical condition of the soil and the increased supply of calcium for plant use. More or less similar results were obtained in the case of diameter growth and dry matter production per plant. The relevant data in respect of dry matter production are shown in Fig. 2.

The effect of high RSC irrigation waters on the growth of cereal crops have been reported by several workers. The highest yield of wheat on poorly drained sandy clay loam soil irrigated with HCO_3 rich water was obtained when gypsum was applied at the rate of 20 t/ha, equivalent to 200 per cent GR, in the case of water having RSC 12.5 me/l (PUNTAMKAR et al. [13]). In a microplot experiment conducted in sandy loam soil at Agra [1] no adverse effect was observed on the growth of wheat and bajra with irrigation waters having RSC as high as 10 me/l. Similarly, GUPTA [5] reported that the growth of wheat does not suffer adversely with waters of RSC as high as 10 me/l. It was further reported that the waters of EC lesser than 2 mmhos/cm and RSC upto 10 me/l could

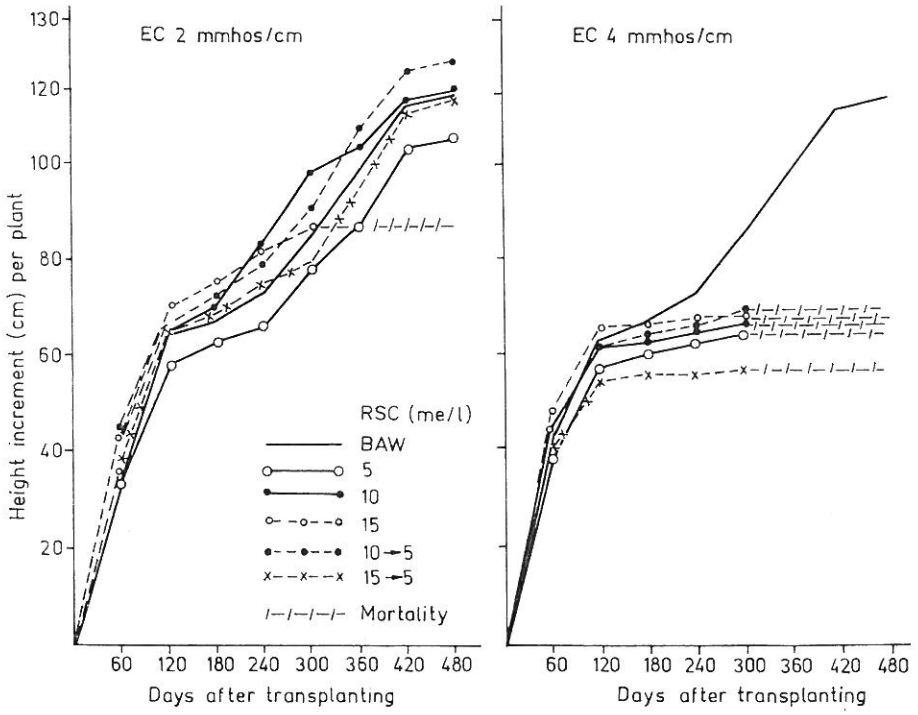

Fig. 1
Effect of irrigation waters of varying EC, RSC levels and of gypsum application on the periodic height increment (cm) per plant of *Eucaliptus* hybrid. BAW = best available water

be used continually for a pretty long period for growing salt tolerant crops without adverse effect provided SAR of the irrigation water is less than 10.

In conclusion, it may be mentioned that *Eucalyptus* hybrid appears to be relatively more tolerant to sodic conditions as compared to the saline conditions, as this species continued to make progressive growth with waters of EC 2 mmhos/cm having RSC upto 10 me/l. BINDER-BERHAVE and RAMATI [4] and YADAV et al. [19] also made almost similar observations. The successful growth of *Eucalyptus* hybrid at least during the early period can be expected on a light-textured soil having upto EC of about 8.5 mmhos/cm, pH 9.4 and SAR about 60. Since the tolerance of the plant generally increases with advancement in growth, it is also likely that these values of the soil characteristics may not have adverse effect in the later period of growth. These are the safest limits of EC, pH and SAR, which can be recommended for raising this forest species on such soils.

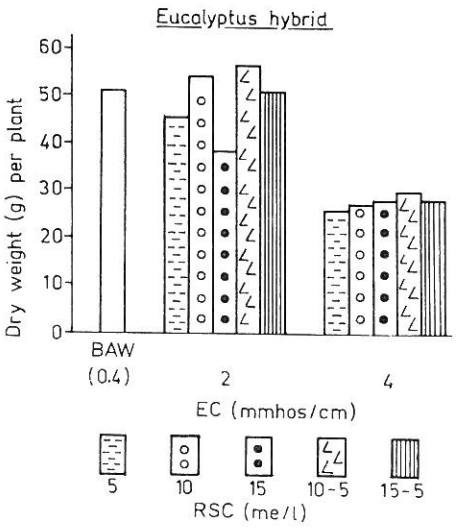

Fig. 2
Effect of saline water irrigation of varying salinity and RSC levels and of gypsum application on dry weight per plant (g)

Summary

In a pot study of 17 months duration on the effect of saline water irrigation on soil properties and growth of *Eucalyptus* hybrid, using a normal soil of sandy loam texture, it was observed that soil salinization and alkalization increased significantly as the EC and RSC of the irrigation water increased. The EC and SAR of the soil at the end of the experiment were about 4—5 times higher than those of the irrigation water, since the pots did not have provision of drainage and were protected from the leaching effect of the rain. The plants died at EC 4 mmhos/cm and above due to development of high soil salinity. The addition of farm yard manure increased plant growth when irrigated with the best available water but not with waters of EC 5 and 10 mmhos/cm. In case of sodic waters at the same level of EC, the EC of the soil decreased, whereas pH and SAR values of the soil increased with an increase in RSC of irrigation water from 5 to 15 me/l. The harmful effect of increasing RSC values on the growth of *Eucalyptus* hybrid was distinctly visible only with irrigation water of EC 2 mmhos/cm, and not with water of EC 4 mmhos/cm, because of the more dominant adverse effect of salinity in the latter case. The application of gypsum was found to be beneficial in keeping lower values of pH and SAR of the soil and in minimizing the adverse effect of high RSC waters on plant growth. The successful growth of *Eucalyptus* hybrid can be expected on the light-textured soil having upto EC 8.5 mmhos/cm, pH 9.4 and SAR about 60.

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