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Full Length Research Paper

Effect of root zone salinity on mineral nutrition and growth of beri (*Zizyphus mauritiana* lam) and jaman (*Eugenia jambolana* lamk)

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Excess of salts in the root zone of plants adversely affects their growth. It may result in loss of stands, reduced rates of plant growth, reduced yields and in severe cases, total crop failure. Salinity limits water uptake by plants by reducing the osmotic potential and thus the total potential of the soil water, additionally certain salts may be specifically toxic to plants or may upset nutritional balance, if they are present in excessive amount or proportion. The problem of increasing salinity implicates the selection and development of salt tolerant plants, in addition to other preventive and management measures. The present study intends to illustrate the effect of root zone salinity on the survival, growth, ionic activity and nutritive value of Beri (*Zizyphus mauritiana* lam) and Jaman (*Eugenia jambolana* Lamk). Experiments were conducted in pots filled with gravel applied with treatment solutions containing nutrients and salts to produce salinity levels of ECi-5, 10, 15, 20 and 25 dSm^{-1}. The relative dry matter production separately for browseable material, shoot and root against salinity was calculated as mean of four replications determine after 30 days of transplantation. Three parts of the plant showed almost similar growth reduction; however, the reduction of root growth being slightly more severe for both the plants.

Key words: Soil salinity, root zone salinity, Indus basin, growth, nutritive value, Beri, Jaman.

INTRODUCTION

Salinization of soil and ground water is a serious land degradation problem in semi arid and arid regions of Pakistan. It is estimated that nearly 6 million hectares (35 to 40% of total irrigated area) are affected with salinity, which has reduced 25% production potential of the Indus basin and it was estimated that two million ha are abandoned due to severe salinity (Wolters and Bhutta, 1997). The extent keeps on changing due to the dynamic nature of the problem about 75% of the population and about half of the Gross National Product (GNP) of Pakistan are directly or indirectly related to the agricultural sector and due to the presence of this shallow and saline groundwater, about 40,000 ha are annually abandoned within the Indus basin due to secondary salinization (WAPDA, 1989). The main causes of increasing threat are poor irrigation and drainage practices, which is depriving the farmers from productive resources and thus, posing negative impacts to their livelihood (Lamkbers, 2003).
Pakistan has given due significance to this issue after the country came into being. A complete and durable solution of the problem of salinity in Pakistan lies in leaching and drainage of excessive salts from the surface and root zone of soil. However, this approach is expensive, energy intensive and time consuming. It is possible saves costs of energy resources. The alternative method to restores saline land is saline agriculture technology. This approach is cost effective. This is basically a pro-poor approach to enhance income of poor farmers, who normally leave the land barren otherwise.

This approach emphasized on using highly saline water and lands on a sustained basis through the profitable and integrated use of genetic resources including plants, animals, fish and insects, and improved agricultural

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practices. Management practices of these soils include chemical amendments, organic matter, mineral fertilizers and judicious selection of the salt tolerant forages and grasses. This approach attempts to promote bio-reclamation techniques using salt tolerant plants, bushes, trees and fodder grasses and production utilization of this biomass. Plants particularly trees are commonly referred as biological pumps and play an important role in the overall hydrological cycle in a given area. Studies in Pakistan showed that, highly saline waters could be used to grow salt tolerant fodder grasses to improve the quality and quantity of livestock (Lennard and Qureshi, 1998; Hussain et al., 1990).

Ziziphus mauritiana (locally knows as Beri) and *Eugenia jambolana* lam (locally known as Jaman) family Rhamnaceae and Myrtaceae respectively, are multi purpose plants of semi arid regions. Besides fruit, these plants also yield timber of marginal value, brushwood, fuel wood and leaf fodder (Pareek, 2001). Leaves and other browseable material of these plants are the primary source of mineral for small browsing animals like goats, sheep and lambs. Under saline condition, mineral ion interaction in the external may effect in the internal requirement of elements essential for plant growth and development (Gratten and Grieve, 1999). The availability, uptake and partitioning of mineral ions within the plants are controlled by numerous environmental factors, including concentration and composition of solutes in the growing medium. These imbalances influence the plants color, texture and mineral nutrition value. The present study intends to illustrate the effect of root zone salinity on growth, survival and chemical composition of different parts of Beri and Jaman plants.

MATERIALS AND METHODS

The experiments were conducted at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan from July till October 2005, in net house salinity environmental division. Seeds of the Beri and Jaman were collected from the local market. Seeds were sown in plastic packets filled with soils, silt and farm yard manure (FYM) at the ratio of 1:1:1 at NIAB, Faisalabad. Beri (*Z. mauritiana*) was sown on 20th July and Jaman (*E. jambolana* lamk) on 22 August, 2006. The soil of plants was dipped in the water for few minutes and then gently removed from the plants with hands. The plants were transplanted at the age of four weeks into pots. The setup consists of 24 sets of plastic pots for each experiment with four replications for each treatment, which were filled with thoroughly acid washed quartz gravel 5 to 25 mm dia (Qureshi et al., 1997).

One week after transplanting, the plants were exposed to salinity. The salinity of the medium was gradually increased by ECi-5 dSm^{-1} increment at one-day interval, until it reached the highest level. The pots were irrigated with water of six different qualities. The control treatment with half strength Hoagland nutritive solution (Hoagland and Arnon, 1950) with electric conductivity (ECi) of 1 dSm^{-1} and five salt treatments, containing ECi- 5,10,15,20 and 25 dSm^{-1} respectively, obtained by adding Na_2SO_4, $CaCl_2$, $MgCl_2$ and NaCl at the ratio of 10:5:1:4. To obtain a subject level of salinity in the pots, NaCl with concentration of 200 g/L of water was added as needed. The pH of the solution was uncontrolled and ranged from 6.5 to 7.5. In the absence of the drainage, salinity was measured with the help of the portable EC meter. To assure that target ion concentrations were maintained, irrigation water was changed twice in a week. Plants were aerated three times in a day by pulling the plants containing pot out of the irrigated water.

At the end of the experiment plants were harvested from the each treatment and divided into three parts, brows able material, shoot and root. The plant parts were washed with distilled water and dried. The shoot, root length and fresh weight of browseable material, shoot and root were determined on all treatments after 30 days of transplanting. Plants dry matter was measured after drying at 70°C for 48 h. The dried parts of the plants were grind separately and were wet digested in HNO_3 and $HClO_4$. Mn^{2+}, Fe^{2+} and Cu^{2+} were determined with the help of Atomic Absorption Spectro-photometer (AASPM), Na^+, Ca^{2+} and K^+ by flame photometer (Jenway PFP7) and P by spectrophotometer. Water content (%) was determined from fresh and dry weight measurements of plants. Mineral nutrient content of plants was calculated from the ion concentration (meq per 100 g dry weight basis). Data were analyzed using MSTATC software and means were tested, using Tukey's standardized range test (SAS institute Inc., 1997) at 5% level of significance ($p<0.05$).

RESULTS AND DISCUSSION

Chemical analyses of the collected data were analyzed using MSTATC software. The results revealed that Na^+ and K^+ concentration in Beri were significantly increased with increase in salinity. Both plants showed burning and darkening of leaves at higher salinity levels (20 to 25 dSm^{-1}). The cause of this disorder was not identified. However, high concentration of Na^+ in the plants tissues may be toxic for the plant survival. For most plants, the presence of higher concentration of Na^+ limits growth and can severely depress acquisition of K^+ and Ca^{2+}. In this study, minimum Na^+ concentration (11.32 meq/100 g dry weight) was recorded in control while maximum was found in (158.4 meq/ 100 g dry weight) ECi-20 dSm^{-1} (Table 1). Browseable material Na^+ in Beri increased significantly as the salinity (ECi) increased from 1.0-10 dSm^{-1} (Table 1). While ion concentration in the shoots and roots of Beri were 50% less then browseable material at higher salinity levels as shown in Table 1. The Jaman was a weaker accumulator of Na^+ than the Beri. The relatively high concentration of Na^+ in the moderately saline irrigation water (ECi-10 dSm^{-1}) resulted in substantially higher Na^+ contents for these plants as compared to the control values.

Under saline condition, maintenance of adequate level of K^+ is essential for plants survival. Higher sodium contents in irrigation water not only interfere with K^+ uptake by the roots but also may disrupt the integrity of root membrane and alter the selectivity of root system K^+ over Na^+ (Grattean and Grieve, 1999). External K^+ concentration was constant in the study. As a result, K^+ concentration in the plants significantly decreased with increase in the salinity, as shown in Tables 1 and 2.

Calcium is an important component of plant nutrition and it plays a vital physiological role in the metabolism of plants. The imbalances of minerals in the substrate also

Table 1. Effect of root zone salinity on chemical composition of Beri.

Element	Plant parts	Control	ECi-5	ECi-10
	BM	501.35^{ns}	492.45^{ns}	458.82^{ns}
Tissue water	Shoot	292.86^{ns}	282.19^{ns}	276.09^{ns}
	Root	478.80^{ns}	567.56^{ns}	448.68^{ns}
	BM	11.32^{c}	41.10^{b}	72.05^{a}
Na^+	Shoot	17.50^{b}	37.92^{a}	41.44^{a}
	Root	23.05^{b}	48.56^{a}	50.56^{a}
	BM	68.31^{ns}	62.20^{ns}	52.56^{ns}
K^+	Shoot	34.08^{a}	23.35^{b}	21.85^{b}
	Root	39.15^{ns}	34.58^{ns}	32.70^{ns}
	BM	15.44^{ns}	12.73^{ns}	8.73^{ns}
Ca^{2+}	Shoot	5.81^{ns}	8.18^{ns}	8.73^{ns}
	Root	19.96^{a}	15.59^{ab}	11.70^{b}
	BM	21.2^{5a}	7.46^{b}	4.31^{b}
P	Shoot	1.58^{ns}	5.07^{ns}	7.76^{ns}
	Root	17.64^{ns}	17.92^{ns}	6.97^{ns}
	BM	2.25^{ns}	1.82^{ns}	1.28^{ns}
Fe^{2+}	Shoot	0.70^{ns}	5.30^{ns}	2.88^{ns}
	Root	6.93^{ns}	3.34^{ns}	2.06^{ns}
	BM	0.30^{ns}	0.22^{ns}	0.09^{ns}
Mn^{2+}	Shoot	0.05^{b}	0.398^{a}	0.23^{ab}
	Root	0.33^{ns}	0.25^{ns}	0.16^{ns}
	BM	0.12^{ns}	0.10^{ns}	0.11^{ns}
Cu^{2+}	Shoot	0.12^{ns}	0.12^{ns}	0.11^{ns}
	Root	0.13^{ns}	0.11^{ns}	0.11^{ns}

Within columns, means followed by different letter are significantly different at the 0.05 probability level according to Tukey's standardized range test.

adversely affect Ca^{2+} availability to plants (Lauchi, 1990; Gratten and Grieve, 1999). The Ca^{2+} concentration, which were adequate for plants growth under non-saline condition may be nutritionally inadequate and growth limiting factor under saline conditions. The Ca^{2+} status of the plant was strongly influenced by ions composition of the external medium, the presence of the other salinizing ions in the substrate may reduce the Ca^{2+} activity and availability to the plants (Saurez and Grieve, 1998; Willumsen et al., 1996). Excessive amount of Na^+ may displace the Ca^{2+} from its extracellular binding sites with plant organ to further disrupt Ca^{2+} acquisitions, uptake and transport. The Ca^{2+} concentrations in the root of Beri and shoot of Jaman were significantly decreased as salinity level increased from 1.0-15 dSm^{-1}.

The Ca^{2+} concentrations in other parts of the plants were found statistically non-significant. The influence of salinity on P accumulation in crop plants is variable and depends upon the plant and experimental conditions (Champagnol, 1979). In many cases, salinity decreased the P concentration in plant tissue (Sharpley et al., 1992); in others, salinity increased P or had no effect. It is not surprising that these differences among studies occur, since P concentrations vary widely in different experiments and other nutrient interactions could be occurring simultaneously. Analysis of data showed that, salinity also significantly decreased P in browseable material of Beri. The browseable material P concentrations in the Beri varied from (21.25 to 4.31 meq/100 g dry weight) basis as salinity increased from 1.0 to 15 dSm^{-1} (Table 1). Fe^{2+} acts as catalyst in the production of the chlorophyll. It is imperative in respiration, affecting the iron-porphyrin protein complex, which is a carrier of oxygen and activator of oxygen in the plants. Reports on the influence

Table 2. Effect of root zone salinity on chemical composition of Jaman.

Element	Plant parts	Control	ECi-5	ECi-10
Tissue water	BM	472.74^{ns}	548.77^{ns}	405.27^{ns}
	Shoot	198.20^{ns}	297.96^{ns}	275.77^{ns}
	Root	188.42^{ns}	211.78^{ns}	241.11^{ns}
Na^+	BM	29.55^{b}	45.42^{b}	79.32^{a}
	Shoot	11.85^{b}	29.25^{b}	55.50^{a}
	Root	8.60^{ns}	12.83^{ns}	23.40^{ns}
K^+	BM	13.13^{a}	7.54^{b}	11.10^{ab}
	Shoot	15.38^{a}	9.80^{b}	12.88^{ab}
	Root	10.63^{ns}	13.93^{ns}	14.95^{ns}
Ca^{2+}	BM	17.47^{ns}	15.50^{ns}	23.35^{ns}
	Shoot	23.45^{a}	4.45^{ab}	0.79^{b}
	Root	16.07^{ns}	15.35^{ns}	12.63^{ns}
P	BM	3.28^{ns}	7.98^{ns}	1.08^{ns}
	Shoot	23.46^{ns}	4.45^{ns}	0.80^{ns}
	Root	59.61^{ns}	4.62^{ns}	0.75^{ns}
Fe^{2+}	BM	2.83^{ns}	1.90^{ns}	1.90^{ns}
	Shoot	0.77^{ns}	3.47^{ns}	3.47^{ns}
	Root	3.55^{ns}	4.04^{ns}	4.04^{ns}
Mn^{2+}	BM	0.07^{ns}	0.04^{ns}	0.07^{ns}
	Shoot	0.02^{ns}	0.01^{ns}	0.03^{ns}
	Root	0.05^{ns}	0.05^{ns}	0.08^{ns}
Cu^{2+}	BM	0.12^{b}	0.12^{b}	0.14^{a}
	Shoot	0.13^{ab}	0.12^{b}	0.14^{a}
	Root	0.13^{ns}	0.13^{ns}	0.14^{ns}

Within columns, means followed by different letter are significantly different at the 0.05 probability level according to Tukey's standardized range test.

of salinity on the iron (Fe^{2+}) concentration in plants are as inconsistent as those that concern Zn^{2+} and Mn^{2+} concentration. Statistical analysis showed that the effect of salinity on the Fe^{2+} contents was non-significant (Table 1) in both the plants.

Although differences were found in the literature regarding the effect of salinity on shoot Mn^{2+} concentration in barley, the differences may be explained in part, by the composition of the salinizing salts (Suhayda, 1992). The irrigation with saline water significantly decreased the Mn^{2+} contents in the shoot of Beri while effect of salinity on the concentrations of Mn^{2+} in Jaman was found statistically non-significant (Table 2). The result of the study further indicated that, Cu^{2+} was found statistically non-significant in Beri. However, the most of Cu^{2+} were accumulated in the browseable material and shoot of the Jaman. The results obtained showed that, shoot growth of both plants progressively decreased with increase in the salinity levels of the root zone. However, this decrease was not of the same extent for both Beri and Jaman. Relative salt tolerance is often quantified as the salt level results in a 50% reduction in shoot growth (yield), on alternatively the threshold salinity level where plants show decline, followed by the rate of or slope yield reduction (Mass and Hoffman, 1977; Carrow and Duncan, 1998).

However, the different species behave differently with respect to their salt tolerance. The 50% reduction in dry weight of Beri and Jaman (as compared to control) were found at ECi level 11 and 10 dSm^{-1} respectively. Overall, plant growth and dry matter production was higher in Beri than in Jaman. The total dry matter production of the

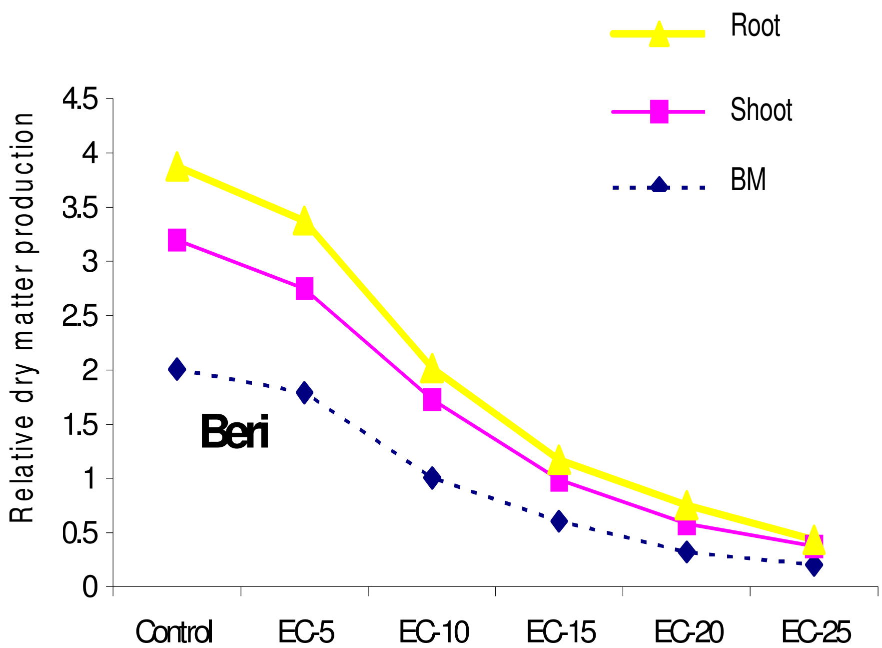

Figure 1. Relative dry matter production of browseable material, shoot and root as affected by salinity.

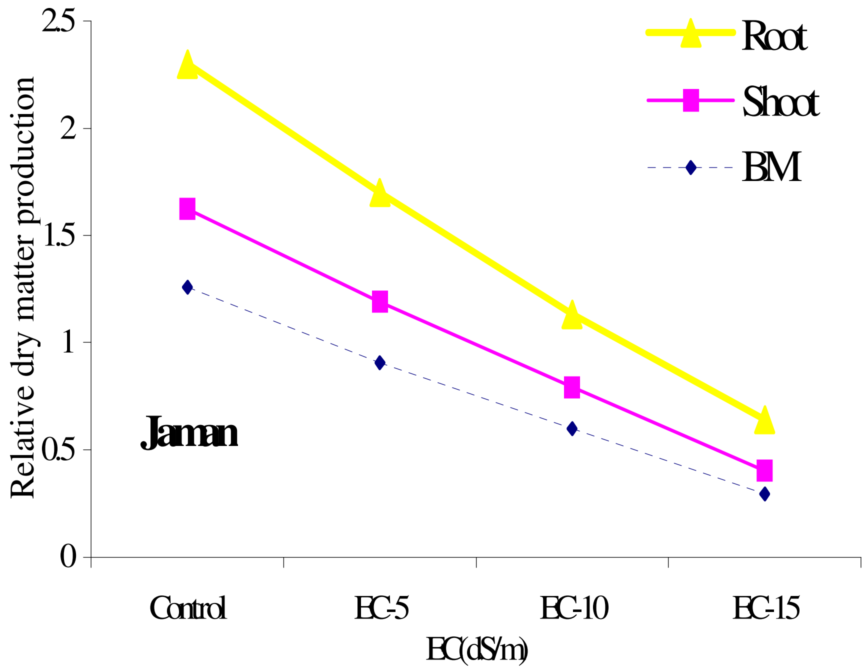

Figure 2. Relative dry matter production of browseable material, shoot and root as affected by salinity.

Jaman was approximately 72% of that of Beri. Another difference between Beri and Jaman was regarding the distribution of dry matter. The ratio between the roots and the total dry matter production was found approximately 0.2 for Beri and 0.3 for Jaman. Increases in the salinity affected the growth and dry matter production in both the plants. Figures 1 and 2 presents the relative dry matter production separately for browseable material, shoot and root against salinity, calculated as mean of four replications determined after 30 days of transplantation.

Table 3. Mineral ion concentration per 100 g dry weight of different salt tolerant plants grown on moderately saline soils. Published values are given for comparison.

Crop	Kallar grass	Lana	Kochea	Mesquite leaves	*Atriplex lentiformis*	*Atriplex amnicola*
Na^+	8.09	24.88	20.53	8.78	23.44	21.77
K^+	39.86	48.46	58.95	55.01	54.86	63.12
Ca^{2+}	15.11	22.20	21.25	41.31	32.13	29.24
P	6.81	8.20	7.42	8.52	8.52	6.32
Fe^{2+}	1.43	1.63	1.50	1.55	1.64	1.42
Mn^{2+}	0.57	0.33	0.029	0.014	0.021	0.010
Cu^{2+}	0.021	0.022	0.020	0.028	0.022	0.021

Source: Data from twenty years of NIAB.

Three parts of the plant showed almost similar growth reduction, however, the reduction of root growth being slightly more severe for both the plants.

Conclusion

Comparison with other salt tolerant species showed that both plants could be used for the browsing of the small animals (Table 3). The use of moderately saline irrigation waters for the production of leaf fodder appears to be a viable option for growers, in areas where the supplies of high quality water are not available. The crop yield can undoubtedly maximize under field conditions, by refinement in the culture and management practices. Such as use of gypsum and farmyard manure and by improving fertilization regime and timing.

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