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Response of Sodium Bicarbonate Sodicity on Survival, Seedling Growth and Plant Nutrients of Four Multipurpose Arid Trees

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Abstract : *Acacia nilotica* (L.) Willd. ex Del., *Albizzia lebbek*, *Pithecellobium dulce* and *Prosopis cineraria,* were grown in sodic soils of 20 to 100 ESP. Seedings did not survive above 45 ESP in *P. dulce*, 60 ESP in *A. nilotica* and *A. lebbek*, and 80 ESP in *P. juliflora*. Seedlings did not survive above 45 ESP in *P. juliflora*. In 5-month-old plants, plant height, biomass production and leaf area decreased, while the leaf thickness increased with rising level of sodicity. Plant nutrient concentration varied significantly ($P < 0.05$) among the species and sodicity levels. N, P, K, Ca and Mg decreased and Na concentration increased with increase in ESP. Maximum reduction in Ca and P concentration was observed in the leaves of *P. juliflora* and *A. nilotica*, and in roots and stems of the remaining two species. The higher content of Na in roots and lower content in leaves may be adaptive strategies of *A. nilotica* and *P. juliflora* to survive under high levels of sodicity. The results are useful for afforestation and management of sodic soils.

Key words : Multipurpose arid trees, sodicity levels, survival, growth, nutrient content.

Sodic soils are a serious problem in many parts of the world and it is estimated that about 7 million ha of cultivable land in India is affected by the salts (Abrol and Bhumbla, 1971). Reclamation of these soils is a costly process, and immediate solution is to grow sodic-tolerant plant species in such soils. Extensive studies are available on the effect of sodicity on agricultural crops (Chhabra *et al*., 1979; Singh *et al.*, 1981), and horticultural trees (Patil *et al.*, 1981; Singh *et al.*, 1983; Banuls *et al.*, 1990), very little is known about the multipurpose trees of arid climate.

The present study was carried out to assess the effect of different levels of sodicity (20 ESP to 100 ESP) on the survival and growth of four important multipurpose tree species growing abundantly in arid climate of India. These species are extensively used in energy plantations and agroforestry systems.

Materials and Methods

Seeds of *Acacia nilotica* (L.) Willd. ex Del., *Albizzia lebbek* (L.) Benth., *Pithecellobium dulce* (Roxb.) Benth. and *Prosopis juliflora* (SW.) DC were collected from the campus of Haryana Agricultural University, Hisar, India (29°10'N lat., 75°46'E long., 215 m alti.). They were sun-dried, surface sterilized with 0.1% $HgCl_2$ solution and stored. Seeds were sown in polythene bags (8 x 6 cm) containing normal soil. One-month-old seedlings of equal height were selected and transplanted into polythene bags (45 x 22 cm) containing soils of various sodicity.

Sodic soils were prepared by the method of Bhumbla *et al.* (1968). The soil (pH 7.7, ECe 0.35 mmhos/cm, organic carbon 0.82%) was passed through a 3 mm mesh screen and spread in a thin layer on a polythene sheet. A measured quantity of salts in solution form (Table 1) was sprayed on the soil to prepare sodicity levels of ESP 20 (pH 8.1) to ESP 100 (pH 10.5) (Bains and Fireman, 1964). The soil at field capacity, was mixed carefully with a spatula and covered with another polythene sheet to limit water evaporation. After one week the soil was thoroughly mixed and allowed to stand for further

Table 1. Quantity of sodium bicarbonate used to prepare soils of different sodicity

Sodicity (ESP)	Salt content (me/kg)	pH (1:2)	ECe (mmhos/cm)	Exchangeable Na (me/kg)
20	31	8.1	1.2	0.35
30	39	8.5	1.3	2.00
45	70	9.0	1.5	3.40
60	82	9.2	2.1	6.10
80	112	9.7	2.7	9.00
100	125	10.5	2.9	9.80

three weeks. Frequent mixing up of the soil speeded up the attainment of an equilibrium in moisture and salt distribution throughout the soil mass and also the attainment of the required sodicity levels. Soil sodicity was monitored by measuring the ESP by the method of Richards (1954) at four-day intervals until the required levels were obtained. The exact ESP of each sub-sample was checked before the seedlings were transplanted to the artificially prepared sodic soils.

Ten replicate seedlings of each species at each ESP level were arranged in a randomized block design with control seedlings transplanted in untreated soil. The plants were irrigated daily with tap water. During the test period the temperature of green house fluctuated on an average between 21°C and 32°C, which is considered near optimum.

Percentage seedling survival was calculated from observations of all the plants. Stem height, collar diameter (by verneer calliper), number of primary branches, number of leaves, leaf thickness (by screw gauge), leaf area (by planimeter), and root length, of five replicate surviving plants were determined after 150 days. These plants were uprooted, thoroughly washed in deionized water, separtated into stems, leaves and roots. They were oven dried at 65°C for 48 hours and powdered for chemical analysis.

Chemical analyses of plant samples were done following the standard procedure (Allen *et al.*, 1974). Na and K were analysed by the flame photometry, Ca and Mg by titrating with the EDTA, P by Vandomolybdo phosphoric colorimetric method, N was determined by micro-kjeldahl's method and chlorophyll by using the DMS method. The data were analysed statistically by analysis of variance (ANOVA).

Results

Growth of seedling

The seedlings showed 100% survival up to 45 ESP in *A. nilotica* and *P. juliflora* and to 30 ESP in the remaining two species. Seedlings did not survive above 45 ESP in *P. dulce*, 60 ESP in *A. nilotica* and *A. lebbek*, and 80 ESP in *P. juliflora* (Table 2). The growth of the plants differed signficantly ($P < 0.05$) among the species and ESP levels. Generally, the plant height, diameter and root length decreased with the increase of sodicity. However, no significant reduction in stem diameter was observed below 45 ESP in *A. nilotica* and *P. juliflora*. The number of branches and number of leaves/plant also varied significantly among species at different levels of sodicity. No branch was observed above 20 ESP in *A. lebbek*, 45 ESP in *A. nilotica* and *P. dulce* and 80 ESP in *P. juliflora* (Table 2). The leaf production occurred up to 45 ESP in *P. dulce* and *A. lebbek*, 60 ESP in *A. nilotica* and 80 ESP in *P juliflora.* The leaf thickness increased and leaf area decreased with the increase of soil ESP.

There was no significant reduction in root length in all the species except in *A. lebbek* up to 30 ESP. The shoot weight decreased 73 to 90% in all the species at 60 ESP (Table 3).

Table 2. Growth parameters of Acacia nilotica (AN), Prosopis juliflora (PJ), Pithecellobium dulce (PD) and Albizzia lebbek (AL) after 150 days in soils of different ESP levels, n = 15

Sodicity (ESP)	Species	Survival (%)	Height (cm)	Diameter (mm)	No. of leaves	Branches	Leaf thickness (cm)	Leaf area (cm^2)	Root length (cm^2)
Control	AN	100	92	7.1	102	13	0.10	937	66
	PJ	100	131	7.3	106	5	0.17	2393	69
	PD	100	89	6.8	52	5	0.13	274	58
	AL	100	60	5.2	20	4	0.11	140	38
20	AN	100	98	6.2	100	8	0.11	717	65
	PJ	100	120	7.0	120	4	0.16	2392	71
	PD	100	81	6.3	38	3	0.15	171	53
	AL	100	59	4.8	12	2	0.11	75	28
30	AN	100	74	5.9	95	6	0.10	508	40
	PJ	100	104	6.8	83	4	0.15	1650	52
	PD	100	52	5.0	25	2	0.14	103	29
	AL	100	49	4.4	3	0	0.13	22	19
45	AN	100	51	4.7	60	4	0.13	256	25
	PJ	100	93	6.1	79	3	0.18	1391	34
	PD	60	35	4.4	18	2	0.17	70	16
	AL	40	25	3.2	2	0	0.14	14	14
60	AN	60	20	2.6	11	0	0.14	63	16
	PJ	80	79	4.2	61	2	0.19	882	26
	PD	0	0	0	0	0	0.0	0	0
	AL	10	12	2.6	01	0	0.11	05	08
80	AN	0	0	0	0	0	0	0	0
	PJ	40	30	4.2	30	1	0.20	291	16
	AL	0	0	0	0	0	0	0	0
CD 5%	Species	2.4	5.5	0.06	3.17	3.2		4.5	2.98
	Sodicity	3.5	5.7	5.7	3.39	4.1		6.1	3.65
	Species x Sodicity	6.2	21.4	21.4	7.78	13.2		13.5	7.30

Nutrient content

The nutrient concentration varied signficantly ($P < 0.05$) among the species and ESP levels. Generally, the N, P, K, Ca and Mg concentrations decreased with the incrèase of sodicity, whereas, the Na concentration showed a reverse trend. The N concentration of stem increased up to 20 and 30 ESP in *A. nilotica* and *P. juliflora*, respectively, as compared to control but beyond 30 ESP the concentrations of N declined markedly. We do not know the reason for a slight increase in N at 20 and 30 ESP. The maximum reduction of P concentration was recorded in the leaves of *A. nilotica* and *P. juliflora*, and in the stems of the remaining two species. The reduction of Ca concentration was maximum in the leaves of *A. nilotica* and *P. juliflora*, and in the roots of the remaining two species. The reduction in Mg concentration with rise in ESP was maximum in the shoots of *A. lebbek* and in the roots of the remaining three species (Fig. 1).

Discussion

In the present study, *P. juliflora* and *A. nilotica* were more tolerant to high sodicity levels as compared to the remaining two species. Decrease of plant growth with the increase of sodicity was also observed for arid and semi-arid fruit tree species such as mango (Thakur *et al.*, 1981), *Ziziphus mauritiana* and *Psidium guajava* (Singh *et al.*, 1983). Kumar and Abrol (1979) reported that grasses are more tolerant to sodicity than crop plants. The reduction in growth and dry matter production may be due to change

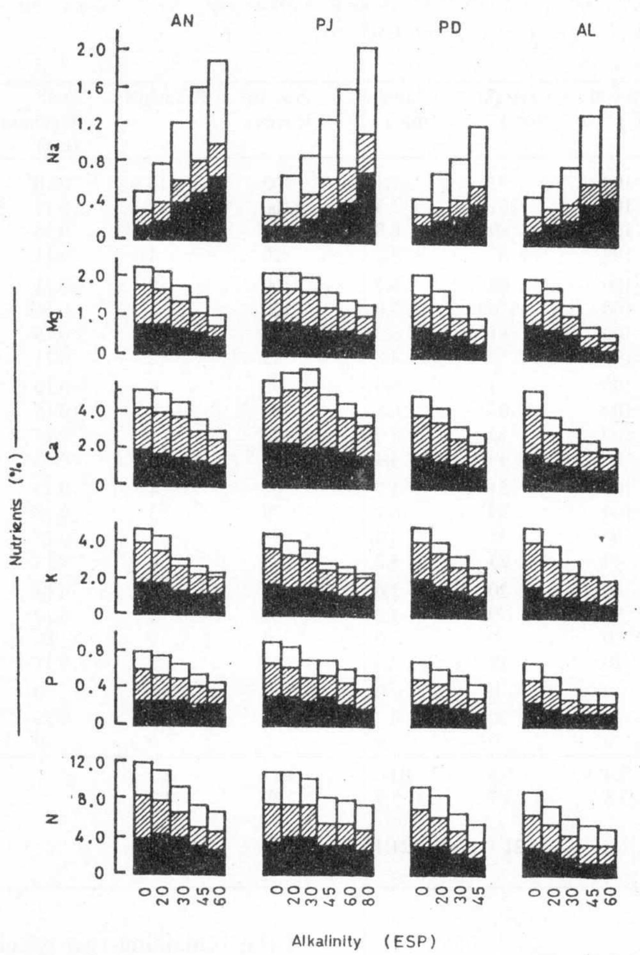

Fig. 1. *Nutrient concentration (%) of Prosopis juliflora (PJ), Acacia nilotica (AN), Albizzia lebbek (AL) and Pithecellobium dulce (PD) at different levels of sodicity. Solid bar, stems; Hatched bar, leaf; Hollow bar, root*

in soil physical properties, nutritional disorder related to high pH and impaired metabolism. The root growth was adversely affected at high sodicity which may be due to an accumulation of toxic ions or to decreased absorption of some essential nutrients and low permeability to air and water and dispersed coloidal structure of sodic soils.

Plants vary widely in their nutritional requirements and ability to absorb specific nutrients. They exclude or selectively absorb ions to regulate internal ionic movements. In the present study, under sodic conditions, plant accumulated comparatively higher Na^+ in the roots. This was due to a regulatory mechanism located within the roots which prevents translocation of excessive cations like Na^+ from roots to the aerial parts (Starck and Czajkowska, 1981; Banuls *et al.*, 1990), or due to high mobility of Na^+ in phloem (Al-Ani Tarique and Ouda Nazar, 1972). The higher content of Na^+ in roots may be an adaptive mechanism for osmotic adjustment and correspondingly less content of Na^+ toxicity under salt stress. With increase of sodium content in the plant, there is a decrease in the nitrogen,

Table 3. Dry weight of Acacia nilotica (AN), Prosopis juliflora (PJ), Pithecellobium dulce (PD) and Albizzia lebbek (AL) after 150 days growth in soils of different sodicity, n=15

Sodicity (ESP)	Species	Dry weight (g/plant) Stem	Leaves	Roots
Control	AN	11.6	2.5	6.7
	PJ	17.2	4.4	6.9
	PD	13.0	2.8	5.0
	AL	8.5	1.5	3.5
20	AN	12.0	2.6	3.3
	PJ	15.2	4.6	6.3
	PD	10.1	1.8	6.1
	AL	6.3	0.9	2.3
30	AN	7.5	2.3	3.0
	PJ	13.0	3.2	5.0
	PD	5.2	0.3	1.8
	AL	4.7	0.3	1.8
45	AN	3.8	1.8	2.7
	PJ	12.9	3.0	4.8
	PD	2.5	1.0	2.4
	AL	2.0	0.2	1.3
60	AN	2.0	0.3	0.4
	PJ	4.6	2.7	1.9
	PD	0	0	0
	AL	0.8	0.1	0.5
80	AN	0	0	0
	PJ	2.2	1.3	3.0
	AL	0	0	0

CD 5%
Species (Sp) = 0.92
Sodicity (Sd) = 1.12
Sp x Sd = 2.25

potassium, phosphorus, calcium and magnesium to such an extent that a deficiency was caused. Similar results were also reported by other workers (Patil *et al.*, 1981; Singh *et al.*, 1981, 1983). Singh (1973) reported that the reduction of P absorption under sodic conditions was due to shift of phosphate equilibria with the change of pH. The reduction in magnesium uptake resulted in the decrease of chlorophyll contents which also affected the growth of the plants.

Thus, it is concluded that *P. juliflora* and *A. nilotica* are more tolerant to the sodic soils. The sodicity not only causes ion imbalance in soil but also causes imbalance even in the plants. The findings of the present study are useful for the revegetation and development of sodic waste-lands.

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