Acacia nilotica: A tree species for amelioration of sodic soils in Central dry zone of Karnataka, India

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Abstract
Acacia nilotica is a leguminous tree species commonly found in interior Karnataka on sodic soils was evaluated for its potentiality to reclaim the sodic soil in Hosadurga taluk of Chitradurga district, Central dry zone of Karnataka,. The results indicated that *Acacia nilotica* plantation over a period of ten years had achieved a marked reduction in saturated extract pH throughout the soil profile and ECe to a depth of 30 cm. A good improvement in saturated extract Ca, Mg and K was noticed throughout the profile depth. However, sodium and anions were drastically reduced in the surface but accumulation of Na and carbonates were noticed at lower depth. Due to reduction in Na^+ and increase of Ca^{2+} and Mg^{2+}, the exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) were also declined in the soil profile. An appreciable improvement in organic carbon, CEC and available major nutrients status of sodic soil was noticed due to tree stand over a period of ten years. Root length and canopy width which are the most important traits for bio-reclamation of sodic soils showed significant and negative association with pHs and ESP while association with CEC was found significant and positive in a desirable direction.

Key words
Salt-affected soils, Bio-rejuvenation, Physico-chemical properties, Saturated extract properties, Growth parameters, Correlation

Introduction
India has a very low per capita land availability of about 0.3 ha and vast areas have lost their productivity due to soil salinity and alkalinity (Shukla and Misra 1993). Reclamation of salt-affected soils and other wastelands will reduce the pressure on the productive lands to fulfill the mouth of the growing population of our country. Therefore, it has become imperative to develop the marginal and sodic wastelands under productive land use system. Planting site-matched tree species in these areas exerts bio-ameliorative effects for their reclamation, in addition to providing forest cover, fuel wood, fodder, timber and preventing water loss through run-off and soil erosion besides improving the micro-climate of that area. Tree roots can act as potential tillage tools to improve soil permeability and release appreciable amount of CO_2 (Robbins, 1986a). This CO_2 solubilizes the soil lime resulting in the release of a reasonable quantity of soluble Ca^{2+} for replacing excess Na^+ present on the exchange complex (Robbins 1986b). The replaced Na^+ is removed either below the root zone or out of the soil profile due to leaching of salts. *Acacia nilotica* is a thorny leguminous tree grown in interior Karnataka, which grows well in water logged, saline, sodic and marginal lands. In this context, an attempt has been made to assess the potentiality of *Acacia nilotica* to reclaim sodic soils.

Methods
Experimental Site
The study area is located in the Hosadurga taluk of Chitradurga district, a part of Central dry zone of Karnataka, India. The soils of the study site are representative of large areas of sodic soils and have been classified as Chromic Halpustalf (Soil Survey Staff 1994). Karnataka State Forest Department, Hosadurga, established the *Acacia nilotica* plantation on sodic wasteland ten years back. The topography is undulating plateau with an average elevation of 800 - 900 m above sea level. The mean maximum monthly temperature ranges between 25.4^{0}C in January to a maximum of 36.4^{0}C in April. The mean monthly minimum temperature varies between 13.3 to 19.8^{0}C during the month of December with a relative humidity of 48.13 to 70.50 per cent. Mean annual rainfall of the area is 567.6 mm. Most of the rainfall occurs in the months of September and October.

Collection and Analysis of Soil Samples
A site supporting 10-year-old plantation of *Acacia nilotica* was selected, and four spots each of 10 m^2 in four

opposite directions were marked. In each spot, one soil profile was excavated at a distance of one meter away from the stem and one profile from nearby barren land was also excavated for the purpose of evaluating the changes undergone by soil due to *Acacia nilotica* plantation. Soil samples were collected from fixed depths of 0-15, 15-30, 30-60 and 60-90 cm from each profile. The soil samples, thus collected, were processed and analysed for their chemical composition like pH_s, EC_e, organic carbon, CEC, available nitrogen, phosphorus and potassium, saturated extract cations *viz.*, Ca^{2+}, Mg^{2+}, Na^+ and K^+ and anions *viz.*, CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} using standard procedures. The exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) were calculated using the methods given by Richards (1954).

Growth Parameters and Statistical Analysis

Stem diameter at stump height (DSH), stem diameter at breast height (DBH), number of branches per tree, canopy width, tree height, root length and roots weight were measured in all the selected sites using the procedures described by Misra (1968). In order to evaluate the bio-ameliorative effect of *Acacia nilotica* tree species on sodic soils, various tree growth parameters recorded were correlated with soil chemical parameters by simple correlation matrix for their significance both at 5 and 1 per cent levels by adopting the procedures outlined by Sundararaj *et al*. (1972).

Results

Effect on Soil Reaction (pHs) and Electrical Conductivity (ECe)

Active desodification was observed under *Acacia nilotica* plantation (Table 1). A remarkable reduction in pHs and ECe of saturated soil paste extract was observed after ten years of tree growth. Although pHs decreased more in the surface layer than at lower depths of soil profile under tree cover in comparison with barren site. However, it was declined at lower depth of study. Soil reaction (pHs) reduced from 9.2 (control) to 7.9 in the surface soil (0 - 15 cm) of *Acacia nilotica* plantation. The study showed that pHs < 8.5 was found throughout the profile depth studied under tree cover. This value is considered to be a threshold that separates the sodic soils from nonsodic soils (Soil Science Society of America, 1997). The greater decrease in pHs of the upper soil layer compared to lower layers in comparison with the barren site may be due to the replacement of Na^+ during Na^+-Ca^{2+} exchange and subsequent leaching (Qadir *et al*. 1996). Likewise, soil electrical conductivity (ECe) declined to an extent of 45 per cent in the surface soil (2.05 dS m^{-1}) from its initial barren soil value of 3.73 dS m^{-1}. This study also showed that the soluble salts leached down below 30 cm of soil profile. This was due to root penetration of tree plantation in the soil that provided channels for the percolating water.

Effect on Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio (SAR)

A remarkable decrease in ESP and SAR values at 0 - 15 cm soil depth after ten years of reclamation from their initial values of 50 to 27 and 32 to 11, respectively was recorded and the decrease was remarkable throughout the profile depth studied with respect to ESP whereas decrease of SAR values was upto a depth of 60 cm. This might be due to the production of CO_2 from decaying roots of tree plantation (Robbins 1986a) which solubilizes $CaCO_3$ present in the soil and releases soluble Ca^{2+} for the exchange reaction with Na^+ on clay complex (Robbins 1986b) and subsequent leaching due to root penetration of tree plantation in the soil that provided channels for the percolating water or Na^+ uptake by the plant roots (Qadir *et al*. 1997). After ten years of reclamation, SAR of the surface soil was <15%. This value separates sodic soil from nonsodic soils.

Effect on Saturated Extract Cations and Anions

The impact of *Acacia nilotica* plantation over ten years on the saturated soil paste extract of Ca^{2+}, Mg^{2+} and K^+ increased throughout the profile depth as compared to barren site and their concentrations were more in the surface soil and decreased with increase in depth of soil profile, whereas a reverse trend was observed with respect to Na^+ concentration in the soil profile. It was interesting to note that the Na^+ concentration decreased in the upper layers and increased in the lower layer probably due to leaching of soluble salts that became possible as a result of improvement in internal drainage consequent upon tree growth (Mishra *et al*. 2002) and accumulated at lower depth.

Carbonates, bicarbonates, chlorides and sulphates were drastically reduced to an extent of 40, 100, 64 and 47%, respectively in the surface soil as compared to nearby barren site. However, at lower depths, the accumulation of CO_3^{2-} was noticed due to *Acacia nilotica* plantation. The decreased anions level under tree cover over ten years was due to increased litter fall, organic carbon content of soil and tree roots activities which upon decomposition produce organic acids which favoured dissolution and translocation of HCO_3^- in soils. These results are in confirmation with the findings of Nadagouda (1996).

Effect on Organic Carbon status and Cation Exchange Capacity (CEC) of soil

The organic carbon content of soil was increased throughout the profile depth. However, the increase was more pronounced in the surface layer of soil profile. Nearly four-fold increase in organic carbon content of soil was observed in *Acacia nilotica* plantation after ten years of tree growth and it was increased from initial value of 0.60 to 2.29 per cent in the surface soil. The CEC of soil that was low in surface layer of barren site [43 cmol(p^+) kg^{-1}] increased to 55 cmol(p^+) kg^{-1} under tree cover over ten years of growth and it had a more impact on CEC of soil to a depth of 90 cm from the surface. The increased CEC due to *Acacia nilotica* plantation may be attributed to accumulation of organic matter and humus in the planted site over ten years of tree growth and this humus as organic colloid, play a major role in enhancing the CEC of the soil (Mishra 2002).

Effect on Available Major Nutrients

The available nitrogen, phosphorus and potassium content of soil were increased throughout the profile depth due to tree growth over ten years as compared to barren site. Available nitrogen content of soil was increased to an extent of 60 per cent from initial value of 280 to 447 kg ha^{-1} in the surface layer. This might be due to increased organic matter content of soil as a result of large quantities of leaf litter fall under tree cover (Yadav and Singh 1970). The available phosphorus and potassium content of soil were also increased from 4.3 to 17.0 kg P_2O_5 $ha^{-1}$and 228 to 273 kg K_2O ha^{-1}, respectively in the surface layer of the soil profile. The per cent increase in available phosphorus content of soil did not differ much with increasing depth of soil profile whereas the per cent increase in available potassium content of soil was more pronounced at lower depths of soil profile as a result of *Acacia nilotica* tree growth over a period of ten years.

Table 1. Impact of *Acacia nilotica* plantation on chemical properties of sodic soils (Mean of four profiles)

Depth (cm)	pHs	ECe (dS m^{-1})	OC (%)	Available major nutrients (kg ha^{-1})			CEC [cmol(p^+)kg^{-1}]	ESP
				N	P_2O_5	K_2O		
0-15	7.9 (9.2)	2.05 (3.73)	2.29 (0.60)	447 (280)	17.0 (4.3)	273 (228)	55 (43)	27 (50)
15-30	8.0 (8.9)	3.08 (4.16)	1.05 (0.53)	318 (145)	11.6 (3.2)	237 (141)	52 (40)	33 (51)
30-60	8.4 (9.2)	5.20 (5.07)	0.93 (0.40)	260 (123)	12.1 (3.2)	208 (129)	47 (37)	39 (55)
60-90	8.4 (8.8)	5.55 (3.55)	0.41 (0.29)	147 (85)	10.8 (3.2)	156 (66)	45 (33)	40 (60)

Table 1 Contd...

Saturated extract cations and anions (me L^{-1})								SAR
Ca^{2+}	Mg^{2+}	K^+	Na^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	
2.6 (1.9)	2.0 (1.3)	3.4 (3.0)	17.0 (40.8)	5.1 (8.4)	0.0 (5.0)	15.5 (43.0)	4.3 (8.1)	11 (32)
1.9 (1.6)	1.5 (1.1)	2.8 (2.3)	21.1 (33.3)	6.1 (6.7)	0.0 (5.8)	23.8 (37.5)	5.8 (9.0)	17 (29)
1.3 (0.9)	1.1 (0.6)	2.1 (1.9)	25.5 (26.1)	7.5 (6.0)	1.0 (3.5)	27.3 (30.1)	5.1 (6.7)	25 (30)
0.9 (0.5)	0.5 (0.2)	1.6 (1.1)	28.5 (20.8)	8.2 (7.5)	0.0 (2.8)	28.9 (30.0)	5.2 (5.7)	36 (35)

*Figures in parenthesis indicate the nearby barren land profile value

Correlation of Soil Characters with Growth Parameters of Acacia nilotica

All the growth parameters except root weight exhibited significant and negative correlation with pHs and ESP while correlation with CEC was found significant and positive in a desirable direction (Table 2). The two important traits *viz.*, root length and canopy width depicted significant and negative association with pHs (-0.7498 and -0.7291, respectively) and ESP (-0.8328 and -0.8163, respectively) while association with CEC was found significant and positive (0.7855 and 0.6808, respectively). However, root length further depicted significant and negative association with SAR (-0.6764) and Na (-0.5593) and root weight with ECe (-0.7313).

Table 2. Relationship between *Acacia nilotica* growth parameters and properties of sodic soil

Soil properties / Growth parameters	pHs	ECe	Na	CEC	SAR	ESP
DSH	- 0.7432**	- 0.0313	- 0.4761*	0.7093**	- 0.3656	- 0.8182**
DBH	- 0.7364**	- 0.0804	- 0.4818*	0.7159**	- 0.3780	- 0.8029**
No. of branches	- 0.7104**	- 0.1479	- 0.3937	0.6057**	- 0.2649	- 0.7946**
Canopy width	- 0.7291**	- 0.0112	- 0.4569*	0.6808**	- 0.3257	- 0.8163**

Tree height	- 0.7095**	- 0.0918	- 0.4924*	0.7171**	- 0.3833	- 0.7927**
Root length	- 0.7498**	- 0.2200	- 0.5593*	0.7855**	- 0.6764**	- 0.8328**
Root weight	- 0.1609	- 0.7313**	- 0.1099	0.0118	- 0.1626	- 0.1835

*Significant at P = 0.05 **Significant at P = 0.01

Conclusion

This can be concluded that *Acacia nilotica* tree species is able to rehabilitate the sodic soil and this tree species not only grows well in harsh sodic conditions but also can ameliorate the saturation extract properties. The pHs, ECe, ESP and SAR decreased whereas, the concentration of Ca^{2+} and Mg^{2+}, organic carbon content, CEC and available major nutrients status of soil increased in the soil profile, which clearly indicated its effectiveness in reclamation of sodic soils. The anions concentration decreased in the saturation extract of soil profile, which reveals favourable changes in the ionic composition of soil solution. Although *Acacia nilotica* reclaim the sodic soils effectively, yet a few more years are required for this tree species to bring the soil to normal level with respect to pHs, ECe, ESP and SAR. The overall growth of *Acacia nilotica* was hindered by soil pHs and ESP and improved by CEC of the soil.

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1 – 6 August 2010, Brisbane, Australia. Published on DVD.