CHAPTER III

PROBLEM SOILS AND THEIR AMELIORATION BY TREES

This chapter concentrates on the characterisation of some specific problem soils, the potential for amelioration of these soils by trees, and the extent to which it has been shown that trees can and do improve the fertility of these problem soils, thereby rendering them more agriculturally productive.

1. SOIL AMELIORATION PROBLEMS OF 'BRIS' SANDY SOIL IN PENINSULAR MALAYSIA

A. B. OTHMAN

Malaysian Agricultural Research and Development Institute, Malaysia

SUMMARY

1. Sandy 'Bris' soils are a problem soil on the sandy costal ridges of the eastern coast of Peninsular Malaysia.

2. They are regarded as 'problem' soils because of their low water and nutrient holding capacity.

3. Introduction of trees and crops could be a solution to this problem.

4. The soil requires a pretreatment before trees can be planted.

INTRODUCTION

Sandy beach deposits, locally termed as 'Bris' soils, have been categorised as problem soils. The soils described are developed on the sandy coastal ridges of the eastern coast of Peninsular Malaysia. Characterised by a sandy texture, these 'Bris' complexes occur as a narrow belt fringing the coastline varying in width between 200m and 6km from the coast. The total of 'Bris' soils in Malaysia is approximately 204,564 ha of which 16,464 ha. are found in Peninsular Malaysia (Wahab, 1982).

Lack of silt and clay in most of these soils render them very infertile in terms of plant nutrients. Additionally, their low water holding capacity results in extremely high irrigation costs for reasonable crop yields. Primarily for these reasons, agricultural planners have disregarded these soils for large scale agricultural development, and not much has been achieved in the improvement of the productivity of 'Bris' soils (Ibrahim, 1981).

Introduction of trees and crops that can be productive on 'Bris' soils seems one of the possible solutions to this long known problem of the 'Bris' area. This can be achieved by giving prime consideration to improving the agricultural technology in this area with specific emphasis on soil management techniques.

FORMATION OF SANDY DEPOSITS

The pattern of soils forming the 'Bris' complex indicates that the soils of beach ridges and swales are of recent age while on old beach ridges of subrecent age. They are formed by a northward longshore littoral drift, periodically influenced by heavy seas during the monsoon that is between August and December.

The soils developed on the 'Bris' complex range from Brown sands to Podsols with transitional groups showing varying degrees of podsolization. In Peninsular Malaysia the 'Bris' soils have the following sequence. Baging series

(Typic Quartzipsammant) of recent marine sand deposits in which there are few or no weatherable minerals, followed by Rusila series (Typic Tropquad), a soil occurring in depressional areas and typically possessing considerable amounts of organic matter at the soil surface; Rudua series (Typic Tropohumud), a ridge sloping soil, and Jambu series (Arenic Tropohumod), a ridge top soil are morphologically similar, but spodic horizons occur at different depths. Rudua has a spodic horizon occurring within 1 m while the Jambu occurs below 1 m.

THE AMELIORATION ASPECTS

The 'Bris' soils are characterised by brown sands. The mineral component is of essentially granular quartz grains. Particle size distribution indicates that the soil contains more than 90% of total sand.

Moisture content by weight for the 'Bris' soils showed that the range of available water in the surface soil is betwen 0.04 to 0.06 cm cm^{-1}, and this indicates that the soil has very low water storage capacity (Othman, 1985). During prolonged dry conditions, 'Bris' soils create a condition similar to that of the drought-prone semi-arid regions of the world, particularly during the months between January and April. This is because of the low water retaining capacity and extremely high infiltration rates. The resultant problems of 'Bris' soil are water holding capacity and nutrient holding capacity. In addition to these, the 'Bris' soils also experience very high soil temperatures and this inhibits germination and retards crop growth. Fortunately the area under the 'Bris' have adequate rainfall, particularly during the wet monsoon season during which some areas in the east coast are completely inundated.

The most important considerations in ameliorating the 'Bris' soils for agriculture are the selection of crops which tolerate the drought conditions in the area and the build up of organic matter content to increase water and nutrient holding capacities. Some of the promising crops that have been cultivated are coconut, cashew, tobacco, watermelon, cabbage, passion fruit, and pigeon pea. Nevertheless, very high fertilizer input and adequate water supply are needed to obtain decent crop yields. Since large doses of fertilizer are necessary for the development of these areas, these beach soils have very low agricultural potential where these are not economically feasible.

Large areas of coconut palm have been planted on these soils but even with liberal doses of fertilizers their performance has been invariably poor. Leguminous crops grown with the idea of improving nutrient status and alleviating the drought conditions periodically experienced in these soils have performed poorly. This is due to poor water retention. Phenomenal infiltration rates in these soil profiles cause fertilizers to be leached out.

To develop these areas there is a need to increase micropores for greater water retention and to increase nutrient holding capacity. This could be achieved by introducing organic manures, composts, and mulches into the system because they provide:

1. organic matter which, according to Wong (1985), not only increases the chemical activities in the 'Bris' soils, but also helps to develop more favourable soil physical conditions for the trees (e.g. cashew, Pilus et al 1982) to grow. Organic matter content also indirectly controls the cation exchange capacity of the 'Bris' soils and increases soil biological activities.

It also thought to have contributed to observed differences in cashew growth performances. It has been confirmed by Pilus et al, (1982) that the amount and quality of organic matter have significant effects on the height as well as the canopy surface area of the cashew tree.

2. plant nutrients, and

3. help to reduce soil temperature. As reported by Wahab (1983), the surface soil temperature recorded at 2:00 pm showed that the temperature under mulching was 6°C lower than that where there was no mulching. The water should also be retained longer in the root zone in the presence of organic materials.

The above factors are of importance but the choice of tree/crop, the economic value of the tree/crop, and the interaction of smaller volumes of soil with organic matter and mulches must be considered in conjunction with these factors. Especially with tree crops where only the volume of soil within a restricted area such as a hole (within the effective rooting volume of the crop) needs to be improved. Trying to completely change the environment and condition of the soil would be extremely difficult and expensive, but partial change might achieve significant results. By the interaction of limited volumes of sand/organic matter mixtures and mulching materials to modify the water retention and transmission properties of the soil within the soil profile, economic costing would be achieved.

The question of the possible practical implications on the use of soil conditioners may be of special relevance on the 'Bris' soil in Malaysia particularly with respect to tree planting. Experimentation and critical economic evaluation is necessary and hopefully a preliminary report on the progress of this work will be published soon. However, an integrated, multidisciplinary approach is necessary, if the potential of soil conditioners are to be exploited. Such factors as irrigation system, drought resistance in plants, economic value of the crop, agronomic techniques designed to conserve on fertilizer usage in conjunction with the improvement of structure must be considered.

ACKNOWLEDGEMENTS

The author would like to express his appreciation to The Director General of MARDI for the permission to publish the paper. Dr. Aminuddin Bin Yusoff for his comment on the content of the manuscript and Puan Zainun Bt. Md. Nor and Cik Norlezah Bt. Baharom for typing the manuscript.

REFERENCES

Ibrahim, T.A. 1981. A report on utilization of 'Bris' soils in Kelantan. Soils and analytical services division, Department of Agriculture Lundang, Kota Bharu. Kelantan. pp. 2-12.

Othman, A.B. 1985. A comparison of selected Entisols and Spodosols occuring in Peninsular Malaysia and Peninsular Florida. A dissertation presented to the graduate school of the University of Florida in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Pilus, M.Z., Othman Yaacob, Abdul Jabar Mohd Kamal, dan S. Paramanathan, 1982. Penentuan faktor-faktor tanah keatas tumbersaran gajus di-kawasan tanah 'Bris': Bahagian I. Pertanika 5 (2), 200 - 206.

Tamin, M.Y., Aminuddin B. Yusoff, and Tan Swee Lian. 1982. A special report on agricultural land use in Peninsular Malaysia p.13.

Wahab, A.N. 1982. Nota syarahan tana 'Bris' bagi kursus tanaman gajus anjuran MARDI yang diadakan di Sungai Baging. Cawangan Sains Tana Stesen MARDI Sg. Baging, Kuantan, Pahang, Malaysia.

Wahab, A.N. 1983. Lapuran ringkas kemajuan penyelidikan tanah 'Bris' submitted to Cawangan Sains Tana MARDI, Serdang, Selangor, Malaysia.

Wong, N.C. 1985. Nutritional studies on cashew, an Annual report submitted to Cawangan Sains Tanah, MARDI, Serdang, Selangor, Malaysia.

2. SALT AFFECTED SOILS AND THEIR AMELIORATION THROUGH AFFORESTATION

H.S. GILL AND I.P. ABROL

Central Soil Salinity Research Institute, Karnal-132001, India

SUMMARY

(1) The extent of the salt affected soils in India and salient characteristics of their broad categories are presented. Afforestation of these problematic soils is envisaged to be a promising land use.

(2) The successful establishment of selected tree plantations was achieved by a relatively easier and economical posthole technique compared to the usual methods of tree planting in an extremely alkali soil.

(3) Data on leaf litter production in a seven years old plantation of Acacia nilotica (L.) Willd. ex. Del. and Eucalyptus tereticornis Sm. grown on an alkali soil is presented.

(4) The ameliorative effect of the two plantations on the soil and micro-climate of a highly alkali soil at selected growth intervals is presented.

INTRODUCTION

Excess salts reduce the productivity of an estimated 7 million ha of the otherwise productive soils in India (Abrol and Bhumbla, 1971). Based on geographical distribution, salt affected soils can be grouped as (i) salt affected soils of the coastal regions, 2.1 million ha; (ii) inland saline soils of the arid and semi-arid regions, 2.5 million ha; and (iii) alkali soils of the sub-humid regions in the Indo-Gangetic plains, 2.5 million ha. Salt affected soils are broadly classified into two categories depending on the nature of salts exerting a dominant influence on the soil properties and plant growth. These are: (i) saline and (ii) alkali soils. While neutral soluble salts consisting of chlorides and sulphates of sodium, magnesium and calcium exert a dominating influence on plant growth in saline soils, presence of sodium carbonate in small to appreciable quantities is responsible for building up excessive exchangeable sodium percentage (ESP) and high pH which in turn have an adverse effect on soil physical properties and plant growth in alkali soils. Apart from the soil characteristics and climatic features, the optimum methods of utilizing salt affected soils of an area depend on the nature and amounts of salts and their distribution in the soil profile.

Utilization of salt affected soils for afforestation appears a promising land use because of the increasing pressure on good soils for food production, fast exhaustion of firewood and timber resources and the need for healthy maintenance of an agro-ecological system. Management of these soils for successful afforestation requires amelioration of the limited root zone for initial establishment and rapid early growth. Thus, a special site preparation treatment is generally a must because tree planting procedures followed for the normal or good soils do not hold good for inhospitable sites (Abrol and Sandhu, 1981, Gill and Abrol, 1986 and Gill, 1986). Only a few efforts have been made to afforest salt affected soils in the past (Yadav et al. 1972) and most of them were almost complete failures for want of scientifically evolved information. This poses a severe restriction on planning and planting operations. Therefore, field experiments were undertaken to work out a suitable technique for raising plantations of Acacia nilotica (L.) Willd. ex. Edl. and Eucalyptus tereticornis Sm. in highly alkali soils. Leaf litter production of the two plantations and their ameliorative effect on the soil and micro-climate were also estimated.

SITE AND METHODS

A highly alkali site was selected for field investigation at an altitude of about 235 m in the Central Soil Salinity Research Institute's experimental farm at Gudha (76° 56'N, 29° 29'E) in the Karnal district of Haryana state. Salient physico-chemical characteristics of the experimental farm are included in Table 1. Soil samples were analyzed following standard procedures outlined by Jackson (1967).

TABLE 1. Important physico-chemical characteristics of a highly alkali experimental site.

Soil	Soil profile horizon in cm					
property	0-15	16-27	28-46	47-87	88-139	140-200
pH[a]	10.5	10.2	10.1	10.0	10.0	9.9
EC[a](dSm^{-1})	3.98	1.76	1.04	1.12	0.96	0.62
Detritus (percent)	0.58	2.46	3.88	5.82	34.26	7.46
$CaCO_3$ Eq (%)	0.68	0.72	0.79	0.92	6.32	9.37
Sand (percent)	54	51	49	54	51	65
Silt (percent)	27	27	26	20	23	18
Clay (percent)	18	23	24	25	19	11
ESP[b]	96	97	98	96	92	72
Textural class	sil	sil	sil	CL	l	ls

a. Measured after occasional shaking soil: water suspension in a ratio of 1:2 for half an hour.

b. Exchangeable sodium percentage.

The selected site preparation techniques comprised planting of Eucalyptus tereticornis Sm. and Acacia nilotica (L.) Willd. ex. Del. in four differently dimensioned (dia. x depth) postholes and a pit dug out using soil augers and an assortment of spades and shovels respectively. Details of the dimensions of postholes and the pit and the quantity of amendments used for their refilling are given below:

Treatment	Dimensions (cm)	Volume $(cm)^3$	Gypsum (kg)	FYM (kg)
T_1	10 x 120	9425	3	4
T_2	10 x 180	14137	3	6
T_3	15 x 120	21206	3	8
T_4	15 x 180	31809	3	12
T_5 Pit	90 x 90	572555	12	24

Given amounts of amendments were mixed with the original highly alkali soil used for refilling of the postholes and pit.

About six month old saplings of the two species were planted on July 17, 1979. The experiment was laid out in a Randomized Block Design layout and replicated four times. Each replicate sized 6 m x 6 m represents four plants with a spacing between the rows and plants of 3 m. Nitrogen (urea) was applied at the rate of 20 and 10 g N $plant^{-1}$ on Aug. 4 and Nov. 26 of 1979 respectively. Plants were watered on the need-felt basis until a year past planting. Percent survival and selected growth parameters were monitored. Acacia trees were lopped off the undesired branches 16 and 42 months after planting. The biomass lopped as foliage and woody matter is expressed on an oven dry basis.

Litter production

Irrespective of site preparation techniques the average leaf litter produced in Acacia and Eucalyptus plantations during July-August, September-October, November-December, January-February, March-April and May-June between July, 1982 and April 1985 was estmated by collection of foliage shed in containers, 120 cm long and 60 cm wide, in numbers sufficient to represent all the possible locations within their canopies. Amounts are expressed on an oven dry basis.

Ameliorative Effect

The ameliorative effect of Acacia and Eucalyptus plantations was evaluated by analyzing the soil samples of the profile (0-5, 6-15, 16-30, 31-45 and 46-60 cm) for ph, EC and organic carbon content in September of 1982 and 1984 besides at the planting time in 1979. Average water infiltration was also measured appropriately.

Micro-climate Modification

During January 1982 to December 1984, the mean soil temperature at 5 and 20 cm depths and the mean air temperature (at 137 cm height from the ground surface) within the canopies of Eucalyptus and Acacia, and at similar locations on the neighbouring dummy bare land, was measured on 15th and 30th day of each month at 07:22 and 14:22 hours.

RESULTS AND DISCUSSION

Survival and Growth

The per cent survival and important growth parameters recorded 6 years after planting showed (Table 2) that the adopted methods of site preparation were equally good for the establishment of Acacia and Eucalyptus on a highly alkali soil. Average height of Eucalyptus and Acacia varied between 7.79 -9.20 m and 5.96 - 6.85 m respectively. Girth diameter at stump or 5 cm height (DSH) and at breast or 137 cm (DBH) height of Eucalyptus ranged between 13.4 to 16.5 cm and 8.9 to 11.5 cm respectively. Corresponding range of DSH and DBH for Acacia was 13.5 to 16.9 cm and 10.2 to 13.2 cm. Growth of both the species occurred at a rapid rate during the initial 2-3 years of planting. However growth was somewhat slow afterwards, particularly that of Eucalyptus. Acacia trees were noticed growing into a dense and lush green closed canopy whereas Eucalyptus exhibited limited growth of chlorotic looking foliage and widely open canopy even after 6 years of growth.

The results, thus, show that planting of the given two tree species in postholes with limited width but greater depth that were refilled with the original sodic soil mixed with limited quantities of amendments like gypsum and FYM, survived as well as in pits of comparatively large volume with high requirements for the amendments. This makes the posthole method of site preparation promising (Abrol and Sandhu, 1981; Gill and Abrol, 1986) because it is easier and more economical than the generally advocated (Pande, 1967; Yadav et al., 1972) pit technique. This new technique of site preparation also holds scope for mechanical adoption.

Biomass Yield on Lopping of Acacia

Crown growth of Acacia was profuse unlike that of Eucalyptus throughout the observed growth period. Thus, to effect a proper balance between the trunk and crown of trees for their desired growth, undesirable shoots on stems were lopped to one-third of the height of Acacia trees 16 and 42 months after planting. This yielded considerable woody matter and foliage (Table 3).

TABLE 2: Effect of site preparation methods on survival and growth of the given trees after 6 years of planting
(DSH = Girth diameter at stump of 5cm height)
(DBH= Girth diameter at breast of 137cm height)

Eucalyptus tereticornis Sm

Treatment	Per cent survival	Height (m)	DSH (cm)	DBH (cm)
T_1	100	7.79	13.4	8.9
T_2	100	8.29	15.1	10.4
T_3	94	7.89	14.3	9.7
T_4	100	8.46	15.8	10.9
T_5	94	9.20	16.5	11.5
Mean	98	8.33	15.0	10.3
LDS (0.05)	NS	NS	NS	NS

Acacia nilotica (L.) Willd. ex Del

Treatment	Per cent survival	Height (m)	DSH (cm)	DBH (cm)
T_1	100	5.96	13.5	10.2
T_2	100	6.39	14.4	11.1
T_3	100	6.47	14.5	11.1
T_4	100	6.47	15.9	12.4
T_5	100	6.85	16.9	13.2
Mean	100	6.43	15.0	11.6
LDS (0.05)	NS	NS	NS	NS

TABLE 3: Biomass (kg ha^{-1}) lopped from the tree bolls after 16(a) and 42(b) months of planting Acacia nilotica (L.) Willd. ex. Del.

	Woody matter			**Foliage**			**Foliage + woody matter**
Treatment	**a**	**b**	**a+b**	**a**	**b**	**a+b**	
T_1	1662	3644	5306	565	1356	1921	7227
T_2	1835	4427	6262	642	1681	2323	7943
T_3	1874	3360	5234	676	1396	2072	6630
T_4	2264	4333	6597	874	1698	2572	9169
T_5	3015	4061	7616	1012	1816	2828	10444
Mean	2130	4073	6203	754	1589	2343	8283
LSD (0.05)	756	NS	NS	106	NS	NS	NS

The average total biomass yield of foliage and woody matter varied between 1921 - 2828 kg ha^{-1} and 5306 - 7616 kg ha^{-1} respectively from these loppings. This suggests that in alkali areas, Acacia may be a promising species for producing woody matter and foliage worthy of firewood and forage respectively. Because of its greater resilience, proper management of the Acacia plantation may be regulated for biomass production shortly after planting. Foliage of Acacia was analysed to be a rich source of crude protein and woody matter having significantly more firewood value than that of Eucalyptus (Gill, 1986).

Litter Production

The Acacia plantation was noted to produce markedly more foliage litter than that of Eucalyptus. Litter production in the Acacia plantation increased regularly with growth years. But it was not observed to be so in the case of Eucalyptus. Bimonthly distribution of litter produced in a year indicates (Table 4) that the winter season (Nov. - Feb.) accounts for more than 40 and 50 per cent of the total for Acacia and Eucalyptus respectively. Higher litter production by the Acacia than the Eucalyptus plantation results from the greater aerial growth of the former species.

The concentration of N, P, S, K and Mg in the litter of Acacia was notably higher than that of Eucalyptus. But the opposite was the case for Ca and Na. Concentration of these nutrients in general declined with the successive growth years. However, chemical composition of the litter produced during the given bimonthly span of 1982 to 1984 did not vary significantly. Such observations were also reported by Ghose et al. (1982). However, the amount of litter production is expected to vary greatly with the species, stocking rate and canopy growth as well as with the edaphic factors.

TABLE 4: Average litter production (Kg ha^{-1}) during given time periods of 1982-1984 by the canopies of Eucalyptus tereticornis Sm and Acacia nilotica (L.) Willd. ex. Del.

Time period	Eucalyptus				Acacia			
	1982	1983	1984	Mean	1982	1983	1984	Mean
July - Aug.	148	152	132	144	252	465	552	423
Sept. - Oct.	165	178	184	176	218	326	386	310
Nov. - Dec.	252	234	262	249	924	1168	1494	1195
Jan. - Feb.	196	212	218	209	635	1096	1225	985
Mar. - April	152	166	180	166	292	378	516	370
May - June	114	132	126	124	216	416	678	462
Total	1027	1072	1102	1067	2537	3849	4851	3746
LSD (0.05)	122	111	136	124	346	208	414	285

Ameliorative Effect

The ameliorative effect of Acacia and Eucalyptus plantations on the soil properties was noted to be considerable. Both the soil pH and EC (Fig. 1) were found to be reduced. Reduction was more in the surface layer and it decreased with depth to almost negligible at 60 cm depth. The soil organic carbon content increased to about double the initial value with Eucalyptus. The increase was about three times under Acacia plantation. The effect of Acacia on the increase in soil organic matter content was notably more than that of Eucalyptus. However, both the species effected a similar change in the soil pH and EC. The greater increase in organic carbon of the soil under the Acacia plantation is ascribed to greater additions of litter to the soil. The water infiltration rates of the soil also (Fig. 2) improved with growth of Acacia and Eucalyptus plantations. These observations corroborate the findings of Vadiunina (1964).

Microclimate Modifications

The mean air temperature under the Acacia canopy was found to be lower by e to 5°C during summer and higher by 2 to 4°C during the winter than in the neighbouring open area. Similar observations were made in respect of the Eucalyptus canopy (Fig. 3) but the magnitude of the modifying effect was less than the canopy of Acacia. The influence of the two canopies on the thermal regime of the soil at 5 and 20 cm (Fig. 4) depths was also of the modifying type. Fluctuations were more marked for the soil temperature recorded at 5 than that at 20 cm depth in the open. Effect of tree plantations during the summer months was that of the blanketing type but it was of the sheltering type during the winter months. Tree plantation modified the thermal characteristics of the environment by their sheltering effect in cutting insolation and by their blanketing effect in restricting the outflow of heat thereby keeping the ground warmer during winter and cooler in the summer season.

Figure 1
Changes in pH, soluble salts (EC) and organic carbon content of a highly alkali soil under Eucalyptus (a) and Acacia (b) plantations.

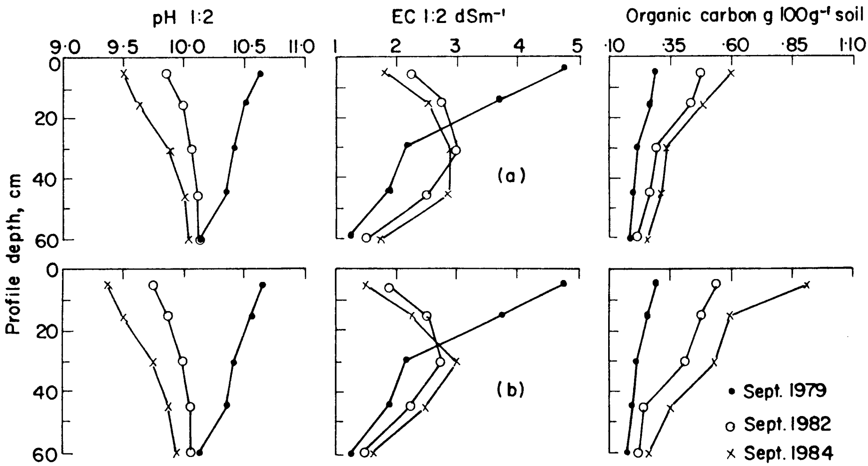


Figure 2
Effect of Eucalyptus (a) and Acacia (b) plantations on cumulative infiltration of a highly alkali soil.

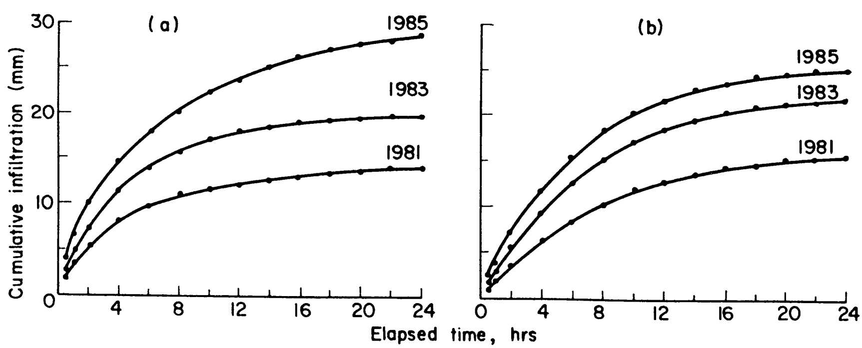


Figure 3
Changes in atmospheric temperature in the open (.) and in canopies of <u>Eucalyptus</u> (o) and <u>Acacia</u> (x)

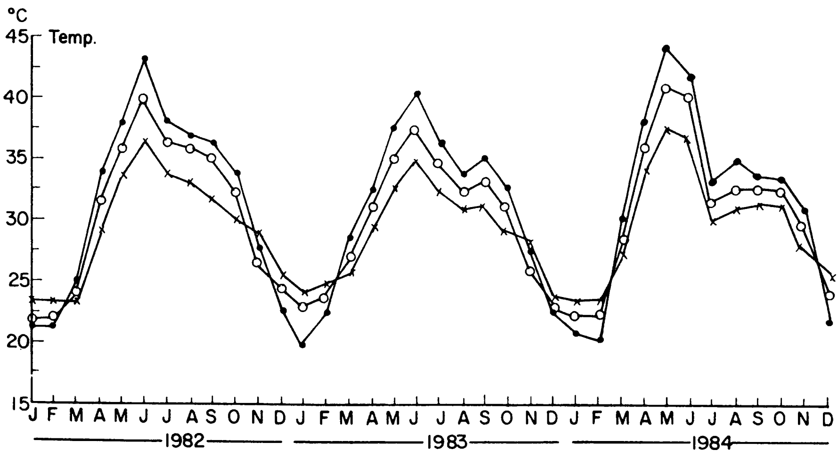
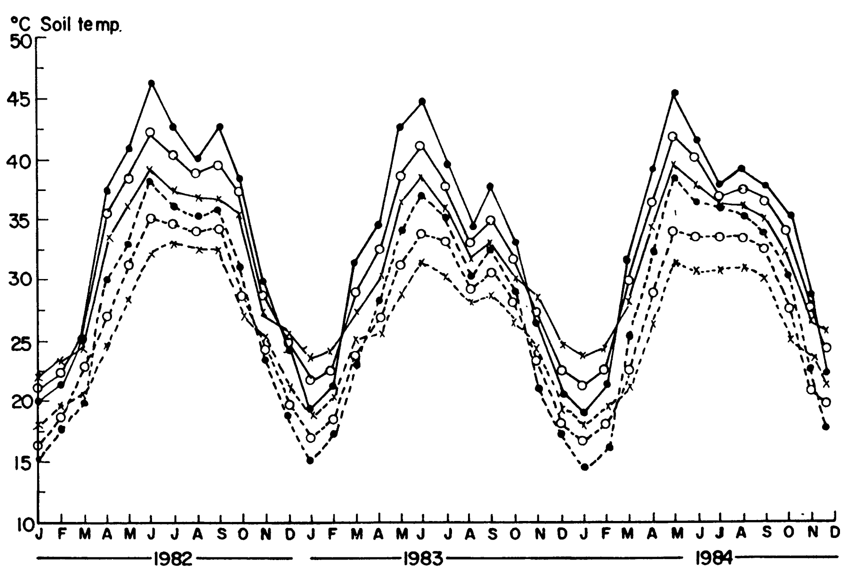


Figure 4
Changes in soil temperature at 5 (-) and 20 (...) cm depths in the open and in canopies of <u>Eucalyptus</u> (o) and <u>Acacia</u> (x).



CONCLUSIONS

The ameliorative effect on the soil of tree plantations is based on the penetration of strong roots, enrichment of the soil in humus and nutrient content through addition of organic substance from decomposed plant parts and on the improvement of N status of the soil through symbiotically fixed N in case of N fixing trees such as Acacia. Plantations also improve water intake rate of impermeable soils and thereby aid in the conservation of rain water which otherwise is lost as run-off.

REFERENCES

Abrol, I.P. and Bhumbla, D.R. (1971). Saline and alkali soils in India - their occurrence and management. World soil Resources Report No. 41, 42-51, FAO, Rome.

Abrol, I.P. and Sandhu, S.S. (1981). Growing trees in alkali soils. Indian Fmg. 30(6):19-20.

Gill, H.S. (1986). Studies on the evaluation of selected tree species for their tolerance to sodicity and mechanical impedance in a highly sodic soil with particular reference to root growth behaviour. Unpublished Ph.D. Dissertation, CSSRI, Karnal.

Gill, H.S. and Abrol, I.P. (1986). Grow Casuarina trees in sodic soils. Indian Fmg. 35(10):31-32.

Ghosh, R.C., Kaul, C.N. and Subba Rao, B.K. (1982). Environmental effects of forests in India. Indian Forest Bulleting No. 275, 20p., FRI, Dehra Dun.

Jackson, M.L. (1967). Soil Chemical Analysis. Asia Publishing House, New Delhi.

Pande, G.C. (1967). Afforestation of usar lands. Proceedings 11th All India Silvicultural Conference, FRI, Dehra Dun.

Vadiunina, A.I. (1964). Ameliorative effect of forest shelter belts on the soils of semi-desert. Proceedings 8th International Congress Soil Science 8, 955-960, Bucharest.

Yadav, J.S.P. (1980). Salt affected soils and their afforestation. Indian Forester 106, 259-272.

Yadav, J.S.P., Bhumbla, D.R. and Sharma, O.P. (1972). Performance of certain forest species on a saline sodic soil. Proceedings of Symposium on New Developments in the Field of Salt Affected Soils, pp. 683-690, International Society of Soil Science, Cairo.

3. UTILIZATION OF ALKALI SOILS IN THE PLAINS OF NORTHERN INDIA - A CASE STUDY

S.D. Khanduja,+ V. Chandra, G.S. Srivastava,
R.K. Jain, P.N. Misra and V.K. Garg

National Botanical Research Institute, Lucknow, India.

SUMMARY

(i) Investigations on the utilization of alkali soils without prior reclamation with chemical amendments conducted at Banthra Research Station for over 30 years are reviewed.

(2) Plants of agricultural, horticultural and silvicultural interest, and also for woody biomass production, which are adaptive to alkali soils have been identified.

(3) The ameliorative effect of tree canopy cover is reflected in reduced soil pH and exchangeable sodium, but increased organic carbon content. A pronounced increase in Ca/Na ratios under a dense canopy cover have been recorded.

(4) Changes in chemical characteristics of soil in the rooting zone are discernible after prolonged growth of trees and depend upon the amount and composition of litter fall.

INTRODUCTION

Soil degradation through salinization and alkalinization has become a major factor limiting crop production in many countries of the world. Amelioration and utilization of salt-affected soils have been the focus of research attention of agricultural scientists for over half a century. In alkali soils, chemical amendments such as gypsum, pyrites, sulphuric acid and sulphur have been used with varying degrees of success. It is being increasingly recognized that the use of chemical amendments is costly in labour and energy. More emphasis is, therefore, being placed on selecting and developing varieties of plants which are tolerant to soil alkalinity.

In India soil alkalinity is a major problem affecting nearly 7 million hectares of land (Abrol and Bhumbla 1971). The problem is more acute in the Gangetic plains of northern India. Investigations carried out at various research institutions in the country have shown the possible utilization of alkali soils for afforestation (Yadav 1980). This paper presents a review of the work on amelioration of alkali soils which have been carried out at the National Botanical Research Institute, Lucknow, for over 30 years since the establishment of a research station at Banthra in 1956.

+ Deceased, May 1986

CHARACTERISTICS OF THE SOIL

Data on physical and chemical characteristics of the soil at Banthra Research Station (Tables 1 & 2) show that the soil is silty loam to silty clay loan in texture. There is a hard impermeable pan of calcium carbonate at 50-75 cm depth (the 'kankar' zone). The carbonates are mainly in the form of gravel. Concretions other than the granules of lime are also noticed. Within the profile, pH goes on increasing and is maximum (10.2) in the vicinity of the 'kankar' zone. Organic carbon is uniformly low. Available phosphorus and potash increase with depth and are maximum in the middle zone. Exchangeable calcium is high on the surface and decreases with the depth of the profile. In contrast, exchangeable magnesium and sodium are low at the surface but increase with the depth. The cation exchange capacity of the surface soil is 12 me/100 g.

TABLE 1: Physical properties of soil profile at Banthra 1964.

Depth	Mechanical composition				Texture	W.H.C.
cm	Gravel	Sand	Silt %	Clay		%
0-20	7.4	43.4	30.0	26.0	Sl	34.02
20-56	12.6	33.4	30.0	36.6	Scl	38.85
56-78	7.2	29.4	28.0	42.6	Scl	37.27
78-110	8.9	23.4	36.0	40.6	Scl	38.42
110-152	14.7	39.7	26.0	Scl	32.90	

TABLE 2: Chemical characteristics of soil profile at Banthra 1964

Depth		TSS*	$CaCO_3$	OC	P_2O_5	K_2O	Ca	Mg	Na	CEC^+
cm	pH	(	%	)	(kg/ha)		(	me/100 g)		
0-20	9.6	0.14	0.82	0.19	14	312	16.2	1.0	9.26	12.6
20-56	10.2	0.22	1.03	0.08	29	280	11.8	4.2	15.26	12.3
57-78	10.2	0.20	0.57	0.10	30	640	5.6	12.4	15.52	14.1
78-110	9.6	0.11	0.50	0.11	32	600	5.8	7.2	11.16	15.1
110-152	9.1	0.08	0.28	0.11	11	380	6.4	9.2	4.36	14.2

* TSS = Total Soluble Solids/Salts
\+ CEC = Cation Exchange Capacity

QUALITY OF IRRIGATION WATER

Good quality irrigation water is essential for amelioration of alkali soils. At Banthra water from cavity tubewells sunk 30-35 metres deep had the following chemical composition (Table 3).

TABLE 3: Quality of irrigation water at Banthra.

Characteristics	Range
pH	7.4-7.9
EC mmhos/cm	610-1220
Cl me/l	0.30-0.80
SAR*	1.30-1.88
RSC*	0.27-4.89
SSP*	33.33-40.36

* SAR = Sodium Absorption Ratio
RSC = Residual Sodium Carbonate
SSP = Soluble Sodium Percentage

According to Bhumbla and Abrol (1972), waters having RSC of 5 me/l with EC less than 400 mmhos/cm are safe for irrigation.

BIOLOGICAL AMELIORATION

A distinctive feature of the experiment at Banthra was improvement of the soil through biological means using organic materials that were available in the vicinity of the farm. No chemical amendments were used.

AMELIORATION BY TREES

In a selected area of 2.5 hectares where amelioration by arboreal plant species was attempted, small bunds having a height of 25 cm were made to impound and regulate rain and irrigation water. On the bunds, trees such as Acacia nilotica, Albizia lebbek, Dalbergia sissoo and Derris indica, were grown by direct seed sowing. Between the bunds, tolerant shrubs such as Clerodendrum indicum, Ipomoea fistulosa, Jatropha gossypifolia, Sesbania aegyptiaca, Sesbania grandiflora, Leucaena glauca and Vitex negundo were grown.

For a number of species, beaking of hard pan was considered necessary. Pits to a depth of 1m were dug and refilled with soil taken from ditches, thin cinders (burnt coal from mills or railways), river sand and available organic matter.

Success in ameliorative afforestation of sodic, or for that matter salt-affected soils, depends on judicious selection of plant species. Alkali soils are characterized by patchiness though they have the common property of preponderance of sodium. In places, where the 'kankar' layer was exposed, Prosopis juliflora, Acacia nilotica, Acacia farnesiana, and Parkinsonia aculeata were found to grow successfully. In waterlogged areas Salix tetrasperma, Typha elephantina, Pandanus tectorius and Acorus calamus could be raised. Amongst shrubs, species such as Thevetia peruviana, Nerium indicum, Clerodendron inerme, Lawsonia inermis and Tecoma stans could be grown successfully.

TERRESTRIAL ECOSYSTEM

Today this 2.5- hectare piece of land, bereft of vegetation 30 years ago, is a thick forest supporting habitation to animals such as langoors, rabbits, birds and reptiles. it is an ecosystem that has been developed directly from halosere (barren alkali soil) through some induced successional stages by human interference.

The forest community is dominated by the following tree species: Acacia nilotica, Albizia procera, Dalbergia sissoo, Ficus benghalensis, Syszygium cumini and Terminalia arjuna. The middle storey consists of shrub species such as Cassia occidentalis, Ipomoea fistulosa and Lantana camara. The ground storey supports several grass species.

TABLE 4: Soil characteristics under canopy cover of trees in man-made forest at Banthra 1982.

Tree species	pH	EC micro mhos/cm	ESP* %	OC %
Open ground	10.2	792	73.4	0.39
Acacia nilotica	8.3	254	52.6	0.75
Albizia procera	7.9	233	43.1	0.90
Bauhinia variegata	8.4	378	47.3	0.90
Dalbergia sissoo	8.8	205	50.3	0.81
Ficus bengalensis	8.7	334	47.9	0.60
Syzygium cumini	8.3	182	45.0	0.84
Terminalia arjuna	8.5	353	52.7	0.90
F. bengalensis + S. cumini	8.0	276	44.7	0.90
T. arjuna + A. nilotica	8.1	242	43.1	0.81
A. nilotica + D. sissoo, S. cumini, F. bengalensis Phyllanthus emblica	7.2	633	42.3	1.17

*ESP = Exchangeable Sodium Percentage

The ameliorative effect of tree canopy cover on soil is evident from the data presented in Table 4. Among the individual tree species, the maximum reduction in soil pH was recorded under Albizia procera followed by Acacia nilotica and Syzygium cumin. The mixed canopy of five species was most effective in reducing soil pH. Electrical conductivity was also reduced under mixed canopy. However, on sodic soils, this parameter is of little significance. Maximum reduction in ESP was brought about under the canopy of Terminalia arjuna and Syzygium cumini. Organic carbon content in the 0-30 cm layer increased from 0.39 to 0.90 per cent. As the changes were more pronounced in 0-30 cm layer, the data on varous characteristics of soil at this depth are presented (Verma et al. 1982). Maximum numbers of annual species grew under the canopy of Albizia procera followed by that of Acacia nilotica. In the open area with no tree cover, a few annual species were found to grow. Variation in the ameliorative effect of different tree species may be attributed to differences in the amount of litter fall and leaf composition.

A concurrent study of soil characteristics in the rooting zone of 10-year old trees of Acacia nilotica var cupressiformis, Bauhinia diphylla, Callistemon phoeniceus, Derris indica and Terminalia arjuna showed that pH in the 0-15 cm layer ranged from 9.1 to 9.6 and at 15-45 cm depth from 9.6 to 9.8. Variations in soil exchangeable cations were not reflected in leaf composition (Garg and Khandjun, 1979). It has been shown by Yadav and Singh (1970) that Acacia nilotica was able to grow well on moderately calcareous soils with pH 9.0. Derris indica and Terminalia arjuna were found to grow satisfactorily on soils with a pH up to 9.8 and soluble salts up to 0.45 per cent. The species included in our study seem to tolerate high levels of soil sodicity.

In another study of interaction of four fruit tree species, Emblica officinalis, Psidium guajava, Mangifera indica and Ziziphus jujuba, with the soil on which they had been growing for over 15 years, it was observed that soil pH was decreased in the 0-15 cm layer. Psidium guajava recorded the lowest pH 8.6 at 15-45 cm and 45-75 cm depths. Organic carbon concentration was increased under the canopy of all the four species with Ziziphus jujuba showing the maximum accumulation of 0.40 per cent. Exchangeable sodium decreased, but potassium increased in the 0-15 cm layer under all the species. Ziziphus jujuba showed the maximum reduction in exchangeable sodium. The increase in calcium content was noticed in the 15-45 cm layer.

These studies show that tree species exert a varied influence on chemical characteristics of the soil under their canopies.

Based on empirical observations on the performance of various tree species on sodic soils of Banthra for over 25 years, a statistically designed experiment to evaluate biomass productivity of twelve selected three species was laid out in 1981. The chemical characteristics of the soil at various depths of the profile excavated at the beginning of the experiment, and of the rooting zone of Prosopis juliflora three years after their establishment, are given in Table 5. the data show that pH in 0-3 cm layer is reduced, organic carbon and Ca+Mg content are increased. A similar trend was discernible under Terminalia arjuna and Acacia nilotica. Ameliorative effects of Prosopis juliflora on the soil have been reported by Yadav and Singh (1970) who observed a decrease in pH soluble salts in the upper 15 cm layer. Recently Rao and Ghai (1985) have reported a reduction in pH and an improvement in organic carbon of soil under tree cover.

TABLE 5: Chemical properties of soil in the rooting zone of Prosopis juliflora three years after planting.

Profile depth cm	pH	EC mmhos/cm	OC %	Na (	K me/100g	Ca+Mg)
Original soil (1981)						
0-15	8.75	.430	0.30	5.67	0.60	16.75
15-45	9.20	.495	0.18	8.64	0.52	14.49
45-75	9.95	1.500	0.51	12.28	0.76	14.37
Three years after (1984)						
0-3	8.21	0.47	0.57	1.30	0.62	37.67
3-15	8.98	0.50	0.29	2.64	0.55	36.83
15-30	8.93	0.54	0.18	5.14	0.53	28.17
30-45	8.94	0.44	0.14	5.25	0.50	29.34

In another experiment with four species of shrubs planted at densities of 25000, 50000 and 75000 plants/ha, an appreciable fall in pH and increase in organic carbon content of soil was recorded as a consequence of plant growth. The most significant change in soil was increase in Ca/Na ratio under all the four species, in particular Sesbania aegyptiaca at density of 75000 plants/ha (see Table 6). This could be due to increased solubility of the calcium existing in immobile state in the alkali soil.

TABLE 6: Chemical characteristics of soil under canopy cover of Sesbania aegyptiaca in high density plantation.

Planting density plants/ ha	Soil depth cm	pH	EC mmhos/cm	OC %	Mg (	Ca me/litre	Na)	Ca/Na ratio
25000	0-15	9.46	0.74	0.34	61.68	239.52	133.48	1.79
	15-30	9.70	0.85	0.26	37.00	149.70	141.74	1.05
50000	0-15	9.79	0.81	0.22	69.90	157.18	94.35	1.66
	15-30	9.80	0.92	0.12	65.79	97.30	142.17	0.56
75000	0-15	9.31	0.55	0.38	26.31	146.70	54.35	2.70
	15-30	9.65	0.82	0.12	23.02	84.33	130.43	0.64

CONCLUSION

This review brings out the possibility of utilizing alkali soils without prior reclamation by planting tree species which are tolerant of soil alkalinity. Success in afforestation of alkali soils will depend upon judicious selection of plant species and proper soil management practices keeping in view the heterogeneous microrelief of the soil. Species with rapid juvenile growth and aggressive root systems that are able to grow successfully on alkali soils have been identified.

The ameliorative effects of tree cover on the soil are reflected in reduced pH and increased organic carbon content, and differ with the tree species depending upon the amount of litter fall and its chemical composition. In densely planted stands, improvement in soil composition is rapid and more pronounced in the surface layer.

REFERENCES

Abrol, I.P. and Bhumbla, D.R. (1971). Saline and alkali soils in India - their occurrence and management. World Soil Resources FAO Report 41: 42-51.

Bhumbla, D.R. and Abrol, I.P. (1972). Is your water suitable for irrigation? Ind. Fmg. 32: 15-17.

Garg, V.K. and Khanduja, S.D. (1979). Mineral composition of leaves of some forest trees grown on alkali soils. Ind. Forester. 105(10): 741-745.

Rao, D.L.N. and Ghai, S.K. (1985). Urease and dehydrogenase activity of alkali and reclaimed soils. Ans. J. Soil Res. 23: 661-665.

Verma, S.C., Jain, R.K., Rao, M.V., Misra, P.n. and Murty, A.S. (1982). Influence of canopy on soil composition of man-made forest in alkali soil of Banthra (Lucknow). Ind. Forester. 108(6): 431-437.

Yadav, J.S.P. and Singh, K. (1970). Tolerance of certain forest species to varying degres of salinity and alkalinity. Ind. Forester. 96: 587-599.

Yadav, J.S.P. (1980). Salt-affected soils and their afforestation. Ind. Forester. 106 (4): 259-272.

4. RECLAMATION OF MINE WASTELAND BY TREES

M.N. JHA

Forest Research Institute, New Forest, Dehra Dun, India

SUMMARY

Reclamation of mine wasteland by tree plantation is essential for recovery of land, from both an environmental and an economic perspective. In India, a country rich in mineral resources, such reclamation of mine wasteland will be necessary due to a substantial increase in mineral exploration. The problem of reclamation would be most acute in Bihar and Madhya Pradesh which are rich in minerals.

The successful reclamation of such lands through plantation of trees has been achieved in Amarkantak (Madhya Pradesh), and this is described.

INTRODUCTION

In the process of mining, the natural and organised sequence of the soil and other biological forms, is destroyed. The exploitation of the land for minerals leaves behind dumped mine wastes or spoils. This is the area which must be reclaimed through biological means. In this presentation, reclamation of mine wasteland by trees has been discussed through a case study.

MINERAL EXPLOITATION IN INDIA

India is well endowed with natural resources. The exploitation of these resources is increasing. The production figures of some recent years is an illustration of this fact. (Table 1).

TABLE 1: Total Value of Mineral Production in Recent Years

Year	Value (in million rupees)
1979	17,420
1981	34,320
1982	48,750

It is important to note that this total production of Rs.48,750 million is mainly composed of mineral fuels such as coal, lignite, petroleum and natural gas. The value and proportion (of total production) of different minerals is described in Table 2.

TABLE 2: Production and % of Total Production of different Minerals

Mineral	Production (in million rupees) (1982)	% of Total Production
Coal, Lignite, Petroleum and Natural Gas	44,220	87.51*
Metallic Minerals	2,780	5.5
Non-metallic Minerals	1,747	3.46
Other Minerals	1,786	3.53

*solid fuel-41.23%, liquid fuel-44.19%, gas-2.09%

Such figures, however, do not illustrate the extent to which exploration results in regions of mine waste. A knowledge concerning the nature of mineral deposits and what mining techniques are to be employed, would provide a good starting point for determining the dimensions of the problem of resulting mine wastes. According to one estimate, the mine waste dumped annually the world over is about 3,000 billion tonnes. The area of land concurrently disturbed by mining approximates 386,000 ha per year and in the last quarter of the century, areas of mine waste amounted to 24 million ha. This is about 0.2% of the earth's surface. The working group on the environment (1981) has listed 20 minerals, whose mining could cause serious problems which would require immediate attention.

FEATURES OF MINE WASTES

These lands can vary from steep slopes to mild undulations (if machines have been used for levelling). They are generally arid and barren with surface material ranging from boulders and stones or loose sand to sticky clay with impeded drainage. A major feature of mine wastes is that they are formed from disorganised material. Thus, the rooting medium can vary greatly. There may be waterlogging, toxic elements and gases which the roots may have to withstand. Planting of these areas with suitable tolerant species is the most suitable way to reclaim the land. Plants have a unique capacity to improve the landscape and at the same time offer economic benefits. However, if they are not revegetated, neglected mine wastes not only ruin the immediate environment but also eventually erode. This results in pollution and silting of water supplies thereby degrading the economic and aesthetic value of the area.

Rehabilitation of mine wastes is a slow and expensive process. In many situations, therefore, it is suggested that reclamation work proceed concurrently with the mining.

RECLAMATION OF MINE WASTE - A CASE STUDY

The effectiveness of reclamation through the use of trees has been shown recently in Amarkantak in the state of Madhya Pradesh (M.P.). This case study is briefly discussed.

Location

Bauxite ores are an important source of aluminium in India. India's total reserve of bauxite is 3,489 million tonnes (1980). M.P. has deposits in as many as five districts. The state has about 100 million tonnes of bauxite reserve. The bauxite is mined in Amarkantak which falls in sal zone and in a catchment area of important rivers such as the Sone, Mahanadi and Ganga. The work was carried out in Ratti Dadar, Nanhu Dadar and Khurkhuri Dadar. BALCO, a public company, is mining the metal in this area. Natural vegetation in the area consists of *Shorea robusta*, *Terminalia tomentosa*, *Pterocarpus marsupium* and *Anogoissus latifolia*.

Mineral

Bauxite is associated with laterites in India. A mixture of ferric hydroxide, aluminium hydroxide and silica in various proportions is termed true laterite. If it contains greater than 50% Al, it is termed bauxite. It is found in the form of colloidal hydrogels, with variable amounts of combined water. Impurities such as silica (as clay mineral or quartz), iron, titanium, lime, magnesium and manganese may also be present. It is a dirty white, light grey, cream pink or reddish brown rock, which may be amorphous, compact, earthy, granular or porous.

Mining

BALCO has mined about 200 ha through the use of heavy machinery for felling trees, shovelling, digging and scraping etc. Top soil is removed along with overburden of laterite and bauxite and dumped on the escarpment. The company only fills up the pits which are 8 to 10m deep. The surface is full of boulders and bauxite rejects.

Plantation of Forest Species

After levelling the site by bulldozing, pits of $45cm^3$ were dug up at 2m x 2m spacing and used for planting different species. Soil from nearby sal forest was imported to fill up the pits, along with additional compost. Some properties of mine wastes are shown in Table 4.

TABLE 4: Some Properties of the Mine Waste

Boulder Area Depth cm	pH	Organic Matter %	*N kg ha^{-1}	*P kg ha^{-1}	*K kg ha^{-1}
0-25	5.50	1.54	380	6.3	840
25-90	6.75	0.82	313	2.7	280
90-180	6.40	0.38	168	0.9	224
180-300	6.30	0.26	90	0.9	112

* average content

The rooting medium for seedlings was essentially the good soil which was initially present in the area. However, the roots beyond the pit faced deficient soil phosphorous although the material was reasonably supplied with nitrogen and potassium. Surface pH was acidic and solubilized Al and associated ions were present in the medium. Some nitrogen could have been left over in the mine waste through unexploded ammonium nitrate (explosive was used in these mines).

Performance of Tree Species

Ten tree species were planted in 1979 in six blocks. The height of the plants and the survival of the species were noted in 1980 to 1985 as per Table 5.

TABLE 5: Performance of different species planted on the mine waste

Species	Year							
	1980		1981		1982		1983	
	ht (cm)	Survival (%)	ht (cm)	Survival (%)	ht (cm)	Survival (%)	ht (cm)	Survival (%)
Moringa Spp				FAILED				
Acacia auriculiformis	101	90	211	87	343	87	412	87
Eucaluptus camaldulensis	352	93	770	93	1365	93	1678	93
Melaleuca leucadendron				FAILED				
Pinus caribae	135	91	234	91	298	91	335	91
Pinus roxburghii	56	97	111	96	177	95	209	95
Grevillea robusta	163	98	250	97	338	96	388	96
Shorea robusta	48	92	77	90	110	90	122	90
Grevillea pteridifolia	220	96	501	94	658	94	728	94
Pongamia pinnata	43	88	94	83	156	83	180	83

The Melaleuca species, which is an exotic, could not survive due to its moisture requirements and biotic interference. The other plant species continue to survive even after 7 years. Two species, Shorea robusta (Sal) and Pongamia pinnata (Karanj), are indigenous varieties, while the remaining species are being tried in the Australian bauxite mines with great success. Of the various species tried, Grevillea pterdifolia, has been contributing maximum litter to the soil surface followed by Eucalyptus and Pinus caribaea.

Suggestions

In order to ensure that reclamation is successful, various factors must be taken into consideration. Before afforestation of mine wastes, the lands must be stabilized by erosion control measures which include grading of steep slopes, partial resurfacing with fertile soil and mulching and spreading of slash. The technique of amelioration varies widely depending on the composition of the regolith or the mine waste, and afforestation must be preceded by careful physical and chemical analysis of the debris. Special attention should be given to the texture of the exposed substratum, its permeability to air and water, aeration at field capacity, content of carbonates, supply of available mineral nutrient elements, electrical conductance and presence of toxic substances. Because of the deficiency of organic matter in the soil, wide use of tree and shrub legumes should be made. The depressions where water collects may also be utilized by planting suitable tree species.

Wastes deficient in nutrients may require the application of fertilizers for the successful establishment of plants species. There may even be a necessity to chemically correct extreme toxicity. Plants may also require protection from disease, pests, biotic interference and frosts.

Clearly, the scope is wide for amelioration of mine waste by trees.

REFERENCES

1. Chaturvedi, J.K. Afforestation of Bausite Mined Area in Central India. Ind. For. 100;458-465 (1983).

2. Kothari's Economic and Industrial Guide of India-Minerals and Metals. pp. 5, (1981).

3. The Times of India Year Book, pp. 58 (1984).

4. The Wealth of India-Raw Material. Vol 1:161 (1948).