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Growth and Nutrient Uptake of Different Trees in Mine Spoils

A.V. Rao and Richa Tak
Central Arid Zone Research Institute, Jodhpur 342 003, India

Abstract: A pot experiment was conducted to compare the growth of different trees, their rhizosphere effect and nutrient uptake in gypsum and limestone mine spoils in relation to those of normal soil. Plant height and dry weight of shoots of different tree species were significantly reduced on an average by 44% and 36% respectively when grown in gypsum and limestone mine spoils compared to those in normal soil. Gypsum mine spoils supported better growth than that of limestone mine spoils. Though the activities of various enzymes and the population of nitrifying bacteria were low in the rhizosphere of different plant species in both mine spoils, the rhizosphere effect was significantly high in mine spoils compared to that of normal soil. The population of *Nitrosomonas* in the rhizosphere of *A. indica* was less by 53% in gypsum mine spoils and 61% in limestone mine spoils. The root infection by AM-fungi and density of viable AMF spores varied among different plant species. Plants grown in gypsum and limestone mine spoils contained significantly lower concentrations of N, P, and Zn while the concentrations of Ca and Mg were significantly higher compared to those of normal soil indicating the deficiency/excess of different elements in these mine spoils. Introduction of different trees on mine spoils enhanced the development of active and diverse microbial community that help in stabilizing the mine spoils.

Key words: Gypsum mine spoils, limestone mine spoils, rhizosphere effect, nutrient uptake, AM fungi, enzyme activities.

Derelict lands with no biological productivity are the consequences of land surface disturbances caused by over-exploitation of natural resources as well as mining of minerals. The concept of sustainable development envisages the resource utilization and the ecological restoration of disturbed ecosystems. Rehabilitation of mine spoils has achieved considerable attention in recent years due to acceleration of mining and associated land disturbances. The reclamation of disturbed lands is necessary for stabilizing the spoil material, returning the land to a level of productivity equal to or greater than existed before mining and improving the aesthetic value of the area so that it will blend into the surrounding landscape and minimise pollution (Power and Barnhisel, 1977). Biological reclamation is one of the approaches adopted/suggested for ecological restoration of derelict lands including mine spoils. The most critical processes involved in the development of better ecosystem are colonization of appropriate species, accumulation of nutrients in plants as well as in soils, changes in soil structure/properties due to plant introduction and reduction in level of excess elements (Babu *et al.*, 1990). Day and Ludeke (1978) reported the establishment of vegetation on newly graded copper mine waste slopes as the most economical method of controlling erosion and providing long term stability. In this paper an attempt has been made to compare the growth of different tree species, their nutrient uptake and the rhizosphere activity in the gypsum and limestone mine spoils in relation to that of normal soil in order to identify better tree species for rehabilitation programmes.

Materials and Methods

Gypsum over-burden (a sandy loam containing 87.9% sand and 12.1% clay + silt + gypsum with 34% WHC) and limestone over-burden (a sandy loam containing 94% sand and 6% clay + silt with 7% WHC) were collected from the respective mined areas and transported to CR Farm, Central Arid Zone Research Institute, Jodhpur. These mine spoils (Rao and Tak, 2001) along with normal soil classified as coarse loamy mixed hyper thermic Typic Haplocambids containing 85% sand, 5.5% silt and 8.9% clay with 10% WHC have been used to fill the earthen pots (30 x 25 x 20 cm) with 10 kg each separately and sown with seeds of *Acacia ampliceps* Maslin, *A. eriopoda*, *F. Muell* ex Benth., *Albizia lebbeck* (L.) Benth., *Azadirachta indica*, *A. juss* and *Colophospermum mopane* (Kirk ex Benth). Five seeds were sown directly in each pot after acid treatment. The plants were grown in a net house under natural sunlight for 10 hours a day during the rainy season (June-September 1997) and watered on alternate days to field capacity. The temperature in the net house during the experiment ranged from 25°C (night) to 35°C (day). The experiment was laid out in a randomized block design with 10 replications for each species. After 15 days seedlings were thinned to two in each pot. After 4 months seedling height was recorded and plants were harvested along with the roots and rhizosphere soil was collected. The percentage of mycorrhizal colonization of the roots was estimated by the root slide technique (Read *et al*., 1976). Viable AM-fungal spores were isolated from 50 g wet soil by the wet sieving and decanting method of Furlan and Fortin (1975). Activities of acid and alkaline phosphatase in the rhizosphere soil were assayed using acetate buffer (pH 5.4) and borax-NaOH buffer (pH 9.4), respectively, with P-nitrophenyl phosphate as the substrate (Tabatabai and Bremner, 1969). Dehydrogenase activity was assayed by incubating the soil sample with 2,3,5-triphenyl tetrazolium chloride (Tabatabai, 1982). Nitrogen fixing potential (N_2-ase activity) of the rhizosphere soil was determined by gas chromatography after incubating 50 mg of soil in 7 ml test tubes containing 3 ml of N-free semi-solid medium for 48 hrs at 30±1°C (Rao and Venkateswarlu, 1982). The population of nitrifying bacteria, *Nitrosomonas* was determined by the MPN method (Alexander and Clark, 1965).

Dry weights of shoots were recorded after drying at 60°C to a constant weight and ground to a fine powder. Concentration of N in shoot tissue using kjeltec auto-analyser (Jackson, 1967), while P was estimated after tri-acid digestion using the vanado-molybdo-phosphoric yellow color method (Jackson, 1967). After wet digestion, Na and K contents were determined by flame photometer method while Ca and Mg by titrimetry employing di-sodium salt of EDTA. Cu, Fe, Mn and Zn were estimated using atomic absorption spectrophotometer (Varian AA1475). When appropriate the data were subjected to analysis of variance and means separated by the least significant difference (LSD) tests (Sokal and Rohlf, 1981).

Results and Discussion

Growth in height and dry weight of shoots of all the five plant species was significantly reduced when grown in gypsum and limestone mine spoils compared to those grown in normal soil (Table 1). There was a significant variation in the growth of different plant species with maximum growth of *Acacia ampliceps* and minimum of *A. eriopoda*. Among mine spoils, gypsum mine spoil recorded less reduction in the growth of all species than those of limestone mine spoils, but their differences were not significant. In general, the per cent reduction in growth of *A. ampliceps* in both mine spoils in comparison with that of normal soil was low while it was significantly high with all other species. The poor growth of different plant species in both mine spoils has been attributed to poor physico-chemical and biological properties. Similar results were reported by Smith *et al.* (1971) while working with different degraded ecosystems including mine spoils. In limestone mine spoils, lack of proper structure, low water holding capacity and reduced nutrient availability might be the reasons for the poor growth of all the plant species (Jha and Singh, 1990). Lunt (1994) also observed

Table 1. Growth of different trees and AM-fungal status in mine spoils in relation to normal soil

Mine spoil	Tree species				
	AA	AE	AL	AI	CM
Plant height (cm)					
Normal soil	35.7	17.8	29.1	28.0	31.1
Limestone mine spoil	27.1	10.2	14.2	15.2	17.2
Gypsum mine spoil	28.4	7.9	14.5	17.2	19.8
LSD (P=0.05)	soil: 4.2; species: 3.4; soils x species: 6.5				
Shoot dry weight (g plant^{-1})					
Normal soil	8.8	4.9	9.3	7.5	9.0
Limestone mine spoil	5.5	3.8	4.6	5.1	5.0
Gypsum mine spoil	6.0	4.0	6.1	4.2	6.1
LSD (P=0.05)	soil: 2.1; species: 1.7; soils x species: 2.9				
AMF spores (No. 100 g^{-1})					
Normal soil	128	90	152	220	125
Limestone mine spoil	80	51	95	136	85
Gypsum mine spoil	91	45	120	96	80
Root infection (%)					
Normal soil	34.3	19.8	54.5	52.5	41.0
Limestone mine spoil	15.0	13.8	15.7	38.8	17.5
Gypsum mine spoil	17.5	16.6	36.0	31.4	20.3

AA: *Acacia ampliceps*; AE: *A. eriopoda*; AL: *Albizia lebbeck*; AI: *Azadirachta indica*; CM: *Colophospermum mopane*

Table 2. Enzyme activitives in the rhizosphere in different mine spoils and normal soil

Enzyme	Gypsum mine spoil	Limestone mine spoil	Normal soil	LSD (P = 0.05)
Dehydrogenase (p Kat)	4.4 (2.6)	3.7 (2.2)	9.3 (7.8)	0.9
Acid phosphatase[a]	8.4 (4.0)	8.5 (5.2)	10.7 (8.0)	0.6
Aklaine phosphatase[a]	6.7 (4.8)	21.4 (9.0)	16.2 (13.6)	3.1
Nitrogenase[b]	144.0 (ND)	127.0 (43)	215.0 (122)	15.0

Average of five plant species; a = n kat 100 g^{-1} soil; b = n mol C_2H4 h^{-1} $tube^{-1}$; Figures in parentheses indicate values of the non-rhizophere soils.

variation in the growth of different plant species on different mine spoils.

The per cent root infection of all the plant species was significantly lower by 16 to 50% and 25 to 57% in gypsum and limestone mine soils respectively, compared to those of the plants grown in normal soils with significant variation among different plant species (Table 1). However, Tinker (1978) made a general observation that AMF root infection was low in fertile soil by about 35% than in unfertile soil. But the low root infection with mine spoil grown plants might be due to lower numbers of viable AMF spores. All the plant species except *A. indica* had shown very low root infection in limestone mine spoils (13.8 to 17.8%) compared to that of gypsum mine spoils (16.6 to 36%). There was a significant improvement in the AM-fungal spore build up in mine spoils upon introduction of plants compared to that of normal soil. This was attributed to the infective nature of AM-fungi present in mine spoils or presence of congenial conditions for plant growth. Graham *et al.* (1981) suggested that root exudates by phosphorus deficient plants stimulate AM fungal colonization as well as build up of spores in the rhizosphere. Alternately this might be a survival mechanism for AM fungi under stress conditions (Diaz and Honrubia, 1994).

Activities of dehydrogenase and phosphatases in the rhizosphere of different plants grown in mine spoils were found to be low by 56% and 21%, respectively compared to those of plants grown in normal soil (Table 2). Low activities in mine spoils are due to low inherent microbial activity in these mine spoils. But alkaline phosphatase activity was maximum in the rhizosphere of plants grown in limestone mine spoils than those of normal soil or plants grown in gypsum mine spoil (Table 3). Nitrogenase activity was not detected in gypsum mine spoils as such. But a significant amount of N_2-ase activity was observed upon plant introduction. The results are in conformity with those of Otrosina *et al.* (1984) who reported higher N_2-ase activity in the re-vegetated Kaolin mine spoils. Similarly the population of nitrifying bacteria was also enhanced with the plant introduction. In general the rhizosphere activity was found to be significantly higher in mine spoils compared to that of the normal soil. Wilson (1965) reported the enhancement in the diversity and activity of microorganisms with the introduction of vegetation in coal mine

*Table 3. Enzyme activities in the rhizosphere of different tree species**

Enzyme	*A. ampliceps*	*A. eriopoda*	*A. lebbeck*	*A. indica*	*C. mopane*	LSD (P=0.05)
Dehydrogenase (p Kat)	6.6	5.8	6.2	5.7	4.8	0.4
Acid phosphatase[a]	8.7	7.8	13.7	7.8	8.0	0.9
Aklaine phosphatase[a]	15.3	15.0	16.0	13.6	13.9	1.3
Nitrogenase[b]	177	142	187	154	150	17

* Average of three soils, a = n kat 100 g^{-1} soil, b = n mol C_2H_4 h^{-1} $tube^{-1}$.

spoils. This was due to the availability of more organic matter in the rhizosphere of mine spoils. In general, plants that experience some sort of stress (either abiotic or biotic) exude more of organic compounds compared to that of the normal plants (Hale *et al.*, 1971). They had further shown that the availability of mineral nutrients in the rhizosphere influences quantity and quality of root exudates. When pine seedlings were grown under N and P deficiency, the amount of amides and amino acids in the root exudates increased significantly (Bowen, 1969). Tate (1985) concluded that successful reclamation and long term stability of mine spoils rely upon the development of an active and diverse soil microbial community that can contribute to the bio-geochemical cycling processes. Muller (1973) suggested that the presence of vegetation was one of the important factors in establishing the soil microflora that help in the stabilisation of mine spoils.

A significant reduction in the concentration of N and P in different plants grown in gypsum and limestone mine spoils compared to those of normal soil (Table 4) is in confirmity with those of Dadhwal *et al.* (1991), who had observed a significant decrease in the concentrations of N and P in grasses grown on limestone mine spoils. This reduction was due to the availability of low amounts of these nutrients. Lack of mineralizable organic matter and lower mineralization rates affect the availability of N to plants in the mine spoils (Reeder and Berg, 1977). Iverson and Wali (1982) observed P as a major limiting nutrient in the coal mine spoils which had resulted in lower P uptake by different trees. The per cent reduction in N and P concentrations was more with limestone mine spoil grown plants compared to that of gypsum mine spoil. The concentration of most of the nutrients viz., K, Ca, Mg, Cu, Fe, and Mn but not Na and Zn were found to be higher in mine spoil grown plants compared to those of the normal soil with maximum concentration in respect to Ca and Mg. Dadhwal and Singh (1989) also recorded significantly higher concentrations of Ca and Mg in various trees grown on limestone mine spoils of the outer Himalayas. It is generally assumed that the uptake of any nutrient by a plant is related to its availability in the growth medium. Shetron (1983) observed that alfalfa plants grown on copper tailings had higher Ca and lower K levels and attributed this to the higher availability of Ca and lower K availability in the mine spoils.

In view of the above it is concluded that growth of various tree species on both gypsum and limestone mine spoils is

Table 4. Concentrations of various nutrients in plants grown in different soils*

Soils	N	P	K	Na	Ca	Mg	Cu	Fe	Mn	Zn
	mg g^{-1}						µg g^{-1}			
Normal soil	15.5	2.2	12.8	0.93	14.41	4.92	16.2	456	47.4	34.8
Gypsum mine spoil	10.3 (-33.3)	1.7 (-21.8)	14.5 (+13.6)	0.82 (-11.8)	20.9 (+44.7)	6.5 (+33.3)	20.8 (+28.8)	508 (+11.4)	56.2 (18.6)	30.0 (-13.8)
Limestone mine spoil	9.9 (-36.2)	1.6 (-26.4)	14.2 (+10.8)	0.73 (-21.5)	25.5 (+77.1)	6.6 (+35.0)	18.7 (+15.7)	519 (+13.8)	53.6 (+13.1)	31.4 (-9.0)
LSD (P = 0.05)	0.5	0.2	1.1	NS	3.7	0.9	1.8	23	NS	NS

* Average of all five species; Figures in parentheses indicate per cent increase/decrease over that of normal soil.

significantly low due to poor physico-chemical and biological properties of these mine spoils. Introduction of plants on these mine spoils had enhanced the development of active and diverse microbial community that help in the stabilization of mine spoils. From the uptake pattern of various nutrients it is possible to develop reclamation technology employing certain group of beneficial microorganisms and amendments for creating better ecosystem.

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