EVALUATION OF COAL MINE SPOIL AS A MEDIUM FOR PLANT GROWTH IN A DRY TROPICAL ENVIRONMENT, INDIA

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Introduction

During mining activites overburden strata displacement may contain materials that may be unfavourable or potentially unfavourable to plant growth (Chichester, 1983). Several workers have identified salinity, acidity, poor water-holding capacity, inadequate supplies of plant nutrients, high rates of litter accumulation, accelerated rate of erosion and spoil texture, as major problems in coalmine spoils that affect revegetation process (Down, 1975; Archibold, 1980; Wali and Freeman, 1973; Safaya and Wali, 1979; Reeder and Berg, 1977; Jha and Singh, 1990).

Soil fertility is a major factor which regulates plant growth Several investigators have reported N and P as limiting growth factors in mine spoils. Day *et al.* (1979) observed in growth chamber experiments that even with adequate irrigation but without proper fertilization, plant growth in spoils and top soil materials was extremely poor. Lack of mineralizable organic N and lower mineralization rates affect the availability of N to plants in mine spoils (Reeder and Berg, 1977).

No data on suitability or unsuitability for plant growth for Indian coal mine spoils are available. Therefore, the objective of this study was to evaluate the mine spoils of different ages of Jhingurda Colliery, Northern Coalfields, Ltd., Singrauli, as a medium for plant growth.

Materials and Methods

The study sites are located in the vicinity of tropical mixed dry deciduous forest dominated by *Boswellia serrata* Roxb. ex Colebr., *Lagerstroemia parviflora* Roxb., *Wrightia tomentosa* R. and S. and *Anogeissus latifolia* Wall.; near Jhingurda (24° 10′ 20″ –20° 12′31″ N, and 82° 42′–82° 44′30″ E and 350-450 m altitude) in Madhya Pradesh, India. The climate is tropical monsoonal and the year can be divided into a cold winter (December-February), a hot summer (May-June), and a rainy season (July-September). Mean monthly minimum temperature within the annual cycle ranges from 6.4-28°C and mean monthly maximum from 20-42°C. The annual rainfall averages 934 mm, of which 795 mm occurs between late June-September. The soils are residual ultisols. The mine spoils are unconsolidated mixed overburden material with the degree of natural revegetation varying with age. Surface coal mining at Jhingurda Colliery was started in 1965.

An age series of coal mine spoils (5, 10, 12, 16 and 20 yr) and adjacent native forest sites were selected at Jhingurda Colliery, NCL, Singrauli, for the present study.

In July 1986 spoil samples were collected from the upper 10 cm layer from mine spoils of different ages and native forest, and were transported to the laboratory. A total of 117 polyethylene pots; each having approximately 1 kg of overburden material except for 39 pots which had one-fifth of native forest soil and four-fifth of overburden material, were prepard for each age of mine spoil. 39 pots for each spoil age received NPK fertilizer equivalent to 120 kg/ha N as urea, 60 kg/ha P as P_2O_5 (single super phosphate) and 60kg/ha K as K_2O (muriate of potash).

Thus each of the treatments were as follows :

- mine spoil alone of five different ages,
- mine spoil of five different ages+NPK,
- mine spoil of five different ages+forest soil.

Each treatment was replicated thrice.

Five seeds were dibbled at 1.5 cm depth in each pot. Plants were thinned to one per pot on the 15th day after seeding. Length of shoot was measured at one month interval for one year.

Following plant species were tried :

Tree-legumes : *Acacia catechu, Acacia nilotica, Albizia procera, Pongamia pinnata, Prosopis juliflora, Dichrostachys cinerea, Leucaena lencocephala.*

Leguminous forbs : *Desmanthus virgatus, Macroptelium abropurpureum, Clitorea ternatea, Stylosanthes hamata, Stylosanthes humilis.*

Grass : *Cenchrus ciliaris*

Results

Length of shoots in various treatments in pot culture experiments after one year growth are given in Table 1.

Analysis of variance indicated significant effects of the age of mine spoil (5, 10, 12, 16 and 20 yr old) and treatments (mine spoil alone, mine spoil+NPK fertilizer, and mine spoil+forest top soil mixture) on shoot growth for all plant species ($p < 0.001$).

The treatment effects were further analysed through multiple range test (SPSS, 1985) (Tables 2 and 3). Significant difference in shoot growth was observed for NPK treated plants compared to those grown in mine spoil only and in mine spoil+forest soil (Table 2). Addition of forest soil showed significant effect only in three plant species (*Albizia procera, Desmanthus virgatus* and *Cenchrus ciliaris*) (Table 2).

Multiple range test indicated that the effect of spoil age on shoot growth was not significant in *Albizia procera* and *Desmanthus virgatus* (Table 3). Shoot growth in 20-yr old mine spoil was significantly higher compared to that in 5, 10, 12 and 16 yr old spoils in *Acacia catechu, Pongamia pinnata, Prosopis juliflora, M. atropurureum, Stylosanthes hamata* and *Cenchrus ciliaris*. In *Acacia nilotica, L. leucocephala* and *S humilis* shoot growth in 16 and 20-yr old spoils were significantly higher compared to 5, 10 and 12 yr old spoils, and shoot growth in 16 and 20-yr old spoils were not significantly different among themselves (Table 3).

Table 1

Shoot length of plants seeded in mine spoils of different ages in different treatments in laboratory conditions after one year.

Treatments	Mine spoil					Mine spoil+NPK					Mine spoil+Forest soil				
Spoil age (yr)	5	10	12	16	20	5	10	12	16	20	5	10	12	16	20
Acacia catechu	19	26	30	23	35	30	34	36	32	60	25	28	32	27	50
	±3.1	3.4	1.4	1.9	2.4	2.4	3.6	4.5	2.5	7.4	2.4	1.7	1.9	1.2	4.7
Acacia nilotica	51	58	54	71	80	72	82	76	100	120	60	69	67	96	100
	±2.5	4.8	2.8	4.0	4.3	1.6	0.9	2.5	10.3	1.6	5.9	4.5	5.3	5.7	6.2
Albizia procera	41	45	43	60	49	92	101	98	150	105	54	66	60	70	67
	±2.5	1.7	3.4	4.1	4.8	8.1	7.1	5.9	2.4	4.7	5.7	9.3	8.5	8.5	9.7
Dichrostachys cinerea	46	48	50	50	60	78	66	75	84	90	69	53	70	78	75
	±5.7	2.9	4.2	4.9	4.7	9.3	6.8	8.5	13.7	7.1	4.0	2.9	3.8	6.2	6.1
Desmanthus virgatus	65	76	74	80	85	93	105	100	116	120	78	92	90	96	98
	±2.1	4.1	4.1	1.9	3.3	3.7	2.1	3.3	3.4	7.4	3.4	5.7	3.8	6.6	5.7
Pongamia pinnata	45	50	48	60	68	68	72	69	74	79	48	56	50	66	72
	±2.1	3.3	2.1	4.2	3.8	2.5	1.9	3.7	1.2	4.8	5.0	6.8	2.4	3.4	4.6
Leucaena leucocephala	60	63	68	76	75	81	72	82	87	90	70	69	74	84	81
	±1.9	3.4	3.9	0.9	1.7	3.4	5.0	6.2	5.0	1.9	2.5	4.0	5.7	3.4	2.5
Prosopis juliflora	62	68	74	76	70	99	90	83	86	110	68	80	78	80	88
	±4.6	5.0	1.7	4.5	4.7	5.4	6.2	5.3	4.3	8.5	3.4	2.4	2.5	1.2	1.2
Clitoria ternatea	104	95	105	115	110	121	106	128	135	130	110	101	117	120	115
	±1.9	6.2	2.1	2.1	3.8	4.0	1.9	2.5	4.7	4.1	4.1	0.5	2.9	4.7	2.4
Macroptelium atropurpureum	78	84	100	95	120	104	101	120	120	140	84	93	116	102	134
	±3.4	4.1	6.2	6.2	1.9	11.1	4.5	1.9	2.1	2.8	2.6	5.7	6.8	4.3	3.4
Stylosanthes hamata	40	50	48	42	60	54	65	60	58	80	43	56	54	47	70
	±4.3	1.4	3.4	5.0	7.1	5.7	2.4	6.2	3.4	0.9	1.2	3.4	2.5	2.5	1.9
Stylosanthes humilis	35	45	41	38	55	44	64	50	47	76	38	54	46	42	65
	±1.7	4.5	1.7	5.0	2.9	1.9	5.7	3.3	3.4	2.5	3.3	4.1	5.0	6.2	3.3
Cenchrus ciliaris	23	25	24	27	40	49	55	53	60	80	40	52	42	54	56
	±0.9	2.1	2.5	1.6	4.1	2.5	4.2	3.4	5.2	3.8	2.4	5.0	0.9	4.0	5.0

Table 2

Effect of application of NPK and forest soil on shoot growth in mine spoil (values are maximum shoot length in cm averaged across spoil ages).

Species	Mine spoil	Mine spoil + NPK	Mine spoil + forest soil
Acacia catechu	26.6^{a}	38.7	32.4^{a}
Acacia nilotica	62.8^{a}	90.0	77.6^{a}
Albizia procera	47.6	109.2	63.4
Dichrostachys cinerea	47.5	80.6^{a}	70.0^{a}
Leucaena leucocephala	68.4^{a}	82.4	74.4^{a}
Pongamia pinnata	54.2^{a}	72.4	58.2^{a}
Prosopis juliflora	78.0^{a}	105.1	92.0^{a}
Clitoria ternatea	105.8^{a}	124.0	112.6^{a}
Desmanthus virgatus	76.0	107.0	93.6
Macroptelium atropurpureum	95.4^{a}	118.6	105.8^{a}
Stylosanthes hamata	48.0^{a}	61.3	56.0^{a}
Stylosanthes humilis	42.8^{a}	56.2^{a}	47.9^{a}
Cenchrus ciliaris	27.8	59.4	48.8

Across row values suffixed with the same letter are not significantly different among themselves at *HSD* 5%.

Table 3

Effect of age of mine spoil on shoot growth (values are maximum shoot length in cm averaged across treatments).

Species	Spoil Age (Yr)				
	5	10	12	16	20
Acacia catechu	24.7^{a}	29.3^{a}	32.7^{a}	27.3^{a}	48.3
Acacia nilotica	6[illegible].0^{a}	69.7^{a}	65.7^{a}	89.0^{b}	100.0^{b}
Albizia procera	—	—	—	—	—
Dichrostachys cinerea	64.3^{a}	55.7	65.0^{a}	70.7^{a}	75.0^{a}
Leucaena leucocephala	70.3^{a}	68.0^{a}	74.7^{a}	82.3^{b}	82.0^{b}
Pongamia pinnata	53.7^{a}	59.3^{a}	55.7^{a}	66.7^{a}	73.0
Prosopis juliflora	76.3^{a}	79.3^{a}	78.3^{a}	80.7^{a}	89.3
Clitoria ternatea	111.7^{a}	100.7^{a}	116.7^{b}	123.3^{b}	118.3^{b}
Desmanthus virgatus	—	—	—	—	—
Macroptelium atropurpureum	88.7^{a}	92.7^{a}	112.0^{b}	105.7^{b}	131.3
Stylosanthes hamata	45.7^{a}	57.0^{a}	54.0^{a}	49.0^{a}	70.0
Stylosanthes humilis	39.0^{a}	45.7	42.3^{a}	54.3^{b}	65.3
Cenchrus ciliaris	37.3^{a}	44.0^{a}	39.7^{a}	47.0^{a}	58.7

Across row values suffixed with the same letter are not significantly different among themselves at HSD 5%.

Among the two *Acacia* spp., *A. nilotica* showed higher shoot growth in mine spoil, mine spoil + NPK and mine spoil + forest soil mixture than *A. catechu* in all ages of mine spoils. *Stylosanthes hamata* showed better growth in all treatments than *S. humilis* (Table 1).

Discussion

Usually mine spoils are N and P deficient, therefore, several workers have found that NPK addition increased above-ground crop yield (Chichester and Hauser, 1984; Dancer and Jansen, 1981; Barker *et al.*, 1977). In the present study NPK additions showed significantly greater shoot growth as compared to mine spoil only and mine spoil + forest soil treatments. Mine spoil + forest soil treatment showed significant greater shoot growth only in three plant species. Forest soil is impoverished (Table 4) therefore, shoot growth response in majority of plant species was not greater after addition of forest soil to mine spoil compared to NPK treatment. Shoot growth in majority of plant species was higher in 20-yr old spoil than in 5, 10, 12 and 16-yr old spoils.

Table 4

Certain properties of the mine spoils and the native forest soil. Values are means ± 1 SE (Based on Srivastava et al., 1989).

Site	Total soil N (%)	Mineral N ($\mu g\ g^{-1}$)	$NaHCO_3$-Pi ($\mu g\ g^{-1}$)
Forest soil	0.291 ± 0.002	16.4 ± 0.1	15.0 ± 1.1
Mine spoil (age in yr)			
5	0.068 ± 0.002	5.8 ± 0.2	5.0 ± 0.5
10	0.074 ± 0.005	7.6 ± 0.3	7.3 ± 0.6
12	0.077 ± 0.005	7.9 ± 0.2	7.0 ± 0.7
16	0.082 ± 0.002	9.9 ± 0.2	8.4 ± 0.7
20	0.086 ± 0.004	15.6 ± 0.2	8.9 ± 0.9

In *Pongamia pinnata* increase in shoot growth due to NPK application was maximum (51 per cent) in 5-yr old spoil and minimum (16 per cent) in 20-yr old spoil. Similarly increase in shoot growth (33 per cent) due to NPK application was higher in *M. atropurpureum* in 5-yr old spoil compared to 20-yr old spoil (17 per cent). In *L. leucocephala* NPK addition showed 35 per cent increase in shoot growth in 5-yr old spoil and only 20 per cent increase in 20-yr old spoil. In *D. cinerea* increase in shoot growth was 70 and 50 per cent, respectively in 5 and 20-yr old spoils. This indicated that with increase in the age of mine spoil there was less effect of NPK addition on shoot growth. This apparently is due to enhanced nutrient content with age of the mine spoil (Table 4). Mineral N is the flush of available soil N to plants which varies annually and seasonally. More rapid increase in mineral N compared to total soil N from 16 to 20-yr old mine spoil (Table 4) was due to increase in biological establishment (Jha, 1990). In the present mine spoils, total soil N, mineral N, $NaHCO_3$-extractable Pi, and exchangeable K increased with age of mine spoil while exchangeable Na decreased with age (Jha, 1990). The recovery of total soil N in the present mine spoils during 20 years of spoil age was 0.0012 per cent per year (Srivastava *et al.*, 1989). Thus it may take about 200 years of natural succession for the total N pool to reach the level of native soil.

Effect of application of NPK was greater in grass *C. ciliaris* compared to leguminous trees and forbs except for *A. procera*. Increase in shoot growth due to NPK fertilization ranged from 16-71% in leguminous species while it ranged from 100-122% in *C ciliaris* Berg (1972) measured a seven fold increase in grass yields and a six fold increase in herbaceous ground cover following nitrogen fertilization of gold tailing from telluride ores. A liner effect of NPK fertilizer on yield was obtained when NPK were applied at higher rates in Southern Ohio coalmine spoil (Sutton and Hall 1987). Redente *et al* (1984) observed that high rate of fertilizer (NP) applications resulted in significantly greater seeded grass production compared to unfertilized seeded grass production in drastically disturbed soils at Colorado. DePuit and Coenenberg (1979) reported increase in grass yield after fertilizer applications on reclaimed areas. Vegetation production on plots with applied P was 10-fold greater than on plots without fertilizer application at North Dakota mine spoils (Sandoval *et al.*, 1973).

In the present study the experiment showed that mine spoils were non-toxic and suitable, although sub-optimal medium, for plant growth. Native forest soil was impoverished, therefore, shoot growth in majority of plants was not greater after addition of forest soil to mine spoil compared to NPK treatment.

Acknowledgements

I gratefully acknowledge the funding support from University Grants Commission, New Delhi and Ministry of Environment and Forests, New Delhi. I am thankful to Professor J S Singh, FNA, FASc, Department of Botany, Banaras Hindu University, Varanasi, for guidance and supervision of this work.

SUMMARY

An age series of coal mine spoils (5, 10, 12, 16 and 20 yr) of Jhingurda colliery, Northern Coalfields Ltd., Singrauli were evaluated as a medium for plant growth. Thirteen plant species were seeded in mine spoil alone of five different ages, mine spoil of five different ages+NPK; and mine spoil of five different ages+forest soil. Shoot growth of seeded plant species was measured. The experiment showed that mine spoils were non-toxic and suitable, although sub-optimal medium, for plant growth. Growth performance was better in NPK treatment compared to as in addition of forest soil to mine spoils due to impoverished nature of forest soil. Effect of application of NPK was greater in grass compared to leguminous trees and forbs, generally. With increase in the age of mine spoil there was less effect of NPK addition on shoot growth due to increase in nutrient content with the age of mine spoil.

भारत के शुष्क उष्ण पर्यावरण में पादप वृद्धि कराने के माध्यम के रूप में कोयला खानों के छोड़े अवशेषों का मूल्यांकन

ए०के० झा

सारांश

झिगरडा कोयला खदान, नार्दर्न कोलफील्ड लि०, सिंगरौली द्वारा छोड़ी गई कोयला खानों के अवशेषों की आयु श्रेणी (5, 10, 12, 16 और 20 वर्ष) का मूल्यांकन पादप वृद्धि कराने के माध्यम के रूप में किया। पांच विभिन्न आयु के खान अवशेष मात्र, पांच विभिन्न आयु के खान

अवशेष+नाइट्रोजन, फास्फोरस और पोटाश तथा पांच विभिन्न आयु के खान अवशेष व वन मृदा में 13 पादप जातियों के बीज बोए गए। बोई पादप जातियों की प्ररोह वृद्धि मापी गई। सपरीक्षण से पता लगा कि खनिज अवशेष विषैले नहीं व उपयुक्त, यद्यपि पादप वृद्धि के लिए अव-इष्ट माध्यम हैं। खनिज अवशेष में वन मृदा मिलाने की तुलना में नाइट्रोजन-फास्फोरस-पोटाश मिलाने के उपचार में वृद्धि सक्रियता अधिक अच्छी रही क्योंकि वन मृदा में पोष्याहार कम रह जाते हैं। सामान्यत: शिम्बिवर्गीय वृक्षों और शाककों के मुकाबले में घास पर नाइट्रोजन-फास्फोरस-पोटाश देने का प्रभाव अधिक पड़ा। खनिज अवशेष छोड़ने का समय बढ़ने के साथ प्ररोह वृद्धि पर नाइट्रोजन फास्फोरस-पोटाश देने का प्रभाव कम होता गया क्योंकि समय बढ़ने के साथ पोष्याहार तत्वों में वृद्धि होती जाती है।

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