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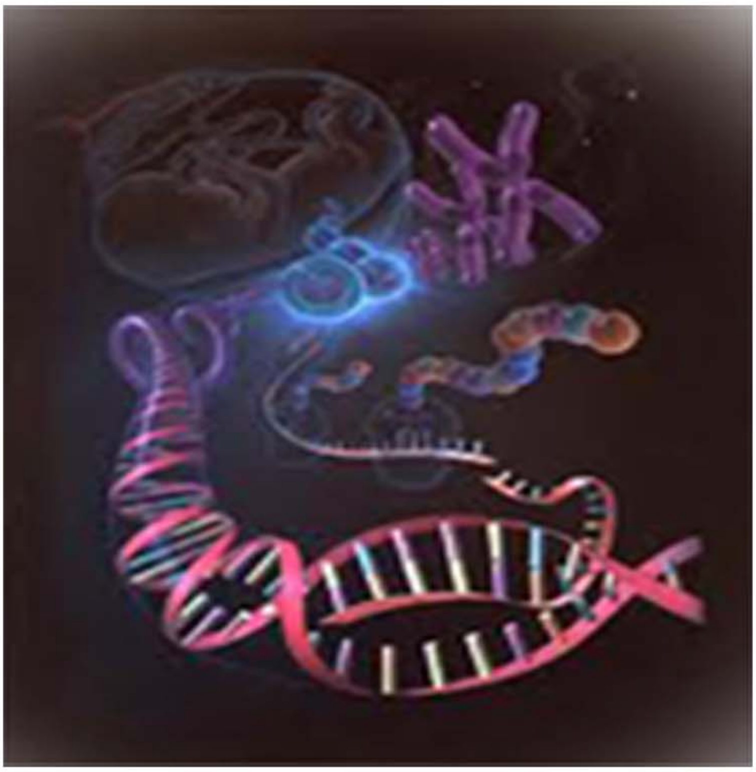

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Research Paper

IMPACT OF PLANTATION ON COAL MINE SPOIL CHARACTERISTIC

Gudadhe S K[1*] and Ramteke D S[1]

Corresponding Author: **Gudadhe S K, ✉ swapnil.k.gudadhe@gmail.com*

The study was conducted for changes the characteristic of coal mine spoil by growth of selected plant species. Soil characteristics of vegetated coal mine spoil land under plantations of plant species were assessed. The data obtained were compared with those of the coal mine spoil and the native forest soils. The results showed an improved soil status under different plantation stands compared to coal mine spoil. The silt and clay particles in soil were higher among different plantation stands in comparison to before plantation in coal mine spoil. Bulk density was highest in the plots of *Azadirachta indica* and lowest in *Pisum sativum* plots. Soil porosity percentage was decrease under different plantations. Water holding capacity was highest in the plots of *Azadirachta indica* and lowest in *Pisum sativum* plots. Organic carbon was decreased by before plantation in coal mine spoil and total nitrogen concentrations were higher in the plantation stands in comparison to the before plantation in coal mine spoil. The plantations enhanced the nutrient status of the degraded coal mine spoil land. The plant species were change the properties of coal mine spoil. The plant species *Gossypium herbaceum*, *Pisum sativum* and *Azadirachta indica* were generally found in the nearest agricultural land of coal mining area.

Keywords: Coal mine spoil, Plant species, Texture, pH, Soluble cations, Organic carbon

INTRODUCTION

Plantation is the oldest technology for the restoration of lands damaged by human activity (Filcheva, 2000). At the early stages of an ecosystem development, soil acts as a critical controlling component. Without the natural processes of soil development, ecosystems would remain in a degraded condition. Coal mine spoil heaps are composed of coarse rocks due to the deep coal mining operations and associated coal processing. These coal mine spoils are not suitable for plant growth because of unfavorable pH, drought arising from coarse texture or oxygen deficiency due to compaction (Agrawal *et al.,* 1993). The other limiting factors for re-vegetation of mine spoil may be salinity, acidity, poor water holding capacity, inadequate supply of plant nutrients and accelerated rate of erosion (Jha and

[1] National Environmental Engineering Research Institute (NEERI), Nehru Marg, Nagpur - 440020, India.

Singh, 1991). During the reclamation of mine spoil, it is often necessary to establish and maintain a vegetative cover without the use of topsoils or other bulky amendments (Rimmer, 1982). Pederson *et al.,* (1988) observed that the surface material from coal mining in Pennsylvania had a high density and low porosity resulting in low infiltration rates. In addition to soil physical characteristics, the nutrient status of overburden soil is also a major factor limiting plant growth. The cycling of nutrients regulates the sustainability of any plant community. Without cycling, nutrients will be lost or immobilized and the plant community will not be capable of regeneration. (Berg and Barrau, 1978) suggested that rapid reestablishment of the nitrogen cycle appears to be particularly important, but often difficult to achieve in mine spoil.

In mine spoils, geomorphic system is in disequilibrium due to the destruction between landform and processes, which accelerates erosion rate (Dutta, 1999). Destruction of soil properties causes reduced soil productivity. Mine spoils present very rigorous conditions for plant growth because of low nutrient contents, either coarse texture and compacted structure (Dutta and Agrawal, 2000). Natural plant succession is also very slow on coal mine spoil land. Rising of plantations may accelerate this process leading to a self sustained ecosystem in a relatively short period of time (Singh and Singh, 1999). Plantations impart a favorable role in the biological reclamation of mine spoil due to changes in coal mine spoil characteristics. The present study was, therefore, conducted to assess the impact of plantations of three plant/crop species on soil physical and chemical characteristics.

MATERIALS AND METHODS

Study Area

This study was conducted on the mine spoils of KECML (Karnataka Easter Coal Mines Ltd.), situated in the Bhadrawati, Chandrapur district of Maharashtra, India (20^0 08' 58.26" N latitude, 079^0 05' 59.89" E longitude, 728 feet above sea level). The climate is hot and dry type. During the study period the mean monthly minimum temperature ranged between 12.8-28.5°C and mean monthly maximum temperature between 28.8-42.8°C in an annual cycle. The annual rainfall was 1365.1mm. The mean relative humidity varied between 31.0 (April) to 84% (August). The climatic data were obtained from The Indian Metrological Department (IMD) of Regional Meteorological Centre, Nagpur.

Natural Vegetation and Soil

The natural vegetation of the area is dry deciduous forest type. The undulating, nearly flat area is under cultivation. The soils of the area are sandy loam to loam texture type and reddish brown colour mainly derived from Bhadravati area. The native forest soil contains 33.78% sand, 36.74% silt and 29.48% clay with the water holding capacity of 47.18%. The pH of the soil is 7.61. The bulk density is 1.18 gm/cm^3. The contents of organic carbon, total N and total P are 1.02%, 576.34 Kg/ha and 58.23 Kg/ha respectively.

Seedlings Plantation on Mine Spoil

Six month old nursery raised seedlings of three exotic plant species i.e. – *Gossypium herbaceum* (Cotton), *Pisum sativum* (Garden Pea) and *Azadirachta indica* (Neem) were planted by us in July 2011(Rainy season) at a spacing of 2 m x 2 m. Three experimental plots for each species size 5 m x 5 m. The experiment was started when the plantations were 6 month old. All the exotic species selected for the present study are commonly grown in Vidarbha Region, India for developing agricultural practice.

Soil Sampling

Triplicate soil samples were collected randomly from each of the three permanent plots using 15 x 15 x 10 cm (depth) monoliths in each of the two seasons, i.e. summer and winter for the analyses of physical and chemical characteristics of coal mine spoil viz., organic carbon, total nitrogen, total phosphorus etc. The samples from within a plot were thoroughly mixed to yield one composite sample per plot. Large pieces of plant materials were removed and the field moist soil was sieved through 2 mm mesh screen. Each soil sample was used for the determination of bulk density, porosity, water holding capacity, pH, Electrical Conductivity (EC), soluble cations (Ca, Mg, Na, K), Cation Exchangeable Capacity (CEC), Exchangeable Sodium Percentage (ESP), Organic Carbon (OC), Nitrogen (N), and Phosphorus (P).

Chemical Analysis

Percentage of sand, silt and clay in the soil was determined by the pipette method as described by Piper (1966). Soil pH and EC was measured in a suspension of 1: 2 (soil : water; W/V) using a photo volt pH meter with a glass electrode (Systronics India Manufactures Microprocessor Based Ph Meter Model 361) and using conductivity meter having Glass Conductivity Electrode (Systronics India Manufactures Microprocessor Based Conductivity Meter Model 306), Soluble Cations was analysed by Flame Photometer Method (Systronic Flame Photo Meter 128 μc) and Versenate method, CEC and ESP was analyzed by Ammonium Acetate Method, Bulk density, water holding capacity and porosity were determined according to (Piper, 1966). Organic C was determined by Walkely and Black's rapid titration method described by (Allison, 1973). Kjeldahl N was determined by the microkjeldahl method (Jackson, 1958), and the digest was analyzed for P using phosphomolybdic acid blue method (Jackson, 1958). All results were expressed on an oven dry soil (105°C, 24 h) basis.

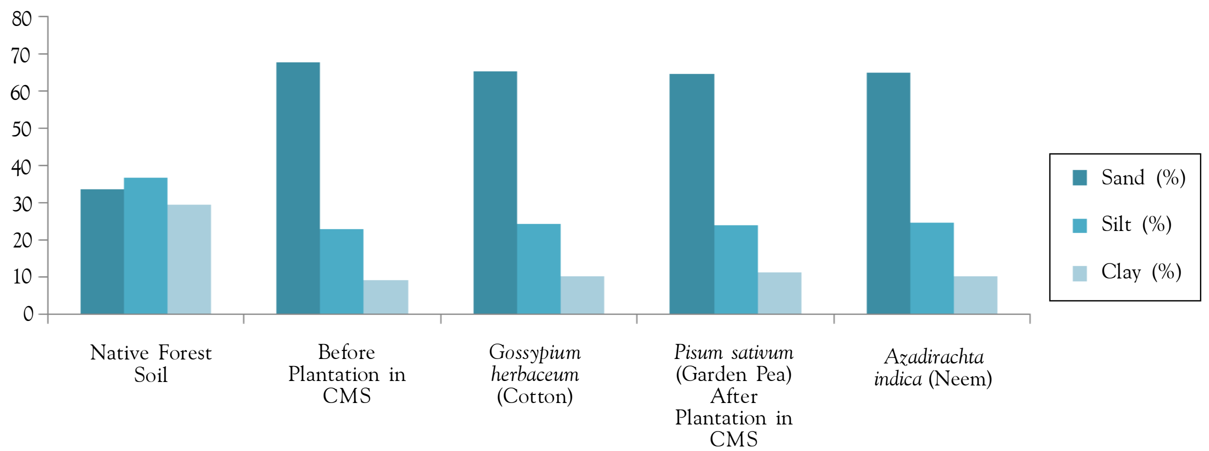
RESULTS AND DISCUSSION

The data obtained for soil characteristics from mine spoils under different plantations were compared with fresh mine spoil. Soil physical properties varied considerably between the plots of different plant species (Table 1 and Figure 1). The percentage of sand was lower after plantation in plots of different plant species (64.67%-65.23%) as compared to before plantation of coal mine spoil (67.72%), whereas silt (24.07%-24.87%) and clay (10.21%-11.26%) percentages were found higher after plantation in the planted plots compared to before plantation of coal mine spoil (silt 23.14% and clay 9.14%). The sand percentage was decreases in between six month are in the range 2.49% - 3.05%. However, silt and clay increase percentages showed significant variations among the plots of different plant species after six month silt was in the range 0.93%-1.73% and clay was in the range 1.07%-2.12%. Significant variations in silt and clay suggested that plantations are capable of changing the soil texture after their establishment and growth in due course. The texture of coal mine spoils drastically disturbed due to irregular pilling of overburden materials. This type of plantation on coal mine spoil is up to five years, and the percentages of sand, silt and clay as in

Table 1: Physical Properties of Coil Mine Spoil (CMS) Before and After Plantation in Coal Mine Spoil (Mean)

Parameter	Native Forest Soil	Before Plantation in CMS	After Plantation in CMS		
			Gossypium herbaceum (Cotton)	*Pisum sativum* (Garden Pea)	*Azadirachta indica* (Neem)
Texture (%)					
Sand	33.78	67.72	65.23	64.67	64.92
Silt	36.74	23.14	24.43	24.07	24.87
Clay	29.48	9.14	10.34	11.26	10.21
Bulk Density (gm/cm^3)	1.18	1.67	1.47	1.32	1.64
Porosity (%)	72.2	59.4	56.2	51.1	53.2
WHC (%)	47.18	29.26	32.76	31.28	34.01
pH	7.61	8.22	8.96	8.65	8.41
EC (μS/cm)	488	216	239	222	231

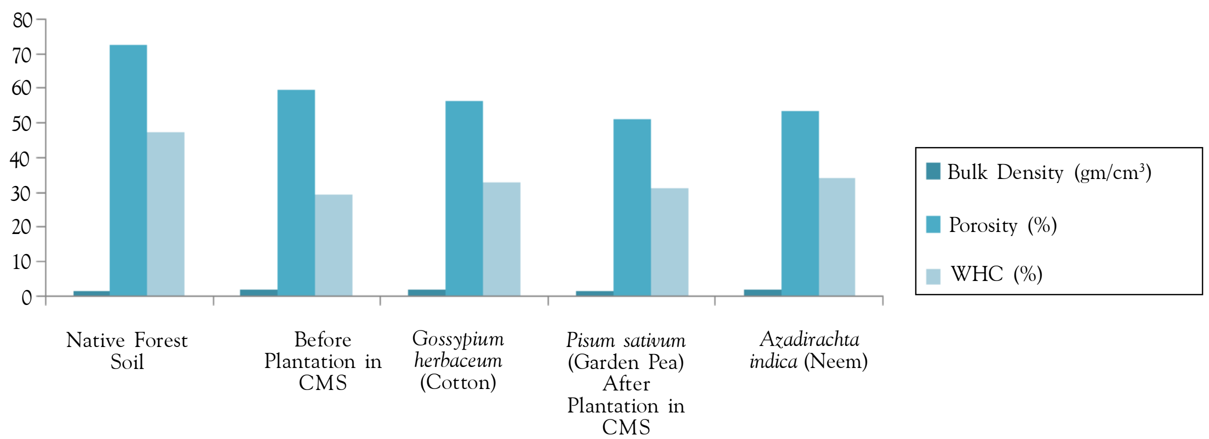
Figure 1: Coal Mine Spoil Texture



range 24.9 – 30.05%, 9.30 – 17.30% and 10.7 – 21.2% respectively (Jha & Singh, 1991).

Particle size distribution is a major factor in governing successful vegetation on reclaimed land as it influences water holding capacity, bulk density, porosity availability and nutrient contents as well as availability (Figure 2). The bulk density was found to be maximum after plantation in the *Azadirachta indica* (1.64 gm/cm^3), and minimum in *Pisum sativum* (1.32 gm/cm^3) plots, but the variations among different plots were not statistically significant. The values obtained for bulk density of reclaimed soil were higher than the native forest soil (1.18 gm/cm^3), but lower than the before plantation in coal mine spoil (1.67 gm/cm^3). The WHC is maximum after plantation in *Azadirachta indica* plots which are directly correlated with the texture of the soil of plantation

Figure 2: Coal Mine Spoil Bulk Density, Porosity and WHC



stand. The *Azadirachta indica* plants improve soil texture, increase water-holding capacity and decreases the porosity, (Badra *et al*., 1979; Godoy *et al*. and RodríguezKábana, 1983). The increment in WHC in comparison to before plantation in coal mine spoil may be attributed to the establishment of plant cover. After plantations in coal mine spoil all three plant species have decreased the porosity than before plantation and native forest soil, which may be attributed to the fragmentation, redistribution and aggregation of particles due to vegetation development and consequent soil processes in different plots.

Soil pH showed significant variations among plots from different plant species. The pH values recorded before plantation in coal mine spoil (8.22) were slightly toxic and closer to neutral. The increase in pH due to plantations (8.41-8.96) suggests that the organic matter input modifies the pH of the soil. Since the plant species are dicotyledonous, these may release more base cations like Ca^{2+} into the soil and thus increase the pH of the soil more than the before plantation in coal mine spoil. Richart *et al.,* 1987 also observed that the change in pH of opencast spoil was directly related to the plant growth. The electrical conductivity (EC) was found to be minimum before plantation in coal mine spoil (216 µS/cm) and it was maximum after plantation all three species in the coal mine spoil (222 µS/cm - 239 µS/cm) plots, but all the EC values was minimum than the native forest soil (488 µS/cm) (Figure 3).

From Table 2 the soluble cations (Ca^{++}, Mg^{++}, Na^+ and K^+) was increased after plantation in coal mine spoil than before plantation (0.47 me/l, 0.026 me/l, 0.43 me/l and 0.069 me/l) and native forest soil (0.30 me/l, 0.028 me/l, 0.58 me/l and 0.039 me/l). After plantation soluble cations (Ca^{++}, Mg^{++}, Na^+ and K^+) was found in *Gossypium herbaceum* (0.49 me/l, 0.031 me/l, 0.45 me/l and 0.078 me/l), *Pisum sativum* (0.54 me/l, 0.052 me/l, 0.48 me/l and 0.074 me/l) *and Azadirachta indica* (0.51 me/l, 0.049 me/l, 0.53 me/l, 0.069 me/l) respectively. The cation exchange capacity (CEC) was maximum after plantation in CMS in *Pisum sativum* (2.50 meq/100 gm) and *Azadirachta indica* (2.40 meq/100 gm) than before plantation (2.30 meq/100 gm) but CEC was maximum in native forest soil (9.60 meq/100gm). The exchangeable sodium percentage (ESP) percentage was maximum after plantation in

Figure 3: Coal Mine Spoil pH and EC

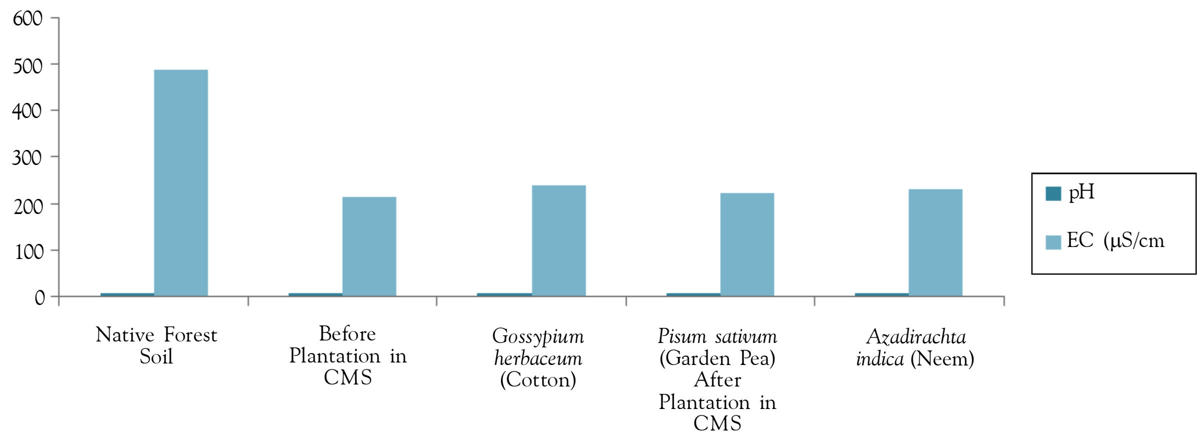


Table 2: Selected Chemical Characteristics of Coil Mine Spoil (CMS) Before And After Plantation In Coal Mine Spoil (Mean)

Parameter	Native Forest Soil	Before Plantation in CMS	After Plantation in CMS		
			Gossypium herbaceum (Cotton)	*Pisum sativum* (Garden Pea)	*Azadirachta indica* (Neem)
Soluble Cations (me/l)					
Ca++	0.30	0.47	0.49	0.54	0.51
Mg++	0.028	0.026	0.031	0.052	0.049
Na+	0.58	0.43	0.45	0.48	0.53
K+	0.039	0.065	0.078	0.074	0.069
CEC (meq/100gm)	9.60	2.30	2.30	2.50	2.40
ESP (%)	2.19	5.65	6.96	7.60	7.50
OC (%)	1.02	0.33	0.25	0.21	0.29
N (kg/ha)	576.34	688.42	669.33	652.04	656.45
P (kg/ha)	58.23	25.47	19.76	19.31	18.78

CMS, in all the species than before plantation (5.65%) but it was minimum in native forest soil (2.19%).

The organic carbon content was maximum in the plots of *Azadirachta indica* (0.29%) and minimum in *Pisum sativum* (0.21%) plots after plantation in CMS but before plantation it was maximum (0.33%) than after plantation. Soil organic carbon content was recorded during the present study in native forest soil is very high (1.02%) in comparison to both before and after plantation in CMS, that reported in the topsoil stock piles of four years old mounds at Cumbria and Staffordshire, UK (Williamson and Johnson, 1990). The lower level of organic carbon in mine spoil soil might be due to the disruption of ecosystem functioning (Stark, 1977), depletion of soil organic pool (Parkinson, 1979) and also due to the loss of litter layer during mining which is an integral storage and exchange site for nutrients. Total nitrogen also followed a similar trend for species wise variation as that of organic carbon (Table 2 and Figure 4).

The total N content was minimum in after plantation in coal mine spoil around different plantations were found in *Gossypium herbaceum* (699.33 kg/ha), *Pisum sativum* (652.04 kg/ha) and *Azadirachta indica* (656.45 kg/ha) and maximum in before plantation (688.42 kg/ha). Lowest values of total N in comparison to fresh mine spoil is due to the organic matter accumulation in soil by roots and leaching of N from the herbaceous, vegetation of the plots. Total nitrogen was found to be minimum after plantation and maximum before plantation in selected areas of Jharia coalfield (Prasunarani *et al.*, 1992). A nitrogen fixing species, showed lowest N content in the soil due to lower growth and nodulation (Dutta, 1999).

The total P was found to be maximum before plantation in coal mine spoil (25.47 kg/ha) and it

Figure 4: Coal Mine Spoil CEC, ESP and OC

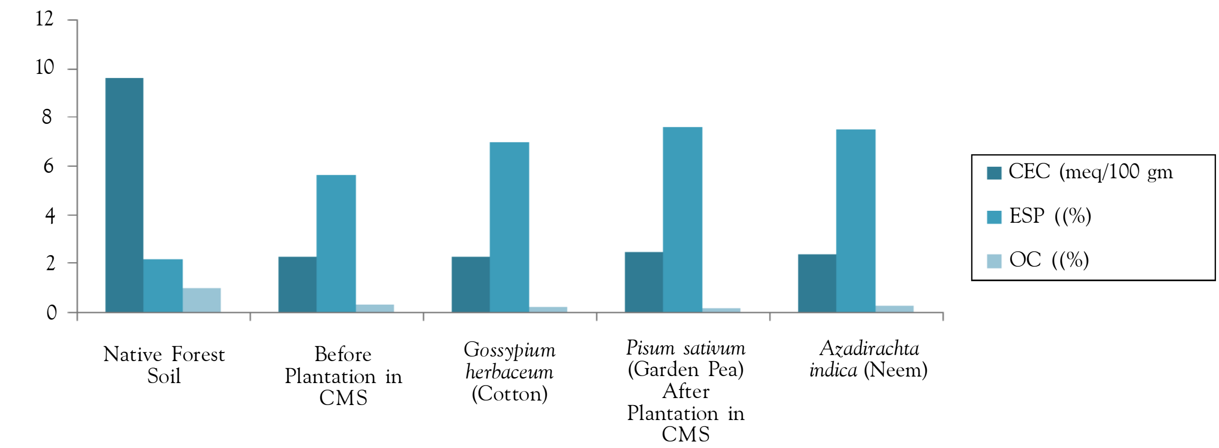
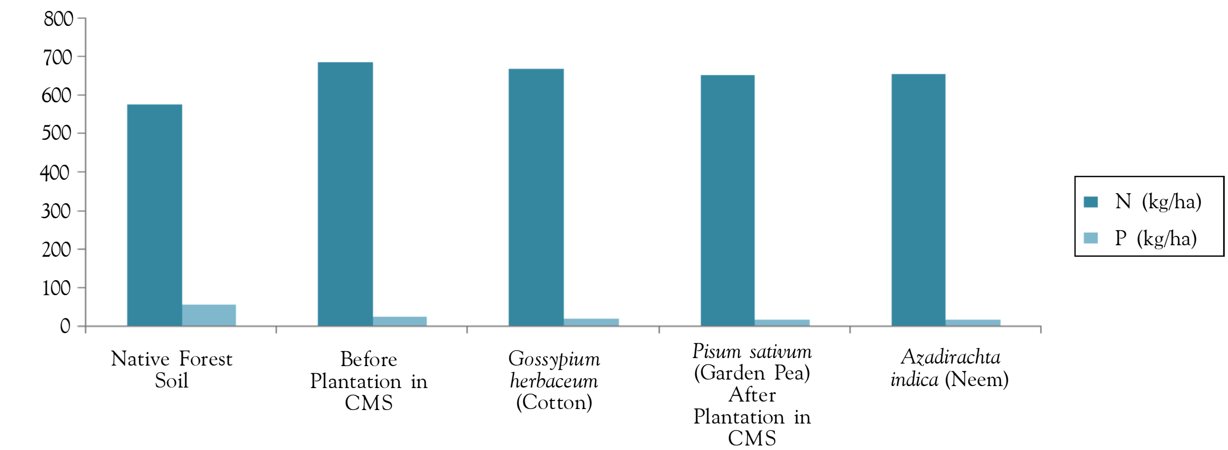


Figure 5: Coal Mine Spoil N and P



was minimum after plantation all three species in the coal mine spoil in *Gossypium herbaceum* (19.76 kg/ha), *Pisum sativum* (19.31kg/ha) and *Azadirachta indica* (18.78 kg/ha) plots, but all the total P values was minimum than the native forest soil (58.23kg/ha), however, the variations in available P were not significant. Development of vegetation cover enhanced the natural soil cycle and the values of available P found during present study is comparable to the reported value of (Srivastava *et al.,*1989) for 5 years old naturally vegetated coal mine spoil (Figure 5).

CONCLUSION

Among different plant species, the physical characteristics are maximally improved by *Gossypium herbaceum, Pisum sativum* and *Azadirachta indica*. In soil texture, maximum silt and clay was found in the plots of *Gossypium herbaceum, Pisum sativum*. Bulk density was higher in *Azadirachta indica* followed by *Gossypium herbaceum* and lowest in *Pisum sativum* plots. WHC, pH and EC was also highest in the plots of *Azadirachta indica*. In chemical characteristics, total N content was higher for *Gossypium herbaceum*, a nitrogen fixing species, whereas *Pisum sativum* showed lowest N content in spoil. Organic Carbon content was higher for *Azadirachta indica* and whereas *Gossypium herbaceum* showed lowest OC content in spoils. Total P content was highest for *Gossypium herbaceum* and lowest for *Azadirachta indica*. These characteristics can be due to the lower growth and poor nodulation of *Pisum sativum* plants (Dutta, 1999). *Gossypium herbaceum*, a non-leguminous nitrogen fixing species showed highest available P content and a higher N level in the spoil.

This study clearly indicates that the plantations on mine spoil modify the soil physicochemical characteristics up to several folds, but the plant species differed in their ability to modify the same. The plantations of different species have maintained the nutrient regeneration due to addition of organic matter and its further decomposition. Increasing availability of organic matter also enhanced N – mineralization, and hence the supply of plant available nutrients. The enhancement in plant available nitrogen due to plantations will be further helpful in soil-nutrient cycling. The study further suggests that *Gossypium herbaceum, Pisum sativum* and *Azadirachta indica* have maximum favorable impact on modifying physical and chemical properties of coal mine spoil.

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