Impact of Bio-reclamation of Coal Mine Spoil on Nutritional and Microbial Characteristics - A Case Study

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Abstract

With the planned increase in coal production, more and more land is being brought under mining operation. This result in drastic changes in land use patterns, as mined lands, prior to mining operations, may have been used for forestry, agriculture and any other productive purpose. The most serious impact of mining is the land degradation. Besides, serious impacts of coal mining are impact on top fertile soil, microbial population, heavy metal toxicity, ecology and vegetation, habitat destruction and degradation of ecosystem as a whole. The mine spoils or overburdens created during opencast mining are devoid of nutrients and have low water holding capacity. These are chemically, physically and biologically unstable.

In the present study, an attempt has been made to assess the changes on nutritional and microbial characteristics brought about by afforestation on overburden dumps of coal mine spoil at Jhingurda, Singrauli (M.P.). Different years overburden plantations raised by Madhya Pradesh Forest Development Corporation has been undertaken for study. For comparison, age series of plantations raised on adjoining areas outside the overburden dumps (mentioned as plain plantations) have been studied on the same attributes. The results were found encouraging with respect to amelioration of sites undertaken for rehabilitation activity.

Keywords: *Rehabilitation, coal mine spoil, overburden dumps, age series of plantations, nutritional and microbial activity, heavy metal toxicity*

1. Introduction

With the planned increase in coal production, more and more land is being brought under mining operation. This result in drastic changes in land use patterns, as mined land, prior to mining operations, may have been used for forestry, agriculture and any other productive purpose. The most serious impact of mining is the land degradation, and habitat destruction of ecosystem as a whole. Opencast mining is associated with many environmental problems. The mine spoils or overburdens created during opencast mining are devoid of nutrients and have low water holding capacity. These are chemically, physically and biologically unstable and deficient.

The heavy metal toxicity of mine spoils inhibit uptake of nutrients, plant growth and microbial population. This needs to develop separate management plans for restoration /reclamation of varying types of landscapes and finally post mine land use planning. The overburden areas have been planted by Madhya Pradesh Forest Development Corporation in different years from 1990-91 onwards. The species planted are comprised of timber, ornamental, fruit bearing, medicinal and ecological values. The names of species planted in different years old overburden dumps and plain plantations are mainly *Dalbergia sissoo*

Roxb., *Pongamia pinnata* L.Pierre, *Gmelina arborea* Roxb., *Azadirachta indica* A. Juss., *Terminalia belerica* (Gaertn.) Roxb., *Emblica officinalis* Gaertn., *Peltaphorum ferruginium* Benth., *Prosopis juliflora* (Sw.) DC, *Grevillea pteridifolia* Knight, *Holoptelea integrifolia* (Roxb.) Planch, *Ziziphus jujuba* (L.) Gaertn. auct, *Acacia catechu* (L. f.) Willd, *Tectona grandis* Linn. f., *Bauhinia variegata* Linn. and *Dendrocalamus strictus* (Roxb.) Nees. The present paper deals with impact of bio-reclamation of mine spoil on edaphic and microbial aspects at Jhingurdah opencast project (OCP).

2. Materials and Methods

Singrauli is the 50th district of Madhya Pradesh State of Union Republic India. The Singrauli coalfields (Lat 24^o 46' 60''- 24^o 78' 33''N and Long- 82^o 49' 59''- 82^0 83' 30''E) is spread over an area of 2200 sq km falling in Madhya Pradesh (eastern part of Sidhi district) and Uttar Pradesh (southern part of Sonebhadra district) in India.

The entire Singrauli coalfield is divided into 11 mining blocks, which are located both in Madhya Pradesh (M.P.) and Uttar Pradesh (U.P.). The present paper deals with the bio reclamation of mine spoil of Jhingurdah coal mine project. The Jhingurdah opencast project of Northern Coalfields Limited, Singrauli, lies between latitude 24^0 11' 46 "to 24^0 11' 75" N and longitude 82^0 41' 53 "to 82^0 41' 86" E. The project is situated on plateau with elevations from 325m to 425m above meter sea level (msl). The zone falls under the influence of south west monsoon. The climate of Singrauli district is tropical. The year is divisible in to three well marked seasons viz., summer (March to June), monsoon (July to October) and winter (November to February). The area receives mean annual rainfall of 1206 mm. The lowest and highest temperature recorded being 4^0 C and 48^0 C respectively during last 50 years. The vegetation of natural forest is dominated by sal (*Shorea robusta* Gaertn.f.). The soil is primarily sandy- loam. The geology of the area is covered by the sediments of Barakar formation with a thin cover of soil and alluvium at places. The overburden dumps are characterized by wide gully erosion and seasonal rain cuts. The angle of repose being 27^0. However, the angle of repose exceeds even 60^0 in some dumps, leading to excessive runoff and sediment transfer, development of gullys and disintegration of loosely packed dumps. The height of overburden dumps varies from 100m to 150m comprising different benches of 20 – 30 meter height each.

In the present study, following plantations of different age groups raised on overburden dumps and plain areas (adjoining plantation outside the overburden areas) of Jhingurdah were studied in detail for edaphic and microbial attributes.

1. 2000-01 Overburden (OB) Plantation
2. 2000-01 Plain Plantation
3. 2003 -04 Overburden (OB) Plantation
4. 1995-96 Plain Plantation
5. 1990-91 Plain Plantation

The detailed methodology used to study the above mentioned objectives is given below:

2.1. Physico- chemical Properties of Soil

Due to rehabilitation activities, aspect like soil structure, organic matter content, CEC, nutrients, pH, soil and heavy metal toxicity are liable to be modified. Assessment on soil development covering above mentioned parameters was made for surface soil (0-30 cm soil

depth) using standard methods prescribed in Tropical Soil Biology and Fertility- A Hand Book of Methods (edited by Anderson and Ingram), C.A.B. International publication(1990) and by Rubio Montoya and Brown (1984).

2.2. VAM Study and Microbial Biomass in Rhizosphere

Under the study of rhizosphere dynamics, spore count of vesicular arbuscular mycorrhiza (VAM) fungi, VAM root infection were assessed on reclaimed soil mine sites of different ages and in adjoining plain plantations.

The 100 gm rhizospheric soil was processed to extract the live spores using method given by Gerdemann and Nicholoson (1963). The root samples were properly washed under running tap water and cleared in near boiling 10% KOH aquous solution for 24 hours. Such roots were again washed and stained in trypan blue following washing in distilled water and mounted in lectophenol mountant (Philip and Hayman, 1970). Usual microscopic techniques were followed to examine the infection in the root of different plant species and the percentage infection was calculated as follows:

$$\text{Percent root colonization} = \frac{\text{Number of root segments colonized}}{\text{Total number of root segments observed}} \text{ X } 100$$

The chloroform fumigation extraction method as proposed by Carter (1991) was used for estimation of microbial biomass. The microbial biomass was expressed on the oven dry (105^0 C for 24 hrs) soil basis.

3. Results and Discussion

3.1. Physico- chemical Properties of Soil and Heavy Metal Analysis

Due to rehabilitation activities, physico-chemical properties of soil like bulk density, water holding capacity, pH, electrical conductivity (ms/cm), organic matter content of soil, fertility status (available N, available P and available K), Ca, Na, and heavy metals toxicity of Cu, Zn, Fe and Mn are liable to be modified. These aspects had been assessed to understand the impact of reclamation on physical attributes of mine spoils.

The soil is primarily sandy- loam. The geology of the area is covered by the sediments of Barakar formation with a thin cover of soil and alluvium at places. The overburden dumps are characterized by wide gully erosion and seasonal rain cuts. The angle of repose being 27^0. However, the angle of repose exceeds even 60^0 in some dumps, leading to excessive runoff and sediment transfer, development of gullys and disintegration of loosely packed dumps. The height of overburden dumps varies from 100m to 150m comprising different benches of 20 – 30m height each.

Table 1 shows the physico-chemical properties, nutritional attributes and heavy metal status of reclaimed over dumps of Jhingurdah OCP. Various properties of different aged plantations are discussed in the following text.

3.1.1. Bulk Density

Bulk density of reclaimed soil was found to be reducing from 1.7g/cm^3 in OB plantation of year 2003-04 to 1.6 g/cm^3 in OB plantation of year 2000-01. This is due to addition of organic matter in the soil after litter decomposition in the soil. Against this, the value of bulk density in plain plantation of 2000-01 was found to be 1.4 g/cm$^{3.}$ In the plain plantation of 1995-96

and 1990-91, the bulk density was found to be 1.3 and 1.4 g/cm^3 respectively. The lower bulk density in plain plantations as compared to OB plantations was due to difference in their ages.

3.1.2. Water Holding Capacity (%)

Water holding capacity of reclaimed soil was found to be increasing from 25.06 % in OB plantation of year 2003-04 to 47.74% in OB plantation of year 2000-01. Against this, the value of water holding capacity in plain plantation of 2000-01 was found to be 25.06%. In the plain plantation of 1995-96 and 1990-91, the water holding capacity was found to be 27.34% and 31.10% respectively.

3.1.3. pH

The pH of reclaimed soil was found to be increasing from 6.30 in OB plantation of year 2003-04 to 6.68 in OB plantation of year 2000-01. Against this, the value of pH in plain plantation of 2000-01 was found to be 6.30. In the plain plantation of 1995-96 and 1990-91, the pH was found to be 5.49 and 5.45 respectively.

3.1.4. Electrical Conductivity

The EC of reclaimed soil was found to be improving from 0.059 ms/cm in OB plantation of year 2003-04 to 0.070ms/cm in OB plantation of year 2000-01. Against this, the value of EC in plain plantation of 2000-01 was found to be 0.059 ms/cm. In the plain plantation of 1995-96 and 1990-91, the EC was found to be 0.033 ms/cm and 0.050 ms/cm respectively. The improvement in electrical conductivity of soil with the increase of age of plantations was due to enrichment in the organic matter of soil and significant improvement in water holding capacity.

3.1.5. Organic Matter

The organic matter of reclaimed soil was found to be increasing from 1.55% in OB plantation of year 2003-04 to 1.627% in OB plantation of year 2000-01. Against this, the value of organic matter in plain plantation of 2000-01 was found to be 1.55%. In the plain plantation of 1995-96 and 1990-91, the organic matter was found to be 2.26% and 1.75% respectively.

3.1.6. Available Nitrogen

The available nitrogen of reclaimed soil was found to be increasing from 311.2 kg/ha in OB plantation of year 2003-04 to 315.5 kg/ha in OB plantation of year 2000-01. Against this, the value of available nitrogen in plain plantation of 2000-01 was found to be 315.2 kg/ha. In the plain plantation of 1995-96 and 1990-91, the available nitrogen was found to be 258.29kg/ha and 332.00 kg/ha respectively.

3.1.7. Available Phosphorus

The available P of reclaimed soil was found to be increasing from 8.38 kg/ha in OB plantation of year 2003-04 to 9.25 kg/ha in OB plantation of year 2000-01. Against this, the

value of available P in plain plantation of 2000-01 was found to be 9.38kg/ha. In the plain plantation of 1995-96 and 1990-91, the available P was found to be 9.47kg/ha and 10.20 kg/ha respectively.

3.1.8. Available Potassium

The available K of reclaimed soil was found to be increasing from 81.76 kg/ha in OB plantation of year 2003-04 to 113.77 kg/ha in OB plantation of year 2000-01. Against this, the value of available K in plain plantation of 2000-01 was found to be 61.76kg/ha. In the plain plantation of 1995-96 and 1990-91, the available K was found to be 64.75kg/ha and 110.42 kg/ha respectively.

3.1.9. Calcium

The Ca of reclaimed soil was found to be increasing from 118.4 kg/ha in OB plantation of year 2003-04 to 338.75 kg/ha in OB plantation of year 2000-01. Against this, the value of Ca in plain plantation of 2000-01 was found to be 118.4kg/ha. In the plain plantation of 1995-96 and 1990-91, the Ca was found to be 298.75kg/ha and 389.00 kg/ha respectively.

3.1.10. Sodium

The Na of reclaimed soil was found to vary from 19.00 kg/ha in OB plantation of year 2003-04 to 21.14 kg/ha in OB plantation of year 2000-01. Against this, the value of Na in plain plantation of 2000-01 was found to be 20.00kg/ha. In the plain plantation of 1995-96 and 1990-91, the Na was found to be 21.50kg/ha and 25.80 kg/ha respectively.

3.1.11. Heavy Metals

As concentration of heavy metals like Cu, Zn, Fe, and Mn is concerned, it showed the decreasing trend with increasing the age of plantations (Table-1).

The gradual improvements in soil properties after reclamation of overburden dumps were due to control of soil erosion, addition of organic matter and humus and with increasing the age of plantations. Similar results were observed by Juwarkar and Jambhulkar (2009), Nath (2009), Jain, *et. al*., (2009). They observed improved soil status under different plantation stands of different ages compared to bare over burden. Moreover, Dutta and Agarwal (2002) assessed soil characteristics and microbial activity of vegetated coal mine spoil land (NCL, Sidhi, MP) under plantations of five exotic species (*Acacia auriculiformis, Casuarina equisetifolia, Cassia siamea, Eucalyptus* hybrid and *Grevelia pleridifolia*) and found improved soil status under different plantation stands of 4 years compared to over burden. They observed that *Eucalyptus* hybrid, *Acacia auriculiformis* and *Casuarina equisetifolia* were the most suitable species in terms of modification of spoil characteristics during the revegetation process. Gradual reduction in the bulk density values of the reclaimed sites was found with increasing the age of plantations. This is in agreement with the findings of Maiti (2003), and Nath (2008). As the concentration of heavy metals like Cu, Zn, Fe, and Mn was concerned, it showed the decreasing trend in soil of rhizosphere with the increase in the age of plantations. It may be due to sorption and desorption characteristics of soil and substantial

amount of organic matter (Krishnamurti, *et. al*., 1999). The metals can also be complexed and sequestered in cellular structure becoming unavailable for translocation to the shoot (Lasat, *et. al*., 1998).

3.2 Study of Arbuscular Mycorrhizal Fungi (AMF) in Rhizosphere

Arbuscular Mycorrhizal Fungi (AMF) the synonym of VAM fungi are important microbes of soil that form symbiotic association with most of the terrestrial plants on the earth. These mycorrhizae can grow inside the roots of plants and serve them in a number of ways. These fungi are able to thrive well on poor physical substrates by extending the hyphal network to the establishing plants. These fungi provide the nutrients and make them available to plants in an utilizable form. Its role in removing heavy metals from overburden soils and their retention in its cell wall and its ability to bind soil particles proved to be very effective in reclamation efforts. The mycorrhizae are reported to moderate the adverse effect of higher temperature, improve plant–water relations and increase stomatal conductance, besides preventing various soil borne diseases. Considering the significance of mycorrhizal fungi, the study of the status of VAM, root colonization with VAM and microbial biomass was undertaken in different species planted in different year's old OB dumps and plain plantations at Jhingurdah OCP projects of NCL Singrauli.

It has been found that older plantations have huge population of AM spores in the overburden soils. In younger plantations, the AM spores were gradually decreased and found almost negligible in fresh overburden spoils. Similarly, the root colonization in different root samples was also noticed. In older plantations, all five genera of VAM fungi including *Acanlospora, Glomus, Gigaspora, Scutellospora* and *Sclerocystis* were recorded. Out of these *Acanlospora* and *Glomus* were in high frequency. The number of spores formulation are more in *Acanlospora* and *Glomus*, while *Gigaspora* and *Scutellospora* species were less in respect of number of spores. *Sclerocystis* was recorded in few samples especially in older plantations. The microbial biomass also varies in different soil samples. There is gradual decrease in biomass from older to younger overburden soil samples. It is possibly due to increase in microbial population in older plantations as the organic matter and humus is increased. The results obtained on above parameters are discussed as under:

Six plantations of different age groups raised on overburden dumps and plain areas of mining sites were taken for study. The ages of OB plantations taken for study were 6 years (2003-04), 9 years (2000-01) and 2 years (2007-08). However, adjoining plain plantations available for study were of 9 years (2001-02), 14 years (1995-1996) and 19 years (1990-91) old. The principal species taken for collection of soil samples for analysis of AM status were *Pongamia pinnata* L.Pierre, *Gmelina arborea* Roxb., *Dalbergia sissoo* Roxb., *Dendrocalamus strictus*(Roxb.) Nees, *Azadirachta indica* A. Juss., *Emblica officinalis* Gaertn., *Jatropha curcas* L., *Pennisetum pedicillatum* Trin., *Tectona grandis* Linn. f. *Eucalyptus camaldulensis* Dehnh. The data on VAM status in terms of number of spores/100 gm soil, percent root infection with VAM fungi and microbial biomass are given in table- 2, 3and 4 respectively. The data revealed that, the *Dalbergia sissoo* was found as most effective species in most of OB and plain plantations followed by *Gmelina arborea, Dendrocalamus*

strictus and *Azadirachta indica*. The results also showed the increasing trend in terms of status of VAM fungi, percent root colonization and microbial biomass, in different species with increasing the age of plantations (Table 2, 3 & 4). The findings are comparable with the observations recorded by Daft and Nicoloson (1974), Gupta and Shukla (1991), Sieverding (1991), Jamaluddin and Chandra (2009) in different studies regarding VAM status and plant succession.

Table 1. Physico -chemical properties of soils as influenced by afforestation on overburden (OB) and plain plantations at Jhingurdah, NCL Singrauli

S.N.	Properties	6 years (2003-04)	9 years (2000-01)		14 years (1995-96)	19 years (1990-91)
		OB	OB	Plain	Plain	Plain
1.	Bulk density (g/cm^3)	1.7±0.051	1.6±0.039	1.4±0.042	1.3±0.031	1.4±0.024
2.	Water holding capacity (%)	25.06±2.54	47.74±1.25	25.06±1.67	27.34 ±1.42	31.10±2.01
3.	pH	6.30±0.036	6.68±0.04	6.30±0.023	5.49±0.021	5.45±0.033
4.	EC (ms/cm)	0.059±0.013	0.070±0.01	0.059±0.021	0.0335±0.023	0.0505±0.026
5.	Organic matter (%)	1.55±0.02	1.627±0.036	1.55±0.034	2.26±0.051	1.75±0.016
6.	Available nitrogen (kg/ha)	311.2±1.75	315.5±1.56	315.2±1.72	258.29±1.96	332±1.16
7.	Available phosphorus(kg/ha)	8.38±2.50	9.95±1.14	9.38±1.34	9.47±1.63	10.20±1.80
8.	Available potassium (kg/ha)	81.76±1.36	113.77±1.43	61.76±1.31	64.75±1.63	110.42±1.26
9.	Calcium (kg/ha)	118.4±1.51	338.75±1.67	118.4±1.67	298.75±1.54	389±1.34
10.	Sodium (kg/ha)	19.00±1.74	21.14±1.36	20.10±1.47	21.50±1.61	25.8±0.97
11.	Cu (mg/kg)	0.635±0.013	0.435±0.014	0.684±0.012	0.515±0.013	0.73±0.023
12.	Zn (mg/kg)	1.68±0.02	1.38±0.02	1.806±0.04	2.07±0.01	2.34±0.04
13.	Fe(mg/kg)	11.82±0.043	14.42±0.04	11.373±0.75	11.8±0.02	-
14.	Mn(mg/kg)	6.92±0.02	5.62±0.03	4.5±0.02	6.006±0.04	6.92±0.03

Table 2. Status of AM fungi (No. of spores/100 g soil) in rhizosphere of various species in different years old OB and plain plantations at Jhingurdah, NCL Singrauli

S.N.	Species	Status of AM fungi (No. of spores/100 g soil) in different years plantations raised on OB dumps					
		19 years (1990-91)	14 years (1995-96)	9 years (2000-01)		6 years (2003-04)	2 years (2007-08)
		Plain	Plain	OB	Plain	OB	OB
1.	*Pongamia pinnata*	-	-	185		151	125
2.	*Gmelina arborea*	-	215	222	228	160	140
3.	*Dalbergia sissoo*	-	250	230		155	123
4.	*Dendrocalamus strictus*	-	-	245	245	181	-
5.	*Azadirachta indica*	-	-	-	165	145	108
6.	*Emblica officinalis*	-	-	-	230	-	105
7.	*Jatropha curcas*	-	-	-		-	128
8.	*Pennisetum pedicillatum*	-	-	-		-	148
9.	*Tectona grandis*	-	246	-	-	-	-
10.	*Eucalyptus camaldulensis*	240	-	-	-	-	-

Table 3. Percent root colonization with AM fungi of various species in different years old OB and plain plantations at Jhingurdah, NCL Singrauli

S.N.	Species	Percent root colonization with AM fungi in different years plantations raised on OB and plain areas									
		19 years (1990-91)		14 years (1995-96)		9 years (2000-01)		6 years (2003-04)		2 years (2007-08)	
		OB	Plain	OB	Plain	OB	Plain	OB	Plain	OB	Plain
1.	*Pongamia pinnata*	-	-	--		55	-	46	-	25	-
2.	*Gmelina arborea*	-	-	-	45	50	55	45	-	32	-
3.	*Dalbergia sissoo*	-	-	-	50	48	-	43	-	37	-
4.	*Dendrocalamus strictus*	-	-	-	-	51	60	50	-		-
5.	*Azadirachta indica*	-	-	-	-	-	35	35	-	26	-
6.	*Emblica officinalis*	-	-	-	-	-	35		-	30	-
7.	*Jatropha curcas*	-	-	-	-	-	-		-	27	-
8.	*Pennisetum pedicillatum*	-	-	-	-	-	-		-	35	-
9.	*Tectona grandis*	-	-	-	60	-	-		-		-
10.	*Eucalyptus camaldulensis*	-	37	-	-	-	-		-		-

Table 4. Microbial biomass (µg/g or mg/kg) in rhizosphere of various species in different years old OB and plain plantations at Jhingurdah, NCL Singrauli

S.N.	Species	Microbial biomass (µg/g or mg/kg) in different years plantations raised on OB and plain areas									
		19 years (1990-91)		14 years (1995-96)		9 years (2000-01)		6 years (2003-04)		2 years (2007-08)	
		OB	Plain	OB	Plain	OB	Plain	OB	Plain	OB	Plain
1.	*Pongamia pinnata*	-	-	-	-	29.0		24.0	-	20.0	-
2.	*Gmelina arborea*	-	-	-	-	28.0	25.7	19.9	-	20.6	-
3.	*Dalbergia sissoo*	-	-	-	48.0	30.0		39.0	-	18.6	-
4.	*Dendrocalamus strictus*	-	-	-	-	26.1	23.9	30.9	-	-	-
5.	*Azadirachta indica*	-	-	-	-	-	26.4	28.4	-	19.0	-
6.	*Emblica officinalis*	-	-	-	-	-	24.3	-	-	25.0	-
7.	*Jatropha curcas*	-	-	-	-	-	-	-	-	25.0	-
8.	*Pennisetum pedicillatum*	-	-	-	-	-	-	-	-	30.0	-
9.	*Tectona grandis*	-	-	-	46.6	-	-	-	-	-	-
10.	*Eucalyptus camaldulensis*	-	43.1	-	-	-	-	-	-	-	-

4. Conclusion

The brief accounts of the findings are summarized below:

1. Due to rehabilitation activities, physico-chmical properties of soil like bulk density, water holding capacity, pH, electrical conductivity (ms/cm), organic matter content of soil, fertility status (available N, available P and available K), Ca, Na, were found to be improved gradually with increase in the age of plantations.
2. As concentration of heavy metals like Cu, Zn, Fe, and Mn is concerned, it showed the decreasing trend with increasing the age of plantations.
3. In terms of VAM status and root colonization with VAM fungi, following species proved promising to reclaim the degraded OB dumps, *Dalbergia sissoo* Roxb., *Gmelina arborea* Roxb., *Dendrocalamus strictus* (Roxb.) Nees., *Azadirachta indica* A. Juss., *Jatropha curcas* L. and *Pennisetum pedicellatum* Trin. The most of above mentioned species were found suitable from microbial as well as from growth performance points of view to reclaim disturbed sites.

4. As far as microbial biomass, VAM status and root colonization of different planted species is concerned, it was found that older plantations have huge population of AM spores in the overburden soil. In younger plantations, the AM spores were gradually found decreasing and found almost negligible in fresh overburden soil. Similarly, the root colonization in different root samples was noticed. In older plantations all five genera of VAM fungi including *Acanlospora, Glomus, Gigaspora, Scutellospora* and *Sclerocystis* were recorded. Out of these *Acanlospora* and *Glomus* were in high frequency. The number of spore formulation are more in *Acanlospora* and *Glomus*, while *Gigaspora* and *Scutellospora* species were less in respect of number of spores. *Sclerocystis* was recorded in few samples especially in older plantations. The microbial biomass was also varied in different soil samples. There was a gradual decreasing trend found pertaining to microbial biomass from older age to younger aged overburden plantations. It is possibly due to more microbial population in older plantations and the rich organic matter and humus.

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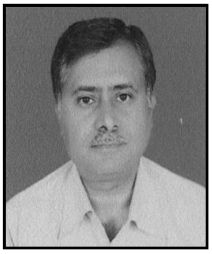

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