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Species Diversity of Arbuscular Mycorrhizal (AM) Fungi in Dalli-Rajhara Iron Mine Overburden Dump of Chhattisgarh (Central India)

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A B S T R A C T

We investigated the diversity of AM fungi in Dalli-Rajhara (Chhattisgarh, India) mine overburden (OB) dump and compares with natural forest soils of adjoining areas. Soil samples were collected from rhizosphere region of planted and naturally growing tree species in mine OB dump. AM spore was isolated by wet sieving and decanting and sucrose floatation method, spore density (per 100g dry soil) was calculated. On the basis of morphological character isolated AM fungi of 9 families and 10 genera were identified namely, Ambisporaceae (*Ambispora*), Archaeosporaceae (*Archaeospora*), Acaulosporaceae (*Acaulospora*), Diversisporaceae (*Diversispora*), Entrophosporaceae (*Entrophospora*), Gigasporaceae (*Gigaspora, Scutellospora*), Pacisporaceae (*Pacispora*), Glomeraceae (*Glomus*) and Paraglomaceae (*Paraglomus*). Total 71 species were identified among them *Glomus* spp. was found to be the most taxonomically diverse with 18 to 29 species followed by *Acaulospora* spp. (10-16 species).

Introduction

The nature bestowed India with highly valuable forest and rich mineral resources. Throughout the human civilization, human has been exploiting these resources without bothering for replenishment. In mining area exploitation of mineral resources is the stepping stone for development (Ghosh, 1990). Mining is the second largest industry after agriculture and has played a vital role in the growth of civilization from ancient days (Khoshoo, 1984). It contribute 2nd to the national GDP (Gross Domestic Product) (4%) occupying 36 lakh ha (0.11%) of total land area (329 m ha) and providing employment generation for 1.1 million people of the country (Saviour, 2012). Chhattisgarh is the richest state in terms of mineral wealth with 28 varieties. Rich deposits of bauxite, limestone, dolomite, coal, iron ore and limestone. Deposits of diamonds, gold, base metal, alexandrite, gemstones, beryl, garnet and rock crystal and corundum are found in the state (CMDC).

Exploitation of mineral resources cannot be avoided since it provides raw materials for many industries. The expansion programme of mining is very fast due to demand of raw

materials. India possesses large resources of good quality iron ore produced about 73.5 million tons of iron ore in 1999-2000 from both public sector and private sector mines and its demand of iron ore will be 190 million tons; similarly, exports have been estimated to be around 100 million tons by 2019-20 (CPCB, 2007). Vast areas of land all over the world have become unproductive by mining activity (Dhar and Thakur, 1995). It is known to leave behind an environmentally and ecologically unpleasant and un-aesthetic landscape (Singh, 2007). It exerts a long lasting impact on landscape, eco-system and socio-cultural-economic considerations (Sahu and Dash, 2011). For iron ore mine, the stripping ratio range around 2-2.5. These means that for every ton of iron ore produced, double the quantity of waste is generated (SAIL, 2008). In mining activity soil was completely altered on the basis of physicochemical properties. After mining plantation was done in degraded land by mining authority. After plantation it was observed that physicochemical properties of soil gradually improved along with the plant age and the concentration of trace elements decreased (Verma *et al.*, 2017a).

Arbuscular mycorrhizae fungi, belonging to the phylum Glomeromycota (Schubler *et al* 2001), are obligate symbionts and form associations with about 80% of plant species (Trappe 1987). Arbuscular mycorrhizal associations are the most frequent symbioses found in nature because of their broad association with plants and cosmopolitan distribution (Harley and Smith 1983; Verma, 2010).

The structural and functional aspects of this association, as evident from fossil records, appear to be quite conserved through time (Phipps and Taylor, 1996; Harley and Smith, 1983). This benevolent relationship has not only helped the emergence of first land plants (Pirozynski and Malloch, 1975) but also supported further successional establishment in widely diversified environments, viz. agricultural soils (Abott and Robson, 1978), mine soils (Jasper *et al*., 1991), coal wastes (Daft and Hacskaylo, 1976; 1977; Nicolson and Johnston, 1979) alkaline soils, desert soils (Sastry and Johri, 1999) and other habitats. Thus, they play a key role in sustainable conservation of tropical gene pool and diversity (Herrera *et al*., 1997). Furthermore, through millions of years of succession, evolution, selection and co-existence, AM fungi have helped in refining the soil quality, texture, structure, fertility and compatibility to suit the indigenous plant species. This microbial component of the plant rhizosphere endows a major task in determining plant species diversity (Moora and Zobel, 1996) and helps in stabilizing highly complex diversity regime of the tropical forests. Unfortunately, a large number of man-made and natural eco-sites have not been studied for the occurrence and the extent of dependency of the plant cover on AM fungi, particularly those representing stressed ecosystems. Now a day's application of AM fungi during raising seedlings is helpful for growth of different seedlings in nurseries condition (Verma and Verma, 2016; Verma et al., 2016; Verma *et al.*, 2017).

It has now become necessary to measure the status of existence of AM fungi in disturbed sites. Against this background, in the present investigations, an attempt was made to determine the arbuscular mycorrhizal status of in Dalli Rajhara mine overburden soil in terms of occurrence of arbuscular mycorrhizal fungi.

Materials and Methods

Study Area

The selected Dalli-Rajhara mine is under Steel Authority of India Limited (SAIL), which is opencast. It is located 100 km away

from Bhilai Nagar city, Central India. It is situated at the geographic location of 20°33'0" and 20°34'30" N latitude and 81°1'0" and 81°4'30" E longitude and Rajhara mines are bounded by 20°33'0" and 20°35'0" N latitude and 81°0'45" and 81° 07' 0" E longitude. The vegetation of natural forest is dominated by teak (*Tectona grandis* Linn. F.).

Sample collection

Waste samples were collected from different age series dump by random sampling method. The samples were collected randomly from 0-15cm depth by digging pits (15 x 15 x 15cm) from five sites for each dump. Samples were collected both from the rhizosphere of plants and from bulk soil and finally mixed to get a homogenous mixture. These sub-samples were brought to the laboratory in sterilized polythene bags and mixed thoroughly to form a composite sample. After sorting out larger pieces of materials and root fragments, the samples were subjected to sieving in 2mm mesh. Each of the samples was divided into three replicates for analysis. Soil sample from adjoining area of the waste dump was taken as control **(**Parkinson, 1979**).**

AM fungi species was isolated by wet sieving and decanting technique (Gerdemann and Nicolson 1963; Sylvia, 1994) and spore density (per 100g dry soil) were measured and described by using the data obtained; the following indices of species structure were assessed:

a) Species richness = No. of species present in a particular site

b) Relative spore density = x 100 Spore density of a particular species Spore density of all species

c) Shannon Diversity Index (H) as per Shannon and Wiener (1963): H= - Σ (ni / N ln ni / N) Where, ni = Relative spore density of each species; N = Total Relative spore density of all species

d) Simpson Diversity index = 1-D As per Simpson (1949), where D (Simpson Dominance Index) = Σ(ni / N)2 ; Where, ni = Relative spore density of each species N = Total Relative density of all species

e) Evenness index (J) as per (Pielous, 1975) J = H/ln S Where, H= Shannon Diversity Index; S = Total no. of species

Results and Discussion

Total 119 soil samples were collected from rhizosphere region of planted and naturally growing tree species in mine OB dump and NS (natural, undisturbed soil). Name of planted and naturally growing tree species was followed *Ailanthus excelsa* Roxbs., *Albizia lebbeck* Benth., *Annona squamosa* L., *Artocarpus heterophyllus* Lam., *Azadirachta indica* A. Juss., Bamboo sp., *Butea monosperma* (Lam.) Taub., *Cassia siamea* Lam., *Cassia fistula* L., *Dalbergia sissoo* DC., *Delonix regia* (Hook.) Raf., *Eucalyptus* hybrid, *Eugenia jambolana* Lamk., *Ficus benghalensis* L., *Ficus religiosa* L., *Gmelina arborea* Linn., *Gmelina robusta* A. Cunn., *Leucaena leucocephala* (Lam.) de Wit, *Mangifera indica* L., *Moringa pterygosperma* Gaertn., *Peltrophorum ptercocarpus* (DC.) K. Heyne, *Phyllanthus officinalis* L., *Polyalthia longifolia* (Sonn.) Thwaites, *Pongamia pinnata* (L.) Pierre, *Psidium guajava* L., *Tamarindus indica* L., *Tectona grandis* L.f., *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn., *Acacia auriculiformis* A. Cunn. ex Benth., *Acacia nilotica* (L.) Delile, *Ailanthus excelsa* Roxbs., *Albizia lebbeck* (L.) Benth., *Albizia odoratissima* (L.f.) Benth., *Alternanthera sessilis* (L.) R. Br. ex DC., *Anogeissum latifolia* Wall, *Argemone maxicana* L., *Azadirachta indica* A. Juss,

Blumea alata (D. Don) DC., *Butea monosperma* (Lam.) Taub., *Calotropis procera* R. Br., *Cassia alata* L., *Dalbergia sissoo* DC., *Dodonaea viscosa* Linn., *Hyptis suaveolens* (L.) Poit, *Lantana camara* L., *Nerium indicum* Mill, *Tecomas stans* (L.) Juss. ex Kunth, *Tridax procumbens* L., *Woodfodiya fruticosa* (L.) Kurz, *Ziziphus jujuba* Lam.

Isolated AM fungi belongs to 9 families and 10 genera, Ambisporaceae (*Ambispora*), Archaeosporaceae (*Archaeospora*), Acaulosporaceae (*Acaulospora*), Diversisporaceae (*Diversispora*), Entrophosporaceae (*Entrophospora*), Gigasporaceae (*Gigaspora, Scutellospora*), Pacisporaceae (*Pacispora*), Glomeraceae (*Glomus*) and Paraglomaceae (*Paraglomus*) (Fig 2).

Species richness and diversity of AM fungi

As evident from the table 1, all the 71 different AM species were isolated from the NS. However from the fresh dump (D_0), no mycorrhizal spores could be detected. From the subsequent age series dumps (D_3, D_7, D_8 and D_9) the numbers of species encountered were 51, 49, 38 and 48 respectively.

All the 71 detected species of AM fungi belong to 10 genera (Fig 2) and the genus *Glomus* was noted to be the taxonomically most diverse with 18 to 29 species. Dominance of *Glomus* was followed by *Acaulospora*.

Species like *Gigaspora* sp., *Glomus etunicatum, G. microcarpum* and *G. mosseae* absent only in 3 year old dump. In 7 year old dump *Acaulospora denticulata, Glomus caledonium* and *Pacispora scintillans* species was absent. In 8 year old dump total 11 species *Acaulospora bireticulata, A. laevis, A. mellea, Glomus clarum, G. constrictum, G. diaphanum, G. geosporum, G. minutum, G. trimurales* and *Paraglomus laccatum* was absent. Species like *Acaulospora koskei, A. scrobiculata, A. thomii, Entrophospora schenckki* and *Scutellospora nigra* was absent only in 9 year old dump. *Acaulospora cavernata, A. foveata, A. lacunosa, A. rehmii, Entrophospora sp., Gigaspora gigantea, Glomus claroides, G. clavisporum, G. coronatum, G. deserticola, G. gibbosum, G. invermaium, G. macrocarpum, G. rubiforme, G. tortuosum, Pacispora franciscana, Scutellospora heterogama* and *Scutellospora* sp. were detected in all waste dumps (Table 3).

Species like *Ambispora callosa* and *Glomus xanthium* were recorded in NS but not recorded in D_3, D_7, D_8 and D_9. *Glomus fasciculatum, G. luteum, G. multiforum* and *G. nanolumen* were only present in 3 years old dump. *G. insculptum* and *G. intraradices* only present in 8 year old dump. *G. walkeri* was only present in 7 year old dump. *Ambispora appendicula, Diversispora spurca, Gigaspora margarita* was only present in 9 year old dump. Species like *Acaulospora delicata* and *A. trappei* was absent in 3 and 9 year old dump. *Acaulospora spinosa, Archaeospora trappei, Entrophospora baltica, Glomus reticulatum* and *G. versiforme* were absent in 8 and 9 year old dumps. *G. aggregatum, G. monosporum, G. heterosporum, G. lamellosum* were absent in 7 and 8 year old dumps. *G. ambisporum* and *Scutellospora pellucida* was absent in 3 and 7 year dump. In 7 and 9 year old dump *Glomus callosum* and *Glomus flavisproum* was absent (Table 3).

Value of species richness, species diversity and evenness of fungi are tabulated in table 1. In dump soil species richness was highest in 3 year old plantation (51) and this gradually decreased with increasing age of OB, expect for 8 year old plantation (38). When compared with species richness of NS (71 species) the OB soil. Shannon wiener diversity index was 1.4 in all age dump soil

and NS, expect 8 year old plantation. Simpson diversity index of all age dumps and NS was all most similar, expect 8 year old plantation. The species evenness ranges from zero to one with zero signifying no evenness and one a complete evenness. The value of evenness ranged between 0.7763-0.86177, which is near complete evenness. Maximum evenness in dump soil was observed in 3 year old plantation followed by 8 year old plantation. Nine and seven year old plantation have almost similar evenness index. The value of evenness index indicated even distribution of the different AM species in all the waste dumps.

Similarity index (Sorensen coefficient) of AM fungi

As per data (Table 2) analysis it was found that species similarity in different age OB dumps. Three year and seven years old dumps species similarity was 76.77%. Maximum species similarity was observed in between 3 year old plantation and natural soil (82.64%) followed by between 7 year old plantation and natural soil (80.67%) and 9 year old plantation and natural soil (80.67%). Minimum species similarity was observed in between 7 and 8 year old plantation (60.42%) followed by between 8 and 9 year old plantation (60.42%).

SHE analysis of AM fungi

Modified SHE analysis was undertaken to observe the changes in pattern of Species richness (S), Diversity (H') and Evenness (E) with the increase age of OB dump. The figure (1) shows that with the increasing age species richness is increasing, the diversity in the OB dumps has decreased from 3 year old dump to 7 year old dump after which it remains constant. The Evenness was constant in all the dumps. AM spore is more influence by species richness with the increase in richness the diversity increased there was negligible effect of evenness (J') on the Diversity index (fig 1).

Mycorrhizae are composed of a complex number of species, which differ in their environment tolerances, physical requirement and most importantly their habitat adaptation. The occurrence and distribution of AM fungi varies with physio-chemical properties of soil. The density of propagules varies from site to site and plant to plant (Allen and Allen, 1980). The measure the potential importance of AM fungi in the recovery of disturbed site and land reclamation. It has now become necessary to measure the status of existence of AM fungi in disturbed sites.

The distribution of AM fungi in stressed soils of iron ore sites was study by Kullu and Behera, 2012; Sastry and Johri, 1999; Jasper *et al*., 1987. Barea *et al*., 1997; Sanchez-Diaz *et al*., 1990; Mehrotra, 1995; Evelin *et al*., 2009; Singh, 2007; Mukhopadhyay and Maiti, 2010 reported that with the improvement of the spoil physico-chemical properties there is an establishment of mycorrhizae in mine spoil OB dumps and such development is expected to play a major role for the plant nutrition ultimately helping in reclamation of the dump.

In the present study as many as 71 mycorrhizae species was recorded the genus *Glomus* spp. was noted to be most abundant mycorrhizae in the mine spoil dump and it was followed by *Acaulospora* spp. Availability of *Glomus* spp. with respect to wild, soil and environmental conditions and host species has been reported by earlier workers (Jha *et al*., 1994; Ruiz-Lozano, 2003; Pande and Tarafda, 2004; Vivas *et al*., 2005; Sharma *et al*., 2009**;** Cano-Bago, 2009; Kullu and Bahera, 2012). The dominance of this genus has been ascribed due to its smaller sized spores, which are reported to take

shorter duration to sporulate and reproduce (Nandakwang *et al.*, 2008). As noted in the present study, three genera *Glomus, Acaulospora,* and *Scutellospora* were the major contributor to this spore density. And this is in confirmation with the findings of many workers (Makonese *et al*., 1999; Sharma *et al*., 2009; Sarwade *et al*., 2011). These results were similar with present finding.

The mycorrhizae spore density which exhibited increasing trend with increasing age of the dump is in confirmation with the findings of earlier workers (Loree and Williams, 1987;Williamson and Johnson, 1991; Mukhopadhyay and Maiti, 2010; Kullu and Behera, 2012). But in present finding observed that no correlation with age, three year dump have maximum spore and its reduced with increasing age of dumps expect eight year dumps. These may be due to age of dump was increase invasive species was grown, and root colonization with invasive species was very poor or absent (Simelane 2002; Sharm *et al*., 2005; Bhale *et al*.,2011; Chandra and Kehri, 2006). Diversity of the AM fungal communities have been related the diversity of the plant communities (Rabatin and Stinner, 1989).

As the age of the sponge iron waste dump increases, diversity of the plant also increases (Kullu and Behera, 2012), this can be correlated with the increasing diversity of the AM fungi in different age series sponge iron solid waste dump.

Gour *et al.,* (1998) reported the occurrence of AM fungi along with tree species namely *Terminalia arjuna, Syzygium cuminii. Populas euphartica* and naturally grown *Typha elephetina* at rehabilitated water logged site. They reported that genera *Glomus* and *Gigaspora* were the dominant ones. Mukerji and Kappor, (1986) reported the dominance of *G. mosseae* and *G. fasciculatum* in alkaline soils**.** Unyal, (2001) reported varied density of AM fungi which *Glomus macrocarpum* dominated in phosphate mined area. The distribution of AM spores in mine spoils may also be affected by carriers like wind and animals, which dispersed the fungi to new habitat (Allen and Allen, 1992).

Ganesan *et al*., (1991) reported *Glomus aggregatum* as a common species in coal, lignite and calcite mine spoils in India. Selvam and Mahadevan, (2002) surveyed the fly ash pond and mined sites of Neyveli Lignite corporation in Tamil nadu and found 15 AM fungi species in ash pond, 4 AM fungi species in OB dumps and 13 AM fungi species in reclaimed OB. In the entire site, *Glomus mosseae* was the dominant AM fungus.

Mehrotra and Prakash, (2006) reported occurrence of 9 described AM fungi species viz. *Acaulospora scrobiculata, Glomus geosporum, G. aggregatum, G. tortuosum, G. microaggregatum, G rubiformis, G. intraradices, Scutellospora calospora* and *Entrophospora colombiana* from a reclaimed surface mining OB at the Jayant open cast coal mine site of Northern coalfields Ltd., Singrauli, Uttar Pradesh. But in present finding in 3 year dump *Glomus lamellosum,* 8 year dump Glomus *microcarpum*, 9 year dump *Glomus diaphanum* and in natural soil *Glomus deserticola.*

Chandra and Jamaluddin, (1999) reported that the occurrence of AM fungi namely *Acaulospora, Glomus, Gigaspora, Scutellospora* and *Sclerocystis* genus in coal mine spoils along with 13 forest tree species of different age groups. They also reported that the genus *Acaulospora* was most dominant fungi in coal mine spoil while *Glomus* and *Gigaspora* species also got significant position. Tarafdar and Rao, (1990)

recorded *Acaculospora* from the rhizosphere of *Azadirachta indica, Parkinsonia aculeata, Albizia lebbek* and *Zizyphus mauritiana.* But in present finding only in 7 year dump *Acaulospora biretiulata* was dominated.

The endomycorrhiza form Arbuscules (Gianinazzi and Gianinazzi-Pearson, 1986), Vesicles and Pelotons (Powell and Bagyaraj, 1984) and some genera produce auxiliary cells, found to occur in more than 90% of vascular plants (Gerdemann, 1968; Sylvia *et al.*, 1993).

The arbuscules are the most significant structures in AM and is the site for the exchange of carbon and phosphate metabolite between the fungus and plant (Smith and Smith, 1990). These structures contain dense non-vacuolated cytoplasm during early stage of development and vacuolation increases with maturity. Vesicles are the lipid filled storage organs (Cox *et al.*, 1975). The external mycelium is dimorphic (Nicolson, 1959) and is essentially a non septate one with one sided angular projections (Butler, 1939).

The occurrence of genus *Gigaspora* in the rhizosphere was reported in *Acacia Senegal* and *Casuarina equsltifolia* by Diem *et al.*, (1981) and in *Acacia amera, A. tortilis, Azadirachta indica, Bauhinia racemosa, Eucalyptus camaldulensis* and *Prosopis juliflora* by Tarafdar and Rao, (1990). Another genus *Sclerocystis* was recorded from *Tectona grandis* and *Dalbergia sissoo* by Gerdemann and Bakshi, (1976). Both AM fungi were also isolated from our study site mine land OB. Kumar *et al*., (2003) reported AM spore density and their colonization also positively correlated.

The most commonly genus of AM spores found are *Glomus, Gigaspora*, *Acaulospora*, *Enterophospora* and *Sclerocystis*. *Glomus* and their size frequency distribution range from 50-75 µm and 75-100 µm.

The highest number of AM spore density/5 g of soil were found as 360.0±12.5 and for AM spore density/100g of soil were found as 702.0 ± 23.87 in mine 3 followed by 193.0±9.45 mine 2 and 174.0±11.67 mine. The highest number of AM spore density was reported under the *Acacia auriculoloformis*.

Table.1 Species richness and diversity of AM fungi in iron ore waste dump and natural soil ((D0= fresh dump, D3 =three years old dump, D7 = seven year, D8 eight year and D9 = nine year old dump)

S.No.	Waste dumps	Species richness	Diversity index		Evenness index
			Shannon	Simpson	
1.	D_0	–	–	–	–
2.	D_3	51	1.44885	0.95096	0.86177
3.	D_7	49	1.43715	0.95846	0.7763
4.	D_8	38	1.29739	0.93952	0.84715
5.	D_9	48	1.43949	0.95715	0.7775
6.	NS	71	1.46709	0.94626	0.79248

Table.2 Similarity index (Sorensen coefficient) of AM fungi ((D0= fresh dump, D3 =three years old dump, D7 = seven year, D8 eight year and D9 = nine year old dump)

	D_3	D_7	D_8	D_9	NS
D_3	1				
D_7	76.77	1			
D_8	62.92	60.42	1		
D_9	70.71	72.92	62.79	1	
NS	82.64	80.67	69.72	80.67	1

Table.3 Relative spore density of AM fungi ((D0= fresh dump, D3 =three years old dump, D7 = seven year, D8 eight year and D9 = nine year old dump)

S. No.	Name of AM fungi	**Relative spore density**				
		D3	D7	D8	D9	NS
1	*Acaulospora bireticulata*	2.88	3.53	0	3.16	2.8
2	*A. cavernata*	0.15	1.09	0.33	0.81	0.147
3	*A. delicate*	0	0.82	0.33	0	0.221
4	*A. denticulate*	0.08	0	4.84	0.73	0.221
5	*A. foveata*	0.91	3.26	1.17	0.08	0.295
6	*A. koskei*	3.03	1.36	0.5	0	0.074
7	*A. lacunose*	2.42	2.85	0.83	1.94	2.579
8	*A. laevis*	0.15	2.45	0	0.32	3.021
9	*A. mellea*	2.57	1.09	0	0.49	0.221
10	*A. rehmii*	0.45	2.85	7.01	3.08	3.095
11	*A. scrobiculata*	4.012	2.85	0.67	0	3.611
12	*A. spinosa*	0.53	2.85	0	0	0.147
13	*A. thomii*	0.3	0.54	0.33	0	0.368
14	*A. trappei*	0	0.41	0.33	0	0.221
15	*Ambispora appendicula*	0	0	0	0.97	0.147
16	*A. callosa*	0	0	0	0	0.074
17	*A. fennica*	0	1.09	0	6.8	0.516
18	*Archaeospora trappe*	0.45	0.14	0	0	0.147
19	*Diversispora spura*	0	0	0	3.97	2.063
20	*Entrophospra baltica*	0.23	0.54	0	0	0.295
21	*E. schenckki*	2.35	0.27	0.84	0	1.326
22	*Entrophospra* sp.	0.68	1.22	4.84	0.4	0.221
23	*Gigaspora gigantean*	3.18	4.35	7.01	3.97	0.368
24	*G. margarita*	0	0	0	0.16	2.874
25	*Gigaspora* sp.	0	2.99	3.56	2.59	0.442
26	*Glomus aggregatum*	1.59	0	0	0.08	7.148

27	*G. ambisporum*	0	0	0.5	0.08	1.179
28	*G. callosum*	2.35	0	0.33	0	0.295
29	*G. caledonium*	0.15	0	0.17	0.16	0.368
30	*G. claroides*	0.3	3.13	7.01	3.64	0.221
31	*G. clarum*	4.47	0.4	0	3.08	0.368
32	*G. clavisporum*	2.73	3.26	8.85	6.4	0.147
33	*G.constrictum*	1.44	2.85	0	0.81	2.8
34	*G. coronatum*	1.21	1.63	3.84	3.4	1.4
35	*G. deserticola*	2.04	5.3	9.85	7.21	3.464
36	*G. diaphanum*	5.45	1.09	0	5.26	0.59
37	*G. etunicatum*	0	3.26	8.01	2.75	1.548
38	*G. fasciculatum*	0.61	0	0	0	12.45
39	*G. flavisproum*	0.91	0	0.33	0	0.147
40	*G. geosporum*	1.82	0.82	0	1.7	4.716
41	*G. gibbosum*	2.12	7.61	4.17	5.59	0.147
42	*G. heterosporum*	3.56	0	0	0.08	0.147
43	*G. insculptum*	0	0	0.33	0	0.368
44	*G. intraradices*	0	0	0.5	0	5.306
45	*G. inveranum*	0.08	5.16	6.01	4.53	0.295
46	*G. lamellosum*	7.95	0	0	0.65	0.221
47	*G. luteum*	2.57	0	0	0	0.368
48	*G. macrocarpum*	0.15	1.22	5.18	0.65	7.59
49	*G. microcarpum*	0	8.7	6.34	5.43	1.326
50	*G. minutum*	13.48	0.54	0	4.78	0.074
51	*G. monosporum*	2.04	0	0	0.08	0.295
52	*G. mosseae*	0	0.41	0.67	4.94	10.91
53	*G. multiforum*	1.97	0	0	0	0.221
54	*G. nanolumen*	0.08	0	0	0	0.147
55	*G. reticulatum*	1.21	0.41	0	0	0.516
56	*G. rubiformi*	0.08	6.39	4.17	1.7	0.442
57	*G. tortuosum*	5.45	6.11	0.84	1.7	0.295
58	*G. trimurales*	5.22	1.36	0	3.97	0.074
59	*G. versiforme*	3.71	0.95	0	0	2.063
60	*G. walker*	0	0.27	0	0	1.326
61	*G. xanthium*	0	0	0	0	0.221
62	*Pacispora franciscan*	0.3	0.41	0.5	0.57	0.221
63	*P. scintillans*	0.38	0	0.33	0.08	0.295
64	*Pacispora* sp.	0	0.41	0	0.16	0.442
65	*Paraglomus lactum*	0.23	0.41	0	0.97	2.284

66	*Scutellospora armeniaca*	0	0	0	0.08	0.147
67	*S. gregaria*	0	3.53	0	3.16	0.147
68	*S. heterogama*	2.88	1.09	0.33	0.81	0.442
69	*S. nigra*	0.15	0.82	0.33	0	1.105
70	*S. pellucid*	0	0	4.84	0.73	0.074
71	*Scutellospora* sp.	0.08	3.26	1.17	0.08	0.147

Fig.1 SHE analysis of AM fungi

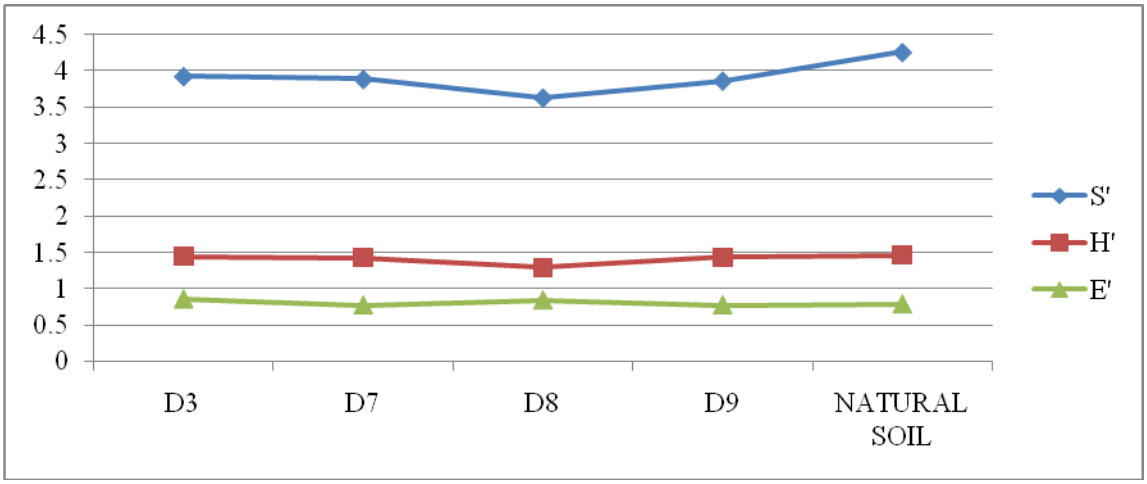
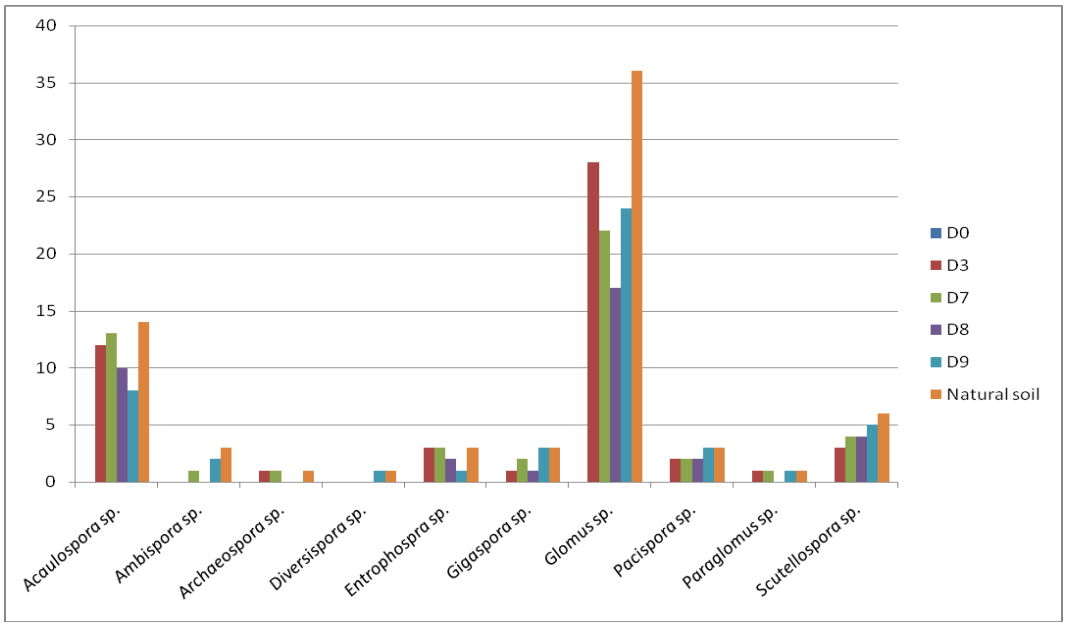


Fig.2 AM genera represented by different number species recorded in iron ore waste dumps and natural soil (NS) (D0= fresh dump, D3 =three years old dump, D7 = seven year, D8 eight year and D9 = nine year old dump)



Chong (1988) and Rathi and Singh (1990) reported AM association in *Acacia*

auriculiformis, Cassia fistula, C. siamea, Leucaena leucocephela, Samanea saman and *Tectona grandis.* Raghupathy and Mahadevan (1993) observed the infection of AM in *Gmelina arborea* and *Bamboo* spp. Santhaguru *et al.,* (1995) reported that AM infection was 100% in *Albizia amara, Peltophorum pterocarpum* and *Pongamia glabra.*

SHE analysis

SHE Graph was plotted against the age of the dumps to study the change in phyto sociological characters and species accumulation on the OB dumps with increasing age. the plot (Fig. 1) showed that the species diversity (H') was highest in the 3 year old dumps, it decreased in 7 year old dumps after which it was near constant. It may be due to (i) availability of phosphorous was increased due to decomposition of parent rock, increased availability of phosphorous decreases the diversity of mycorhiza in soil (Abbott and Robson, 1977; Smith, 1982; Olsson *et al*., 1997) (ii) after 7 year of plantation the empty spaces in the plantations were occupied by the fast growing Invasive species, it was found during the study that there was no mycorhizal association with *Lanatana camara*, this may be one of the reason of low mycorhizal diversity in dumps more than 7 year old. There was no change in evenness of the species with increasing age of dump, while species richness increased through time. It can be concluded from SHE analysis that the diversity index in the overburden areas is mostly regulated by evenness in the community. As observed in the present study, mycorrhizae spore density (in terms of Shannon's diversity index H) also showed an increasing trend with the increase in the age of the dump. Such increasing trend has also been noticed by Mukhopadhyay and Maiti, (2010) for some Indian coal mine spoil.

In conclusion, total 71 species of AM fungi belonging 9 families and 10 genera were identified from mine overburden dump and adjoining natural forest soil. *Glomus* species were found to be the most taxonomically diverse with 18 to 29 species followed by *Acaulospora* spp (10-16 species).

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