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Mini Review

Arbuscular Mycorrhiza: Their distribution and association with plants in the revegetated mine spoils of India – an overview

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Reclamation of mine spoils is receiving considerable attention in the recent years due to the ill effects of mining and dumping of the mine spoil waste leading to various environmental hazards. Mycorrhizal inoculation of mine spoils and mine spoil dumps is essential for the establishment of a diverse plant community and a better ecosystem. This review focuses on the status of AM fungi, their distribution, diversity and density in the various mine spoils and mine spoil dumps of India. Species belonging to the genus *Glomus* was found to be widely distributed among the mine spoils. Legumes were the dominant and tolerant plants of the mine spoils supporting mycorrhizal colonisation.

Keywords: AM fungi, *Glomus*, India, legumes, mine spoils.

Arbuscular mycorrhiza helps in the maintenance of plant biodiversity, microbial community, ecosystem stability and function. They play an indomitable role in the restoration of the degraded lands. India is the second largest country with a total land area of 5.7 lakh sq.kms in working mines. Mining leads to excessive soil damage by altering the natural ecosystem, ecological integrity and the mycorrhizal network prevailing in the soil. In spite of the vast mining operations and serious hazards involved due to mining, only very little research has been done on the mycorrhizal status in the mine spoils of India. No serious attempts have been made on the reclamation technology for the reclamation of mine spoils in India. Hence there is an urging need to establish a suitable mycorrhizal technology for the reclamation of mine spoils in India. This paper gives an overview of the dominant AM Fungal species and the mycotrophic plants of the mine spoils. A suitable reclamation technology may be developed with these plant species for the speedy revegetation of the mine spoils.

Distribution of AM fungi in various mine spoils

Nine species of VAM fungi belonging to the 3 major genera *viz.*, *Acaulospora*, *Glomus* and *Gigaspora* were identified from a rehabilitated coal mine spoil at Bisrampur, Madhya Pradesh (Dugaya et al., 1996). *Acaulospora*, *Glomus* and *Gigaspora* species were commonly found, while *Scutellospora* and *Sclerocystis* species were scarce in the coal mine overburden spoils at Kusmunda in Bilaspur district of Madhya Pradesh (Chandra and Jamaluddin, 1999).

VAM fungal infection varied from plant to plant among the thirty one plant

species, including legumes, grasses and sedges found growing naturally in the gypsum mine spoil in Rajasthan. The percent root infection was higher among the plants growing in mine spoil than those found in the normal soil (Tarafdar and Rao, 1997).

Only *Glomus globiferum* was present in the recently revegetated lignite mine spoil (1-2 years old) of Neyveli, while the adjacent undisturbed area possessed 23 VAM species (*Entrophospora colombiana, Gigaspora albida, Gi. gigantea, Gi. margarita, Glomus albidum, G. aggregatum, G. ambisporum, G. citricoloum, G. claroidium, G. clarum, G. constrictum, G. deserticola, G. dimorphicum, G. etunicatum, G. fecundisporum, G. heterosporum, G. intraradices, G. macrocarpum, G. maculosum, G. mosseae, G. pustulatum, G. tenue, Sclerocystis coremioides, Sc. papillosa, Scutellospora aurigloba* and *S. pakistanica*). Only *G. aggregatum* and *G. pustulatum* were present in the oldest (25 years) disturbed mine spoil site (Ganesan et al., 1990).

Glomus was the most dominant genus isolated among the various mine spoils and mine spoil dumps in India (Ganesan et al., 1990; Dugaya et al., 1996; Selvam and Mahadevan, 2002; Mukhopadhyay and Maiti, 2010).

Glomus mosseae was commonly found in various mine spoils (Ganesan et al., 1990; Selvam and Mahadevan, 2002; Mukhopadhyay and Maiti, 2010; Singh and Jamaluddin; 2011). *G. aggregatum* was present in the coal, lignite and magnesite mine spoils, while *G. ambisporum* was common in the calcite, coal and lignite mine spoils. The other dominant species colonising the mine spoils in their decreasing order of magnitude were *G. deserticola, G. fasciculatum, G. heterosporum* and *G. intraradices.* The dominant status of the genus *Glomus* over the other genera might be due to the sporogenous characteristics of the fungi. Species of *Glomus* and *Acaulospora* produce small spores in a short time compared to the large spores produced by species of *Gigaspora* and *Scutellospora* in the same environment (Nandakwang et al., 2008).

Entrophospora colombiana was the only species in the genus *Entrophospora* to be found in the mine spoils and dumps. It was commonly present among the coal and lignite mine spoils (Ganesan et al., 1990; Mehrotra, 1998).

Some of the other species commonly found in various mine spoils and dumps were *Acaulospora scrobiculata, Gigaspora gigantea, Gi. margarita, Sclerocystis microcarpus, Sc. pachycaulis, Scutellospora aurigloba, S. erythropa* and *S. Persica* (Table 1).

Most of the plants growing in the mine spoil possessed mycorrhizal association. The intensity of infection increased with the increasing age of mine spoils. The mycorrhizal inoculum needed for the infection seem to be available from the adjoining forest areas or rehabilitated sites. *Acacia auriculiformis, A. nilotica, Azadirachta indica*, *Dalbergia sissoo*, *Dendrocalamus strictus, Casuarina equisetifolia, Cassia siamea, Pithecellobium dulce* and *Gmelina arborea* were some of the dominant mycotrophic plants of the mine spoils in India (Table 2).

Most of these plants belong to the order leguminosae and possess nodules in their roots which help them in fixing atmospheric nitrogen. With the help of mycorrhizal association and root nodules, these plants were able to survive efficiently in the degraded soils. Plants belonging to the family Amarantaceae and Cyperaceae (*Achyranthes aspera, Alternanthera sessilis, A. pungens, Celosia argentea Cyperus difformis* and *C. rotundus*) which were reported to be non-mycorrhizal, were found to be mycorrhizal. The low levels of phosphorus and nitrogen in the soil might have lead to the increased probability of infection in such plants as reported by Mosse and Phillips, 1971. However, the plants of the family Cleomaceae were found to be non-mycorhhizal, irrespective of the soil conditions.

Factors affecting mycorrhizal colonisation in mine spoils

The density and distribution of AM fungi depends on the age of the revegetated site, degree of surface soil disturbance, amount of homogeneous topsoil, and presence of susceptible root material (Loree at al., 1987; Maiti, 1997; Singh and Jamaluddin, 2006), depth of the soil (Kabir et al., 1998; Xueli et al., 2002) and the physico-chemical nature of the soil.

Table-1: AM Fungi collected from various naturally revegetated mine spoils of India

Place of Collection	*Acaulospora* sps.,	*Entrophospora* sps.,	*Gigaspora* sps.,	*Glomus* sps.,	*Sclerocystis* sps.,	*Scutellospor a* sps.,	Reference
Calcite mine spoil, Thazhaiyuthu, Tirunelveli, Tamil Nadu	_	_	_	*G. ambisporum* *G. claroidium* *G. deserticola* *G. dimorphicum* *G. heterosporum* *G. multicaule* *G. pulvinatum* *G. pustulatum*	*Sc. pachycaulis* *Sc. sinuosa*	*S. gregaria*	Ganesan *et al.,* 1990
Coal mine spoils, Kothagudem, Andhra Pradesh	*A. foveata*	*E. colombiana*	_	*G. aggregatum* *G. ambisporum* *G. botryoides* *G. citricoloum* *G. claroidium* *G. fasciculatum* *G. heterosporum* *G. mosseae*	*Sc. microcarpus* *Sc. rubiformis*	_	Ganesan *et al.,* 1990
Coal mine site, Chandrapur, Maharashtra	*A. scrobiculata*	*E. colombiana*	_	*G. aggregatum* *G. ambisporum* *Glomus* spp.,	_	*S. calospora*	Mehrotra, 1998
Lignite mine spoil, Neyveli, Tamil Nadu	_	*E. colombiana*	*Gi. albida* *Gi. gigantea* *Gi. margarita*	*G. albidum* *G. aggregatum* *G. ambisporum* *G. citricoloum* *G. claroidium* *G. clarum* *G. constrictum* *G. deserticola* *G. dimorphicum* *G. etunicatum* *G. fecundisporum* *G. heterosporum* *G. intraradices* *G. macrocarpum* *G. maculosum* *G. mosseae* *G. pustulatum* *G. tenue*	*Sc. coremioides* *Sc. papillosa*	*S. aurigloba* *S. pakistanica*	Ganesan *et al.,* 1990
Overburden dumps of Neyveli Lignite Corporation, Neyveli, Tamil Nadu	*A. gerdemanii*	*E. colombiana*	*Gi. gigantea* *Gi. margarita*	*G. fasciculatum* *G. macrocarpum* *G. mosseae* *G. vesciculiformis*	*Sc. microcarpus* *Sc. pachycaulis*	*S. corolloidea* *S. erythropa* *S. persica* *S. verrucosa*	Selvam and Mahadev an, 2002
Magnesite mine spoil, Salem, Tamil Nadu	*A. bireticulata*	_		*G. aggregatum* *G. fasciculatum* *G. intraradices*	*Sc.microcarpus* *Sc. dussii* *Sc. pachycaulis*	*S. aurigloba* *S. erythropa* *S. nigra* *S. persica*	Raman *et al.,* 1992
Limestone mine spoil, Odisha	*A. denticulata* *A. scrobiculata* *A. delicata*	_	*Gi. rosea,* *Gi. gigantea,* *Gi. margarita*	*G. arborense* *G. deserticola* *G. fasciculatum* *G. intraradices* *G. mosseae*	_	*S. heterogama* *S. persica* *S. verrucosa*	Singh and Jamaludd in, 2011

Table-2: Mycorrhizal status of plants occurring in various revegetated mine spoils of India

Name of the plants	C	Co	L	Li	M	AM Colonisation	Percent root colonisation
Monocot plants							
Agavaceae	-	-	+	-	-	+	10
Agave angustifolia[1]							
Arecaceae							
Cocos nucifera[1]	-	-	+	-	-	Soil only	
Phoenix sylvestris[2]	-	-	-	-	+	+	58
Cyperaceae							
Cyperus difformis[2]	-	-	-	-	+	+	32
C. rotundus[5]	-	+	-	-	-	+	45
Poaceae							
Bambusa arundinacea[1]	+	-	-	-	-	+	80
Chloris barbata[1]	+	-	+	-	-	+	10
Chrysopogon zeylanicus[1]	+	-	+	-	-	+	40
Cynodon dactylon[1,5]	-	+	+	-	-	+	0,50
Dactyloctenium aegyptium[5]	-	+	-	-	-	+	60
Desmodium triflorum[5]	-	+	-	-	-	+	48
Dendrocalamus strictus[1,5,6]	-	+	+	-	-	+	0,30,55
Dichanthium annulatum[5]	-	+	-	-	-	+	65
Digitaria bicornis[5]	-	+	-	-	-	+	57
Eragrostis tenella[5]	-	+	-	-	-	+	40
E. uniloides[5]	-	+	-	-	-	+	50
Eragrostis spp.,[1]	-	-	+	-	-	+	20
Grevillea pteridofolia[5]	-	+	-	-	-	+	30
Heteropogan contortus[5]	-	+	-	-	-	+	30
Phragmities karka[1]	-	-	+	-	-	+	0
Saccharum arundinaceum[5]	-	+	-	-	-	+	70
S. spontaneum[5]	-	+	-	-	-	+	55
Sporobolus indicus[5]	-	+	-	-	-	+	20
Dicot plants							
Amarantaceae							
Achyranthes aspera[1,5]	-	+	-	-	-	-	0,45
Aerva lanata[1]	+	-	-	-	-	-	0
Alternanthera sessilis[5]	-	+	-	-	-	+	42
A. pungens[5]	-	+	-	-	-	+	38
Celosia argentea[5]	-	+	-	-	-	+	25
Anacardiaceae							
Anacardium occidentale[1,5]	-	+	+	-	-	+	0,20
Annonaceae							
Annona squamosa[2]	-	-	-	-	+	+	56
Apocynaceae							
Holarrhena antidysentrica[5]	-	+	-	-	-	+	65
Asclepediaceae							
Calotropis gigantea[2]	-	-	-	-	+	+	62
C. procera[5]	-	+	-	-	-	+	60
Asteraceae							
Ageratum conyzoides[5]	-	+	-	-	-	+	50
Bidens biternata[5]	-	+	-	-	-	+	40
Blumea spp.[5]	-	+	-	-	-	-	0
Eclipta prostata[5]	-	+	-	-	-	+	52
Parthenium hysterophorus[5,7]	-	+	-	-	-	+	20,20
Tridax procumbens[5,7]	-	+	-	-	-	+	45,40
Vicoa indica[1]	-	+	-	-	-	+	10
Capparidaceae							
Cleome aspera[1]	-	+	-	-	-	-	0
C. chelidonii[1]	+	-	-	-	-	-	0
C. viscosa[1]	-	+	-	-	-	-	0

Casuarinaceae							
Casuarina equisetifolia[1,2,5]	-	+	+	-	+	+	40,78,40
Ceasalpiniaceae							
Cassia auriculata[1,2]	+	-	-	-	+	+	20,56
C. fistula[5]	-	+	-	-	-	+	45
C. occidentalis[1]	-	+	-	-	-	+	10
C. siamea[1,4,5,6]	-	+	+	-	-	+	60,‡,73,90
C. tora[1,5]	-	+	-	-	-	+	45
Caesalpinia pulcherrima[1]	+	-	-	-	-	+	50
Delonix regia[1]	+	-	+	-	-	+	80
Peltophorum pterocarpum[4]	-	+	-	-	-	+	‡
Tamarindus indica[1,5]	+	+	-	-	-	+	45,50
Combretaceae							
Terminalia arjuna[5,6]	-	+	-	-	-	+	60,58
T. bellerica[5]	-	+	-	-	-	+	50
Convolvulaceae							
Evolvulus alsinoides[5]	-	+	-	-	-	+	60
Ipomoea carnea[2]	-	-	-	-	+	+	48
I.hispida[5]	-	+	-	-	-	-	0
Merremia tridentata[5]	-	+	-	-	-	+	56
Cucurbitaceae							
Citrullus colocynthis[1]	+	-	-	-	-	+	80
Mukia maderaspatana[1]	+	-	-	-	-	+	60
Dipterocarpaceae							
Shorea robusta[5]	-	+	-	-	-	+	30
Ebenaceae							
Diospyros melanoxylon[5]	-	+	-	-	-	+	40
Euphorbiaceae							
Croton bonplandianus[1]	-	+	-	-	-	+	85
Euphorbia hirta[1,5]	-	+	-	-	-	+	72,48
Phyllanthus amarus[1]	-	+	-	-	-	+	40
P. emblica[5]	-	+	-	-	-	+	40
P. niruri[7]	-	+	-	-	-	+	30
P. virgatus[1,5]	-	+	-	-	-	+	75,60
Lamiaceae							
Leucas plukenetii[5]	-	+	-	-	-	+	42
Ocimum basilicum[5]	-	+	-	-	-	+	55
O. gratissimum[7]	-	+	-	-	-	+	30
Plectranthus caninus[2]	-	-	-	-	+	+	82
Lythraceae							
Woodfordia fruticosa[5]	-	+	-	-	-	-	0
Malvaceae							
Sida acuta[1]	-	+	-	-	-	+	60
S. cordata[1,5]	-	+	-	-	-	-	0
Meliaceae							
Azadirachta indica[1,2,5]	-	+	+	-	+	+	40,64,70
Melia azedarach[5]	-	+	-	-	-	+	30
Mimosaceae							
Acacia auriculiformis[1,2,4,5,6]	-	+	+	-	+	+	10,20,‡,68,89
A. catechu[4,5]	-	+	-	-	-	+	‡,43
A. mearnsii[2]	-	-	-	-	+	+	64
A. niloticas[1,4,5,7]	-	+	+	-	-	+	0,‡,55,20
Acacia spp.,[3]	-	+	-	-	-		‡
Albizia lebbeck[1]	-	+	+	-	-	+	90
A. procera[4]	-	+	-	-	-	+	‡
Albizia spp.,[3]	-	+	-	-	-		†
Leuceana leucocephala[6]	-	-	+	-	-	+	68
Pithecellobium dulce[1,3,4]	-	+	+	-	-	+	0,‡,‡
Prosopis juliflora[5]	-	+	-	-	-	+	30
P. spicigera[1]	-	-	+	-	-	-	

Moraceae	-	+	-	-	-	+	65
Ficus benghalensis[5]	-	+	-	-	-	+	30
F. elastica[5]	-	+	-	-	-	+	20
F. religiosa[5]	-	+	-	-	-	+	60
Morus alba[5]							
Myrtaceae							
Eucalyptus globulus[1,2]	-	-	+	-	+	+	0,62
E. hybrida[4,5]	-	+	-	-	-	+	‡,40
Syzygium cumini[5]	-	+	-	-	-	+	52
Nyctaginaceae							
Boerhaavia diffusa[1]	-	+	-	-	-	-	0
Oxalidaceae							
Biophytum sensitivum[1]	+	-	-	-	-	+	70
Papavaraceae							
Argemone mexicana[5,7]	-	+	-	-	-	-	35,40
Papilionaceae							
Alysicarpus vaginalis[1]	-	+	-	-	-	+	85
Atylosia scarabaeoides[5]	-	+	-	-	-	+	20
Butea monosperma[5]	-	+	-	-	-	+	50
Clitoria sp.[5]	-	+	-	-	-	+	30
Crotalaria albida[5]	-	+	-	-	-	+	10
Dalbergia sissoo[1,3,4,5,6]	+	+	+	-	-	+	15,‡,‡,58,94
Indigofera linnifolia[5]	-	+	-	-	-	+	70
Pongamia glabra[5]	-	+	-	-	-	+	40
P. pinnata[2,3]	-	+	-	-	+	+	48
Tephrosia purpurea[1]	-	+	-	-	-	+	35
Zornia gibbosa[5]	-	+	-	-	-	+	58
Portulaceae							
Portulaca pilosa[1]	-	-	-	-	-	-	0
Proteceae							
Grevillea robusta[1]	-	-	+	-	-	Soil only	
Rhamnaceae							
Zizyphus glaberrima[5]	-	+	-	-	+	-	30
Z. mauritiana[7]	-	-	-	-	+	+	20
Rubiaceae							
Ixora pavetta[2]	-	-	-	-	+	+	52
Spermococe hispida[1]	-	+	-	-	-	+	50
Rutaceae							
Aegle marmelos[5]	-	+	-	-	+	-	40
Sapotaceae							
Madhuca indica[5]	-	+	-	-	+	-	56
Scrophulariaceae							
Hedyotis affinis[5]	-	+	-	-	+	-	35
Scoparia dulcis[5]	-	+	-	-	+	-	0
Simarubaceae							
Ailanthus excelsa[4]	-	+	-	-	-	+	‡
Solanaceae							
Datura metel[1]	+	-	-	-	-	+	8
Solanum xanthocarpum[1]	+	-	-	-	-	+	8
Typhaceae							
Typha angustata[1]	+	-	-	-	-	+	50
Ulmaceae							
Holoptelia integrifolia[5]	-	+	-	-	+	+	55
Verbenaceae							
Gmelina arborea[3,4,6]	-	+	-	-	-	+	‡,‡,38
Tectona grandis[1]	-	+	+	-	-	-	68,0

C-Calcite mine spoil; Co- Coal mine spoil; L-Lignite mine spoil; Li-Lime stone mine spoil; M-Magnesite mine spoil; AM- Arbuscular Mycorrhiza. + Presence; - Absence; ‡ Not known.

[1]-Ganesan *et al.,* (1990); [2]- Raman *et al.,* (1992); [3]- Dugaya *et al.,* (1996); [4]- Chandra and Jamaluddin (1999); [5]- Kumar *et al.,* (2003); [6]-Mukhopadhyay and Maiti (2010); [7]-Singh and Jamaluddin (2011).

Conclusion

Naturally revegetated mine spoils had lower level of mycorrhizal colonisation compared to the artificially reclaimed mine spoils. This may be due to the inoculation of AM spores to the planted species which promotes the colonisers for establishment (Singh and Jamaluddin, 2011). Enriching the soil with AM fungi by planting of legumes can be the best approach for the reclamation of mine spoils and mine spoil dumps.

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