

Reclamation of Mine Spoils with Vesicular Arbuscular Mycorrhiza (VAM) Fungi—A Review

SANGEETA MUKHOPADHYAY AND SUBODH KUMAR MAITI

*Department of Environmental Science & Engineering, ISM University
 Dhanbad 826004 (Jharkhand), India
 E-mail : subodh_maiti@yahoo.com*

Abstract

Mycorrhizal inoculation of mine waste is critical for the establishment of a viable, diverse and self-sustaining plant community. Mycorrhiza fungi has a crucial role to play for the ecorestoration of coal and lignite mine overburden dumps, gypsum mine spoils, iron ore spoils, limestone, magnesite and uranium mine spoils. Following conclusions could be drawn based on the present review : (i) Host plants having higher-root infections are suitable for the biological reclamation of mining wastes, (ii) plant survival at revegetating mine spoil is affected by VAM infection and the source of infection seems to be the adjoining forest, (iii) pioneering plant species on mine spoils could cause the development of different populations of AM fungi.

Key words : Mine spoils, Reclamation, Mycorrhiza, Tree species.

Mining operations in India are mostly of the opencast type, and mine spoils, severely affect the land reuse pattern. Mining operations and surface subsidence due to underground mining operations have serious adverse effects on the growth of vegetation and on the general landscape of the area. Restoration of a vegetation cover can fulfill the objectives of stabilization, pollution control, visual improvement and removal of threats to surrounding population. Tate (1) states that long-term plant community stability relies upon the development of a functional soil microbial community. One group of soil microorganisms important to the development of long-term plant community structure is mycorrhizal fungi. The overburden dumps initially lack viable mycorrhizal fungal population, and thus, the establishment of a vegetative community may be delayed. Schramm (2) stressed the role of mycorrhizal fungi in the successful establishment of vegetation on mine overburden as the mycorrhizal fungi help in mobilizing plant nutrients especially phosphorus and alleviating effects of moisture stress. Daft and Hacsakayla (3) reported better establishment of vegetation in different mine spoils with the use of mycorrhizal fungi. However mining disturbances can significantly alter the soil physical, chemical and biological characteristics of a site, which can substantially reduce vigor and functioning of mycorrhizal population in the soil.

Reclamation of Mine Spoils with Mycorrhiza Fungi

Mycorrhiza fungi are being used for the reclamation of phosphate mine spoils, iron ore spoils, lignite overburden dumps, tin mine overburdens, kaolin spoils, bauxite mine spoils, chromite mine spoils and molybdenum mine spoils (4).

In studies conducted at the Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan, India, out of 31 plant species occurring naturally on surface mine spoils, 10 species were selected for their establishment on surface mine spoils after inoculation with *Glomus fasciculatum* (isolated from mine spoils) at the rate of 10 spores/g of soil. Percent infection increased 2—9 fold in inoculated plants. Shoot biomass, N, P, K, Zn and Cu concentrations were significantly improved over normal in all cases (5).

Reclamation of Coal Mine Spoils

Maiti et al. (6) investigated the vesicular arbuscular mycorrhiza (VAM) spore density in the rhizosphere of host plants and intensity of root infection in the plants growing in the afforested overburden (OB) dumps of Jharia coalfields, Jharkhand. The study revealed that five species of VAM fungi

(*Glomus*, *Gigaspora*, *Acaulospora*, *Enterophospora* and *Sclerocystis*) were present in revegetated OB dumps. *Glomus* is the most predominant genus found in the mining area. The density of VAM spore was found to be maximum in mining area in the range of 595 spores/5 g than non-mining area (308 spores/5 g of soil). The spore density in rhizosphere of 9 host plant was found in the range of 425 to 600 spores/5 g of soil. Maximum infections were recorded in *D. sissoo* (99%) followed by *Prosopis juliflora* (95%), *Acacia auriculiformis* and *Tectona grandis* (93%), *Melia azadirach* (83%), *Alstonia scholaris* (78%), *Polyalthia* (66%), *Cassia seamea* (44%) and *Azadirachta indica* (35%), *Eucalyptus* (0%). The study concluded that these host plants having higher-root infections are suitable for the biological reclamation of OB dumps. The occurrences of VAM spores in coalmine OB dumps are found to be double than non-mining areas due to higher disturbance.

Maiti (7) reviewed the importance of mycorrhiza inoculation for ecorestoration of coalmine OB dumps and concluded that successful colonization of VAM fungi depends on spoil pH, organic matter, moisture, nutrients, temperature, topsoil cover and age of dumps.

The VAM association in plants colonizing and growing naturally on reclaimed mine dumps of Jayant project, Northern Coal Fields Ltd., Singrauli, M. P., was studied by Kumar et al. (8). Total of 79 plant species belonging to 30 families were surveyed and found only 94% of total plant species possessed VAM colonization, and only 41% of the plants possessed arbuscules. They concluded that plant survival at revegetating coal mine spoil is affected by VAM infection and sources of infection seem to be the adjoining forest.

The possible host and edaphic influence on the occurrence of arbuscular mycorrhizal (AM) fungi in some pioneering plants colonizing on reclaimed mine spoil at an opencast coal mine site at Chandrapur, Maharashtra State, India was studied by Mehrotra (9). Thirteen plant species were studied and it was found that the range of infection varied from 20—95% and concluded that fungal spore densities were not related to the mycorrhizal infection levels. He also concluded that the pioneering plant species on mine spoils could cause the development of different populations of AM fungi. The revegetated coalmine spoil

was used as source of mycorrhiza inoculum for inoculating nursery seedling (10).

Ganesan et al. (11) studied the distribution pattern of VAM fungi in coal and lignite mine spoils located in Kothagudem and Neyveli, India. In coal spoils 72% plant species had mycorrhizal infections ranging from 10—85%, while in recently revegetated lignite mine spoils, only 60% of plants had mycorrhizal association with lower infections (10—30%). However, in 25 years old lignite spoils, infection was found to increase from 20—60%. In lignite spoils, maximum infection was noticed in *Albizia lebbek* (90%), *Cassia siamea* (60%) and *Tamarindus indica* (45%). Spores from 23 VAM species were found but mostly dominated by *Glomus* sp. while in virgin dumps *G. globiferum* was found. They concluded that VAM population depends on age of revegetated site, the degree of surface soil disturbance, amount of top soil and presence of susceptible root material.

Two revegetated OB dumps of Chirimari (10.2 ha) and Bisrampur (10.5 ha) areas, located in South Eastern Coalfields Limited (SECL) were reclaimed by application of VAM technology (12). The pit size was 60 cm × 60 cm × 60 cm, and filled with 4 parts of OB, 1 part of top soil and 15 kg of farm yard manure. The leguminous plants were infected with *Rhizobium* and VAM and non-leguminous were infected with *Azotobacter* and VAM. The VAM association causes profuse root development, 3 to 5 fold increase in biomass and survival rate was observed to be more than 92%. The percentage VAM infection was found in the range of 10 to 85%. Maximum level of infection was noted in *Croton bonplandianum* (80%), *Sida acuta* (60%) and *Tectona grandis* (68%). The species were planted successfully in the dumps consisting of timber (*Tectona grandis*, *Gravillia pteridifolia*, *Gmelina arborea*, *Azadirachta indica*, and *Dalbergia sissoo*) and fruit bearing trees (*Psidium guajava*, *Mangifera indica*, *Emblia officinalis*, *Zizyphus jujuba*).

Norland (13) while reviewing the soil factors affecting mycorrhizal use in surface mine reclamation for the US Department of Interior concluded: (a) mining wastes initially lack viable mycorrhizal fungal populations, and thus, the establishment of a vegetative community will be delayed, (b) mycorrhiza inoculations can enhance the productivity of mine

waste sites if mycorrhizae are absent, available phosphorus is low, and the plant species used in revegetation respond to mycorrhizal infection, (c) mycorrhizal inoculation of mine waste may be critical for the establishment of a viable, diverse, and self-sustaining plant community.

Reclamation of Gypsum Mine Spoils

Rao and Tarafdar (14) selected 10 plant species for rehabilitation of gypsum mine spoil in arid zone. They found that per cent root infection and number of viable AM fungal spores in the rhizosphere of the plant species grown in mine spoil were higher compared to those in normal cultivated soil and also observed that the concentrations of phosphorus, potassium and calcium in plants growing on gypsum mine spoil were higher than in normal soil.

In Central Arid Zone Research Institute, Jodhpur, the effects of inoculation with an AM fungus (*Glomus fasciculatum* isolated from gypsum mine spoil) in five tree species growing in gypsum mine spoil were studied (15). They observed that dry matter production was significantly enhanced upon inoculation to various degrees depending on the tree species. The level of root infection increased by 14–30% and spore densities in the rhizosphere increased by 49–81%. AM fungal inoculation resulted in enhanced activities of various soil enzymes and nutrients uptake. They concluded that AM fungi are important symbionts for use in the revegetation of gypsum mine spoils.

Reclamation of Iron Ore Spoils

Sastry and Johri (16) studied the occurrence, distribution and diversity of arbuscular mycorrhizal (AM) fungi in iron-stressed soils of Bailadila Iron Ore Project (BIOP), Bastar, Madhya Pradesh. In the 18 soil and 10 plant samples collected, 89 species of AM fungi scattered over 6 genera were recovered. *Glomus* species were the most dominant constituting 56.82% of the total isolates followed by *Acaulospora* (21.35%), *Scutellospora* (15.73%) and *Gigaspora* (3.37%). *Enterophospora* and *Sclerocystis* were represented by a single species each. They observed that natural AM infection in plants collected from various sites varied between 25 and

90%. They concluded that AM dependency of the host species in the iron-stressed habitats seems to be quite high and may play a significant role in establishment under metallotoxic conditions. The capacity of the native AM isolates to survive under iron stress may be instrumental in reclamation of disturbed sites.

Iron mine spoil dumps located at Codli (Sesa Goa limited, Goa) was reclaimed by using VAM biofertilizer mixed with farm yard manure (17). The VAM fungal spores were extracted from the rhizospheric soil samples collected from iron mine site by using wet sieving and decanting method. Out of 30 tree species planted, eight species showed better growth in terms of aerial height and uptake of trace metals. They concluded that biofertilizers enable plants to develop stress tolerance and promoted profuse rooting and its establishment in spoil dumps.

Reclamation of Limestone Mine Spoils

Influence of mycorrhizal fungi on the growth of different tree species and their nutrient uptake in limestone mine spoil was studied by Rao and Tak (18) at CAZRI, Jodhpur, India. They observed that inoculation with *G. mosseae* had significantly enhanced plant growth and biomass production in limestone mine spoils and the enhancement varied from one species to the other. Further, there was an improvement in per cent root infection and AM spore density in the rhizosphere indicating the establishment of *G. mosseae* in limestone mine spoil. Activities of various enzymes (dehydrogenase, phosphatases and nitrogenase) and population of nitrifying bacteria and *Azotobacter* were also improved upon inoculation with AM-fungus besides improvement in the uptake of many nutrients except Na and K. Because of the ability of AM-fungi in improving the water uptake and transport in plants, enhancing the uptake of various nutrients and enabling the plants to withstand high temperatures, AM-fungi native to limestone mine spoils may play a critical role in revegetating these spoils in arid areas. In view of these results, they concluded that the use of AM fungi may be adopted for the rehabilitation of limestone mine spoils for creating a better ecosystem.

Malaviya and Jamaluddin (19) studied the status of VAM fungi in lime quarries at three different sites in the Katni district of Madhya Pradesh. They ob-

served that VAM flora was less in lime quarries as compared to the adjoining degraded forests. It was also observed that isolated VAM flora grow well in pure soil and also in lime soil amended with normal soil. They concluded that the VAM consortium obtained from such harsh sites was suitable as inoculum for afforestation in lime-mined areas. Chandra and Jamaluddin (20) also recorded less VAM fungi in coalmines overburden dumps compared to natural forest areas.

The occurrence and status of VAM fungi, occurring in limestone mined soils of different age groups, including 5-year, 10-year old and fresh dumps were investigated by Singh and Jamaluddin (21) in the nursery of the forest pathology division, Tropical Forest Research Institute, Jabalpur. They observed that there was a considerable difference in the population of VAM spores in the soil of limestone mine overburden dumps of different age groups, with the highest number in 10-year old dumps. They concluded that the population of VAM spores is increasing with the aging of dumps.

Reclamation of Magnesite Mine Spoils

Raman et al. (22) reported VAM association with 14 plant species colonizing a magnesite mine spoil in Salem, Tamil Nadu, India. The soil was poor in Olsen-available P (5-45 kg/ha). They observed hyphal, arbuscular and vesicular infection; infection ranged from 32 to 82% and 13 VAM fungal species were identified. Spores of *Glomus fasciculatum* and *Gigaspora gigantea* were commonly found in the magnesite mine spoil.

Reclamation of Uranium Mine Spoils

Studies conducted by Chen et al. (23) in Denmark, to examine whether medic and ryegrass plants would be used as host plants for inoculation with an AM fungus, *Glomus intraradices*, for phytostabilization of Uranium tailings. Medic roots were extensively colonized by *G. intraradices* whereas ryegrass was more sparsely colonized. Plant growth was not improved by mycorrhizae, which, however, improved P nutrition of medic plants. Medic plants contained higher U concentrations and showed higher

specific U uptake efficiency compared to ryegrass. In the presence of U tailings, most U was retained in plant roots, and this distribution pattern was further enhanced by mycorrhizal colonization. They concluded that AM fungi play an important role for the phytostabilization of U tailings.

Straker et al. (24) examined the status of AM fungi in gold and uranium tailings and surrounding soils of South Africa's deep level gold mines in the North-West province, with respect to the root colonization and spore levels. Host species and substratum type showed significant effects on AM root parameters. No differences in spore densities between host species or age categories were found but total spore densities between depths were significantly different. Barren slopes had the lowest pH, aerial cover, organic matter and total P but highest potential acidity and weak relationships were found between pH and mycorrhizal colonization.

Conclusion

Mining wastes initially lack viable mycorrhizal fungal populations, and thus, the establishment of a vegetative community will be delayed. In that case mycorrhiza inoculations can enhance the productivity of mine waste sites if mycorrhizae are absent, available phosphorus is low, and the plant species used in revegetation respond to mycorrhizal infection. Mycorrhiza fungi have long been used for the reclamation of phosphate mine spoils, iron ore spoils, lignite overburden dumps, tin mine overburdens, kaolin spoils, bauxite mine spoils, chromite mine spoils and molybdenum mine spoils. Following conclusions could be drawn based on the present review: Host plants having higher-root infections are suitable for the biological reclamation of mining wastes. Plant survival at revegetating coal mine spoil is affected by VAM infection and the source of infection seems to be the adjoining forest. Pioneering plant species on mine spoils could cause the development of different populations of AM fungi. Activities of various enzymes (dehydrogenase, phosphatase and nitrogenase) and population of nitrifying bacteria and *Azotobacter* are improved upon inoculation with AM-fungus besides improvement in the uptake of many nutrients except Na and K.

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