CHAPTER 2

2. REVIEW OF LITERATURE

Ecosystem disturbance may be defined as an event or series of events that alters the relationship of organisms and their habitat in time and space. Mining of coal causes enormous damage to the flora, fauna, hydrological relations and soil biological systems. Destruction of the vegetal cover during the mining activity is invariably accompanied by an extensive damage and loss of the system. Nutrient deficient, acidity and sandy soils generating during mining activities are generally hostile to plant growth and the regevetation and reclamation strategies other than natural colonization of mine spoils are very tardy process. Literatures and some of the important researches/works that are relevant to the present study have been studied, reviewed and are summarized chronologically as far as practicable under the following heads:

2.1 ECOSYSTEM DISTURBANCES DUE TO CONTINUOUS COAL MINING ACTIVITIES

2.2 RECLAMATION ATTEMPTS

2.2.1 Restoration of mine spoils by Topsoil Management Practice.

2.2.2 Restoration of mine spoils by Direct Plantation Method.

2.2.3 Restoration of mine spoils by using microorganisms.
2.1 ECOSYSTEM DISTURBANCES DUE TO CONTINUOUS COAL MINING ACTIVITIES

Mining operation, undoubtedly has brought wealth and employment opportunities, but simultaneously has lead to extensive environmental degradation and erosion of traditional values in the society. Continuous unscientific coal mining operations and surface subsidence due to opencast and underground mining activities has lead to serious adverse effects on the growth of vegetations as well as on the general landscape of the operating and neighboring areas. It not only causes greater reduction in the forest cover due to continuous mining activities but also associated with large scale destruction of the flora, fauna, hydrological relations, soil biological systems and complete loss of the system.

Selected relevant literatures on impact of coal mining on the environment have been mentioned and summarized chronologically as below.

Surface mining generally generates huge amount of mine spoils. These spoils present a special habitat where conditions are extremely unfavorable for plant growth and establishment. Thus natural succession on the coal mine spoils is a slow process due to surface mining altering physico-chemical properties of soil (Chadwick 1973). Down (1974) stated that the mining environment alters the climatic and edaphic complexes of the plant communities leading to a drastic reduction in the plant growth and development.
Due to continuous mining, large extent of the land is spoiled and entire vegetal cover of the area is destroyed by dumping and storage of coal and overburden soil (William 1975). He reported that nitrogen and phosphorus as two limiting nutrient on coalmine spoils which plays a major factor for regulating plant growth.

Chemicals released from the coal mines, overburden and tailings contains high concentration of metals such as Cu, Cd, Fe, Hg and Zn, which affect the organisms adversely. Wali (1975) reported that water-soluble B, Cu, Fe, and Li, Sr & Zn contents were greater in mine spoils compared to unmined sites. These metals associated with mining are known to have toxic properties if present above certain levels (Dulka et al. 1976).

Degradation of soil quality depends upon the climatic conditions and various other factors. Power (1978) considered soil physico-chemical characteristics like texture, pH, electrical conductivity, soluble Ca, Mg, Na, B, cation exchange capacity, exchangeable cations, gypsum and calcium carbonate equivalents as crucial to the prediction of plant growth potential of mine overburdens with water holding capacity and infiltration rates as the other important variables.

The physical factors such as high temperature, stress, severe acidity and moisture retard the plant establishment and survival in the coalmine degraded land. Bell et al. (1981) stated that high temperature and low moisture are the two important factors which limit the plant growth in coal mine sites. Similar reports on affects of temperature and moisture on plant growth was also stated earlier by
Bradshaw et al. (1975). However, Costigan et al. (1981) stated that continued acidification for many years may lead to die back of well established vegetation. Similar reports were also reported by Alexander (1964), Barnishel (1977) and Arminger et al. (1996).

Vogel (1982) observed poor plant growth and survival in coalmine spoils due to low nutrient and organic matter content, low water holding capacity, and low pH of soil.

Chadwick et al. (1987) outlined the environmental implications of increased coal production and utilization. They stated that indiscriminate and unscientific mining, absence of post mining treatment and management of mined areas are making the fragile ecosystems more vulnerable to environmental degradation and lead to large scale destruction of the environment resulting in the reduction of forest cover, erosion of soil in a greater scale, pollution of air, water and land and reduction in biodiversity. Land degradation is generally associated with surface and sub-surface mining causing large scale damage to the environment (Mukherjee 1987, 1988). Similar reports were also stated earlier by UNESCO (1985).

Ecosystem destruction by mining is an inevitable part of industrialization and civilization (Jha and Singh 1990). However, unscientific and continuous extraction of coal causes serious impacts on the environment. Chaudhury (1992) dealt with the impact on mining activities on environment and also the management and protection of the mined areas. The pH is major determinant in controlling plant growth on impoverished lands such as mine spoils. Choudhury
(1996) observed high acidity in mine spoils due to oxidation of residual elemental or iron sulphur. They stated that highly acidic soil is the major constraint for revegetation, which hampers root-growth of plant and reduces the population of beneficial microorganisms such as free living N-fixers. Similar problems were also reported earlier by Johnson and Bradshaw (1977). Their report indicated pH of 3.5, which confirmed the acute acidity of the soil.

In the process of opencast mining, several changes occur in the physical, chemical and microbiological properties of soil (Kundu & Ghose 1998a). Goretti (1998) found that the waste rock dumps become devastating to the landscape in and around the mining areas.

Dadhwal (1999) reported that coal is being indiscriminately mined in most unscientific manners, causing large-scale damage to the natural ecosystems as earlier stated by Tiwari (1996). Open cast mining and quarries coupled with rapid unplanned urbanization are some of the factors responsible for depletion of flora & fauna and unproductive wasteland (Sarma et al. 1999).

In Makum Coalfield of Assam, land degradation, loss of fertility of the surrounding agricultural land, deforestation, severe acidity, presence of excessive toxic substances in soil and water of the surrounding areas, air and noise pollution were some of the serious affects of open cast mining (Bhattacharya et al. 1999).

Tiwary (2001) observed that huge amounts of acidic water containing high amount of sulphate, TDS and heavy metals such as Iron (Fe) and Manganese (Mn) were discharged during excavation of coal by both opencast and
Regreening of degraded soil of Tirap Colliery of Makum Coalfield of Assam, India

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Underground mining. Similar kinds of problems were also reported earlier by Chadwick (1973).

Due to surface mining, the flora, hydrological relations and soil biological systems were drastically disturbed. Swer and Singh (2004) studied the impact of mining on the aquatic fauna and flora of the Meghalaya region. They analyzed the water quality and its availability in the coal mining areas. Pandey et al. (2005) stated that disturbed and haphazardly mixed infertile, consolidated and unconsolidated materials overlying the coal seams were known as overburdens. These overburdens when dumped in un-mined areas in the vicinity of the coal mines create mine spoils and massive damage to the environment.

Rawat et al. (2006) reported that coal contain significant amount of ferrous sulphate in the form of pyrites. They found high sulphate content ranging up to 1500 ppm and iron content up to 40 ppm in mine water of Margherita of North Eastern Coalfield. They confirmed the presence of iron oxidizing, sulphur oxidizing and iron sulphur oxidizing bacteria in mine water. These bacteria accelerate the sulphur leaching rate from coal and are indigenous to mine drainages.

The main problems associated with mining activities includes land degradation, disposal of overburden, deforestation, subsidence, water and air pollution, acid mine drainage, mine fires, damage to forest, flora and fauna etc. (Warhate et al. 2006).

The unscientific mining had caused severe ecological imbalance such as huge degradation of land, massive subsidence of strata and disturbance of water
table. The mining operations degrade significant areas of lands and replace existing ecosystem with undesirable waste material in the form of mine spoil dumps. The coal extraction process drastically alters the physical and biological nature of the mined area (Singh et al. 2007).

Singh (2008) stated that opencast mines had damaged large land surface area, displaced people from their ancestral homesteads and caused severe agricultural losses. This problem is very acute in India and large areas are continuously becoming unproductive every year (Kundu and Ghose 2000). Mining of coal resources either by opencast or by underground process has serious insinuation for environmental security if proper management strategies are not adopted (Singh et al. 1995).

2.2 RECLAMATION ATTEMPTS

Reclamation of degraded land has been attempted in different region of the world applying different scientific principles. The attempts for rehabilitation / regreening of degraded coalmine sites are often very difficult. If biological reclamation is not done in proper time, leaching will lose the nutrients released by microbiological activity and erosion by rainwater which ultimately lead to unproductive soil (Ghose 2005). However, many scientists have made various attempts for re-establishment of vegetation in the over burden/degraded soil and these attempts have been mentioned in three parts and literatures are summarized chronologically as below.
2.2.1 Restoration by Top Soil Management Practice

The addition of an amendments would be necessary to establish and stimulate soil microbial activity, if mine spoils in the arid waste were not top soiled prior to reclamation attempts. Lindemann et al. (1984) demonstrated in their research that the addition of either sewage sludge or hay or top soiling at a depth of 30 cm increased the number of soil microorganisms, enzyme activity and fungal genera distribution in non rhizosphere spoil.

Rothwell and Eagleston (1985) suggested that in situations where top soil was shallow, highly eroded, or leached, replacement of that material with topsoil having an array of beneficial microorganisms helped in successful revegetation on mine spoil. They also reported that addition of amendments to mining wastes had a role in re-establishment of heterotrophic soil. Similar reports on use of amendments like carbon and other nutrients as an initial source for quick re-establishment of micro flora and micro fauna in degraded mine soil was earlier reported by Santos and Whitford (1981). However, use of organic residues on selected spoil as an additional amendment to increase the soil microbial community was reported by Stroo and Jencks (1982).

Top soil is an essential component of land reclamation in mining areas. Kundu and Ghose (1991) stated that mine spoils devoid of topsoil have adverse chemical and physical properties that can persist for many years. Such sites are not considered as stable, as the revegetation attempts are very much difficult.
Helm and Carling (1993) reported successful restoration of degraded soil of coal mine area using top soil as microbial inoculum. Similar reports were also stated by Lambert and Cole (1980) and Bellgard (1993) about the suitability of topsoil as an amendment for restoration/reclamation of coalmine degraded soil.

Top soil management practice is an essential process in the abandoned mine sites for growth of vegetation and post mining land reclamation (Kundu and Ghose 1994). However, Munshower (1994) reported that topsoil management and application practices may damage the soil structure, complex nutrient cycles, mycorrhizal associations, surface litter distribution, absorption of solar radiation and surface micro topography. These disruptions may prohibit the development of species.

Top soil is known to improve the physical, chemical and biological properties of mine spoil and it is one of the several options to increase plant growth and productivity (Larson et al. 1995). Mine spoils that received topsoil had similar chemical, physical and biological properties to that of an adjacent undisturbed site within 3 to 5 years (Ghose 1996).

Top soil is necessary to protect the primary root medium from contamination, erosion and also for its productivity Kundu and Ghose (1997a). Truong and Baker (1998) observed that addition of top soil on overburden dump soil helped in increasing plant height and biomass as reported earlier by Plass (1975).
Ghose (2001) stated that the top soil got seriously damaged if that was not mined out separately in the beginning with the view to replacement in the area. He also stated that nutrients and soil amendments in the amounts determined by soil tests when applied to the redistributed surface soil layers, that supported the approved post-mining land use and met the revegetation requirements.

Stahl et al. (2002) reported greater degree of soil degradation in the stockpiled soil which included mainly the loss of organic matter. Similar results were found by Ghose and Kundu (2004). They also reported the quality deterioration of topsoil, when it was stored for a long time.

Top soil is used to cover poor substrate and to provide improved growing condition for plants (Wong 2003). Kumar Nikhil (2004) stated that it was necessary to suitably amend the over burden soil to enhanced the growth and survivability of plant species.

Top soil management practice is more economic as an amendment for the revegetation practices of coalmine overburden (OBD) spoils (Hazarika et al. 2004). They suggested that addition of topsoil from natural forest/revegetated 10-year-old OBD improved biomass production in overburden spoils over lime treatment.

Top soil is an essential component for land reclamation in coalmine area. Top-soil supports plant growth and provide habitat for large numbers of microorganisms and other animals (Singh et al. 2007).
Singh (2008) stated the mitigation of degraded land of opencast mine could be done by separating/removing and handling of top and sub-soils carefully from the mine site and again could be re-laid at the time of reclamation for developing the land uses of the reclaimed surface.

In India an important factor inhibiting reclamation success is that there is a near total absence of appropriate topsoil management practices. Absence of topsoil is the most common feature of the mine spoils or dumps which is essential for plant growth. In addition, the sandy nature of mine wastes also aggravates the situation further for vegetation establishment by developing low infiltration rates and water retention problems. Thus there is a need for a well-directed applied research on top soil management.

### 2.2.2 Restoration of Mine Spoils by Direct Plantation Method

Revegetation of iron-ore mine areas of Madhya Pradesh by plantation was performed by Prasad (1989). His study revealed that plantation enhanced the nutrient status of the degraded mine soil. He observed better growth performance of *Dalbergia sisso, Albizzia procera, Pongamia pinnata* etc. in the manured pits and spoil land. Similar study was reported earlier by Saxena (1979). He studied the vegetation characteristics of the mined areas in Rajasthan and listed the plant species for revegetation program on gypsum, bentomite and fuller's earth mined areas.
Restoration of degraded land is a challenging ecological problem and natural recovery in mine spoil is a slow process (Jha and Singh 1991). However, through plantation, eco-restoration of degraded land can be achieved successfully.

Plantation of trees helped in building up new self-sustaining soils and also promoted the development of a large and active community of soil organisms (Haigh 1992).

Schaller et al. (1993) reported that plantation played a critical role in restoring productivity, ecosystem stability and biological diversity to degraded areas. Similar reports were also reported earlier by Sanchez et al. (1985), Gill et al. (1987), Chakraborty et al. (1989), Sharma et al. (1989) and Montagnini et al. (1990) that plantation increased soil organic matter and other nutrients and could reverse the degradation process by stabilizing soils through development of extensive root systems. However, Greenfield (1995) stated that plantation played an important role in protecting the overburden dump surface from erosion and allowed the accumulation of fine particles.

Restoration of coalmine degraded soil largely depends on the ability of the plant species to proliferate in the soil. Banerjee et al. (1996) stated the use of native and indigenous plant species for the revegetation programs with a view to maintain essential processes and life support system, preservation of genetic diversity and to ensure sustainable utilization of species and ecosystem as stated earlier by other workers (Soni et al. 1989, Jha and Singh 1993).
Nikhil et al. (1998), Truong and Baker (1998) and Zheng et al. (1998) reported that the pH, heavy metals and salts were reduced by plantation of resistance and tolerant species of grass like Vetiver grass which was not only resistant to the heavy metal toxicity but also uptake the excess metals without accumulating them and thus helped in quick restoration of degraded lands.

Plantation is the oldest technology for the restoration of lands damaged by human activity. Species like Azadirachta indica and Dalbergia sissoo, both early successional fast growing, hold the promise for the rehabilitation of nutrient-poor coal mine spoils. However, S. robusta, the late successional slow-growing plant disadvantageous in view of its small litter fall and slower decomposition rate (Singh et al. 1999). So, selective plantation method is desired for successful restoration program as the progress of natural vegetation process is very slow on mine spoils (Filcheva et al. 2000).

Plantation enhanced the nutrient status of the degraded mine spoil land. Dutta and Agarwal (2002) assessed soil characteristics and microbial activity of vegetated coalmine spoil under plantation of five exotic tree species. They found Eucalyptus hybrid, Acacia auriculiformis and Casuarina equisetifolia were the most suitable for modification of spoil characteristics during the revegetation process.

Plantation is the common practice for the restoration of overburden dump (Kumar Nikhil 2004). He stated that coalmine dump soil rehabilitation benefits from plantation because that allowed jump-start succession. He used Vetiver grass (Vetiveria zizanioides) for the reclamation of coalmine degraded soil and
found maximum growth of the plant was in mixed soil than that of dump soil. The growth of the plant attained the average height of 95 cm after 1 year of plantation.

Maiti et al. (2004) found D. *sissoo* as the most suited of all plants for the purpose of afforestation of overburden dumps. The species also contributed towards improvement of field moisture capacity, pH, organic carbon and macro nutrients (NPK) in mine-soils. Acidic nature of mine-soils in overburden dumps increased bioavailability of trace elements (micronutrients) but, except for Zn, such accumulations seldom caused any toxicity problem for the plants.

Progress of natural vegetation processes is very slow on mine spoils, so selective plantation of suitable native species is desired in most cases (Singh 2004). Similar reports were also mentioned earlier by Bradshaw (1987) that the success of reclamation schemes greatly depended upon the choice of plant species and their methods of establishments.

Impact of plantation on restoration of mine spoil was studied by Singh and Singh (2006). They studied the growth of 17 indigenous species in the mine spoil with soil amendments using Nitrogen, Phosphorus and potassium (NPK) fertilizers and found that plantation of trees significantly accelerated the soil redevelopment process on the mine spoil.

Stabilization of mine spoil is difficult as natural revegetation of mine spoil is a very slow process (Singh 2007). However, he stated that through plantation of woody species, seeding of grasses and leguminous crops its stabilization could be achieved.
Restoration of over burden dumps by tree species improves the moisture contents, bulk density, pH and overall nutrient contents of mine soils (Maiti 2007). His study indicated that tree species like *D. sissoo*, *Eucalyptus* sp., *Cassia* sp., *Acaccia mangium* and *Peltaphorum* sp. were the best species for biorecalmation of overburden dumps.

Biological activity in soil increases with density of vegetation. Profuse plantation of trees, shrubs and grass on crowns of dumps, ring, slopes, etc ensure thick biological growth and commence the natural succession process (Singh 2008).

Singh et al. (2008) conducted a study on high-density young plantations of three native trees (*Albiza lebbeck*, *A. procera* and *Tectona grandis*) and one native woody grass species (*Dendrocalamus strictus*). They examined the influence on total nutrient concentrations of coalmine spoil during early phase of plantation establishment. They found that plantation of *A. lebbeck* showed greater soil organic carbon (SOC) and nutrient concentrations followed by *D. strictus*, *A. procera* and *T. grandis*, respectively.

For eco-restoration of mine OBD soil of Tirap Colliery, screening of plant species was performed *in situ* by Dowarah et al. (2009). They studied and screened thirty-six different plant species representing twenty different families belonging to the herbaceous, liane, shrub and tree groups. They found that herbaceous plant species such as *Axonopus* sp., *Saccharum spontaneum* and the economically important essential-oil bearing plants *Cymbopogon winterianus* Jowitt and *C. flexuosus* were the most stress-tolerant. They also reported that
these plants were able to resist the stress conditions of mine OBD soil due to the nature of their fibrous root systems. In addition, liane species like *Mimosa pigra*, *M. streata*, and *M. strigillosa*; the shrub species *Cassia streata* and *Sesbania rostrata* and the tree species gomari (*Gmelina arborea*) and sissoo (*D. sissoo*) were determined to be resistant to mine OB stress in the Tirap Colliery.

Tree species growing in coal mining areas have diverse effects on their respective rhizosphere microbial processes, which can directly or indirectly determine the survival and performance of the planted tree species in degraded coal mining areas. Sinha *et al.* (2009) recommended the use of tree species like *A. indica*, *A. marmelos*, *B. monosperma*, *E. jambolana* and *M. oleifra* with higher Rhizosphere soil microbial index (RSMI) values for revegetation of degraded coal mining area.

Regreening of degraded land has become a great problem to the Indian mining industry. Numerous studies have demonstrated land rehabilitation benefits from plantations because it allows jump-starting succession (Khemnark 1994, Ang 1994, Majid *et al.* 1994, Shepherd 1994). However this approach has not been adopted in coal-mining sector because efforts to grow the vegetation on damaged land as part of biological reclamation is very difficult.

### 2.2.3 Restoration of mine spoils by using microorganisms

AM fungi can accelerate the revegetation of severely degraded lands such as coal mines or waste sites containing high levels of heavy metals. It modifies
plant root system and thus plays a critical role in nutrient cycling in the ecosystem (Marx 1975). Daft et al. (1975) observed an improvement in growth of different plants in mine spoils upon the introduction of AM fungi isolated from the mine spoil areas. Similar reports have been reported earlier by Daft and Nicolson (1974) that most of the grasses and nearly all the dicotyledon plants growing on three coal tips in Scotland were infected by VAM fungi, and the root infection level ranged from 20 to 90 spores of *Glomus fasciulatum* and *Scutellospora calospora* were identified from coal waste. Parkinson (1978) reported the restoration of degraded soil disturbed through mining by introduction of specific groups of decomposers and symbiotic microorganisms. Soil formation and structural characteristics were affected by mycorrhizae and other microbes through the production of humic compounds (Tan et al. 1978). Decomposition of primary minerals was accelerated by mycorrhizae as stated by Cromack et al. (1979). Danielson et al. (1979) pointed out the mycorrhizal status of plants as an important factor in revegetation of severely disturbed soils. In adverse environmental conditions the impact of mycorrhizae is very important in rehabilitation of coalmine spoils (Marx et al. 1979).

Microorganisms play an important role in the growth of mine spoils, by regulating the uptake of nutrients, increasing the absorbing surface area and mobilizing the sparingly available nutrient source (Marx 1980). This report was later on supported by Kothari et al. (1990), Lix L. et al. (1991) and Cunningham et al. (1992).
Fresquez and Lindemann (1982) suggested that the low diversity of fungi found in non top soiled spoil might result in reduced enzymatic activity that reduced normal nutrient cycling and decomposition, thus slowing the process of soil microbial community development to its pre disturbance composition. Successful development of mycorrhizae in amendment soils influences the restoration process (Zak and Parkinson, 1983). They stated that native AMF were potential candidates for the inoculation programs. However, AM Fungi were unfortunately considered physiologically obligate symbionts because of failure to grow them on synthetic media. These fungi might not be adapted to the new conditions resulting from mining activities as stated earlier by Pederson et al. (1978), Smith et al. (1979), Mosse et al. (1981), Zak et al. (1982) and Severson et al. (1983).

The legume Rhizobium – AM fungi association was reported by Bagayaraj (1984). He stated that legume with both AM fungi and Rhizobium bacteria gave improved plant growth.

Vesicular-arbuscular mycorrhiza (VAM) increases the success of rehabilitation of disturbed and degraded lands (Jasper et al. 1988). They reported the beneficial role of vesicular arbuscular mycorrhizae for successful establishment of plants in mine spoil ecosystems. Many plant species derived benefit from mycorrhizae through increased nutrient uptake, tolerance to higher substrate temperature and pH, resistance to drought, protection of higher plant against root pathogens and increased root life as reported earlier by Gerdermann.
(1975), Ried and Grossnickle (1978), Harley and Smith (1983) and Skujiins et al. (1986).

The reclamation strategy for mine spoils in India was studied by Ganesan et al. (1991). They examined the presence of VAM fungi in different spoils viz, coal wastes; a lignite mine and a calcite mine. Their study reported that mycorrhizae profoundly influenced the development of vegetation and hence helped in reclamation of mine-waste spoil.

Feldmann and Idezak (1992) stated that groups like AM fungi which were in obligate biotrophic association with plants, strategies of co-cultivation with plants and of inoculum production was necessary for successful restoration/regreening of degraded soil.

The mycorrhizal fungi are potential biological tools for wasteland reclamation. The occurrence and distribution of VAM fungal species in mine spoils and their beneficial role in the survival and growth of plant species in the degraded soil sites are very useful because of their effective deployment in the revegetation programs Raman et al. (1993).

Applications of suitable strains of AM Fungi in inhospitable site such as coalmine area are indispensable for any successful plantation program and for mitigation of adverse environmental conditions (Dugya et al. 1996). Nurlaneny et al. (1996) observed that lime and mycorrhizal inoculation were effective in enhancing P uptake and plant growth. They further concluded that root colonized by arbuscular mycorrhizae enabled the plant to better tolerate soil acidity. They
also observed that re-establishment of microbial relationship in mine spoil had yet to recognize as an important component of an overall reclamation strategy.

Pascual et al. (2000) stated that microbial activity was fundamental in the process that made energy and nutrients available for recycling in the ecosystem and thus soil microorganisms played crucial roles in the biogeochemical cycling of carbon (C), nitrogen (N), and phosphorus (P) as stated earlier by Bandick et al. (1999).

Enkhtuya et al. (2002) and Jamal et al. (2002) reported that AM Fungi could increase plant establishment and growth despite high levels of soil heavy metals and played a vital role in metal tolerance and accumulation as reported earlier by del Val et al. (1999) and Zhu et al. (2001).

Kumar et al. (2003) surveyed and reported that 79 plant species belonging to 30 families formed the mycorrhizal association at coalmine dumps of various ages. Their study indicated that 94% of total plant species possessed VAM colonization. Among all plants, only one plant possessed low level of VAM colonization. 51% plants possessed moderate level of VAM colonization and 42% plants possessed high to very high level of VAM colonization. Six families namely Poaceae (13 species), Fabaceae (7 species), Mimosaceae (5 species), Asteraceae (6 species), Moraceae (4 species) and Amaranthaceae (4 species) possessed most frequent VAM association.

AM fungi play a vital role in the growth of plants under natural as well as stress conditions particularly in nutrient deficient soils Katdare et al. (2004). They observed maximum association of VAM spores with the rhizosphere soil.
of Cyperaceae members. Hazarika et al. (2004) reported the successful growth of two herbaceous plant species *M. pudica* and *Crotalaria striata* in coalmine overburden spoils using native AM Fungi inoculum, lime and FYM on growth and biomass production for restoration and revegetation of coal mine overburdens of Margherita Coal belt.

Garcia et al. (2005) found that rhizosphere with higher organic carbon contents such as those associated with *Stipa tenacissima*, *Retama sphaerocarpa*, *Rhamnus lycioides*, showed increased plant biomass and root elongation, and hence these species might be suggested to be used for soil restoration under semiarid climate conditions.

Application of appropriate amendments, inoculation of free and symbiotic nitrogen-fixing bacteria and mycorrhizae would facilitate reconstruction of self sustained ecosystems (Juwarkar et al. 2006). Singh and Jamaluddin (2006) reported that VAM (vesicular arbuscular mycorrhiza) fungi played a vital role in the establishment and growth of plants under natural as well as stress conditions, particularly in nutrient-deficient soils. They reported that population of VAM spores increased with the age of dumps. Soil from ten-year-old overburden dumps had the highest spore population (760 per 100 g soil) with 70% root colonization. While soils from five-year-old and fresh overburden dumps were found to be less populated with VAM spores.

Roy et al. (2007) stated that Alders were resilient pioneer plants that had adapted to a wide range of environments worldwide. Frankiae, mycorrhizae,
alders and their symbioses could tolerate and thrived in highly contaminated degraded soil and hence helped in soil revegetation and remediation.

Mycorrhizal fungi play a major role in increasing the productivity of leguminous tree plants in wastelands (Tewari et al. 2008). They stated that the mycorrhizal fungi and the bacteria (Rhizobium sp.) were very responsive for mycorrhizal colonization and their association resulted in increased survival rates as well as enhanced growth of plants in degraded soil.

Another major function of Arbuscular mycorrhizal (AM) fungi is to increase the surface area of plant root systems, greatly facilitating uptake of soil water and nutrients, especially in unfavorable conditions (Juwarkar et al. 2009). They stated that Arbuscular mycorrhizal (AM) fungi provide tolerance to host plants against extreme stress and toxic conditions. They stated that restoration through Microbe Assisted Green Technology (MAGT) is a novel approach to attain a sustainable bionetwork on barren mine spoil dump in a short span of period. This approach included the exploitation of different plant growth promoting microorganisms, viz. free living (Azotobacter) and nitrogen fixers (Rhizobium), Vesicular Arbuscular Mycorrhizae (VAM) fungi and others to assist plant survival and perpetuation in stressed environment. They also stated that site specific microbial inoculants enhanced the biogeochemical cycles and the regeneration capacity of the spoil. According to their study, MAGT is an eco-friendly, cost effective and rapid bio-network development process, which can be replicated on other overburden dumps and metal contaminated sites.
Matias et al. (2009) observed that double inoculation of rhizobia and mycorrhizal fungi benefited plant growth by increasing the nitrogen and phosphorus in the plant biomass, which resulted in an improvement of soil nutrient availability, and survival index, as well as soil organic matter and water-holding capacity in mine spoils.

In general, mine spoils are not suitable for both plant and microbial growth because of low organic matter, and other unfavorable physico-chemical characteristics, especially insufficient amount of essential nutrients (N and P) (Singh et al. 1995, Singh and Singh 1999, Singh et al. 2004a, 2004b). The recovery by natural succession is also very slow process. Srivastava et al. (1989) estimated that it might take about 200 years of natural succession on a mine spoil to recover to the level of native natural forest soil. Due to this situation, recovery of degraded ecosystems into original state needs a carefully scientific approach to manage the problem. The best approach for the reclamation of mine spoil is by plantation of desired species along with enrichment of soil with potential microorganism's especially mycorrhizal fungi for rapid soil stabilization. However, the addition of amendments like use of topsoil, manure/compost and microbial inoculum are only means of quickly re-establishing the coalmine degraded soil.