ROLE OF SYMBIOTIC SOIL FUNGI IN CONTROLLING ROAD SIDE EROSION AND IN THE ESTABLISHMENT OF PLANT COMMUNITIES

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ABSTRACT

Mycorrhizal fungi are an important component of the rhizosphere of a vast majority of plants. The fungi form mutually beneficial relationship with the roots of these plants. These associations are often obligatory but can be facultative. The benefits conferred to host plants are increased nutrient (minerals, etc.) uptake, increased water availability, increased tolerance to pH and temperature, growth factors (from fungus) enhances / influences root development, increased longevity of feeder roots, better rhizosphere development and protection of feeder roots from pathogens. The benefits to mycobiont are carbohydrate food for fungus in most cases (exception orchid mycorrhizae), plant roots release / secrete vitamins (thiamine, etc.) and “Factors” - stimulate spore germination & hyphal growth.

Four different stands in the Northern areas of Pakistan were sampled and analysed using simple ecological methods. The stands sampled were situated in Nalter and Astore, Gilgit. The stands included undisturbed natural vegetation stands and disturbed stands. The disturbed stands were characterized by excessive cutting and felling of trees and overgrazing leading to entirely changed picture of the plant communities and associated mycoflora. For mycological studies the roots of plants of the above mentioned stands along with the rhizosphere soil were sampled and processed. It was recorded that the types of ectomycorrhizal fungi varied as the forest stands matured. The fungi almost trend to disappear when the forest trees are cut. The number of root tips with ectomycorrhiza decreased when the stands were disturbed. So was the case with vesicular arbuscular mycorrhiza forming endogonaceous spores number.

The weight of water stable aggregates also reduced in the soils of disturbed stands. These disastrous situations then end up with removal of rest of the forest vegetation and excessive erosion or removal of top fertile soil. This can be avoided with proper management of these fungi.

Keywords: mycorrhizal fungi, plant ecology, erosion.

RESUMO

Fungos micorrízicos são um componente importante da rizosfera da grande maioria das plantas. Os fungos formam relação mutualmente benéfica com as raízes destas plantas. Estas associações são frequentemente obrigatórias mas podem também ser facultativas. Os benefícios conferidos a planta hospedeira são um aumento na incorporação de nutrientes (como fósforo, potássio, etc...), aumento na disponibilidade de água, maior tolerância a pH e temperatura, fatores de crescimento, influência no desenvolvimento de raízes, aumento na longevidade e proteção das raízes a patógenos. Neste experimento 4 diferentes áreas do norte do Paquistão foram estudadas utilizando-se de métodos ecológicos simples. As áreas localizam-se na região de Nalter e Astore, Gilgit, incluindo áreas de vegetação natural e antropizada. Estas últimas são caracterizadas pelo desmatamento acentuado e pastoreio, modificando completamente a vegetação e a micoflora associada. Para os estudos micológicos, as raízes das plantas destas áreas e o solo da rizosfera foram coletados e processados. O tipo de fungo ectomicorrízico varia com a maturação da floresta. Os fungos tendem ao desaparecimento quando as árvores florestais são cortadas. O número de ápices radiculares com ectomicorriza diminuiu nas áreas antropizadas. Este também foi o caso com o número de esporos de micorriza arbuscular. O peso de agregados estáveis em água também foi reduzido em solos de áreas modificadas. Esta situação desastrosa resulta na remoção do restante da vegetação, processos erosivos e remoção de solo fértil das camadas superiores. Isto pode ser evitado com o manejo apropriado destes fungos.

1 INTRODUCTION

Much of the world’s vegetation appears to have roots associated with mycorrhizal fungi: Eighty three percent of dicots, seventy nine percent of monocots and all gymnosperms regularly form mycorrhizal associations (WILCOX, 1991). In the case of arbuscular mycorrhizal fungi the hyphae provide the surface area where the fungus extract soil resource for transport to host. The hyphae transport resources such as $\mathrm{HPO}_4^-$, $\mathrm{NH}_4^+$, $\mathrm{Ca}$, $\mathrm{S}$, $\mathrm{K}$, $\mathrm{Zn}$, Cu, $\mathrm{H}_2\mathrm{O}$ to the host. These hyphae also provide structure capable of colonizing new root tissues.

Little is known about the mechanism by which the mineral nutrients absorbed by mycorrhizal fungi are transferred to the cells of plant roots. Nutrients may diffuse from intact arbuscules to root cortical cells. Alternatively because some root arbuscules are continually degenerating while new ones are forming, degenerating arbuscules may release their internal contents to the host root cells.

These fungi also play a vital role in alleviating the effects of salinity. By improved nutrient acquisition, VAM fungi compensate for the nutritional imbalances imposed by salinization, (SYLVIA & WILLIAMS, 1992). Some other environmental stresses such as micronutrient imbalances, heavy metal toxicity, biocide treatment, slurry application (Chistie & Kilpatrick, 1992), sulfur dioxide fumigation (CLAPPERT and REID, 1990) and wild fire recovery (PUPI & TARTANLINI, 1991), involves the use of AM fungi, (BAREA et al., 1993). Some AM fungi are adapted to adverse conditions so they can benefit plants under a variety of environmental stresses, (MOSSE et al., 1981). AM can also reduce the toxicity of certain metals for plants, while at non-toxic or such optimal level, their acquisition is enhanced by symbioses, (BETHLENFALVAY, 1992; SYLVIA & WILLIAMS, 1992; BAREA et al., 1993). AM also plays positive role in protecting plants from pH extremes, (SYLVIA & WILLIAMS, 1992). Plants having arbuscular mycorrhizal fungi in their roots are better tolerant to root borne diseases as compared to plants without such associations, (IQBAL & NASIM, 1988).

In a nutrient poor environment such as sand dunes, AMF contributes not only to plant nutrition but also to the process of dune stabilization by binding sand grains into wind-resistant aggregates, (KOSKE et al., 1975; FORSTER & NICOLSON, 1981). They do so by binding the soil particles together (MILLER & JASTROW, 1992). Koske et al., (1975), found extensive hyphal networks of endogonaceous fungi binding sand among plant roots in sand dunes. Lynch & Bragg (1985), suggested an indirect role of the fungi in soil binding. They emphasized that the hyphae may be serving as substrate for other polysaccharide-producing microorganisms. The bacterial polysaccharides cement the soil particles together, (TISDALL & OADS, 1979).

One major line of work entailed studying the role of the mycorrhizal communities to cutting and grazing stress, since under field condition these fungi are crucial for the transfer of minerals from the soil solution to tree roots (HARLEY and SMITH, 1983). Effects of disturbances like excessive felling of trees and overgrazing have been shown to reduce root growth and hence effect the picture of mycorrhizal fungal communities. Indirect effects of cutting and grazing in reducing photosynthesis and hence carbon allocation to the root system, may also inhibit mycorrhizal development. The effects of these factors have therefore been reviewed for the first time in the present study.

2 MATERIALS AND METHODS

2.1 The study area

The study area included undisturbed and disturbed stands in Nalter and Astore (Gilgit) (Fig. 1). Vegetation analyses were made for ecological studies and the roots of plants in that area along with the rhizosphere soil were collected for mycorrhizal studies. The samples were collected in triplicate.

![Fig. 1 - Map of northern areas of Pakistan showing study sites.](image-url)
2.2 Field methods
Vegetation and sites were sampled at four sites in Nalter and Astore. All sites were carefully studied and important points were recorded. On each of the study site vegetation records were made following the releve method of Braun-Blanquet, (1964) and Mueller-Mueller-Dombois & Ellenberg, (1974). Vertical strips of 10 m x 50 m dimensions were marked and the vegetation composition was recorded in the area. Later on the stand structure was analysed following the method of Schichkoff, (1992). The parameters like tree species, height, BHD (breast height diameter), stratification, vitality, dynamic tendency, crown length, crown radius, and crown development, stem quality, intensity of damage, and epiphytic cover. For stumps, mortality, degree of decay, and cause of death was recorded following the methods of Leibundgut, (1959, 1966) and Lamprecht, (1980). Additionally, the natural regeneration was investigated by recording the quantity and height of the seedlings of the different tree species as well as the parameters distribution, damage by browsing, vitality, growth form, and development chances.

2.3 Sample collection
Samples for study were collected in a way that their aerial portions and root systems (particularly fine roots) were least disturbed. Extra care was taken to sample decaying leaf bases, runners of the grasses and rhizosphere soil.

Aerial portions were pressed in the folds of blotting paper at the spot. While roots, runners, decaying leaf bases along with rhizosphere soil were carefully brought back to the Lab., for further processing and staining in plastic bags.

2.4 Laboratory Methods
2.4.1 Processing of plant materials
The role of arbuscular mycorrhizae in the development and establishment of plant communities in these hilly areas of Pakistan were investigated by examination of the roots of mature plants for the presence of mycorrhizae. The direct examination of soil samples and rhizome fragments was also done. For the presence of AM in decaying plant parts, these were also processed for examining the role of organic matter in the spread of arbuscular mycorrhizal fungi.

Different plant portions were processed separately. Plant parts like roots, leaf bases and rhizome fragments were sorted out. Each of the sample was washed under tap water. Clearing was done in 10% KOH by autoclaving for 2-3 minutes. Samples that remained dark coloured after clearing in KOH were bleached in alkaline Hydrogen peroxided (KOSKE and GEMMA, 1989). These bleached plant portions were washed with 0.01N HCL to neutralize. Staining was done in acidic glycerophenol containing 0.0% trypan blue (PHILLIPS and HAYMAN, 1970) with some modifications (NASIM and IQBAL, 1990).

2.4.2 Mounting and slide preparation
Stained materials were examined under a dissecting microscope. Portions carrying mycorrhizal structures were gently picked up with the help of a hypodermic needle and were mounted in lactophenol. Care was taken while transferring these pieces that not to disturb intact extramatrical mycelia, spores and auxiliary cells. Unless otherwise stated all microscopic examinations were made with mounts in lactophenol. Lactophenol trypan blue is useful for emphasizing hyphal characteristics and for interpreting some types of apparent surface ornamentations of spores.

For the assessment of mycorrhizal extent and frequency of various infections, stained root materials of each sample were cut up into one-cm long pieces. Ten such root pieces were mounted parallel to each other on a microscope slide. Such slides were prepared in triplicates.

2.4.3 Microscopic studies
Prepared slides were observed and mycorrhizal infections were assessed under light microscope.

2.4.4 Parameters of arbuscular mycorrhizal study in roots and non-root portions
Intensity of AM colonized was quantified by assigning a score of 0-3 to root samples on the bases of extent of root system colonized and density of AM structures (arbuscules, vesicles, hyphal coils internal hyphae and spores) present: 0= no AM infections; 1=light infections with less than 25% of root length colonized; 2=moderate intensity, 25-75% colonization; 3=dense colonization with more than 75% of length colonized.

Only plants in which arbuscules were observed in the root system were classified as strongly arbuscules mycorrhizal. Species for which all collected specimens possessed AM were classified as consistently mycorrhizal. Dead and decaying leaves of selected species ad scales of the runners of rhizomatous grasses were examined for AM on the surface and underneath the leaf sheaths.
2.4.5 AM propagule estimation

Endogonaceous spore in the rhizosphere were extracted by wet sieving and decanting technique (WSDT) of Gerdemann and Nicolson, (1963) and soil paste method (SPM) of Nasim and Iqbal, (1990).

For WSDT, 100 g of soil from each sample was suspended in one litre of water ad wet sieved using sieves of 400, 105 and 63 um pore diameter, placed one above the other in descending order. The contents retained on each sieve were transferred to a beaker of water. The supernatant was filtered and filter paper was examined under a microscope. Total number of spores on the filter paper was counted. Similarly materials collected from each sieve was examined and the total number of spores on all sieves indicated the total number of endogonaceous spores of different sizes in 100 g of soil samples.

To record species diversity slides (semi permanent) of each morphologically different spore were prepared. Identification was done following the keys of Scheck and Perez, (1987) and Morton, (1988).

For soil paste method (SPM) of spore extraction, 20 g of soil was spread into a thick paste and spores were directly picked up with a sharpened tooth pick or hypodermal needle under a dissecting microscope. After washing several times, spores were mounted in lactophenol and observed under the light microscope.

2.4.6. Ectomycorrhizal studies

The intensity of ectomycorrhizalae was determined in terms of number of ectomycorrhizal tips per 100g of soil taken 10cm deep from forest floor, (DEACON, et al., 1983).

3 RESULTS AND DISCUSSION

List of major tree species, herbs and shrubs recorded in the study area is given in the form of Table 1.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Plant name</th>
<th>Sr. No.</th>
<th>Plant Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cedrus deodara</td>
<td>36.</td>
<td>Achyranthes aspera</td>
</tr>
<tr>
<td>2.</td>
<td>Picea smithina</td>
<td>37.</td>
<td>Amerone falconeri</td>
</tr>
<tr>
<td>3.</td>
<td>Betula utilis</td>
<td>38.</td>
<td>Androdiscus bicorneata</td>
</tr>
<tr>
<td>4.</td>
<td>Juniperus macropoda</td>
<td>39.</td>
<td>Lepidicea cercera</td>
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<tr>
<td>5.</td>
<td>J. turkistanika</td>
<td>40.</td>
<td>Clematis montana</td>
</tr>
<tr>
<td>6.</td>
<td>Pinus wallichiana</td>
<td>41.</td>
<td>Rhodola fastigiata</td>
</tr>
<tr>
<td>7.</td>
<td>Major Shrubs and Herbaceous plants:</td>
<td>42.</td>
<td>Pediocaric pilocornuta</td>
</tr>
<tr>
<td>8.</td>
<td>Geranium pretense</td>
<td>43.</td>
<td>Rumex runcinfolium</td>
</tr>
<tr>
<td>9.</td>
<td>Senecio sp.</td>
<td>44.</td>
<td>Androdiscus acephale</td>
</tr>
<tr>
<td>10.</td>
<td>Vaccinium sikkimensis</td>
<td>45.</td>
<td>Arenaria bryophilla</td>
</tr>
<tr>
<td>11.</td>
<td>Madenia himalica</td>
<td>46.</td>
<td>Oxyropis densa</td>
</tr>
<tr>
<td>12.</td>
<td>Androssace spp.</td>
<td>47.</td>
<td>O. tatarica</td>
</tr>
<tr>
<td>13.</td>
<td>Draba spp.</td>
<td>48.</td>
<td>Incarvillia youngusbandii</td>
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<tr>
<td>14.</td>
<td>Sibaldia parviflora</td>
<td>49.</td>
<td>Astragalus rotaephate</td>
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<tr>
<td>15.</td>
<td>Bistorta affinis</td>
<td>50.</td>
<td>Thalictrum alpinum</td>
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<tr>
<td>16.</td>
<td>Lagotis crassifolia</td>
<td>51.</td>
<td>Dreisolen wattii</td>
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<tr>
<td>17.</td>
<td>Sibaldia parviflora</td>
<td>52.</td>
<td>Sipapurpurea</td>
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<tr>
<td>18.</td>
<td>Carex montis Everesti</td>
<td>53.</td>
<td>Carex montis Everesti</td>
</tr>
<tr>
<td>19.</td>
<td>S. truxifolia</td>
<td>54.</td>
<td>Kobresia pygmaea</td>
</tr>
<tr>
<td>20.</td>
<td>S. graminea</td>
<td>55.</td>
<td>K. Capillifolia</td>
</tr>
<tr>
<td>21.</td>
<td>Pedicularis spp.</td>
<td>56.</td>
<td>K. tibetica</td>
</tr>
<tr>
<td>22.</td>
<td>Elymus spp.</td>
<td>57.</td>
<td>Bupleurum falcatum</td>
</tr>
<tr>
<td>23.</td>
<td>Alopecurus spp.</td>
<td>58.</td>
<td>Verbasum thapsus</td>
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<tr>
<td>25.</td>
<td>Pulsatilla wallichiana</td>
<td>60.</td>
<td>Carthamus tinctorius</td>
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<tr>
<td>26.</td>
<td>Polygonum plebeium</td>
<td>61.</td>
<td>Echinops eclinata</td>
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<tr>
<td>27.</td>
<td>Fragaria vesca</td>
<td>62.</td>
<td>Epipactus sp.</td>
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<tr>
<td>28.</td>
<td>Potentilla nepalensis</td>
<td>63.</td>
<td>Poenia emodi</td>
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<tr>
<td>29.</td>
<td>Viola spp.</td>
<td>64.</td>
<td>Corydalis sp.</td>
</tr>
<tr>
<td>31.</td>
<td>Taraxacum spp.</td>
<td>66.</td>
<td>Epilium sp.</td>
</tr>
<tr>
<td>32.</td>
<td>Trifolium spp.</td>
<td>67.</td>
<td>Popatens sp.</td>
</tr>
<tr>
<td>33.</td>
<td>Achellia millfolium</td>
<td>68.</td>
<td>Haracleum canadense</td>
</tr>
<tr>
<td>34.</td>
<td>Rosa microphylla</td>
<td>69.</td>
<td>Fagopyrum sp.</td>
</tr>
<tr>
<td>35.</td>
<td>Ranunculus leatus</td>
<td>70.</td>
<td>Sísymbrium sp.</td>
</tr>
<tr>
<td>36.</td>
<td>Mentha sylvestris</td>
<td>71.</td>
<td>Acer alba</td>
</tr>
<tr>
<td>37.</td>
<td>Tamurix tropii</td>
<td>72.</td>
<td>Fems</td>
</tr>
</tbody>
</table>

From the data recorded in the present study it was concluded that the forests in the area of Nalter and Astore are being affected at a very rapid rate. The factors responsible to cause major damage in these areas are the same as indicated by Schickhoff (1992) and are shown in the following scheme:
The roots of forest trees are invariably associated with fungal hyphae (Harley, 1989), and the feeder roots are often branched and encased in a sheath or mantle of fungal pseudoparenchyma. The ensheathing fungus penetrates between the cortical cells forming single-layered flattened sheets of closely packed hyphae, the hartig net. Infection does not extend into the stele and the living cortical cells are not penetrated. This kind of association is an example of mutualistic symbiosis. The fungal partners or the mycobiont acquires the bulk of its carbon supply from the chlorophyllous host or autobiont, whilst the mineral supply of the host is enhanced as a result of infection by the fungus which may form an extensive network of hyphae ramifying through the litter layers of the soil. The mycorrhizal root systems themselves are concentrated in the surface layers of the litter and their mycelia are mainly in the F horizon where the resource quality of the litter and its decomposition rate are high. These ectomycorrhizae are characteristic of roots of conifers (e.g. Pinaceae) and broad leaved trees (e.g. members of the Fagaceae, Betulaceae and Myrtaceae). They are particularly well-developed in forests on moder, mull or brown earth soils in zones of moderate latitude and altitude, especially where the climate shows seasonal change, with some surface drying of the soil (Read, 1984, 1991). Mycorrhiza of this sort develop very poorly in waterlogged soil, (Read and Boyd, 1986).

Most of the ectomycorrhizal fungi belong to the Agaricales, Boletales and the Gasteromycetes. They may also be produced by members of the Tuberales (ascomycetes) and Endogone (zygomycetes). Some of the more common genera of ectomycorrhizal basidiomycetes as given by Dix and Webster (1995) are:

- **Agaricales & Boletales:**
  - Russulaceae: Russula, Lactarius
  - Cortinariaceae: Cortinarius, Hebeloma
  - Boletaceae: Boletus, Leccinum
  - Russulaceae: Russula, Lactarius
  - Tricholomataceae: Hydnum
  - Hydnaceae: Hydnum
  - Thelephoraceae: Thelephora

Fungi, which form mycorrhiza, differed in their host specificity. The ability to cause the mycorrhizal infections and the ability to fruit in association with a given host are two different characteristics of these fungi. According to Molina and Trappe (1982), three different groups may be distinguished amongst these fungi:

- **Group I:** Fungi with wide ectomycorrhizal host potential, low specificity, whose basidioecarps are usually associated in the field with diverse hosts.
- **Group II:** Fungi with intermediate host potential yet specific or limited in basidioecarp-host associations.
- **Group III:** A more specialized group of fungi with a very narrow host potential.

The reasons for the different degrees of host specificity by ectomycorrhizal fungi are not known.

Our results are in line with a series of subsequent studies distinguishing early- and late-stage stage mycorrhiza formers, (Deacon et al., 1983). Typical early stage fungi were species of Hebeloma, Lactaria and Thelephora. Late stage fungi included Cortinarius spp., Leccinum spp., Russula spp. and Amanita sp. A clear-cut difference was found between early-stage fungi all of which are capable of infecting tree seedlings and late stage fungi which are unable to do
so. Deacon and Fleming, (1992) have suggested that the early stage fungi may be capable of infecting roots in the monokaryotic state in contrast with late-stage fungi where only dikaryotic mycelia can successfully infect. Assuming that most ectomycorrhizal fungi have tetrapolar mating system and a low number of basidiospores germinating near the host root surface, ability to infect in the monokaryotic state would greatly increase the chance of establishing a successful partnership.

As the tree age, and their capacity to produce foliage increases, changes occur in the soil and litter layers. Canopy closure tends to eliminate the ground flora (Fig. 4). As the tree litter accumulates in quantity, its quality declines and the proportion of lignin and phenolic substances increases. The early stage fungi are generally non-host specific. With the increase in time, the range of fungal species increases and then declines to a small number of more host-specific late stage fungi (DIGHTON et al., 1986). It has been suggested that the early-stage prolifically fruiting fungi with their wide host range are R-selected, i.e. show ruderal characteristics. The relatively few less-prolific fungi found on older trees following canopy closure, with their narrower host range, seem to be S-selected, i.e. have stress tolerant characteristics. The early stage fungi are able to colonize roots in soils with little or no tree litter, whilst the late stage fungi colonize roots in soils with accumulation of plant litter. (LAST at al., 1987). During the intermediate stages of forest stand development, when the species diversity of the fungi is greatest, and when the early stage fungi are being displaced by others, there is also an implication of C-selection, i.e. selection of fungi with combative characters, (Fig. 4). At later stages when a forest stand is mature and host specificity is at its peak, if the stand is disturbed, the associated mycoflora would disappear. The soil of the forest floor tends to become sterile and the same cycle of seedling establishment and fungal selection would be repeated.

Arbuscular mycorrhizal fungi are present virtually everywhere in the soil all over the world. This type of mycorrhizae are so prevalent that Gerdemann (1968, 1975) said, it is easier to list plant families where relationship is not known than those where it is establish. Malloch et al., (1980) asserts that four fifths of all land plants form endomycorrhizae. The group of fungi involved in the
associations comprise a small number of taxa (approximately 150 spp.) have been estimated to form symbiosis with over 22,500 host plant species (MORTON, 1988).

The association of vesicular arbuscular fungi facilitates the uptake of phosphorus and trace metals such as zinc and copper. By extending beyond the depletion zone for phosphorus around the root, the external mycelium improves phosphorus absorption. Calculations by Sanders & Tinker (1971) show that a root associated with mycorrhizal fungi can transport phosphate at a rate more than four times higher than that of a root not associated with mycorrhizae. This physical exploitation of soil P is facilitated by fine external hyphae ranging in diameter between 2-15 \( \mu \text{m} \) (FRIES & ALLEN, 1991) with 3-4 \( \mu \text{m} \) as average value (OKEEF & SYLVIA, 1992). The fungal hyphae are abundant in soil. Kjoller and Struwe (1982) summarizing data from three ecosystems i.e. tundra, grassland and woodland, reported that total hyphal length in the 20cm at the surface ranged from 100 to 10,000 m/g of soil. It is suggested by several studies that this mass of hyphae would act to bind soil particles together. Koske, Sutton and Sheppard (1975) found extensive hyphal networks of endogonaceous fungi binding sand among plant roots in sand dunes. Koske et al., (1975) showed experimentally that reduced mycorrhiza resulted in reduced aggregation of soil particles. Their conclusion was that the major mechanism linking sand grains in aggregation was the binding action of the extensive and persistent Glomus hyphae. Tisdale and Oades 

Fig. 3.4 - Number of glomalean spores per 100g forest soil in disturbed (DS) and undisturbed stands at four different sites.

(1979), found a good correlation between the amount of hyphae produced in soil and the production of water stable aggregates. While Lynch and Bragg (1985) felt that the role of hyphae may be indirect, serving as a substrate for other polysaccharide-producing microorganisms. Polysaccharides have been observed on the surface of AM hyphae (LYNCH & BRAGG, 1985). A tenable model for enhanced soil stabilization by AM fungi is that the external hyphae, along with plant roots, produce a frame work for aggregation, while bacterial polysaccharides cement the soil particles together. Our study also indicates same kind of results i.e. showing positive correlation between arbuscular mycorrhizae and water stable aggregates, (Figs. 5 & 6).

Numerous stresses and (or) external constrains limit productivity in alpine plant communities (GRIME, 1979). These include short growing season, low temperature, mineral nutrient stress and felling of trees & overgrazing. The ability of mycorrhizal fungi to exploit soil nutrient pools efficiently, suggests that mycorrhizal plants have an adaptive advantage in nutrient poor environments (HARLEY, 1969; GRIM, 1979). Most species occurring at high elevation are mycorrhizal but little was known about the mycorrhizal propagules associated with the plants of these areas of Pakistan. It can be hypothesized that a greater dependency on mycotrophy may be associated with these soils. It may be suggested that a series of surveys and experiments should be carried out to enlist the fungi associated and the efficacy of these fungi in survival and improving the degree of nutrient absorption by these plants.

Fig. 3.5 - Weight in grams of water stable aggregates per 100g of forest soils of disturbed (DS) and undisturbed (UDS) stands at four different sites.
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REFERENCES


