International Journal of Science, Environment and Technology, Vol. 6, No 5, 2017, 3185 – 3190
ISSN 2278-3687 (O)
2277-663X (P)

Review Paper

SIGNIFICANCE OF MYCORRHIZAL ASSOCIATIONS OF TREE SPECIES WITH SPECIAL REFERENCE TO KASHMIR HIMALAYAS

Shabir Ahmad Rather* and Sabeena Nabi
Faculty of Forestry, SKUAST-Kashmir, Benhama, Ganderbal, J&K, India
E-mail: sshab32@gmail.com (**Corresponding Author)*

Abstract: Mycorrhizal asoociations involve members of the fungus kingdom (Basidomycetes, Ascomycetes and Zygomycetes) and most vascular plants. They are developed on more than 90% of plant species. Mycorrhizal fungi profoundly affect forest ecosystems by mediating nutrient and water uptake, protecting roots from pathogens and environmental extremes. During the recent years mycorrhizal research has received much attention and studies on plant-fungus mycorrhizal association have indicated increase in growth attributes, nutrient uptake, plant survival and consequently plant yield.

Mycorrhizae are a symbiotic mutualistic relationship between special soil fungi and plant roots: it is the resultant structure from the fungus and the root. Since the association is mutualistic, both individulas benefit from the association. They are present naturally in almost all ecosystems. They are present in more than 90% of plant species. Ectomycorrhizae or ECM, are most typically formed between the roots of about 10% of plant families, mostly woody individuals including *Pinus, Picea, Abies, Populus, Salix, Fagas, Betula, Quercus*, *Dipterocarpus, Eucalyptus* and fungi belonging to the Basidiomycota, Ascomycota, and Zygomycota. Endomycorrhizae are characterized by the development of unique structures, arbuscules and vesicles by fungi of the phylum Glomeromycota. Endomycorrhizae are developed in 80% of plants mostly deciduous and herbaceous (Agarwal and Sah, 2009 and Moore, 2011).

In the western Himalayan region, forests naturally occur from the foothills to about 3500 m altitude and almost all dominant tree species have ectomycorrhizal association. The dominant tree species include *Shorea robusta* (Sal) in the foothills, *Pinus roxburghii* from 1000 to 1800 m, *Quercus* sp. from 1000 to 3000 m, *Cedrus deodara* from 1800 to 2200 m, *Abies pindrow* from 2400 to 3000 m and *Betula utilis* from 2800 to 3500 m altitude (Lakhanpal, 1996). The temperate forest zone has two major forest types, viz. oak forest and mixed conifer forest.

*Received Sep 11, 2017 * Published Oct 2, 2017 * www.ijset.net*

The coniferous forests of Kashmir Himalayas serve as an excellent habitat for macro-fungi emanating in different seasons due to wide variability in climate, altitude, slope and type of forests etc. but the study on Kashmir Himalayas regarding diversity of macro-fungi and their ectomycorrhizae have been started in the recent years and is still in an exploratory or pioneering stage (Watling and Abraham, 1992). A few preliminary studies done in the different forest sites of the region more specifically deal with the symbiosis rather than the function of ectomycorrhizae in the forest ecosystem. Up to late 2009 hardly 250 macro-fungal species were reported from the whole of Jammu and Kashmir. The most dominant ectomycorrhizae include *Amanita*, *Russula*, *Boletus*, *Lactarius*, *Suillus* and *Cortinarius* etc. (Dar *et al.,* 2009). Moreover, Dar *et al.* (2010) added four new species viz., *Russula aurea, Russula atropurpurea, Suillus variegates* and *Boletus rhodoxanthus* to the list. The identification of macro-fungal species in Kashmir Himalaya assumes great significance with respect to their future use either as edible mushrooms or as medicinal source or as mycorrhizae to support plant growth under stressed conditions.

It is very well-known that AM (Arbuscular mycorrhizae) fungi considerably enhance plant phosphorus (P) acquisition by extending hyphae beyond the nutrient depletion zones, but their role in acquiring nitrogen (N)–the primary limiting nutrient in most of the temperate ecosystems – has only been recognized recently (Fellbaum *et al*., 2012). AM hyphae very rapidly colonize soil aggregates rich in organic N and take up both inorganic and organic N forms. As most of the AM fungi have limited saprotrophic abilities and inorganic N forms are relatively more mobile in soils where AM plants are dominant, it is therefore believed that these plants primarily utilize inorganic N forms (Smith and Smith, 2011).

ECM fungi form a thick mantle around root tips from which mycelium extend beyond the root zone and turn over slowly as compared to AM hyphae (Anderson and Cairney, 2007). ECM fungi are therefore believed to represent a greater C cost for the plant than AM fungi (Smith and Read, 2008), a cost which is likely to offset by the special ability of these fungi to access nutrients that are inaccessible to AM fungi. ECM fungi produce hydrolytic and oxidative enzymes to decompose soil organic matter (SOM) thereby enabling these fungi to mine soils for N-bearing compounds such as chitin, proteins and phenol– protein complexes as well as P-bearing inositol phosphates (Courty *et al*., 2010). ECM fungi and not AM fungi can weather minerals by releasing low-molecular-weight chelators and hydrogen ions to increase P and calcium availability (Taylor *et al*., 2009).

The variable nutrient acquisition mechanisms in AM and ECM plants reflect the different decomposition rates of AM and ECM leaf litters. AM plants scavenge for nutrients released by saprotrophic microbes – generally have leaf litter that decomposes rapidly whereas ECM fungi can mine nutrients from organic matter and are less dependent on saprotrophic microbes for nutrient release – generally have slow rate of decomposition . In a 32-yr-old common garden in Poland, AM leaf litter decomposed 51% faster than ECM leaf litter (Hobbie *et al*., 2006). Collectively, these studies reflect that in addition to being a good indicator of leaf litter decomposition rates, the mycorrhizal association of a given tree species may influence C and nutrient availability in temperate forests.

The plants are more often exposed to pathogenic attacks, particularly those causing root rot and wilt diseases at primary stages of plant establishment. Root rot, wilt and die-back on container-grown conifers such as spruce and pine is major problem since 1990's in Europe (Lilja *et al.,* 2010). The root rot fungi which pose considerable threat to forest nurseries include *Fusarium, Phytophthora, Pyihium, Rhizoctonia, Macrophomina* and *Cylindrocladium* (Wafaa and Haggag, 2002). These pathogens often invade terminal unsuberized roots of young seedlings and result in late damping off or root rot/wilt thereby kill the host. The fungi enter into root epidermal cell wall, grow inter-cellularly, decompose cell wall constituents and persist by metabolising cell contents. Root rot is world-wide a serious problem in pine seedlings and serious losses due to this disease have been reported from many parts of the world. In view of highly devastating nature of root rot pathogens, effective disease management is of great importance to raise healthy pine seedlings for successful implementation of reforestation and afforestation programmes.

The use of biocontrol agents is presently gaining tremendous momentum as a supplement to chemical treatment in integrated disease management module. The use of antagonistic bacteria, actinomycetes and fungi as biocontrol agents against several soil-borne pathogens have been demonstrated in several field and horticultural crops. The fungal antagonists may compete for an ecological niche by consuming available nutrients and by secreting a series of biochemicals effective against various fungal pathogens. These biochemicals may include cell wall-degrading enzymes, siderophores, chelating iron and a variety of volatile and non-volatile antibiotics, etc. The success in biocontrol process depends on the antagonisitic strain, the antagonized fungus, the crop plant and the environmental conditions, including nutrient availability, pH, temperature and iron concentration.

Mycorrhizal inoculants significantly improve the quality of seedling production in nursery and also the establishment of plantation to increase the forest productivity. Bio-inoculants are cost effective, ecofriendly, cheaper and renewable sources of plant nutrients and play a significant role in maintaining soil fertility and sustainability. Thus, to meet the challenges like poor regeneration, deforestation and spread of wastelands, introduction of mycorrhizal inoculants at the nursery stage of forest trees has become inevitable. Mycorrhizae reportedly aid young seedlings in their early survival and establishment through intricate and complex system of hyphal networks thereby not only ensures the sustained nutrient supply but also provides protection against invading pathogens. The culture filtrate of mycorrhiza, *Suillus cdlinius Hebeloma mesophaeum* and *Paxillus* sp., reportedly exhibit antagonistic effect on the mycelial growth and spore germination of *Fusarium oxysporum* and *Pyihium vexans* and the antifungal activity has been attributed to oxalic acid production (Yamaji *et al.,* 2005). Efforts are underway to improve the quality of forest nursery seedlings through inoculation of suitable mycorrhizal strain in association with other compatible bioagents. Dar *et al*., 2011 revealed that mycorrhizal fungi, *Pisolithus tinctorius* and *Laccaria laccata,* significantly inhibited the growth of *R. solani* and *F. oxysporum* by 46.2 and 45.4 and 44.7 and 43.7%, respectively in blue pine. Bioagents significantly improved seedling biomass and root/shoot length. Mycorrhizal plants showed 5-13 fold higher rhizosphere phosphatase activity than non-mycorrhizal ones. Four effective fungal bioagents, inoculated individually and in combination with pathogen under nursery conditions, significantly improved seedling biomass and height. This implies that bioagents, especially mycorrhizae, effectively mitigate root rot in trees and can be efficiently exploited in integrated disease management module. Asif *et al*., 2012, Ahangar *et al*., 2012, and Asif *et al*., 2013 used inoculum for introduction of mycorrhizal fungi in the forest nurseries. These studies revealed increased uptake of nutrients, improved growth attributes and increase in survival percentage (Table 1).

Table 1. Nutrient uptake, growth attributes and survival percentage of different host plants inoculated with different mycorrhizal fungi and in parallel controls with mycorrhizal mycelium absent.

Mycorrhizal inoculant	**Host plant**	**Nutrient uptake**			**Reference**
		N	P	K	
Pisolithus tinctorius	*Cupressus torulosa*	1.08 %	0.12 %	0.36 %	Asif *et al*., 2012
Laccaria laccata		1.02 %	0.10 %	0.34 %	
Control		0. 79 %	0.05 %	0.25 %	
Laccaria	*Pinus*	6.47	0.46	3.75	Ahangar *et*

laccata	*wallichiana*	mg/plant	mg/plant	mg/plant	*al.*, 2012
Control		3.25 mg/plant	0.13 mg/plant	1.53 mg/plant	
Mycorrhizal inoculant	**Host plant**	Plant height (cm)	Root length (cm)	Seedling survival (%)	
Laccaria laccata	*Pinus wallichiana*	9.60	11.0	-	Ahangar *et al.*, 2012
Control		7.70	7.30	-	
Pisolithus tinctorius	*Cupressus torulosa*	24.78	24.02	93.92	Asif *et al.*, 2013
Laccaria laccata		23.86	23.77	91.62	
Control		14.13	19.44	74.14	

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