Mycorrhiza: A Potential Application for Increased Crop Productivity in a Degraded Soil.

ABSTRACT

Mycorrhiza is obtained from two Greek expressions, namely: mykes (fungus) and rhiza (root). In otherwise, mycorrhiza means fungus-root as coined by Frank in 1885. So, mycorrhiza association is defined as the mutual relationship between fungus and plant root in which the fungus derive carbon from its host plant while the host plants obtain minerals from the fungus. Mycorrhizas are found in different biomes ranging from high latitudes and altitudes, deserts, lowland tropical forest to aquatic ecosystems. It is a known fact that several plants cannot thrive in their natural habitats without this mutualism, as 95-99 % of all plant species have been estimated to belong to genera that generally form mycorrhizas. It is only three families of plant that do not enter into mutual relationship with fungus. These families are as follows: Cyperaceae, Chenopodiaceae, and Brassicaceae. There are now seven types of mycorrhizas among which are arbuscular (AM) endomycorrhiza, ericoid endomycorrhizas, arbutoid endomycorrhizas, monotropoid endomycorrhizas, orchidaeous endomycorrhizas, ectomycorhizas and ectendomycorrhizas. The benefits of mycorrhiza association cannot be overemphasized as studies have shown that it improves nutrient supply of carbon, phosphorus and nitrogen to both plant and fungus that might not normally be made available to plant roots in large amount. It also enhances the performance of plant growing in soils with high amounts of heavy metals and water absorption of desert plants.

Keywords: Mycorrhizas, fungus plants, mutualism, ecosystem.

1.1 DEFINITION OF MYCORRHIZAL ASSOCIATION

Mycorrhizal association is defined as the mutual relationship between fungi and plant roots.

1.2 MEANING OF MYCORRHIZA

The expression “mycorrhiza” was initially used by Professor A.B. Frank in the 1880s who first described it as the relationship between trees and fungi. Mycorrhiza was derived from Greek words, “mykes” and “rhiza” which mean fungus-root. According to studies, more than 90 % of all plant families in both agricultural and non-agricultural environments possess mycorrhizal relationship. Mycorrhizas are important for plant nutrition (Allen, 1992).

1.3 DISTRIBUTION OF MYCORRHIZAS

Mycorrhizas can be found in several habitats such as deserts, lowland tropical rainforest, high latitudes and altitudes, and aquatic ecosystems. Many non-mycorrhizal plant families possess highly specialized strategies such as carnivorous plants (e.g. Droseraceae, Lentibulariaceae, Nepenthaceae, Serraceniaceae), parasites usually having no roots (Apodanthaceae, Balanophoraceae, parasitic convolvulariaceae, orobanchaceae, santalaceae) or plants with dense roots with long root hairs, e.g. protoaceae numbers particularly those found in highly infertile soils of Western Australia and South Africa. However, non-mycorrhizal cluster roots also are seen in the myricaceae and some genera of the fabaceae (e.g. Lupinus) (Stanley *et al.*, 1993).

1.4 TYPES OF MYCORRHIZA

Mycorrhizas were traditionally categorized into two, namely: ectotrophic and endotrophic which classification was on the basis of location of the fungal hyphae in connection with plant roots (Moore *et al.*, 2011). This grouping is now considered as too simplistic, and there is now a name which has identified seven mycorizas. However, there are three major types of mycorrhiza.

1.4.1 Endomycorrhizas: These are types of mycorrhizas in which the fungal structure is nearly confined in the host root. This type consists of three main and two minor classes:

(i) Arbuscular (AM) endomycorrhizas

These are the first to evolve and the most common mycorrhizas which fungi are members of the Glomeromycota. They are obligate biotrophs and are connected with about 80 % of plant species as well as many crop plants. The Arbuscular endomycorrhiza formerly known as vesicular-arbuscular mycorrhiza (VAM) has been changed to Arbuscular mycorrhiza (AM) due to the fact that not all of the fungi form vesicles (Selosse and Le Tacon, 1998).

(ii) Ericoid endomycorrhizas

These are mycorrhizas of Erica (heather), Calluna (ling) and Vaccinium (bulberry), i.e. plants that endure moorlands and likely challenging conditions. Here, fungi are those of the Ascomycota. The plant's rootlets are covered with a sparse network of hyphae. The fungi digest polypeptide saprotrophically and passes absorbed nitrogen to the plant host. The mycorrhiza may also provide the host with carbon sources in extremely adverse environment. This type of mycorrhiza is sub-divided into two groups, namely: Arbutoid endomycorrhizas and Monotropoid endomycorrhiza. These are mycorrhizal relationship formed by the adilorophyllous plants of the Montropaceae.

(iii) Orchidaceous endomycorrhizas

These are first-like ericoid mycorrhizas but their carbon nutrition even is more dedicated to supporting the host plant as the young orchid seedling is non-photosynthetic. The young orchid seedling relies on the fungus partner using complex carbon sources in the soil and making carbohydrates available to the young orchid. Note that all orchids are achlorophyllous in the early seedling stages and chlorophyllous as adults. A good example of fungus is the basideiomycete genus Rhizoctonia.

1.4.2 Ectomycorrhizas: These are the most developed mutualistic relationship between higher plants and fungi, consisting of about 3 % of seed plants and many forest trees. In this relationship, the plant root system is entirely covered by a sheath of fungal tissue which can be more than 100 cm thick, though it is often up to 50 cm thick (Brundrett, 1991). The hyphae penetrate between the outermost cell layers to form Hartig net from which hyphal elements stretch out to explore the soil rhizosphere and meet with the fungal tissues of the plant roots.

Ectomycorrhizal fungi are commonly Basidiomycota and woodland mushroom like Boletus elegans, Tricholoma species as well as Amanita species. Ectomycorrhizal could be specific (e.g. *Boleta elegans*, *Tricholoma* species as well as Amaniita species. Ectomycorrhiza starch) and non-specific (e.g. Amanita muscaria with 20 or more species of tress). Ectomycorrhizas can join different groups of trees together with the submerged mycelium behaving as a "word-wide web". Pines can have mycorrhizas with forty fungal species. Ectomycorrhizal fungi rely upon the host plant for carbon source, often being uncompetitive like saprotrophs. The fungi cannot digest cellulose and lignin. However, the fungus provides enormously increased absorption of mineral ion for the plant and the fungus can capture nutrients especially ammonium and phosphate ions which the root are not capable of accessing.

1.5 IMPORTANCE OF MYCORRHIZA IN THE ECOSYSTEM

i. Mycorrhiza improves the supply of crop nutrients by sourcing different forms of nutrients that could not be actually accessible to crops.

ii. Certain ectomycorrhiza (ECM) and ericoid fungi can break down phenolic compounds in soils that can hinder the normal absorption of nutrients (Bending and Read, 1999).

iii. The colonization of crop roots by ectomycorrhiza and vesicular-ambuscular mycorrhiza (VAM) fungi can protect crop plants against nematodal attacks infestation (Morin *et al.*, 1999).

iv. Mycorrhizal association increases crop yield, accumulation of nutrients and/or reproductive performance of crop plants (Stanley *et al.,* 1993).

v. It can also bring about changes in growth from root, architertude and vascular tissue (Miller *et al.,* 1997).

vi. Simard *et al.* (1997) observed transfer of significant quantities of carbon thorough fungal mycelia that link different plant species.

vii. It improves the establishment and growth of shaded under storey plants through hyphal networks of dominant trees (Horton *et al.*, 1999).

viii. Eason and Newman (1990) observed that transfer of nutrients from dead to living plants might take place.

ix. Soil hyphae are useful in nutrient cycling by helping to avoid losses from the ecosystems particularly when plant roots are not active (Lussenhop and Fogel, 1999).

x. Soil hyphae are conduits in collaboration with other members of the decomposition soil food web to transfer carbon from plant roots to other soil organisms involved in the cycling processes of plant nutrients.

xi. It affects soil microbial populations and exudates in the mycorrhizosphere and hyphosphere (Andrade *et al.*, 1998).

xii. Hyphae of vesicular-arbuscular mycorrhizas improves soil structure (Griffiths *et al.*, 1994).

xiii. Mycoirrhizal association also improves storage of carbon in the soil by changing the quality and amount of soil organic matter (Ryglewiez and Anderson, 1994).

xiv. Ectomycorrhizal fungi (mushrooms) are sources of food to man (Kalotas, 1996).

xv. Mogan (1995) asserted that these mushrooms are used as medicines and natural dyes.

xvi. Mogan (1995) also noted that larger fungi are aesthetic in nature and form part of people's culture and nature appreciation.

1.6 MODE OF OPERATION

Mycorrhizal hyphae which extend far from the plant roots can penetrate and exploit a greater volume of soil to obtain soil nutrients. The nutrients taken up by hyphae are transported within the hyphal network to the fungal sheath intercellularly to the hartig net and intracellularly into the plant cells with the exception of ectomycorrhizas and monotropoid mycorrhizas (Allen, 1992). The fungal sheath acts as a storage site for nutrients to allow the fungus continue to make nutrients available to host plant when nutrient concentration of the soil is limiting. Mycorrhizal plants lose about 10 - 20 % of the starch they produce for the formation, maintenance and functioning of the mycorrhizal fungi and their associated structures in return for getting surplus nutrients. Carbohydrates that enter the fungi appear in the hyphae as trehalose and in certain strains as mannitol as regards the transfer of carbon from plant to fungi. The reverse is the case with trehalose and mannitol when carbohydrates are transferred from fungus to plant as in orchid and monotropoid mycorrhizas. However, in arbuscular mycorrhizas exchange of nutrients takes place through the arbuscles which is an intracellular interface that is also seen in ericoid mycorrhizas. On the other hand, the interface between plant and fungus occurs in the Hartig net, an intercellular structure of different thickness (Allen, 1992).

1.7 **A CASE STUDY OF MYCORRHIZAL APPLICATION TO CROP PRODUCTION**.

The research was conducted by Hota *et al.* (2014) in an acidic affisol at the farm of the Regional Centre of Central Tuber Crops Research Institute, Bhubaneswa Government of India between 2011 and 2012 to study the effect of integrated use of lime, biological, inorganic and organic sources on *Colocasia esculenta.* The following results on (Table 1) revealed that the treatments, rich in vesicular-arbuscular mycorrhizas (VAM) significantly produced the highest yield (14 t/ha) compared to other treatments.

Table 1: effect of lime, inorganic, biological, and organic sources on yield of *Colocasia esculenta*

Treatments	Cormel/plant	Av. cormel weight (g)	Cormel yield (kgha^{-1})	Yield response (%)
Control	6.67	21.95	6637.7±155.15	-
100 %N	7.80	24.78	8491.7±82.41	27.9
100 % P	7.33	25.14	7898.3±132.77	19.0
100 %K	7.67	23.89	7971.7±38.69	20.1
100 %NP	9.83	26.40	10476.7±77.69	57.8
100 %NK	9.60	25.04	10608.3±106.29	59.8
50 % NPK	9.40	22.28	9113.3±159.08	37.3
100 % NPK	10.53	30.63	13138.3±406.20	97.9
150 % NPK	11.17	32.47	14297.7±959.38	115.40
FYM + 100%NPK[a]	11,07	32.25	14163.3±200.48	113.40
Lime + FYM + ½ NPK	10.70	27.45	11053.3±260.34	66.5
Lime + GM + ½ NPK	10.80	29.16	12365.0±183.76	86.3

FYM + ½NPK + $ZnSO_4$[b]	10.07	31.86	14263.3±152.28	114.9
Lime + FYM + ½NPK + ZnSO4[b]	11.40	32.07	14691.7±140.04	121.3
FYM + ½NPK + B [c]	9.53	29.84	13593.3±138..42	104.8
Lime + FYM + ½NPK + B [c]	9.70	30.69	13933.3±261.48	109.9
FYM + ½NPK + $MgSO_4$ [c]	10.40	30.59	14108.3±52.551	112.5
Lime + FYM + ½NPK + $MgSO_4$[c]	10.77	32.75	14273.3±168.56	115.0
FYM + ½NPK + VAM	10.33	29.45	13968.3±234.78	110.4
Lime + FYM + ½NPK + VAM	10.90	30.38	14041.7±120.67	111.5

Source: Hota *et al*. (2014).

Key: a = Based on soil test; b = 10 $kgha^{-1}$; GM = Green manure; c = 2.5 $kgha^{-1}$; Result of ANOVA was significant at 0.05 probability level.

Conclusions

The need to integrate mycorrhizas with the conventional organic and inorganic treatments in crop production for improved yield cannot be overstressed as a study carried out by Hota *et al.* (2014) proved its added advantage over other conventional soil amendments. Mycorrhizas should be applied in soils polluted with heavy metals, marginal soils and deserts to enhance water economy.

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