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Review Article

The role of arbuscular mycorrhizal fungi on agricultural crop productivity and ecosystem service: A review

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Arbuscular mycorrhiza a constitute a key functional group of soil organism that can greatly contribute to crop productivity and ecosystem sustainability in new plant production strategies. The activity of soil microorganisms and microbial processes is reducing the environmental pollution which can cause by heavy metals and others adverse condition. AM fungi efficiently use for agricultural productivity in sustainable manner in which the diversity and function of soil microorganism is the decisive issue in the agrarian activities and ecosystem service. AM used to enhance the agricultural productivities and ecosystem stability by ameliorate the environmental stress. AM fungal species and diversity play the crucial role in bioremediation, nutrient and water uptake, improve of soil properties, generate and establish vary seeds, and improve the mineralization processes. AM fungal root colonization, the use of mycorrhizal crops in rotation used to increases the abundance of AM fungi in the soil which in turn treat toxic elements and thereby lead to improve agricultural productivities and stabile ecosystem service.

Key words: Arbuscular mycorrhiza fungi, crop productivity, ecosystem

INTRODUCTION

Arbuscular Mycorrhiza (AM) constitute a key functional group of soil biota that can greatly contribute to crop productivity and ecosystem sustainability in new plant production strategies (Jeffries et al., 2003). AM fungi, able to establish symbiotic interaction with the root organs of 80% of plant families, not only improve the growth of plants through increased uptake of available soil phosphorus (P) and other on-labile mineral nutrients essential for plant growth, they have also 'non-nutritional' effects in stabilizing soil aggregates, in preventing erosion, and in alleviating plant stress caused by biotic and abiotic factors (Smith et al., 2011). The beneficial effects of AM fungi on plant performance and soil health are essential for the sustainable management of agricultural ecosystems (Barrios, 2007).

Nevertheless, since the 'first green revolution', less attention has been given to beneficial soil microorganisms in general and to AM in particular (Robertson and Swinton, 2005). Human society benefits from a multitude of resources and processes from natural and managed ecosystems, to which AM make a crucial contribution. These resources and processes, which are called ecosystem services, include products like food and processes like nutrient transfer (Nziguheba and Smolders, 2008). Growing human needs and demands have led to an increase in resource demands imposed on ecosystems, greater global consumption of natural resources and a significant decline in ecosystem services (Fisher and Turner, 2008). Many people have been under the illusion that these ecosystem services are free, invulnerable and infinitely available; taken for granted as public benefits, they lack a formal market and are traditionally absent from society's balance sheet. Since 1997, economists and ecologists have joined forces to estimate the annual value of the services that ecosystems provide (Banzhaf, 2007).

Although most services lie outside the market and are difficult to calculate, minimum estimates equal or exceed global gross national product (Munkvold et al., 2004). In 1997, a team of researchers from the USA, Argentina and the Netherlands put an approximate price tag of US $33 trillion a year on these fundamental ecosystem services (Wallace, 2007). This is nearly twice the value of the world's gross national product. In this study, two major ecosystem services, 'soil formation' and 'nutrient cycling', were respectively estimated to represent US $17.1 and 2.3 trillion (Perner et al., 2008). Whilst some countries use tax systems to protect the environment by restraining levels of polluting activities (e.g.

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carbon tax) or to stimulate development of environmentally friendly policies (Ecological Tax Reform), Costa Rica is one of the first countries to make a national effort to protect ecosystem services (Pagiola, 2008).

In 1996, this country adopted a law (Forestry Law No. 7575) recognizing four Critical services provided by the nation's forests: carbon sequestration, hydrological services, biodiversity protection and scenic beauty (Sailo and Bagyaraj, 2005). This law establishes a framework for Payment for ecosystem services, set forth in a programmed entitled Pagospor Service's Ambien (PSA) administered by the National Forestry Fund (FONAFIFO), in which landowners and all future purchasers of the land contract to provide against payment ecosystem services, for 20 years, via reforestation, sustainable management, preservation and regeneration activities (Whipps, 2004). The supply of agricultural products and ecosystem services are evidently essential to human existence and quality of life; however, recent agricultural practices that have greatly increased global food supply have had inadvertent, detrimental impacts on the environment and on ecosystem services (Stan et al., 2008).

High-intensity agriculture has principally focused on productivity instead of integrating natural resource management into food production security; mechanization, monocultures, and increased uses of synthetic inputs (chemical fertilizers, pesticides) have degraded water quality, reduced arable lands and forest resources, and soil fertility (Farmer et al., 2005). In consequence, novel and expedient methods are needed to manage earth's ecosystem services, the loss of which will have important consequences for sustainable food production in the face of an increasing world population (Cummings and Kovacic, 2009). Agriculture is the largest interface between humans and environment, thus reconciling crop production and environmental integrity, in other words sustainable crop production, is a major challenge for agriculture and future farmers (Robertson and Swinton, 2005). This implies the need to develop crop management strategies that optimize soil fertility, biological diversity and crop robustness by creating forms of agro ecosystems that respect natural ecological processes and support productivity in the long term (Banzhaf, 2007).

In this context, the ecosystem services rendered by soil biota in maintaining soil quality, plant health and soil resilience are extremely pertinent (Smith and Read, 2009). In particular, soil microorganisms that form mutually beneficial relationships with plant roots have become a target of increasing interest in agricultural research and development because they offer a biological alternative to promote plant growth and reduce inputs in sustainable cropping systems (Hart and Trevors, 2005). The ubiquity of AM fungi at the interface between soil and plant roots makes them a key functional group of soil biota which by their nutritional and non-nutritional activities profoundly influences ecosystem processes that contribute to agricultural crop production and the ecosystem services in agro ecology (Leake et al., 2004). The aims in this review are to highlight the key role that the AM symbiosis can play as an ecosystem service provider to guarantee crop productivity and quality in emerging systems of sustainable agriculture (Copetta et al., 2006). The appropriate management of ecosystem services rendered by AM will impact on natural resource conservation and utilization with an obvious net gain for human society. Therefore, the overall objective of this paper is to review the role of Arbuscular Mycorrhizal Fungi on agricultural crop productivity and ecosystem service.

LITERATURE REVIEW

Basic concepts and terminologies

Ectomycorrhizae: It is characterized by the presence of hyphal plexus between root cortical cells producing a net like structure called 'Hartig net'. The fungal partner in an ectomycorrhizae most frequently belongs to the *Basidomycota* though in some cases, it is *Ascomycete*.

Endomycorrhizae: Endomycorrhizae are characterized by the fungal hyphae which penetrate the cortical cells of host root tissues. It comprises of both septate and aseptate fungi. They do not have external sheath and the hyphae are present intracellular as well as intercellular within roots. This type of association occurs in all agronomic crops and basically falls in three categories: (i) Ericaceous mycorrhizal, (ii) Orchidaceous mycorrhizal, (iii) Arbuscular mycorrhizal fungi (Oehl et al., 2005).

Ericaceous mycorrhizal: This type of association is found in plants of the order Ericales. Arbuscular are not formed. This is further divided into 3 types: (i) Ericoid mycorrhizal, (ii) Arbutoid mycorrhiza, and (iii) Monotropoid mycorrhiza.

Orchidaceous mycorrhizal: Mycorrhizal fungi penetrate the host cells and form intracellular hyphal coils called peloton coil. Majority of orchid mycobionts are member of *Basidiomycota*, e.g. *Armillaria, Rhizoctonia*, *Tulasnella* etc. A striking exception has been the fungal partners of *Epilates* spp. *Wilcoxon* and *Phialophora* are potential mycorrhizal *Ascomycete*s in orchids (Bidartondo et al., 2004).

Arbuscular Mycorrhizal Fungi (AMF): These Fungi are characterized by the presence of intracellular hyphae in the primary cortex which form vesicles and arbuscular later on. Vesicles are thin-walled or thick-walled globose to subglobose, irregular shaped structures. AMF are found in all angiosperm families, except some families such as Betulaceae, Urticaceae, Commelinaceae, Cyperaceous and Polygonaceae. Earlier, the name Vesicular Arbuscular Mycorrhizal (VAM) fungus was used, but since not all the groups produce vesicles, the term AMF is preferred. Some of the important genera are *Glomus*, *Acaulospora*, *Gigaspora*, *Scutellospora*, *Enterophospora* and *Sclerocystis*.

Ectendomycorrhiza: It is an intermediate type of association and showing features of both ecto and endomycorrhizae (Martin et al., 2001). Mantle is thin or lacking. It is having both intracellular as well as intercellular hyphae in cortical region of roots. *Alnus*sp, *Salix* spp, *Populus* spp and *Eucalyptus* spp. can have both endomycorrhizal and ectomycorrhizal associations.

Role of AM fungi in agricultural crops

The AMF symbiosis has also been shown to contribute substantially to soil conservation via its role in the formation of water-stable soil aggregates by the extrametrical hyphae (Strack and Fester, 2006). These aggregates are crucial for creating and maintaining a macro porous, water permeable soil structure, which is prerequisite for erosion resistance and also necessary for efficient nutrient cycling (Perner et al., 2008). The profuse use of phosphate fertilizers and chemicals causes pollution problems and health hazards. So the use of AMF is being encouraged in agriculture. The exploitation of Mycorrhiza fungi is not easy because large scale production of AMF on field scale is not yet possible (Martinez-Medina et al., 2009).

Apart from effects of fertilizer application on AMF, other practices like crop rotation, minimal cultivation, monoculture, tillage, organic amendments, and application of biocides affects the AMF (Gorlach et al., 2004). Mycorrhiza symbiosis plays an important role in the tropical agricultural crops because in tropical region, the soil is phosphorus deficient (Hildermann et al., 2010). Nziguheba and Smolders reported that 75% of the phosphorus applied to the crops is not utilized by them but get converted to forms unavailable to plants (Nziguheba and Smolders, 2008).

Crop dependency on mycorrhiza

The relative dependency on AMF for nutrient uptake in crop plants depend on root factors such as surface area, root hair abundance and length, growth rate, response to soil conditions and exudations (Smith and Read, 2008). Crops such as corn (*Zea mays*) and flax (*Linum usitatissiumum*) are highly dependent on AMF to meet their early phosphorus requirements. Legumes, beans and potatoes also benefit significantly from mycorrhizal. Barley, wheat and oat benefit from mycorrhiza symbiosis (Orfanoudakis and Alifragis, 2008).

Crop rotation: A crop rotation is a system of growing crop plants in a repeated defined sequence. Crop rotation is a tool for managing nutrient supply, weeds, pests and diseases. It is well known that the preceding crop will affect the growth of the subsequent crop (Barrios, 2007). This phenomenon, known as the 'rotation effect', cannot be explained entirely by nutritional effects and other factors such as AMF may play an important role in the success of crop rotation (Robertson and Swinton, 2005). It has been well established that the AMF activity is decreased by non mycorrhizal fungi host plants and highly mycorrhizal host crop increase AMF inoculum potential of the soil and colonization of the subsequent crops (Schliemann et al., 2008).

An increase in AMF colonization and growth in maize occurred following sunflower (*Helianthus annuus*, mycorrhizal) when compared to corn following mustard (non–mycorrhizal) (Johnson et al., 2002). Here non mycorrhizal plants in the rotation reduce the rate of AMF colonization in following crops. Strack and Fester also observed delayed AMF colonization of corn (*Zea mays*) following canola (*Brassica napus*); a non–mycorrhizal host species, when compared to the colonization of corn following the AMF host species brome grass (Bromus spp.) and alfalfa (*Medicago sativa*) (Strack and Fester, 2006). The corn following canola had significantly lower AMF colonization for up to 62 days after planting after which the colonization was equal to that following an AMF host species. These observations suggest that AMF populations can be built up and the inhibitory effect of a non-mycorrhizal crop can be reversed after cropping with a mycorrhizal crop (Watson, 2004).

Phosphorus fertility: The benefits of AMF are greatest in systems where P in the soil is low (Herring and Fantel, 1993). As the level of P available to plants increases, the plant tissue phosphorus also increases and the plant carbon investment in Mycorrhiza is not economically beneficial to the plant (Toussaint et al., 2007). Encouragement of mycorrhizal symbiosis may increase early uptake of phosphorus, improving crop yield potential without starter P fertilizer application (Bouamri et al., 2006).

Seedling establishment: AMF also play an important role in successful reforestation and there are several reports of increased establishment of many of forest seedlings in the field, like *Quercus rubra* (Harrier and Watson, 2004). In a study conducted by Whipps on establishment of *Desmoncus orthacanthos* along with inoculation of AM fungi resulted in a threefold increase in survival of seedlings in the field (Whipps, 2004).

Roles of AM fungi in ecosystem and alleviation of environmental stress

It can be hypothesized that a diverse community of AM fungi may offer a diverse pool of ecosystem services, but clearly more work is needed on diversity/function relationships in order to be able to answer this question (Banzhaf, 2007). On the one hand, AM fungal species/isolates can show clear physiological diversity (Munkvold et al., 2004), whilst, on the other, selection or breeding for plant varieties under high-nutrient conditions which ignore symbiotic activity can lead to the generation of plant genotypes which are less or non-receptive to mycorrhizal (Zhu et al., 2001). The early morphological Mycorrhiza integration of plant and fungal tissues is likely to be reflected in both partners by basic genomic and metabolic programme which have persisted throughout the ages (Bouamri et al., 2006).

However, plants have strongly diversified with evolution, reaching approximately 260,000 extant species, which in many cases can be assigned to defined ecological niches or habitats (Roth-Nebelsick and Konrad, 2003). In contrast, Glomeromycetes appear to have remained relatively unchanged over hundreds of millions of years, a situation that has been interpreted as morphological stasis (Croll and Sanders, 2009), and no more than 200 morph species of these fungi are known today (Schüssler et al., 2001). Similar loss of symbiotic activity due to selection has been observed for soya bean (Kiers et al., 2007). Such deleterious effects on symbiotic function, which are likely to go unnoticed in high-input agriculture, will be highly relevant under low-input conditions. In this context, efforts need to be made to elucidate the possible negative impact of breeding on AM function by comparing conventionally bred varieties with those adapted to low-input conditions (Hildermann et al., 2010).

However, it should be underlined that no case is known where a host plant has completely lost its ability to form AM through regular selection or breeding activities (Porras-Soriano et al., 2009). It has even been suggested that in the absence of a positive growth response of the host plant, the fungal symbiosis may still be responsible for a large part of phosphate uptake in AM plants (Smith et al., 2009). Based on the finding that plant diversity influences AM fungal diversity (Johnson et al., 2002), evidence is accumulating that long-term monocropping may have a deleterious effect on AM fungal diversity although it may be difficult in each case to separate direct effects from accompanying factors of intensive agricultural management such as high-nutrient and pesticide input, soil disturbance (Oehl et al., 2003).

Wasteland reclamation: AMF have a great potential in the recovery of disturbed lands and these can be used in reclamation of wastelands in which inoculation with AM fungi can improve the growth and survival of desirable revegetation species (Evelin et al., 2009). Colonization with AMF can cause a beneficial physiological effect on host plant in increasing uptake of soil phosphorus. Nziguheba and Smolders suggested that plant growth in wastelands could be effectively improved by incorporating AMF (Nziguheba and Smolders, 2008). It has been suggested that many plants may require mycorrhizal infection in order to survive on disturbed land (Gensel, 2008). The absorptive surface area contributed by soil mycelium allows phosphorus uptake from a much greater volume. Host growth is also enhanced particularly in phosphorus-deficient soils (Munkvold et al., 2004).

AM fungi have been conclusively shown to improve revegetation of coal spoils, strip mines, waste areas, road sites and other disturbed areas (Bidartondo et al., 2004). Addition of AMF provides a nutritional advantage to associated plants in addition to providing possible resistance to low pH, heavy metal toxicants and high temperature (Gamalero et al., 2009). Presence and utilization of AMF has markedly increased the success of rehabilitation to this moisture deficient zone. Pre-inoculation of nursery seedlings with appropriate mycorrhizal fungi would benefit in re-vegetation of disturbed mined land.

Alleviation of water stress: Water stress is a major agricultural constraint in the semi-arid tropics. It is well known to have a considerable negative impact on nodule function (Diedhiou et al., 2003). It inhibits photosynthesis and disturbs the delicate mechanism of oxygen control in nodules. The latter is essential for active nitrogen fixation. AMF symbiosis can protect host plants against detrimental effects caused by water stress. Quilambo reported that inoculation with indigenous inoculants resulted in increased leaf and root growth and prevented the expected increase in root to shoot ratio and root–weight ratio that is normally observed under phosphorus deficient and water stress conditions in peanut (Rivera-Becerril et al., 2000). AMF improve the uptake of nutrients like N and P in water stressed conditions (Stan et al., 2008).

Water scarcity in soil is conveyed to the shoots by means of non–hydraulic chemical signal that is relayed from the dehydrating roots to the aerial shoots by the transpiration system. The response is expressed by the leaves in terms of stunted growth and decreased stomata conductance. AMF alters this non–hydraulic root–to–shoot signaling of soil drying by eliminating the leaf response (Kapoor et al., 2004). The extra radical AMF hyphae increase the absorptive surface area of the roots (Strack and Fester, 2006) which in turns reduces the resistance to water uptake. Hence, the role played by AMF in alleviating water stress of plants has been investigated and it appears that drought resistance is enhanced. An increase reliance on AMF for nutrient uptake can frequently be detected. Hence, AMF help to alleviate the water stress conditions (Evelin et al., 2009).

Bioremediation: The activity of soil microorganisms and microbial processes is reduced by the pollution caused by heavy metals. The high toxicity of heavy metals to the soil microbes and microbiological processes, associated to the long term effects in the soil, are recognized as important facts (Hijri et al., 2006). All microorganisms including AMF show resistance to heavy metals by ‘tolerance’ when the organism survives in the presence of high internal metal concentrations, or by ‘avoidance’ when the organism is able to restrict metal uptake (López-Millán et al., 2009). The use of plants to remove toxic metals from soils (phytoremediation) is emerging as a potential strategy for cost-effective and environmentally sound remediation of contaminated soil (Helgason et al., 1998). AMF have been reported to evolve strategies which can alleviate heavy metal threats in mixed culture systems and thus, from the food chains (Araim et al., 2009), which involve immobilization of metal compounds, precipitation of polyphosphate granules in the soil, adsorption of chitin in the fungal cell wall and finally chelation of heavy metal in the AMF (Gorlach et al., 2004).

Mycorrhiza colonization of plant roots can reduce translocation of heavy metals to shoots by binding of the heavy metals to the cell walls of the fungal hyphae in roots. In this way, Mycorrhiza can help higher plants to adapt and survive in contaminated habitats. The existence of synergistic effects of saprobe fungi such as *Fusarium concolor* and *Trichoderma koningii* on plant root colonization by AMF and on the effectiveness of AMF on plant resistance to heavy metals in soil has been proved. Marulanda and Barea (2000) suggested that the AM hyphae, by sequestering the potentially toxic elements into the polyphosphate granules, might be acting as metal filters in the plant. Different strains of AM fungi have different sensitivity to metal toxicity. Therefore, the AMF strain colonizing a plant determines its ability to withstand toxicity (Wallace, 2007). The abundance of the external hyphae produced by the fungus may be involved in capturing the metal by the fungi and thereby leading to plant protection. This would, however, depend on the ecological adaptations of the AM involved to the presence of toxic metals. *Glomus caledonium* seems to be a promising mycorrhizal fungus for bioremediation of heavy metal contaminated soil (Hetrick et al., 2003).

Salinity stress: AMF are able to alter plant physiological and morphological properties in a way by which plant handle the stress (Marulanda and Barea, 2000).AM fungi facilitate better survival of plants under stress conditions through a boost up in uptake of nutrients particularly P, Zn, Cu and water (Cavagnaro, 2008).They make the host resilient to adverse conditions created by unfavorable factors related to soil or climate. The role played by these fungi in alleviating the stress on the plant due to drought, metal pollution, salinity and grazing is briefly described (Khaosaad et al., 2006).

Salinization of soil is a serious problem and is increasing steadily in many parts of the world, in particular in arid and semi-arid areas (Diedhiou et al., 2003). AMF can help to overcome the problem of salinity stress. Plants growing in saline soils are subjected to physiological stresses. The toxic effects of specific ions such as Na and Cl present in saline soils, which disrupt the structure of enzymes and other macromolecules, damage cell organelles, disrupt photosynthesis and respiration, inhibit protein synthesis and induce ion deficiencies (Strack and Fester, 2006). AMF have been found to occur naturally in saline environments despite the comparatively low Mycorrhiza affinity of many halophytic plants. AMF can protect some non–halophytic plants against yield losses in moderately saline soils. Possible mechanisms include the stimulation of root growth, improved plant nutrition (Liu, 1995) and increased synthesis of plant polyols in mycorrhiza plants. AMF help in improved acquisition of phosphorus, nitrogen and other growth promoting nutrients which are helpful for the normal growth of plants in saline soil (Evelin et al., 2009).

Significances of AMF in soil fertility

Many thousands of experiments have shown that AMF can overcome nutrient limitation to plant growth by enhancing nutrient acquisition (Cavagnaro, 2008). Most studies have investigated P uptake but mycorrhizal have been implicated in the uptake of other essential nutrients also. The increase in inorganic nutrient uptake in mycorrhizal plants is mainly because fungal hyphae provide the large surface area for nutrient acquisition to external root surface as compared to uninfected roots (Harrison et al., 2001). As the fungal mycelium grows through soil, it scavenges for mineral nutrients and is able to make contact with uninfected roots, sometimes of different host species (Jeffries et al., 2003). The small extra-radical mycelium compared to roots which allows penetration into some crystalline minerals, aggregates and organic matter with smaller pores than could be exploited by root alone thereby unavailable forms of phosphate can be solubilized with the secretion of enzymes.

Phosphorus uptake: Phosphorus is a major plant nutrient required in relatively large amounts and plays a vital role in all biological functions in energy transfer through the formation of energy-rich phosphate esters and is also an essential component of macromolecules such as nucleotides, phospholipids and sugar phosphates (Lopez-Bucio et al., 2003). The most important benefits of mycorrhizal are the increase in the phosphorus uptake by the plant. The general process of phosphorus uptake consists of three sub-processes; (i) absorption from soil by AMF hyphae, (ii) translocation along the hyphae from external to internal (root cortex) mycelia, (iii) the transfer of phosphate to cortical root cells (Porras-Soriano et al., 2009).

The various mechanisms proposed to account for enhanced nutrient uptake include (i) increased exploration of soil; (ii) increased translocation of phosphorus into plants through Arbuscular; (iii) modification of root environment; (iv) efficient utilization of P within plants; (v) efficient transfer of P to plant roots; and (vi) increased storage of absorbed P (Herring and Fantel, 1993). Uptake of phosphate by roots is much faster than diffusion of ions to the absorption surfaces of the root (Bødker, 2002). This causes phosphate depletion zone around the roots. The extensive extrametrical hyphae of AMF extend out into the soil for several centimeters so that it bridges the zone of nutrient depletion. Thus, the plant is able to exploit microhabitats beyond the nutrient depleted area where rootlets and root hair cannot thrive.

Nitrogen uptake: Nitrogen is needed for the formation of amino acids, purines, pyrimidine's and, is thus, indirectly involved in protein and nucleic acid synthesis (Sailo and Bagyaraj, 2005). AMF associated plants have increased nitrogen content in shoots. A number of mechanisms are suggested for this effects, namely (i) improvement of symbiotic nitrogen fixation; (ii) direct uptake of combined nitrogen by mycorrhizal fungi; (iii) facilitated nitrogen transfer, a process by which a part of nitrogen fixed by nodulated plants benefits the non-nodulated plants; (iv) increased enzymatic activities involved in nitrogen metabolism like pectinase, xyloglucanase and cellulose which are able to decompose soil organic matter (Adholeyavan, 2009). The hyphae of AMF have the tendency to extract nitrogen and transport it from the soil to plants. They contain enzymes that breakdown organic nitrogen and contain nitrogen reductase which alters the forms of nitrogen in the soil (Bouamri, 2006).

AM improves growth, nodulation and nitrogen fixation in legume-*Rhizobium* symbiosis. They also uptake NH4+ readily from soil which forms the larger fraction of available nitrogen in many natural ecosystems (Nziguheba and Smolders, 2008). In soils where nitrate is the dominant nitrogen source, AMF have only a minor influence in acquisition of nitrogen by plants (Johnson et al., 2002). According to Kosuta more than 50% of plant N requirement is supplied by mycorrhiza association (Kosuta, 2003). Mycorrhizal inoculation enhanced activities of nitrate reductase, glutamine synthetase and glutamine synthase in the roots and shoots of mycorrhizal corn (*Zea mays* L.) (Strack and Fester, 2006). Recently, a plant ammonium transporter, which is activated in the presence of AMF has been identified and indicated that the way by which N is transferred in plant may be similar to P transfer (Gamalero et al., 2004).

Supply of organic mineral nutrients: Although many mycorrhizal fungi can access inorganic forms of N and P, some litter-inhabiting mycorrhizal fungi produce proteases and distribute soluble amino compounds through hyphal networks into the root (Redecker et al., 2000). Recently, *Glomus* has been shown to transport the amino acids glycine and glutamine into wheat (Helgason et al., 1998).

Uptake of water: The AMF association improves the hydraulic conductivity of the roots and improves water uptake by the plants or otherwise alters the plant physiology to reduce the stress response to soil drought (Hijri et al., 2006). It reveals that mycelia network extends deeper and wider in the soil in search of water and nutrients (Kapoor et al., 2004). The permeability of cell membrane to water may also be altered by mycorrhizal colonization though the improved phosphorus nutrition and colonization by AMF can improve the drought resistance of plants (Pozo et al., 2002).

Under conditions of drought stress, AMF exert their influence by increasing the transpiration rate and lowering stomata resistance or by altering the balance of plant hormones (Hao et al., 2009). The change in leaf elasticity due to AMF inoculation improves water and turgor potential of leaf and also increase root length and depth (Krishna et al., 2005) and may also influence water relations and therefore, the drought resistance of the plants. The probable reasons for the enhanced water and nutrient uptake rates by mycorrhizal plants which can be due to better distribution of absorbing hyphal network, more favorable geometry of hyphae in comparison to roots, greater surface area and faster extension rate, increased functional longevity, chemical alteration in soil rhizosphere, altered rhizosphere microbial population, uptake kinetics, greater hydraulic conductivities, lower transportation rates per unit leaf area, extraction of water from soil to lower water potentials and more rapid recovery form water stress (Gamalero et al., 2009).

Soil aggregation and soil stabilization: Disturbances in ecosystem affect the physical, chemical and biological processes in the soil. AMF help in the binding of soil particles and improve soil aggregation and soil conservation (Armstrong, 2000). Arbuscular mycorrhizal fungi are also known to enhance soil fertility, as they produce glomalin which upon accumulation in soil, along with the AMF hyphae forms micro aggregates and finally macro aggregates and, thus, acts as a backbone for soil aggregation and soil stabilization directly. It also releases exudates in the soil and thus promotes aggregate stability and also boost up other microorganism growth (Johnson et al., 2002). During development of AM, the fungal symbiosis grow out from the mycorrhizal root to develop a complex, ramifying network into the surrounding soil which can reach up to 30 m of fungal hyphae per gm. of soil (Cavagnaro et al., 2006).

This network can make up to 50% of fungal mycelium in soil (Rillig et al., 2002) thereby representing a major part of the soil microbial biomass (Leake et al., 2004). In addition, the secretion by AM fungi of hydrophobic, 'sticky' protein acetous substances, referred to as glomalin (Rillig et al., 2002), also contributes to soil stability and water retention (Martinez et al., 2009). AM function Ecosystem service(s) provided Root morphology modification and development of a complex, ramifying mycelia network in soil increase plant/soil adherence and soil stability (binding action and improvement of soil structure). Increasing mineral nutrient and water uptake by plants promote plant growth while reducing fertilizer requirement (Kapoor et al., 2004). Buffering effect against abiotic stresses increased plant resistance to drought, salinity, heavy metals pollution and mineral nutrient depletion secretion of 'glomalin' into the soil increased soil stability and water retention protecting against root pathogens increased plant resistance against biotic stresses (Caravaca et al., 2006).

Mycorrhiza considered to be an important element in helping to stabilize soil aggregates (Rillig and Mummey, 2006), thereby leading to increased soil structural stability and quality (Bouamri, 2006). Agronomic practices such as monoculture cropping, ploughing, or fertilization have frequently been observed to have a negative impact on the amount as well as the diversity of AM fungi present in soils (Oehl et al., 2005). A reduction in fungal biomass will result in a negative effect on soil stability and consequently increase the risk of soil erosion. This is not to be underestimated; in the UK, productivity loss due to soil erosion of agricultural soils has been estimated to 9.99 million €/year (Gorlach et al., 2004). Since soil is a nonrenewable resource on a human time-scale, the impact of erosion is often cumulative and in most instances irreversible. AM fungi reduce the need for phosphate fertilizer inputs Phosphate, which is an essential mineral nutrient for plant growth, is one of the three main mineral nutrients applied in agriculture. Rock phosphate sources are limited and on the basis of the presently known world phosphate reserves, most of the phosphate mines will be depleted in about 100 years (Herring and Fantel, 2008).

Although the consumption of triple-phosphate has been reduced in developed countries between 2000 and 2006 by 36%, reaching an annual amount of 0.3 million tonnes, whereas in the meantime it increased by 36% in the developing countries reaching an annual amount of 2.1 million tonnes (Lopez-Bucio et al., 2003). Excess application of phosphate fertilizers is an important cause of water eutrophication, and therefore improvement of phosphate uptake efficiency by plants is a priority (Leake et al., 2004). Inorganic phosphate (Pi) has very limited diffusion capacities in soils and its rapid absorption from the soil solution by plant roots generates Pi depletion zones at the root surface resulting in a decline of directly absorbed Pi by the plant surface. The network of fungal mycelium connected to AM roots increases by several orders of magnitude the soil volume which can be explored by a plant so that a mycorrhizal root is more efficient in phosphate uptake than a non-mycorrhizal root (Smith and Read, 2009). Under given field conditions, it has been estimated that a reduction of 80% of the recommended phosphate fertilizer could be supplemented by inoculation with AM fungi (Wilson et al., 2009).

DISCUSSION AND CONCLUSION

With the development of industrial agriculture, field labor and chemical input have substituted ecosystem services but the high amounts of energy and chemical products needed to support this production system have reached a limit. This means integrating the development of crop management strategies that optimize the impact of beneficial microbes, like AM fungi, on plant production. Present-day industrial agricultural practices place several constraints on the use of services provided by mycorrhiza. Hence AM fungi efficiently use for agricultural productivity in sustainable manner in which the diversity and function of soil microorganism is the decisive issue in the agrarian activities and ecosystem service. AM can also enhance the agricultural productivities and ecosystem stability by reduce natural resource deterioration and ameliorate the environmental stress. AM fungal species and diversity play the crucial role in bioremediation, nutrient and water uptake, improvement of soil properties, generation and establishment of vary seeds, and improve mineralization processes. AM fungal root colonization, the use of mycorrhizal crops in rotation used to increases the abundance of AM fungi in the soil which in turn treat toxic elements and thereby lead to improve agricultural productivities and stabile ecosystem service.

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