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Arbuscular Mycorrhizal Fungi as Bridge between Plants, Soils and Human

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Abstract

The main aim of this review is to provide the roles of arbuscular mycorrhizal fungi as bridge between plants, soils and humans, in general and specifically in ecosystem, comparing with current research trends and to indicate future benefits of plants to acclimatize from biotic (insect and disease) and abiotic (drought, Salinity, heavy metals, nutrition and temperature) stress investigations. This paper reviewed that application of arbuscular mycorrhizal fungi under optimum condition is bridge between plants, soils and humans, which may help to maximizing crop yield and human nutrition by against biotic and abiotic stress. These abiotic and biotic stresses have been the major bottlenecks of crops production and productivity; since the crop has a very stunted growth that requires the roles of arbuscular mycorrhizal fungi. They provide direct or indirect interconnection among the soil systems, plant roots and humans through transferring and exchange of nutrient, soil remediation, pest control and improving plant and human nutrition quality. Most people in the world are awareness the bridge roles of this fungi, which symbiotic relationships with more than 80% of plant species; but they are seldom able to apply them. However, there was an opportunity to increase crop yields and human nutrition quality through reduce the stresses. Therefore, AM fungi was the bridge between roots, soil and humans to increase both yield potential and quality of crop, human nutrition and sustainable environment-friendship and agricultural production.

Keywords: *Arbuscular mycorrhizal* fungi, Bridge, Plant growth, Symbiosis, Stress tolerance

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Introduction

Soil microorganisms are the most important to increasing agriculture crop production through N_2 fixation, recycling of nutrients like N, P, S and C, formation and maintenance of soil structure, Pest control and the degradation of agro-chemicals and pollutants [1]. Arbuscular mycorrhizal fungi are one of the most soil microorganism used in agriculture to enhance crop production, which are symbionts associations with almost all habitats [2]. They are root symbionts more than 80% of vascular plants [3, 4]. It can penetrates the cortical cells of the roots a vascular plant by arbuscules [5] which help to transfer nutrients (P, S, N, C and micronutrients) from the soil to plants. They are associate mutually with plant species in the rhizosphere to facilitate uptake of nutrients and pest control [6]. AM fungi also help to improve soil structures, which reduce soil erosion through enhance water holding capacity of soil and facilitate a better plant rooting capacity. It also improves soil nutrient deficient or polluted soil environments [7]. It enhanced suitable agro ecosystems through improving drought stress [8]. AMF also important for improving human diets by transferring unavailable mineral nutrients as Iron (Fe), Zinc (Zn), iodine (I), selenium (Se), calcium (Ca), Mg, and Cu from the soil to plant parts [9]. These mineral nutrients are enhancing productivity and nutritional qualities of plants are closely related to human diets. This review focused on arbuscular mycorrhizal fungi as a bridge between plants, soils humans for enhancing crop production and human nutrition. They are great roles for sustainable environment-friendship and agricultural production.

Taxonomy and Morphology

Arbuscular mycorrhiza fungus is common symbiotic interaction

with the plant root through nutrients transfer and improving stress tolerance. AM fungi has belongs to Kingdom of Fungus, phylum *Glomeromycota*, class of *Glomeromycetes*, order *Glomerales*, familiy *Glomeraceae*, genera *Glomus* and the 214 species [10]. The major morphology structures of AM fungi are Arbuscules, Vesicles, Spores and External Hyphae. Arbuscules are the major junction used for exchange of nutrients among the fungus and host plant whereas Vesicles are rounded intercellular structures which act as storage organs of phosphorus, oil droplets and also function as propagules [11]. External hyphae are thick and runner type which responsible for nutrient acquisition and spore formation. These hyphae contain two modifications hyphae networks such as *Paris*-type and *Arum*-type. *Paris*-type where hyphae development is completely intracellular, forming coils in host plant cortical cells, increase the growth of hyphae from one cell to the next whereas the *Arum*-type is forms arbuscules, which are intra-radical hyphae development in the root cortical cells [12]. It is the sites of exchange for phosphorus, carbon, water, and other nutrients to enhance the growth of hyphae in plant cells [13]. Spores is another AMF structure which is multi-nucleate, heterokaryotic [14], and formed a sexually [15]. The spores are multi-walled and large (40-400 µm). It found in the soil or in the roots [11]. This structure used for survival and dispersal mechanism of AM fungi by wind, water, invertebrates, birds and mammals [16]. The spores also can germinate under favorable conditions of the soil environment [13].

AMF as Bridge between Plants, Soils and Humans

AMF is ability to create a "bridge" among the soil and the plant through exchange of nutrients between them [17]. It can promote plant growth by providing inorganic nutrients from the soil [18]. They also received carbon from the plant [19, 20]. The role of AM fungi are absorb unavailable mineral nutrient from the soil then transfer to the plant organ and also release carbon element from the host plant in to the soil. In addition, it was connecting the plant root with the surrounding soil microorganisms [21]. This connection is important for promoting plant-growth through improve nutrient and reduce the pest [22] AMF develop symbiosis converting of toxic mineral nutrients such as N, P, K, Ca, Zn, and S return to the plant root cells [9]. AMF have increased and nitrogen, potassium, calcium, and phosphorus contents in plant leaf area, to enhanced plant growth [23]. The AMF is used for flows amino acids concentration between soil, plants and humans. AMF used as Bio-fertilizers to enhance nutrients recycling and improve soil structure which are important for plant growth [24]. Mycorrhizal fungi hyphae also benefit for formation of soil structure, which retain the moisture in the soil [17]. The improved soil structure is increase the ability of root to penetrate the soil and encourage plant development [25-27]. AMF contains Glomalin hydrophobic glycoprotein is involved in soil-crumb aggregation [4]. AMF is released the mucilaginous glue contribution to binding soil matrix [4]. It maintains moisture content in the soils [28] to regulate water between the soils and plants which to balance osmotic potential. The hyphae released 30-40% C in the glomalin which enhancing the soil moisture [29]. AMF has improved soil health and crop production by reduced the use of inorganic fertilizer especially, phosphorus [30]. AMF is indirectly important to improve human nutrition. AMF is facilitate the transfer of nutrients (N, P, K, Ca, Zn, and S) from the soil to plant part then to human [9] which, means humans obtain these nutrient from the consumption of plant parts. Crop productivity and nutritional quality of plants are closely related to human nutrition. AMF can improve nutrient deficiency by increasing minerals contents in staple food crops such as rice, wheat, maize, pearl millet, and others [31]. AMF is 28-60% micronutrient content can be increased in wheat [32], which symbiotic association are improvement of macro- and micronutrients in the crop to increase food quality by minimize the risk of inorganic fertilizers and pesticides in the diet [33].

AMF symbiosis with Plant

AMF is the most mutualistic symbiosis association with plant root over 80% of all terrestrial plants [11] which interact to exchange of nutrient and tolerance of stress [8, 16]. This mutualistic symbiosis association has signal molecules between AMF and the host plant which, used for communications between them [8, 34]. These communications signal are phytohormones (strigolactones) and Myc factors. Plant roots produce phytohormones/or strigolactones which, able to stimulate fungal metabolism as well as hyphael branching [35 ,36]. The fungal signal molecule is Myc factors which recognized by Plant genes. After, the recognition it modified the physiological functions of the host plant under stress condition [2, 37]. The hyphae structure especially, vesicles can help the host plant by store large molecules such as salt ions (sodium and chloride) under salinity stress and toxic heavy metals in the soils [36]. This can reduce the effects of stress on plant growth [38]. AMF can produce of phytoalexins and antioxidant enzymes in to the plants which inducing defense mechanisms of the pathogens [39, 40]. Therefore, AMF and plants are positive symbiotic effect in rhizosphere [41] but, the symbiosis association is differ with plant species. The mycorrhizal are 27% of symbiosis association with pearl millet roots and 48% with cowpea roots [42. Hence, the legume residues are increase mycorrhizal colonization than cereal crops which, contain food source for Mycorrhizae [43].

Roles of AMF as Abiotic stress Tolerance

Abiotic stresses are stunted plant growth and reduce its production. These stresses are including drought, salinity, temperature, nutrients, and heavy metals [9].

Phytoremediation heavy metal pollution

These stresses are reducing by the symbiotic association of AMF and hyper concentration plants. Such stresses are trace elements (nickel, molybdenum, cobalt, iron) and insoluble phosphorus which is not absorbed by plant root. They need to arbuscular mycorrhiza activates which can modify the physiology of the host plants to tolerance heavy metal toxicity [44], which promote the migration and transformation of heavy metals from roots zone to aboveground parts [45, 46] and also influence root

microbial composition [46]. This transformation mechanism of heavy metals is direct or indirect effects on the plant growth [46]. The Direct effects of AMF can stronger absorbing ability of metal than plant root [47]. Its adsorption capacity may be related to the structure of the cell wall. Fungi cell wall is composed of polysaccharides and chitin can be used as a barrier of metal ions and other solutes to enter cells, controlling their absorption [48]. Free amino acids in the cell walls and functional groups such as hydroxyl and carboxyl groups can form a negatively charged structure that has the ability to adsorb the majority of the metal ions in the soil [49]. The Indirect effect of AM fungi has secreted organic acids which can activate insoluble phosphate which are easily absorbed and transported by plants under low available of phosphorus in the soil [50]. The use of AMF can help plants to resist environmental stress as well as promote the restoration and reconstruction of heavy metal contaminated soil [51].

Salinity and Drought Tolerance

These Soil stresses are cause huge losses in crop production and productivity [52-54] . The combination of drought and salinity causes highly injurious to plants [52, 55].

The direct effects of salt & drought on plant growth through reduction in the osmotic potential of the soil solution which, prevent water movement from soil into the plant parts [56, 57]; the accumulation of excessive Na^+ and Cl_2 ions towards the cell which toxic effects on the destruction of structure of enzymes and the damage plasma membrane cause disruption of photosynthesis, respiration and protein synthesis [56, 58]; and nutrient imbalance also affect the transport of nutrient in to the shoot which cause deficiencies [52]. These stresses are suppressing the growth of plants by reduce the absorption and photosynthesis rate which reduced crop yields [59, 60]. The applications of AMF are the better option to alleviate this abiotic stress [52]. They can helping the plant by provide different mechanisms through enhancing nutrient acquisition, water absorption capacity, producing plant growth hormones, improving rhizosphere and soil conditions which improve these stress by the altering the physiological and biochemical properties of the host [52] and also inducing defending against soil-borne diseases. For example, the symbioses association among wheat and *Glomus mosseae* can increased crop yield under salinity and drought stress [61, 62]. AMF also can increase plant tolerance to under heat or cold stress [63].

Roles of AMF as Biotic Stress Tolerance

Arbuscular mycorrhizal fungi are symbioses with the most of plant species which can give many benefits to the host plant as improved nutrient uptake, resistance to drought and the pests [64]. AMF are supporting plants by resistance to pests which considering as biocontrol. AMF are the reduction of severity soil-borne pathogens such as root rot or wilting caused by fungi (*Fusarium, Rhizoctonia, Macrophomina* or *Verticillium),* bacteria (*Erwinia carotovora)* and oomycetes(*Phytophthora, Pythium* and *Aphanomyces)* [65,66]. It also reduced the severity of the plant parasitic nematodes (*Pratylenchus* and *Meloidogyne)* [67,68]. AMF can induce resistance by the production of phytoalexins and the antioxidant enzymes in plants [39,40]. And also another mechanism of mycorrhizal to protection plant from fungal disease by increase the accumulation of non-soluble polysaccharides and lignin in the cell walls of plant roots, which can constitute a physical barrier of fungal disease infections [17,69]. The symbiotic association among AMF and strawberry are produce exudates, which reduction the severity about 64-89% of *Phytopthora fragariae*, compared with untreated of AMF strawberry [70]. *Glomus mossae* can reduce about 30-39%, of severity of *Phytopthora parasitica* disease on root and 30 % reduction in fruit necrosis [71]. The synergistic stimulation of maize and microbial inoculants (*Azospirillum*, *Pseudomonas*, *and Trichoderma)* can increases enzyme activities in the rhizosphere to enhance plant growth [72]. Mycorrhizal fungi can direct or indirect influence of plant defense to herbivory by changes plant nutrition, by altering plant gene expression or generate hormone [73],which helps plant that act to deter herbivore or attraction of enemies considered as 'defense syndrome' [74]. Many agricultural plants produce both direct or indirect defenses against herbivory. For example, cotton, tobacco and maize plants produce the direct defenses chemical such as gossypol, nicotine and 2, 4-dihydroxy-7-methoxy-1,4- benzoxazin-3-one, respectively [73,75] and also it releasing volatile organic compounds upon herbivore attack that attract natural enemies [73].

Roles of AMF Agriculture Sustainability

Arbuscular Mycorrhizal Fungi (AMF) can key role for enhance crop production by improving plant nutrition, soil microbe activity, altering the availability of nutrients and controlling of pests [76]. AMF are the most ample in agricultural soils, which used for crop production among 5%-50% of the total soil microbial biomass [77]. They can enhance the plant growth and yield by refining acquisition of nutrients, improved resistance to pests, drought, salinity and increased soil structure [76,78]. AMF are used as prominent of bio-fertilizers to enhance crop production and productivity [79]. Today, microbial-based biofertilizers are important for improve agriculture crop productivity and contribute to sustainable agro-ecosystems [76]. AMF are produce glomalin-related soil protein, which maintain moisture content in soils reduced to different abiotic stresses [28,29]. This regulates water content among soil and plants, automatically prompting plant growth. In addition, application of AMF is enhances moisture uptake from the soil to improving plant tolerance drought and salinity. Therefore, AMF are the most important environment-friendly and a sustainable crop production as a replacement of pesticides and chemical fertilizers [18] , which contribute greatly improves organic farming for yield maximization.

Conclusion

Arbuscular mycorrhizal Fungi are the greatest common symbiotic relationships with almost all plant species. The most important roles of mycorrhizal fungi (AMF) are their ability to create a "bridge" between the plant, soil and humans. Bridge means linking among the soil, plant and the human through exchange of nutrients. The

main importance *Arbuscular* mycorrhiza fungi are enhanced plant performance or crop yield in many ways, including maintains soil condition by improving soil structure; availability of essential and mineral nutrients (Zn, S, Fe, Ca, Mg and NPK), phytoremediation of heavy metals pollution and immobile phosphorus, tolerance of drought and salinity stress and biocontrol of pests. This review focused on the roles of arbuscular mycorrhizal fungi to enhancing crop production and human nutrition. Generally, the application of AM Fungi could be replacement the use of inorganic fertilizers and pesticides through sustainable environment-friendly and agricultural production.

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