MYCORRHIZAL MECHANISMS IN THE GRASSLAND ECOSYSTEMS-SHORT REVIEW

Author: Larisa Nicoleta, CORCOZ, Roxana VIDICAN, Vlad STOIAN
[1]*University of Agricultural Sciences and Veterinary Medcine Cluj- Napoca, Faculty of Agriculture*
Corresponding author: Roxana VIDICAN, roxana.vidican@usamvcluj.ro

***Abstract.* In recent years the focus has been on finding procedures in agriculture to satisfy the food requirements for a growing population and new technologies whose main purpose is to protect the environment. Mycorrhizas represent a symbiotic system that involves terrestrial plants and soil fungi. It is a beneficial-balanced process between plants and fungi, where the fungal hyphae colonize root of plants and increase the absorption process of nutrients. Fungi receive part of the metabolites produced through photosynthesis by plant.**

The aim of this review is to raise awareness over the importance of mycorrhizal mechanisms in grassland ecosystems. Researches have shown that grassland biomes have a high microbial and plant diversity, which stimulate the simultaneous presence of positive interactions in rhizosphere. Soil fungi interconnect all plant species and in addition improve their nutrition, with an increase in plant's ability to compete and reduction of abiotic stress. Mycorrhized plants benefit from better resistance against pathogens and limit the absorption of toxic elements, which fungi stores in vesicles. Besides the benefits to the plants, mycorrhizas are able to release nutrients in soil for other microbial communities, including their sporocarps which are a favorite food source for edaphic micro- and macrophages. The reduced anthropic activity in grassland ecosystems facilitate the development of extensive hyphal networks, that connect directly and indirectly a large number of species. Diversity of symbiotic fungal species can also be accounted within plant biodiversity. The analysis of root symbiosis is necessary for a large number of actions in grassland: assessment of phytocoenosis stability with the understanding of mycoheterotrophy level for each species; future expansion of invasive plants in relation with secondary and tertiary successions; integrative models of plant – microorganism – climate interactions and survival potential in new climatic conditions.

Therefore, mycorrhizae play a very important role in the good development of plants and a more detailed study is needed to understand mycorrhizal mechanisms because they can be a biological source of rehabilitation and improvement of grassland ecosystems.

***Keywords**: symbiotic system, biological fertility, mycorrhizal mechanism*

INTRODUCTION

Grassland ecosystems have the highest microbial and plant diversity, which stimulates the simultaneous presence of positive rhizosphere interactions (CARLIER, 2009). Natural and semi-natural grassland plant communities are home to a much wider diversity of mycorrhizal fungi than arable soils (SANDERS, 1996). The presence of an extensive hyphal network in soil that connect a large number of species is a result of reduced anthropic activity in grasslands. Due to the benefits brought by mycorrhiza to plants, micro and macrophage soil and the environment, it is absolutely necessary to deepen studies on their mechanisms. The study of mycorrhizal functioning in natural and semi-natural ecosystems remains a challenge due to the high diversity of species that carry out these associations, the lack of specificity of symbiotic species and the formation of a common hyphal network that connects root systems of plants within the same species or different species. New methods of enhancing these interactions from the rhizome level can be discovered only if the processes underlying them are fully understood (RILLIG, 2004). Mycorrhizal mechanisms can fall into this category of positive interactions in the rhizome (LIN, 1991).The primary advantage of mycorrhizas is the biological anchoring directly at the root level, so that the risks are smoothed as the fertilizers decrease.

Symbiotic relationships between plant roots and fungi (mycorrhizas) have been recognized since the early 19th century and it is now clear that these symbiotic associations are the most widespread on the world map. Mycorrhizal associations are ubiquitous in ecosystems and species of interest in crops, grasslands and forests. Fungi are symbiotic in the roots of most terrestrial plants. A reduced number of fungal species form mycorrhizal associations with nearly 250.000 plant species (BRUNDRETT, 2009). These associations vary in structure and function but the most common interactions are arbuscular. It is estimated that the percentage of terrestrial plants that form this type of association exceeds 80% (SMITH, 1997) from angiosperms to gymnosperms. The symbiotic mechanism is given by the process by which the fungal hyphae adhere to the surface of the plant roots and colonize it. As a result of this process the plant enjoys a greater amount of water and nutrients, and at the opposite pole the fungus receives a part of the metabolites assimilated to the vascular plant through the process of photosynthesis. In addition to the main role, the supply of nutrients with host plants, mycorrhizal fungi intervenes in the circuit of the elements and in the decomposition of organic matter. (KYASCHENKO et al., 2017). Mycorrhizal plants are often more resistant to diseases, such as those caused by microbial pathogens present in the soil. These associations offer protection for plants both for above- and belowground pressors. Mycorrhizas can secrete enzymes that are toxic to soil organisms, such as nematodes (JUNG, 2012). Plants with this type of symbiosis have a higher capacity for drought resistance (NIKOLAOU, 2003) and also shows improved performance under saline stress conditions (PORCEL, 2012). Mycorrhizal symbiosis was also significantly correlated with soil biological fertility indicators, such as soil microfungi and bacteria (KAMINSKYJ, 2010). They can also play a protective role for plants rooted in soils with high concentrations of metal, such as acid and contaminated soils (RICHARDSON , 2000).

DEVELOPMENT OF MICORRHIZAL HYPHAL NETWORKS

The stability of mycelial plant-fungi networks depends on the ability of neighboring plants and plants to enter mycorrhizal associations with compatible fungal species. Such compatibility is governed by the specific potential of symbiont (BRUNDRETT, 1991). Mycorrhizal specificities exist along a continuous flow from low specificity (association with several partners) to high specificity (association with one or several partners). Establishment of mycorrhizal networks is given by the plant-fungal interactions but we cannot omit the influences of the abiotic factors (soil, climate) that interfere in this process. The specificity of mycorrhiza dramatically influences the dynamics of the plant community, especially the succession of plants (CHEEKE et al., 2019). Another role played by mycorrhizas is to incorporate small particles of soil into the fabric of the mycelium, forming new aggregates, which are more stable than larger aggregates (LEHMANN et al., 2017). The fungus secretes glue-like proteinaceous substances, a glycoprotein, which by its hydrophobic nature allows an increase in the amount of air in the air /water ratio (STOIAN, 2015). Another favorable aspect of this protein is the reduction of soil disaggregation due to moisture-drought cycles by delaying wetting. The result is the creation of a superior environment in terms of favorability for plant growth and development. The hyphae networks of soil fungi can extend from 2.7 to 20.5 m per gram of soil, depending on the fungal species (GIOVANNETTI and AVIO 2004; MIKKELSEN et al., 2008). The ability to produce large, interconnected extracellular mycelium increases the absorption area of the fungi and feeding capacity, facilitating the translocation and flow of mineral nutrients from soil to host plants, resulting in increased and increased plant nutrition (FINLAY, 2008). These networks creates a continuous flow of nutrients with several host plants and different symbionts.

Mycorrhizal networks are strictly governed by the type of mycorrhiza (VAN DER HEIJDEN et al., 2015). In ectomycorrhizae, which have trees as photosynthesizing partners, the hyphal network covers the root (mantle) with the roof, and inside the root cells interfere with those of the fungal hyphae forming the Hartig network. It develops continuously in accordance with the growth of the root and limits the development of the absorbent growths resulting in a sheath that encloses the root tip. As new roots emerge, they are colonized by the hyphae that already exist in the roots, spores or mycelium that is in symbiosis with neighboring plants. A single *Populus tremula* tree hosted over 200 fungal species associated with the root, as well as dozens of individuals of the same species (BAHRAM et al. 2011). Another role played by the network of hyphae is carbon storage, received from the host plants following the photosynthesis process, in fast soil and in significant quantities, with estimates ranging from 50 to 900 kg/ha (CLEMMENSEN, 2013). Due to the network of hyphae, the expansion of hyphae has formed mycoheterotrophy plants that can enjoy products of assimilation of the photosynthesis process without them being able to initiate this process.

THE ROLE OF MYCORRHIZAS IN GRASSLAND COMUNITY

Processes that regulate the composition and diversity of natural communities have been a central point in ecology (HAINES-YOUNG and POTSCHIN, 2010; LOREAU, 2010). The studies focused first on the biotic interactions between plant species occupying the same niche and the relationship of herbivorous plants, and secondly on the interdependence of abiotic factors plants. (HARTNETT, 2002). Plants that establish a symbiotic mycorrhizal relationship directly influence the coexistence of adjacent plant species, their relative abundances and diversity by changing the intensity of competition between plants (JORGENSEN and FATH, 2014). Given the interspecific differences between plants in terms of mycorrhizal effects on growth and competitive ability, any change in mycorrhizal colonization or symbiotic function will alter the effects and responses of plant species competition, leading to changes in dominance, coexistence and species diversity.

An issue that has been raised on a large scale in recent years is the emergence and good development of invasive species from different ecosystems, but especially in grassland ecosystems, as these species have strongly developed associations with soil fungi and affect the native biodiversity of plants. One study indicates that the majority (approximately 82%) of the 199 listed invasive plant species are associated with mycorrhizal fungi (WANG, 2006), which suggests that mycorrhizal plants may be related to plant invasion (DICKIE 2014). Therefore, understanding the mechanisms that contribute to plant invasion is essential for ecosystem conservation (DICKIE et al. 2017). According to another study in which or used as host species flax and sorghum are shown that mycorrhizal fungi play an important role in mediating both intraspecific and interspecific competition, by unequal allocation of mineral nutrients between plants of interest (AWAYDUL 2019). The governance of the plant community is also done through the specificity of the host plants vis-à-vis fungal symbionts and the stage of plant development. Colonization of the roots of different symbioses may act differently depending on the different phenophases of the plants (CRIȘAN, 2018). Given that there is competition for nutrients between plants of interest and weeds, root exploration is essential when some resources may be scarce and, consequently, stimulate mycorrhizal fungi colonization and sporulation.

MYCORRHIZAS-MICROORGANISM COMMUNITY OF THE SOIL

Stability of terrestrial ecosystems are determined by their biodiversity and the ecological mechanisms through species composition are regulated and maintained (VAN DER HEIJDEN, 1998). These mechanisms need to be identified to ensure successful management for the conservation and restoration of various natural ecosystems. Biodiversity in ecosystems is the main concern of researchers lately (MARON et al., 2018). In a narrower sense, the focus is on biodiversity of soil microbiota and their multitude of elementary processes: decomposition of organic matter, flow of nutrients, maintenance of soil structures. The soil is the most diverse and favorable environment for microorganisms, performing from the simplest function (foundation for plant fixation) to complex processes (decomposition of organic matter). Soil is the key to managing global environmental problems facing humanity, such as climate change, biodiversity loss and water management. Diversity of the mycorrhizal fungal community is considered to be a major contributing factor to maintaining plant biodiversity and ecosystem functioning (MOHAMMADI, 2011). Mycorrhizae are considered key mediators that have the ability to influence soil functions and the activity of microorganisms. Their development area is a niche that hosts specific inhabitants, fungal hyphae and spores have long been recognized as important niches that can be colonized, both externally and internally, by certain bacterial classes, including *Pseudomonas spp*. and bacteria from families: *Oxalobacteriaceae*, *Bacillaceae* and *Burkholderiaceae* (HASSANI, 2018). Fungal exudates appear to play a specific role for microsphere colonization by stimulating bacterial growth or inducing changes in the bacterial community structure. In particular, the exudates produced by *Rhizophagus irregularis* fungus have been shown to stimulate bacterial growth and alter the bacterial community structure, which is marked by an increased abundance of several *Gammaproteobacteria*. (FILION, 1999). Analysis of bacterial soil community in the presence and absence of mycorrhizal fungi *Glomus hoi* was proved by a microcosm experiment, the significant effect of the fungus on the bacterial community structures was also observed and suggests that the nitrogen provided by the fungus is an important source for thus the bacterial community explaining its change (NUCCIO, 2013). It has been found that in the soil, the nutrient concentrations made available to the microorganism communities are higher near the hyphae and gradually decrease with the distance of the hyphae, thus creating a relatively small area from which the microorganisms can take up the nutrients (WILPISZESKI et al, 2019). In addition to the release of nutrients in the soil and that are finally made available to the community of edaphic mycorrhizalisms, mycorrhizal systems have a major implication in shaping soil pH. The efficiency of the fungal-plant association is determined by the adaptability of the fungal partner to a certain soil pH level. The pH affects both the germination of the spores and their development. The relationship between soil pH and mycorrhizal effects depends on the host species, soil type, phosphorus forms and the fungal species involved (BEGUM et al., 2019; CARRENHO et al., 2007). This process can govern the structure of the soil micro biota.

MYCOHETEROTROPHIC PLANTS

Mycoheterotrophyc plants are partially or wholly non-photosynthetic species, which form symbiosis with mycorrhizal fungi to meet their nutrient and energy needs (MERCKX et al., 2009). Plant gives carbon from photosynthesis, in exchange for the minerals acquired by fungi, which allows both partners to grow and complete their life cycles. There are over 400 species of fully mycoheterotrophyc plants and almost 20.000 partially mycoheterotrophyc plants (LEAKE, 2005). Initially it was thought that the mycoheterotrophyc plants feed directly on the decaying matter being considered long saprophytes, but analyzing their structure they did not present breakers but the hyphae from the root level could be noticed. Factors that limit the geographical distribution of plants are generally recognized as abiotic and biotic components, such as water, temperature, light, nutrients, pathogens and insects for pollination or seed dispersal (COX and MOORE, 2005, YUKI, 2008).

Most mycoheterotropycs are completely underground for most of their life and these stages have consistent adaptations with a change in function from the absorption organs to the storage organs, they present an almost universal loss of rooting branches, shortening of the surface, in short cylindrical, vermiform and tuberous roots or, in extreme cases, complete suppression of the roots and formation of a tuber or swollen rhizome (LEAKE, 2005). The increased width of the root cortex often hosts mycorrhizal infection and deposits of carbohydrates and other materials obtained from the fungal symbiotic. Mycorrhizal infection is limited to the lower parts of plants, but can be found in modified stems as well as in roots. McKENDRICK (2000) performed a study in order to observe the influence of mycorrhizal fungi on germinating *Corallorhiza trifida* seeds, a mycoheterotrophyc species. The seeds were placed in the soil at different distances from the adult plants and near the trees. Germination took place within eight months of sowing under *Betula-alnus* and within seven months under *Salix repens*. It has been associated with the symbiotic process between mycorrhizal fungi, tree and mycobacterial plants.

THE IMPORTANCE OF MYCORRHIZAS IN GRASSLAND ECOSYSTEMS

Grassland are one of the most complex agricultural ecosystems in Romania. Due to the fact that most applied management is extensive there is an exceptional biodiversity and indicate the need to focus future studies on their protection (HOPKINS and HOLZ, 2006; VAN OIJEN et al., 2018). The main causes that lead to the degradation of the grasslands are overgrazing, incorrect management, collection of wood for fuel, herbs for medicines, destruction of rodents, the return of new species and not least global warming. The contribution of grassland ecosystems has received more attention recently due to its large surface area, high carbon footprint and fragile properties that it presents to disruptive factors. According to the information, 25% of all carbon in the terrestrial biome is stored in pasture ecosystems (AKIYAMA, 2007).

Research on mycorrhizal associations in grasslands has focused on appreciating the important role of this symbiosis in the functioning and performance of plants from a wide range of terrestrial ecosystems (CHEN et al., 2018; CLINE et al., 2018). We now understand that the role of mycorrhizal fungi extends beyond the symbiotic acquisition of nutrients for the host and the mutual supply of carbon from the host to the fungus. Additional effects of fungal mycorrhiza on host plant functioning including increased disease resistance, improved water relationships, acquisition of other nutrients from the soil, and changes in soil physico-chemical properties. Other aspects of mycorrhizal ecology, including the variation of the costs and benefits of carbon and nutrient exchange, the ecological significance of mycelial networks, the role of mycorrhizal symbiosis in interactions with multiple species, and the extent and consequences of host specificity in these associations have also recently been explored. This ancient mutualistic symbiosis may be one of the most important, but least understood in terms of the interactions that regulate the structure of the plant community and its dynamics. Assessing the degree of dependence of mycorrhizal symbiont plants can be an important step in estimating the strength and sustainability of a species in natural ecosystems (STOIAN, 2016), so mycorrhizal mechanisms play a very important role in ensuring the perinity of plant species and in ensuring stability of the entire ecosystem.

CONCLUSIONS

Plants that carry out this symbiosis have an improved resistance capacity against pests, hydric and saline stress. Regarding the benefits to soil, mycorrhizal systems regulate the pH, interfere in the change of structure of the aggregates, the air-water balance, nutrient circuits and soil quality.

Mycorrhizal systems in the grassland ecosystems benefits from a greater diversity of soil fungal species that can be directly correlated with the diversity of the above-ground biota (plant species) as well as the belowground biota (communities of edaphic organisms). They are involved in the stability and structure of plant and microbial communities.

Due to the major implications in carbon storage and accumulation of heavy metals in vesicles they can be widely used as biological source in remediation of different level of anthropic pressor.

Mycorrhizas play a very important role in the development of plants and a more detailed study is needed to understand the mycorrhizal mechanisms, as they can be a biological source of rehabilitation and improvement of grassland ecosystems.

BIBLIOGRAPHY

AKIYAMA TSUYOSHI , KENSUKE KAWAMURA, 2007- Grassland degradation in China: Methods of monitoring, management and restoration, https://doi.org/10.1111/j.1744-697X.2007.00073.x.

AWAYDUL, A., ZHU, W., YUAN, 2019- Common mycorrhizal networks influence the distribution of mineral nutrients between an invasive plant, Solidago canadensis, and a native plant, Kummerowa striata, Mycorrhiza, 2019 29: 29. https://doi.org/10.1007/s00572-018-0873-5.

BAHRAM M., PÕLME S., KÕLJALG U., TEDERSOO L., 2011- A single European aspen (Populus tremula) tree individual may potentially harbour dozens of Cenococcum geophilum ITS genotypes and hundreds of species of ectomycorrhizal fungi, FEMS Microbiol Ecol 75:313–320. https://doi.org/10.1111/j.1574-6941.2010.01000.x.

BEGUM N, QIN C, AHANGER MA, RAZA S, KHAN MI, AHMED N, ASHRAF M, ZHANG L. 2019- Role of Arbuscular Mycorrhizal Fungi in Plant Growth Regulation: Implications in Abiotic Stress Tolerance. Frontiers in plant science. 10:1068.

BRUNDRETT, M., 1991, Mycorrhizas in natural ecosystems. In Advances in ecological research (Vol. 21, pp. 171-313). Academic Press.

BRUNDRETT, M., 2009, Mycorrhizal associations and other means of nutrition of vascular plants: understanding the global diversity of host plants by resolving conflicting information and developing reliable means of diagnosis, Plant Soil (2009) 320: 37. https://doi.org/10.1007/s11104-008-9877-9.

CARLIER, L., ROTAR, I., VLAHOVA, M., & VIDICAN, R., 2009, Importance and Functions of Grasslands. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 37(1), 25-30. https://doi.org/10.15835/nbha3713090.

CARRENHO R, TRUFEM SF, BONONI VL, SILVA ES, 2007- The effect of different soil properties on arbuscular mycorrhizal colonization of peanuts, sorghum and maize. Acta Botanica Brasilica. 21(3):723-30.

CHEEKE TE, ZHENG C, KOZIOL L, GURHOLT CR, BEVER JD., 2019- Sensitivity to AMF species is greater in late-successional than early-successional native or non-native grassland plants. Ecology. Jul 30.

CHEN W, XU R, WU Y, CHEN J, ZHANG Y, HU T, YUAN X, ZHOU L, TAN T, FAN J., 2018- Plant diversity is coupled with beta not alpha diversity of soil fungal communities following N enrichment in a semi-arid grassland. Soil Biology and Biochemistry. s116:388-98.

CLEMMENSEN K., BAHR O., OVASKAINEN O., DAHLBERG A., A. EKBLAD, H. WALLANDER, J. STENLID, R. D. FINLAY, D. A. WARDLE, B. D. LINDAHL, 2013- Roots and Associated Fungi Drive Long-Term Carbon Sequestration in Boreal Forest, Science29 Mar 2013 : 1615-1618.

CLINE LC, HOBBIE SE, MADRITCH MD, BUYARSKI CR, TILMAN D, CAVENDER-BARES JM., 2018- Resource availability underlies the plant-fungal diversity relationship in a grassland ecosystem. Ecology. 99(1):204-16.

COX , C . B . , AND P . D . MOORE, 2005- Biogeography: an ecological and evolutionary approach, 7th ed. Blackwell Publishing, Malden, Massachusetts, USA.

CRIȘAN I, R. VIDICAN, V. STOIAN, M. ȘANDOR, A. STOIE, 2018- Arbuscular mycorrhizae of five summer geophytes from Cluj county.

DICKIE ORCHARD, S. , HILTON, S. , BENDING, G. D., DICKIE, I. A., STANDISH, R. J., GLEESON, D. B., JEFFERY, R. P., POWELL, J. R., WALKER, C. , BASS, D. , MONK, J. , SIMONIN, A. AND RYAN, M. H., 2017- Fine endophytes (Glomus tenue) are related to Mucoromycotina, not Glomeromycota, New Phytol, 213: 481-486. doi:10.1111/nph.14268.

DICKIE, I.A., BENNETT, B.M., BURROWS, L.E., 2014- Conflicting values: ecosystem services and invasive tree management, Biol Invasions 16: 705. https://doi.org/10.1007/s10530-013-0609-6.

FILION, M., ST-ARNAUD, M., & FORTIN, J., 1999- Direct interaction between the arbuscular mycorrhizal fungus Glomus intraradices and different rhizosphere microorganisms. New Phytologist, 141(3), 525-533. doi:10.1046/j.1469-8137.1999.00366.x.

FINLAY RD, 2008- Ecological aspects of mycorrhizal symbiosis: with special emphasis on the functional diversity of interactions involving the extraradical mycelium. Journal of experimental botany. 59(5):1115-26.

GIOVANNETTI M, SBRANA C., AVIO L., STRANI P., 2004- Patterns of belowground plant interconnections established by means of arbuscular mycorrhizal mycorrhizal networks, New Phytol 164:175–181.

HAINES-YOUNG R, POTSCHIN M., 2010- The links between biodiversity, ecosystem services and human well-being. Ecosystem Ecology: a new synthesis. 1:110-39.

HARTNETT, D.C. & WILSON, G.W.T, 2002- The role of mycorrhizas in plant community structure and dynamics: lessons from grasslands, Plant and Soil, 244: 319. https://doi.org/10.1023/A:1020287726382.

HASSANI, M.A., DURÁN, P. & HACQUARD, S., 2018- Microbial interactions within the plant holobiont, Microbiome, 6: 58. https://doi.org/10.1186/s40168-018-0445-0.

HOFFMAN MT, ARNOLD AE., 2010- Diverse bacteria inhabit living hyphae of phylogenetically diverse fungal endophytes. Appl Environ Microbiol. 2010;76:4063–75.

HOPKINS A, HOLZ B., 2006- Grassland for agriculture and nature conservation: production, quality and multi-functionality. Agronomy research.4(1):3-20.

JORGENSEN SE, FATH BD. 2014- Encyclopedia of ecology. Newnes.

JUNG, MARTINEZ-MEDINA, LOPEZ-RAEZ, POZO, SABINE C., AINHOA, JUAN A., MARIA J., 2012- Mycorrhiza-Induced Resistance and Priming of Plant Defenses, J Chem Ecol. 38 (6): 651–664. doi:10.1007/s10886-012-0134-6. PMID 22623151.

KAMINSKYJ SUSAN, 2010- Endorhizal Fungi. Usask.ca. Archived from the original on 2010-11-04. Retrieved 2010-09-30.

KYASCHENKO J, CLEMMENSEN KE, HAGENBO A, KARLTUN E, LINDAHL BD.,2017- Shift in fungal communities and associated enzyme activities along an age gradient of managed Pinus sylvestris stands, ISME J 11, 863–874 (2017) doi:10.1038/ismej.2016.184.

LEAKE JR., 2005- Plants parasitic on fungi: unearthing the fungi in mycoheterotrophs and debunking the 'saprophytic' plant myth. Mycologist 19: 113–122.

LEHMANN A, ZHENG W, RILLIG MC., 2017- Soil biota contributions to soil aggregation. Nature ecology & evolution. 1(12):1828.

LIN, X., E. GEORGE AND H. MARSCHNER, 1991- Extension of the phosphorus depletion zone in VA-mycorrhizal white clover in a calcareous soil. Plant Soil., 136: 41-48.

LOREAU M., 2010- Linking biodiversity and ecosystems: towards a unifying ecological theory. Philosophical Transactions of the Royal Society B: Biological Sciences. 365(1537):49-60.

MARON PA, SARR A, KAISERMANN A, LÉVÊQUE J, MATHIEU O, GUIGUE J, KARIMI B, BERNARD L, DEQUIEDT S, TERRAT S, CHABBI A., 2018- High microbial diversity promotes soil ecosystem functioning. Appl. Environ. Microbiol. 84(9):e02738-17.

McKENDRICK, S., LEAKE, J., & READ, D., 2000- Symbiotic germination and development of myco-heterotrophic plants in nature: Transfer of carbon from ectomycorrhizal Salix repens and Betula pendula to the orchid Corallorhiza trifida through shared hyphal connections, New Phytologist, 145(3), 539-548. doi:10.1046/j.1469-8137.2000.00592.x.

MERCKX V, BIDARTONDO MI, HYNSON NA., 2009- Myco-heterotrophy: when fungi host plants. Annals of Botany. 104(7):1255-61.

MIKKELSEN BL., ROSENDAHL S., JAKOBSEN I., 2008- Underground resourceallocation between individual of mycorrhizal fungi, NewPhytol 180:890–898.

MOHAMMADI K., 2011. Soil, plant and microbe interactions. Lambert Academic Publishing., 113 pp.

NIKOLAOU, N., ANGELOPOULOS, K., KARAGIANNIDIS, N., 2003- Effects of Drought Stress on Mycorrhizal and Non-Mycorrhizal Cabernet Sauvignon Grapevine, Grafted Onto Various Rootstocks, Experimental Agriculture 39 (3): 241–252.doi:10.1017/S001447970300125X.

NUCCIO EE, HODGE A, PETT-RIDGE J, HERMAN DJ, WEBER PK, FIRESTONE MK., 2013- An arbuscular mycorrhizal fungus significantly modifies the soil bacterial community and nitrogen cycling during litter decomposition. Environ Microbiol. 2013;15:1870–81.

PORCEL R, AROCA, R, RUIZ-LOZANO JM, 2012- Salinity stress alleviation using arbuscular mycorrhizal fungi A review, Agronomy for Sustainable Development 32: 181-200.

RICHARDSON DM, ALLSOPP N, D'ANTONIO CM, MILTON SJ, REJMÁNEK M, 2000- Plant invasions – the role of mutualisms, Biol Rev 75:65–93.

RILLIG M C., 2004- Arbuscular mycorrhizae and terrestrial ecosystem processes. Ecol Lett,7: 740–754.

SANDERS I.R., CLAPP J.P. & WIEMKEN A., 1996- The genetic diversity of arbuscular mycorrhizal fungi in natural ecosystems - a key to understanding the ecology and functioning of the mycorrhizal symbiosis. New Phytol. 133: 123-134.

SMITH, F., & SMITH, S., 1997- Tansley Review No. 96 Structural diversity in (vesicular)–arbuscular mycorrhizal symbioses, New Phytologist, 137(3), 373-388. doi:10.1046/j.1469-8137.1997.00848.x.

STOIAN V., ROXANA VIDICAN, I. ROTAR, F. PĂCURAR, ADRIANA MOREA, 2016- Mycorrhizas in Trifolium Repens – A Short Term High Experiment Approach, Agriculture and Agricultural Science Procedia, Volume 10,2016, Pages 39-46, ISSN 2210-7843.

STOIAN, V.; VIDICAN, R.; ROTAR, I., 2015- Mycorrhizal Circuit In The Root Of Avena Sativa. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture, [S.l.], v. 72, n. 2, p. 597-598, nov. 2015. ISSN 1843-5386.

VAN DER HEIJDEN MG, KLIRONOMOS JN, URSIC M, MOUTOGLIS P, STREITWOLF-ENGEL R, BOLLER T, WIEMKEN A, SANDERS IR., 1998- Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. Nature. Nov;396(6706):69.

VAN DER HEIJDEN MG, MARTIN FM, SELOSSE MA, SANDERS IR., 2015- Mycorrhizal ecology and evolution: the past, the present, and the future. New Phytologist. 205(4):1406-23.

VAN OIJEN M, BELLOCCHI G, HÖGLIND M., 2018- Effects of climate change on grassland biodiversity and productivity: the need for a diversity of models. Agronomy. 8(2):14.

WANG, B., QIU, Y.L., 2006- Phylogenetic distribution and evolution of mycorrhizas in land plants, Mycorrhiza. 16 (5): 299–363. doi:10.1007/s00572-005-0033-6. PMID 16845554.

WILPISZESKI RL, AUFRECHT JA, RETTERER ST, SULLIVAN MB, GRAHAM DE, PIERCE EM, ZABLOCKI OD, PALUMBO AV, ELIAS DA., 2019- Soil aggregate microbial communities: Towards understanding microbiome interactions at biologically relevant scales. Applied and environmental microbiology. 85(14):e00324-19.

YUKI OGURA- TSUJITA, TOMOHISA YUKAWA., 2008- High mycorrhizal specificity in a widespread mycoheterotrophic plant, Eulophia zollingeri (Orchidaceae). American Journal of Botany 95(1):93-97.

***, 2017, Mycorrhizal Status of Plants, www.mycorrhizae.com
***, https://www.mycorrhizalproducts.com
***, http://www.soilmoist.com/products
***, https://mycorrhizas.info/ozplants.html