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Mycorrhizal Association in Industrial Wastelands in Kota, Rajasthan, India

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ABSTRACT

Mycorrhizal symbiosis occurs between arbuscular mycorrhizal fungi and most of the vascular plants and is a highly evolved mutually beneficial relationship occurring within the rhizosphere of the vascular plants. The host plants are directly conferred benefits to the growth and development due to this symbiotic association. Their function ranges from stress alleviation to bioremediation in polluted soils besides their importance in the restoration of degraded wastelands. In this investigation colonization percentage and spore density of VAM fungi were studied in industrial waste dump sites and soil having natural vegetation. Industrial waste dump sites are characteristically dominated by *Glomus.* Mycorrhizal association and spore formation potential of AMF was significantly lowered in soil disturbed due to industrial waste dumping.

Keywords- Arbuscular vmycorrhizal fungi, wastelands, mycorrhizal association, spore density, Glomus.

I. INTRODUCTION

About 93% of the flowering plant's families (Brundrett, 2009) and 92% of families of the total terrestrial plant (Wang and Qiu, 2006) are estimated to have mycorrhizal associations in their rhizosphere and form mutualistic associations with the roots of most land plants. Arbuscular mycorrhizal fungi (AMF) are obligate symbiotic fungi belonging to the phylum *Glomeromycota* (Schubler *et. al.*, 2001) that are found in the rhizosphere. Mycorrhiza is the essential component of microbial soil community which forms the most common symbiotic relationship with the roots of the majority of land plants (Wang *et al*, 2008).

AMF's has an important role to play in the restoration and recovery of disturbed lands and this great potential can be used in the reclamation of wastelands. By their ability to increase the roots surface and mineral uptake efficiency, mycorrhizal associations help the host plants to thrive in adverse soil conditions and drought situations prevailing in disturbed and degraded land. Mycorrhiza increases the absorbing surface area of the root by 100 or even 1000 fold (Larcher, 1995) thus increasing the plant's nutrient uptake and water relations (Birhane *et. al.,* 2010; Banerjee *et. al.*, 2013; Birhane *et. al.,* 2015). AMF not only improves soil structure, but soil water relations resulting in increased nutrient supply to the plant. Thus accelerating growth and yield, reproductive success, tolerance of the plant to biotic and a biotic stresses, and also reduces the requirement of the fertilizer (Finlay, 2008; Gianinazzi *et. al.*, 2010; Simard and Austin, 2010; Barea *et. al.*, 2011; Soka and Ritchie, 2014). In this way, AMF can improve field survival of the seedlings and their establishment (Pouyu-Rojas and Siqueira, 2000; Habte *et. al.,* 2001; Ouahmane *et. al.*, 2006; Dag *et. al.*, 2009; Kapulnik *et. al.*, 2010; Karthikeyan and Krishnakumar, 2012; Manaut *et. al.*, 2015) on degraded lands.

Mycorrhiza plays an important role in the ecological restoration of degraded land *vis-a-vis* degraded vegetation. During the natural regeneration process, AMF influence the community structure of vegetation (Van der Heijden *et. al.*, 1998; Hartnett and Wilson, 1999; Renker *et. al.*, 2004; Heneghan *et. al.*, 2008; Lin *et. al.*, 2015) and are thus considered to have a pivotal role in the establishment of plant community and their assembly and succession (Janos, 1980; Renker *et. al.*, 2004; Kikvidze *et. al.*, 2010). Not only natural vegetation but agriculture is also affected by AMF diversity and distribution. Studies on agricultural fields have shown that disturbance in soil not only reduces abundance, diversity, and infectivity of AMF but also results in a drastic shift in the mycorrhiza community (Schnoor *et. al.*, 2011).

Kota in Rajasthan, India is an industrial city (cartographic coordinates; $24^0 33^{'}$ - $25^0 50$' N latitude and $75^0 37$'-$76^0 31$'E longitude), building limestone (*Kota Stone*) mining being the most important industry in this area. The thermal power station and fertilizer industry are other industries of major importance as the district is surrounded by five power stations within a 50 km radius. These industries create a huge amount of waste that is dumped in the surrounding area. The present study was conducted to evaluate the mycorrhizal association and spore density of AMF in natural vegetation areas and vegetation available on waste dump sites.

II. METHODOLOGY

In the present study mycorrhizal association between plants occurring on varying natural regeneration stages on wastelands is studied. Laboratory experiments

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were carried out to study microscopic examination of spore density and AMF association between common plants available in natural vegetation as well as in waste dump sites. The wet sieving and decanting method of Gerdemann and Nicolson (1963) was used to extract AM spores in the rhizosphere soil and Schenk and Perez (1988) manual was referred for identification of AMF and percent association with host plant was calculated. For the quantitative and qualitative estimation of AM fungi, seedlings of the plants were collected. Feeder roots were collected after washing the root system thoroughly in slow-running tap water. Stain the roots for mycorrhizal association was done by Philips and Hayman (1970) method. The percentage of association (infection) was calculated by the method given by Giovanetti and Mosse (1980).

The data recorded for the number of spores and percentage association (%) was subjected to statistical analysis using regression analysis. The investigations and experimental work were carried out in the Department of Botany, J.D.B. Govt. Girls College, Kota (Rajasthan).

III. OBSERVATION AND RESULTS

Only four genera of mycorrhiza were found in the study area. They are represented by *Acaulospora, Gigaspora, Glomus,* and *Sclerocystis.* Maximum diversity was exhibited by *Glomus.* In the control site as well as DCM industrial area all the four species of *Glomus* were found but in the Thermal power plant site, only 2 species*; G. fasciculatum and G. Macrocarpum* were found. In mining waste dump site *G. intraradiaces, G. Mossae* and *G. intraradiaces* were reported. *Acaulospora* was represented by 3 species in control site as well as in DCM industrial area; *A. foveata, A. niger, A. levis* whereas in 2 species were found in thermal power plant; *A. levis, A. Niger* and in mining waste dump site 2 species; *A. Foveata* and *A. levis* were found. *Gigaspora* was represented by *G. margarita* and *G. Albida* in natural vegetation sites whereas in DCM industrial area only *G. Albida* was reported. In the other two sites, only *G. margarita* was found. Two species of *Sclerocystis* were found in the control site; *S. microcorpum, S. Celvispora* whereas only *S. Microcorpum* was reported from DCM industrial area and only *S. Celvispora* was found in mining waste dump sites.

Acaulospora levis and *Glomus marcocarpum* were the most successful species found in all the sites including all degraded wastelands. *Sclerocystis calvispora* and *Sclerocystis microcarpum* were not very much adapted to the wasteland soil and hence reported in only one out of three wasteland sites. All other species were found in at least two out of three wasteland sites.

Table 1: Spore density/ 10 gm soil (SD) and mycorrhizal association (MA %) of AMF species found in natural vegetation site (control) and three experimental sites (waste dump sites).

	Control site		DCM industrial area		Thermal Power Plant		Mining waste dump site	
Name	**SD**	**M A (%)**	**SD**	**M A (%)**	**SD**	**M A (%)**	**SD**	**M A (%)**
Acaulospora foveata	40	90	35	20	0	0	10	10
Acaulospora levis	20	65.45	18	18.81	25	25	20	14.4
Acaulospora niger	35	44	30	21	13	39.81	0	0
Gigaspora albida	25	61	25	59	0	0	0	0
Gigaspora margartia	40	41.75	0	0	10	18	15	27
Glomus fasciculatum	30	63	20	25.33	22	33	0	0
Glomus intraradiaces	26	53	20	45	0	0	5	27
Glomus marcocarpum	30	62	40	10	35	9	10	14
Glomus mossae	10	54	7	18	0	0	10	12
Sclerocystis microcarpum	20	30	15	30	0	0	0	0
Sclerosystis calvispora	10	36	0	0	0	0	6	24

A critical perusal of Tables 1 & 2 shows a significant difference in the three waste dump sites and control sites. Mycorrhizal colonization, in all the three different waste dump sites, ranged between 8 - 24% whereas 30 and 90% in natural vegetation sites. The number of resting mycorrhiza spores and root association differed from one species to another. In contrast to the percentage of association, there is a lot of quantitative variation in mycorrhiza spore density. In both the sites (control and experimental), spore density in the rhizosphere was found to be directly proportional to the mycorrhizal association in the root. Mycorrhiza species have shown more root association and spore density than those found in three waste dump sites. Various factors such as physico-chemical characteristics of the soil can be attributed to such variation.

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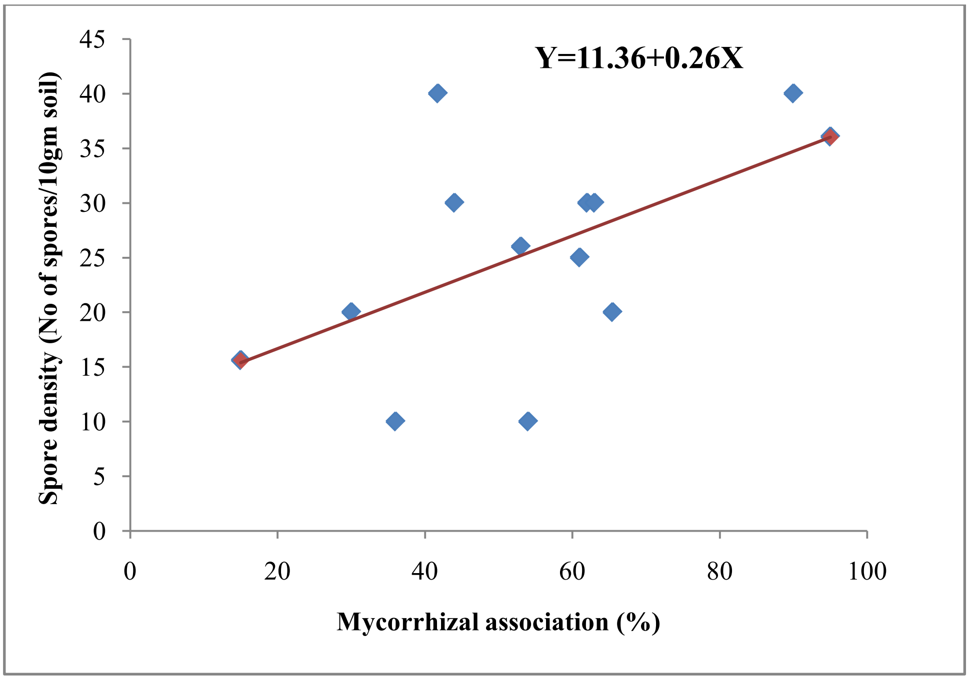

Figure1: Simple Regression analysis of Mycorrhiza species in control sites (natural vegetation sites); Spore density against Mycorrhiza association (%). The regression line is drawn in red.

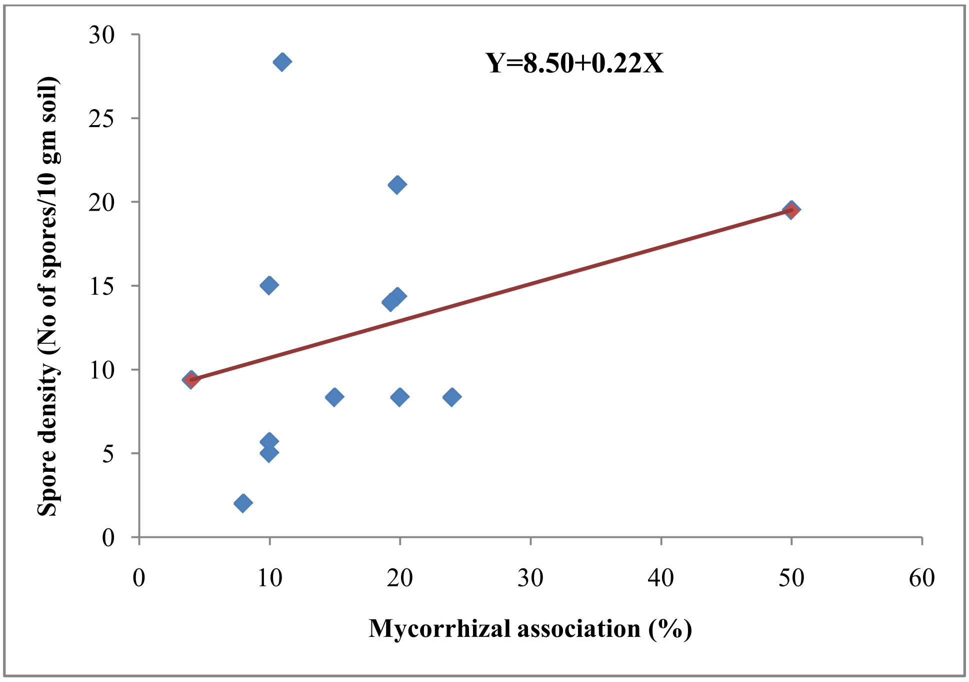

Figure 2: Simple Regression analysis of Mycorrhiza species in experimental sites (waste dump sites); Spore density against Mycorrhiza association (%). The regression line is drawn in red.

As shown in Figure 1 and 2, Mycorrhizal association (%) which have lower spore density are shown below the regression line (they had negative residuals to root infection), thus contribute less in spore production. Spores having the greater association (%) are shown above the regression line (they had positive residuals to root infection), thus contribute to more unique diversity. In the control site (figure 1), more mycorrhiza species are found to have greater spore densities as compared to waste dump sites (figure 2). The steepness of the regression line in figures 1 and 2 indicates a better correlation between mycorrhizal association and spore density in the control site than degraded wastelands.

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IV. DISCUSSION

In the present study area, most waste dumps and seen as small hills having slop thus the surface is highly eroded due to rainfall and wind. AMF could be lost completely due to soil erosion (Habte, 1989). In the study site, water limiting conditions make the waste dump site very dry. Though the infective potential of AMF was significantly lowered in the disturbed soil (Jasper *et. al*., 1989) but AMF maintained its infective potential to some extent in such soil conditions which were extremely dry. Mycorrhizal hyphae are the source of inoculum for the seedlings growing on the wastelands and degraded land but are very susceptible to disturbances and hence, disturbances lead to the lowered AMF infective potential (Brundrett and Abbott, 2002). Although AMF are ubiquitous, severely eroded or disturbed areas can be devoid of AMF (Abbott and Robson, 1991; Schnoor *et al*., 2011). Low levels of diversity and abundance of AMF are characteristic of degraded lands. With increasing the scale of degradation, the AMF diversity and abundance reduces (Cardozo-Junior *et. al*., 2012). Due to severe disturbance during opencast mining and other industrial activities, native vegetation is disturbed heavily, and species richness of plants decreases heavily as compared to control sites. In such areas, in the absence of the host plant, there is a decline in the number of surviving propagules of AMF in soils with time (Brundrett and Abbott, 2002). Environmental factors may have an impact on the diversity and function of mycorrhizal symbiosis (Cotton, 2018).

In the present study, *Glomus* is the most abundant genus having 4 species. These findings go with the fact that on disturbed sites AMF communities are characteristically dominated by members of the family Glomeraceae more specifically the genus *Glomus,* which is considered a disturbance tolerant species (Chagnon *et. al*., 2013). Glomeraceae are ruderals while Gigasporaceae are competitors and Acaulosporaceae are stress tolerators (Chagnon *et. al*., 2013). Ruderal AMF species are usually disturbance tolerant having comparatively short extra-radical mycelium and faster-growing, having short life cycle, and produce abundant spore and fragmented hyphae fuse more readily (Chagnon *et. al*., 2013). In the present study, *Acaulospora* and *Gigaspora* are other important genera. Arbuscular mycorrhizal fungi are very ubiquitous, found almost in all types of soil, and show no host specificity to forge a symbiotic relationship with plants (Abbott and Robson, 1991; Brundrett and Abbott, 2002; Barea *et. al*., 2011; Al Karaki, 2013). But there is a low level of infective AMF on degraded lands and due to lack of sufficient AMF in degraded soil, seedlings may less likely to be infected with AMF (Michelsen, 1992).

Mycorrhizal diversity is important for the sustainability of restoration attempts. Arbuscular mycorrhizal fungi may synergistically interact with each other and AMF effects are greater when AMF consortium having multiple AMF inoculums were applied than single AMF (Banerjee *et. al*., 2013). It was also observed that the use of native AMF consortia occurring on natural undisturbed soil has the maximum effect in restoration (Barea *et. al*., 2011). Results of a meta-analysis indicated that plant response to AMF was substantially lower in plants inoculated with single AMF species, as compared to inoculations with multiple AMF species (Hoeksema *et. al*., 2010). Hence diversity of mycorrhiza is important for restoration attempts to be successful. Water stress conditions of the degraded mining waste and other industrial waste dumps are a major barrier to vegetation establishment. Mycorrhizal associations help the seedlings of host plants to survive in drought situations and adverse soil conditions of degraded soil by increasing the roots surface and enhancing mineral uptake efficiency thus helps to increase water uptake and/or otherwise alter the plant physiology to reduce the stress response caused due to drought and salinity.

V. CONCLUSION

Industrial waste dump sites are dominated by genus *Glomus* belonging to the family Glomeraceae indicating it to be a disturbance tolerant species.Mycorrhizal association and spore formation potential l of AMF was significantly lowered in soil disturbed due to industrial waste dumping.

REFERENCES

[1] Abbott L. K., Robson A. D. (1991). Factors influencing the occurrence of vesicular-arbuscular mycorrhizas. *Agric. Ecosyst. Environ.* **35:** 121–150.10.1016/0167-8809(91)90048-3

[2] Al-Karaki G. N. (2013). The role of mycorrhiza in the reclamation of degraded lands in arid environments, in *Developments in Soil Classification, Land Use Planning and Policy Implications: Innovative Thinking of Soil Inventory for Land Use Planning and Management of Land Resources*, Eds. Shahid S. A., Taha F. K., Abdelfattah M. A. (Dordrecht: Springer Science+Business Media;), 823–836.

[3] Banerjee K., Gadani M. H., Srivastava K. K., Verma N., Jasrai Y. T., Jain N. K. (2013). Screening of efficient arbuscular mycorrhizal fungi for *Azadirachta indica* under nursery condition: a step towards afforestation of semi-arid region of Western India. *Braz. J. Microbiol.* **44**: 587–593.10.1590/S1517-83822013005000046

[4] Barea J. M., Palenzuela J., Cornejo P., Sánchez-Castro I., Navarro-Fernández C., Lopéz- García A., *et al.* (2011). Ecological and functional roles of mycorrhizas in semi-arid ecosystems of Southeast Spain. *J. Arid Environ.* **75:** 1292–1301. 10.1016/j.jaridenv.2011.06.001

[5] Birhane E., Kuyper T. W., Sterck F. J., Bongers F. (2010). Arbuscular mycorrhizal associations in

Boswellia papyrifera (frankincense-tree) dominated dry deciduous woodlands of Northern Ethiopia. *For. Ecol. Manag.* **260**: 2160–2169. 10.1016/j.foreco.2010.09.010

[6] Birhane E., Kuyper T. W., Sterck F. J., Gebrehiwot K., Bongers F. (2015). Arbuscular mycorrhiza and water and nutrient supply differently impact seedling performance of acquisitive and conservative dry woodland species. *Plant Ecol. Divr.* **8**: 1–13. 10.1080/17550874.2014.992488

[7] Brundrett M. C. (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,* **320:** 37–77. 10.1007/s11104-008-9877-9

[8] Brundrett M. C., Abbott L. K. (2002). Arbuscular mycorrhiza in plant communities, in *Plant Conservation and Biodiversity*, Eds. Sivasithamparam K., Dixon K. W., Barrett R. L. (Dordrecht: Kluwer Academic Publishers), 151–193.

[9] Cardozo-Junior F. M., Carneiro R. F. V., Goto B. T., Bezerra A. A. C., Araújo A. S. F., Nunes L. A. P. L. (2012). Arbuscular mycorrhizal fungi in degraded lands in Northeast Brazil. *Afr. J. Microbiol. Res.* **6**: 7198–7205.10.5897/AJMR12.1132

[10] Chagnon P. L., Bradley R. L., Maherali H., Klironomos J. N. (2013). A trait-based framework to understand life history of mycorrhizal fungi. *Trends Plant Sci.* **18**: 484–491. 10.1016/j.tplants.2013.05.001

[11] Cotton, T. A. (2018). Arbuscular mycorrhizal fungal communities and global change: An uncertain future. *FEMS Microbiology Ecology*, **94**(11), fiy179. https://doi.org/10.1093/femsec/fiy179

[12] Dag A., Yermiyahu U., Ben-Gal A., Zipori I., Kapulnik Y. (2009). Nursery and post-transplant field response of olive trees to arbuscular mycorrhizal fungi in an arid region. *Crop Pasture Sci.* **60:** 427–433. 10.1071/CP08143

[13] Finlay R. D. (2008). Ecological aspects of mycorrhizal symbiosis: with special emphasis on the functional diversity of interactions involving the extra radical mycelium. *J. Exp. Bot.* **59**: 1115–1126. 10.1093/jxb/ern059

[14] Gerdemann J. W., Nicolson T.H., (1963). Spores of arbuscular mycorrhizal Endogone extracted from soil by wet sieving and decanting. *Trans Br Mycol Soc,* **46**: 235-244

[15] Giovannetti M. and Mosse B. (1980). An evaluation of techniques for measuring vesicular-arbuscular mycorrhizal infections in roots. *New Phytologist*, **84**: 489-500

[16] Gianinazzi S., Gollotte A., Binet M.-N., van Tuinen D., Redecker D., Wipf D. (2010). Agroecology: the key role of arbuscular mycorrhizas in ecosystem services. *Mycorrhiza,* **20**: 519–530. 10.1007/s00572-010-0333-3

[17] Habte M. (1989). Impact of simulated erosion on the abundance and activity of indigenous vesicular-arbuscular mycorrhizal endophytes in an Oxisol. *Biol. Fer. Soils,* **7:** 164–167. 10.1007/BF00292576

[18] Hartnett D. C., Wilson G. W. T. (1999). Mycorrhiza influence plant community structure and diversity in tall grass Prairie. *Ecology,* **80:** 1187–1195. 10.1890/0012-9658(1999)080[1187:MIPCSA]2.0.CO;2

[19] Heneghan L., Miller S. P., Baer S., Callaham M. A., Montgomery J., Pavao-Zuckerman M., *et al.* (2008). Integrating soil ecological knowledge into restoration management. *Restor. Ecol.* **16**: 608–617. 10.1111/j.1526-100X.2008.00477.x

[20] Hoeksema J. D., Chaudhary V. B., Gehring C. A., Johnson N. C., Karst J., Koide R. T., *et al.* (2010). A meta-analysis of context-dependency in plant response to inoculation with mycorrhizal fungi. *Ecol. Lett.* **13**: 267–407.10.1111/j.1461-0248.2009.01430.x

[21] Janos D. P. (1980). Mycorrhizae influence tropical succession. *Biotropica,* **12**: 56–64. 10.1007/s00572-012-0464-9

[22] Jasper D. A., Abbott L. K., Robson A. D. (1989). Hyphae of a vesicular-arbuscular mycorrhizal fungus maintain infectivity in dry soil, except when the soil is disturbed. *New Phytol.* **112:** 101–107. 10.1111/j.1469-8137.1989.tb00314.x

[23] Kapulnik Y., Tsror L., Zipori I., Hazanovsky M., Wininger S., Dag A.(2010). Effect of AMF application on growth, productivity and susceptibility to Verticillium wilt of olives grown under desert conditions. *Symbiosis,* **52**: 103–111. 10.1007/s13199-010-0085-z

[24] Karthikeyan A., Krishnakumar N. (2012). Reforestation of bauxite minespoils with *Eucalyptus tereticornis* Sm. seedlings inoculated with arbuscular mycorrhizal fungi. *Ann. For. Res.* **55**: 207–216.

[25] Kikvidze Z., Armas C., Fukuda K., Martínez-García L. B., Miyata M., Oda-Tanaka A., *et al.* (2010). The role of arbuscular mycorrhizae in primary succession: differences and similarities across habitats. *Web Ecol.***10**: 50–57. 10.5194/we-10-50-2010

[26] Larcher W. (1995). *Physiological Plant Ecology.* Berlin: Springer-Verlag.

[27] Lin G., McCormack M. L., Guo D. (2015). Arbuscularmycorrhizal fungal effects on plant competition and community structure. *J. Ecol.* **103**: 1224–1232. 10.1111/1365-2745.12429

[28] Manaut N., Sanguin H., Ouahmane L., Bressan M., Thioulouse J., Baudoin E., *et al.* (2015). Potentialities of ecological engineering strategy based on native arbuscular mycorrhizal community for improving afforestation programs with carob trees in degraded environments. *Ecol. Eng.* **79**: 113–119. 10.1016/j.ecoleng.2015.03.007

[29] Michelsen A. (1992). Mycorrhiza and root nodulation in tree seedlings from five nurseries in Ethiopia and Somalia. *For. Ecol. Manag.* **48**: 335–344. 10.1016/0378-1127(92)90154-2

[30] Ouahmane L., Hafidi M., Thioulouse J., Ducousso M., Kisa M., Prin Y., etal. (2006). Improvement of *Cupressus atlantica* Gaussen growth by inoculation with

ISSN: 2349-8889
Volume-8, Issue-3 (May 2021)

https://doi.org/10.31033/ijrasb.8.3.28

native arbuscular mycorrhizal fungi. *J. Appl. Microbiol.* **103**: 683–690. 10.1111/j.1365-2672.2007.03296.x

[31] Phillips, J.H. and Hayman, D.S. (1970). Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. *Transection of the British Mycological Society*, **55**(1): 158-161.

[32] Pouyu-Rojas E., Siqueira J. O. (2000). Arbuscular mycorrhizal and soil fertilization on post-transplant development of out plants of seven forest species. *Pesqui. Agropecu. Bras.* **35:** 103–114. 10.1590/S0100-204X2000000100013

[33] Renker C., Zobel M., Öpik M., Allen M. F., Allen E. B., Vosátka M., *et al.* (2004). Structure, dynamics, and restoration of plant communities: do arbuscular mycorrhizae matter?, in *Assembly Rules and Restoration Ecology: Bridging the Gap Between Theory and Practice*, Eds. Temperton V. M., Hobbs R. J., Nuttle T., Halle S. (Washington, DC: Island Press),189–229.

[34] Schnoor T. K., Lekberg Y., Rosendahl S., Olsson P. A. (2011). Mechanical soil disturbance as a determinant of arbuscular mycorrhizal fungal communities in semi-natural grassland. *Mycorrhiza,* **21**: 211–220.10.1007/s00572-010-0325-3

[35] Schenck NC, Pérez Y, *Manual for identification of VAM fungi.* INVAM, University of Florida, Gainesville, USA, 1988.

[36] Schubler, A., Schwarzott, D. and Walker, C. (2001). A new fungal phylum, the Glomeromycota: phylogeny and evolution. *Mycol Res*., 105(12): 1413-1421

[37] Simard S. W., Austin M. E. (2010). The role of mycorrhizas in forest soil stability with climate change, in *Climate Change and Variability*, Ed. Simard S. W. (Rijeka: In Tech Open Access), 275–302.

[38] Soka G., Ritchie M. (2014). Arbuscular mycorrhizal symbiosis and ecosystem processes: prospects for future research in tropical soils. *Open J. Ecol.* **4**: 11–22. 10.4236/oje.2014.41002

[39] Van der Heijden M. G. A., Klironomos J. N., Ursic M., Moutoglis P., Streitwolf-Engel R., Boller T., *et al*. (1998). Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. *Nature* **396**: 69–72. 10.1038/23932

[40] Wang B., Qiu Y. L. (2006). Phylogenetic distribution and evolution of mycorrhizas in land plants. *Mycorrhiza,* **16**: 299–363. 10.1007/s00572-005-0033-6

[41] Wang YY, Vestberg M, Walker C, Hurme T, Zhang X, Lindstrom K. (2008). Diversity and infectivity of arbuscular mycorrhizal fungi in agricultural soils of the Sichuan Province of mainland China. *Mycorrhiza*18:59-68.