PRINT ISSN 2319-1775 e-ISSN 2320-7876, www.ijfans.org
Volume.11, Issue13, Nov- 2022

Research Paper
UGC CARE Listed (Group -I) Journal

Arbuscular Mycorrhizal Species Composition During Rainy Season From Polluted Sites And Their Role As Biofertilizer

Mrs. Ashwini Deshpande[1], Dr. Mahavir Gosavi[2]
[1]Assistant Professor, Department of Botany, SIES College of Arts, Science and Commerce (Autonomous), Sion(W), Mumbai. [University of Mumbai]
[2]Associate Professor and Head, Department of Botany, SIES College of Arts, Science and Commerce (Autonomous), Sion(W), Mumbai. [University of Mumbai]

Abstract:
Arbuscular mycorrhizae (AM) exhibit the most positive obligate symbiotic relationship, with roots of majority of plants. They show higher ecological amplitude under adverse environmental conditions. The current study deals with the study of diversity of AM fungi during rainy season with respect to rhizosphere soil analysis for AM species composition and their subsequent role as bio-fertilizer. Spores of *Glomus, Sclerocystis* and *Scutellospora* were observed. The observed species were also detected in root colonization analysis, using standard staining methods. The spore density was highest for *Glomus*. It proved to be a dominant species. The application of bio-fertilizer product prepared with these dominant species was proved to be a potent bio-fertilizer in the field trials with chili crop.
Keywords: -ArbuscularMycorrhiza (AM)*, Glomus,Sclerocystis,Scutellospora*

Introduction:
The mutually beneficial relationship between the feeder roots of plants and fungi is called mycorrhiza (Frank, 1885)'*Mycos'* meaning fungus and '*rhiza'* meaning root (Trappe,2005).Arbuscular Mycorrhizal(AM) fungi show obligatory symbiosis and form natural partnership with Bryophytes, Pteridophytes, Gymnosperms and Angiosperms. They are even found in nutrient deficient soils. AM fungi play an essential role in plant growth, plant protection (from drought, temperature, and salinity) and soil quality. Around 80% of plants are colonized by AM fungi which belong to Glomeromycota and members of family Endogonaceae.AM fungi are employed both in agriculture and forestry (Rodrigues and Muthukumar, 2009).

The present paper deals with investigation of species composition of Arbuscular Mycorrhizae in industrially polluted MIDC area of Dombivli in Thane district of Maharashtra, with respect to their association with seasonal weeds surrounding fifteen industries of MIDC area, located at Sagarli in Dombivli (East) during rainy season.Thus, in present context, study of AM fungi for myco-remediation is an emerging significant alternative technology in the clean-up of metal contaminated soil to maintain status of environment and to use it as biofertilizer inoculums in more efficient way to serve in better way for fulfilling the growing nutritional needs of humankind.

Statement of the problem: The current study deals with identifying AM fungi species prevalent during rainy season that can be used as bio-fertilizers.

Scope of research: The seasonal AM fungi species found during rainy season can be effectively used as bio-fertilizer, with increased concentration of macronutrients.

Need of research subject: AM spores that are isolated during rainy season can be multiplied through trap culture and can be successfully used as bio fertilizer, throughout the year.

Hypothesis of problem: The pure inoculum of AM species, observed during rainy season can be used to clean up heavy metal pollution from the soils around industries, thus mycoremediation through AM fungi can be used as effective and ecofriendly technology**.**

Research methodology: The selected study sites were fifteen industries from MIDC, Sagarli of Dombivli (East). Different seasonal weed samples were collected growing near selected industries, along with rhizosphere soil and the spores were isolated, identified and recorded. The original percentage of carbon, nitrogen, phosphorus and potassium was estimated in the soil collected from paddy field and the field trials were taken with chili (*Capsicum annuum*, L.) crop in the same paddy field by using VAM bio fertilizer product with composition of same species, raised through trap culture technique.

Research techniques: For collection of roots and rhizosphere soil samples, a steel pipe was inclined and driven into soil up to 25cm of root zone at different depths.AM fungal spores were isolated from rhizosphere soil samples, by wet sieving and decanting method (Gerdemann and Nicolson, 1963). The isolated spores were observed by lifting them with pinhead and mounting on the slide containing lactophenol as mounting medium. The isolated spores were observed under stereomicroscope, identified, and categorized. Ink and vinegar staining (Vierheilig *et.al.,* 1998) and Trypan blue staining (Philips and Hayman, 1970) of roots were carried out for root colonization of AM fungal species. Thus, AM fungal species, inhabitants of soil polluted sites were surveyed during winter season (November 2021-February, 2022). The percent root colonization with soils of rhizosphere zone from all the weed samples was calculated. The percentage frequency with individual industry was also calculated. Root colonization was

calculated using formula:-

$$\textbf{Percent AM colonization} = \frac{\textbf{No. of root segments with AM structures}}{\textbf{Total no. of root segments examined}} \times \mathbf{100}$$

Data analysis: The percent root colonization, presence of vesicles, arbuscules, spores and coiled hyphae were noticed. The spore density was also calculated. The data of percentage of organic carbon, nitrogen, potassium and phosphorus of the field soil samples, taken before the field trials was compared with data of percentage of organic carbon, nitrogen, potassium and phosphorus of the field soil samples taken after the field trials, carried out by using VAM bio-fertilizer product.

Testing hypothesis: The data was analyzed and tested for significant increase in uptake of macronutrients after the treatment of VAM bio-fertilizer. Thus the hypothesis of role of VAM as bio-fertilizer was tested.

Observations: About 80% of *Glomus* species were recorded from genus *Glomus* such as *G. albidium, G. badium, G.citricola, G. coronatum G. diphanum, G. fecundisporum, G. hoi G. leptotichum, G. macrocarpum, Glomus occultum, Glomus reticulatum* and *G. tenerum* along with species of *Sclerocystis* like *S. rubiformis* and *S. sinuosus*. The species recorded from genus *Scutellospora* were *S. calospora* and *S. persica* respectively. There was significant increase in macronutrient contents after the treatment of bio-fertilizer product with composition of above mentioned AM fungi species.

Description of spores observed:

1) *Glomus albidum*- Walker & Rhodes (1981)

The spores were isolated from rhizosphere soil of *Commelinabenghalensis* and *Oxaliscorniculata*collected during growing season and *Paspalam conjugatum* and *Cynodon dactylon* during winter season.The spores are observed with one subtending hypha borne singly in the soil on coenocytic hyphae. Mature spore shows diameter about 196 x 140 µm, globose to sub globose, occasionally ovoid or irregular. The observed spores were yellowish to brownish yellow. Spore walls continuous with hyphal walls consisting of an outer hyaline wall and light-yellow inner wall. The subtending hypha was bilayered, straight with 12 µm, in thickness. Spores of *Glomus albidum* can be easily distinguished from others due to their brownish yellow colouration, globose to sub globose shape and size ranging from 150-200 µm (Gehlot and Singh, 2015). This species is closely related to *G. gibbosum* (Walker *et. al.*, 1995) and can be distinguished based on four layered walls in the *G. gibbosum* as compared to two layered in *G. albidum* (Blaszkowski *et. al.,* 2001).

2) *Glomus badium*- Oehl, Redecker and Sieverd (2005)

The spores were isolated from rhizosphere soil of *Phyllanthus amarus* collected during winter and summer season, *Eragrostistenella (Poatenella) in* summer season and *Cleome rutidosperma* and *Commelinabenghalensis* in rainy season. The observed spores were brownish, globose with diameter of 280 µm. The germ tubes initiation is observed at two positions. The spore wall consists of three layers. The subtending hypha is recurved.

The most distinguishing characters of *G. badium* are its small sporocarps lacking a peridium and composed of many, brownish orange to reddish brown, relatively small spores. The innermost flexible to semi-flexible and coloured layer of the three-layered spore wall also is a diagnostic property of this species (Ohel *et.al.,* 2005; Blaszkowski, *et.al.,* 2010 and Goto *et.al.,* 2012).

3) *Glomus citricola*- Tang and Zang (1984)

The spores were isolated from rhizosphere soil of *Commelinabenghalensis, Cynodon dactylon* and *Oxalis corniculata* during rainy season and rhizosphere soil of *Scoparia dulcis* from summer season. The single spores were observed in sporocarps. The observed spores were globose with dimensions of about 56 x 84 µm. The subtending hypha was hyaline. The spore wall is thick.

The observed spores were sub-pyriform, the average observed dimensions are 112 x 56 µm. The spore wall is thin, composed of two walls. The attachment of spore is sublateral.

This species is reported by several authors from India before (Jayaprakash& Nagarajan, 2017; Shrivastava *et.al.,* 2012).Like other Species of *Glomus* it also shows globoid spores produced on soil surface (Frank *et.al.,* 2003). Not much literature is available on the said species.

4) *Glomus coronatum*- Giovannetti(1983) and (1991)

The spores, present in sporocarps, were isolated from rhizosphere soil of *Calotropis gigantea* in summer, rhizosphere soil of *Commelina benghalensis. Oxalis corniculata* and *Cynodon dactylon* collected during rainy season. The sporocarps were surrounded by a peridium. The isolated spores were globose, brownish orange in colour with single funnel-shaped subtending hypha. The observed diameter was 252 µm. The observed spore wall was bilayered.

The distinctive characters of *G. coronatum* are its large and greyish orange to brownish orange spores and the wide, funnel-shaped subtending hypha. The wall of spores consists of two layers (Blaszkowski, 1994 and Cavagnaro *et. al.,* 2001). According to Giovannetti *et. al.,* (1991), *G. coronatum* produces spores in sporocarps surrounded by a peridium.

5) *Glomus diphanum*- Morton & Walker (1984)

The spores were isolated singly from rhizosphere soil of *Commelinabenghalensis*, *Heliotropium indicum* and *Cleome rutidosperma* during rainy season. The spores were found in isolated clusters. The observed spores were globose, hyaline, blackish, with about 56 µm in diameter. The spore wall comprises of three layers and elongated subtending hypha was observed. The length observed was about 196 µm and the diameter was 28 µm.

Glomus diaphanum probably has a worldwide distribution. The spores of *G. diaphanum* occur singly in the soil, globoid and hyaline with flexible to semi-flexible innermost wall layer (Morton & Walker, 1984; Morton 1985; Oehl *et. al.,* 2003 and Oehl *et. al.,* 2005).

6) *Glomus fecundisporum*- Schenck and Smith(1982)

The spores were isolated from rhizosphere soil of *Commelina benghalensis* and *Oxalis corniculata* during rainy season. The spores were formed singly or in loose clusters, with globose, pale yellow to white in colour. The observed diameter was140 µm. The spore wall was smooth in young spores and rough in mature spores. The subtending hyphae were hyaline, about 84 µm in length and 28 µm in diameter. The hyphal coils were seen in root colonization samples of *Commelina benghalensis.*

Glomus fecundisporum is a hyaline to dirty-white spored species with spores frequently borne in clusters. The spores consisting of inner and outer walls of approximately equal thickness (Lee *et.al.,* 1993).

It forms mycorrhizal associations with plant roots but not forming typical vesicles or arbuscules; coiling hyphae formed in outer cortical cells with hypha, walls becoming indistinct and after growth through 2 to 3 cortical cells; hypha contents frequently enlarging to fill cell lumen (Schenck & Smith, 1982).

7) *Glomus hoi*– Berch and Trappe (1985)

The spores were isolated from rhizosphere soil of *Commelinabenghalensis*and*Cleome rutidosperma*, during rainy season and *Phyllanthus amarus and Heliotropium indicum* during winter season.

The spores were as single spore in the soil. Each one of them was globose, subglobose, ellipsoidal or irregular in shape, in diameter, light brown in colour. The observed diameter is 140 µm x 112µm.

The spores can be easily distinguished from other species on the basis of solitary appearnce; globose, subglobose, ellipsoidal or irregular in shape and light brown in colour. The spore wall is composed of two distinct, separable layers. (Berch& Trappe, 1985; Blaszkowski, 2003 and Wilde *et.al.,* 2009).

8) *Glomus leptotichum* –Schenck and Smith (1982)

The spores were isolated from *Commelina benghalensis*, *Cleome rutidosperma* and *Oxalis corniculata* during rainy season. The spores were found singly but in loose clusters. The spores were globose, hyaline, light yellow to pinkish in colour (as collected from polluted environment). The observed diameter ranges from 56 µm to 252 µm. The length of subtending hypha was about 112 µm and diameter was 28 µm. The spore wall is composed of three layers some ornamentations are also observed. The root colonization in the roots of *Cleome rutidosperma* is observed in the form of hyphal coiling.

Glomus leptotichum typically has large, white to cream-colored spores with hyaline walls bearing a faint reticulum of ridges. Spores and extrametrical vesicles are produced both terminally and in an intercalary manner (Schenck and Smith, 1982). Because of its large size and white to cream-colored spores it could possibly be confused with *G. lacteum* but *G. leptotichum* lacks the merging hyphae on the attachment associated with *G. lacteum*. *Glomus fecundisporum* which *G. leptotichum* resembles somewhat, has generally smaller spores with yellow to brown walls, gray-white contents, and lacks a reticulum (Morton *et.al.,* 1997; Johnson *et. al*., 1991 and Murakoshi *et. al*., (1998).

9) *Glomus macrocarpum*- Tulasne and Tulasne (1845)

The spores were isolated from *Cynodon dactylon* during summer season. *Cleome rutidosperma*, *Commelina benghlensis* and *Oxalis corniculata* during rainy season.

The spores were found singly in the soil. The observed spores were globose, pear shaped, orange to reddish. The diameter observed was 112 µm. The spore wall was 14 µm, in thickness. The thin, curved subtending hypha. The breadth of observed hypha was 14µm.

Literature indicates that it is a widely distributed throughout the world, although it occurs irregularly (Blaszkowski *et. al.,* 2002).

Spores usually slightly longer than wide, sub globose, avg. of 150–250 µm. Spore wall composed of two distinct layers, spores tapering to the point of attachment of the single persistent hypha (Gehlot & Singh, 2015)

10) *Glomus occultum*- Walker (1982)

The spores were isolated from *Paspalam conjugatum* rhizosphere soil during winter and *Oxalis corniculata* rhizosphere soil from rainy season. The spores occur singly and are sub globose. The observed diameter is 56X86 µm. The spore wall consists of two layers. The sub tending hypha, observed appeared as funnel- shaped 28 µm in length and 14 µm in diameter.

It is probably globally widespread (Walker, 1982; Miller *et al.,* 1985; Morton, 1985 and Puppi *et al.,* 1986). Although it is one of the most widespread but difficult to detect (Millner,2001).
Glomus occultum spores are often colorless, and globose, ellipsoid, or irregular, possessing three thin walls, the inner two often adhering tightly (Morton, 1985).

11) *Glomus reticulatum-* Bhattacharjee and Mukerji (1980)

The spores were extracted from rhizosphere soil of *Commelina benghalensis* and *Portulaca oleracea* from rainy season and *Eclipta prostrata* and *Vernonia sinusoroides* collected during summer season. The spores were found singly, dark brown to reddish or black, globose with 140 µm in diameter. The outer and inner walls of the spores are clearly visible under 100X. The outer wall was about 5 µm in thickness. The subtending hyphae were funnel- shaped and about 10 µm wide (Bhattacharjee & Mukerji, 1980).
Spores are borne freely and singly in soil, globose to subglobose or ellipsoidal, dark brown to brownish black, having reticulate ornamentation. Spore wall structure consists of double wall. Outer wall is laminated, and inner wall is with regular reticulate (Manoharachary*et.al.,* 2005; Kulkarni *et.al.,* 1997; Mishra *et.al.,* 2016; Wang *et.al.,* 2015 and Shekhar and Basu, 2017).

12) *Glomus tenerum-* Tandy (1975)

The spores were isolated from rhizosphere soil of *Commelinabenghalensis* collected during rainy season, *Calotropis gigantea* and *Vernonia sinusoroides*collected during summer season and from Phyllanthus amarus in winter season. The observed spores were shiny, translucent, yellowish brown, thin walled, with some oil globules. The diameter of observed spores was about 56 µm.
The spores are yellow, orange to brown, globose rarely pyriform. Subtending hyphae are cylindrical with globose thick-walled vesicles (Tandy, 1975).
Glomus tenerum differs from other *Glomus* species in having two walls, larger spores, a plug cutting off spore contents and finer-subtending hyphae (McGee, 1986; McGee & Trappe, 2002 and Oehl *et.al.,* 2011).

13) *Scelerocystis rubiformis* - (Gerd. & Trappe, 1974) Almeida and Schenck (1990)

The spores were isolated from rhizosphere soil of *Paspalam conjugatum* collected in winter, *Cassia tora* soil collected in rainy season and rhizosphere soil of *Cleome rutidosperma* collected during summer season. The sporocarps were dark brown, with 392 µm in diameter. The peridium was not found. The spores were found in tightly interwoven hyphae. The spores were dark brown, ellipsoidal with 112 µm in diameter. The small, stalk like projection was observed protruding near the base of spores. The subtending hypha was thick walled.
It probably is a widely distributed fungus in the world and very common in India (Bhattacharjee *et. al.,* 1980; Ragupathy and Mahadevan 1993).
The distinctive features of *G. rubiforme* are its sporocarps with relatively small, coloured spores originated from a centrally positioned hyphal plexus (Almedia and Schenck, 1990; Blaszkowski *et. al.,* 1998; Wu, 1993).
The wall of *G. rubiforme* spores is composed of two layers: outer layer is a thin and hyaline whereas the inner layer is thicker and laminated. The subtending hypha is funnel shaped (Gerdemann and Trappe, 1974 and Almeida and Schenck, 1990).

14) *Sclerocystis sinuosus-* Gerdemann and Bakshi (1976)

=*Glomus sinuosum*

The spores were isolated from rhizosphere soil of *Commelina benghalensis*, *Oxalis corniculata* and *Phyllanthus* amarus from rainy season. The spores are found in compact, thick walled reddish brown sporocarps with sinuous or wavy hyphae, occurring in the soil in groups. The observed diameter of sporocarps was 280 µm. The observed spores were orange to brownish orange or were reddish brown, sub globose, pulvinate and ellipsoidal, the dimensions observed were 28 µm X 56 µm, radiating and in single layer with single subtending hypha.
The spores are obovate, elliptical, fusiform-elliptical to clavate, radiating out in a single layer from a central plexus of hyphae (Ammani *et.al.,* 1986; Almeida and Schenck, 1990 and Muthukumar *et.al*., 2000). The spore wall is brown and thick, generally thickest near spore base. The thick-walled sinuous hyphae that tightly enclose the sporocarps easily distinguish *S. sinuosa* from all other *Sclerocystis* (Gerdemann and Bakshi, 1976).

15) Scutellospora calospora- Nicolson and Gerdemann (1968) Walker and Sanders (1986)

The spores were isolated from rhizosphere soil of *Cleome rutidosperma* during winter season, *Scoparia dulcis* from summer soil sample collection and *Commelina benghaensis* in rainy season. The spores were found singly, terminally on a subtending hypha, which was bulbous, suspensor-like cell. It was ovoid, pale greenish yellow in colour, with dimensions of 196X252 µm. The spore wall consists of two tightly attached layers. The bulbous sporogenous cells were found terminally on septate subtending hypha. The germination shield was ellipsoidal and hyaline.
The shape of spore ranges from sub globose to ellipsoid to oblong, sometimes irregular. Both the wall layers are of same thickness (Nicolson and Gerdemann, 1968).
Spores resemble those of spores of *S. pellucida* except they have a smaller size and are oblong. They are very similar to the spores of *S. dipurpurascens*, in size, shape, and color and differs in its inner wall structure (Koske and Walker, 1986; Morton, 2000)

16) *Scutellospora persica-* Koske and Walker (1985)

The spores were isolated from summer collection from rhizosphere soil of *Eragrostistenella (Poatenella*) and rainy season rhizosphere soil collection of *Commelinabenghalensis*. The observed spore was found as single spore, terminally on a bulbous suspensor-like cell, apricot yellow in colour, subglobose, with dimensions as 364 µm in length and 336 µm in width. The germination shield is light yellow to brownish. The germ pore was protruding out, prominently visible as globoid structure. (Deshpande and Gosavi, 2022)

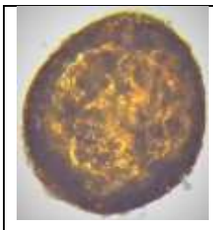
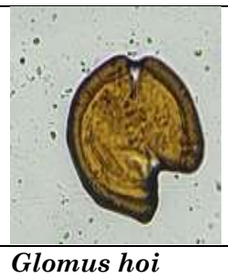
Spores are formed singly in the soil, terminally on a bulbous suspensor-like cell. They are globose to subglobose. The distinctive properties of *S. persica* are its large and dark yellow to apricot yellow spores ornamented with small warts (Morton, 1995)

Tables and figures for observation: -

TABLE I Root colonization with AM species found in rhizosphere soil of rainy season weeds:

Name of the weeds	**AM Spores observed from rhizosphere soil**	**Average percentage of root colonization**
Cynodon dactylon	*Acaulospora mellea, Glomus citricola, Glomus coronatum,*	**40**
Commelina benghalensis	*Acaulospora mellea, Glomus albidum, Glomus ambisporum, Glomus aurantium, Glomus badium, Glomus caledonium, Glomus citricola, Glomus claroideum, Glomus convolutum, Glomus coronatum, Glomus diphanum, Glomus etunicatum, Glomus fecundisporum, Glomus glomerulatum, Glomus hoi, Glomus leptotichum, Glomus macrocarpum, Glomus pubescens, Glomus reticulatum, Gloms tenerum, Glomus trimurales, Sclerocystissinuosa, , Scutellosporacalospora, Scutellosporapersica*	**80**
Oxalis corniculata	*Acaulospora mellea, Glomus albidum, Glomus ambisporum, Glomus citricola, Glomus claroideum, Glomus convolutum, Glomus coronatum, Glomus fecundisporum, Glomus fulvum, Glomus glomerulatum, Glomus leptotichum, Glomus macrocarpum, Glomus occultum, Glomus pubescens, Glomus pulvinatum, Sclerocystissinuosa*	**70**
Cleome rutidosperma	*Gigasoracalospora, Glomus badium, Glomus diphanum, Glomus hoi, Glomus leptotichum, Glomus macrocarpum, Glomus monosporum*	**30**
Portulaca oleracea	*Glomus pubescens, Glomus reticulatum*	**50**
Heliotropium indicum	*Glomus diphanum*	**40**
Phyllanthus amarus	*Sclerocystissinuosa*	**10**
Cassia tora	*Sclerocystisrubiformis*	**10**

TABLE II AM Fungi spore diversity (Source-Primary)

			
Glomus albidum	***Glomus badium***	***Glomus citricola***	***Glomus coronatum***
			
Glomus diphanum	***Glomus fecundisporum***	***Glomus hoi***	***Glomus leptotichum***

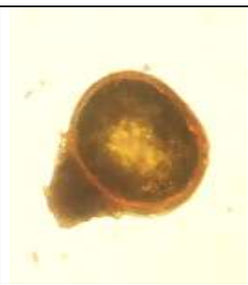
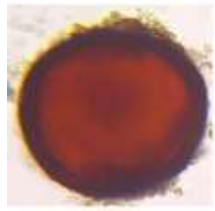
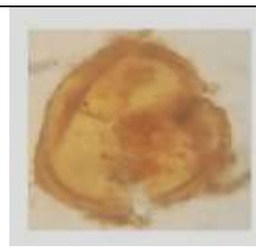
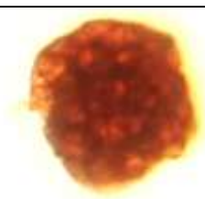
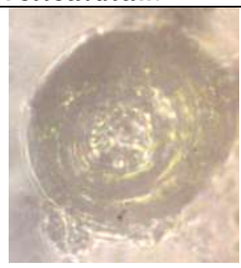
			
Glomus macrocarpum	***Glomus occultum***	***Glomus reticulatum***	***Glomus tenerum***
			
Sclerocystis rubiformis	***Sclerocystis sinuosus***	***Scutellospora calospora***	***Scutellospora persica***

TABLE III-Percentage of organic carbon, nitrogen and phosphorus in a field before and after the application of VAM bio-fertilizer product

Field condition	% carbon(C) in the field soil	%nitrogen (N) in the field soil	% phosphous (P) in the field soil	% potassium (K) in the field soil
Before the application of VAM bio-fertilizer product	1.14	0.13	0.14	0.20
After the application of VAM- biofertilizer product	1.75	0.20	0.24	0.26

Discussion: Based on current survey, seasonal weeds like *Commelina benghalensis* and *Oxalis corniculata* show more diversity by harboring different species of AM fungi in their rhizosphere soil. Root colonization studies also support this observation. The most common and potent AM fungi species have adapted for polluted habitats but their colour and size has been deviated from spores growing symbiotically with weeds of normal habitat. Plant receives support from AM fungi, with the help of its symbiotic association, in the aspect of uptake of Phosphorus and other nutrients (Hart and Forsythe, 2012), enhancement of growth hormones, increase of protein content, increase of lipid, sugars, amino acid levels, increase of tolerance to heavy metals, increase of salinity tolerance and resistance to root-borne pathogens (Upadhyaya *et al.,* 2010; Orwin *et al.*, 2011 and Jacott *et al.*, 2017).

Conclusions: Thus, it may be concluded that these rainy season species of AM fungi especially genus *Glomus* from Endogonaceae can play a significant role as biofertilizer. Thus, *Glomus* as dominant genera, along with other genera like *Sclerocystis* and *Scutellospora* have played a great role as potent bio-fertilizers that are not only eco-friendly, but have shown remarkable increase in uptake of all the macronutrients, responsible for increasing soil fertility and thereby supporting the boosted plant growth.

Suggestions and recommendations: It is further suggested that the potential role of AM fungi in mycoremediation of soil polluted with heavy metals can be enhanced by inoculating hyper-accumulator plants with mycorrhizal fungi, most appropriate for the polluted site. However, there is a need to develop new methods and to optimize the conditions to grow in enormous quantities and characterize, develop, and screen considerable number of AM fungi for tolerance to metals (Miransari, 2011). The dominant species of AM fungi observed during rainy season can be used to degrade heavy metals in the soil and thus can be used as a great tool for safe environmental cleanup strategy. Thus, mycoremediation through local dominant AM fungal species can be used as cost effective, highly specific, easy, eco-friendly model for such industrial belts all over the world.

Acknowledgements:
Dr V. Mohan, Senior Scientist- G, IFGTB, Coimbatore. (For authentification of identified spores)
Dr. Uma Maheshwari Shankar (Principal, SIES College, for providing laboratory facility)

References:

1. Berch, S. M. and J. M. Trappe. 1985. A new species of Endogonaceae, *Glomus hoi. Mycologia* 77:654-657.
2. Bhattacharjee, M. and Mukerji K G. (1980). Studies on Indian Endogonaceae II. The genus Glomus. *Sydowia* (AnnalesMycologici), 1980 , 39:14- 17.
3. Blaszkowski J. (1994) First record and notes on *Glomus coronatum* in Poland and Germany. Mycologia 86, 630-634.
4. Blaszkowski J. (2003) Arbuscularmycorrhizal fungi (Glomeromycota), Endogone, and Complexipes species deposited in the Department of Plant Pathology, University of Agriculture in Szczecin, Poland. http://www.agro.ar.szczecin.pl/~jblaszkowski.
5. Blaszkowski J., Tadych M., Madej T. (2002) Arbuscularmycorrhizal fungi (Glomales, Zygomycota) of the Bledowska Desert, Poland. Acta Soc. Bot. Pol. 71, 71-85.
6. Blaszkowski J., Tadych M., Madej T., Adamska I., Iwaniuk A. (2001) Arbuscular mycorrhizal fungi (Glomales, Zygomycota) of Israeli soils. Mat. II Polsko-IzraelskiejKonf. Nauk. nt. Gospodarowaniezasobamiwodnymi i nawadnianieroslinuprawnych". PrzegladnaukowyWydz. Inz. Ksztalt. Srod. 22, 8-27.
7. Blaszkowski, J., Czerniawska, B., Kowalczyk, S., Turnau, K., &Zubek, S. (2010). Ambisporagerdemannii and Glomus badium, two species of arbuscular fungi (Glomeromycota) new for Europe and Poland, respectively. *ActaMycologica*, 45(1) 17-25.
8. Cavagnaro, T. R., Smith, F. A., Lorimer, M. F., Haskard, K. A., Ayling, S. M., & Smith, S. E. (2001). Quantitative development of Paris-type arbuscularmycorrhizas formed between Asphodelusfistulosus and Glomus coronatum. *New Phytologist*, 149(1), 105-113.
9. Deshpande, A and Gosavi, M. (2022)Arbuscularmycorrhizae spores diversity in summer from polluted sites. Journal of the Asiatic Society Of Mumbai. 96(12), 17-23.
10. Frank, AB (1885) Uber die auf WurzelsymbioseberuhendeEmahrungge-wisser Baume durchunterirdischePilze. Berichte Deutsche BotanischeGesellschaft, 3:128-145.
11. Frank, D. A., Gehring, C. A., Machut, L., & Phillips, M. (2003). Soil community composition and the regulation of grazed temperate grassland. *Oecologia*, 137, 603-609.
12. Gehlot P and Singh J. (2015). Arbuscular mycorrhizal fungi, Glomus spp. (Glomeromycetes), associated with drought tolerant plants of the Indian Thar desert.
13. Gerdemann J W and Bakshi B K (1976) Endogonaceae of India: Two new species; *Trans. Br. Mycol*. Soc. 66 340-343.
14. Gerdemann J. W. and Trappe J. M. (1974) TheEndogonaceae of the Pacific Northwest. *MycologiaMemoir*, No. 5, 1-76.
15. Gerdemann, J. W. and Nicolson, T. H. (1963). Spores of mycorrhizalendogene species extracted from soil by wet sieving and decanting. Transactions of the British Mycological Society;46: 235-244.
16. Giovannetti M., Avio L., Salutini L. (1991) Morphological, cytochemical, and ontogenetic characteristics of a new species of vesicular-arbuscular mycorrhizal fungus. Canad. J. Bot. 69, 161-167.
17. Giovannetti M., Nicolson T. H. (1983) Vesicular-arbuscular my- corrhizas in Italian sand dunes. Trans. Br. Mycol. Soc. 80, 552-557.
18. Goto, B. T., Jardim, J. G., Silva, G. A. D., Furrazola, E., Torres-Arias, Y., &Oehl, F. (2012). Glomus trufemii (Glomeromycetes), a new sporocarpic species from Brazilian sand dunes. *Mycotaxon*, 120(1), 1-9.
19. Hart, M. and Forsythe, J. (2012) Scientia Horticulturae Using arbuscular mycorrhizal fungi to improve the nutrient quality of crops; nutritional benefits in addition to phosphorus. *Sci Hortic (Amsterdam)* 2012; 148:206–214. doi: 10.1016/j.scienta.2012.09.018.
20. Jacott, C., Murray, J, Ridout, C. (2017). Trade-off sin ArbuscularMycorrhizal symbiosis: Disease Resistance Growth Responses and Perspectives for crop breeding. *Agronomy* (7), pp.75-79.
21. Jayaprakash, S. B., & Nagarajan, N. (2017). Studies on mycorrhizal biodiversity in medicinal plant species of Pookode Lake area, Wayanad, India. *Annals of Plant Sciences*, 1835-1844.
22. Koske R. E., Walker C. 1985. Species of Gigaspora (Endogonaceae) with roughened outer walls. Mycologia 77, 702-720.
23. Koske R. E., Walker C. 1986. Species of Scutellospora (Endogonaceae) with smooth-walled spores from maritime sand dunes: two new species and a redescription of the spores of Scutellosporapellucida and Scutellosporacalospora. Mycotaxon 27, 219-235.
24. Miller D.D., Domoto, P.A. & Walker, C. (1985) Mycor- rhlzat fungi at eighteen apple rootstock plantings in the United States.- New Phytol. 100:379-391.

25. Millner P.,MulbryW.and Reynolds S. (2001), Taxon-specific oligonucleotide primers for detection of two ancient endomycorrhizal fungi, *Glomus occultum* and *Glomus brasilianum*, *FEMS Microbiology Letters*,196(2),165-170, https://doi.org/10.1111/j.15746968.2001.tb10559.
26. Miransari M. (2011). Hyperaccumulators are arbuscular mycorrhizal fungi and stress of heavy metals. Biotechnology Advances, 29 (6): 645-653.
27. Morton J. B. 2000. International Culture Collection of Arbuscular and Vesicular-Arbuscular Mycorrhizal Fungi. West Virginia University.
28. Morton J. B. and Walker C. (1984). *Glomus diaphanum*: a new species in the Endogonaceae common to West Virginia. *Mycotaxon* 21, 431-440.
29. Morton, J. B. (1985). Variation in mycorrhizal and spore morphology of Glomus occultum and Glomus diaphanum as influenced by plant host and soil environment. *Mycologia*, *77*(2), 192-204.
30. Morton, J. B. (1995). Taxonomic and phylogenetic divergence among five Scutellospora species based on comparative developmental sequences. *Mycologia*, *87*(1), 127-137.
31. Morton, J.B. 1985: Variation in mycorrhizal and spore morphology of Glomus occultum and .Glom~ diaphanum as influenced by plant host and soil envtronment. - Mycologia 77:192-204
32. Nicolson T. H., Gerdemann J. W. 1968. MycorrhizalEndogone species. Mycologia 60, 313-325.
33. Oehl F., Redecker D., Sieverding E. (2005). Glomus badium, a new sporocarpic mycorrhizal fungal species from European grasslands with higher soil pH. J. Appl. Bot. and Food Qual.
34. 79, 38-43.
35. Orwin,K., Kirschbaum, M. (2011). Organic nutrient uptake by mycorrhizal fungi enhance ecosystem carbons –a model based assessment. *Ecology letters*. 14(5): pp.493-502.
36. Philips, J.M., D.S.Hayman (1970). Improved procedures for clearing roots and staining parasiticand vesicular-arbuscularmycorrhizal fungi for rapid assessment of infection. Trans.Br.Mycol.Soc(.55),158-161.
37. Puppi, G., Chiapperi, F., Tabacchini, P., Sanvito, A. &Carpigo, F. (1986) Endogonaceae del litoraletirrenico.-Micol. Italiana 2:7-14.
38. Rodrigues, B.F., Muthukumar, T. (2009). Arbuscular Mycorrhizae of Goa- A manual of identification, Goa University protocol, 1-22, and 27-41.
39. Schenck, N. C., & Smith, G. S. (1982). Additional new and unreported species of mycorrhizal fungi (Endogonaceae) from Florida. *Mycologia*, *74*(1), 77-92.
40. Srivastava, N. K., Srivastava, D. K., & Singh, P. (2012). A preliminary survey of the vesicular arbuscular mycorrhizal status of vegetable and fruit yielding plants in eastern UP. *Indian Journal of Life Sciences*, *1*(2), 79-83.
41. Takács, T., &Bratek, Z. (2006). Description of AM fungi species from semiarid open sandy grasslands in Hungary. *ActaBotanicaHungarica*, *48*(1-2), 179-188.
42. Tandy, P. A. (1975). Sporocarpic species of Endogonaceae in Australia. *Australian Journal of Botany* 23, 849-866.
43. Tang, D and Zang, M. (1984). Acta Bot. Yunn. 6: 301.
44. Trappe, James, and A.B. Frank. (2005). Mycorrhizae: The challenge to evolutionary and ecologic theory.Mycorrhiza(2005)15: 277-281.
45. Tulasne LR, Tulasne C 1845 Fungi nonnullihypogaei, novi v. minus cogniti act. Giorn Bot Ital 2(Pt. 1):35–63
46. Upadhyaya, H., Panda, S. K.; Bhattacharjee, M. K. and Dutta, S. (2010). Role of ArbuscularMycorrhizain heavy metal tolerance in plants- Prospects for phytoremediation. *Journal of Phytology* 2(7): pp16-27.
47. Vierheilig, H., Coughlan AP., Wyss, U., Piche Y. (1998). Ink and vinegar, a simple staining technique for arbuscular- mycorrhizal fungi. Applied and Environmental Microbiology 1998;64 (12) : 5004-5007.
48. Walker C and Rhodes LH. (1981). *Glomus albidum*: a new species in the Endogonaceae. Mycotaxon 12: 509–514.
49. Walker C and Vestberg, M. 1998. Synonymy Amongst the ArbuscularMycorrhizal Fungi: *Glomus claroideum, G. maculosum, G. multisubstenum and G. fistulosum*. Annals of Botany 82: 601–624, 1998.
50. Walker C., Giovannetti M., Avio L., Citernesi A. S., Nicolson T. H. 1995. A new fungal species forming arbuscularmycorrhizas: Glomus viscosum. Mycol. Res. 99, 1500-1506.
51. Walker, C. 1982. Species in the Endogonaceae: a new species (*Glomus occultum*) and a new combination (*Glomus geosporum*). Mycotaxon 15: 49-61.
52. Walker, C. and Sanders, F.E. (1986). Taxonomic concepts in the Endogonaceae: III. The separation of *Scutellospora* gen. nov. from *Gigaspora* Gerd. & Trappe. *Mycotaxon* 27: 169-182.
53. Wilde, P., Manal, A., Stodden, M., Sieverding, E., Hildebrandt, U., & Bothe, H. (2009). Biodiversity of arbuscular mycorrhizal fungi in roots and soils of two salt marshes. *Environmental Microbiology*, *11*(6), 1548-1561.