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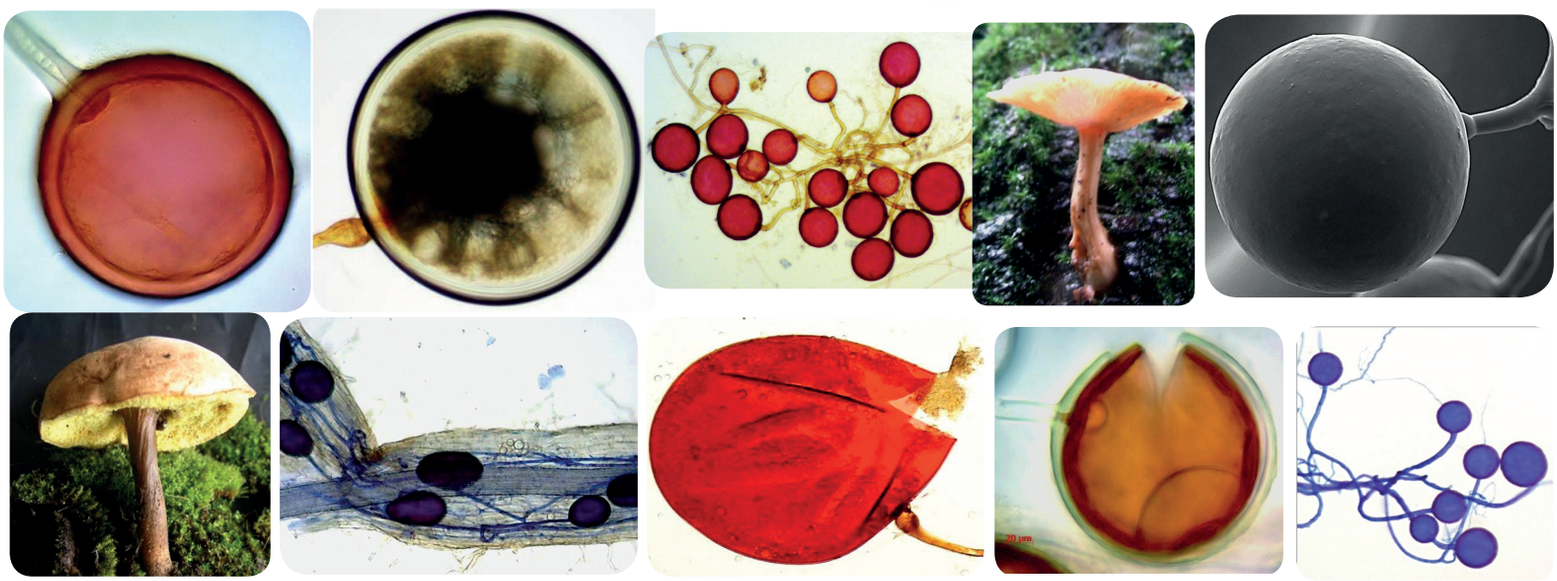

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Mycorrhiza News

The *Mycorrhiza News* provides a forum for the dissemination of scientific information on mycorrhiza research and activities; publishes state-of-the-art papers from eminent scientists; notes on important breakthroughs; brief accounts of new approaches and techniques; publishes papers complied from its RIZA database; provides information on forthcoming events on mycorrhiza and related subjects; lists important research references published during the quarter; and highlights the activities of the CMCC.

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RESEARCH FINDING PAPER

Study of Arbuscular Mycorrhizal Status of Crops and Soil Physico-chemical Characteristics with Different Agricultural Applications in Lateritic Zones of Midnapore District, West Bengal

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INTRODUCTION

Arbuscular mycorrhizal fungi (AMF) have been found to increase the growth and yield of various agricultural crops (Johansen *et al.*, 1994; Sengupta *et al.*, 2001, 2006; Samanta and Verma, 2006). Arbuscular mycorrhizae (AM) play a key role in uptake of phosphorous along with other less mobile nutrients (Bolan, 1991); particularly in P deficient soils (Powell and Daniel, 1978). AM fungi also absorb water from low water gradient and prevent wilting (Aúge *et al.*, 2001). The arbuscular mycorrhizal (AM) symbiosis has evolved in most terrestrial environments as an efficient system of phosphorus uptake in plants (Brundrett, 2009). But, despite increasing fertilizer costs and disappearing world phosphorus reserves (Gilbert, 2009), progression in the use of the AM symbiosis in plant production has been extremely slow. Although the causes of this poor performance have been diverse, it is true that the conditions for the expression of mycorrhizal effectiveness are poorly known, leading to inconsistency in response to AM inoculation (Ryan and Graham, 2002). According to the principles in ecology, the success of an AM symbiosis depends not only on the plant and fungal genotypes, but also on the conditions of the environment. The functional specificity that exists between plants and AM fungi has been documented (Helgason *et al.*, 2002; Klironomos, 2003). The factors controlling the effectiveness of AM fungal strains must be understood before AM inoculation. It is well-known that plants influence AM fungi through the provision of C substrate, but the influence of the soil on these fungi should not be overlooked. The soil not only provides mineral nutrients to AM fungi, but also constitutes the chemical and physical environment where both these fungi and their plant associates live.

There is much evidence supporting the hypothesis of a large influence of soil properties on AM fungi (Hamel *et al.*, 1994; Frey and Ellis, 1997; van Aarle *et al.*, 2002). It appears that AM strains may survive and function well only within a range of soil environmental conditions.

The present study was conducted last year (2017) to acquire first hand preliminary information on the AM status of some agricultural crops growing in Midnapore district lateritic belt region of south-west West Bengal. The study includes a survey in five agricultural sites of Kadamdiha, Paikarapur, Anandapur, Kanshijora, and Gopgarh area, where farmers cultivated the vegetable crops via conventional agricultural practices.

MATERIALS AND METHODS

Sampling was done in agricultural field located in Paschim Medinipur district of West Bengal (22.30^0 N latitude and 87.20^0 E longitude). Root and rhizospheric soil from each site up to 15 cm soil depth of approximately 60–90 day old agricultural crops

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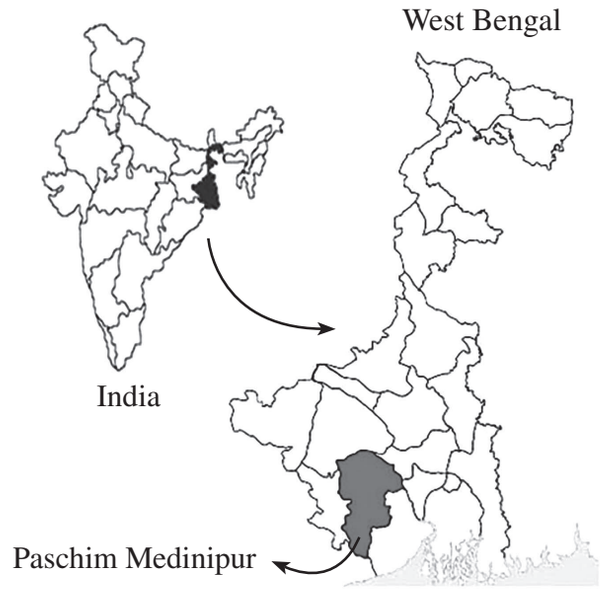

were collected in three replicates for all the crops and site during the summer months of March to June 2017. Soil texture of agricultural fields from five different surveyed sites were examined. At Kadamdiha, the soil was sandy-clay loam (coarse sand 27.8%, fine sand 28.5%, silt 20.3%, clay 20.5%), at Paikarapur, soil was sandy loam (coarse sand 25%, fine sand 28%, silt 24%, clay 19%), at Anandapur, soil was sandy loam (coarse sand 30%, fine sand 28.7%, silt 21.3%, clay 18.5%), at Kanshijora, soil was sandy loam (coarse sand 33.4%, fine sand 28.7%, silt 21.3%, clay 15.1%), and at Gopgarh, the soil was loam (coarse sand 23%, fine sand 27%, silt 15%, clay 30%).

The soil pH and electrical conductivity (EC) were measured using a digital meter. Soil samples were tested for moisture content, organic carbon (OC), available P_2O_5, available K_2O according to Jackson (1973).

The total number of spores were counted in 100 g soil (Gerderman and Nicolson, 1963) and root colonization percentage was measured (Phillips and Hayman, 1970). Fifty root pieces were examined for each sample and root colonization percentage was calculated. The root colonization percentage was calculated by the formula:

$$\text{Root colonisation percentage} = \frac{\text{No. of root pieces colonised}}{\text{Total No. of root pieces observed}} \times 100$$

The fertilizer used to grow these crops was noted through personal interactions with the farmers. The main fertilizer used was semi-dried cow dung compost, urea (46% N), di amino phosphate (DAP) (18% N, 46% P), and single super phosphate (SSP) and potash (52% K, 12% sulphate). In case of potato, tomato, and eggplant (brinjal), fertilizers were used in the maximum percentage. Other than winter crops, such as carrot, peanut, *Cicer* (chickpea), most other summer vegetables were cultivated in the harvested field of potato. Minimum or no fertilizers were used in the post potato sesame. Information about crop wise irrigation practices and total nitrogen content of different agricultural sites was collected from farmers of respective fields as per the soil testing data from the different village/panchayat agricultural centres situated in the Paschim–Medinipur District. The statistical analyses were carried out with 'Statistica 10'.

RESULTS

Though soil samples of different sites were detected with low nitrogen content while phosphorus was high for almost all crops and potassium was found sufficient or moderately high as crops vary in requirements. Mycorrhizal colonization and the spore number was maximum in Kashijhora followed by Anandapur site; both were sandy loam soil. From the survey it was found that, at Kadamdiha, the average field soil pH range was between 5.2–5.5 (Table 1A), the range of moisture content (5.7%–6.7%), EC (0.58–0.61 m.mohs/cm), OC (0.67–0.70 g/100 g soil), total nitrogen (0.06–0.07 g/100 g soil), available P_2O_5 (268–275 kg/hector), and available K_2O (419–442 kg/hector). Mycorrizal colonization was highest in *Momordica charantia* (51%) followed by *Vigna radiata* (47%), *Capsicum fruitescens* (41%), and *Sesamum indicum* (40%); and lowest was in *Solanum melongena* (24%) followed by *Abelmoschus esculentus* (31%). The total rhizospheric spore number was also in accordance with colonization into these plant species.

At Paikarapur, the average soil pH range is 4.7–4.9 (Table 1B). The moisture content (6.4%–7.6%), EC (0.20–0.23 m.mohs/cm), OC (0.8 g/100 g soil), total nitrogen (0.07–0.08 g/100g soil), available P_2O_5 (245–254 kg/hector) and available K_2O (335–348 kg/hector) of the agricultural land were ranged respectively. Mycorrhizal colonization was highest in *Momordica charantia* (59%), followed by *Cucumis sativua* (55%) and *Capsicum frutescens* (43%). The root colonization was found minimum in *Solanum melongena* (16%) followed by *Abelmoschus esculentus* (17%). No root infection was found in *Solanum tuberosum*. The total rhizospheric spore number was in accordance with colonization in *Momordica charantia* (79/100 g soil), minimum in *Solanum tuberosum* (27/100 g soil).

At Anandapur, the average field soil pH range was between 5.0–5.5 (Table 1C). The moisture content (5.2%–6.9%), EC (0.32–0.35 m.mohs/cm), OC (0.34–0.38 g/100g soil), total nitrogen (0.03–0.04 g/100 g soil), available P_2O_5 (284–293 kg/hector) and available K_2O (317 – 326 kg/hector) of the agricultural land were ranged respectively. Mycorrizal colonization was highest in *Momordica charantia* (51%), followed by *Cucumis sativa* (49%), *Cucurbita maxima* (48%) and *Abelmoschus esculentus* (48%) and found lowest

in *Solanum melongena* (21%) followed by *Lycopersicon esculentum* (27%). No root infection was found in *Solanum tuberosum*. Rhizospheric spore number/ 100 g soil was maximum in *Vigna radiata* (116) followed by *Momordica charantia* (112) and *Cucumis sativa* (110); and minimum in *Solanum tuberosum* (29).

At Kanshijora village, the average field soil pH range lied between 5.6–5.9 (Table 1D). The moisture content (5.9%–7.6%), EC (0.40-0.43 m.mohs/cm), OC (0.62-0.69 g/100g soil), total nitrogen (0.06 g/100g soil), available P_2O_5 (235–255 kg/hector) and available K_2O (312–321 kg/hector) of the agricultural land were measured respectively. Mycorrizal colonization was highest in *Vigna radiata* (68%), followed by *Momordica charantia* (62%), *Capsicum frutescens* (61%) and *Cucurbita maxima* (59%) and found lowest in *Solanum tuberosum* (11%) followed by *Solanum melongena* (38%). Total rhizospheric spore number was found maximum in *Capsicum frutescens* (127/100 g soil) and *Cucurbita maxima* (127/100 g soil) followed by *Abelmoschus esculentus* (124/100 g soil), *Vigna radiatea* (121/100 g soil) and *Sesamum indicum* (121/100 g soil) and minimum in *Solanum tuberosum* (42/100 g soil) followed by *Lycopersicon esculentum* (91/100 g soil).

At Gopgarh, the average field soil pH range lied between 5.5–6.2 (Table 1E), the moisture content (7.2%–7.7%), EC (0.30–0.34 m.mohs/cm), OC (1.01–1.06 g/100 g soil), total nitrogen (0.1 g/100 g soil), available P_2O_5 (274–278 kg/hector) and available K_2O (525–531 kg/hector) of the agricultural land, respectively. Mycorrizal colonization was maximum in *Arachis hypogaea* (66%), followed by *Capsicum frutescens* (47%), *Momordica charantia* (45%) and *Vigna radiata* (42%). Mycorrizal colonization was minimum in *Allium sp.* (15%) followed by *Solanum tuberosum* (20%). Total rhizospheric spore number was found highest in *Arachis hypogaea* (140/100 g soil) followed by *Cicer arietinum* (135/100 g soil) and *Capsicum frutescens* (127/100 g soil) and was minimum in *Allium cepa* (52/100 g soil) followed by *Solanum tuberosum* (62/100 g soil).

Though not significant, positive correlation was found in colonization with pH (r = 0.211) and E.C (r = 0.207) while negative correlation was found, nitrogen (r = - 0.102), available phosphorus (r = - 0.177) and potassium content (r = - 0.125) and negligible negative correlation with soil moisture content (r = - 0.003) and organic carbon (r = - 0.090). Spore density showed significant positive correlation with pH (r = 0.359, 5% significant level) and E.C (r = 0.473, both 1% and 5% significant level), negligible positive correlation with moisture (r = 0.050), nitrogen (r = 0.017), available P (r = 0.017), and available K(r = 0.089); negligible negative correlation with organic carbon (r = - 0.026). Spore population was positively correlated with mycorrhizal colonization (r = 0.700).

DISCUSSION

The nitrogen deficiency of the soil was tried to saturate by application of organic N manure and urea mainly. For high productivity, farmers used them in huge quantity along with phosphate and potash, especially for economic crops. The tendency to use cow dung in large amount with or without DAP in *Solanum tuberosum, Solanum melongena, Lycopersicum esculentum, Allium cepa,* etc., in different sites reduced the colonization %, intensity and arbuscle formation that indicates inactive symbiosis. Where plants received fertilizer application near to their need as per the description given in the fertilizer schedule for vegetable crops in TNAU web portal (http://agritech.tnau.ac.in/horticulture), showed a good colonization percentage and intensity with vesicle and/or arbuscle formation. Almost the same result was also mostly reflected in the plants fertilized with usual dose cow dung and minimum DAP. Though organic manure increased AM colonization (Bullock, 2002; Kumar *et al.*, 1995); heavy supply of nitrogen (Ellis, 1981) or any organic or inorganic nitrogen reduces it (Lonhienne *et al.*, 2015).

The high P content in the soil is the major cause of poor AM symbiosis. Application of P-fertilizer develops nutrient-enriched micro-sites in the rhizosphere that is vital for plant nutrient status (Chapin, 1980*)*. Development of AMF in roots in such micro-sites might be reduced if the nutrient requirement of plants gets satisfied (Koide and Li, 1990). High P induces a higher growth rate that appears to give the plants resistance against colonization (Bruce *et al.*, 1994; Menge *et al.*, 1978) as fungal attachment sites to the roots was drastically reduced (Balzergue *et al.*, 2013). However, though response of AMF to P-fertilizers was found to be strain dependent (Sylvia and Schenck, 1983), herein the good response of some crops irrespective of treatments indicates that the effect of phosphate fertilizer on AM symbiosis also varies from one crop to another (Sing and Mishra, 1995) that is related to their mycorrhizal dependency (Ba *et al.*, 2000; Sharma *et al.*, 1999). Nitrogen and phosphate content in soil or fertilizers mainly determined the symbiosis nature of AM in this experiment and is in accordance with study of Lonhienne *et al.* (2015).

The residual fertilizers in field should also be taken in account for successive crops after harvesting of potato—a crop grown with huge fertilizer application; another cause for poor mycotrophy. Residual chemical fertilizer and other agro-chemicals

may affect colonization and spore density (Ghosh, 2007).

Sporulation in non-infected potato and poorly infected crop rhizosphere by some AM species indicates they have strain dependent resistance to high N and P (Sylvia and Schenck, 1983) or they have turned parasitically associated (Schmidt *et al.*, 2011) with weeds.

Application of mustard cake also reduced mycelia and arbuscular colonization except for *Cucurbita maxima* (site 4), may be for presence of glucogenolates (Ghosh *et al.*, 2004). Also it was found that, heavy irrigation reduced colonization in some sites. Application of potassium has been found to have a positive effect on colonization in earlier reports (Furlan, 1989), though in our work it is not always the same.

Some plant species, *Momordica charantia*, *Vigna radiata*, *Cucumis sativa,* and *Cucurbita maxima* were found to show production of high root colonization with arbuscle than other plants, in same site/ conditions or even when they are treated with heavy uses of organic or inorganic nitrogen and phosphate fertilizers. The high root colonization with arbuscle indicates active AM symbiosis. This is due to host specificity of mycorrhizal association (Torrecillas, 2012; van der Heijden, 1998).

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RESULTS

Table 1. **Details of physico-chemical and mycorrhizal status of different agricultural sites and collected vegetable crops:**

Table 1A.Site 1- **Kadamdiha**

Plant name	Fertilizer used (per hectare)	Irrigation	pH	Moisture %	EC (m.mohs/cm)	Organic Carbon (g/100 g)	Total Nitrogen (g/100 g)	Available P_2O_5 (kg/hector)	Available K_2O (kg/hector)	Total Spore (100 g soil)	Root Colonization			
											Mycellium %	Arbuscle %	Vesicle %	Infection Class
Abelmoschus esculentus	Cow dung 8.8 tonne, Urea 60 kg, SSP 158 kg potash 300 kg,	Medium irrigation	5.2	6.7	0.59	0.67	0.07	271	442	68	31	-	-	I

Plant name	Fertilizer used (per hectare)	Irrigation	pH	Moisture %	EC (m.mohs/ cm)	Organic Carbon (g/100 g)	Total Nitrogen (g/100 g)	Available P_2O_5 (kg/hector)	Available K_2O (kg/hector)	Total Spore (100 g soil)	Root Colonization			
											Mycellium %	Arbuscle %	Vesicle %	Infection Class
Lycopersicon esculentum	Cow dung 16 tonne, mastered Cake 60 kg, DAP 130 kg	Light to medium irrigation	5.3	6.3	0.61	0.69	0.06	274	424	71	34	-	-	I
Momordica charantia	Cow dung 4 tonne, Urea 68 kg	Light to medium irrigation,	5.4	6.5	0.60	0.70	0.06	272	427	179	51	19	-	I
Solanum melongena	Heavy cow dung 18 tonne, DAP 140 kg, potash 90 kg	Medium irrigation	5.2	6.7	0.58	0.68	0.06	275	441	64	24	-	-	I
Vigna radiata	Cow dung 6 tonne, DAP 140 kg	Medium irrigation	5.3	6.7	0.60	0.69	0.06	274	425	153	47	-	-	I
Capsicum frutescens	Cow dung 8 tonne, mastered cake 60 kg, urea 60 kg	Light irrigation	5.2	6.1	0.61	0.69	0.06	272	427	127	41	-	-	I
Sesamum indicum	Cow dung 50 kg	Light irrigation	5.5	5.7	0.58	0.68	0.06	268	419	102	40	-	-	I

Table 1B. Site 2- Paikarapur

Plant name	Fertilizer used (per hector)	Irrigation	pH	Moisture %	EC (m.mohs/ cm)	Organic Carbon (g/100 g)	Total Nitrogen (g/100 g)	Available P_2O_5 (kg/hector)	Available K_2O (kg/hector)	Total Spore (100 g soil)	Root Colonization			
											Mycellium %	Arbuscle %	Vesicle %	Infection Class
Abelmoschus esculentus	Cow dung 8 tonne, urea 150 kg, SSP 140 kg, potash 50 kg	Medium irrigation	4.9	6.5	0.21	0.8	0.08	245	344	47	17	3	-	I
Cucumis sativus	Cow dung 6 tonne, mastered cake 30 kg, DAP 60 kg	Heavy irrigation	4.7	7.6	0.20	0.8	0.08	247	348	71	55	-	-	I
Lycopersicon esculentum	Cow dung 24 tonne, DAP 160 kg	Medium irrigation	4.9	6.6	0.22	0.8	0.07	249	338	43	18	7	-	I
Momordica charantia	Cow dung 2.8 tonne, urea 60 kg, SSP 130 kg	Medium irrigation	4.8	6.4	0.21	0.8	0.08	248	339	79	59	14	-	II
Solanum melongena	Cow dung 9 tonne, urea 160 kg, DAP 400 kg	Medium to high irrigation	4.8	7.3	0.23	0.8	0.08	246	341	44	16	-	-	I
Solanum tuberosum	Cow dung 32 tonne, DAP 400 kg, urea 150 kg, SSP 120 kg	High to low medium irrigation	4.9	6.6	0.21	0.8	0.08	254	340	27	-	-	-	-
Capsicum frutescens	Cow dung 9 tonne, Mastered cake 66 kg, urea 130 kg	Medium irrigation	4.7	6.4	0.22	0.8	0.07	248	338	67	43	-	-	I
Sesamum indicum	Cow dung 160 kg, SSP 160 kg	Low irrigation	4.8	6.1	0.20	0.8	0.08	245	335	51	37	-	-	I

Table 1C. Site 3- Anandapur

Plant name	Fertilizer used (per hector)	Irrigation	pH	Moisture %	EC (m.mohs/ cm)	Organic Carbon (g/100 g)	Total Nitrogen (g/100 g)	Available P_2O_5 (kg/hector)	Available K_2O (kg/hector)	Total Spore (100 g soil)	Root Colonization			
											Mycellium %	Arbuscle %	Vesicle %	Infection Class
Abelmoschus esculentus	Cow dung 5.6 tonne, urea 60 kg	Medium irrigation	5.5	6.6	0.32	0.36	0.03	288	323	53	48	12	-	I,II
Cucumis sativus	Cow dung 5 tonne, urea 80 kg	Medium to high irrigation	5.3	6.9	0.36	0.37	0.03	284	320	110	49	11	-	I,II
Cucurbita maxima	Heavy Cow dung18 tonne	Medium irrigation	5.2	6.5	0.34	0.35	0.04	290	317	99	48	11	-	I,II
Lufa acutangula	Heavy Cow dung 22 tonne, Heavy urea 160 kg	Medium irrigation	5.1	6.6	0.35	0.38	0.03	292	320	58	38	9	-	I
Lycopersicon esculentum	Cow dung 24.5 tonne, DAP 130 kg	Medium irrigation	5.5	6.4	0.32	0.37	0.03	291	319	98	27	7	-	I
Momordica charantia	Cow dung 5 tonne, urea 60 kg, SSP 136 kg	Medium irrigation	5.5	6.3	0.34	0.36	0.03	287	320	112	51	21	-	II
Solanum melongena	Heavy Cow dung 27.6 tonne, Heavy urea 170 kg	Medium irrigation	5.2	6.7	0.33	0.35	0.03	289	326	95	21	-	-	I
Solanum tuberosum	Cow dung 35.4 tonne, urea 200 kg, SSP 150 kg	Medium irrigation	5.0	6.5	0.34	0.34	0.03	292	322	29	-	-	-	-
Vigna radiata	Cow dung 18 tonne, Mastered cake 80kg, urea 60 kg	Medium irrigation	5.2	6.6	0.35	0.36	0.03	293	324	116	46	-	-	II
Capsicum frutescens	Cow dung 12 tonne, urea 60 kg	Medium irrigation	5.5	6.5	0.35	0.38	0.03	287	320	97	43	26	-	I
Sesamum indicum	With residual fertilizer after potato	Low irrigation	5.5	5.2	0.32	0.37	0.03	289	317	72	32	-	-	I

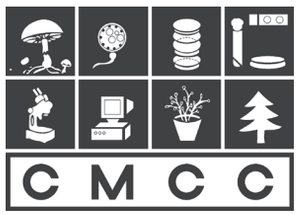
Table 1D. Site 4- Kanshijora

Plant name	Fertilizer used (per hector)	Irrigation	pH	Moisture %	EC (m.mohs/ cm)	Organic Carbon (g/100 g)	Total Nitrogen (g/100 g)	Available P_2O_5 (kg/hector)	Available K_2O (kg/hector)	Total Spore (100 g soil)	Root Colonization			
											Mycellium %	Arbuscle %	Vesicle %	Infection Class
Abelmoschus esculentus	Cow dung 11 tonne, urea 60 kg	High to medium irrigation	5.7	7.4	0.41	0.62	0.06	240	315	124	41	-	-	I
Cucumis sativua	Cow dung 4.4 tonne, urea 40 kg	Medium irrigation	5.8	7.3	0.42	0.64	0.06	255	316	119	56	23	-	I
Cucurbita maxima	Cow dung 9 tonne, urea 30 kg, SSP 60 kg	Medium irrigation	5.8	6.5	0.43	0.66	0.06	245	318	127	59	16	-	I
Lufa acutangula	Heavy cow dung 18 tonne, heavy urea 140 kg	High to medium irrigation	5.7	7.2	0.40	0.69	0.06	264	318	109	43	8	-	I
Lycopersicon esculentum	Cow dung 28 tonne, SSP 80 kg	High to medium irrigation	5.9	7.4	0.41	0.65	0.06	242	319	91	42	9	-	I
Momordica charantia	Cow dung 6 tonne, urea 60 kg	Medium irrigation	5.8	6.3	0.43	0.63	0.06	245	321	98	62	27	-	I
Solanum melongena	Cow dung 16 tonne, mastered cake 60 kg, urea 60 kg	High to medium irrigation	5.7	7.6	0.42	0.67	0.06	249	317	93	38	10	-	I
Solanum tuberosum	Cow dung 29.5 tonne, DAP 200 kg	Medium irrigation	5.6	6.4	0.40	0.66	0.06	254	315	42	11	-	-	I
Vigna radiata	Cow dung 8 tonne, urea 40 kg	High to medium irrigation	5.9	7.4	0.41	0.64	0.06	238	318	121	68	29	7	II
Capsicum frutescens	Cow dung 4 tonne, urea 30 kg, SSP 50 kg	Low to Medium irrigation	5.8	6.3	0.43	0.65	0.06	246	321	127	61	31	11	I
Sesamum indicum	Cow dung 6 quintal	Low irrigation	5.3	5.9	0.40	0.62	0.06	235	312	121	40	24	-	I

Table 1E. Site 5- **Gopgarh**

Plant name	Fertilizer used (per hector)	Irrigation	pH	Moisture %	EC (m.mohs/ cm)	Organic Carbon (g/100 g)	Total Nitrogen (g/100 g)	Available P_2O_5 (kg/hector)	Available K_2O (kg/hector)	Total Spore (100 g soil)	Root Colonization			
											Mycellium %	Arbuscle %	Vesicle %	Infection Class
Arachis hypogaea	Cow dung 12 tonne, urea 100 kg	Medium irrigation	5.9	7.2	0.32	1.05	0.1	275	528	140	66	16	-	II
Allium cepa	Heavy Cow dung 26 tonne, Heavy DAP 180 kg	Medium irrigation	6.1	7.4	0.30	1.04	0.1	276	527	52	15	-	-	I,II
Cicer arietinum	Cow dung 10 tonne, urea 130 kg	Medium irrigation	5.7	7.3	0.32	1.06	0.1	278	530	135	40	16	6	I,II

Plant name	Fertilizer used (per hector)	Irrigation	pH	Moisture %	EC (m.mohs/ cm)	Organic Carbon (g/100 g)	Total Nitrogen (g/100 g)	Available P_2O_5 (kg/hector)	Available K_2O (kg/hector)	Total Spore (100 g soil)	Root Colonization			
											Mycellium %	Arbuscle %	Vesicle %	Infection Class
Coccinia indica	Heavy cow dung 20 tonne, Heavy urea 160 kg, SSP 100kg, potash 100 kg	Medium irrigation	5.8	7.6	0.33	1.03	0.1	275	528	80	20	5	-	I,II
Daucus carota	Heavy cow dung 26.6 tonne, urea 150 kg, SSP 150 kg, potash 140 kg	Medium irrigation	6.2	7.5	0.31	1.01	0.1	277	525	65	22	11	-	I,II
Lycopersicon esculentum	Heavy cow dung 18.6 tonne	Medium irrigation	6.0	7.7	0.33	1.05	0.1	276	529	112	33	06	-	I,II
Momordica charantia	Cow dung 5 tonne	Medium irrigation	5.8	7.3	0.30	1.06	0.1	278	527	103	45	08	-	I,II
Solanum melongena	Heavy cow dung 26 tonne	Medium irrigation	5.9	7.2	0.34	1.04	0.1	274	526	64	35	-	-	I,II
Solanum tuberosum	Cow dung 12.2 tonne	Medium irrigation	5.7	7.4	0.32	1.02	0.1	278	531	62	20	-	-	I,II
Vigna radiata	Cow dung 6.8 tonne, urea 140 kg	Medium irrigation	5.8	7.5	0.31	1.03	0.1	275	528	80	42	25	8	I,II
Capsicum frutescens	Cow dung 4.2 tonne, urea 140 kg	Medium irrigation	5.5	7.4	0.32	1.02	0.1	274	526	127	47	31	11	II
Sesamum indicum	Cow dung 160 kg	Medium to low irrigation	5.8	7.2	0.34	1.04	0.1	274	526	87	35	-	-	I



Centre for Mycorrhizal Culture Collection

Morpho Taxonomy of *Glomus clarum* (Accession CMCC/AM-3102)

*Aditi Pandit, Varsha, and Alok Adholeya**

Introduction

Arbuscular mycorrhiza fungi (AMF) are symbiotic association found with more than 80% of the land plants. They are ubiquitous and belong to the phylum of *Glomeromycota*. AMF association has been found important for the function of plant ecosystem as it helps in the mobilization of water and nutrients, such as nitrogen, phosphorous, and potassium. The mineral and water uptake task is performed efficiently by the fungal extra-radical mycelium in the soil. Once the AMF colonize the host roots, it produces different structures. Within root cells, it forms tree-like structures which are termed as arbuscules or hyphal coils and some species form special storage structures known as vesicles. Though different AMF genera have been found with different morphology due to their intra-radical structures but it is not considered feasible to identify AMF species based on such structures (Opik *et al.*, 2010). The *Glomeromycotan* fungi have large spores with layered spore walls, enclosing hundred to thousands of nuclei. So, to identify this unique group of micro-organisms, analysis would be conducted on the basis of morphological characterization which includes identification on various features, such as spore size, number of wall layer, spore, hyphae size, hyphal wall orientation, hyphal attachments, and spore reaction with different mounting reagents (Souza, 2015). There are also different research approaches for identification of the AMF species but one of the initial and crucial steps is the morpho-taxonomic analysis.

In continuation to our previous articles, this current issue will put emphasis on the morpho-taxonomical study of the culture which was maintained under the controlled in-situ conditions in the Centre for Mycorrhizal Culture Collection (CMCC), TERI, with the accession number of CMCC/AM-3102. The study has a detailed description of the morphology of CMCC/AM-3102.

Monosporal Establishment

The culture of this accession CMCC/AM-3102 was raised and isolated from the soil of Asia for enhancing the sporulation wherein the trap cultures were raised under controlled greenhouse under pot conditions. The host for raising the species was *Sorghum bicolor.* The plants were allowed to grow for 3–4 months till the adequate life cycle of the host plant completes, thereafter the soil samples were screened for diversity of spores using wet sieving and decanting method (Gerdemann and Nicolson, 1963). Firstly, the weighed soil was suspended in the distilled water and was mixed properly and then the suspension was seived through sieve size of 60,100, and 300 British Standard Size (BSS). The sieving was analysed critically using light microscope for density and diversity of AMF. All mature, healthy, and morphologically similar spores were collected and selected to raise pure cultures of the accession CMCC/AM-3102. For examining the detailed analysis of the morphological features, voucher specimens of the cultures were prepared. The voucher slides were prepared using two different mounting reagents, Polyvinyl lacto glycerol (PVLG) and Polyvinyl lacto glycerol: Melzer's reagent (1:1). The pure cultures were grown under greenhouse for 3–6 months. After adequate time, the soil was observed for sporulation and the roots were harvested and stained to screen for colonization (Figure 1). A detailed morpho-taxonomic description of this accession has been presented as adopted by various workers for identification.

Spore Morphology and Shape

From the pure monosporals cultures, healthy and mature spores were collected and found to be present in single in the soil. Mostly, the colour of the spores varies from hyaline to yellow-brown to pale yellow with one subtending hypha. The shape of the spores varied

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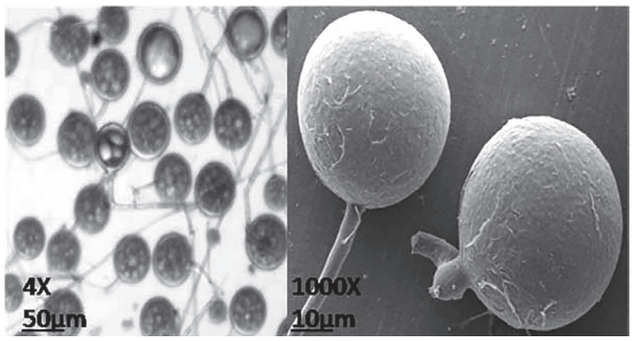

Figure 1: Compound microscopic images (4x) and scanning electron micrographs (SEM) of CMCC/AM-3102 showing spore with small subtending hyphae

from globose to sub-globose sometimes elliptical or oblong. Scanning electron micrograph (SEM) of the spores showed that the outer surface of the spore has smooth surface with subtending hyphae (Figure 2). The average diameter of the spores was found to be in the range of 100–(140)-165µm (Figure 3).

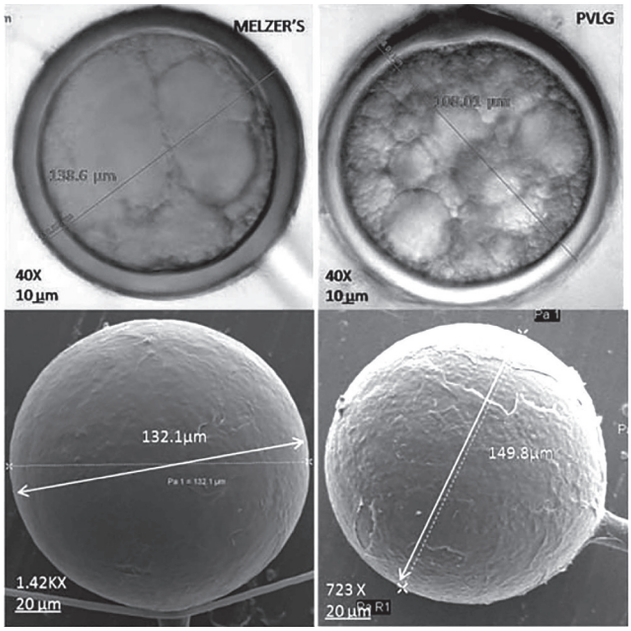

Figure 2: Compound microscopic images (40x) and SEM of mature spores of accession CMCC/AM-3102 showing globose- to sub-globose-shaped spores with single subtending hyphae. SEM images reveal slightly rough outer layer of the spore

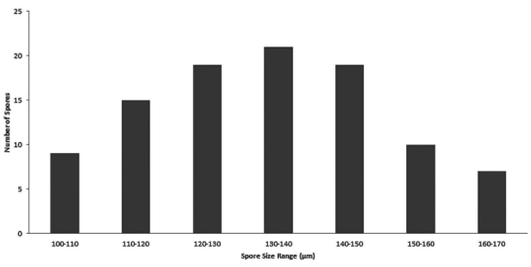

Figure 3: Analysis of spore diameter of 100 healthy and cleaned spores obtained from 1-year-old monosporal culture of accession CMCC/AM-3102

Subcellular Structure of the Spore

The spore of this accession showed reaction with both the reagents polyvinyl lacto glycerol: Melzer's reagent and polyvinyl lacto glycerol (PVLG). On staining with Melzer's: PVLG reagent the spores turn into pinkish red in colour while with PVLG, it remains hyaline. The surface of this spore often appears patchy. However, the mature spores are composed of three wall layers (L1-L3) while L1 and L2 are completely adhered to one another and L3 is separated (Figure 4).

- **Spore Wall Layer 1 (L1):** The first and the outermost hyalinemucilaginous layer of spore is designated as L1 and forms the spore surface. When stained with Melzer's: PVLG reagent, it is a thin dark pink layer. The average thickness of this outer wall layer is 0.30(0.6)-0.9µm thick. This layer usually deteriorates and gets sloughed off with the aging of spore. This layer appears laminate in juvenile spores.
- **Spore Wall Layer 2 (L2):** This layer is permanent hyaline. It is a laminate and smooth wall layer. This layer is semi-flexible in nature. The average thickness of this spore wall layer is 5–(10)-14 µm.
- **Spore Wall Layer 3 (L3):** The innermost wall layer of the spore wall on reaction with Melzer's reagent, shows a pale yellow colour. This layer is smooth and laminate in nature. The average thickness of this layer is 2–8 µm. It is the permanent wall layer and is considered as the innermost layer of the spore wall.

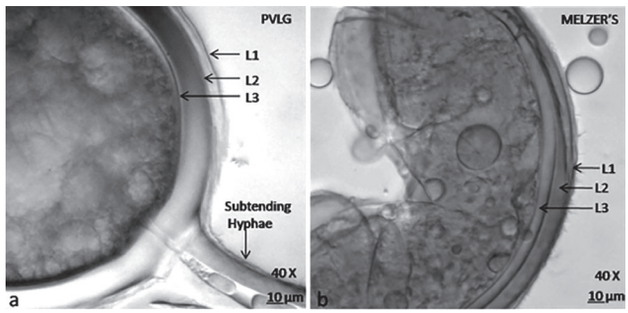

Figure 4: Compound microscopic images of spore wall layers of CMCC/AM-3102, after mounting in PVLG and PVLG: Melzer's Reagent (a and b)

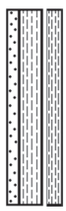

Figure 5: Murograph of composite wall of spore showing L1 and L2 closly adhered with one another while L3 is seperated. Both L2 and L3 are permanent laminated layers

Subtending Hyphae

All the spores showed straight, curved, cylindrical to flared, and also sometimes irregular subtending hyphae. Mostly, the colour of the hypha varies from hyaline to pale yellow. The width of the subtending hyphae at the point of attachment with the base of the spore varies from 10–(13)- 15µm. The hyphal wall of the subtending hyphae has three layers (HWL1, HWL2, and HWL3) (Figure 6).

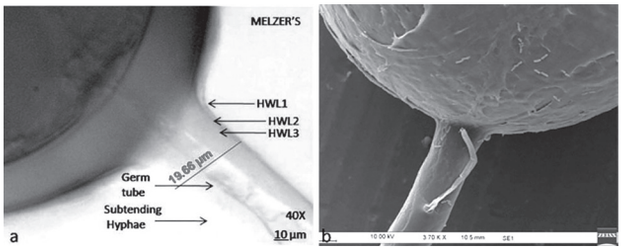

Figure 6: Compound microscopic images of spore of CMCC/AM-3102 showing subtending hyphae after mounting in PVLG: Melzer's ad PVLG along with hyphal wall layers (L1, L2, and L3)

Mycorrhiza

The roots of the host plant *Sorghum*, in which the monosporal culture of this accession were raised were harvested. The roots were stained in ink-vinegar (Phillips and Hayman,1970)) to screen the structures present after colonization. Different mycorrhiza structures, such as arbuscules, vesicles, hyphae, and spores were observed. Both intra-radical and extra-radical hyphae were seen. Abundant amount of intra-radical vesicles and arbuscules were observed in the root cortex (Figure 7).

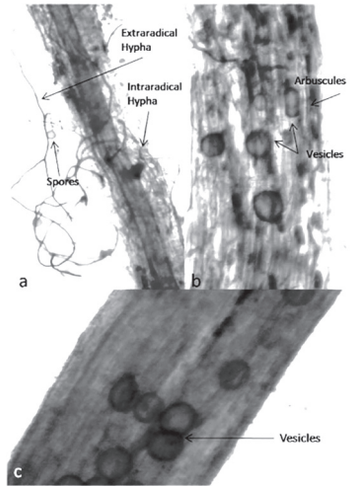

Figure 7: Compound microscopic images (10x) of roots of Sorghum bicolor stained in ink vinegar and observed for root colonization by CMCC/AM-3102 showing extra-radical hypha, intraradical hyphae and spores attached to extra-radical hypha(a), arbuscules and vesicles(b), and abundant vesicles in the cortical cells(c).

Conclusion and Classification Level

On the basis of above morpho-taxonomic analysis of the accession CMCC/AM-3102, many distinguishing features regarding the family, genera, and the species could be derived. The following features were taken into consideration for characterization and identification:

- Globose to sub-globose, asexual spores produced singly from three-layered spore walls
- Spore wall layer is composed of outer hyaline layer followed by one inner fine sub-layer which is semi-flexible followed by a third layer
- Spores are of varying shapes and sizes ranging from globose to sub-globose
- Formation of both intra-radical and extra-radical hyphae and abundant vesicles

All these features suggest that the culture CMCC/AM-3102 belongs to the family of *Glomus clarum* (Blaszkowski, 1994).
Some of the unique morpho-taxonomic features of the accession are detailed as follows:

- From pale yellow to pale orange-brown to orange in colour, globose to sub-globose, asexual spores produced singly with layered spore walls; spores are of varying shapes and sizes ranging from globose to sub-globose. Size ranges 100–(140)-165 µm.
- Spore wall layer is composed of outer hyaline layer, inner fine layer tightly adhered to the outmost layer, a third flexible innermost layer.
- Formation of both intra-radical and extra-radical hyphae and abundant vesicles and intracellular arbuscules.

The taxonomic feature of the accession CMCC/AM-3102 matches the characters of *Glomus clarum* (Blaszkowski, 1994).

Systematic Classification

Glomeromycota
Glomeromycetes
Glomerales
Glomeraceae
Glomus

Most of the work on AMF focusses on taxonomy, functional properties, phylogeny, ecology, and genetics. Identification of morphological features of these micro-organisms has been used as a conventional method for identifying the organism and comparing it with existing reference or species type. Morphological features about AMF spore wall layers, hyphal attachment, reaction with reagents, and so on, help to connect information about genera and species to

which the AMF belongs. However, this conventional approach can be problematic in identification of the organism at species level. Therefore, using alternative methods has more significant advantages over traditional taxonomic approaches. Molecular characterization techniques, such as biochemical characterization through fatty acid methyl ester profiles and sequencing of ITS region of 18s rDNA (molecular characterization), have become more popular. An analyses of rDNA regions has often confirmed the morphologically defined species.

Acknowledgements

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Simulation of Ectomycorrhizal Association in Forests: A Review

C Manoharachary[a] and Anurag Nath[b]*

The existence of ectomycorrhiza in association with plants has a considerable influence on the growth, development, and progress of the host plant. The ectomycorrhizal fungi improves the influx of nutrients into the metabolic pathways of the host plant facilitating the growth of a healthy plant. It influences the carbon and nitrogen flux between the soil rhizosphere and the plant. Ectomycorrhiza are generally neglected of their potential power as they are not included in majority of the ecosystem models (Deckmyn *et al.,* 2014). This study was focussed on investigating ectomycorrhiza as an integral part of the ecosystem and for the same they have implemented the MYCOFON model (Meyer *et al.*, 2012 into the CoupModel. About five ecosystem models have been known to implement ectomycorrhizal fungi. MYCOFON is specific to describe about the carbon and nitrogen fluxes in the soil while CoupModel is a one-dimensional approach which describes all the biotic and abiotic factors associated with the soil-plant system. The new Coup-Mycofon model emphasizes on both the carbon-nitrogen flux and also addresses the forest growth conditions. It was observed that the earlier models could not explicitly describe both the soil and forest conditions associated with the ectomycorrhiza and plant. It provides a deeper insight into the ecosystem fluxes and the feedback mechanisms associated with the intake and uptake of carbon and nitrogen involved in the plant-soil system. . It also considers multiple parameters simultaneously unlike other models calibrating single parameters (He *et al.,* 2016). Further previous models assume nitrogen cycle to be open such that the constant nitrogen flow limits the plant growth (Franklin *et al.,* 2014). Incorporating ectomycorrhizal fungi into the structural model shall pave the way for a better description about the ecosystem and would assist in better prediction about the dynamics involved in the influx and uptake of carbon and nitrogen even under low nitrogen condition (Lindahl *et al.,* 2015). The current model is indicative of the higher mineralization in the soil due to the humus decomposition. This collaborate with the previous findings of soil enhancement by nitrogen transformation in humus under low nitrogen levels (Baskaran *et al.,* 2017, Moore *et al.,* 2015). This model would help in designing strategies towards better developing enhanced mycorrhizal associations which might help in better plant growth and development. Their study provides a key towards the fungal parameters which can be further used for the analysis and evaluation of mycorrhizal studies in future.

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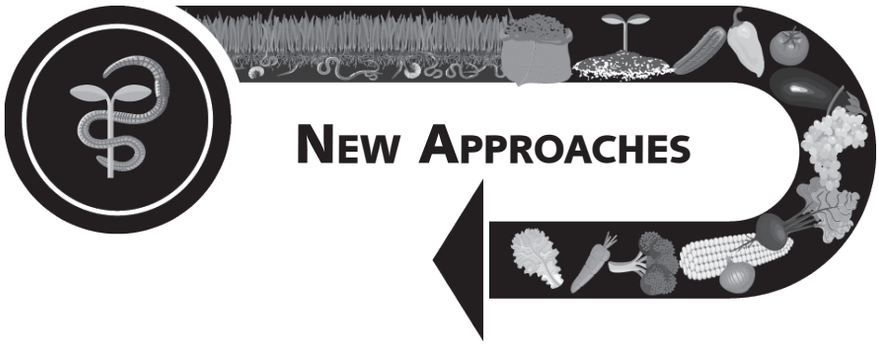


New Approaches and Techniques

DNA Sequencing using Barcoded Primers

There are multiple varieties of mycorrhiza which are associated with the roots of different plants. Increasing the specificity of the mycorrhiza towards a particular plant association could promote improved plant-mycorrhizal association thereby enhancing the plant growth. The employment of DNA sequences with barcoded primers is a modernized technique which has been observed to provide promising results in the field of mycorrhizal research. In this method, specially designed primers have been developed for the identification of different fungal species. These can be employed for detecting various mycorrhizal species, their associates, and the changes incorporated into the mycorrhizal systems as a response to the alternating environment. The barcoded primers would enable the specific detection and identification of the genetic modifications which shall assist in enhancing the use of mycorrhizae for increased agricultural productivity.

MALDI TOF-based biotyping for the identification of arbuscular mycorrhiza

The mutual symbionts, arbuscular mycorrhiza often found associated with plants enhance the plant growth and tolerance against diseases. However, the identification of specific arbuscular mycorrhiza is a challenge. Generally, mycorrhizal identification is associated with the morphology of the spore produced by them. The traditional methods might not be well-adapted for the quality control associated with the mycorrhizal cultures. The new technology employing the use of Matrix-Assisted Laser Desorption Ionisation Time of Flight Mass Spectrometry (MALDI TOF MS)-based proteomic biotyping can be efficiently used for the identification of the arbuscular mycorrhiza. MALDI biotyping can assist in clear intraspecific differentiation of the species. This technique can be fast, reliable, accurate, and less expensive when compared to the conventional methods used for the morphological identification of the AMF.

Training Workshop on Advanced Techniques in Mycorrhizal Research

February 21–23, 2018

TERI Gram, Gual Pahari, Gurugram, Haryana

A Report

BACKGROUND

The Mycorrhiza Network at TERI has been actively involved in development and application of mycorrhizal biofertilizer, technology development and its transfer; and information dissemination activities. The Network is responsible for linking scientists with the latest mycorrhiza information, besides helping scientists and students carry out research in the field of Mycorrhiza and in promoting communication among mycorrhizologists. The Centre for Mycorrhizal Culture Collection (CMCC) of the Network provides researchers an opportunity to obtain specific cultures of interest; preserve germplasm available in India and elsewhere; procure strains of both ecto-mycorrhizal (EcM) fungi and arbuscular mycorrhizal (AM) fungi from India and abroad; multiplies and maintains these fungi in pure culture; and provides starter cultures for various research activities. The network publishes a quarterly newsletter *Mycorrhiza News* in order to promote communication among mycorrhiza scientists in India and other countries; and caters to the needs of the mycorrhiza researchers. This Centre is also involved in imparting training to promising youngsters who are interested in mycorrhizal research. Earlier it has conducted three training programmes. As part of the Mycorrhiza Network Programme, TERI organized a three-day training workshop on "Advanced Techniques in Mycorrhizal Research" at TERI Retreat and TERI-Deakin Nano-Biotechnology Centre, TERI Gram, Gual Pahari, Gurugram from February 21–23, 2018. The event was sponsored by the Department of Biotechnology, Government of India, New Delhi.

OBJECTIVES

The workshop aimed at imparting hands-on training in research techniques on mycorrhizal research so that the participants can apply these in their research programmes. Therefore, besides demonstrating the techniques, participants were encouraged to learn the techniques and carry out laboratory exercises by themselves. The specific areas included:

1. Quantitative and qualitative analyses, Taxonomy, identification criteria (Morphotaxonomy), Molecular tools, viability, Germplasm maintenance, Root colonization, mycorrhizal dependency;
2. Work involving selection, culture, and inoculation of arbuscular mycorrhizal fungi under nursery and field conditions;
3. Demonstration of advanced techniques, involving molecular, biochemical, and bioinformatics tools;
4. Promoting understanding on the relevance of mycorrhizal research in the Indian context; and
5. Field visit and visit to various laboratories.

PROGRAMME

The course was essentially practical oriented. Laboratory sessions were supported by lectures and discussions. It included the following:

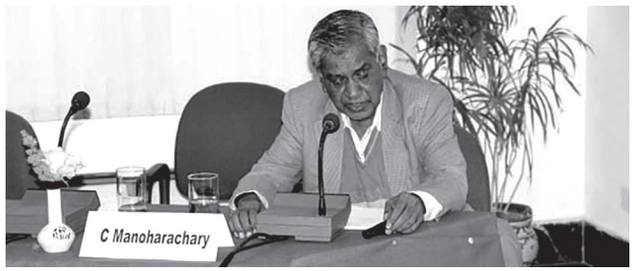
- A quantitative estimation of AM (arbuscular mycorrhizal) spores from soil, root colonization
- Image analysis of AM spores
- Assessment of intra-radical colonization by AM fungi
- Trap culturing and monosporal culturing for AM
- Morphotaxonomy, biochemical, and molecular characterization of AM fungi and information on bioinformatics tools associated with Mycorrhizal Research
- Bio-safety issues
- Impact of IPR (intellectual property rights) regimes on agricultural biotechnology issues

In addition, a lab tour of the TERI-Deakin Nano-Biotechnology Research Centre (TDNBC) was organized along with a visit to other specialized facilities such as Centre for Mycorrhizal Culture Collection (CMCC), Biomass Gasifier-based Power Generation, etc., provided by TERI, at TERI Gram, Gual Pahari, Gurugram.

WORKSHOP SESSIONS

Inaugural Session

The workshop initiated with opening remarks by Dr Alok Adholeya, Senior Director, Sustainable Agriculture Division, TERI. Dr Adholeya, while setting the theme of the workshop, spoke on the role



of mycorrhiza in sustainable agriculture and traced the origin and development of mycorrhizae, followed by the role of TERI in establishing mycorrhizal research network and the Centre for Mycorrhizal Culture Collection and the importance of organizing workshops in order to disseminate the information to a wide range of researchers. The welcome speech was given by Prof. C Manoharachary, NASI Senior Scientist, Osmania University, followed by the inaugural address by Dr T Madhan Mohan, Adviser, Department of Biotechnology, Government of India. He stressed the role of mycorrhizal research and its utility as a biofertilizer and emphasized the need for technological innovations. He appreciated TERI for hosting the workshop and explained how such workshops will bring experts and learners to interact, besides honing their hands-on skills. In future as well, such technical workshops should be conducted at the national and international levels. Further, Mr T P Sankar, Fellow, Knowledge Management, TERI, gave a brief introduction about the Mycorrhiza Information Centre, which plays a crucial role in bringing researchers and students from different parts of the world to communicate and access information on mycorrhiza and assists in its progress and development following which Dr Reena Singh, Fellow and Area Convenor, Centre for Mycorrhizal Research, TERI, delivered the vote of thanks to all the fellow speakers for being a constant source of inspiration and in motivating others to carry forward the mycorrhizal research.

Technical Session

DAY 1

Topic: Mycorrhizae: Evolution, Techniques, and Taxonomy—Indian Scenario

Prof. C. Manoharachary, NASI Senior Scientist, Osmania University, Hyderabad, elaborated on the accomplishments of Indian mycorrhizologists and provided basic information on the identification and taxonomical data which influences the classification of mycorrhiza. Further, he also explained the properties and features based on which the fungal classification and methods for their identification are associated. He presented data on the mycorrhizal dependency of crop and forest plants. Methods of inoculation and building of inoculum were also explained. Finally, he emphasized on the role of mycorrhizae in the sustenance of agriculture and forestry, respectively.

Topic: Identification and Multiplication of Ectomycorrhizal Fungi and Inoculum Production

Prof. N. Raaman, UGC-BSR Faculty, Former Director, Centre for Advanced Studies in Botany, University of Madras, Guindy Campus, Chennai, explored the different aspects of mycorrhizal phylogenetics and their identification. He also explained the various techniques through which the ectomycorrhizal community can be multiplied and employed for forest seedling establishments. He also stressed on the carrier materials.

Topic: Modern Tools in Characterization of Fungi

Dr Praveen Rahi, National Centre for Microbial Resource, NCCS, Pune, discussed the techniques which can be employed for the characterization of fungi. He also described molecular techniques and their advantages.

Topic: Scope of Patentability and Guidelines for Biotechnological Inventions, including microorganisms.

Dr Anushri Gupta, Founder, Anushri Gupta and Associates, Delhi, explained the intellectual property rights associated with the invention of various microbiological products. She described how these can be explained and used for the advantage of the human race. Patenting methodologies, registration and commercialization of the product, etc., were also explained.

DAY 2

Topic: Sustainable Crop Production by Mycorrhiza: Journey and Successful Case Studies for Application in Agriculture and Bioremediation

Dr Reena Singh, Fellow and Area Convenor, Centre for Mycorrhizal Research, TERI, explained the association of mycorrhiza with plants and the subsequent increase in their efficiency which can be employed for sustainable development and increasing the crop yield. She also spoke on molecular characterization, inoculum production strategies, and application of mycorrhizae as benefactor in agriculture and bioremediation.

Topic: Molecular and Biochemical Characterization of Fungi

Prof. Rohit Sharma, Curator – Fungi, National Centre for Microbial Resource, NCCS, Pune, spoke about the different characteristics which can be used for the characterization and identification of fungi. He also described the phylogenetic relation among the classes of fungi and their corresponding association.

DAY 3

Topic: Molecular Markers for Identification of AMF.

Dr Pushpalata Singh, Fellow, Computational Genomics, TERI, explained the different molecular markers associated with the AMF and described in details the subsequent identification techniques.

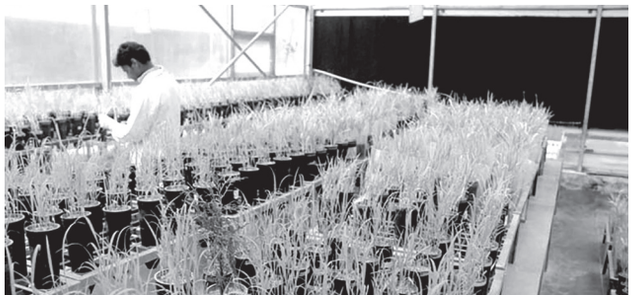
Interactive Session

During the three-day workshop, the participants interacted with the fellow speakers by raising questions on the suitability of mycorrhiza with plants, the suitability of AM fungi for different crops, the role of soil conditions, nutrient status of the soil, the different perspectives that need to be assessed before the commercial use of mycorrhiza, and effective bio inoculants, purity of inoculum, quality, and shelf life of commercialized mycorrhizal products and other related issues, such as the bioinformatics tools used. The experts answered the questions raised by the participants, and thus provided them knowledge on the technical aspects.

Practical Session

DAY 1: A tour of the TERI-Deakin Nano-Biotechnology Centre was organized and training on various basic laboratory techniques and safety such as washing, sterilizing, and culturing was provided to the participants.

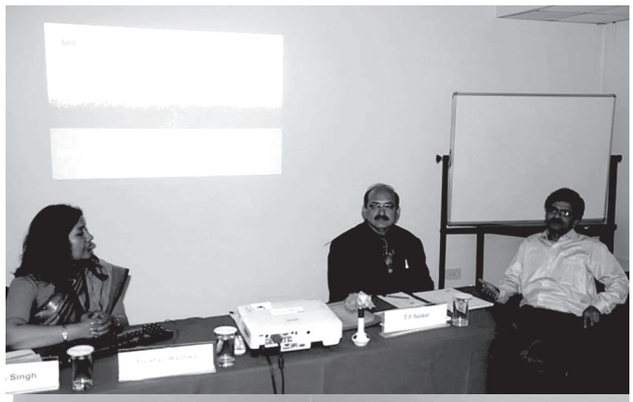
DAY 2: A tour of the CMCC (Centre for Mycorrhizal Culture Colvlection) was organized and the various mycorrhizal cultures were explored. The participants were given basic knowledge on the differential aspects of culturing and culture maintenance.



DAY 3: The participants were conferred hands-on experience of different techniques and were allowed to explore the same.

Valedictory Session

Dr Reena Singh, in her valedictory address, appreciated the overwhelming response from the participants and summed up the 3-day workshop by expressing her interest to hold more such events in the near future to impart quality knowledge to students. Dr Gulshan Wadhwa, Joint Director, Department of Biotechnology, Government of India, in his special address, described about the favourable association of plants and mycorrhizae. He explained the use of mycorrhiza for the benefit of agricultural economy and described the advantages of mycorrhizal research in the sustainable development and progress of agriculture. Mr T P Sankar delivered the vote of thanks and concluded the session.



KEY MESSAGES AND RECOMMENDATIONS

The key messages and recommendations that emerged out from the workshop for the participants and policymakers are listed below:

a. The current agricultural practices involving the use of chemicals and fertilizers for producing crops are not sustainable as they have a residual effect. In some cases, chemical resistance in crops has also been noticed;

b. The chemical fertilizers that are used for agricultural crops are mostly converted into forms that are not available for the plants;

c. The mycorrhizal association with plants increases the absorbing area of the roots at least 100 to 1000 times which makes the nutrients available in the soil help the plants grow efficiently;

d. Mycorrhizae make the unavailable and other tightly bound soil essential nutrients available to the plants, and thereby facilitates the ability of the plants to utilize soil resources more efficiently;

e. Mycorrhizae increase the absorption and translocation of nutrients from soil to plants and they also assist in improving the tolerance of

plants towards biotic and abiotic stresses, namely, high soil temperature, drought, heavy metal toxicity, salinity, etc.

f. The mycorrhizal association improves the resistance of plants towards plant pathogens, pests, and improves their sustainability and growth and development.

g. They build up macro-porous structure of soil through their extraradical hyphae that allows penetration of water as well as air and prevents erosion. Mycorrhizae, are thus, a viable alternative to current agro-chemicals and can play a vital role in sustainable agriculture;

h. It has been recommended that such a 3-day training workshop on mycorrhiza should be organized by TERI on a regular basis wherein training may be imparted to the researchers on different aspects of mycorrhiza research so that they can continue to conduct the research (mycorrhiza) at their respective institutes.

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Email: anurag.nath@teri.res.in

Recent references

The latest additions to the network's database on mycorrhiza are published here for the members' information. The list consists of papers from the following journals:

- *Applied Soil Ecology*
- *Biochemical Systematics and Ecology*
- *Ecological Engineering*
- *Environmental and Experimental Botany*
- *European Journal of Soil Biology*
- *Food Research International*
- *Fungal Biology*
- *Geoderma*
- *Industrial Crops and Products*
- *Journal of Hazardous Materials*
- *Journal of Photochemistry and Photobiology B: Biology*
- *Journal of Plant Physiology*
- *Mycoscience*
- *Rhizosphere*
- *Science of The Total Environment*
- *Scientia Horticulturae*
- *Soil Biology and Biochemistry*
- *South African Journal of Botany*

Copies of papers published by mycorrhizologists during this quarter may please be sent to:
Mr Anurag Nath (anurag.nath@teri.res.in) for inclusion in the next issue.

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Forthcoming events
conferences, congresses, seminars, symposiums, and workshops

Toronto, Ontario, **Canada**
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Email: environmentalmicrobiology@microbiologyconferences.org
Website: https://environmentalmicrobiology.conferenceseries.com/

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July 11–12, 2018

2nd International Conference on Microbial Ecology and Ecosystems

E-mail: microbialecology@microbiologyconferences.org
Website: https://microbialecology.conferenceseries.com/

San Juan, **Puerto Rico**
July 15–20, 2018

11th International Mycological Congress (IMC11)
Sharon A Cantrell Rodríguez

Tel.: 1-650-889-4686
Email: scantrel@suagm.edu
Website: http://imc11.com/

Rome, **Italy**
July 19–20,2018

13th International Conference on Microbial Interactions and Microbial Ecology

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Boston, Massachusetts, **USA**
July 29–03 August, 2018

International Congress of Plant Pathology
General Information, ICPP2018, 3340 Pilot Knob Road, St. Paul, MN 55121 USA

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Email: icpp2018@scisoc.org
Website: http://www.icpp2018.org/Pages/default.aspx

Dublin, **Ireland**
August 19–24, 2018

International Association for Plant Biotechnology Congress 2018

Tel.: + 353-86-860-9818
Email: iapbhome@gmail.com
Website: http://iapb2018.com/

Zurich, **Switzerland**
September 10–12, 2018

13th International Conference on Agriculture & Horticulture

Email: agri@agriconferences.com
Website: https://agricultureconference.wordpress.com/

London, **England**
October 6–7 ,2018

UK Fungus Day, British Mycological Society
UK Fungus Day, c/o British Mycological Society, Charles Darwin House,12 Roger St, London WC1N 2JU

Tel.: +44 (0) 161 818 8630
Email: ukfungusday@britmycolsoc.info
Website: http://www.ukfungusday.co.uk/

Ho Chi Minh City, **Vietnam**
October 10–13, 2018

Asian Mycological Congress (AMC)

Tel.: (84) 913 154508
Email: pndhoang@amcfungi2017.com, amcfungi2017@gmail.com
Website: http://amcfungi2017.com/

Valencia, **Spain**
October 29–30, 2018

6th Global Summit on Plant Science

Email: plantscience@agriconferences.com
Website: http://plantscience.global-summit.com/

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