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Mycorrhiza News

The Mycorrhiza News provides a forum for 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 compiled 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.



Contents

RESEARCH FINDING PAPERS

AM fungi in wild banana I: distribution and ecology	2
Diversity of arbuscular mycorrhizal fungi associated with the rhizosphere of some existing plants in iron ore mines of Chhattisgarh, India	7
Non-target effect of two fungicides on <i>Glomus mosseae</i> colonization of chilli roots	11

CMCC article

Grasses: a trusted model plant for Mycorrhiza study	15
Recent references	17
Forthcoming events	20

RESEARCH FINDING PAPERS

AM fungi in wild banana I: distribution and ecology*

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Introduction

The Western Ghats, one of the 25 mega-diversity 'hot spots of the world', embodies more than 4,000 of the country's endemic plant species distributed along wide range of geo-climatic conditions (Bhat 2002). The state of Goa lies in the heart of Western Ghats (Khade and Rodrigues 2002). The major portion of the slopes of Western Ghat belt falls in this region encompassing luxuriant forests with good diversity (Rao 1985). Three talukas of Goa namely, Sattari, Sanguem, and Canacona come under Western Ghat's belt exhibiting deciduous/semi-evergreen forest, abandoned lands, roadsides, low lying land tracks, cultivated plantations, and wild gardens (Bhat 2002).

Banana belonging to family Musaceae contains two genera -namely, *Musa* and *Ensete*. *Musa* is best divided into four sections one of which (*Emusa*) contains the great majority of the edible bananas (derived from *M. acuminata* and *M. balbisiana*) and the other three yield one important fibre (*Abaca*, from *M. textalis*, *Australimusa*), one minor group of edible cultivar and others are used as, vegetables and ornamentals (Khade 1999).

At present, in the state of Goa, banana occupies an area of 1,875 ha with corresponding production of 10,650 tonnes which is sufficient to meet 40% of the requirement of the state. The balance 60% is met by import from neighbouring states (Khade 1999). The crop is grown in almost all parts of Goa but concentrated in talukas of Bicholim, Sattari, Sanguem, Ponda, Pernem, and Canacona. The varieties like

Poovan *Musa* (AAB), *Raspali* (AAB), *Hazari* (AB), *Saldatti* (AAB), and *Savarbondi* (ABB) etc., are grown, of which *Raspali*, *Hazari*, and *Saldatti* are commonly cultivated and are of economic importance (Khade 1999). Keri, at the foot hills of Chorlem Ghat is also known for extensive banana cultivation. Wild species of banana were observed for the first time in Chorlem Ghat during a survey on inventorization and documentation of plants from Western Ghat region of Goa. Following which survey was carried out to ascertain AM fungal association in wild banana from Chorlem Ghat region of Goa.

Materials and Methods

Root samples and the rhizosphere soil samples of wild banana (Figure 1 B, C, D) were collected during the post monsoons (October 2001) and summer (March 2002), from Chorlem Ghat (Figure 1A) region of Goa. Further, freshly collected roots of wild banana were washed in water, cleared with 10% KOH, acidified with 1N HCl and stained in 0.05% Trypan Blue in lactoglycerol (Phillips and Hayman 1970). Quantification of root colonization of AM fungi was carried out using slide method (Giovannetti and Mosse 1980). Spores of AM fungi were extracted from the rhizosphere using wet sieving and decanting method (Gerdemann and Nicolson 1963). Quantification of spore density of AM fungi was carried out using a method given by Gaur and Adholeya (1994). Diagnostic slides with spores were prepared using Polyvinyl Alcohol Lacto Glycerol

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[#] This paper is a part of the series of a paper on wild banana. Part 2 and part 3 of the series have been already published previously.



(A)



(B)



(C)



(D)

Figure 1 (A)–(C) An overview of Chorlem Ghat; (B) - (D) Wild banana in its natural habitat

(PVLG) as mountant. Identification of AM fungi was carried out using manual of identification of the AM fungi (Schenck and Perez 1990). Taxonomic identification of spores was matched with the descriptions provided by International Collection of Vesicular AM fungi ([http:// invam.caf.wvu.edu](http://invam.caf.wvu.edu)). Standard deviation was calculated for mean root colonization and mean spore density of AM fungi.

Results

The climatic conditions prevailing during the study period at site Chorlem and AM fungal status of wild banana is recorded in Table 2. The humid climatic conditions prevailing during October and March were favorable for conducting study on the AM fungi. This study recorded the presence of hyphal and vesicular colonization of AM fungi (Figure 2A)

Table 2 Arbuscular mycorrhizal association in wild banana

Plant species	Region	Sampling time	Rainfall (mm)	Temperature		*Root Colonization (%)	*Spore density /100g soil	Species of AM fungi
				(Min °C)	(Max °C)			
<i>Musa</i> sp. (wild banana)	North Goa (Western Ghat- Chorlem)	October 2001	61.6	31.5	24.6	20 ± 0.07	100 ± 2.86	<i>Glomus fasciculatum</i>
		March 2002	—	32.9	25.9	10 ± 0.14	26 ± 1.48	<i>Glomus clarum</i> <i>Glomus goaensis</i> <i>Indiana bulbigoa</i>

* n= 5 ± 1SD

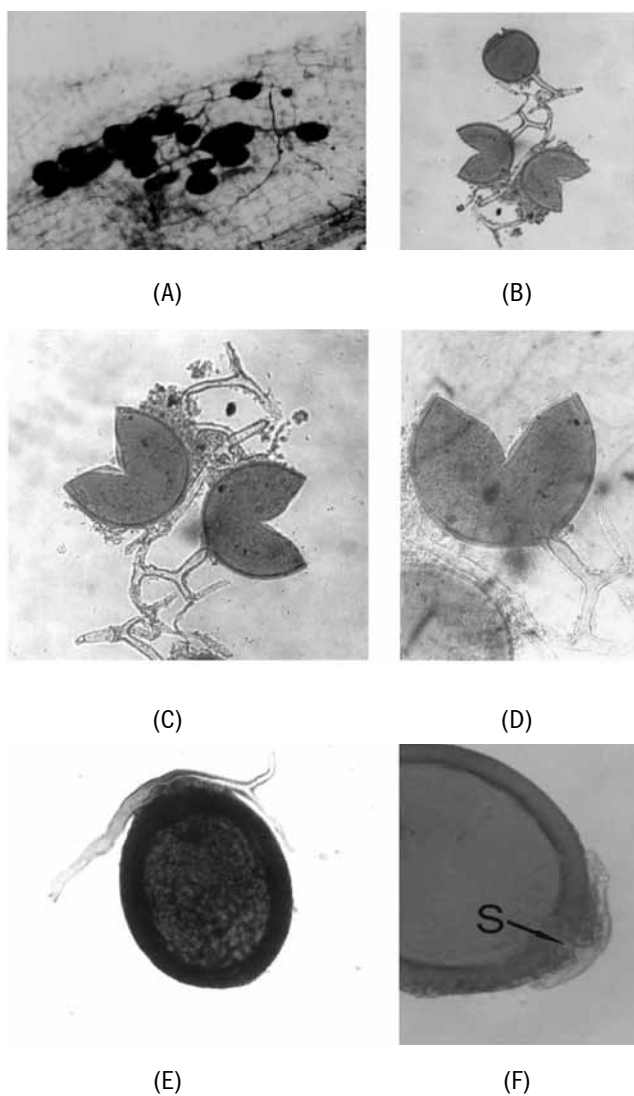


Figure 2 A) Hyphae and Vesicles stained in trypan blue (x 400). B), C) Spores of *Glomus fasciculatum* occurring in clusters (fascicles) (x 400). D) Crushed spore of *Glomus fasciculatum* showing the extension of spore wall into the hyphal attachment (x 1000). E) Mature brown spore of *Glomus clarum* with hyphal attachment (x 400). F) A portion of reddish brown spore of *Glomus clarum* showing bulging septum (S) at the point of attachment (x 400).

during post monsoon. With mild rain showers during October, the root colonization (20%) and spore density (100 spore/100g soil) of AM fungi was higher as compared to March where the root colonization (10%) and spore density (26 spore/100g soil) of AM fungi was low (Table 2). In contrast to the above findings, the number of species of AM fungi was lower in post monsoon (1 species) as compared to summer (3 species) in the absence of rain showers and comparatively higher temperatures. The study recorded the presence of *Glomus fasciculatum* (Thaxter) Gerd. & Trappe emend Walker & Koske (Figure 2 B, C, D) in October and recorded three species of AM fungi namely, *Glomus clarum* Nicol, and Schenck (Figure 2 E, F), *Glomus goaensis* Khade and *Indiana bulbigoa* Khade during March (Table 2).

Discussion

AM fungi forming symbiotic association with majority of land plants mainly comprises three phases of growth within the host root namely, hyphae, arbuscules, and vesicles. Apart from these, spores of some species develop within the roots and in most cases spores are formed outside the root on the runner hyphae (Khade and Adholeya, 2005). In the present study, intraradical hyphal and vesicular colonization was evident in epidermal and cortical root region of wild banana while the functional stage of AM fungi namely, dichotomously branched arbuscules was absent. The globose and ellipsoidal vesicles encountered in the present study represented genus *Glomus*. The AM status and diversity of AM fungi associated with cultivated *Musa* species in India is represented in Table 1.

In Kerala (India), the banana cultivar (*Musa sapientum* L) recorded 18.1% to 60.9% root colonization of AM fungi (Girija and Nair, 1988). In South Goa, banana cultivar (*Musa paradisiacal* L) recorded 66% root colonization and 20 spores/100g rhizosphere soil (Bukhari *et al.*, 2003) (Table 1). Similarly in North Goa, the banana cultivar *Saverbondi* (ABB) recorded 426 spores/100g rhizosphere soil in monsoon and 250 spores/100g rhizosphere soil post monsoon (Khade and Rodrigues, 2004) (Table 1). In

Table 1 Comparative account of AM status of cultivated banana variety in India

Area/ Region	Variety/ Cultivar	Sampling time	Root Colonization (%)	Spore density/ 100g soil	Species of AM fungi	Reference
Kerela	<i>Musa sapetium</i> L.					
	<i>Padatti</i>	–	26.6	–	–	Girija & Nair, 1988
	<i>Red banana</i>	–	57.7	–	–	
	<i>Monthan</i>	–	38.5	–	–	
	<i>Pacha kappa</i>	–	19	–	–	
	<i>Rasthali</i>	–	24.4	–	–	
	<i>Chingan</i>	–	18.1	–	–	
	<i>Palayanthodan</i>	–	60.9	–	–	
	<i>Nendran</i>	–	22.7	–	–	
Goa	<i>Musa paradisiaca</i> L.					
South Goa, Sanguem, (Quepem)			66 ± 6.9	20 ± 8	<i>Glomu macrocarpum</i> , <i>Acaulospora spinosa</i>	Bukhari et al. 2003
North Goa, Sattari, (Valpoi)	<i>Savarbondi</i>	May 1998		426 ± 21.45	<i>Acaulospora foveata</i> <i>Acaulospora nicolsonii</i> <i>Acaulospora scrobiculata</i> <i>Glomus claroideum</i> <i>Glomus monosporum</i> <i>Glomus gerdmanii</i> <i>Glomus clavisporum</i>	Khade & Rodrigues, 2004
		August 1998		384 ± 29.40	<i>Acaulospora foveata</i> <i>Acaulospora scrobiculata</i> <i>Glomus claroideum</i> <i>Glomus monosporum</i> <i>Glomus clavispora</i>	
		November 1998		250 ± 20.22	<i>Acaulospora scrobiculata</i> <i>Glomus claroideum</i> <i>Glomus monosporu m</i> <i>Glomus clavisporum</i>	

contrast to the earlier findings on banana cultivars, present study recorded lower root colonization and spore density of AM fungi in wild banana and that these parameters decline from post monsoon to the onset of summer in Goa, India.

Further, Bukhari *et al.*, (2003) and Khade and Rodrigues (2004) reported two genera of AM fungi (*Acaulospora* and *Glomus*) from rhizosphere of banana cultivar in South Goa and North Goa (Table 1). Similarly, the present study on wild banana reported the presence of two genera of AM fungi - namely, *Glomus* and *Indiana*. The study supports the findings of Khade and Rodrigues (2004), that maximum number

of species of AM fungi are present in summer, as compared to post monsoon and in the present study species number actually increased from post monsoon to onset of summer in Goa, India.

Conclusions

Wild banana documented in the present study occurs in rocky areas near earth cutting along the road sides and therefore an attempt was made to report the gene pool of AM fungi associated with it in the Western Ghat region (Chorlem) of Goa, India. Though the role of AM fungi in agro-ecosystem is enhancing

plant growth, yield, and reducing the hazardous effect of chemical fertilizers, but in natural ecosystem like Western Ghat, AM fungi (hyphae) acts as an extension and increases the root surface area for uptake of water and nutrients, thus enabling survival of plant species like wild banana in inhospitable sites.

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References

Bhat D J. 2002. Terminal project report on Plant fungus biodiversity, inventory, conservation, and utilization efforts for Western Ghats Goa region. Phase -1: 1-197

Bukhari M J, Khade S W, Jaiswal V, Gaonkar U C, and Rodrigues B F. 2003. AM status of medicinal plants: A field survey of AM fungal association in herbs. *Plant archives* 3 (2): 167-174

Girija V K and Nair S K. 1988. Incidence of VAM in banana varieties. *Indian Journal of Microbiology* 28(4): 294-295

Gaur A and Adholeya A. 1994. Estimation of VAM spores in the soil – A modified method. *Mycorrhiza News* 6(1): 10-11

Gerdemann J W, and Nicolson T H. 1963. Spores of mycorrhizal *Endogone* species extracted from soil wet sieving and decanting. *Transactions of British Mycological Society* 46: 235-244

Giovannetti M and Mosse B. 1980. An evaluation of techniques for measuring vesicular AM infection in roots. *New Phytologist* 84: 489-500

Khade S W. 1999. Mycorrhizal association in different varieties of Banana (*Musa* sp.) in soils of Goa. M.Sc dissertation 1-84.

Khade S W and Rodrigues B F. 2002. AM fungi associated with some pteridophytes from Western Ghat region of Goa. *Tropical Ecology* 43(2): 251- 256

Khade S W and Rodrigues B F. 2004. Populations of AM fungi associated with rhizosphere of banana (*Musa* sp.) as influenced by seasons. *Mycorrhiza News* 16(1): 11-13

Khade S W and Adholeya A. 2005. Arbuscular mycorrhizae in natural ecosystem: Incentives in diversity and ecology. In. *Current Perspectives and potential applications*, edited by T Satyanarayana and B N Johri , I K International Pvt. Ltd, New Delhi: 225-258

Phillips J M and Hayman D S. 1970. Improved procedure for clearing roots and staining of mycorrhizal fungi for rapid assessment of infection. *Transactions of British Mycological Society* 55: 158-161

Rao R S (ed.) 1985. *Flora of Goa, Diu, Daman, Dadra & Nagar Haveli*. Vol I. Botanical Survey of India publication, Howrah.

Schenck N C and Perez Y. 1990. *Manual for identification of VA Mycorrhizal fungi* edited by N C Schenck and Y Perez , INVAM, University of Florida, Gainesville, USA.

Diversity of arbuscular mycorrhizal fungi associated with the rhizosphere of some existing plants in iron ore mines of Chhattisgarh, India

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Introduction

'Mycorrhizas are symbiotic associations essential for one or the both partners, between a fungus (specialized for life in soils and plants) and a root (or other substrate-contacting organ) of a living plant, that is primarily responsible for nutrient transfer. Mycorrhizas occur in a specialized plant organ where intimate contact results from synchronized plant-fungus development.' *Arbuscular mycorrhizae* (AM) are generally aseptate fungi classified under *Glomeromycota*. Arbuscular mycorrhizal fungi (AMF) have a loose external mycelium extending the hyphae into the soil beyond the depletion zone from which penetration of the host root cells takes place (Baruah and Borthakur, 1997; Jacobsen, 2004).

Mining land sites are generally known to be nutrient-poor and contain soils that are in direct need of stabilization to prevent erosion. Marked by the beginning works of J R Schramm, mine reclamation practices have included the use of mycorrhizal inocula to establish successful plant communities on mine sites (Danielson, 1985). Mycorrhizae benefit the vegetation by increasing a plant's ability to survive in a nutrient-poor, water-deficient environment in undisturbed ecosystems, and mycorrhizal relationships occur naturally. Mined sites, however, are chemically, physically, and biologically, altered and often lack the necessary quantity of mycorrhizal fungi to sustain a tolerant plant community (Norland, 1993). Several types of mycorrhizal inocula are currently in use and will be examined according to their practicality and economy to site specificity (Sturges Susan, 1997). The survey was conducted in mine sites known to harbor the plants present in the area. Generally *Dulbergia sisso*, *Adina cardifolia*, *Tactona grandis*, *Gmelina arborea*, *Shorea robusta*, *Diospyros melanoxylon*, *Delonix regia*, *Dendrocalamus strictus*, *Terminalia tomentosa*, *Pterocarpus marsupium*, *Cleistanthus collinus*, *Croton bonplandianum*, *Madhuca indica*, *Anogeissus latifolia*, and others.

Materials and Methods

Study and Geology of area

The present study was carried out of two iron ore mine areas of Chhattisgarh, the name are Rajhara

mines and Ari Dongari mines. Rajhara iron mine is situated at latitude 20°35' N and longitude 81°05' E, to south of Dalli-Rajhara taluk, Durg. It is located at about 83 KM south of Durg district, and comes under the south eastern section of the Indian Railways. The Rajhara mine has been mined systematically for iron over four decades. Rajhara mines occur in the semi-arid region in the southern plains of Chhattisgarh. The region is characterized by annual rainfall of 1071.16 mm. The day temperature during the year is around 25-45°C. Ari Dongari iron mines is of the 4.8 km long ridge extending in a N-S direction west of the village Kachche, which is located at about 26 km from the Rajhara mines on the fair weather road between Balod and Narainpur of Kanker district. The region is characterized by annual rainfall of 1190 mm, the day temperature during the year is around 20-40°C (Figure 1). (Department of mineral resources, Government of Chhattisgarh).

Collection of Soil Samples and Root

Soil samples were collected from the three regions of iron ore mines; unmined area, mined area, and dumped area (topsoil before mining). The sampling location sites were randomized after site facing. The soil sample collected from ten different locations of all three areas. The core method will be used to take samples from 30cm depth of the selected site soil samples.

Root samples were collected from each mine, of few plants like *Dulbergia sissoo*, *Cleistanthus collinus*, *Croton bonplandianum*, *Madhuca indica*, *Anogeissus latifolia*. Each sample had five replicates. Fine roots of mature trees were excavated after tracing larger roots from the stem collar of plants. They were packed in polythene bags, along with the roots, and kept in a refrigerator in the laboratory until they were analysed.

Physical Properties of Soil

Three soils were checked for their physical parameters like temperature, pH, total dissolve solids, and conductivity (Table 1). (Deluxe soil and water analysis kit model 172, company EI).

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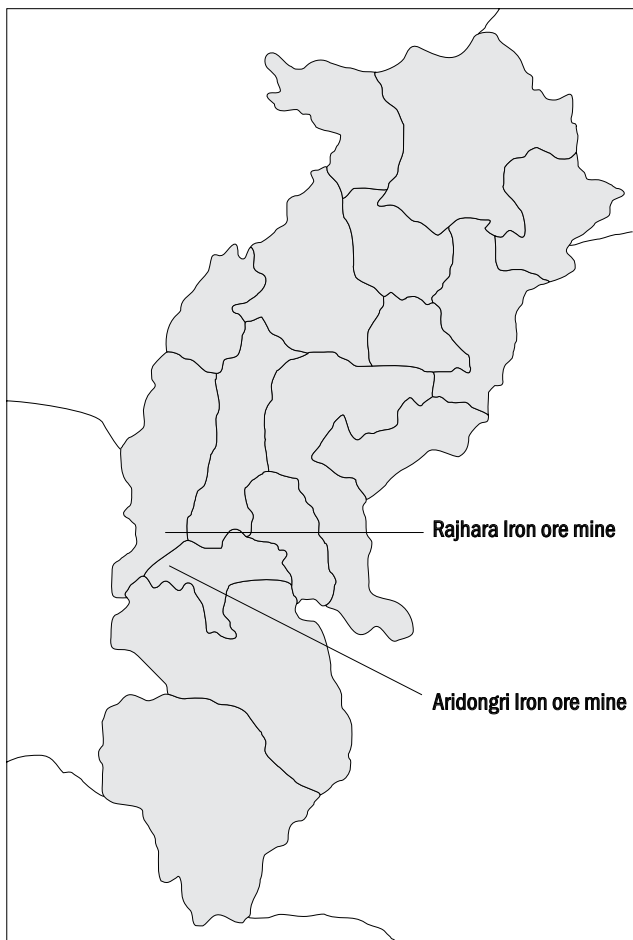


Figure 1 Map of Chhattisgarh showing location of Rajhara mines and Ari Dongri iron ore mines.

Mycorrhizal Percentage Infection

Trypan blue method (Phillips and Hayman 1970) was used for the determination of the intensity of root percentage infection. The method was also suitable for the determination of the root percentage infection of mycorrhiza, rate of colonization, and comparison of structures. The percentage root infection was calculated using the following formula:

$$\% \text{ root infection} = \frac{\text{Total number of root segments infected}}{\text{Total number of root segments examined}}$$

Spore Extraction and Identification

Spore extraction from the soil was carried out using wet sieving and decanting technique (Gerdemann and Nicolson 1963). Sieves size ranging from 500 μm to 75 μm were used to separate the spores from the soil samples. The sieves spore were placed in filter paper and observed with a stereo-microscope under

reflected light. The spore density was expressed as the total number of spores occurring in 100 gm of soil. The spores were then observed for distinguishing morphological characters such as size, shape, and wall characteristics under a compound microscope (model: Labomed CXL PLUS). The spores were identified according to the manual of identification of vesicular-arbuscular mycorrhizal (AM) fungi by Schenck and Perez (1990), Morton and Benny (1990), and Mukerjee (1994). The INVAM worksheet for spore characterization was used for diagnosing the spores.

Result and Discussion

Pioneer research work on AM in mine reclamation practices were conducted by Danielson (1985), Norland (1993) and Sturges Susan (1997), who reported that the plants existing in mines area were found associated with arbuscular endotrophic mycorrhiza. The mycelia were found extended in the cells of the primary cortex, except in the root tips. Similarly, *Gigaspora*, *Glomus*, *Sclerocystis* were identified in the Rajhara iron ore mines soil and only the two order *Gigaspora* and *Glomus* were found in Ari Dongari iron ore mine's soils.

Six soil samples were collected from three different zones of mine unmined and old dumped zone of Rajhara, and Ari-dongari iron ore mines area.

Mycorrhizal population of Rajhara iron ore mines has been presented in Figure 2. Spore population/100 gm soil was calculated. The spore population ranged from 0 to 03 spore/g of soil. Soils of unmined zone are harboured with highest spore population, the soils of dumped zone having less spore population, and the soil of mining zone is negligible spore

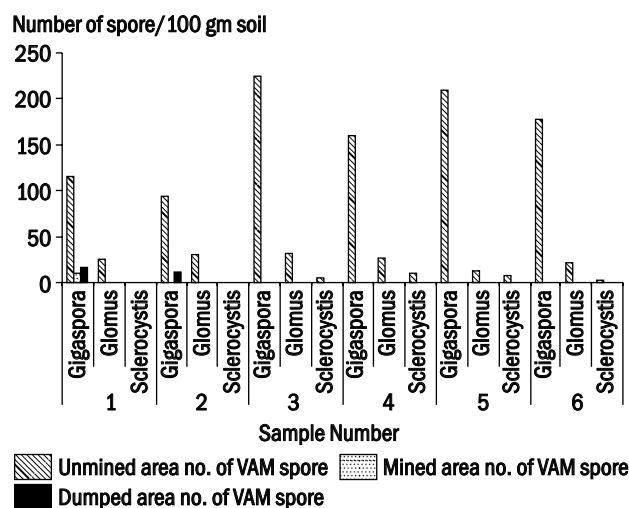


Figure 2 Number of arbuscular mycorrhizal fungi spores per 100 gm of soil (Rajhara iron ore mines)

Table 1 Physical properties of soil Parameters

	Soil samples of Rajhara iron ore mines (mean value)			Soil samples of Aridongri iron ore mines (mean value)		
	Unmined zone	Mined zone	Dumped zone	Unmined zone	Mined zone	Dumped zone
Temperature (°C)	30.50	30.50	30.50	30.50	30.50	30.50
pH	6.55	7.28	7.48	6.32	7.26	7.66
Conductivity (ms/cm)	0.05	0.20	0.09	0.05	0.26	0.14
TDS(ppm)	31.67	141.00	39.33	37.67	147.00	43.00

population. Overall, three genus of AMF were detected from the study areas. The genus *Gigaspora* was found to be dominating in the unmined zone. *Glomus* and *Sclerocystis* are the secondary, and tertiary, moderately distributed genus in the unmined zone and very less in mined area.

Mycorrhizal population of Ari-dongari iron ore mines with their order has been presented in Figure 3. Spore population of 100 gm soil was calculated. The spore population ranged from 0 to 0.5 spore/g of soil. Soils of unmined zone are harboured with highest spore population, the soils of dumped zone having less spore population, and the soil of mining zone is negligible spore population. Overall, two genus of AMF was detected from the study areas. The genus *Glomus* was found to be dominating in the unmined zone. *Gigaspora* is the second moderately distributed genus in the unmined zone and very negligible number in few sample of dumped and mined zone are also absent in few sample of soils.

Physical parameter of soil samples are temperature, pH, total dissolve solids, and conductivity tested from randomly three sample

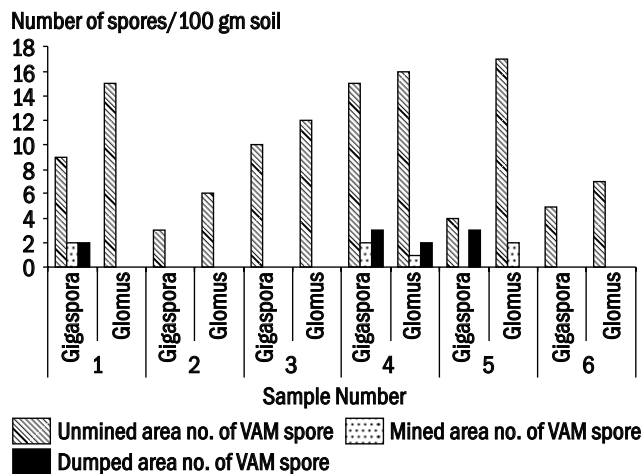


Figure 3 Number of arbuscular mycorrhizal fungi spores per 100 gm. of soil (Ari-Dongari iron ore mines)

of each zone. The result has been presented in Table 1. The pH of dumped zone soil is higher than mined zone soil. Soil testing helps us to know the nutritional status of the soil, to assess the profitability of applying a particular nutrient. If soil pH is very high then there is no use of adding fertilizer for revegetation. The conductivity (ms/cm) and total dissolve solid (ppm) are more in soil collected from mined zone, as compared to soil collected from dumped zone. The excessive conductivity and total dissolve solid can also lower the efficiency of applied fertilizer for revegetation as well as mycorrhizal spore germination.

Percentage root infection of arbuscular mycorrhiza fungi of some existing plant root is given Figure 4. The percentage root infection by arbuscular mycorrhiza was found to be significantly influenced by physio-chemical properties of mines zone soil.

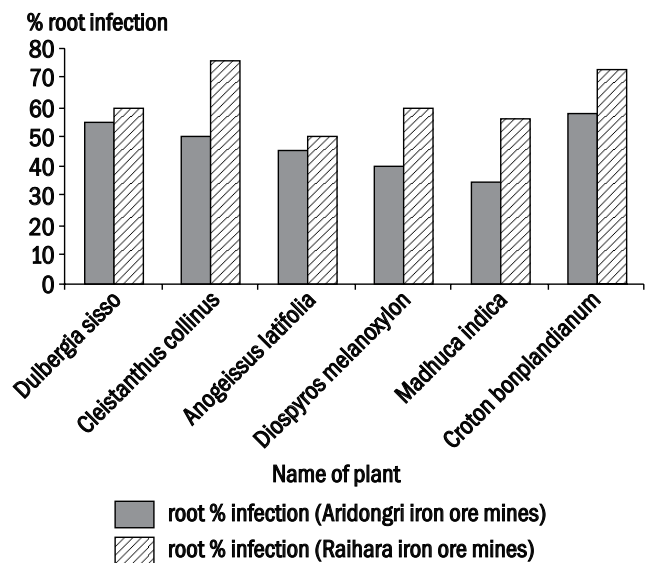


Figure 4 Root percentage infection of mycorrhizal

Conclusion

Following are the important experimental findings of the prevent investigation

- The excessive conductivity and total dissolve solid can also lower the efficiency of applied fertilizer for revegetation, as well as mycorrhiza spore germination.
- Soil testing helps us to know the nutritional status of the soil to assess the profitability of applying a particular nutrient.
- If soil pH is very high there is no use of adding fertilizer for revegetation.

Chhattisgarh is geologically one of the most important terrains in the Indian shield, comprising litho logical sequence ranging in age from archaean to recent. Mineral resources and mining activities from major contribution in industrial and economic development of an area. However, indiscriminate mining of the non-renewable resources not only depletes the natural resources but also involves inevitable disturbances to an ecological set up. Continued advancement in industrialization and the increasing demand for mineral resources have led to a spurd in mining activity, causing imbalance in ecological equilibrium, followed by many environmental hazards.

The restoration of site is difficult if scientifically not attended well in time. The upper surface of the soil is very active and is full of micro-organisms. They develop a particular type of symbiotic relationship which is unique to the type of soil and environmental conditions prevailing in the area, and the stabilization of such symbiotic relationship takes long time to develop mycorrhiza with plant roots. This association helps the plant to establish on sites, such as saline, alkaline, eroded, or distributed due to human activities. The present investigation is proposed with an objective to find out suitable host VAM associations in dominant plant species in selected mines of Chhattisgarh.

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References

- Baruah T C and Borthakur H P. 1997. *A Text Book of Soil Analysis*. New Delhi: Vikas Publishing House. Pp. 334.
- Danielson, R. 1985. *Mycorrhizae and reclamation of stressed terrestrial environments. Ch. In soil reclamation processes*. Ed. by Tate, R. III. and A. Klein. Marcel Dekker, Inc. pp. 173 – 201.
- Department of mineral resources Government of Chhattisgarh.
- Gerdemann JW and Nicolson T H. 1963. *Spore of mycorrhizal endogone species extracted from the soil by wet sieving and decanting*. Transaction British Mycological Society **46**:235-244.
- Jacobsen I. 2004. *Hypal fusion to plant species connection-gaint mycelia and community nutrient flow*. New Phytologist **164**: 4-7.
- Morton J B and Benny G L. 1990. *Revised classification of arbuscular mycorrhizal fungi (Zygomycetes): new order, Glomales two new sub- orders Glomineae and Gigasporineae, and two new families, Aculospororaceae and Gigasporaceae with emendation of Glomaceae*. Mycotaxon **37**: 471-491.
- Mukerjee K G. 1996. *Taxonomy of endomycorrhizal fungi*. In advances in Botany, pp 211-221, edited by K G Mukerjee, B Mathur. B P Chamola, and P Chitralakha. New Delhi: APH Publication Corporation.
- Norland, M. 1993. *Soil factors affecting mycorrhizal use in surface mine reclamation. Bureau of mines information circular*. United States Department of the Interior.
- Phillips J M and Hayman D. J. 1970. *Improved procedure for clearing and staining parasitic and vesicular arbuscular mycorrhizal fungi for rapid assessment of infection*. Transactions of the British Mycological Society **55**: 158-161.
- Schenck N C and Perez Y (eds). 1990. *Manual for identification of VA Mycorrhizal fungi*. 3rdedn. Gainesville, Florida: Synergistic publication.
- Sturges Susan 1997. *The Use of Mycorrhizae in Mined Land Reclamation*. Restoration and reclamation review, student online journal vol. 2, no. 7, spring 1997.

Non-target effect of two fungicides on *Glomus mosseae* colonization of chilli roots

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Introduction

As fungicides either inhibit or kill fungi, they are expected to influence the population and root colonization by Arbuscular Mycorrhizae (AM) fungi. Since AM benefit plants variously by enhancing their nutrient and water status and/or increasing root resistance to soil-borne pathogens, such benefits may be reduced if the AM colonization is hampered. Detrimental effects of several fungicides on AM fungi have been reported previously (Meng, 1982; Kough et al., 1987; Dodd and Jeffries, 1989; Kjoller and Rosendahl, 2000; Chiochio et al., 2000). The activities of Alkaline Phosphatase (ALP) (Thingstrup and Rosendahl, 1994; Kjoller and Rosendahl, 2000), and Succinate Dehydrogenase (SDH) (Kough et al., 1987; Kling and Jakobsen, 1997) in both the external and internal fungal hyphae have been used as criteria for rapid assessment of the effect of fungicides. These enzymes are important because they indicate active fungal metabolism. SDH, a mitochondrial enzyme, is considered an indicator of viability of mycorrhiza (Vierheilig & Ocampo, 1989, Guillemin et al., 1995) while ALP activity, located within the phosphate-accumulating vacuoles of AM hyphae (Gianinazziet al., 1979), has been proposed as a physiological marker for analyzing its efficiency (Tisserant et al., 1993).

Mancozeb, a polymeric dithiocarbamate protectant, and the systemic organ-phosphorus Kitazin are commonly used by local farmers in the management of foliar diseases of chilli. While the non-target effect of the contact fungicide in other crops has been reported, similar effect of systemic Kitazin has not been reported earlier. Hence, one of our objectives was to evaluate the non-target effect these fungicides on mycorrhizal colonization in chilli roots and to record SDH and ALP activity of the fungal structures.

Imaging technique, like laser scanning confocal microscopy (LSCM) using different fluorochromes, has been effectively used to study AM and ECM structures (Czymmek et al., 1994; Kobayashi et al., 1994; Schelkle et al., 1996; Dickson and Kolesik, 1999). Kumar et al., (2008), successfully used and reported the suitability of trypan blue, a non-vital stain, as a dye in fluorescence microscopy. Following their work, we decided to study and compare the

LSCM images of fungicide treated and untreated roots, using trypan blue as a fluorochrome.

Material and Methods

2.1. Experimental set-up

Seeds of *Capsicum annum* (chilli) were surface sterilized, sown into plastic pots (6" height) containing sterilized alluvial soil. *Glomusmosseae*, isolated from the same soil, was mixed with the sterilized soil, seven days before sowing (@ 25g of infected roots pieces of *Zea mays* L + external mycelium and spores/kg of soil). Mancozeb and Kitazin were applied as a single application to the foliage of two-month-old plants with a hand-sprayer, without covering the soil in the pot, at the recommended field-rate concentration of application. A non-fungicidal treatment was set up as control. Each treatment was replicated thrice. The plants were grown in the greenhouse under controlled conditions.

Harvest and Analysis

Root samples were collected randomly from each treatment, per replication, three and fourteen days after fungicidal application. The roots were washed separately in cold tap water, blotted dry, cut into 1 cm segments, and suspended in cold tap water. Each lot was divided into three portions of twenty fragments each. One fraction was cleared by 10% KOH and stained for fungal structures with trypan blue (TB) (Phillips and Hayman 1970). The second was stained for fungal ALP activity (Tisserant et al., 1993) and the third for SDH activity (Macdonald & Lewis, 1978). Established protocols were used for scoring the percentage of colonization by *G. mosseae*, ALP and SDH activity in the root fragments. MYCOCALC online computer program was used to calculate the intensity of the mycorrhizal colonization in the root system (M %) and arbuscule abundance in the root system (A %).

2.3. LSCM study

Root samples for LSCM study were harvested, fourteen days after fungicidal application, from treated and corresponding control plants of the same age. Roots were cleared and stained as mentioned earlier (Phillips and Hayman 1970). TB dye was freshly

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prepared and served as a flouochrome. Laser scanned and bright-field images of the root segments were obtained on a Leica Confocal System-TCS SP2. Emission was observed through high magnification oil-emersion objective using laser beams with 488 and 543 nm excitation wavelengths and a 585 nm Long Pass (LP) emission filter.

2.4. Statistical analysis

Percentage data were arcsine-transformed before analysis and subjected to one-way Analysis of Variance (ANOVA). The treatment means were separated by a Student-Newman-Keul's test.

3. Results

3.1. Effect on AM fungus root colonization and arbuscle formation

Application of both fungicides significantly reduced total mycorrhization in the root system (M %) of chilli plants as compared to the percent colonization in the untreated ones (Table 1). In Kitazin, percentage root colonization further decreased from three to fourteen days after application, while in Mancozeb treatment there was no further reduction in mycorrhization of roots recorded on the fourteenth day after the initial reduction. Arbuscle formation in the roots was significantly reduced by fungicide treatment, the effect being greater in Kitazin than in Mancozeb (Table 1).

3.2. Effect on SDH and ALP activity

In Kitazin treatment, activities of SDH and ALP in the internal hyphae were significantly depressed after three days of fungicide application and a further decrease was recorded in root samples collected fourteen days after application while Mancozeb appeared to have no effect on either of the enzyme activities within the internal hyphae, irrespective of the days after application (Table 1).

While some SDH and ALP activity was recorded in the arbuscles in untreated roots, neither SDH nor ALP- active arbuscles were observed in either of the fungicide treated roots collected three days after application. However, in Mancozeb treated roots, trace SDH and ALP activity was recorded in the arbuscles, fourteen days after application.

3.3. LSCM image analysis

LSCM images (Figure 1) of roots, collected fourteen days after fungicide application, showed bright green fluorescing structures of *G mosseae* only in TB-stained control and Mancozeb treatment. In roots treated with Kitazin, most of the fungal structures did not fluoresce. The fungal structures were clearly visible in the corresponding bright-field images (Figure 1).

4. Discussion

Fungicides have been variously reported to either harmfully effect or have no effect on AM fungi. Tubulin-biosynthesis inhibitor benomyl and its breakdown product carbendazim, the heterocyclic phthalimidecaptan, sterol inhibitors fenpropimorph, and propiconazole are reported to inhibit the internal and external hyphae, hyphal ALP-activity, hyphae, and arbuscle - SDH activity and P uptake at concentrations lower or higher than the recommended field application dosages (Trappe et al., 1984; Kough et al., 1987; Kling and Jakobsen, 1997; Schweiger and Jakobsen, 1998; Kjoller and Rosendahl, 2000). The inhibitory effects of some dithiocarbamates (Ziram and Mancozeb) on root colonization by the fungus and on spore production and germination have also been noted in literature (Sreenivasa and Bagyaraj, 1989; Vijayalakshmi 1993; Giovannetti et al., 2006; Saleh and Al-Garni, 2006). However, fungicides, like the broad-spectrum, strobilurins like azoxystrobin and kresoxim-methyl were not found to affect mycorrhization of crop plants at the recommended dosages (Diedhiou et al., 2004).

Table 1 Mycorrhization, arbuscle formation, SDH and ALP activity in the chilli root system treated with Kitazin and Mancozeb.

Treatment	Mycorrhizal colonization in the root system (M%)						Arbuscule abundance in the root system (A%)					
	Internal hyphae (%)		SDH-active fraction (%)		ALP-active fraction (%)		Arbuscles (%)		SDH-active fraction (%)		ALP-active fraction (%)	
	3	14	3	14	3	14	3	14	3	14	3	14
Control	55.99*a	67.33a	44.54a	48.59a	39.57a	45.81a	23.24a	27.37a	6.56	12.95a	5.70	12.94a
Kitazin	27.25b	22.12b	18.54b	16.56b	15.29b	14.39b	2.12b	0	0	0	0	0
Mancozeb	29.02b	30.30c	24.33c	24.77c	21.31c	23.15c	12.86c	5.71b	0	4.21b	0	2.92b

*Each value is the mean of three replications. Data followed by the same letters within each column were not significantly different (P<0.05, Student Newman-Keuls' test). All percentage values were arc sin transformed before statistical analysis.

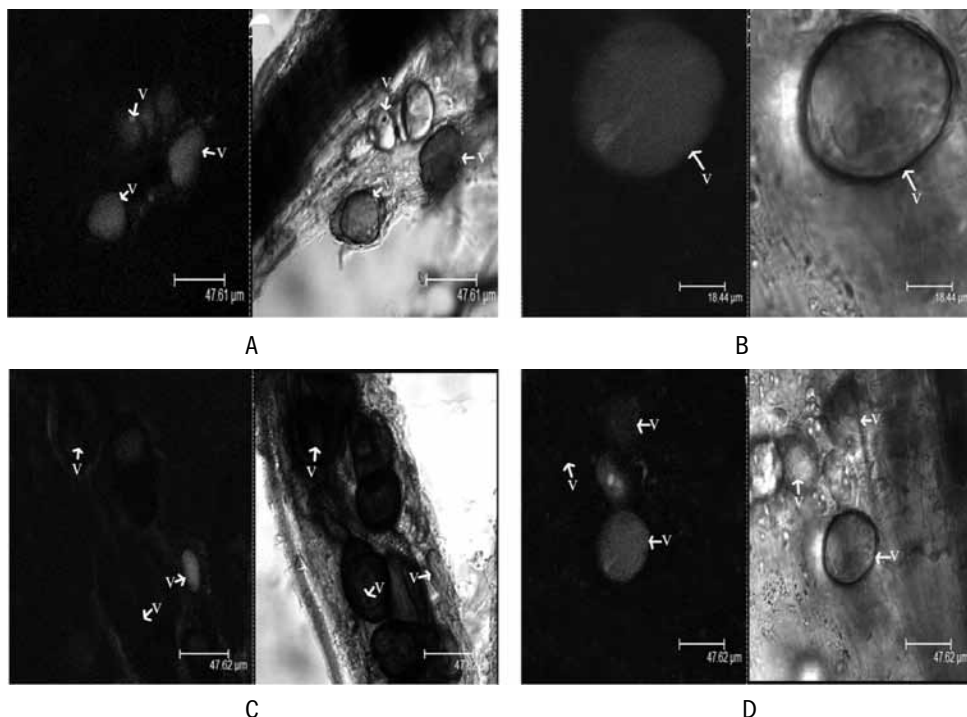


Figure 1 LSCM and bright-field images of chilli roots, fourteen days after fungicide application, showing vesicles (v) of *G. Mosseae*. Untreated (A and B), Kitazin-treated (C) and Mancozeb-treated (D).

In the present experiment, both fungicides were found to reduce root colonization and arbuscule formation by *G. mosseae*, to statistically significant degrees at the recommended field rates of application. These results were in agreement with some of the earlier findings mostly on the effect of mancozeb. SDH and ALP activity in the hyphae appeared to be more sensitive to the systemic than the contact fungicide. However, the apparent reduction in the percentage of SDH-ALP active hyphae in the latter was probably due to the overall reduced fungal colonization. No enzyme activity was recorded in the arbuscules in Kitazin treatment but in Mancozeb treated roots, the effect of the fungicide appeared to wear off with time and low enzyme activity was recorded in the arbuscules after fourteen days.

Assuming that chitin, a major constituent of fungal cell wall, is the chief component stained by TB (Vierheiligt et al., 2001), it could be presumed that fluorescence or non-fluorescence of the mycorrhizal structures could be due to the action of the fungicide directly on chitin cell wall of the fungus. This would cause the differential staining and hence the fungal structures would fluoresce depending on the amount of stain taken up by the cell wall.

The suggested mode of action of Kitazin is inhibition of chitin biosynthesis by inhibiting the incorporation of methioninemethyl-14C into phospholipids, especially phosphatidylcholine (Akatsukao et al., 1977). Treatment with Kitazin, might have either reduced the chitin content and

consequently the thickness of the cell wall or may have resulted in changes in the chitin composition of the walls which affected their capacity to take up the dye.

Mancozeb, an ethylenebisdithiocarbamate (EBDC) group of non-systemic (surface acting) fungicide, acts by being metabolised to an isothiocyanate radical which inactivates the sulphhydryl groups in amino acids contained within individual fungal cells and disrupts lipid metabolism. The overall effect may reduce the infestation and arbuscule formation by the mycorrhizal fungus but since it did not affect the cell wall directly, it did not make any impact on the TB staining of the fungal structure. Therefore, fluorescence was observed.

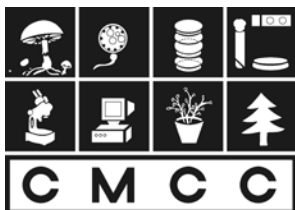
Acknowledgements

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References

- Akatsukao T, Kodama S, and Yamada H. 1977. **A novel mode of action of Kitazin P in *Pyricularia oryzae*.** *Agricultural and Biological Chemistry* 41: 2111 – 2112
- Chiocchio V, Venedikian N, Martinez AE, Menendez A, Ocampo J A, and Godeas A. 2000. **Effect of the fungicide benomyl on spore germination and hyphal length of the arbuscular mycorrhizal fungus *Glomus mosseae*.** *Internat Microbiol* 3:173–175

- Czymmek K J, Whallon J H, and Klomparens K L. 1994. **Confocal microscopy in mycological research.** *Experimental Mycology* 18: 275–293
- Dickson S and Kolesik P. 1999. **Visualisation of mycorrhizal fungal structures and quantification of their surface area and volume using laser scanning confocal microscopy.** *Mycorrhiza* 9: 205–213
- Diedhiou P M, Oerke E C and Dehne H W. 2004. **Effects of the strobilurin fungicides azoxystrobin and kresoximmethylon arbuscular mycorrhiza.** *Z. Pflanzenkrankh. Pflanzenschutz* 111:545–556
- Dodd J C and Jeffries P. 1989. Effects of fungicides on three vesicular–arbuscular mycorrhizal fungi associated with winter wheat. *Biology and Fertility of Soils* 7: 120–128
- Gianinazzi S, Gianinazzi-Pearson V and Dexheimer J. 1979. **Enzymatic studies on the metabolism of vesicular-arbuscular mycorrhiza. III. Ultrastructural localization of acid and alkaline phosphatase in onion roots infected by *Glomus mosseae* (Nicol.&Gerd).** *New Phytologist* 82:127–132
- Giovannetti M A, Turrini P, Strani C, Sbrana L, Avio B, Pietrangeli. 2006. **Mycorrhizal fungi in eco-toxicological studies: Soil impact of Fungicides, Insecticides and Herbicides.** *Prevention Today* 2: 47–62
- Guillemin J P, Orozco M O, Gianinazzi-Pearson V, Gianinazzi S. 1995. **Influence of phosphate fertilization on fungal alkaline phosphatase and succinate dehydrogenase activities in arbuscular mycorrhiza on soybean and pineapple.** *Agriculture, Ecosystems & Environment* 53: 63–69
- Kjoller R and Rosendahl S. 2000. **Effects of fungicides on arbuscular mycorrhizal fungi : Differential responses in alkaline phosphatase activity of internal and external hyphae.** *Biology and Fertility of Soils* 31: 361–365
- Kling M and Jakobsen I. 1997. **Direct application of carbendazim and propiconazole at field rates to the external mycelium of three arbuscular mycorrhizal fungal species: effect on ³²P transport and succinate dehydrogenase activity.** *Mycorrhiza* 7: 33–37
- Kobayashi I, Kobayashi Y and Hardham A. 1994. **Dynamic reorganization of microtubules and microfilaments in flax cells during the resistance response to flax rust infection.** *Planta* 195: 237–247
- Kough J L, Gianinazzi-Pearson V, and Gianinazzi S. 1987. **Depressed metabolic activity of vesicular - arbuscular mycorrhizal fungi after fungicide applications.** *New Phytologist* 106:707–715
- Kumar T, Majumdar A, Das P, Sarafis V, and Ghose M, 2008. **Trypan blue as a fluorochrome for confocal laser scanning microscopy of arbuscular mycorrhizae in three mangroves.** *Biotechnic & Histochemistry* 83: 153–159
- MacDonald R M and Lewis M. 1978. **The occurrence of some acid phosphatases and dehydrogenases in the vesicular-arbuscular mycorrhizal fungus *Glomus mosseae*.** *New Phytologist* 80:135–141
- Meng J A. 1982. **Effect of soil fumigants and fungicides on vesicular arbuscular fungi.** *Phytopathology* 58:522
- Phillips J M and Hayman D S. 1970. **Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular fungi for rapid assessment of infection.** *Transactions of the British Mycological Society* 55:158–161
- Saleh M Saleh and Al-Garni. 2006. **Influence of Malathion and Mancozeb on mycorrhizal colonization and growth of *Zea mays* and *Vicia faba*.** *World Journal of Agricultural Sciences* 2(3): 303–310
- Schelkle M, Ursie M, Farquhar M, and Peterson L. 1996. **The use of laser confocal microscopy to characterize mycorrhizas of *Pinus strobus* L. and to localize associated bacteria.** *Mycorrhiza* 6: 431–440
- Schweiger P F and Jakobsen I. 1998. **Dose-response relationships between four pesticides and phosphorus uptake by hyphae of arbuscular mycorrhizas.** *Soil Biology & Biochemistry* 30: 1415–1422
- Sreenivasa M N and Bagyaraj D J. 1989. **Use of pesticides for mass production of VAM inoculum.** *Plant and Soil* 119:127–32
- Tisserant B, Gianinazzi-Pearson V, Gianinazzi S, Gollotte A. 1993. **In plant histochemical staining of fungal alkaline phosphatase activity for analysis of efficient arbuscular mycorrhizal infections.** *Mycological Research* 97: 245–250
- Thingstrup I and Rosendahl S. 1994. **Quantification of fungal activity in arbuscular mycorrhizal symbiosis by polyacrylamide electrophoresis and densitometry of malate dehydrogenase.** *Soil Biology & Biochemistry* 26:1483–1489
- Trappe J M, Molina R, and Castellano M. 1984. **Reactions of mycorrhizal fungi and mycorrhiza formation to pesticide.** *Annual Review of Phytopathology* 22:331–359
- Vierheilig H, Knoblauch M, Juergensen K, VanBel A J E, Grundler F M W, Piche Y. 2001. **Imaging arbuscular mycorrhizal structures in living roots of *Nicotiana tabacum* by light, pifluorescence and confocal laser scanning microscopy.** *Canadian Journal of Botany* 79: 231–237
- Vierheilig H and Ocampo J A. 1989. **Relationship between SDH-activity and VA Mycorrhizal infection** *Agriculture, Ecosystems & Environment* 29: 439–442
- Vijayalakshmi M. 1993. **Effects of six insecticides and one fungicide (Ziram) on development of VAM in *Arachis hypogea*.** *Zentralblatt für Mikrobiologie* 148:60–5



CENTRE FOR MYCORRHIZAL CULTURE COLLECTION

Grasses: a trusted model plant for Mycorrhiza study

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In this edition, we would like to communicate to our readers the significance and role of the appropriate selection of a host plant towards successful symbiosis amidst the plant and Mycorrhiza. As we all know, the occurrence of this mutualism dates back to 400 million years. Barring a few families in the plant Kingdom, almost all types of flora choose to get involved in this symbiosis due to the enormous benefits that are imparted to the plant by this miracle fungus. The major outcome of this plant–fungus association involves the translocation of carbon from the plant to the fungus and also enhances uptake and transport of soil nutrients, primarily phosphorus, to the plant via the fungus. Other potential benefits of fungal colonization to host plants include improved uptake of poorly mobile nutrients such as zinc and copper, improved plant water relations, and reduced pathogenic infections.

Why do we need to think about the host at this point of time? The unpretentious answer would be, “as a collection bank, we are in hunt of a host that would be a WonderWand and can reproduce oodles of spores/inoculum from the single spore that we use to develop pure culture”. In one of our last editions, we had taught the art of raising monospores. The major prerequisite for being a suitable host for inoculum production would be, primarily, the capability of rapidly being colonized and furthermore the root architecture of the plant should be such, that it has fine roots with good biomass. In order to search for one, we decided to review literature and find out the most favourite host on which researchers have done most of their Mycorrhizal studies. To our amazement we found that quite a large number of research articles rivet around plants belonging to Graminoids, more commonly known as grasses.

Grasses are monocotyledonous, usually herbaceous plants with narrow leaves growing from the base. They are conventionally categorized into three types. The first category includes the ‘true grasses’ of the Poaceae (or Gramineae) family, the second refer to the sedges (Cyperaceae), and the third is the rushes (Juncaceae). The true grasses include cereals, bamboo,

and the grasses of the lawns (turf) and grasslands. Sedges include many wild marsh and grassland plants, and some cultivated ones such as water chestnut (*Eleocharis dulcis*) and papyrus sedge (*Cyperus papyrus*). After reviewing deeper, we comprehended that on one end the true grasses are considered to be an exceptional host for Mycorrhiza, and on the other hand both sedges as well as rushes are found to be incapable of having any symbiosis with Mycorrhiza. Hence, the statement that all grasses can be mycorrhized would be highly incorrect and deleterious.

Grasses are primarily divided into two physiological groups—C3 and C4—depending upon the photosynthetic pathway they follow during carbon fixation. The C4 grasses are considered to be warm season grasses and grow in atmospheres which are low in carbon dioxide, e.g., corn, Sudan grass, pearl millet, etc. Similarly, C3 grasses are referred to as ‘cool-season’ grasses, e.g., wheat, rye, oat, lolium, etc. Certain studies done on the tallgrass of prairie plants have demonstrated that all grass types belonging to the Poaceae get colonized in the presence of mycorrhiza but their dependence on mycorrhizal symbiosis for nutrient acquisition and growth differs. The warm-season, grasses C4 are extremely dependent (obligate mycotrophs) on mycorrhiza symbiosis, whereas cool-season grasses C3 are significantly less dependent on the symbiosis (facultative mycotrophs) (Kitt, and Wilson, 1988; Wilson, and Todd, 1990). Hence, we infer that it may be advisable to select the warm season grasses for maintaining cultures for inoculum production.

While trying to analyse the different grass varieties that have been used for taking up mycorrhizal studies, we found that a lot of research has been done on Bermuda grass (*Cynodon dactylon* L). It is an important turfgrass widely used in playgrounds and greenbelt areas. It has been found that the coarse root of these grasses show good colonization with correspondingly high plant performance in terms of grass establishment, root growth, fertilizer utilization, cover percentage, drought, nematode, and disease resistance (Jin Wu et

al., 2011). A series of grasses that include *Dasyochloa pulchella*, *Bouteloua barbata*, *Chloris virgata*, *Scleropogon brevifolius*, *Pleuraphis mutica*, *Trichloris crinite*, *Prosopis glandulosa* var. *torreyana*, *Flourensia cernua*, *Lippia graveolens*, and *Larrea tridentate* were used in a study to prove a hypothesis that plant species are more responsive to mycorrhiza in late than in early succession stages (Fabiana Pezzani et al., 2006). We would not elaborate on this hypothesis, but mention here that the grasses mentioned were all of the warm-season variety.

One of the areas where there has been some very extensive study on the interaction of Mycorrhiza and the tall grasses is the Prairie region. A microcosms was created using different species of grasses *Andropogon gerardii* (C4), *Sorghastrum nutans* (C4), *Koeleria pyramidata* (C3), and *Poa pratensis* (C3) to investigate the influence of arbuscular mycorrhizal fungi on plant species composition, relative abundances, and diversity (Wilson and Hartnett, 1997). On similar grounds, another study was conducted in which the effects of five different host plant species *Poa pratensis* L., *Sporobolus heterolepis*, *Panicum virgatum* L., *Baptisia bracteata* Muhl., and *Solidago missouriensis* were analysed on spore communities of AM fungi in tallgrass of prairie. Spore abundances and species composition of fungal communities of soil samples collected from patches within tallgrass prairie were significantly influenced by the host plant species that dominated the patch. The AM fungal spore community associated with *B bracteata* showed the highest species diversity and the fungi associated with *Pa virgatum* showed the lowest diversity. These results strongly suggest that AM fungi show some degree of host-specificity and are not randomly distributed (AH Eom et al., 2000). Another arena where a lot of research has been done is the effect of Mycorrhiza on pathogen. Grasses like *vulpia ciliata* spp *ambigua* has been inoculated with *fusarium oxysporum* and it was found that AMF alters the root infecting mycoflora. In one of the articles about impact of host species on the culture of arbuscular fungi mentioned in the INVAM site, it was concluded that widely used tropical hosts plants for AMF studies included, *Stylosanthes* species, *bahia grass* (*Paspalum notatum*), and *kudzu* (*Pueraria phaseoloides*). Under conditions of low-light intensity and cooler

temperatures, *Plantago lanceolata* appears to be a highly suited host. *Andropogon gerardii* (big bluestem), a C4 plant is also widely accepted since it is very similar to Sudan grass and has high mycorrhizal dependency.

This short review of literature proves that the success story of symbiosis between grasses and mycorrhiza is infinite. Trying to enlist all the grasses that have been used by different researchers till date in doing Mycorrhizal research is a Herculean task. But, we would like to conclude that grasses as host recommendation should be done after evaluating every parameter which is responsible for its growth since results and practices are not pertinent to every circumstance. However, we personally always prefer C4 grasses over C3.

Bibliography

- Kitt DG and Wilson GWT. 1988. **Mycorrhizal dependence and growth habit of warm-season and cool-season tallgrass prairie plants.** *Canadian Journal of Botany* **66**: 1376–1380
- Wilson and Todd TC. 1990. **Differential responses of C3 and C4 grasses to mycorrhizal symbiosis, P fertilization, and soil microorganisms.** *Canadian Journal of Botany* **68**: 461–467
- Eom AH, Hartnett DC, and Wilson GWT. 2000. **Host plant species effects on arbuscular mycorrhizal fungal communities in tallgrass prairie.** *Oecologia* **122** (3): 435–444
- Pezzani Fabiana, Montaña Carlos, and Guevara Roger. 2006. **Associations between arbuscular mycorrhizal fungi and grasses in the successional context of a two-phase mosaic in the Chihuahuan Desert.** *Mycorrhiza* **16**: 285–295
- Jin WU, Bin Sun, Yutao Wang, and Guorong Xin. 2011. **Arbuscular mycorrhizal fungal colonization improves regrowth of bermudagrass (*Cynodon dactylon* L.) after cutting.** *Pakistan Journal of Botany* **43**(1): 85–93
- Wilson GWT and Hartnett DC. 1997. **Effects of mycorrhizae on plant growth and dynamics in experimental tallgrass prairie microcosms** *American Journal of Botany* **84** (4): 478–482
- <http://invam.caf.wvu.edu/otherinfo/articles/host.htm>

Announcement

We are proud to announce the availability of different pure Arbuscular Mycorrhizal Cultures for researchers who are interested in conducting research in the field of Mycorrhiza. The present cultures include:

- *Glomus intraradices*
- *Glomus etunicatum*
- *Funneliformis mosseae*
- *Glomus coronatum*
- *Glomus hoi*
- *Diversispora spurca*

These spores are available in two convenient sample sizes of 1000 and 2000 spores mixed with 100 gms of inert soil substrate.

* Please check the next issue for additions to the existing list.

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.

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- *Applied Soil Ecology*
- *Current Opinion in Plant Biology*
- *Environmental and Experimental Botany*
- *European Journal of Soil Biology*
- *Fungal Ecology*
- *Fungal Genetics and Biology*
- *Industrial Crops and Products*
- *Journal of Hazardous Materials*
- *Journal of Plant Physiology*
- *Pedobiologia*
- *Pedosphere*
- *Scientia Horticulturae*
- *Soil Biology and Biochemistry*

Name of the author(s) and year of publication	Title of the article, name of the journal, volume number, issue number, page numbers (address of the first author or of the corresponding author, marked with an asterisk)
Abbaspour H, Saeidi-Sar S, Afshari H, Abdel-Wahhab M A. 2012	Tolerance of Mycorrhiza infected Pistachio (<i>Pistacia vera</i> L) seedling to drought stress under glasshouse conditions. <i>Journal of Plant Physiology</i> 169 (7): 704–709 [Department of Biology, Damghan Branch, Islamic Azad University, Damghan, Iran]
Angela Cicutelli, Guido Lingua, Valeria Todeschini, Stefania Biondi, Patrizia Torrigiani, Stefano Castiglione. 2012	Arbuscular mycorrhizal fungi modulate the leaf transcriptome of a <i>Populus alba</i> L clone grown on a zinc and copper-contaminated soil. <i>Environmental and Experimental Botany</i> 75 : 25–35 [Dipartimento di Chimica, Università di Salerno, Stecca 8, Via Ponte don Melillo, 84084 Fisciano (SA), Italy]
Arocena J M, Velde B, Robertson S J. 2012	Weathering of biotite in the presence of arbuscular mycorrhizae in selected agricultural crops. <i>Applied Clay Science</i> 64 : 12–17 [University of Northern British Columbia, Prince George, BC, Canada V2N4Z9]
Carocho Márcio, Ferreira Isabel C.F.R., Barros Lillian, Barreira João C.M, Martins Anabela. 2012	Antioxidants in <i>Pinus pinaster</i> roots and mycorrhizal fungi during the early steps of symbiosis. <i>Industrial Crops and Products</i> 38 : 99–106 [CIMO-ESA, Instituto Politécnico de Bragança, Campus de Santa Apolónia, Apartado 1172, 5301-855 Bragança, Portugal]
Cartmill Donita L, Alarcón Alejandro, Volder Astrid, Valdez-Aguilar Luis A, Arnold Michael A, Cartmill Andrew D. 2012	Arbuscular mycorrhizal fungi alleviate growth of <i>Ulmus parvifolia</i> Jacq. at suboptimal planting depths. <i>Scientia Horticulturae</i> 144 : 74–80 [School of Agriculture, University of Wisconsin-Platteville, Platteville, WI 53818, United States]
Carvalho Filipa Arminda, Ferreira C F R Isabel, Barreira João C M, Barros Lillian, Martins Anabela. 2012	Evaluation of the chemical interactions in co-culture elements of <i>Castanea sativa</i> Miller mycorrhization. <i>Industrial Crops and Products</i> 42 : 105–112 [CIMO-ESA, Instituto Politécnico de Bragança, Campus de Santa Apolónia, Apartado 1172, 5301-855 Bragança, Portugal]
Eftekhari M, Alizadeh M, Ebrahimi P. 2012	Evaluation of the total phenolics and quercetin content of foliage in mycorrhizal grape (<i>Vitis vinifera</i> L) varieties and effect of postharvest drying on quercetin yield. <i>Industrial Crops and Products</i> 38 : 160–165 [Department of Horticulture, Faculty of Plant Production, Gorgan University of Agricultural Sciences and Natural Resources (GUASNR), Golestan, Gorgan, Islamic Republic of Iran]
Fujimura Kei E, Egger Keith N. 2012	Host plant and environment influence community assembly of High Arctic root-associated fungal communities. <i>Fungal Ecology</i> 5 (4): 409–418 [Ecosystem Science & Management Program, University of Northern British Columbia, Prince George, BC, V2N 4Z9, Canada]
Geurts Rene, Lillo Alessandra, Bisseling Ton. 2012	Exploiting an ancient signalling machinery to enjoy a nitrogen fixing symbiosis. <i>Current Opinion in Plant Biology</i> 15 (4): 438–443 [Wageningen University, Department of Plant Science, Laboratory of Molecular Biology, Droevendaalsesteeg 1, 6709BP Wageningen, The Netherlands]

Name of the author(s) and year of publication	Title of the article, name of the journal, volume number, issue number, page numbers (address of the first author or of the corresponding author is marked with an asterisk)
Jefwa J M, Okoth S, Wachira P, Karanja N, Kahindi J, Njuguini S, Ichami S, Mung'atu J, Okoth P, Huising J. 2012	Impact of land use types and farming practices on occurrence of arbuscular mycorrhizal fungi (AMF) Taita-Taveta district in Kenya <i>Agriculture, Ecosystems & Environment</i> 157: 32–39 [CIAT-Tropical Biology and Fertility Institute (TSBF), P.O. Box 823-00621, Nairobi, Kenya]
Juge C, Prévost D, Bertrand A, Bipfubusa M, Chalifour F P. 2012	Growth and biochemical responses of soybean to double and triple microbial associations with <i>Bradyrhizobium</i>, <i>Azospirillum</i>, and arbuscular mycorrhizae. <i>Applied Soil Ecology</i> 61:147–157 [Agriculture and Agri-Food Canada, 2560 Hochelaga Blvd, Québec City, QC, Canada G1V 2J3]
Lanfranco Luisa, Young J Peter W. 2012	Genetic and genomic glimpses of the elusive arbuscular mycorrhizal fungi <i>Current Opinion in Plant Biology</i> 15(4): 454–461 [Dipartimento di Scienze della Vita e Biologia dei Sistemi, Università di Torino, and IPP-CNR, Viale Mattioli 25, 10125 Torino, Italy]
Martin S L, Mooney S J, Dickinson M J, West H M. 2012	The effects of simultaneous root colonisation by three <i>Glomus</i> species on soil pore characteristics. <i>Soil Biology and Biochemistry</i> 49: 167–173 [School of Biosciences, University of Nottingham, Sutton Bonington Campus, Leicestershire, LE12 5RD, UK]
Martin Sarah L, Mooney Sacha J, Dickinson Matthew J, West Helen M. 2012	Soil structural responses to alterations in soil microbiota induced by the dilution method and mycorrhizal fungal inoculation. <i>Pedobiologia</i> 55(5): 271–281 [School of Biosciences, University of Nottingham, Sutton Bonington Campus, Leicestershire LE12 5RD, UK]
Plett Jonathan M, Gibon Julien, Kohler Annegret, Duffy Kecia, Hoegger Patrik J, Velagapudi Rajesh, Han James, Kües Ursula, Grigoriev Igor V, Martin Francis. 2012	Phylogenetic, genomic organization, and expression analysis of hydrophobin genes in the ectomycorrhizal basidiomycete <i>Laccaria bicolor</i> <i>Fungal Genetics and Biology</i> 49(3): 199–209 [INRA, UMR 1136 INRA – University Henri Poincaré, Interactions Arbres/Microorganismes, INRA-Nancy, 54280 Champenoux, France]
Rafiqi Maryam, Ellis Jeffrey G, Ludowici Victoria A, Hardham Adrienne R, Dodds Adrienne R. 2012	Challenges and progress towards understanding the role of effectors in plant-fungal interactions. <i>Current Opinion in Plant Biology</i> 15(4): 477–482 [Institute of Phytopathology and Applied Zoology, Research Centre for BioSystems, LandUse, and Nutrition, Justus Liebig University, Giessen, Germany]
Schneider Jerusa, Labory Claudia Regina Gontijo, Rangel Wesley Melo, Alves Eduardo, Guilherme Luiz Roberto Guimarães. 2012	Anatomy and ultrastructure alterations of <i>Leucaena leucocephala</i> (Lam.) inoculated with mycorrhizal fungi in response to arsenic-contaminated soil. <i>Journal of Hazardous Materials</i> , In Press, Corrected Proof, Available online 4 June 2012 [Departamento de Ciência do Solo, Universidade Federal de Lavras (UFLA), PO Box 3037, Lavras, Minas Gerais, 37200-000, Brazil]
Sene Godar, Samba-Mbaye Ramatoulaye, Thiao Mansour, Khasa Damase, Kane Aboubacry, Manga Anicet, Mbaye Mame Samba, Sylla Samba Ndao. 2012	The abundance and diversity of legume-nodulating rhizobia and arbuscular mycorrhizal fungal communities in soil samples from deforested and man-made forest systems in a semiarid Sahel region in Senegal. <i>European Journal of Soil Biology</i> 52: 30–40 [Laboratoire Commun de Microbiologie LCM IRD/ISRA/UCAD, Bel-Air BP 1386, CP 18524, Dakar, Sénégal]
Timling Ina, Taylor D. Lee. 2012	Peeking through a frosty window: molecular insights into the ecology of Arctic soil fungi. <i>Fungal Ecology</i> 5(4): 419–429 [Institute of Arctic Biology, University of Alaska, Fairbanks, AK 99775, USA]
Veresoglou S D. 2012	Arbuscular Mycorrhiza Prevents Suppression of Actual Nitrification Rates in the (Myc-)Rhizosphere of <i>Plantago lanceolata</i> . <i>Pedosphere</i> 22(2): 225–229 [Faculty of Agriculture, Laboratory of Ecology and Environmental Protection, Aristotle University of Thessaloniki, 541 24 Thessaloniki]

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Veresoglou Stavros D, Chen Baodong, Rillig Matthias C. 2012	Arbuscular mycorrhiza and soil nitrogen cycling. <i>Soil Biology and Biochemistry</i> 46 : 53–62 [Freie Universität Berlin – Institut für Biologie, Dahlem Center of Plant Sciences, Plant Ecology, Altensteinstr. 6, D-14195 Berlin, Germany]
Veresoglou Stavros D, Shaw Liz J, Hooker John E, Sen Robin. 2012	Arbuscular mycorrhizal modulation of diazotrophic and denitrifying microbial communities in the (mycor)rhizosphere of <i>Plantago lanceolata</i> <i>Soil Biology and Biochemistry</i> 53 : 78–81 [Division of Biology and Conservation Ecology, School of Science and the Environment, Manchester Metropolitan University, Manchester M1 5GD, UK]
Vos Christine, Broucke Daphné Van Den, Lombi Franklin Mbongo, Waele Dirk De, Elsen Annemie. 2012	Mycorrhiza-induced resistance in banana acts on nematode host location and penetration. <i>Soil Biology and Biochemistry</i> 47 : 60–66 [Laboratory of Tropical Crop Improvement, Department of Biosystems, University of Leuven, Kasteelpark Arenberg 13, 3001 Leuven, Belgium]
Wakelin Steve, Mander Carolyn, Gerard Emily, Jansa Jan, Erb Angela, Young Sandra, Condrón Leo, O’Callaghan Maureen. 2012	Response of soil microbial communities to contrasted histories of phosphorus fertilisation in pastures. <i>Applied Soil Ecology</i> 61 : 40–48 [AgResearch Ltd, Lincoln Science Centre, Cnr Springs Road and Gerald Street, Private Bag 4749, Christchurch 8140, New Zealand]
Zhang Guoyi, Raza Wasim, Wang Xiaohui, Ran Wei, Shen Qirong. 2012	Systemic modification of cotton root exudates induced by arbuscular mycorrhizal fungi and <i>Bacillus vallismortis</i> HJ-5 and their effects on <i>Verticillium</i> wilt disease. <i>Applied Soil Ecology</i> 61 : 85–91 [Jiangsu Key Lab for Organic Solid Waste Utilization, College of Resources and Environmental Sciences, Nanjing Agricultural University, Nanjing 210095, PR China]
Zubek Szymon, Stefanowicz Anna M, Błaszowski Janusz, Niklińska Maria, Seidler-Łożykowska Katarzyna. 2012	Arbuscular mycorrhizal fungi and soil microbial communities under contrasting fertilization of three medicinal plants. <i>Applied Soil Ecology</i> 59 : 106–115 [Laboratory of Mycology, Institute of Botany, Jagiellonian University, Lubicz 46, 31-512 Kraków, Poland]

FORTHCOMING EVENTS

CONFERENCES, CONGRESSES, SEMINARS, SYMPOSIUMS, AND WORKSHOPS

- Gandhinagar, Gujarat, India
3-6 September 2012 **Agritech Asia 2012**
Website <http://www2.kenes.com/agritech-asia>
- Istanbul, Turkey
3-7 September 2012 Food Microbiology World Congress 2012
Prof. Dr. Dilek Heperkan, Chair. Istanbul Technical University, Chemical and Metallurgical Engineering Faculty, Department of Food Engineering, Maslak / Istanbul / Turkey
Tel. +90 212 285 6041 • *Fax* +90 212 285 2925
Email heperkan@itu.edu.tr • *Website:* <http://www.foodmicro2012.com>
- Poland
10-12 September 2012 **International Conference on Biotechnology and plant breeding perspectives towards food security and sustainability**
Karolina Mitura
Email: k.mitura@ihar.edu.pl or Agata Krukowska at email: a.krukowska@ihar.edu.pl
http://www.ihar.edu.pl/en/international_conference_on_biotechnology_and_plant_breeding_perspectives_towards_food_security_and_sustainability_september_2012.php
- Fremantle, Australia
17-20 September 2012 **7th Australasian Soilborne Diseases Symposium**
Australian Society for Microbiology, 210/55 Flemington Road, North Melbourne VIC, Australia 3051
Tel. 1300 656 423 • *Fax* 1300 655 841
Email: admin@theasm.com.au • *Website:* <http://www.theasm.org.au/Meetings/calendar/2012-ASDS>
- Turkey
23-26 September 2012 **15th European Congress on Biotechnology**
Em. Prof. Marc Van Montagu, President of European Federation of Biotechnology, The Grand Cevahir Hotel and Congress Center, Darülaceze Cad. No: 9 Okmeydanı / Şişli, İstanbul / Türkiye
Tel. +90 312 219 57 00/385 • *Fax* +90 312 219 57 01
Email gozde@zed.com.tr • *Website:* <http://www.ecb15.org/>
- Nairobi, Kenya
22-26 October 2012 **Integrated Soil Fertility Management in Africa: From Microbes to Markets (ISFM Africa)**
Dr Saidou Koala, Co-chair
Prof. Nancy Karanja, Coordinator of AABNF 15 Sessions, International Centre for Tropical Agriculture. c/o: ICIPE Duduville Complex, off Kasarani Road, PO Box 823-00621, Nairobi, Kenya
Tel. +254-20-8632800 • *Cell:* +254-72157496 • *Website:* <http://www.ISFMAfrica2012.org/>
- University College Cork, Ireland
14-16 November 2012 **Marine Microbiology and Biotechnology; Biodiscovery, Biodiversity and Bioremediation**
Tel. 353 (0)21 4901972 • *Fax* 353 (0)21 4901932
Email mmb2012@ucc.ie • *Website:* <http://www.ucc.ie/en/mmbiotech2012/>
- Chiang Mai, India
14-18 November 2012 **ICAPS - 2012 — International Conference on Advances in Plant Sciences**
<http://www.plants2012.com>
- New Delhi, India
6-12 January 2013 **International Conference on Mycorrhiza – ICOM-7**
Dr Alok Adholeya, Director, Biotechnology & Bioresources, Centre for Mycorrhizal Research, The Energy and Resources Institute (TERI), Darbari Seth Block India Habitat Centre, Lodhi Road, New Delhi-110 003, India
Tel. +11 (0) 24682100, • *Cell:* 9811628889 • *Fax* +44 (0) 24682145
Email aloka@teri.res.in • *Website:* www.teriin.org
- Arusha, Tanzania.
28 January -1 February 2013 **International Plant Virus Epidemiology Symposium**
Website <http://www.iita.org/ipve>
- Dubai, UAE
18-21 February 2013 **2nd Biotechnology World Congress**
P.O. Box 121223, SAIF Zone, Sharjah, U.A.E.
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Email: info@biotechworldcongress.com or mahmood@biotechworldcongress.com
Website: www.biotechworldcongress.com
- Singapore.
18-19 March 2013 **3rd Annual International Conference on Advances in Biotechnology BIOTECH 2013**
Global Science & Technology Forum (GSTF), 10 Anson Road, International Plaza, Singapore 079903
Tel. +65 6327 0166 • *Fax* +65 6327 0162
Email: secretariat@advbiotech.org, info@advbiotech.org • *Website:* <http://www.advbiotech.org>
- Sitges (near Barcelona), Spain
13-15 May 2013 **BITE2013 — 3rd International Conference on Bio-Sensing Technology**
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