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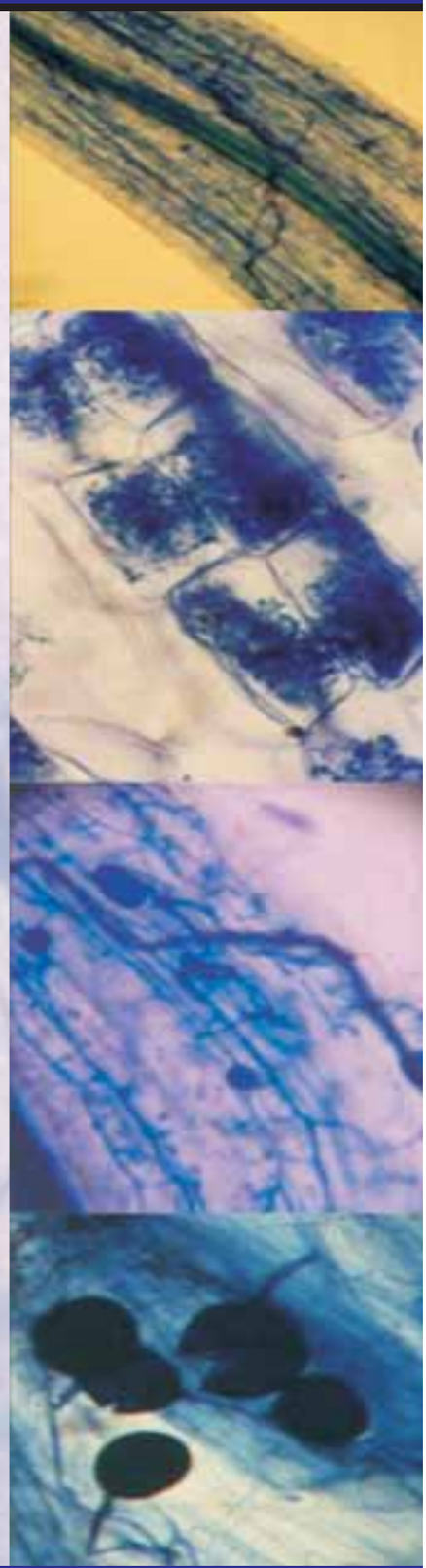

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**Mycorrhiza News**

The Mycorrhiza News provides a forum for dissemination of scientific information on mycorrhiza research and activities; publishes significantly important papers from eminent scientists, notes on important breakthroughs, brief accounts of new approaches and techniques, papers compiled from the RIZA database. It also 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

## Taxonomic series: *Glomus* from Goa

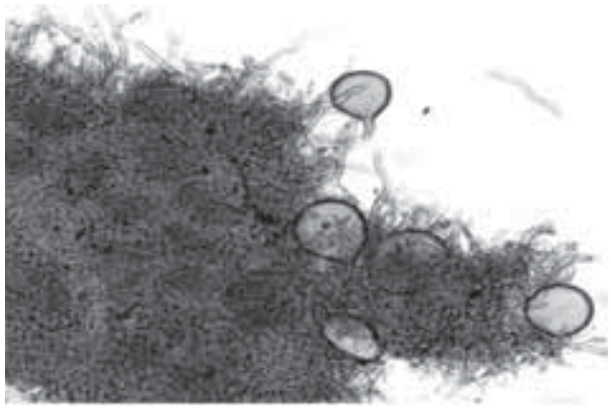

*Sharda W Khade**


### *6. Glomus coremioides* (Berk. and Broome) Redecker, Morton, and Bruns

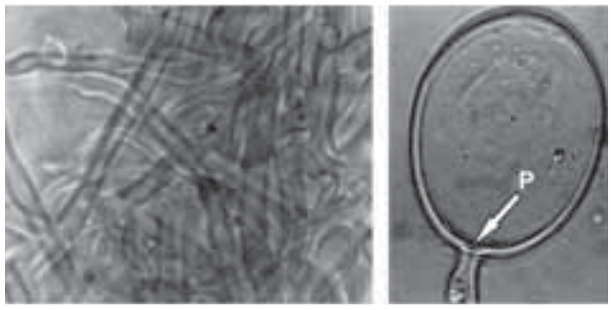
*Mycologia* **92:** 282–285, 2000 (Plate 6).

The sporocarps are 300–600 µm broad, pulvinate to subglobose, flattened at the base, and are borne on a short stalk of up to 100 µm. The stalk is normally absent in hypogaeous sporocarps. The sporocarps are white when immature and tan to dull brown (sometimes dark brown) when formed singly in soil (Plate 6a). When mature, the sporocarps become expensive in mats containing a large number fused together laterally and vertically, forming columns of up to four sporocarps.

The peridium of the sporocarps is 20–70 µm thick and composed of thick walled, sparingly septate interwoven hyphae that are 4–10 µm in diameter (Plate 6b). The chlamydospores are 65–100 µm × 40–75 µm in diameter, obvoid-ellipsoid to oblong-ellipsoid in shape, and are often but not always separate from the subtending hyphae by septa present below the spore base (Plate 6c). In most cases, the pore is present at the point of attachment of the hypha to the chlamydospores (Plate 6c). The chlamydospores are arranged in a single layer and are tightly grouped in a hemisphere around a central plexus of hyphae. Spores are absent at the base of the sporocarp. The brown chlamydospore wall is up to 4 µm thick at the base and 2 µm thick at the apex.



(a)




(b) (c)

**Plate 6 (a)** Crushed sporocarp of *Glomus coremioides* with peridial hypha interspersed with chlamydospores (× 200). **Plate 6 (b)** Peridial hyphae of *Glomus coremioides* (× 1000). **Plate 6 (c)** A non-septate chlamydospore of *Glomus coremioides* (× 1000). [Note the presence of pore (P) at the point of attachment of the hypha to the chlamydospore.]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***Distinguishing feature*** Presence of peridium enclosing non-septate spores.

***Distribution*** Recorded in (1) December from Valpoi, Old Goa, Quepem, Colva, Kodar, and Collem (83.33% frequency of occurrence), (2) April and October from Valpoi (50% frequency of occurrence), (3) January, April, July, and October from Kodar (75% frequency of occurrence), (4) January, April, and July from Old Goa (75% frequency of occurrence), and (5) June, July, August, and September from Old Goa (100% frequency of occurrence).

***Association*** Found in association with *Carica papaya* L. plants in the Western Ghats of Goa, India.

## *7. Glomus liquidambaris* (Wu and Chen) Almeida and Schenck

*Mycologia* **82**:703–714, 1990
= *Glomus cunninghamia* (Hu)
*Quarterly Journal of Chinese Forestry* **21**: 45–72, 1988 (Plate 7).

Sporocarps are globose to subglobose, 300–440 µm × 310–600 µm in diameter, golden brown to brown, consist of chlamydospores formed radially within the paraphysis-like structures (Plate 7d) that are cylindro-clavate to spathulate, thick walled, up to 200 µm long, and protrude from the central plexus of hyphae through the chlamydospore layer (Plates 7a, 7d, and 7e). The apices of paraphysis-like structure are also tightly packed into the peridium (Plates 7a, 7d, and 7e) enclosing the sporocarp. Chlamydospores are ellipsoid to obovoid (Plates 7b and 7c), yellowish-brown to reddish-brown, sometimes with septum at the base, and 35–56 µm × 60–135 µm in diameter. Chlamydospore walls are brown to reddish-brown, 7–30 µm, 6–10 µm, and 2–5 µm thick at the apices, base, and sides, respectively (Plate 7c). Subtending hypha is 4–10 µm diameter.

***Distinguishing feature*** Presence of paraphysis tufts enclosing the peridium and sporocarp.

***Distribution*** Recorded in December from Collem with 16.66% frequency of occurrence.

***Association*** Found in association with *C. papaya* L. plants in the Western Ghats of Goa, India.

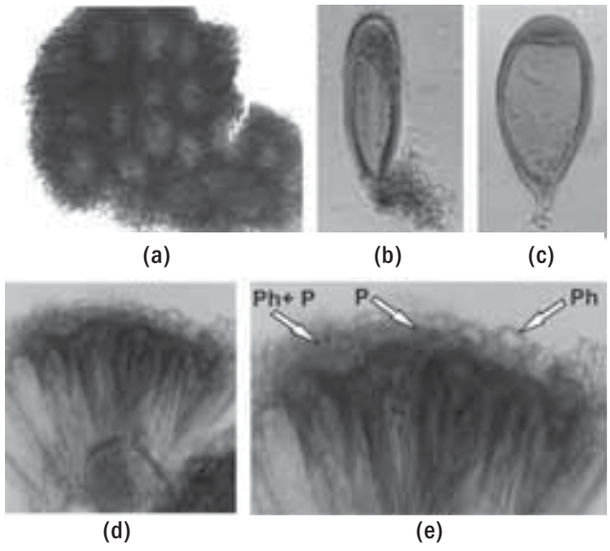



**Plate 7 (a)** Sporocarp with paraphysis-like structures protruding from the central plexus of hyphae through the chlamydospore layer (× 400).
**Plate 7 (b)** A young chlamydospore of *Glomus cunninghamia* (× 400).
**Plate 7 (c)** An old chlamydospore of *Glomus cunninghamia* with thickened apex (× 400).
**Plate 7 (d)** Portion of sporocarp showing the radially arranged thick apexed chlamydospores (× 400)
**Plate 7 (e)** Portion of sporocarp with paraphysal hyphae (Ph) tightly appressed into peridium (P) enclosing chlamydospores (× 600). [Note the portion of sporocarp where the paraphysal hyphae (Ph) and the peridium (P) are seen separately.]

## *8. Glomus coremioides* (Berk. and Broome) Redecker, Morton, and Bruns

*Mycologia* **92:** 282–285, 2000
= *Sclerocystis dussii* (Patouillard) Von Hőnnel
*Mycologia* **5:** 76, 1974 (Plate 8)

Sporocarps are 250–500 µm broad, globose, pyriform or pulvinate to subglobose (Plate 8a). They are single or fused together laterally and vertically to a depth of 3 or 4, forming a tuberculate crust on the soil surface (Plate 8b). They are white when young and acquire a light brown colour on maturing or when bruised. The upper surface of the crust is covered with thin-walled vesicles of up to 340 µm × 77 µm in diameter, globose when young and obovoid, ellipsoid, clavate or broadly clavate with rounded tips when mature. The peridium of individual sporocarps is a 20–60 µm thick and composed of thick walled interwoven hyphae (Plate 8a).

The chlamydospores are hyaline to yellow, 50–80 µm × 32–54 µm in diameter, obovate to clavate, ellipsoid or oblong-ellipsoid (Plates 8c, 8d, and 8e). They are cut off from subtending hypha by septa just

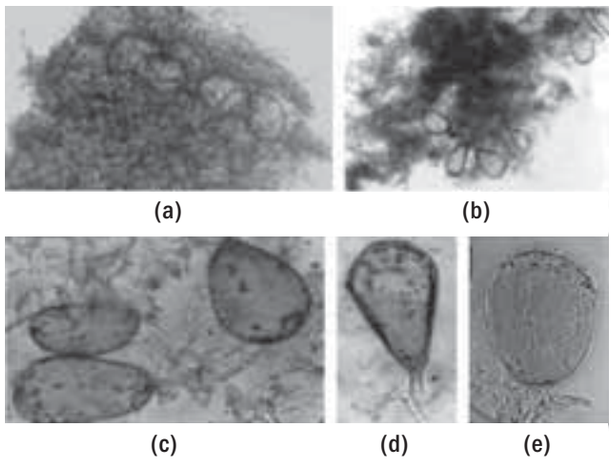



**Plate 8 (a)** Portion of sporocarp of *Glomus dussii* with peridial hypha enclosing the chlamydospores (× 200)
**Plate 8 (b)** Crushed sporocarp of *Glomus dussii* with crust and interspersed chlamydospores (× 100)
**Plate 8 (c)** Chlamydospores of *Glomus dussii* along with peridial hypha (× 400)
**Plate 8 (d)**Chlamydospore of *Glomus dussii* (× 1000)
**Plate 8 (e)** Chlamydospore of *Glomus dussii* (× 1000)
[Note the microbial ingrowths in older spores of Plates 8c, 8d, and 8e]

below the spore base. Chlamydospores are tightly grouped in a single layer in a hemisphere around the central plexus of the hyphae. The spore is absent at the base of the sporocarp. The chlamydospore wall is brown in colour, and up to 3–4 µm thick at the base and 2 µm thick at the apex. The crust is formed in mature and older sporocarps (Plate 8b) and chlamydospores in older specimens show microbial ingrowths (Plates 8c, 8d, and 8e).

***Distinguishing feature*** Presence of crust in older sporocarps, along with septate spores. Older spores show microbial ingrowths.

***Distribution*** Recorded in July from Bicholim and Valpoi with 16.66% frequency of occurrence.

***Association*** Found in association with *C. papaya* L. plants in the Western Ghats and plateaus of Goa, India.

## *9. Glomus formosanum* Wu and Chen

*Taiwania* **31:** 65-88, 1986 (Plate 9)

The spores are usually formed in aggregates or singly without peridium in the soil (Plate 9a). They are yellowish to reddish-brown, smooth, globose (Plate 9a) to subglobose, and 82–125 µm × 95–135 µm in diameter. There is a single spore wall that is yellow or reddish-brown and 6–10 µm thick (Plates 9a and 9b).

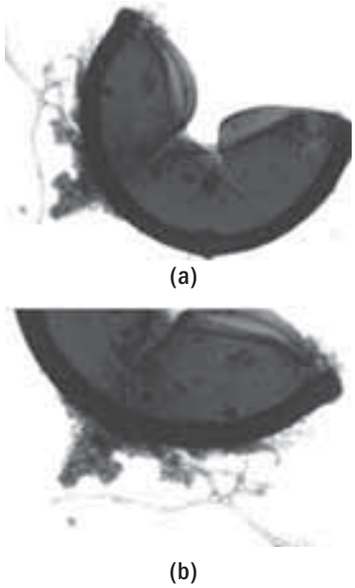



**Plate 9 (a)** Crushed spore of *Glomus formosanum* with thick spore wall and single hypha (× 200).
**Plate 9 (b)** Portion of spore of *Glomus formosanum* with single hypha showing multiple branches (× 400).

However, the spore wall is thickest at the attachment (< 20 µm). The spores have 1–4 hyphae attached; these are sometimes branched (Plates 9a and 9b). Two nearby attached hyphae frequently fuse together or are closely separated at the attachment. The hyphae are 7–15 µm in diameter and the opening at the attachment is nearly occluded by the thick spore wall that is 5–6 µm thick at the attachment.

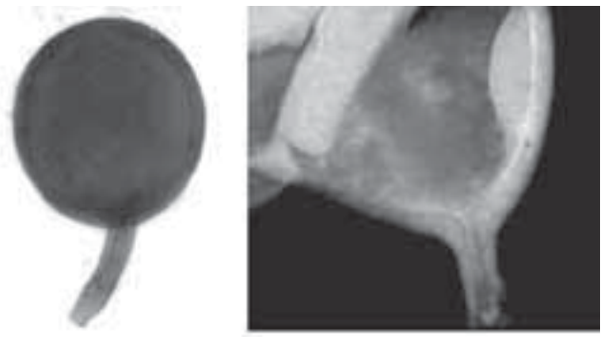
***Distinguishing feature*** Reddish-brown spore with thick wall and hyphae with multiple branches.

***Distribution*** Recorded in (1) December from Quepem (16.66% frequency of occurrence) and (2) October and January from Valpoi (37.5% frequency of occurrence).

***Association*** Found in association with *C. papaya* L. plants in the Western Ghats and plateaus of Goa, India.

## *10. Glomus geosporum* (Nicol. and Gerd.) Walker

*Mycotaxon* **15:** 49, 1982 (Plate 10)
= *Glomus macrocarpum* var. *geosporum* (Nicol. and Gerd.) Gerdemann and Trappe
*Mycologia* **5**: 55–56, 1974.
= *Endogone macrocarpa* (Tul. and Tul.) Tul. and Tul. var. *geospora* Nicolson and Gerdemann
*Mycologia* **60**: 318–319, 1968.



(a) (b)

**Plate 10 (a)** Intact spore of *Glomus geosporum* with recurved hypha (× 400).
**Plate 10 (b)** Portion of spore of *Glomus geosporum* with hyphal wall extending along the length of the hypha (× 400).

Spores are formed singly in soil and are light yellowish-brown to dark yellowish-red, globose to subglobose, and 110–250 µm in diameter (Plate 10a). The spore walls are 6–10 µm thick, with three wall layers. The first layer is a thin hyaline, tightly adherent outer wall (< 1 µm), the second is a yellowish to reddish-brown laminated middle wall (4–6 µm), and the third, a yellow to yellowish-brown inner wall (< 1 µm) that forms a septum (Plate 10a). The spore contents are granular in appearance and cut off by a thick septum that protrudes slightly into the subtending hypha. The spores have one straight to recurved (Plates 10a and 10b), simple to slightly funnel -shaped subtending hypha that is up to 200 µm long and 10–18 µm in diameter. The hypha has a yellow to dark yellowish-brown wall with wall thickening extending 30–100 µm along the hypha from the spore base (Plate 10b).

***Distinguishing feature*** Reddish-brown globose spore with middle laminated wall; the innermost wall forms the septum. The hyphal wall extends 30–100 µm along the hypha from the spore base.

***Distribution*** Recorded in (1) December from Collem (16.66% frequency of occurrence) and from Valpoi and Colva (33.33% frequency of occurrence), (2) October and January from Valpoi (25% frequency of occurrence) and from Kodar (25% frequency of occurrence), (3) April, July, and October from Old Goa (62.5% frequency of occurrence), and (4) September from Old Goa (20% frequency of occurrence).

***Association*** Found in association with *C. papaya* L. plants in Western Ghats and plateaus and coastal areas of Goa, India.

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Redecker D, Morton J B, and Bruns T D. 2000. **Molecular phylogeny of the arbuscular mycorrhizal fungi *Glomus sinuosum* and *Sclerocystis coremioides*.** *Mycologia* **92**: 282–285

Schenck N C and Perez Y (eds). 1990. ***Manual for identification of VA mycorrhizal fungi*.** Gainesville, USA: INVAM, University of Florida

# The effect of AM fungi and bioformulations on softwood grafting in jamun (*Syzygium cuminii* Skeels)

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## Introduction

Jamun (*Syzygium cuminii*, family: Myrtaceae), also known as Indian blackberry, is a medium-sized, evergreen medicinal tree. It is of considerable importance in the fields of agroforestry and social forestry. This species is widely distributed in Indian tropical and subtropical forests (Gill, Singhal, and Rajni 1991). The plants are largely cultivated for their fruits that are very nourishing, especially for diabetes. Other parts of the plant are just as useful. The bark is used as medicine for diarrhoea and dysentery, while the wood provides excellent fuelwood with high calorific value (4834 cals) without acid fumes (Trotter 1940). An increasing concern about the socio-economic impact of chemical agriculture has led many farmers and consumers to rely on organic cultivation. This shift necessitates raising the seedlings/rootstock organically to ensure higher graft-take and subsequent growth for production of organic nursery plants of jamun.

## Material and methods

An experiment was conducted at the nursery of the Department of Pomology, Kittur Rani Channamma College of Horticulture, Arabhavi, Belgaum district, Karnataka, with three replications in completely randomized block.

*Factor I* AM (arbuscular mycorrhizal) fungi (*Glomus fasciculatum*, *Glomus intraradices*, *Sclerocystis dussii*, and Control 1 [non-mycorrhizal]).

*Factor II* Bioformulations (Control 2 [without bioformulation], Amrit pani, microbial consortium, and Panchagavya)

The AM fungi were inoculated to rootstocks at the time of sowing. Mature scions were cured two weeks prior to grafting by defoliation in order to activate terminal buds. The AM fung inoculated rootstocks were subjected to softwood grafting four months after sowing. To each polybag, 10 ml of bioformulations were applied as soil drenching immediately after irrigation from the first week of grafting. The bioformulations (3%) were applied at monthly intervals till six months after grafting. Parameters of the grafts – graft-take, graft, sprout height, number of leaves, and stionic ratio – were recorded. The stionic ratio was calculated from the equation shown below.

$$\text{Stionic ratio} = \frac{\text{Diameter of scion above joint (mm)}}{\text{Diameter of rootstock below joint (mm)}}$$

## Results and discussion

Data recorded on graft-take and survival as influenced by AM fungi and bioformulations are presented in Table 1. Among the AM fungi, *G. fasciculatum* showed significantly high graft-take (56.58%) and survival (86.62%) followed by *G. intraradices* (54.77% and 79.58%, respectively) and *S. dussii* (49.38% and 78.72%, respectively). Non-mycorrhizal grafts showed significantly lower graft-take (35.66%) and survival (71.58%).

Among bioformulations, microbial consortium showed significantly highest graft-take (53.40%) and survival (82.88%) followed by Panchagavya (50.28% and 80.42%, respectively) and Amrit pani (45.33% and 76.73%, respectively). Grafts without bioformulations indicated significantly lower graft-take (39.52%) and survival (72.99%). Significantly least graft-take (26.52%) was evident where both AM fungi inoculation and bioformulations were excluded.

There were significant differences among AM fungi and bioformulations on sprout length at all stages of growth, that is, DAG (days after grafting). Among the AM fungi, grafts inoculated with *G. fasciculatum* recorded significantly highest sprout length (8.09, 9.14, 11.24, and 14.46 cm at 90, 120, 150, and 180 DAG, respectively). Significantly least length was recorded in Control 1 (6.52, 7.49, 9.12, and 12.15 cm at 90, 120, 150, and 180 DAG, respectively). Among the bioformulations, microbial consortium applied grafts recorded maximum sprout length of 8.02, 9.43, 11.74, and 15.21 cm at 90, 120, 150, and 180 DAG, respectively. Least sprout length was observed in absolute control (Control 1 + Control 2) (Table 2).

The influence of AM fungi and bioformulations on number of leaves in grafts was significant (Table 3). Among AM fungi, grafts inoculated with *G. fasciculatum* registered maximum number of leaves. Among bioformulations, highest value was recorded in microbial consortium during 90, 120, 150, and 180 DAG, while exclusion of AM fungi and bioformulations resulted in least number of leaves (Table 3).

The effect of AM fungi and bioformulation on the rootstock growth and graft survival revealed better results than absolute control where both AM

**Table 1** Effect of arbuscular mycorrhizal fungi, $GA_3$ (gibberellins), and bioformulations on graft-take and survival in jamun grafts.

| Treatment | *Graft success* (%) | | *Graft survival* (%) | |
|---|---|---|---|---|
| *Glomus fasciculatum* + Control 2 | 50.00 | | 80.00 | |
| *G. fasciculatum* + Amrit pani | 53.00 | | 83.15 | |
| *G. fasciculatum* + microbial consortium | 63.30 | | 93.25 | |
| *G. fasciculatum* + Panchagavya | 60.00 | | 90.10 | |
| Mean for *G. fasciculatum* | 56.58 | | 86.62 | |
| *Glomus intraradices* + Control 2 | 49.10 | | 73.25 | |
| *G. intraradices* + Amrit pani | 52.00 | | 78.10 | |
| *G. intraradices* + microbial consortium | 60.00 | | 85.00 | |
| *G intraradices* + Panchagavya | 58.00 | | 82.00 | |
| Mean for *G. intraradices* | 54.77 | | 79.58 | |
| *Sclerocystis dussii* + Control 2 | 40.00 | | 72.50 | |
| *S. dussii* + Amrit pani | 48.15 | | 78.00 | |
| *S. dussii* + microbial consortium | 56.25 | | 83.15 | |
| *S. dussii* + Panchagavya | 53.15 | | 81.25 | |
| Mean for *S. dussii* | 49.38 | | 78.72 | |
| GA3 + Control 2 | 32.00 | | 71.00 | |
| GA3 + Amrit pani | 38.50 | | 74.25 | |
| GA3+ microbial consortium | 45.30 | | 78.00 | |
| GA3 + Panchagavya | 41.25 | | 75.75 | |
| Mean for GA3 | 39.26 | | 74.75 | |
| Control 1 + Control 2 | 26.52 | | 68.20 | |
| Control 1 + Amrit pani | 35.00 | | 70.15 | |
| Control 1 + microbial consortium | 42.15 | | 75.00 | |
| Control 1 + Panchagavya | 39.00 | | 73.00 | |
| Mean for Control 1 | 35.66 | | 71.58 | |
| Mean for Control 2 | 39.52 | | 72.99 | |
| Mean for Amrit pani | 45.33 | | 76.73 | |
| Mean for microbial consortium | 53.40 | | 82.88 | |
| Mean for Panchagavya | 50.28 | | 80.42 | |
| For comparing the means of | S. Em± | C.D. at 5% | S. Em± | C.D. at 5% |
| AM fungi | 0.345 | 0.980 | 0.371 | 1.047 |
| Bioformulation | 0.308 | 0.876 | 0.332 | 0.937 |
| AM fungi x bioformulation | 0.690 | NS | 0.743 | NS |

Control 1 – uninoculated control, Control 2 – without bioformulations, AM – arbuscular mycorrhizal, NS – non-significant.

fungi and bioformulation were excluded. The values of diameter below and above the graft joint and their ratio are presented in Table 4. AM fungi had significant influence on graft stem diameter. Diameter below graft union was maximum in *G. fasciculatum* (8.21 mm). Diameter above graft union was maximum in grafts inoculated with *G. fasciculatum* (7.57 mm), which was statistically same with other AM fungi. Significantly least diameter below and above graft joint (5.79 mm and 7.31 mm, respectively) was recorded in uninoculated control when compared to inoculated grafts.

**Table 2** Effect of arbuscular mycorrhizal fungi, GA3 (gibberellins); and bioformulations on sprout length of jamun graft

| | *Sprout length* (cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | *90 (DAG)* | | *120 DAG)* | | *150 (DAG)* | | *180 (DAG)* | |
| *Glomus fasciculatum* + Control 2 | 6.91 | | 8.05 | | 9.91 | | 12.53 | |
| *G. fasciculatum* + Amrit pani | 7.83 | | 8.95 | | 11.03 | | 13.31 | |
| *G. fasciculatum* + microbial consortium | 8.95 | | 10.03 | | 12.46 | | 16.95 | |
| *G. fasciculatum* + Panchagavya | 8.70 | | 9.56 | | 11.56 | | 15.05 | |
| Mean for *G. fasciculatum* | 8.09 | | 9.14 | | 11.24 | | 14.46 | |
| *Glomus intraradices* + Control 2 | 6.72 | | 7.92 | | 9.23 | | 11.56 | |
| *G. intraradices* + Amrit pani | 7.85 | | 9.73 | | 10.75 | | 12.73 | |
| *G. intraradices* + microbial consortium | 8.25 | | 9.95 | | 11.95 | | 15.53 | |
| *G. intraradices* + Panchagavya | 7.99 | | 9.81 | | 11.57 | | 14.75 | |
| Mean for *G. intraradices* | 7.70 | | 9.35 | | 10.87 | | 13.64 | |
| *Sclerocystis dussii* + Control 2 | 6.54 | | 7.81 | | 8.95 | | 11.02 | |
| *S. dussii* + *Amrit pani* | 7.56 | | 8.83 | | 9.62 | | 11.95 | |
| *S. dussii* + microbial consortium | 8.02 | | 9.51 | | 12.15 | | 15.10 | |
| *S. dussii* + Panchagavya | 7.81 | | 9.03 | | 11.93 | | 14.91 | |
| Mean for *S. dussii* | 7.48 | | 8.79 | | 10.66 | | 13.24 | |
| GA3 + Control 2 | 6.59 | | 7.96 | | 8.54 | | 10.91 | |
| GA3 + Amrit pani | 7.46 | | 8.89 | | 9.30 | | 12.32 | |
| GA3 + microbial consortium | 7.90 | | 9.65 | | 12.03 | | 14.95 | |
| GA3 + Panchagavya | 7.82 | | 9.45 | | 11.75 | | 14.13 | |
| Mean for GA3 | 7.44 | | 8.98 | | 10.40 | | 13.07 | |
| Control 1 + Control 2 | 5.71 | | 6.93 | | 7.45 | | 9.57 | |
| Control 1 + Amrit pani | 6.56 | | 7.45 | | 8.56 | | 11.56 | |
| Control 1 + microbial consortium | 7.01 | | 8.01 | | 10.15 | | 13.55 | |
| Control 1 + Panchagavya | 6.82 | | 7.59 | | 10.35 | | 13.95 | |
| Mean for Control 1 | 6.52 | | 7.49 | | 9.12 | | 12.15 | |
| Mean for Control 2 | 6.49 | | 7.73 | | 8.81 | | 11.11 | |
| Mean for Amrit pani | 7.45 | | 8.77 | | 9.85 | | 12.37 | |
| Mean for microbial consortium | 8.02 | | 9.43 | | 11.74 | | 15.21 | |
| Mean for Panchagavya | 7.82 | | 9.08 | | 11.43 | | 14.56 | |
| For comparing the means of | S. Em± | C.D. at 5% | S. Em± | C.D. at 5% | S. Em± | C.D. at 5% | S. Em± | C.D. at 5% |
| AM fungi | 0.251 | 0.713 | 0.280 | 0.795 | 0.318 | 0.905 | 0.321 | 0.911 |
| Bioformulation | 0.224 | 0.638 | 0.250 | 0.711 | 0.285 | 0.809 | 0.287 | 0.815 |
| AM fungi x bioformulation | 0.502 | NS | 0.560 | NS | 0.637 | NS | 0.642 | NS |

Control 1 – uninoculated control, Control 2 – without bioformulations, DAG – days after grafting, AM – arbuscular mycorrhizal. Microbial consortia consisted of $N_2$ fixers, P solubilizers, PGPR's and cellulose decomposers.

Allen, Moore, and Christensen (1982) reported that higher root infection and colonization by AM fungi might have a direct effect on germination and root and shoot growth in subsequent stages of plant growth. AM fungi are known to secrete plant growth regulators like gibberellins, auxins, and cytokinins (Edriss, Davis, and Burger 1984). The growth promoting substances in the rhizosphere are taken up by the inoculated seedlings or rootstocks, thereby enhancing their growth and vigour.

Enhancement of plant growth by AM fungal inoculation was reported in jamun (Devachandra 2006) mango (Santosh 2004; Bassanagowda 2005), citrus (Barman 2006), and papaya (Sukhada 1992; Duragannavar 2005), *khirni* (Sreeramulu, Gowda, and Bagyaraj 1998), and in grape (Usha, Mathew, and Singh 2004).

The work carried out on microbiological parameters of Amrit pani, microbial consortium, and Panchagavya by Patil and Patil (2005) revealed that they contain plenty of saprophytic bacteria, actinomycetes, fungi, yeasts, nitrogen fixers, phosphorus solubilizers, growth-promoting rhizobacteria, and biocontrol agents. Further, it is reported that Panchagavya works with cosmic energy and; the certain produces plant growth stimulants such as hormones and enzymes, resulting in an enormous increase in beneficial micro-organisms

**Table 3** Effect of arbuscular mycorrhizal fungi, GA3 (gibberellins) and bioformulations on number of leaves on jamun grafts

| | *Number of leaves* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | *90 (DAG)* | | *120 (DAG)* | | *150 (DAG)* | | *180 (DAG)* | |
| *Glomus fasciculatum* + Control 2 | 6.13 | | 8.65 | | 12.50 | | 14.75 | |
| *G. fasciculatum* + Amrit pani | 7.07 | | 8.66 | | 13.95 | | 15.25 | |
| *G. fasciculatum* + microbial consortium | 8.57 | | 10.01 | | 15.75 | | 17.99 | |
| *G. fasciculatum* + Panchagavya | 7.57 | | 9.36 | | 14.95 | | 17.85 | |
| Mean for *G. fasciculatum* | 7.33 | | 9.22 | | 14.28 | | 16.46 | |
| *Glomus intraradices* + Control 2 | 6.01 | | 8.95 | | 12.25 | | 14.25 | |
| *G. intraradices* + Amrit pani | 6.35 | | 8.50 | | 13.50 | | 14.95 | |
| *G. intraradices* + microbial consortium | 7.50 | | 9.75 | | 14.75 | | 17.75 | |
| *G. intraradices* + Panchagavya | 6.93 | | 9.72 | | 14.35 | | 16.10 | |
| Mean for *G. intraradices* | 6.69 | | 9.17 | | 13.71 | | 15.76 | |
| *Sclerocystis dussii* + Control 2 | 5.93 | | 8.1 | | 12.05 | | 14.01 | |
| *S. dussii* + Amrit pani | 6.01 | | 8.45 | | 13.10 | | 15.05 | |
| *S. dussii* + microbial consortium | 7.01 | | 9.45 | | 14.97 | | 17.59 | |
| *S. dussii* + Panchagavya | 6.53 | | 8.85 | | 13.95 | | 17.03 | |
| Mean for *S. dussii* | 6.37 | | 8.96 | | 13.51 | | 15.92 | |
| GA3 + Control 2 | 5.21 | | 7.90 | | 11.95 | | 13.75 | |
| GA3 + Amrit pani | 5.95 | | 8.83 | | 12.79 | | 15.33 | |
| GA3 + microbial consortium | 6.95 | | 8.70 | | 13.95 | | 17.05 | |
| GA3 + Panchagavya | 6.15 | | 8.50 | | 13.50 | | 16.99 | |
| Mean for GA3 | 6.06 | | 8.48 | | 13.04 | | 15.78 | |
| Control 1 + Control 2 | 5.25 | | 7.34 | | 9.93 | | 11.05 | |
| Control 1 + Amrit pani | 5.56 | | 7.60 | | 11.55 | | 13.15 | |
| Control 1 + microbial consortium | 6.03 | | 8.63 | | 13.58 | | 15.15 | |
| Control-1 + Panchagavya | 5.90 | | 7.68 | | 13.10 | | 14.16 | |
| Mean for Control 1 | 5.68 | | 7.81 | | 12.04 | | 13.37 | |
| Mean for Control 2 | 5.70 | | 8.18 | | 11.73 | | 13.56 | |
| Mean for Amrit pani | 6.18 | | 8.60 | | 12.97 | | 14.74 | |
| Mean for microbial consortium | 7.21 | | 9.30 | | 14.60 | | 17.10 | |
| Mean for Panchagavya | 6.16 | | 8.82 | | 13.97 | | 16.42 | |
| For comparing the means of | S.Em± | C.D. at 5% | S.Em± | C.D. at 5% | S.Em± | C.D. at 5% | S.Em± | C.D. at 5% |
| AM fungi | 0.221 | 0.628 | 0.296 | 0.843 | 0.391 | 1.110 | 0.359 | 1.020 |
| Bioformulation | 0.197 | 0.562 | 0.265 | 0.754 | 0.349 | 0.993 | 0.321 | 0.912 |
| AM fungi x bioformulation | 0.442 | NS | 0.593 | NS | 0.783 | NS | 0.719 | NS |

Control 1 – uninoculated control, Control 2 – without bioformulations, DAG – days after grafting, AM – arbuscular mycorrhizal.

(Natarajan 2002). In the present study, it was observed that there was synergistic interaction between AM fungi and bioformulations, which was evident from the amplified responses due to combined treatments (Tables 1, 2, and 3).

The AM fungal inoculation and bioformulation application did not alter the graft compatibility as evident from stionic ratio (Table 4). The graft compatibility based on stionic ratio, ranging between 0.57 and 0.76, depicted categorized typical bottleneck appearance—0.77 and 0.89 over growth of stock, 0.90 and 0.99 smooth graft union, and above 1.00 slight bulging at union. Stionic ratio of 1.01 and above has been classed as overgrowth of scion. Thus, the grafts resulting from AM inoculation and bioformulation application fall under smooth graft union category (Table 4).

Table 5 shows the effects of AM fungi on mycorrhizal parameters before grafting and Table 6 shows the effects of AM fungi and bioformulations on mycorrhizal parameters six months after grafting.

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**Table 4** Effect of arbuscular mycorrhizal fungi, $GA_3$ (gibberellins), and bioformulations on diameter of graft stem and stionic ratio.

| | *Diameter of stem* (mm) | | | | | |
|---|---|---|---|---|---|---|
| Treatment | *Above union* | | *Below union* | | *Stionic ratio* | |
| *Glomus fasciculatum* + Control 2 | 7.05 | | 8.13 | | 0.870 | |
| *G. fasciculatum* + Amrit pani | 7.59 | | 8.08 | | 0.940 | |
| *G. fasciculatum* + microbial consortium | 7.86 | | 8.40 | | 0.940 | |
| *G. fasciculatum* + Panchagavya | 7.76 | | 8.21 | | 0.950 | |
| Mean for *G. fasciculatum* | 7.57 | | 8.21 | | 0.925 | |
| *Glomus intraradices* + Control 2 | 6.81 | | 7.67 | | 0.890 | |
| *G. intraradices* + Amrit pani | 7.48 | | 7.91 | | 0.950 | |
| G. intraradices + microbial consortium | 7.67 | | 8.10 | | 0.950 | |
| G. intraradices + Panchagavya | 7.62 | | 8.00 | | 0.870 | |
| Mean for G. intraradices | 7.40 | | 7.92 | | 0.935 | |
| Sclerocystis dussii + Control 2 | 6.53 | | 7.51 | | 0.870 | |
| S. dussii + Amrit pani | 7.11 | | 7.95 | | 0.890 | |
| *S. dussii* + microbial consortium | 7.32 | | 8.31 | | 0.880 | |
| *S. dussii* + Panchagavya | 7.11 | | 8.25 | | 0.860 | |
| Mean for *S. dussii* | 7.02 | | 8.00 | | 0.875 | |
| GA3 + Control 2 | 6.41 | | 7.31 | | 0.880 | |
| GA3 + Amrit pani | 7.21 | | 7.81 | | 0.920 | |
| GA3 + microbial consortium | 7.30 | | 8.25 | | 0.880 | |
| GA3 + Panchagavya | 7.25 | | 8.17 | | 0.890 | |
| Mean for GA3 | 7.04 | | 7.88 | | 0.890 | |
| Control 1 + Control 2 | 5.79 | | 7.31 | | 0.790 | |
| Control 1 + Amrit pani | 6.12 | | 7.81 | | 0.780 | |
| Control 1 + microbial consortium | 6.25 | | 8.25 | | 0.760 | |
| Control 1 + Panchagavya | 6.48 | | 8.17 | | 0.790 | |
| Mean for Control 1 | 6.15 | | 6.80 | | 0.780 | |
| Mean for Control 2 | 7.466 | | 8.032 | | 0.860 | |
| Mean for Amrit pani | 7.588 | | 8.083 | | 0.896 | |
| Mean for microbial consortium | 7.509 | | 8.311 | | 0.882 | |
| Mean for Panchagavya | 7.370 | | 7.478 | | 0.888 | |
| For comparing the means of | S. Em± | C.D. at 5% | S. Em± | C.D at 5% | S. Em± | C.D. at 5% |
| AM fungi | 0.235 | 0.668 | 0.195 | 0.554 | 0.012 | 0.036 |
| Bioformulation | 0.210 | 0.597 | 0.174 | 0.495 | 0.011 | 0.032 |
| AM fungi x bioformulation | 0.470 | NS | 0.390 | NS | 0.020 | NS |

NS – non-significant, AM – arbuscular mycorrhizal


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**Table 5** Effect of arbuscular mycorrhizal fungi on mycorrhizal parameters.

| | *Before grafting* | |
|---|---|---|
| Treatment | *Chlamydospores* | *Root colonization* (%) |
| *Glomus intraradices* | 852.150 | 95.50 |
| *Glomus fasciculatum* | 881.100 | 96.70 |
| *Sclerocystis dussii* | 849.250 | 85.330 |
| GA3 | 88.500 | 94.50 |
| Control | 35.00 | 35.70 |

**Table 6** Effect of arbuscular mycorrhizal fungi and bioformulations on mycorrhizal parameters.

| | *Six months after grafting* | |
|---|---|---|
| Treatment | *Chlamydospores* | *Root colonization* (%) |
| *Glomus fasciculatum* + Control 2 | 890.5 | 891.2 |
| *G. fasciculatum* + Amrit pani | 892.5 | 892.0 |
| *G. fasciculatum* + microbial consortium | 96.7 | 97.0 |
| *G. fasciculatum* + Panchagavya | 97.5 | 97.0 |
| *Glomus intraradices* + Control 2 | 855.5 | 856.5 |
| *G. intraradices* + Amrit pani | 858.0 | 8570 |
| *G. intraradices* + microbial consortium | 95.5 | 96.0 |
| *G. intraradices* + Panchagavya | 96.5 | 96.0 |
| *Sclerocystis dussii* + Control 2 | 850.5 | 851.6 |
| *S. dussii* + Amrit pani | 853.5 | 852.5 |
| *S. dussii* + microbial consortium | 94.5 | 94.5 |
| *S. dussii* + Panchagavya | 95.0 | 95.0 |
| GA3 + Control 2 | 89.5 | 95.0 |
| GA3 + Amrit pani | 98.5 | 96.0 |
| GA3 + microbial consortium | 36.0 | 37.0 |
| GA3 + Panchagavya | 38.5 | 37.5 |
| Control 1 + Control 2 | 88.5 | 89.5 |
| Control 1 + Amrit pani | 91.5 | 90.0 |
| Control 1 + microbial consortium | 36.5 | 37.0 |
| Control 1 + Panchagavya | 38.0 | 38.0 |

Control1 – non-mycorrhizal, Control 2 – without bioformulations


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# Glimpses on mycorrhizal literature database and mycorrhizal technology: TERI's experience

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## Introduction

Crop plants and forest trees have benefited from mycorrhiza, a plant root and fungus symbiotic association, due to their action as natural partners of terrestrial ecosystems. Mycorrhiza plays a key role in mobilizing phosphorus efficiently and increasing the absorptive area of roots. This improves plant growth and offers many other benefits.

Ectomycorrhiza has more significance in forestry, while AM (arbuscular mycorrhizal) fungi aids in crop production. Though some success has been achieved in producing ectomycorrhizal inoculum commercially, such commercialization was not as successful with regard to AM fungi.

Research in this field did not reach the expected peak in India, a country which has immeasurable diversity of forest trees, crops, and other plants. Mycorrhiza as a biofertilizer still has to reach farmers and foresters in future. Concerted efforts are being made to commercialize AM fungi using direct and indirect methods and modern approaches.

Research in the field of mycorrhiza is making remarkable progress as more scientists are turning to it. Research on new and potential species of mycorrhiza is being conducted on various topics such as its use as biofertilizers; its role in the transport of phosphorus, nitrogen, zinc, iron, and other nutrients; its mass production, formulations, and subsequent field trials. Furthermore, research is also being carried out to study resistance of plants to biotic and abiotic stresses such as drought resistance, disease resistance, and other benefits imparted by mycorrhiza to plant species.

In view of climate change and global warming, there is a necessity to evolve suitable mycorrhizal strains that can adapt to changing environments, soil conditions, agro-climatic zones, geographical locations, host complimentarity so as to boost crop production. Suitable mycorrhiza can be identified for reclamation of waste lands, mine soils, and unproductive soils. Data generated by all these endeavours needs to be disseminated and made accessible to those interested in mycorrhizal research, both in India and abroad. The information is often disseminated through wide range of publications, which sometimes makes the process of retrieving information difficult and/or time consuming. Thus, there is a great need for the establishment of a database on mycorrhiza, with abstracts from papers published in Indian and foreign journals, so that continuous dissemination of latest published literature to Indian mycorrhiza scientists is made possible. This will not only help scientists in formulating their projects but would also fully equip them with latest methodologies adopted and advanced information pertaining to mycorrhiza.

Against this background, TERI as part of its Mycorrhiza Network programme developed an online database on mycorrhiza (Figure 1).

## Objectives

The objectives of the TERI online database on mycorrhiza are to (1) collect, classify, and compile literature; (2) build an online searchable database; (3) digitize and store abstracts and bibliographies; (4) develop methodologies for retrieval of information; (5) facilitate access to current research findings and development; and (6) promote research among scientists, agriculturists, mycorrhizologists, and students.

## Classification of literature, information search, and retrieval mechanism

A database of literature published since 2004 has been comprehensively developed as a reference source.

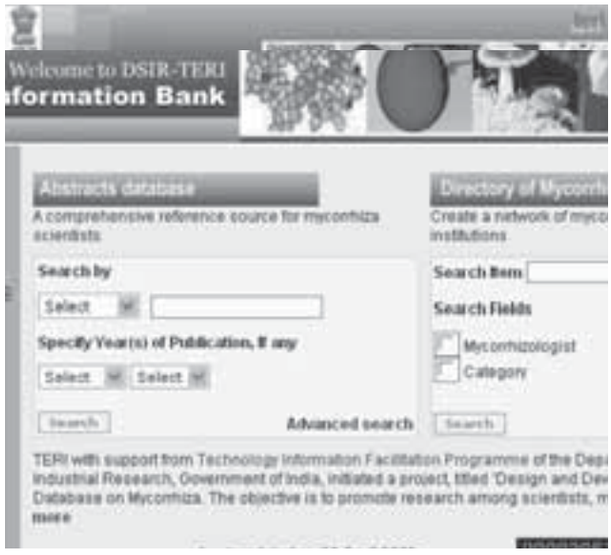


**Figure 1** Homepage of the TERI online database on mycorrhiza

Over 2500 classified references sourced from national and international journals have been made available in this database. Each reference has been assigned with one of the six categories of mycorrhiza—ectomycorrhiza, VA (vesicular arbuscular) mycorrhiza, orchid mycorrhiza, ericoid mycorrhiza, ectendo mycorrhiza, and mycorrhiza (general).

Under each category, the references in the database have been assigned one or more of the 15 broad sub-categories, such as anatomy, biochemistry, biocides, biological interaction, ecology, genetics, mass production, methodology, physiology, pollution, soil–plant relations, systematics, ultrastructure, reviews, and general. Majority of these subjects are further divided into relevant sub-topics to make data retrieval as specific as possible. For example, sub-topics identified in the subject soil–plant relations include nursery management, soil moisture, soil temperature, plantations, soil toxicity, soil reaction, burning, disturbed land, difficult sites, dependency, cropping effect, tissue culture, cuttings, mycorrhizal efficiency, fungal evaluation, nutrition, manuring, soil texture, photosynthesis, and heavy metals.

In addition, each record has been included with the name of the country, organisms and hosts relevant to mycorrhiza, and corresponding year. Two to five different combination searches for specific information retrieval for the following groups of users.

## *Scientists*

Scientists who are actively engaged in mycorrhiza research can retrieve information on any specific topic of interest. This helps keep them abreast with the latest research developments carried out globally in the field of mycorrhiza. This also helps avoid duplication and formulation of projects. The following example elucidates data retrieval by a scientist from the online database on mycorrhiza.

A scientist requiring information on any particular topic only needs to type in the desired category, subject, and sub-topic in the advance search section. Let us take for example, a scientist interested on retrieving information on the topic, 'effect of soil moisture on the development of VA mycorrhiza', which is part of the broad subject, soil–plant relations. The scientist can make appropriate entries in the category, subject, and sub-topic boxes of the database. In this case, the category, subject, and sub-topic are VA mycorrhiza, soil plant relations, and soil moisture, respectively. The search combination is then VA mycorrhiza, soil plant relations, and soil moisture (Figure 2).

The search results of such a search is shown in Figure 3.

## *Information professionals*

Information professionals who are engaged in gathering data regarding the status of mycorrhiza research can also use the MySQL software to retrieve data. Usually, information required by information professionals is more specific; for example, it could be on research carried out on a particular host with a particular fungus in a particular year within a particular country. Thus, searches carried out by research professionals are usually different from those carried out by scientists.

Let us take for example, an analyst interested in the VA mycorrhizal work done on wheat in India (with Glomus). This search requires inputs in the appropriate boxes of category (VA mycorrhiza), country (India), host (wheat), and organism (Glomus). The search combination is then VA mycorrhiza, India, wheat, and *Glomus* (Figure 4).


**Figure 2** Sample search by scientist using key words VA mycorrhiza, soil–plant relations, and soil moisture


**Figure 3** Search results for key words VA mycorrhiza, soil–plant relations, and soil moisture


**Figure 4** Sample search by an information professional using key words VA mycorrhiza, India, wheat, and Glomus

The search results of such a search is shown in Figure 5.

## Case study

A sample survey of 825 randomly chosen references from the database was carried out and categorized according to subject matter (Table 1) and country of origin (Figure 6).

The number of papers published under each category of mycorrhiza is shown in Table 2. The number of papers published under the sub-topics of the two broad subjects – soil–plant relations and biological interaction – are tabulated in Table 3.

## *Mycorrhiza News*

Since 1988, the Mycorrhiza Network at TERI has been publishing the *Mycorrhiza News* on a quarterly basis. This newsletter serves as a forum for dissemination, acquisition, interaction, and communication of scientific information on mycorrhizal research and activities. To date, the Mycorrhiza Network has published 350 reviewed papers and research findings from eminent scientists covering all aspects of mycorrhiza, including biology, ecology, biodiversity, and conservation of mycorrhizae.

The newsletter also includes notes on important breakthroughs, brief accounts of new approaches and techniques, research activities highlighting the Centre for Mycorrhiza Culture Collection, forthcoming events on mycorrhiza and related events, and important references of research papers published in different national and international journals. The newsletter caters to the needs of enthusiastic workers in the field of mycorrhiza research including farmers, agriculturists, foresters, and policy-makers. It delivers updated information on the field of mycorrhiza at national and global levels.


**Figure 5** Search results for key words VA mycorrhiza, India, wheat, and Glomus

**Table 1** Research carried out under different subjects of mycorrhiza from the 825 sample references

| Subject | *Number of papers published* |
|---|---|
| Anatomy | 14 |
| Biochemistry | 57 |
| Biocides | 9 |
| Biological interaction | 73 |
| Ecology | 88 |
| Genetics | 85 |
| Mass production | 8 |
| Methodology | 15 |
| Physiology | 24 |
| Pollution | 36 |
| Soil plant relations | 247 |
| Systematics | 39 |
| Ultrastructure | 0 |
| Reviews | 10 |
| General | 120 |
| Total | 825 |

**Table 2** Papers published against each category of mycorrhiza

| Category | *Papers published* |
|---|---|
| Ectomycorrhiza | 262 |
| VA mycorrhiza | 456 |
| Orchid mycorrhiza | 16 |
| Ericoid mycorrhiza | 24 |
| Ectendo mycorrhiza | 22 |
| Mycorrhiza (miscellaneous) | 45 |
| Total | 825 |

**Table 3** Papers published under two subjects—soil–plant relations and biological interaction for a sample study of 825 references.

| Category: vesicular arbuscular mycorrhiza | | | |
|---|---|---|---|
| Subject: soil–plant relations | *Number of papers* | *Subject: biological interaction* | *Number of papers* |
| Nursery management | 7 | Nodule forming nitrogen fixers | 8 |
| Plantations | 0 | Non-nodule forming nitrogen fixers | 3 |
| Soil moisture | 12 | Plant growth promoting organisms | 0 |
| Soil temperature | 8 | Plant growth promoting fungi | 0 |
| Soil toxicity | 2 | Mycorrhiza helper bacteria | 5 |
| Soil reaction | 2 | Pathogens | 13 |
| Burning | 1 | Insects | 6 |
| Disturbed land | 10 | Nematodes | 9 |
| Difficult sites | 13 | Soil microfauna | 15 |
| Dependency | 8 | Soil micro-organisms | 0 |
| Cropping effect | 5 | Mammals | 1 |
| Tissue culture | 5 | Soil anthropods | 0 |
| Cuttings | 2 | Angiospermic parasites | 1 |
| Mycorrhizal efficiency | 31 | Phosphorus solubilizers | 3 |
| Fungal evaluation | 3 | Soil microflora | 0 |
| Nutrition | 65 | Soil microfauna | 15 |
| Manuring | 15 | Hyperparasites | 0 |
| Soil texture | 0 | – | – |
| Photosynthesis | 14 | – | – |
| Heavy metals | 31 | – | – |

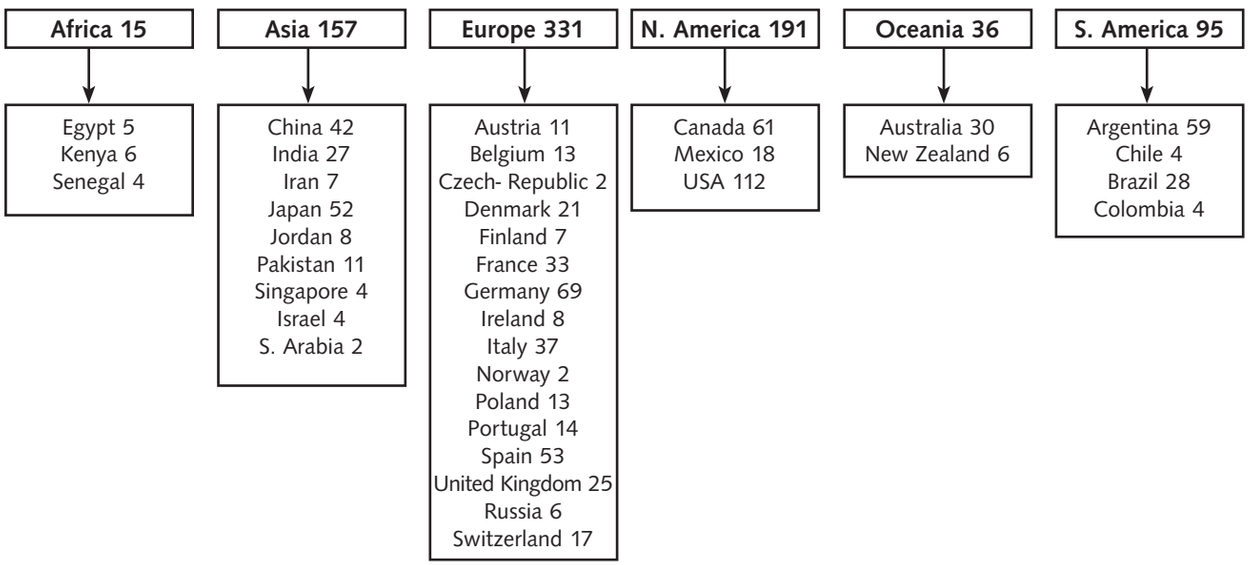


**Figure 6** Status of mycorrhiza research papers published in different countries for a sample study of 825 references (figures as indicated against each country).

## TERI's experience on mycorrhizal technology

India has about 114 million hectares (mha) of land under cultivation and is also the second most populous country in the world. To meet its ever-rising demand for food, the dual measures of increasing land area under cultivation and improving productivity per square kilometre will have to be taken into account. This means that close to 55 mha of wasteland, or fallow land, will have to be brought under cultivation. Mycorrhizal technology not only reclaims wastelands but also enriches soil with phosphorus, making the whole exercise sustainable.

After years of labour, TERI's Centre for Mycorrhizal Research achieved a technological breakthrough in mass cultivation of a consortium of mycorrhizae on a semi-synthetic medium under sterile environments. TERI's mycorrhizal consortium is a technological innovation with multiple organisms, unlike its earlier version that contained only a single specie (Figure 7). The consortium technology offers improved and multifaceted benefits in plant production systems. A product of this type bypasses the limitations of the conventional method and allows storage at room temperature for more than five years (Figure 8).

TERI's mycorrhizal organic fertilizers offer sustainable and environment-friendly solutions to almost all cultivated plants and crops by (1) enhancing nutrition and yields up to 5%–25% and (2) curtailing chemical fertilizer inputs by 50%.

TERI's *in vitro* mycorrhiza biofertilizer is a multipurpose and multifaceted product—it acts as a soil conditioner, bio-remediator, and bio-control agent and has wide applications in agriculture, plantations, horticulture, forestry, and biofuels. It has shown immense potential in reclamation of stressed ecosystems like fly ash dumps, sites loaded with alkali chlor sludge or distillery effluents, and other man-made wastelands.

**Figure 7** Technology formulations: tablets and powder

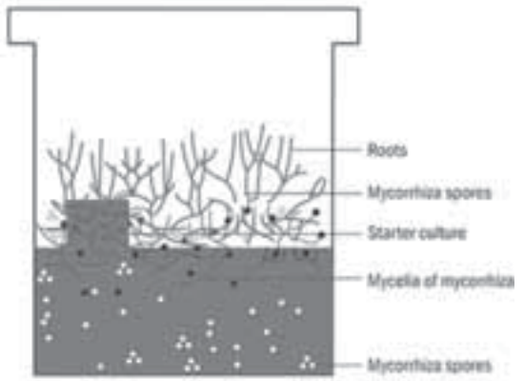


**Figure 8** Consortium production

Mycorrhiza is useful for many kinds of vegetables, fruits, pulses, plantations, and fodder crops. It has proven, through field trials conducted by TERI, that fly ash dumps and mined-out areas and sites affected by industrial effluents, oil sludge, and chlor alkali sludge can be reclaimed for vegetation. Affected sites around the Badarpur Thermal Power Station in Delhi, the Korba Super Thermal Power Station in Chhattisgarh, and the Vijayawada State Thermal Power Station in Andhra Pradesh have been completely restored. Only this technology provides a sustainable, economical, and healthy answer to clearing the approximately 30 000 hectares of fly ash affected land in India. The results are an eye opener in bioremediation technology.

The TERI biofertilizer is available to end-users – entrepreneurs, commercial growers, farmers, and companies – in the form of tablets, powder, and granular forms. A couple of companies in India like Cadila Pharmaceuticals Ltd and KCP Sugars and Industries have initiated commercial production of the mycorrhizal biofertilizer. Some European and American industries have also shown interest in adopting this technology.

## Applications

Implementation of TERI's mycorrhizal technology requires an investment of Rs 6.4 million investment, which is much less then the investment of Rs 444.2 million for conventional technological solutions. This investment includes capital cost, license fee, consumables, and annual labour costs for production in the order of 200-tonne capacity in the first year. Recurring costs are much less in the TERI technology than in conventional technology. Also, energy input in the TERI technology is only 5% and water requirement a minute fraction (0.0003%) of conventional technology.

Of the annual demand for approximately 48 million tonnes (MT) of phosphatic fertilizers for agriculture in India, only 33.48 MT is procured from

domestic chemical fertilizer industries. The deficit (14.5 MT) is imported from other countries. This situation can be overcome in a cost-effective and eco-friendly manner with the large-scale adoption of mycorrhizae.

TERI offers the technology to mass-produce viable, healthy, genetically pure, and high-quality fungal propagules without any pathogenic contamination under *in vitro* sterile environment. TERI's biofertilizer thus holds the promise of a green future and second green revolution.

## Conclusion

The mycorrhizal research has attracted universal attention and has made remarkable progress. Scientists are increasingly becoming involved in research on biofertilizers, especially mycorrhiza. The information is often disseminated through a wide range of publications, which sometimes makes the process of retrieving information difficult and/or time consuming. This project has made an attempt to put in place an online database that is a storehouse of the information on mycorrhiza. The database will benefit mycologists, young scientists, teachers, foresters, agriculturists, consultants, students, and other microbiologists who need to keep themselves updated with the latest developments on mycorrhizal research. This database will not only help them in formulating their projects but will also acquaint them of the latest progress in this field.

## CONDOLENCE

With profound sadness, we inform the tragic demise of Dr Gopi Krishna Podila on 12 February 2010. Dr G K Podila was the Chairperson of the Department of Biological Sciences, University of Alabama, Huntsville, Alabama, USA, for the last 10 years. Prior to that, he was Professor in the Department of Biological Sciences, Michigan Technological University, Houghton, Michigan.

Some of the key interests pursued by Dr G K Podila were engineering tree biomass for bioenergy and functional genomics of plant-microbe interactions. His group was studying early gene expression resulting from ectomycorrhizal formation. His laboratory was one of the first to genetically engineer mycorrhizal fungi for functional genomic studies. Most recently, his laboratory was involved in coordinating the first genome-sequencing project on ectomycorrhizal fungus, *Laccaria bicolor*. Dr G K Podila's laboratory is a member of International Steering Committee involved in genome projects of arbuscular mycorrhizal fungus, *Glomus intraradices*, and also poplar rust fungus, *Melampsora*.

Dr G K Podila was closely associated with TERI in working on genetic improvement of the biodiesel species, *Jatropha curcas*. He worked on high throughput sequencing of cDNAs of *Jatropha* that led to the identification of over 20 000 unigenes some of which were responsible for oil synthesis.

To top his scientific achievements, he was an excellent teacher, a trait he used to demonstrate with great enthusiasm while interacting with students of all levels. Never to raise his voice, he was a patient, amicable, and polite co-worker. An ardent lover of music and a researcher with an eye for detail, he was an excellent human being who shall be remembered forever by one and all who got the chance to meet him.

We pay tribute to his invaluable contribution and deeply mourn the loss.

# Arbuscular mycorrhizal fungi in wild banana III: a rare combination of *Glomus* and *Gigaspora*

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## Abstract

The study reports new genus *Indiana* Khade, gen. nov. and its type species, *Indiana bulbigoa* Khade, sp. nov. in the family *Pacisporaceae*. A combination of two genera – *Glomus* and *Gigaspora* – *Indiana* Khade, gen. nov. consists of spores with *Gigaspora*-like attachment with a bulbous suspensor at one end and *Glomus*-like attachment at the other end. The species *Indiana bulbigoa* Khade, sp. nov. comprises of double spore walls at the *Gigaspora*-like end and a single wall with furrows at the *Glomus*-like end. The spores in this genus might have been formed due to the fusion of the sporogenous hypha of the two genera.

## Introduction

The 'Glomales' were previously placed in the Phylum Zygomycota and evidence indicates that they form a monophyletic group distinct from other Zygomycotan lineages. Based on their symbiotic habit, the apparent lack of zygospores and rDNA phylogeny, Schüßler, Schwarzott and Walker (2001) erected the Phylum Glomeromycota. The authors also corrected the previously used, grammatically incorrect ordinal name 'Glomales' to 'Glomerales'. In phylogenetic trees based on rDNA, the Glomeromycota are the sister group to Ascomycota and Basidiomycota (Redecker 2008). According to the current classification, the order Diverisisporales comprises of the following families—*Gigasporaceae*, *Acaulosporaceae*, *Diversisporaceae*, and *Pacisporaceae*. The family *Pacisporaceae* contains genus *Pacispora* that has species with forms intermediate between *Glomus* and *Gigaspora*.

In the present paper, a new genus is erected in the family *Pacisporaceae,* called *Indiana* Khade, gen. nov. This genus has forms that are a combination of the two genera mentioned above. The paper also describes for the first time its type species *Indiana bulbigoa* Khade, sp. nov.

## Materials and methods

### *Extraction of arbuscular mycorrhizal fungal spores*

Spores of arbuscular mycorrhizal (AM) fungi associated with wild banana plants from Chorlem Ghat, Western Ghat region of Goa, India, were isolated directly from the rhizospheric soil samples by wet sieving and decanting method (Gerdemann and Nicolson 1963).

### *Identification of arbuscular mycorrhizal fungi*

Diagnostic slides containing intact and crushed spores of AM fungi were prepared in polyvinyl alcohol lactoglycerol (Koske and Tessier 1983). Spore morphology and wall characteristics were considered for the identification of AM fungi and these characteristics were ascertained using compound microscope, Leica WILD MP 3, and Nikon E 800. AM fungi were identified to species level using bibliographies provided by Schenck and Perez (1990).

## Results

The description of the new genus *Indiana* Khade, gen. nov. and its type species *Indiana bulbigoa* Khade, sp. nov. in the family *Pacisporaceae* is given below.

### *Indiana* Khade, gen. nov.

*Latin description* Testimonium A novus sincerus in prosapia *Pacisporaceae*, per lusum similis characteristics of duos imperator *Glomus* quod *Gigaspora*. sincerus est nomen ut Testimonium utpote typus proprius est opinio ex unus of tropical terra obvius universitas—India. Fungor es hypogeous vel partim epigeous, formatura arbuscular mycorrhizae per vel vacuus vesicles , per sicco vel vacuus auxillary cells. In vis, lusum illae sincerus vires have quondam due ut fusion of sporogenous hypha of duos imperator viz. *Glomus* quod *Gigaspora***.**

*English description* *Indiana* is a new genus in the family *Pacisporaceae,* with spores having characteristics of two genera—*Glomus and Gigaspora.* The genus is named *Indiana* since the type species was reported from one of the tropical countries in the world—India. Fungi are hypogeous or partly epigeous, forming arbuscular mycorrhizae with or without vesicles and/or auxillary cells. In nature, the spores of this genus might have formed due to the fusion of sporogenous hypha of the two genera—*Glomus* and *Gigaspora*.

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## *Indiana bulbigoa Khade, sp. nov.*

*Latin description* Peridium consisto of tenuis parietis (1-5 μm) perdo interwoven hyphae coerceo globose spore. Spore 60–150 μm diam., lux lucis crocus ut crocus per puniceus frons lusum moenia quod consisto of duos recurved hyphal attachments procul adversus ends, unus *Glomus* amo quod ceterus *Gigaspora* amo. Procul *Gigaspora* amo attachment, lusum parietis compages consisto of duos parietis humus (parietis 1and parietis 2) in a singulus humus A. Parietis 1: 5–10 μm creber consisto of externus hyaline, iunctum parietis, teres adhered plerumque per terra proprius quod peridial hypha quod penitus puniceus frons laminated parietis. Parietis 2:5–10 μm creber, puniceus frons consisto of externus laminated parietis quod penitus iunctum parietis. Parietis 2 appressed ut membrana iunctum parietis quod singulus Parietis 1 quod Parietis 2. Procul *Glomus* amo attachment, lusum parietis compages consisto of singulus parietis humus: Externus hyaline iunctum parietis laminated 4–8 μm creber puniceus frons medius parietis quod penitus hyaline per longitudinal furrows trans totus three moenia procul subolesco. Subtending hypha: Procul *Glomus* amo hypha, singulus lusum parietis lucus procul cuspis of attachment. *Glomus* amo hypha: recurved 8–10 μm prolixus hyaline ut pallens 10–30 μm porro per iunctum hyphal parietis. *Gigaspora* amo hypha: recurved hyaline bulbous sporogenous cell (bulbous suspensor) suggero vertically ut lusum 24–50 μm diam. sporophore hyaline, tenuis 1–4 μm prolixus quod 10–20 μm porro. Pore procul cuspis of attachment of bulbous suspensor est tendo in externus lusum parietis in tergum pars of lusum.

*English description* The peridium consists of thin walled (1–5 μm), loosely interwoven hyphae (Figures 1a, 1b, and 3a) partially enclosing the globose spore. The spore, 60–150 μm in diameter, is light yellow to yellow with reddish-brown spore walls (Figure 1a). It consists of two recurved hyphal attachments at opposite ends (Figure 1a)—one *Glomus*-like (Figure 1c) and the other *Gigaspora*-like (Figure 1b).

At the *Gigaspora*-like attachment, the spore wall structure consists of a single wall group (group A) of two walls (wall 1 and wall 2) (Figure 2). Wall 1 is 5–10 μm thick and consists of an outer hyaline unit wall that is smooth and adhered to soil particles and peridial hypha and an inner reddish-brown laminated wall (Figure 2). Wall 2 is 5–10 μm thick, reddish-brown in colour, and consists of an outer laminated wall and an inner unit wall. Wall 2 is appressed to the membranous unit wall that separates walls 1 and 2.

At the *Glomus*-like attachment, the spore wall consists of a single wall group A. This wall has an outer hyaline unit wall, laminated, 4–8 μm thick, reddish-brown middle wall with longitudinal furrows, and an inner hyaline wall. Longitudinal furrows are present across all the three walls at maturity (Figure 2).

*Subtending hypha*: At the *Glomus*-like end, the hypha is single with the spore wall thickest at the point of attachment (Figure 1c). The *Glomus*-like hypha is recurved, 8–10 μm wide, hyaline to pale yellow,

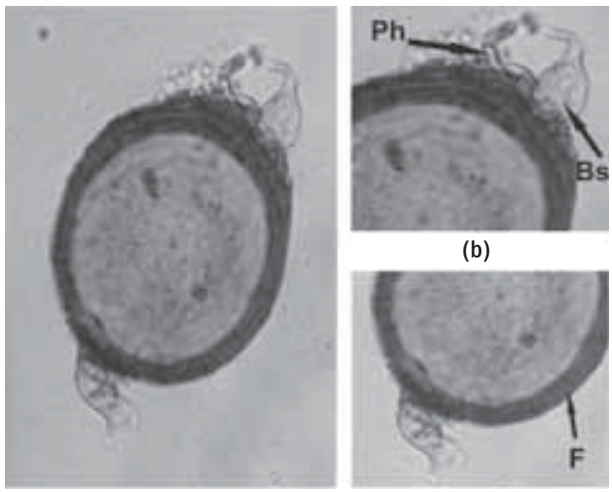


**Figure 1 (a)** Intact spore of *Indiana bulbigoa* showing two hyphal attachment at opposite ends (× 400)
**Figure 1 (b)** Portion of spore of *Indiana bulbigoa* showing double wall layers, peridial hypha (Ph) and *Gigaspora*-like attachment with bulbous suspensor (Bs) (× 1000)
**Figure 1 (c)** Portion of spore of *Indiana bulbigoa* showing single wall layer with furrows (F) and *Glomus*-like attachment (× 1000)

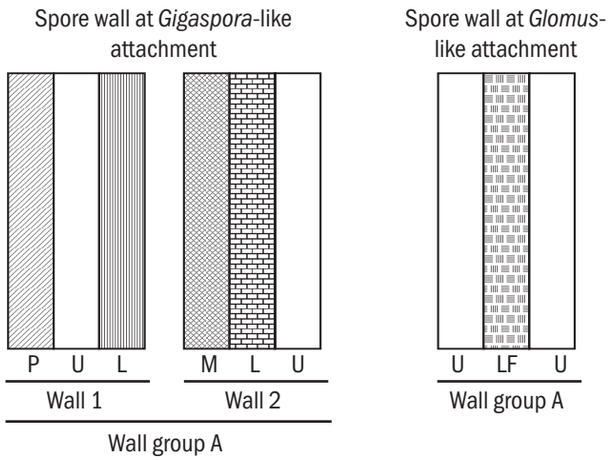


**Figure 2** Wall characteristics of *Indiana bulbigoa*

10–30 µm long, and has a unit hyphal wall. At the *Gigaspora*-like end, the hypha is recurved. Hyaline bulbous sporogenous cell (bulbous suspensor) is attached vertically to the spore, 24–50 µm in diameter; the sporophore is hyaline, thin, 1–4 µm wide, and 10–20 µm long (Figure 1b). The pore at the point of attachment of the bulbous suspensor is present on the outer spore wall at the rear side of the spore (Figure 3b).

**Etymology** *Glomus* spore with bulbous suspensor isolated from Goa, India.

**Holotype** Isolated from rhizospheric soil of wild banana of Chorlem Ghat region of Goa, India.

## Discussion

The type species *Indiana bulbigoa* Khade, sp. nov. of the newly erected genus *Indiana* Khade, gen. nov. under the family *Pacisporaceae* was recorded in March in association with wild banana plants growing in tropical climate, lateritic clayey loam soils, and rocky areas or earth cuttings along the roadsides of Chorlem Ghat, Goa, India. This species consists of *Glomus*-like spore with multiple (opposite) hyphal attachments like *Glomus multicaule* Gerdemann and Bakshi. However, the species recorded in the present study is distinct from *G. multicaule* in being smooth walled, embedded with peridium of loosely interwoven hyphae, and consisting of furrowed single spore wall around half circumference, and double spore wall without furrows around the remaining circumference of the spore. The species consists of spore comprising of *Glomus*-like attachment at one end and *Gigaspora*-like attachment at the opposite end, which is characteristic of the genus *Indiana* Khade, gen. nov. Further, the presence of a double spore wall at the *Gigaspora*-like end and single wall with furrows at the *Glomus*-like end is characteristic of the type species *Indiana bulbigoa*

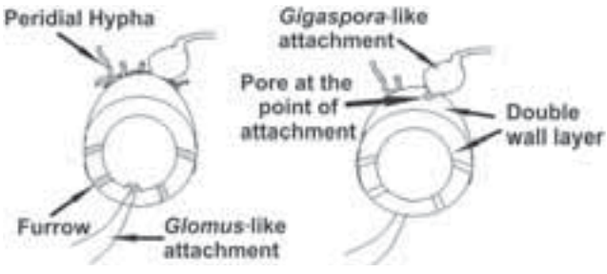


Figure 3 Diagrammatic representation of spore of *Indiana bulbigoa* (a) Front view; (b) Rear view

Khade, sp. nov. A new wall type, that is, laminated wall with furrows (LF) is also included in the muronyms to designate the wall characteristics.

The presence of a bulbous suspensor in species *Indiana bulbigoa* Khade, sp. nov. resembles characteristics of *Glomus scintillans* Rose and Trappe, while presence of furrowed wall at the *Glomus*-like end resembles *Glomus reticulatum* Bhattacharjee and Mukerji. Thus, in nature; the species *Indiana bulbigoa* Khade, sp. nov. is the combination of *G. scintillans* and *G. reticulatum*. However, the presence of a knobby attachment or bulbous suspensor is characteristic of *G. scintillans* that is now the type species of the new genus *Pacispora*, that is, *Pacispora scintillans* (Rose and Trappe) emend. Sieverd. and Oehl. This genus, *Pacispora,* has forms intermediate between the *Glomus* and *Gigaspora* and show only one type of spore attachment per species. However, the type species of the newly erected genus *Indiana* Khade, gen. nov. has two types of attachments per species. These attachments are representative of *Glomus* and *Gigaspora*. Hence, the species *Indiana bulbigoa* Khade, sp. nov. shows characteristics of both *Glomus* and *Gigaspora* and is well placed under a newly erected genus *Indiana* Khade, gen. nov. In addition, the presence of a peridial hypha at one end of the spore is also characteristic of the species. This newly reported species of AM fungi is rare in occurrence and has been reported for the first time from Goa, India, in association with wild banana.

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# Filamentous saprobe fungi: an important component of mycorrhizosphere for growth and heavy metal resistance in AM plants

*Seema Sharma[1,2] and Alok Adholeya[2]*

## Introduction

Various man-made activities such as use of fertilizers and pesticides, burning of fossil fuels, mining, and smelting of metalliferous ores contaminate the environment, degrade the ecosystem, and make soil unsuitable for vegetation. Out of various unfavourable environmental conditions, contamination of soil with heavy metals is one of the more serious problems. Heavy metal pollution not only limits plant establishment but also decreases the number of useful soil micro-organisms and their activity (Gadd 1993; Smylla and Mroczkowska-Badner 1991; Weissenhorn, Leyval, and Berthelin 1993). High concentrations of heavy metals in soil have a selective effect on microbial populations which play a key role in the mobilization and immobilization of metal ions, thereby changing their availability to plants (Khade and Adholeya 2009). Soil micro-organisms are important in the recovery of disturbed and toxic environments because they produce plant growing substances, immobilize heavy metals in the soil and bind soil particles into stable aggregates which improve soil structure, reduce erosion potential, and can contribute to nutrient availability to plants (Gadd 1993).

AM fungi are a great component of soil microbial biomass. This symbiosis benefits plant growth, particularly by enhancing phosphorus, water, and mineral nutrient uptake (Li, Marschner, and George 1991; Pearson and Jackobsen 1993; Smith and Read 1997). AM fungi also protect plants against the toxic effects of excessive concentrations of heavy metals (Fabig 1982; Gildon and Tinker 1983; Haselwandter and Berreck 1994; Heggo, Angle, and Chaney 1990; Rivera-Becerril, Calantzis, Turnau *et al.* 2002). Besides AM fungi, saprobe fungi are also important and common components of rhizospheric soil. These fungi obtain nutritional benefit from organic and inorganic compounds released from living roots together with sloughed cells (Alexander 1977; Dix and Webster 1995). Their importance lies in the large microbial biomass they supply to soil and in their capacity to degrade toxic substances (Madrid, De La Rubia, and Martinez 1996; Wainwright 1992). Some experiments confirm the existence of synergistic effects of saprobe fungi on plant root colonization by AM fungi (Fracchia, Mujica, García-Romera *et al.* 1998; García-Romera, García-Garrido, Martín *et al.* 1998; McAllister, García-Garrido, García-Romera *et al.* 1996). Because soil contamination with heavy metals reduces the size of microbial population, the role of AM fungi and saprobe fungi in restoration of such soil is significant. This review presents highlights on the effects of filamentous saprobe fungi on mycorrhizosphere and its role on AM plant growth promotion and heavy metal uptake by AM plants.

## Interactions in mycorrhizosphere

The hyphae of AM fungi play an important role in the formation and stability of soil aggregates and contribute to the composition of plant community structures. Mycorrhizal symbiosis generally increases root exudation and influences rhizosphere microbial communities. Mycorrhizal hyphae exude chemical compounds that have a selective effect on microbial communities in the rhizosphere and soil. These microbial compartments are referred to as mycorrhizosphere. There has been increasing evidence that the mycorrhizospheric communities play an important role in heavy metal resistance in plants, plant growth, and soil fertility.

Soil micro-organisms influence AM fungal development and symbiosis establishment but no clear pattern of response has been found—positive (Gryndler, Hrselova, and Chvatalova 1996; Meyer and Linderman 1986), negative (McAllister, García-Romera, Martin *et al.* 1995; Wyss, Boller, and Wiemken 1992), and neutral (Edwards, Young, and Fitter 1998) interactions have all been reported. The

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factors influencing AM plant growth are the timing of addition of micro-organisms, type of AM fungus present, and plant species in which the AM fungus has colonized (McAllister, García-Romera, Godeas *et al*. 1994; McAllister, García-Romera, Martin *et al*. 1995; Tylka, Hussey, and Roncadori 1991). It is difficult to draw any useful generalizations based on these factors and the complex and dynamic nature of the soil environment. Indeed, even the same genus has been shown to have either a beneficial, negative or neutral effect upon AM fungi, as has been reported for *Trichoderma* spp. (Dhillion 1992; Edwards, Young, and Fitter 1998; McAllister, García-Romera, Godeas *et al*. 1994; Meyer and Linderman 1986; Wyss, Boller, and Wiemken 1992). Recent advances in both biochemical and molecular techniques should provide more useful insights into the nature of the interactions between AM fungi and other soil micro-organisms. For example, although the presence of *Trichoderma harzianum* decreased AM fungi root colonization, the addition of an organic nutrient source did not decrease external hyphal density of the AM fungus *Glomus intraradices*, the living AM mycelial biomass was measured as the content of a membrane fatty acid, (PFLA16:1g5), and the AM hyphal efficacy for phosphorus was measured using radio-labelled 33P (Green, Larsen, Olsson *et al*. 1999). An investigation on the interaction between *Glomus mosseae* and *Trichoderma* spp. *in vitro* brought out that spore germination and hyphal development of *G. mosseae* is stimulated by *Trichoderma* spp. (Calvet, Barea, and Pera 1992). The stimulation was attributed to the production of volatile compounds by *Trichoderma* spp.

Once mycorrhizal colonization has occurred, subsequent exudation release by the root may be modified both through the mycorrhizal fungus acting as a considerable carbon sink for photoassimilate and through hyphal exudation. This may be expected to lead to changes in both the qualitative and quantitative release of exudates into the mycorrhizosphere. AM colonization generally decreases root exudation, (Graham, Leonard, and Menge 1981) although not always (Azaizeh, Marschner, Romheld *et al*. 1995), and may be influenced by the species of fungus present (Marschner, Crowley, and Higashi 1997). In addition, a reduction in sugar and amino acid release has been reported in some studies (Dixon, Garrett, and Cox 1989; Graham, Leonard, and Menge 1981) but there is no clear pattern as to the consistency of this phenomenon. Similarly, the reported impact on the mycorrhizosphere community is equally inconsistent with, for example, Filion, St-Arnaud, and Fortin (1999) examined the release of soluble unidentified substances by the external mycelium of *G. intraradices* on the conidial germination of two saprobe fungi *T. Harzianum* and *Fusarium oxysporum* f. sp. *chrysanthemi*. Conidial germination of *T. harzianum* was stimulated, whereas that of *F. oxysporum* f. sp. *chrysanthemi* was reduced. These observed effects were generally correlated with the extract concentration. The authors (Filion, St-Arnaud, and Fortin 1999) suggested that this was a possible means by which the AM mycelium may alter the microbial environment so that it was detrimental to pathogens. In contrast, Green, Larsen, Olsson *et al.* (1999) examined the interaction between *G. intraradices* and *T. harzianum* and observed that the AM external mycelium had no effect on the population density of *T. harzianum*, except in the presence of an organic substrate when population densities and metabolic activity of *T. harzianum* were actually reduced. The differing results reported on the interactions of AM fungi and saprobe fungi, therefore, are probably not only due to the type of AM fungus and saprobe fungi present but also the conditions, such as soil nutrient availability, in which the interaction is studied.

## Synergistic effects on plant growth

The interactions of AM fungus and saprobe fungi in the plant rhizosphere may affect plant growth and microbial community composition. Mixtures of these micro-organisms generally increase genetic diversity in the rhizosphere of micro-organisms that may persist longer and utilize a wide array of mechanisms to establish the plants in metal contaminated site and increase plant growth.

The filamentous saprobe fungi improve plant growth by producing growth-promoting substances and suppressing root pathogens. But information available on the interaction between AM fungi and filamentous saprobe fungi is scanty. There are reports on the positive effects of using filamentous saprobe fungi and mycorrhiza fungi on the growth of plants and the increase uptake of phosphorus by plants. The presence of the saprobe fungi, *Fusarium concolor* and *Trichoderma koningii*, show enhanced shoot dry weight, nitrogen (N), phosphorus (P), and potassium (K) content of Eucalyptus plant when co-inoculated with *G. mosseae* in contaminated soil (Arriagada, Herrera, Borie *et al*. 2007). Tarafdar and Marschner (1995) has reported higher shoot and root dry biomass, phosphatase activity, and shoot P concentration in wheat when co-inoculated with *Aspergillus fumigates* and *G. mosseae*. In another study, Godeas, Fracchia, Mujica *et al*. (1999) reported the highest effect of co-inoculation of *G. mosseae* and *Trichoderma pseudokoningii* in soybean plant growth in impoverished soil conditions. In case of micopropagated *Ficus benjamina* plantlets, enhanced plant height was obtained when plant was co-inoculated with *G. mosseae* and *T. harzianum* (Srinath, Bagyaraj, and Satyanarayana 2003). Due

to the synergistic interaction between saprobe fungi and AM fungi in terms of enhanced mycorrhizal root colonization and sporulation and its combined positive effect on plant growth, saprobe fungi are considered as a mycorrhiza helper organism (MHO). MHOs are similar to mycorrhiza helper bacteria (MHB) that is a well studied and established category of mycorrhizosphere (Caroline and Bagyaraj 1995; Srinath, Bagyaraj, and Satyanarayana 2003). It has been suggested that MHB produce hydrolytic enzymes that dilate the cortical cells and provide wider intercellular space, enabling AM fungi to penetrate and ramify more easily in the root system, thus resulting in denser mycorrhizal colonization. Similar mechanisms may be adopted by these mycorrhiza helping saprobe fungi but at present, this is only an assumption and cannot be generalized. There is a great need to carry out research in this area and to establish these saprobe fungi as MHOs.

## Heavy metal resistance in plants

The use of plants to remove toxic metals from soils (phytoremediation) is emerging as a potential strategy for cost-effective and environment-friendly remediation of contaminated soils (Cunningham and Berti 2000). Plant sensitivity to heavy metals varies according to the different plant species—some can accumulate high concentrations of heavy metals and can be used in experimental assays for phytoremediation of contaminated soils (Huang and Cunningham 1996; McGrath, Zhao, and Lombi 2002).

Soil micro-organisms play an important role in plant health, nutrient uptake, and resistance against heavy metals (Kabata-Pendias 2004). There are reports that the co-inoculation of AM fungi and filamentous saprobe fungi contribute to the increase in resistance of plants to heavy metals (Arriagada, Herrera, and Ocampo 2005) but very limited study has been done in this area. The fact that saprobe fungi can absorb heavy metal and that can increase AM colonization of plants may explain that the combined inoculation of AM fungi and saprobe fungi increased the tolerance of plants in heavy metal contaminated soil (Arriagada, Herrera, García-Romera *et al.* 2004; Joner and Leyval 1997; Schüepp, Dehn, and Sticher 1987). Studies report the potential role of interaction of saprobe fungi and AM fungi in elevating phytoextraction efficiency of plants and in stimulating plant growth under soil contaminated with heavy metal (Arriagada, Herrera, García-Romera *et al.* 2004; 2005). Arriagada, Herrera, García-Romera *et al.* (2004) have reported the higher Cd metal uptake in Eucalyptus co-inoculated with *Glomus deserticola* and *T. koningii*. In another study, they have reported the increase in dry weight, total nutrient concentration, chlorophyll content of the shoot, percentage of AM root length colonization, and succinate dehydrogenase activity of AM mycelia of *Eucalyptus globulus* in presence of 1500 mg/kg of Pb when co-inoculated with *G. deserticola* and *T. koningii* (Arriagada, Herrera, and Ocampo 2005). Although the potential of saprobe fungi as an MHO in contaminated soil is evident from the aforementioned studies, the overall efficiency of saprobe fungi and AM fungi to establish plants in such soil depends on the type of soil, micro-organisms involved, and concentration of heavy metals in the soil. Thus, for effective bioremediation of heavy metal contaminated soil, selection of effective combination of soil micro-organisms for particular type of soil conditions is a prerequisite and priority should be given to indigenous micro-organisms.

## Discussion and conclusion

Various studies have been carried out on the interaction between rhizospheric bacteria and AM fungi and their effect on metal uptake. However, studies on the filamentous saprobe fungi of mycorrhizosphere have been neglected till date. There is a great need to concentrate on this specific issue as filamentous saprobe fungi are also an important component of the soil rhizosphere (Dix and Webster 1995). Their importance lie in the large microbial biomass they supply to soil. They can grow out from the sites of microbial activity. The hyphae extend into the soil, producing fine mycelial networks that facilitate substrate collection (Wainwright 1992). Some research studies confirm the existence of synergistic effect of saprobe fungi on AM spore germination and plant root colonization by AM fungi (Calvet, Barea, and Pera 1992; Fracchia, Mujica, García-Romera *et al.* 1998; Gracía-Romera, García-Garrido, Martín *et al.* 1998; McAllister, García-Garrido, García-Romera *et al.* 1996). Along with this, studies also confirm the existence of a synergistic effect between both the fungi in plant resistance to heavy metal in soil and its uptake and translocation from lower to upper parts of plants. However, further studies need to be carried out to explore and establish the beneficial aspect of saprobe fungi and AM fungi to strengthen the mycorrhizosphere and to grow plants in metal stressed soil conditions. In conclusion, on the basis of research studies, there is great possibility that understanding the mechanism behind the symbiotic association between AM fungi and saprobe fungi may provide unique opportunity to bioremediate contaminated sites more effectively.

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# 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.

- *Agriculture, Ecosystems and Environment*
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| Aponte C*, García L V, Marañón T, and Gardes M. 2010 | **Indirect host effect on ectomycorrhizal fungi: leaf fall and litter quality explain changes in fungal communities on the roots of co-occurring Mediterranean oaks.** *Soil Biology and Biochemistry* **42**(5): 788–796 [*Instituto de Recursos Naturales y Agrobiología de Sevilla – CSIC, PO Box 1052, 41080 Sevilla, Spain] |
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Croix du Sud, B-1348 Louvain-la-Neuve, Belgium

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*Fax* +32 10 45 15 01
*E-mail* cranenbrouck@mbla.ucl.ac.be (Sylvie Cranenbrouck)
*Website* http://emma.agro.ucl.ac.be/Formation/in_vitro_culture_AMF

Edinburgh, **UK**
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*E-mail* woodyrts@uvic.ca
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22–27 August 2010

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6–10 September 2010

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**Dr Alejandro Alarcon, Mexican Society on Mycorrhizal Symbiosis SOMESIMI**

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