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About TERI

A dynamic and flexible organization with a global vision and a local focus, TERI was established in 1974. While in the initial period the focus was mainly on documentation and information dissemination activities, research activities in the fields of energy, environment, and sustainable development were initiated towards the end of 1982. The genesis of these activities lay in TERI's firm belief that efficient utilization of energy, sustainable use of natural resources, large-scale adoption of renewable energy technologies, and reduction of all forms of waste would move the process of development towards the goal of sustainability.

The Bioresources and Biotechnology Division

Focusing on ecological, environmental, and food security issues, the Division's activities include working with a wide variety of living organisms, sophisticated genetic engineering techniques, and, at the grassroots level, with village communities. The Division functions through four areas: Microbial Biotechnology, Plant Molecular Biology, Plant Tissue Culture, and Forestry/Biodiversity. The Division is actively engaged in mycorrhizal research. The Mycorrhiza Network has specifically been created to help scientists across the globe in carrying out research on mycorrhiza.

The Mycorrhiza Network and the Centre for Mycorrhizal Culture Collection

Established in April 1988 at TERI, New Delhi, the Mycorrhiza Network first set up the MIC (Mycorrhiza Information Centre), the same year, and the CMCC (Centre for Mycorrhizal Culture Collection) – a national germplasm bank of mycorrhizal fungi – in 1993. The general objectives of the Mycorrhiza Network are to strengthen research, encourage participation, promote information exchange, and publish the quarterly newsletter, *Mycorrhiza News*.

The MIC has been primarily responsible for establishing an information network, which facilitates information sharing among the network members and makes the growing literature on mycorrhiza available to researchers. Comprehensive databases on Asian mycorrhizologists and mycorrhizal literature (RIZA) allow information retrieval and supply documents on request.

The main objectives of the CMCC are to procure strains of both ecto and VA mycorrhizal fungi from India and abroad; multiply and maintain these fungi in pure culture; screen, isolate, identify, multiply, and maintain native mycorrhizal fungi; develop a database on cultures maintained, and provide starter cultures on request. Cultures are available on an exchange basis or on specific requests at nominal costs for spore extraction/handling.

Contents

Effect of edaphic and climatic factors on the development of mycorrhiza in tree nurseries (part I): effect of soil moisture, soil texture, and temperature

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Edaphic and climatic factors such as soil moisture, soil texture, temperature, pH, light, and carbon dioxide may affect the efficacy of mycorrhizal fungi. This article includes the effect of soil moisture, soil texture, and temperature.

Effect of soil moisture

Excess moisture in the soil and moisture stress affects the composition of mycorrhizal flora and their efficiency on the host plants.

Effect of excess moisture in soil

Studies were conducted at the Division of Forestry and Forest Products, Commonwealth Scientific and Industrial Research Organization, Wembley, Australia on the seedlings of *Eucalyptus diversicolor*. Seedlings of eucalyptus, raised in a green house on yellow sand with moisture gradient ranging from –4.5 kPa (above field capacity) to –0.14 kPa (near water logged), showed that all the tested fungi namely *Discolea maculata, P. tinctorius,* and *Laccaria laccata* enhanced seedling growth above that of uninoculated seedlings. However, in soils near saturation, there was no response to inoculation. Reduced mycorrhizal formation in relation to increasing soil moisture occurred to various degrees for all fungi, it was particularly marked with *P. tinctorius*. In contrast, *L. laccata* maintained a comparatively high number of mycorrhizal roots at all moisture levels except at the wettest soil treatment. An isolate of *D. maculata* from a swampy environment did not produce greater number of mycorrhizal roots than an isolate of this species from a forest environment (Bougher and Melajczuk 1990).

In studies conducted at the Department of Forest Mycology and Pathology, Swedish University of Agricultural Sciences, Uppsala, Sweden, *Pinus sylvestris* seedlings were grown in vertical petridish system and inoculated with five ECMF (ectomycorrhizal fungi) namely *Thelephora terrestris, L. laccata, Hebeloma crustuliniforme, Suillus flavidus,* and *S. bovinu*s. Half of the root system in the petridish was subjected to periodic flooding. Among the five ECMF, *T. terrestris, L. laccata, and H. crustuliniforme* were not sensitive to flooding, whereas *S. flavidus* and *S. bovinus* were highly sensitive to flooding. The latter failed to colonize the root when flooded for only 2 minutes per day, 4 times a week (Stenstrom 1991). In further studies conducted at the above University, pine germlings were rooted in a brick pellet–peat mixture enclosed in vertically standing plastic petridishes, and the entire root inoculated either with *H. crustuliniforme* or *S. bovinus* after 7 days. When *H.crustuliniforme* was flooded in the lower half of the petridishes for up to 3 hours a day, 4 days a week, mycorrhiza formation and extrarhizal mycelial growth took place both in the lower and upper part of the petridishes. With *S. bovinus*, the same treatment totally prevented mycorrhiza formation, mycelial growth, and strand development in the flooded part, but all three parameters were extensive in the upper part. Flooding for as little as 10 minutes (4 days per week) only allowed sparse mycelial growth in the uppermost 2 cm but no mycorrhiza development occurred. Control plants subjected to no flooding for 3 weeks and subsequently flooding up to 18 hours (4 days per week) did not eliminate already established mycorrhiza (Stenstrom and Unestam 1987).

* Compiled from TERI database – Riza

Effect of water stress

Tolerance of mycorrhizal fungi/plants to water stress

The tolerance ability of imposed water stress in pure culture was studied on 55 isolates of 18 species of ECMF at the College of Forest Resources, University of Washington, USA. Water potential treatments adjusted with polyethylene glycol were applied to the petridish units. These units allowed colony diameter measurements of fungi grown on liquid media. Delayed growth initiation and inhibition of growth rate occurred with increasing water stress. For about 87% of the isolates, the growth rate was inhibited by the applied initial water potential treatment, leaving only seven isolates where growth increased with initial water potential treatments. No growth was evident under the imposed stress treatments for isolates of *L. bicolor, L. laccata,* and *Lactarius controversus,* and growth occurred only in control. *Boletus edulis, Cenococcum geophilum, Rhizopogon vinicolor,* and 5 *Suillus* species were noticed to be drought tolerant and demonstrated their ability to grow at a water potential of –3MPa. *H. crustuliniforme, L. bicolor, L. laccata,* and *S. caerulescens* are species which can tolerate –1MPa. However, fungal drought tolerance was poorly correlated with estimates of annual precipitation for collection localities. Also, reisolation of *L. bicolor* increased the growth rate and water stress tolerance when compared with the same fungus prior to reisolation (Coleman, Bledsoe, and Lopushinskyw 1989). Studies conducted at the Department of Botany, Northeastern Hill University, Shillong, India, showed that *Scleroderma aurantium* colonized roots of *Pinus kesiya* better at 30% moisture level and *Bolitus edulis* gave best results at 55% moisture level (Raj Kumar, Sharma, and Mishra 1990). Laboratory screening tests conducted at the Nova Scotia Research Foundation Corporation, Canada, on several mycorrhizal fungi in various media for alleviating drought stress in *Picea mariana* showed that isolate No. 302, *Paxillus involutus,* and *P. tinctorius* formed rhizomorphs in any of the tests. Only the first two (isolate No. 302 and *Paxillus involutus*) grew well at the temperature found in Northern latitude soils, and isolate No. 302 grew well at water potentials close to those causing drought stress. This fungus also appeared to help maintain the photosynthetic rate of seedlings at low water potentials (Boyle and Salonium 1988). Studies were conducted at the Department des Sciences, Forestiers, Universite Laval, Quebec, Canada, on 5 mycorrhizal fungal isolates in pure culture under conditions of low water potential and also with the same isolates in symbiotic association with black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*) to determine whether prescreening tests correlated with each other. Mycorrhizal seedlings were subjected to known water stress by exposing their roots to a solution of polyethylene glycol or alternatively, they were planted into a specially designed system, which allowed the simulation of a drought cycle in a forest soil. Fungi which grew well in pure culture under low water potential generally increased the drought resistance of black spruce but had little effect on the drought tolerance of jack pine seedlings. The ability of some fungi to form rhizomorphs extending into mineral soil layer or to stimulate root growth also correlated with increased drought tolerance of black spruce under the experimental conditions used. Jackpine seedlings showed a relatively high tolerance to water stress independent of their mycorrhizal status (Boyle 1990). In further studies, seedlings of black spruce (*Picea mariana*) and jack pine *(Pinus banksiana*) were inoculated with 5 ECMF whose growth rates in pure culture had been determined at various water potentials and temperatures. Growth and apparent photosynthetic rates of these seedlings (after inoculation with these five fungi) in response to water stress and subsequent rewetting were assessed by exposing roots to polyethylene glycol or by planting in forest soil subjected to simulated drought. Fungal growth varied considerably in response to water stress (from –0.26 to –2.12 MPa) and temperature (from 5 to 30°C). Fungi that tolerated low water potential in pure culture showed potential for improving the performance of black spruce during drought cycle but had little consistent effect on the performance of jackpine in which uninoculated control seedlings often showed the best performance (Boyle and Hellenbrand 1991).

Studies conducted at the University of Ibadan, Ibadan, Nigeria showed that inoculation with *Boletus suillus* increased drought resistance of *Acacia auriculaeformis* but did not improve drought resistance of *A. mangium* (Osonubi and Mulongoy 1991). Studies conducted at the Forestry Canada, Quebec, Canada, on seedlings of *Pinus pinaster* inoculated with different dikaryons of *Pisolithus tinctorius* showed that the seedlings inoculated with dikaryons which had an extensive extramatrical phase and large diameter mycelical strands showed higher PSIs (–2MPa) during severe water stress than seedlings inoculated with dikaryons producing fine hyphae and sparse extramatrical phases (–3.8 MPa). Also, seedlings inoculated with strand forming dikaryons recovered faster from water stress than non-inoculated seedlings or seedlings inoculated with non-strand forming dikaryons. When water stress was not

limiting, the architecture of extramatrical phase did not have a large effect on PSIs. The results suggested that the architecture of extramatrical phase influenced resistance to water flow through the soil/root interphase and large mycelial strands increased water flow by bridging the gap between soil and root (Lamhamedi, Bernier, and Fortin 1992).

Studies conducted at the Department of Biosciences, Himachal Pradesh University, India on the effect of water stress (artificially induced by polyethylene glycol) on mycorrhizal and non-mycorrhizal seedlings of *Abies pindrow* showed that mycorrhizal seedlings tolerated higher level of water stress compared to non-mycorrhizal seedlings. Increase in water saturation deficit was observed to be less significant in mycorrhizal seedlings than in non-mycorrhizal seedlings (Lakhanpal and Sharma 1988).

Effect of water stress on mycorrhizal efficiency on ectomycorrhizae

Effect on photosynthetic rate and stomatal conductance

Studies were conducted at the School of Forestry, Auburn University, USA, on *Eucalyptus camaldulensis* seedlings. The seedlings inoculated with *Pisolithus tinctorius* and *Thelephora terrestris* were grown in well-watered soil (–0.03 MPa) or were subjected to long-term water stress of up to 1.0 MPa over 13-week period. All seedling containers, after a period of 13 weeks were watered to field capacity, and water was then withheld to induce short-term drought. Diurnal measurements of seedling photosynthesis rate, leaf stomatal conductance, and leaf water potential completed before, during, and after short-term drought showed that these parameters were similar in larger seedlings with *P. tinctorius* mycorrhizae and smaller seedlings with *T. terrestris* mycorrhizae during the short-term drought.

P. tinctorius inoculated seedlings maintained higher photosynthetic rates (Dixon and Hiol-Hiol 1992). In studies conducted at the Department of Soil Science, Oregon State University, Corvallis, Oregon, USA, *Pseudotsuga menziesii* seedlings were inoculated with ECMF and grown for 6 months under well-watered conditions, and then transferred to a growth chamber where measurements were made as the soil dried. *Rhizopogon vinicolor* enhanced both net photosynthetic rate and stomatal conductance compared to non-mycorrhizal plants in the soil water potential range of then –0.05 to –0.50 MPa, despite 0.2 to 0.3 MPa leaf water potential. *H. crustuliniforme* tended to enhance while *L. laccata* decreased the net photosynthetic rate and stomatal conductance of the host seedlings in this range of soil water potential but neither fungus affected leaf water potential (Dosskey, Boersma, and Linderman 1991).

In studies conduced at the Institute of Terrestrial Ecology, Bush Estate, Midlothian, UK, *Picea sitchensis* (Sitka spruce) seedlings inoculated or non-inoculated with *Paxillus involutus* were either subjected to drought conditions or were watered adequately. Stomatal conductance, net photosynthetic rate, and water potential were higher in well-watered mycorrhizal plants than in non-mycorrhizal plants. The effect of mycorrhizal infection was interpreted as both stomatal effect and effect on photosynthetic apparatus. During drought treatment, the mycorrhizal plants dried out the substrate sooner than the non-mycorrhizal plants which were smaller. However, stomatal conductance, net photosynthetic rate, and shoot water potential in mycorrhizal plants were similar to the non-mycorrhizal plants. A correlation between P (phosphorus) concentration in shoots and net photosynthetic rate was shown. The improved performance of mycorrhizal seedlings was probably due to their better P and K (potassium) content and their more extensive root system with mycelial strands (Lehto 1992a, 1992b). In further studies at the above Institute, mycorrhizal (with *Paxillus involutus*) and non-mycorrhizal sitka spruce seedlings were grown to comparable size and with comparable N (nitrogen), P, and K concentration in a parlite nutrient solution culture. Shoot water potentials of mycorrhizal and non-mycorrhizal seedlings were related to the moisture contents of the substrate during a drying cycle. At any given substrate moisture content, mycorrhizal plants had significantly lower water potentials than the non-mycorrhizal plants, the difference being about 0–1 MPa. There was no effect of mycorrhizal infection on stomatal conductance and net photosynthetic rate in either well-watered or drought seedlings (Lehto 1992b).

In studies conducted at the Department of Botany and Microbiology, University of Ibadan, Nigeria, seedlings of *Gmelina arborea* were subjected to three treatments namely ectomycorrhizal control, ectomycorrhizal droughted, and non-mycorrhizal droughted. Stomatal closure and reduction in leaf turgor of ectomycorrhizal droughted plants occurred after two-thirds of the available soil moisture had been extracted whereas in non-mycorrhizal droughted plants, stomata closed linearly with reduction in extracted soil water. In another experiment, osmoregulation and P concentration in xylem sap and leaf were higher in ectomycorrhizal droughted plants than in non-mycorrhizal droughted plants after subjecting them to two to three periods of soil drying. Osmoregulation in

ectomycorrhizal droughted and non-mycorrhizal droughted plants correlated with the ratio of leaf dry weight to turgor weight. After the first droughting cycle, seedlings began to wilt at the lower xylem pressure potentials but with more negative values in ectomycorrhizal droughted plants as compared to non-mycorrhizal droughted plants. The enhanced drought tolerance of ectomycorrhizal droughted plants was attributed to the maintenance of water potential gradient for water absorption by osmotic adjustment and with increased growth parameters due to P (Osonubi 1989).

Effect on growth parameters

Studies conducted at the Department of Biosciences, Himachal Pradesh University, India, on *Pinus gerardiana* showed that the seedlings grown in thermally sterile soil and inoculated with basidiomycetous mycelium developed mycorrhiza after 6 weeks attained better height, shoot/root ratio, and exhibited higher survival percentages than non-mycorrhizal plants. Also, mycorrhizal seedlings were tolerant to higher level of water stress, and increase in water saturation deficit was less significant as compared to non-mycorrhizal seedlings (Lakhanpal and Chaudhery 1988).

On vesicular–arbuscular mycorrhizae

Studies conducted at the Department of Agronomy and Soil Science, University of Hawaii, USA, showed that *Leucaena leucocephala* plants infected with *Glomus fasciculatum* had five times greater leaf area and leaf conductance to water vapour diffusion nearly double than non-mycorrhizal plants. The differences between xylem pressure potential and soil water potential were considerably less in mycorrhizal plants than in non-mycorrhizal plants. Stomatal responses to the humidity deficits of air during the day were nearly twice as great in non-mycorrhizal plants as in mycorrhizal plants. Leaflet folding and orientation responses to avoid direct sunlight during the day were greater in non-mycorrhizal plants (Huang, Smith, and Yost 1985). Studies conducted at the Citrus Research and Education Centre, University of Florida, USA on *Citrus sinensis*, *C. aurantium,* and *Poncirus trifoliata* seedlings showed that 5-month old seedlings, both non-mycorrhizal (fertilized with soluble phosphorus) and mycorrhizal (inoculated with *Glomus intraradices*) of each root stock were comparable in size, P sufficiency, and relative growth rates whether they were well watered or subjected to two drought stress cycles of short duration. Under well-watered conditions, whole plant transpiration, leaf water status, and root hydraulic conductivity were similar for VAM (vesicular–arbuscular mycorrhizae) and non-VAM plants of each root stock. During drought stress and recovery period, VAM plants also had very comparable whole plant transpiration rates and leaf water potential to non-VAM plants but mycorrhizae reduced root hydraulic conductivity of *P. trifoliata* and *C.aurantium* by 66% and 40% respectively, during drought stress and recovery period (Graham, Syvertsen, and Smith 1987). Studies conducted at the Agricultural Research Organization, Negev, Israel, on *Citrus jambhiri* seedlings showed that infection by *Glomus intraradices* increased root growth and transpiration rate, and reduced leaf water potentials relative to non-VAM plants. The hydraulic conductivity of the root system subjected to three drying cycles, each of 5 to 7 days duration, was lower than that of well-watered plants, and VAM infection further reduced root conductivity. Evidently, the higher root densities and higher transpiration rates of VAM-infected plants may have depleted soil water more quickly than non-infected seedlings and resulted in severe water stress conditions during drought cycles (Levy, Syvertsen, and Nemec 1983). In studies conducted at the Institute of Plant Ecology, University of Copenhagen, Denmark, *Acacia nilotica* and *Leucaena leucocephala* were inoculated on seeds before planting with a mixture of *Glomus etunicatum, G. mosseae,* and *G. occultum,* and subjected to treatments namely plus or minus VAM, plus or minus P fertilizer, and plus or minus repeated drought treatment from week 7. Drought treatment reduced seedling biomass in *A. nilotica* by 39% and by 27% in *L. leucocephala*. *A. nilotica* was more drought resistant than *L. leucocephala* (Michelsen and Rosendahl 1990). In studies conducted at the Department of Ornamental Horticulture, University of Florida, Gainesville, USA, *Carrizo citrange* seedlings inoculated with *Glomus intraradices* or provided with an inoculum filtrate were exposed to drought stress after transplanting into large containers filled with P amended medium (30 mg P per gram of soil). Drought stress caused P reduction in leaf tissues and dry matter accumulation in VAM plants. However, P levels, dry weights, and transpiration of VAM seedlings were greater than non-VAM plants. Mycorrhizal infection thus appears to improve establishment of citrus into transplant situations by improving P uptake and reducing plant stress (Johnson and Hummel 1995).

Effect of soil texture/soil types

Soil texture may affect plant growth as well as mycorrhizal efficiency in various ways including drainage, aeration, limiting nutrient availability, etc. The effect of soil texture on efficiency of mycorrhiza is briefly discussed here.

On vesicular–arbuscular mycorrhizal fungi

In studies conducted at the Section of Microbiologia, Centre de Edafologia, Colegio de Postgraduados, Montecillo, Mexico, 15-day old *Acacia farnesiana* seedlings were transplanted to bags containing three types of soils namely clay loam (with pH 6.5, 12 ppm P), sandy loam (with pH 4.5, 5 ppm P), and bromide with least P content. The seedlings were supplied with 0, 50, and 100 ppm P_2O_5 and inoculated with six local strains of Glomus grown on onion roots. After 170 days on clay loam soil, none of the treatments had significant effect on plant growth, whereas mycorrhizal colonization was 80%–98%. In bromide soil, mycorrhizal treatment increased growth more than P fertilization even at 100 ppm P whereas mycorrhizal colonization was 52%–83%, with three Glomus strains being more effective than others. Only on sandy loam soil, P fertilization treatments produced best results where as mycorrhizal colonization was 23%–59% (Gardezi et al. 1990). Studies conducted at the Centre National de Recherches, Forestieres, Champenoux, Seichamps, France, on young seedlings of *Acer pseudoplatanus* raised on three different soils namely very poor rendzina (pH 8.3), a humus rich rendzina (pH 7), and leached soil (pH 5.3) showed that on very poor rendzina soil and on humus rich rendzina soil, artificial mycorrhization by *Glomus mosseae* was much more efficient than by natural microflora. On leached acid soil (pH 5.3), artificial inoculation was inefficient whereas natural micro flora of VAM was very efficient. On poor rendzina soil, artificial inoculation by *G. mosseae* gave the same results as that with fertilization with NPK. The effect of mycorrhization seemed due to improvement of nutrition in P, Cu, and Z which resulted in insufficient availability of N in the soil and decrease of total N contents in leaves (Tacon, Kabre, and Garbaye 1979).

Studies conducted at the Rubber Research Institute, Kuala Lumpur, Malaysia, on rubber (*Hevea brasiliensis*) seedlings inoculated with mixed VAM fungal species at two nursery sites namely sandy site and clayey site showed that after 26 weeks, at the sandy site, VAM increased shoot dry weight, stem diameter, and plant height only in treatments without P application. The increase in shoot dry weight due to VAM colonization was 70% greater than uninoculated controls although increase was reduced to 5% when P was applied. At clayey site, the shoot dry weight response due to VAM colonization was only 29%. Application of P to non-inoculated plants did not increase shoot yield further. At sandy site, leaf contents of P, K, Mg, and Cu increased while at clayey soil, N and P contents of leaf increased by VAM inoculation (Ikram et al. 1992)

Studies conducted at the United States Department of Agriculture, Agricultural Research Service, Orlando FL., USA, on citrus grown on vermiculite and saw dust, peat and vermiculite, sand and perlite, and sand and vermiculite showed that *Glomus intraradices* enhanced plant growth in all combinations of sand and vermiculite, but was more efficient in sand and in mixes containing up to 29% vermiculite. Plant growth depression increased and VAM infection decreased as the level of saw dust increased in mixes with vermiculite. Fungus mediated plant growth and VAM infection were generally superior in peat vermiculite mixes containing vermiculite in the range of 14.3% and 29%. In sand–perlite mixes, best fungus mediated growth occurred in sand containing 14.3%–42% perlite (Nemec 1987).

Experiments were conducted at the University of California, Riverside, California, USA, on *Citrus aurantiun* which was grown in different soil mixes supplied with 38 mg or 128 mg P per cc of mix and inoculated with *Glomus fasciculatum* inoculum consisting of soil, roots, and chlamydospores from *Sorghum vulgare* infected pots. Significant growth responses due to VAM inoculation were found in 38 mg P treatment in sand, in 2/3 sand + 1/3 red wood shaving, in 2/3 sand + 1/3 peat moss, and in 1/3 sand + 1/3 red wood shavings + 1/6 peat moss + 1/6 perlite. No significant growth responses due to VAM were found in 1/3 sand + 2/3 red wood shavings, 1/2 sand + 1/2 peat moss, 1/3 sand + 2/3 peat moss, and 1/3 sand + 1/3 peat moss + 1/3 red wood shavings. At 128 mg P treatment, significant growth responses due to VAM inoculation occurred only in sand and 2/3 sand + 1/3 peat moss. Greatest dry weights were found from mycorrhizal treatments in sand (Menge et al. 1979).

On ectomycorrhizal fungi

Studies conducted at the College of Agriculture, Chonnan National University, Korea showed that the number of short roots, growth in height, and total dry weight in seedlings of blackpine (*Pinus thunbergii*) (pricked at one-year age) were greater for seedlings grown in vermiculite than in sandy loam soil at 2 years age. Seedlings inoculated with *Pisolithus tinctorius* showed significant increases in primary lateral roots, short roots, and total dry weights after 2 years growth compared with those of uninoculated controls (Oh and park 1990).

In studies conducted at the Heffley Reforestation Centre Ltd, Kamloops, British Columbia, Canada, coarse-textured, well-drained peat moss was found essential for good fungal colonization in Engelmann spruce seedlings. A coarse-fine ratio

(based on fraction larger and smaller than 2.0 mm) greater than 0.60 was found desirable (Husted 1990). Studies conducted at the Wageningen University of Agriculture, Biological Station, Kampsweg, The Netherlands, on *Pinus sylvestris* seedlings showed that after 9 months growth, ectomycorrhizal development with *Suillus bovinus* was significantly greater in peat and primary stand humus than in secondary stand humus or podsolic sandy soil. With *Rhizopogon luteolus*, growth on secondary stand humus was higher than in primary stand humus. Ectomycorrhizae development with *Laccaria bicolor* on podsolic sandy soil did not differ from that on primary stand humus. The degree of ectomycorrhizal development was related to K concentration, organic matter content, and pH of the soil (Baar and Elferink 1996). Studies were conducted at the Department of Forestry, National Taiwan University, Taipei, Taiwan to find the effect of volcanic ash soil with low pH, red coral limestone soil with high Ca concentration, and litho soil of metamorphic limestone low in available nutrients, on ectomycorrhizal formation of *Quercus gracillipes* and *Q. pubescens* inoculated with *Tuber aestivum* 1001 or *T. sp* 004. The results showed that red coral limestone soil with high Ca was most suitable (Tao 1988).

Effect of temperature

Soil temperature has a direct bearing on the growth of mycorrhizal fungi and their survival in soil. The following sections discuss the effect of soil as well as air temperature on mycorrhizal efficiency.

On vesicular–arbuscular mycorrhiza

An experiment was conducted at the Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, USA, on *Fraxinus pennsylvanica* inoculated or not with *Glomus etunicatum* to measure leaf area and plant height of intact seedlings exposed to low root temperatures ranging from 7.5°C to 20°C for 24 days. Another experiment was conducted to measure the growth variables and biomass of seedlings exposed to root temperatures of 12°C, 16°C, and 20°C for 30 days by destructively harvesting seedlings at 6 days intervals. In the first experiment, leaf area and growth rate were greater in mycorrhizal than in non-mycorrhizal seedlings at 7.5°C and 11.5°C, were similar at 5°C and 15°C in both seedlings, and greater in non-mycorrhizal seedlings at 20°C. In the second experiment, these parameters were greater in mycorrhizal seedlings at all temperatures. Phosphorus concentration and the total P content in roots and leaves did not differ significantly between mycorrhizal treatments at any temperature. However, mycorrhizal seedlings had consistently greater leaf P content than non-mycorrhizal controls (Andersen, Sucoff, and Dixon 1987).

In studies conducted at the Texas A and M University and Texas Agricultural Experimental Station, USA, high root-zone temperatures were found to stress container grown plants and reduce nursery productivity. Pre-dawn xylem water potential in stems increased initially in response to high root-zone temperatures (40–50°C) and then decreased over a 5-day period in glasshouse grown *Berbaris thunbergii*, *Buxus mycrophylla,* and *Peltosporum tobera* plants which were either colonized with *Glomus etunicatum* and *G. fasciculatum* or non-colonized. Stomatal conductance and evapotranspiration were reduced incrementally over time in response to high root-zone temperatures. Root damage occurred as indicated by reduction in root quality and stomatal conductance at 35°C and 40°C for *B. thunbergii* and *P. tobera,* and at 40–50°C for the more high temperature resistant *B. mycorphylla*. Mycorrhizal colonization increased stomatal conductivity and evapotranspiration of *B.mycorphylla* at ambient (25°C) and high (45°C) temperatures, and increased evapotranspiration of *B.thunbergii* at 25°C. Colonized plants had lower pre-dawn xylem water potential in shoots with initial exposure to increased root zone temperatures. However, throughout the remaining part of the study, there was little reduction in plant stress with the mycorrhizal isolates used (Newman and Davies 1988). In studies conducted at the Departmento de Engenharia Florestal, Universidade Federal De Vicosa, Brazil, *Fraxinus pennsylvanica* seedlings inoculated or not with *Glomus macrocarpum* or *G.fasciculatum* were grown in a green house for 16 weeks at root temperatures of 15°C, 25°C, and 35°C. Seedling growth responded rapidly to mycorrhizal inoculation at room temperatures of 25°C or 35°C but this response was delayed at 15°C. However, seedlings at 15°C finally attained the size of those at 25°C and 35°C. The growth of non-inoculated plants was best at 15°C and 25°C. Infection of roots by both fungi was greater at 25°C than at 15°C or 35°C. Sugar contents increased, and starch and soluble sugar contents were less in mycorrhizal than in non-mycorrhizal seedlings (Borges and Chaney 1989).

In studies conducted at the United State Department of Agriculture, Forest Service, Tempe, Az, USA, microcosms were constructed in the laboratory from soil, litter, and duff collected beneath canopies of *Pinus edulis, Juniperus osteosperma,* and the open (interspace). Burning was conducted over wet and dry soils. VAM colonization was lower for plants grown in soils burnt when dry than in those grown in soils (over 95%). Plants grown in inter

space soil burnt when wet were least affected. Decrease in VAM colonization was positively correlated with soil temperature as a result of fire and amount of litter burnt (Klopatek, Debona, and Klopatek 1988).

On ecto- and vesicular–arbuscular mycorrhizal fungi

In studies conducted at the Department of Botany and Plant Pathology, Oregon State University, Corvallis, USA, seedlings of *Pseudotsuga menziesii, Pinus ponderosa,* and *Trifoluim subterraneum* grown on soils collected from 5 disturbed (1–1.5 year old clear cut areas) and undisturbed (forest soils) sites were subjected to root-zone temperatures ranging from 7.5°C to 35°C. Maximum formation of both endo- and ecto mycorrhiza occurred at 18.5–24°C in soils from all sites. There was no significant qualitative and quantitative difference between soils from disturbed and undisturbed sites. Mycorrhiza formation was moderate even at 7.5°C but was greatly reduced or prevented at or above 29.5°C. Treatment of soil at 35°C for one week did not appear to adversely affect the viability of EMF propagules but young mycorrhizae subjected to the same treatment appeared to be severely injured (Parke, Linderman, and Trappe 1983).

On ectomycorrhizal fungi

In studies conducted at the Department of Forest Science, Faculty of Forestry, University of British Columbia, Vancouver, Canada, cold-stored container seedlings of white spruce (*Picea glauca*) inoculated with either forest soil from vigorous spruce plantations or with pure mycelial cultures of *Thelephora terrestris, Laccaria bicolor, Hebeloma crustuliniforme, Amphenema byssoides,* E.strain, and autoclaved agar were transferred to forest soil collected from vigorous spruce plantations and subjected to temperatures of 6°C and 12°C. These seedlings were then grown for three months in a controlled environment chamber. Shoot growth was not affected by interaction between temperature and inoculation treatments. Regardless of the soil temperature, seedlings inoculated with forest soil and *L. bicolor* had the greatest shoot growth with 40–45% greater caliper growth, and 63%–85% greater current foliage biomass than control seedlings. Shoot growth did not differ significantly between seedlings inoculated with *A. byssoides* or *T. terrestris* and control seedlings. In E. strain and *H. crustuliniforme* inoculated seedlings, caliper growth was reduced by 5%–25%, foliage biomass by 25%–35% though at the time of transfer to soil, 95% of the short roots were colonized by these fungi. Similarly N and P uptake were greatest in forest soil and *L. bicolor* infected seedlings, intermediate in *A. byssoides* or *T. terrestris* inoculated seedlings, and control seedlings, and lowest for those inoculated with E. strain and *H. crustuliniforme* (Husted 1990).

Studies conducted at the University of Missouri, Columbia, USA, on *Quercus velutina* seedlings inoculated with *Pisolithus tinctorius* and subjected to all possible combinations of four growth media temperatures (18°C, 23°C, 28°C, and 30°C), two watering treatments (daily and alternate days), and two nutrient treatments showed that mycorrhizal development occurred only at the growth media temperature of 35°C. Within 35°C treatments, alternate day watering and fertilization with NPK both individually and in combination produced the greatest mycorrhizal development (Behrns, Garrett, and Cox 1979).

In studies conducted at the Division of Botany and Zoology, Australian National University, Canberra, the paper-sandwich technique for axenic synthesis of ectomycorrhizas by eucalyptus seedlings was used. The technique involves growing of plant roots and fungus separately and then bringing them together in a way which immediately initiates infection. It was found that altering either temperature or the carbohydrate status of the fungus, *Pisolithus tinctorius* (isolated from *Eucalyptus citriodora* plantations) markedly affected the proportion of root apices of *E. globulus* sub sp. *bicostata* seedlings converted to mycorrhizas (McInnes and Chilvers 1994).

References

Andersen C P, Sucoff E I, and Dixon R K. 1987
The influence of low soil temperature on the growth of vesicular–arbuscular mycorrhizal *Fraxinus pennsylvanica*
Canadian Journal of Forest Research **17**(8): 951–956

Baar J and Elferink M O. 1996
Ectomycorrhizal development on Scots pine (*Pinus sylvestris* L.) seedlings in different soils
Plant and Soil **179**(2)*:* 287–292

Behrns G T, Garrett H E, and Cox G S. 1979
Mycorrhizal relationships of *Quercus velutina* and *Pisolithus tinctorius* as influenced by growth media temperature, nutrients, and moisture
In: Proceedings of the Fourth North American Conference on Mycorrhiza, 24–28 June 1979, Colorado State University, Fort Collins, Colorado, USA.

Borges R G and Chaney W R. 1989
Root temperature affects mycorrhizal efficacy in *Fraxinus pennsylvanica* Marsh
New Phytologist **112**(3): 411–417

Bougher N L and Malajczuk N. 1990
Effect of high soil moisture on formation of

ectomycorrhizas and growth of karri (*Eucalyptus diversicolor*) seedlings inoculated with *Descolea maculata, Pisolithus tinctorius,* and *Laccaria laccata*
New Phytologist **114**(1): 87–91

Boyle C D. 1990
Assessment of the effect of mycorrhizal fungi on the drought tolerance of conifers
In: *Innovation and Hierarchical Integration,* compiled by M F Allen and S E William
[Proceedings of the Eighth North American Conference on Mycorrhiza, 5-8 September 1990, Jackson,Wyoming]
Wyoming, USA: University of Wyoming. 34 pp.

Boyle C D and Hellenbrand K E. 1991
Assessment of the effect of mycorrhizal fungi on drought tolerance of conifer seedlings
Canadian Journal of Botany **69**(8): 1764–1771

Boyle C D and Salonium P O. 1988
Feasibility of using ectomycorrhizal fungi to alleviate drought-related problems of containerized black spruce
ENFOR project P-338
Ottawa: Forestry Canada, ENFOR. 27 pp.

Coleman D, Bledsoe S, and Lopushinskyw. 1989
Pure culture response of ectomycorrhizal fungi to imposed water stress
Canadian Journal of Botany **67**(1): 29–39

Dixon R K and Hiol-Hiol F. 1992
Gas exchange and photosynthesis of *Eucalyptus camaldulensis* seedlings inoculated with different ectomycorrhizal symbionts
Plant and Soil **147**(1): 143-149

Dosskey M G, Boersma L, and Linderman R G. 1991
Role for the photosynthate demand of ectomycorrhizas in the response of Douglas fir seedlings to drying soil
New Phytologist **117**(2): 327–334

Gardezi A K, Jaen Contreras D, Guzman-Plazola R A, Ferrera-Cerrato R. 1990
Growth of *Acacia farnesiana* associated with mycorrhizal fungi in three types of Mexican soils
Nitrogen Fixing Tree Research Reports **8**: 99–102

Gary A Hunt. 1990
Nursery and field applications of ectomycorrhizal fungi in western Canada
In: *Innovation and Hierarchical Integration,* compiled by M F Allen and S E William
[Proceedings of the Eighth North American Conference on Mycorrhiza, 5-8 September 1990, Jackson,Wyoming]
Wyoming, USA: University of Wyoming. 147 pp.

Graham J H, Syvertsen J P, and Smith M L jr. 1987
Water relations of mycorrhizal and phosphorus-fertilized non-mycorrhizal citrus under drought stress
New Phytologist **105**(3): 411-420

Huang R S, Smith W K, and Yost R S. 1985
Influence of vesicular-arbuscular mycorrhiza on growth, water relations, leaf orientation in *Leucaena leucocephala* (Lam) de Wit
New Phytologist **99**(2): 229–243

Hu Hung Tao. 1988
Studies on the symbiotic relationship between truffles and trees (III). Effect of soil characteristics on the mycorrhiza formation
Quarterly Journal of Chinese Forestry **21**(4): 111–118

Husted L D. 1990
Effect of inoculation and soil temperature on white spruce seedling (*Picea glauca* (Moench) Moss) growth and nutrition
In: *Innovation and Hierarchical Integration,* compiled by M F Allen and S E William
[Proceedings of the Eighth North American Conference on Mycorrhiza, 5-8 September 1990, Jackson,Wyoming]
Wyoming, USA: University of Wyoming. 148 pp.

Ikram A, Mahmud A W, Ghani M N, Ibrahim M T, Zainal A B. 1992
Field nursery inoculation of *Hevea brasiliensis* Muell. Arg. seedling rootstock with vesicular–arbuscular mycorrhizal (VAM) fungi
Plant and Soil **145**(2): 231–236

Johnson C R and Hummel R L. 1995
Influence of mycorrhizae and drought stress on growth of Poncirus x Citrus seedlings
Hortscience **20**(4): 754–755

Klopatek CC, Debano L F, and Klopatek J M. 1998
Effects of simulated fire in vesicular-arbuscular mycorrhizae in panyan-juniper wood land soil
Plant and Soil **109**(2): 245–249

Lakhanpal T N and Chaudhery S K. 1988
Studies on the mycorrhizae of Pinus gerardiana
In: *Mycorrhizae for Green Asia,* edited by Mahadevan A, Raman N, and Nalarajan K, pp. 283–285
[Proceedings of the First Asia Conference on Mycorrhizal, 29–31 January 1998, Madras, India]
Madras: University of Madras.

Lakhanpal T N and Sharma DD. 1988.
Water stress level tolerance in mycorrhizal and non-mycorrhizal seedlings of silver fir (*Abiesipindrow*)
In: *Mycorrhiza Round Table,* Manuscript Report 201 c, edited by Verma A K, Oka A K, Mukerji K G, Tilak K V B R, Janak Raj, pp. 137–140
[Proceedings of a workshop, 13–15 March 1987, New Delhi]
New Delhi: Jawaharlal Nehru University.

Lamhamedi M S, Bernier P Y, and Fortin J A. 1992.
Hydraulic conductance and soil water potential at the soil-root interface of *Pinus pinaster* seedlings inoculated with different dikaryons of *Pisolithus* sp.
Tree Physiology **10**(3): 231–244

Lehto T H. 1990
Effects of mycorrhiza and drought on Photosynthesis and water relations of sitka spruce
Agriculture, Ecosystems and Environment **28**(1/4): 299–303

Lehto T H. 1992a
Mycorrhizas and drought resistance of *Picea sitchensis* (Bong.) Carr.I. In conditions of nutrient deficiency
New Phytologist **122**(4): 661–668

Lehto T H. 1992b
Mycorrhizas and drought resistance of *Picea sitchensis* (Bong.) Carr.II. In conditions of adequate nutrition
New Phytologist **122**(4): 669–673

Levy Y, Syvertsen J P, and Nemec S L. 1983
Effect of drought stress and vesicular arbuscular mycorrhiza on citrus transpiration and hydraulic conductivity of roots
New Phytologist **93**(1): 61-66

McInnes A and Chilvers G A. 1994
Influence of environmental factors on ectomycorrhizal infection in axenically cultured eucalyptus seedlings
Australian Journal of Botany **42**(5): 595–604

Menge J A, Labanauskas C K, Johnson E L V, Sibert D. 1979
Problems with the utilization of mycorrhizal fungi in the production of containerized citrus in the nursery or greenhouse
In: *Program and Abstracts*
[Proceedings of the Fourth North American Conference on Mycorrhiza, 24-28, June 1979, Colorado State University, Fort Collins, Colorado, USA]
Colorado: Colorado State University.

Michelsen A and Rosendahl S. 1990.
The effect of VA mycorrhizal fungi, phosphorus and drought stress on the growth of *Acacia nilotica* and *Leucaena leucocephala* seedlings
Plant and Soil **124**(1): 7–13

Nemec S. 1987
Citrus seedling growth and *Glomus intraradices* infection as affected by various soil-free potting media
In: *Mycorrhiza in the next decade: practical applications and research priorities*, edited by D M Slyvia, L L Hung, and J H Graham
[Proceedings of the Seventh North American Conference on Mycorrhiza, 3–8 May 1987, Gainesville, Florida]
Florida: University of Florida. 364 pp.

Newman S E and Davies F T Jr. 1988
High root-zone temperatures, mycorrhizal fungi, water relations and root hydraulic conductivity of container-grown woody plants
Journal of American Society of Horticultural Science **113**(1): 138–146

Oh K I and Park W S. 1990
The effects of soil mixtures, nitrogen levels and ectomycorrhizal inoculation on formation of mycorrhizae and growth of two-year-old black pine seedlings
Journal of Korean Forestry Society **79**(3): 309–315

Osonubi O. 1989
Osmotic adjustment in mycorrhizal *Gmelina arborea* (roxb.) seedlings
Functional Ecology **3**(2): 143–51

Osonubi O and Mulongoy K. 1991
Response of two Acacia species to drought and inoculation with an ectomycorrhizal fungus
The Rhizosphere and Plant Growth **14**: 375

Parke J L, Linderman R G, and Trappe J M. 1983
Effect of root zone temperature on ectomycorrhiza and vesicular arbuscular mycorrhiza formation in disturbed and undisturbed forest soils of southwest oregon USA
Canadian Journal of Forest Research ***13***(4): 657–65

Rajkumar, Sharma G D, and Mishra R R. 1990
Development of ectomycorrhizae on pine and its effect on the growth of *Pinus kesiya* under different moisture regimes
In: *Current Trends in Mycorrhiza Research,* edited by Jalali B L, and Chand H, pp. 199–200
[Proceedings of the First National Conference on Mycorrhiza, Hisar Haryana Agricultural University]
Hisar: Haryana Agricultural University.

Stenstrom E. 1991
The Effect of flooding on the formation of ectomycorrhizae in *Pinus syslvestris* seedlings
Plant and Soil **131**(2): 247–250

Stenstrom E and Unestam T. 1987
Susceptibility to flooding in pine mycorrhiza development using different mycorrhizal fungi
In: *Mycorrhiza in the next decade: practical applications and research priorities*, edited by D M Slyvia, L L Hung, and J H Graham
[Proceedings of the Seventh North American Conference on Mycorrhiza, 3–8 May 1987, Gainesville, Florida]
Florida: University of Florida. 364 pp.

Tacon F Le, Kabre A, and Garbaye J. 1979
Influence of endomycorrhizae on mineral nutrition of *Acer pseudoplatanus*
In: *Program and Abstracts*
[Proceedings of Fourth North American Conference on Mycorrhiza, 24–28 June 1979, Colorado State University, Fort Collins, Colorado, USA]
Colorado: Colorado State University.

Comparative efficacy of VAM fungi in combination with neem cake against *Meloidogyne incognita* on *Crossandra undulaefolia*

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Introduction

Crossandra undulaefolia L. is an important tropical flower plant grown widely for cut flower and garland purposes. An important biotic limiting factor in the cultivation of crossandra is the root-knot nematode, *Meloidogyne incognita,* affecting its seedling establishment in the nursery, and growth and yield in the main field (Nagesh and Reddy 1997a).

The use of VAM (vesicular–arbuscular mycorrhizae) in combination with oil cakes in transplantable crops was found to be highly beneficial in terms of reduced nematode infection and increased yields (Reddy, Nagesh, and Rao 1997; and Rao, Reddy, and Mohandas 1996). Earlier studies revealed that *Glomus mosseae* in combination with different oil cakes, especially neem cake, significantly reduced root-knot nematode infection in crossandra and enhanced the flower yield (Nagesh and Reddy 1997b).

The present investigation has been carried out to evaluate the comparative efficacy of four VAM fungi viz. *G. fasciculatum, G. intraradices, G. mosseae,* and *Acaulospora laevis* in combination with neem cake against *M. incognita* on crossandra. The main objective was to test the difference in efficacy among the four VAM fungi experimentally and to identify the most efficient VAM fungus for commercial production.

Materials and methods

The experiment was carried out in earthen pots (16 inches in diameter) containing 4 kg autoclaved soil mixture (3 parts soil : 1 part sand : 1 part compost). The soil was made nematode sick by thoroughly mixing freshly hatched second-stage juveniles (J_2) of *Meloidogyne incognita* at the rate of 10 000 J_2 per plant. The four VAM fungi viz., *G. fasciculatum, G. intraradices, G. mosseae,* and *A. laevis* were mass multiplied separately on finger millet (*Eleucina coracana* L.) and an inoculum rate of 2000 chlamydospores per plant were used. Finely powdered neem cake (*Azadirachta indica* A. juss.) at the rate of 100 gram per plant was incorporated into the potted soil involving neem cake treatment. Mycorrhizal inoculation and neem cake were given at half the dose each in combined treatments. The treatments included are listed in Table 1. Each treatment listed in Table 1 was replicated 10 times. Mycorrhizal inoculum was placed as a thin layer (3–4 cm) below the soil surface in each pot involving mycorrhizal treatment. Two days later, 45 days old crossandra seedlings (raised in seed pans containing autoclaved soil) were transplanted individually into each treated pot.

Table 1 Comparative effect of the vesicular–arbuscular mycorrhizae in combination with neem cake on growth and flower yield of crossandra

Treatment	Dose per plant	Plant height (cm)	Root		Shoot dry wt (g)	Flower yield (g)
			Length (cm)	Weight (g)		
Neem cake (NC)	100 g	36	18	12.3	14.6	14.6
Carbofuran (3G)	15 g	33	18	11.2	12.8	12.2
G. mosseae	2000 spores	34	20	13.0	13.9	13.0
G. fasciculatum	2000 spores	36	19	13.8	14.5	13.0
G. intraraditis	2000 spores	30	18	11.8	12.5	11.5
Aucalospora laevis	2000 spores	30	17	11.5	12.0	11.0
NC + *G.mosseae*	50 g+100 spores	46	29	21.2	20.4	18.9
NC + *G.fasciculatum*	50 g+100 spores	46	27	23.9	22.5	22.2
NC + *G. intraraditis*	50 g+100 spores	38	24	16.6	17.3	16.5
NC + *A. Laevis*	50 g+100 spores	39	22	15.0	16.0	15.0
Control	—	26	12	10.0	11.6	9.8
C.D (P=0.05)	—	3.45	1.88	2.24	2.11	1.38

CD–critical difference

After 30 days of transplantation, five plants (replicates) from mycorrhiza-treated pots were harvested, roots cleared of soil, and washed in water. Mycorrhizal colonization of roots was estimated by trypan blue staining technique (Phillips and Hayman 1970). Similarly, rest of the plants were harvested after 120 days of transplantation for recording plant growth characters viz., plant height, shoot weight, root length and weight, RGI (root gall index), and nematode multiplication rate (final nematode population in root and soil/initial nematode population). The soil was also analysed for mycorrhizal chlamydospores through wet sieving and decantation technique (Gerdmann and Nicolson 1963). The flower height per plant was recorded at weekly intervals from first flowering to 120 days after transplantation. The data was statistically analysed for variance.

Results and discussion

In general, mycorrhizal inoculation (especially in combination with neem cake) not only reduced nematode infection but also significantly enhanced plant growth parameters and flower yield (Tables 1 and 2). Further, mycorrhizae in combination with neem cake, recorded higher plant growth parameters and flower yield compared to carbofuran-treated plants indicating that the application of these combinations were superior to that of carbofuran although *G. fasciculatum* when applied singly or in combination with neem cake recorded highest values of plant growth characters and flower yield. *G. mosseae* treatment plants also recorded almost similar values. Similarly, *G. intraradices* treatment plants recorded higher plant growth characters and flower yield compared to *A. laevis* but the difference was not significant for the parameters under report.

Root galling and nematode multiplication rate were least in *G. fasciculatum* + neem cake treated plants followed by *G. mosseae* + neem cake treated plants, and differed significantly over *G. intraradices* + neem cake, *A. laevis* + neem cake, or carbofuran-treated plants. Maximum mycorrhizal root colonization occurred in plants treated with *G. fasciculatum* + neem cake followed by *G. mosseae* + neem cake. Similarly, chlamydospore production was highest in plants treated with *G. fasciculatum* + neem cake followed by *G. mosseae*+ neem cake.

Among the four VAM fungi that are mentioned above, *G. fasciculatum* (singly or in combination with neem cake) colonized better followed by *G. mosseae*. However, *A. laevis* did not colonize crossandra roots efficiently and produced least number of chlamydospores even in the presence of neem cake. Previous studies on tomato showed that root colonization by *G. fasciculatum* recorded a negative correlation with RGI and nematode multiplication rate (Nagesh and Reddy 1999). In view of these observations, it can be inferred that since *G. fasciculatum* and *G. mosseae* colonized crossandra roots better compared to *G. intraradices* and *A. laevis*, there was comparatively lower nematode infection and multiplication, thus promoting better root health and plant health in the former species. Thus, we can conclude that, although all the four fungi in combination with neem cake gave better control of nematodes over carbofuran treatment, two species namely, *G. fasciculatum* and *G. mosseae* were found to be more efficient.

Earlier reports indicated that there was no host preference or host specificity in the case of mycorrhizal

Table 2 Comparative effect of vesicular–arbuscular mycorrhizae in combination with neem cake on *Meloidogyne incognita*, and mycorrhizal colonization and chlamydospore production

Treatment	Dose per plant	RGI*	NMR**	Mycorrhizal colonization (%)	Chlamydospores (100 cc soil)
Neem cake (NC)	100g	3.4	2.9	—	—
Carbofuran (3G)	15g	3.4	2.6	—	—
G. *mosseae*	2000 spores	3.2	2.8	20.3	348
G. *fasciculatum*	2000 spores	3.2	2.9	23.0	412
G. intraradices	2000 spores	3.5	3.0	16.8	263
A. laevis	2000 spores	3.9	3.3	14.5	196
NC + *G. mosseae*	50 g + 1000 spores	1.8	1.5	39.6	554
NC + *G. fasciculatum*	50 g + 1000 spores	1.6	1.6	43.5	635
NC + *G. intraradices*	50 g + 1000 spores	2.3	2.0	30.3	438
NC + *A. laevis*	50 g + 1000 spores	2.7	2.5	26.8	335
Control	—	4.6	3.9	—	—
C D (P=0.05)		0.32	0.18	2.16	11.24

*RGI–root-gall index, NMR–nematode multiplication rate, CD–critical difference

fungi. However, from the investigation under report, it is evident that mycorrhizal fungi differ in their root colonization efficiency and rate of root colonization.

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References

Gerdmann J W and Nicolson T H. 1963
Spores of mycorrhizal endogone spp. extracted from soil by wet sieving and decanting
Transactions of the British Mycological Society **46** (2): 235–244

Nagesh M and Parvatha Reddy P. 1997a
Nematode management in ornamental crops
In*: **Progressive Floriculture**,* edited by I S Yadav and M L Choudhary, pp. 46–58
Bangalore: The House of Sarpan (Media).

Nagesh M and Parvatha Reddy P. 1997b
Management of *Meloidogyne incognita* on *Crossandra undulaefolia* using vesicular arbuscular mycorrhiza, *Glomus mosseae* and oilcakes
Mycorrhiza News **9**(1): 12–14

Nagesh M and Parvatha Reddy P. 1999
Studies on correlation between *Glomus fasciculatum* spore density, root colonisation and *Meloidogyne incognita* infection on *Lycopersicon esculentum*
Zietshrift fur Pflanzenkrankheiten und Pflanzenschutz **106**(1): 82–87

Parvatha Reddy P, Nagesh M, and Rao M S. 1997
Integrated management of burrowing nematode, *Radopholus similis* using endomycorrhiza, *Glomus mosseae* and oil cakes
Pest Management in Horiticultural Ecosystems **3**(1): 25-31

Phillips J M and Hayman D S. 1970
Improved procedures for clearing and staining parasitic and vesicular arbuscular mycorrhizal fungi for rapid assessment of infection
Transactions of the British Mycological Society **55**(2): 158–161

Rao M S, Parvatha Reddy P, and Mohandas S. 1996
Effect of integration of *Calotropis procera* leaf and *Glomus fasciculatum* on the management of *Meloidogyne incognita* infesting tomato
Nematologia Mediterranea **24**(1): 59–61

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Centre for Mycorrhizal Culture Collection (CMCC)

List of cultures available from CMCC as on 6 September 1999

S No.	Bank code	Name of the fungus	Host
1	EM-1001	*Alpova diplophloeus*	*Pseudotsuga menziesii/Alnus rubra*
2	EM-1129	*Alpova olivaceotinctus*	*Abies concolor, Pinus jeffreyi*
3	EM-1145	*Amanita murina*	*Eucalyptus bridgesina*
4	EM-1100	*Amanita muscaria* var. *farmosa*	*Populus tremuloides*
5	EM-1084	*Amanita muscaria*	*Pinus patula*
6	EM-1069	*Amanita muscaria*	—
7	EM-1146	*Amanita muscaria*	*Sous resineux*
8	EM-1060	*Amanita muscaria*	—
9	EM-1148	*Boletus cavipes*	—
10	EM-1277	*Boletus cavipes*	—
11	EM-1072	*Boletus edulis*	—
12	EM-1151	*Cenococcum geophyllum*	Picea
13	EM-1037	*Cenococcum geophyllum*	*Tsuga mertensiana*
14	EM-1036	*Cenococcum geophyllum*	*Tsuga mertensiana*
15	EM-1035	*Cenococcum geophyllum*	*Pseudotsuga menziesii*
16	EM-1150	*Cenococcum geophyllum*	Picea
17	EM-1149	*Cenococcum geophyllum*	Tilleul
18	EM-1252	*Cenococcum geophyllum*	Douglas
19	EM-1088	*Cenococcum geophyllum*	—
20	EM-1253	*Chalciporus piperatus*	—
21	EM-1153	*Ectendomycorrhizae*	*Pinus sylvestris*
22	EM-1154	*Ectendomycorrhizae*	*Pinus sylvestris*
23	EM-1155	*Ectendomycorrhizae*	—
24	EM-1157	*Elaphomyces granulatus*	Chene
25	EM-1156	*Elaphomyces granulatus*	Chene
26	EM-1108	*Gautieria otthii*	*Pinus bankesiana*
27	EM-1138	*Gautieria caudata*	*Arbutus menziesii, Pseudotsuga menziesii*
28	AM-1005	*Gigaspora margarita*	—
29	AM-1001	*Glomus etunicatum*	—
30	AM-1119	*Glomus geosporum*	—
31	AM-1004	*Glomus intraradices*	—
32	AM-1006	*Glomus mosseae*	—
33	EM-1158	*Gyrodon lividus*	*Alnus*
34	EM-1163	*Hebeloma crustuliniforme*	Pin noir d' Autricha
35	EM-1161	*Hebeloma crustuliniforme*	Picea
36	EM-1160	*Hebeloma circinans*	Picea
37	EM-1159	*Hebeloma calyptosporum*	Lisierie de pre
38	EM-1164	*Hebeloma crustuliniforme*	—
39	EM-1171	*Hebeloma crustuliniforme*	Douglas
40	EM-1172	*Hebeloma cylindrosporum*	Picea
41	EM-1173	*Hebeloma cylindrosporum*	—
42	EM-1170	*Hebeloma crustuliniforme*	Hetre
43	EM-1169	*Hebeloma crustuliniforme*	Picea
44	EM-1174	*Hebeloma edurum*	Picea
45	EM-1168	*Hebeloma crustuliniforme*	Chene
46	EM-1165	*Hebeloma crustuliniforme*	—

S No.	Bank code	Name of the fungus	Host
47	EM-1175	*Hebeloma edurum*	Hetre
48	EM-1008	*Hebeloma crustuliniforme*	*Pinus monticola, Tsuga heterophylla*
49	EM-1180	*Hebeloma sinapizans*	Picea
50	EM-1015	*Hebeloma crustuliniforme*	*Pseudotsuga menziesii*
51	EM-1183	*Hebeloma truncatum*	—
52	EM-1182	*Hebeloma sinapizans*	Hetre
53	EM-1184	*Hebeloma vaccinum*	—
54	EM-1176	*Hebeloma ingratum*	*Tremble feuillus*
55	EM-1177	*Hebeloma mesophaeum*	—
56	EM-1185	*Hysterangium incarceratum*	Eucalyptus sp.
57	EM-1263	*Lactarius quietus*	Chene
58	EM-1122	*Laccaria farinacea*	*Tsuga mertensiana*
59	EM-1103	*Laccaria bicolor*	*Picea glauca*
60	EM-1105	*Laccaria laccata*	*Pinus resinosa*
61	EM-1186	*Laccaria amethystina*	Sousdes
62	EM-1079	*Laccaria laccata*	*Pinus patula*
63	EM-1076	*Laccaria laccata*	*Pinus patula*
64	EM-1083	*Laccaria fraterna*	*Eucalyptus globulus*
65	EM-1086	*Laccaria proxima*	Betula
66	EM-1085	*Laccaria laccata*	Betula
67	EM-1187	*Laccaria bicolor*	—
68	EM-1188	*Laccaria laccata*	*Picea sitchensis*
69	EM-1193	*Laccaria laccata*	Sitka spruce
70	EM-1196	*Laccaria tortilis*	Bouleau
71	EM-1195	*Laccaria proxima*	—
72	EM-1102	*Laccaria bicolor*	*Picea mariana*
73	EM-1192	*Laccaria laccata*	Sitka spruce
74	EM-1189	*Laccaria laccata*	*Quescus ilex*
75	EM-1190	*Laccaria laccata*	Hetre
76	EM-1191	*Laccaria laccata*	Eucalyptus sp.
77	EM-1104	*Laccaria laccata*	—
78	EM-1091	*Laccaria amethystina*	*Pseudotsuga menziesii*
79	EM-1058	*Laccaria laccata*	—
80	EM-1032	*Laccaria laccata*	Hemlock
81	EM-1033	*Laccaria laccata*	*Pseudotsuga menziesii*
82	EM-1042	*Laccaria laccata*	*Pseudotsuga menziesii*
83	EM-1275	*Laccaria proxima*	Picea, Pinus
84	EM-1066	*Laccaria laccata*	—
85	EM-1031	*Laccaria laccata*	*Pseudotsuga menziesii*
86	EM-1067	*Laccaria laccata*	—
87	EM-1065	*Laccaria laccata*	—
88	EM-1090	*Laccaria laccata*	—
89	EM-1009	*Laccaria laccata*	Alpine
90	EM-1207	*Laccinum scaber*	Charme
91	EM-1207A	*Laccinum scaber*	Charme
92	EM-1261	*Lactarius deliciosus*	*Pinus sylvestris*
93	EM-1279	*Lactarius hepaticus*	—
94	EM-1264	*Lactarius rufus*	*Sous resineux*
95	EM-1052	*Lactarius rufus*	*Larix larcina, Picea mariana*
96	EM-1260	*Lactarius chrysorrheus*	Chene
97	EM-1262	*Lactarius deterrimus*	—
98	EM-1206	*Lactarius tabidus*	—
99	EM-1199	*Lactarius deterrimus*	—
100	EM-1198	*Lactarius controversus*	*Populus euramericana*
101	EM-1259	*Lactarius chrysornheus*	Hetre
102	EM-1205	*Lactarius subdulcis*	Chene

S No.	Bank code	Name of the fungus	Host
103	EM-1203	*Lactarius rufus*	*Sous resineux*
104	EM-1133	*Leccinum scabrum*	*Picea pungens, Betula*
105	EM-1106	*Leccinum insigne*	Mixed hardwood forest
106	EM-1281	*Leccinum aurantiacum*	Tremble
107	EM-1113	*Martellia ellipsospora*	*Pseudotsuga menziesii*
108	EM-1130	*Melanogaster tuberiformis*	*Arctostaphylos viscidia*
109	EM-1125	*Melanogaster tuberiformis*	—
110	EM-1134	*Paxillus involutus*	*Picea pungens,* Betula sp.
111	EM-1209	*Paxillus involutus*	—
112	EM-1270	*Paxillus involutus*	—
113	EM-1267	*Paxillus involutus*	*Eucalyptus darlympleana*
114	EM-1268	*Paxillus involutus*	Chene
115	EM-1269	*Paxillus involutus*	Tremble
116	EM-1073	*Paxillus involutus*	—
117	EM-1208	*Paxillus involutus*	—
118	EM-1141	*Paxillus involutus*	*Castanea sativa*
119	EM-1217	*Paxillus involutus*	Chene
120	EM-1212	*Paxillus involutus*	*Populus euramericana*
121	EM-1282	*Paxillus involutus*	Abies, Piecea
122	EM-1055	*Phaeolepiota aurea*	Sitka spruce
123	EM-1047	*Phialocephala fortinii*	*Pinus*
124	EM-1219	*Piloderma*	—
125	EM-1002	*Pisolithus tinctorius*	*Tsuga canadensis*
126	EM-1057	*Pisolithus tinctorius*	—
127	EM-1010	*Pisolithus tinctorius*	*Loblolly pine, Pinus teada*
128	EM-1081	*Pisolithus tinctorius*	*Eucalyptus tereticornis*
129	EM-1059	*Pisolithus tinctorius*	—
130	EM-1005	*Pisolithus tinctorius*	Saw tooth oak
131	EM-1006	*Pisolithus tinctorius*	Pin oak
132	EM-1034	*Pisolithus tinctorius*	Loblolly pine
133	EM-1271	*Pisolithus tinctorius*	*Pinus elliotii*
134	EM-1221	*Pisolithus tinctorius*	Chene
135	EM-1223	*Pisolithus tinctorius*	*Pinus caribaea*
136	EM-1224	*Pisolithus tinctorius*	Chene
137	EM-1004	*Pisolithus tinctorius*	Virginia pine
138	EM-1022	*Rhizopogon subareolatus*	*Pseudotsuga menziesii*
139	EM-1019	*Rhizopogon fuscorubens*	*Pinus contorta*
140	EM-1025	*Rhizopogon vulgaris*	*Pinus ponderosa, Pseudotsuga menziesii, Abies*
141	EM-1043	*Rhizopogon smithii*	*Pinus contorta*
142	EM-1040	*Rhizopogon mutabilis*	*Pinus ponderosa*
143	EM-1039	*Rhizopogon vulgaris*	*Pinus ponderosa*
144	EM-1029	*Rhizopogon cusickensis*	*Pinus ponderosa, Arbutus menziesii*
145	EM-1024	*Rhizopogon subcaerulescens*	Tsuga, *Pseudotsuga menziesii*
146	EM-1023	*Rhizopogon vulgaris*	*Pinus contorta, Abies amabilis*
147	EM-1013	*Rhizopogon arenicola*	Sitka spruce, lodge pole pine
148	EM-1044	*Rhizopogon colossus*	*Pinus ponderosa, Pseudotsuga menziesii*
149	EM-1038	*Rhizopogon ellenae*	*Arbutus menziesii, Pinus ponderosa*
150	EM-1017	*Rhizopogon occidentalis*	*Pinus ponderosa*
151	EM-1049	*Rhizopogon rubescens*	*Pinus contorta, Abies lasiocarpa, Picea engelmani*
152	EM-1053	*Rhizopogon parksii*	*Picea engelmani*
153	EM-1048	*Rhizopogon subcaerulescens*	*Pinus contorta, Abies lasiocarpa, Picea engelmani*
154	EM-1054	*Rhizopogon vulgaris*	*Tsuga mertensiana*
155	EM-1014	*Rhizopogon vinicolor*	*Tsuga heterophylla, Pseudotsuga menziesii*
156	EM-1050	*Rhizopogon rubescens*	*Pinus contorta, Abies lasiocarpa, Picea engelmani*
157	EM-1056	*Rhizopogon villosulus*	*Pseudotsuga menziesii*
158	EM-1028	*Rhizopogon clavitisporus*	*Pseudotsuga menziesii, Pinus ponderosa*

S No.	Bank code	Name of the fungus	Host
159	EM-1027	*Rhizopogon hawkerae*	*Pseudotsuga menziesii, Pinus ponderosa, Abies*
160	EM-1007	*Rhizopogon subcaerulescens* var. *subpannosus*	*Abies grandis, Pseudotsuga menziesii*
161	EM-1026	*Rhizopogon ochraceorubens*	*Pinus contorta*
162	EM-1018	*Rhizopogon subcaerulescens*	*Abies grandis, Pseudotsuga menziesii*
163	EM-1118	*Rhizopogon vinicolor*	Mixed coniferous forest
164	EM-1227	*Rhizopogon luteolus*	—
165	EM-1226	*Rhizopogon luteolus*	—
166	EM-1128	*Rhizopogon smithii*	Shasta fir
167	EM-1127	*Rhizopogon reaii*	*Pinus caribaea* var. *hondurensis*
168	EM-1228	*Rhizopogon nigrescens*	*Pinus caribaea*
169	EM-1229	*Rhizopogon roseolus*	Pinus
170	EM-1232	*Rhizopogon vulgaris*	—
171	EM-1231	*Rhizopogon subrerolatus*	Douglas
172	EM-1230	*Rhizopogon rubescens*	Pine
173	EM-1012	*Rhizopogon ochraceorubens*	*Pinus contorta, Abies lasicarpa*
174	EM-1119	*Rhizopogon occidentalis*	*Pinus ponderosa*
175	EM-1046	*Rhizopogon ellenae*	*Pseudotsuga menziesii*
176	EM-1063	*Rhizopogon vulgaris*	—
177	EM-1061	*Rhizopogon rubescens*	—
178	EM-1011	*Rhizopogon parksii*	*Pseudotsuga menziesii, Pinus lambertianas, Abies concolor*
179	EM-1109	*Rhizopogon rubescens*	*Pinus banksiana*
180	EM-1116	*Rhizopogon vulgaris*	*Pinus jeffreyi*
181	EM-1115	*Rhizopogon ochraceorubens*	*Pinus contorta*
182	EM-1114	*Rhizopogon hawkerae*	Douglas fir
183	EM-1112	*Rhizopogon smithii*	*Pinus contorta*
184	EM-1126	*Rhizopogon fuscorubens*	*Pinus radiata*
185	EM-1140	*Rhizopogon ochraceisporus*	*Pinus ponderosa, Pseudotsuga menziesii*
186	EM-1142	*Rhizopogon rubescens*	*Pinus nigra*
187	EM-1143	*Rhizopogon vinicolor*	*Pseudotsuga menziesii*
188	EM-1132	*Sarcodon scabrosus*	*Alnus sinnata*
189	EM-1273	*Scleroderma aurantium*	—
190	EM-1235	*Scleroderma flavidum*	*Eucalyptus camaldulencis*
191	EM-1233	*Scleroderma cepa*	*Eucalyptus sp.*
192	EM-1107	*Scleroderma citrinum*	Hardwood forest
193	EM-1240	*Suillus granulatus*	*Pinus sylvestris*
194	EM-1030	*Suillus americanus*	*Pinus strobus*
195	EM-1075	*Suillus variegatus*	—
196	EM-1244	*Suillus luteus*	*Pinus sylvestris*
197	EM-1074	*Suillus bovinus*	—
198	EM-1071	*Suillus luteous*	—
199	EM-1111	*Suillus lakei*	Douglas fir, Hemlock
200	EM-1123	*Suillus tomentosus*	*Pinus monticola, Tsuga heterophylla*
201	EM-1121	*Suillus brevipes*	*Pinus contorta*
202	EM-1124	*Suillus brevipes*	*Pinus contorta*
203	EM-1051	*Suillus tomentosus*	*Pinus ponderosa*
204	EM-1120	*Suillus granulatus*	*Pinus contorta*
205	EM-1021	*Suillus tomentosus*	Alder, Spruce, lodgepole pine
206	EM-1117	*Suillus punctatipes*	*Tsuga mertensiana, Abies lasiocarpa*
207	EM-1247	*Thelephora terrestris*	—
208	EM-1077	*Thelephora terrestris*	*Pinus patula*
209	EM-1062	*Thelephora terrestris*	—
210	EM-1249	*Tricholoma populinum*	*Populus euramericana*
211	EM-1248	*Tricholoma albobruneum*	Pine
212	EM-1250	*Tricholoma scalpturatum*	*Populus euramericana*
213	EM-1041	*Tuber melanosporum*	—

New approaches

A rapid microinjection technique for sensitive detection of root exudate signals stimulating branching and growth of VAM fungal spores

Nagahashi, Gerald, David Douds, and Gloria Abney developed an *in vitro* method to study the response of VAM (vesicular–arbuscular mycorrhizal) fungus spores to root exudates. Pregerminated spores of *Gigaspora gigantea* were transferred to a petriplate containing M medium. Small holes near growing hyphal tips (which attain growth period of 2 days to 16 days) were made in the gellan with a disposable sterilized Pasteur pipette. The holes were filled with concentrated, filtered and sterilized, crude exudate using a tuberculin syringe. Prolific branching of actively growing hyphal tips of *G. gigantea* was noticed within 10 to 12 hours after injection. The 'excited' branching pattern was identical to the pattern observed when a hyphal tip grows near an Ri T-DNA transformed carrot root. *G.margarita* has a slightly different response to the crude exudate but the response was similar to that observed when the hyphal tips approached a host root. A dose dependent signal response was observed for both mycorrhizal fungi. This method must lead to identification of signal molecules in host root exudates, which will stimulate the growth and differentiation of VAM fungal hyphae.

Use of laser scanning confocal microscopy to characterize ectomycorrhiza and associated bacteria

Schelkle, Michelle, Margot Kronick, Melissa Farquhar, and R Larry Peterson used LSCM (laser scanning confocal microscopy), LM (light microscopy), and EM (epifluorescence microscopy) techniques to observe extramatrical hyphae, mantle patterns, and associated bacteria on mycorrhizal tips of *Pinus strobus* seedlings grown in pot cultures. *Laccaria* sp. and *Tuber* sp. formed ectomycorrhizae with *P. strobus,* while *Phialophora finlandia* and E-strain formed ect-endomycorrhizae. Distinct mantle patterns and cystidia were observed under greater resolution using LSCM and intracellular hyphae as visualized in three dimensions. Trypan blue is an excellent stain in visualizing fungal hyphae and bacteria using LSCM. This stain penetrated fresh whole mounts to 20 aem. Fluorescein isothiocyanate and acridine orange were used in conjunction with LSCM and EM to localize bacteria on ectomycorrhizal tips. With LSCM, bacteria were visible on the surface mucigel and optical sectioning through the root tip showed the presence of bacteria also within the mantle. LSCM is a non-intrusive and fast method for visualizing ectomycorrhizal structures and their associated bacteria on fresh, whole root tips.

Source Proceedings of the First International Conference on Mycorrhiza, 4-9 August 1996, Berkley, California. <http://plantbio.berkley.edu/~burns/icom.htm>

Recent references

Name of the author(s) and year of publication	Title of the article, name of the journal, volume no., issue no., page nos [*address of the corresponding author]
Eason W R*, Scullion J, and Scott E P. 1999	**Soil parameters and plant responses associated with arbuscular mycorrhizas from contrasting grassland management regimes** *Agriculture Ecosystems and Environment* **73**(3): 245–255 [*AFRC, Institute Grassland & Environment Research, Plas Goggerdan, Aberystwyth SY23 3EB, Dyfed, Wales]
Klironomos J N*, Rillig M C, and Allen M F. 1999	**Designing belowground field experiments with the help of semi-variance and power analyses** *Applied Soil Ecology* **12**(3): 227–238 [*University of Guelph, Department of Botany, Fungal & Soil Ecology Lab, Guelph, ON N1G 2W1, Canada]

Name of the authors and year of publication	Title of the article, name of the journal, volume no., issue no., page nos, and corresponding address
Rozycki H, Dahm H, Strzelczyk E*, Li C Y. 1999	**Diazotrophic bacteria in root-free soil and in the root zone of pine (*Pinus sylvestris* L.) and oak (*Quercus robur* L.)** *Applied Soil Ecology* **12**(3): 239–250 [*Nicholas Copernicus University, Institute of General and Molecular Biology, Department of Microbiology, Ul Gagarina 9, PL-87100 Torun, Poland]
Sundari S K and Adholeya A*. 1999	**Freeze-drying vegetative mycelium of *Laccaria fraterna* and its subsequent regeneration** *Biotechnology Techniques* **13**(7): 491–495 [*Tata Energy Research Institute, Darbari Seth Block, Habitat Palace, Lodhi Road, New Delhi – 110 003, India]
Imhof S*. 1998	**Subterranean structures and mycotrophy of the achlorophyllous *Triuris hyalina* (Triuridaceae)** *Canadian Journal of Botany - Revue Canadienne de Botanyanique* **76**(12): 2011–2019 [*University of Marburg, Fachbereich Biology, D-35032 Marburg, Germany]
RuizLozano J M and Bonfante P*. 1999	**Identification of a putative P-transporter operon in the genome of a Burkholderia strain living inside the arbuscular mycorrhizal fungus *Gigaspora margarita*** *Journal of Bacteriology* **181**(13): 4106–4109 [*University of Turin, Dipartimento Biology Vegetale, CNR,CSMT, Viale PA Mattioli 25, I-10125 Turin, Italy]
Yamanaka T*. 1999	**Utilization of inorganic and organic nitrogen in pure cultures by saprotrophic and ectomycorrhizal fungi producing sporophores on urea-treated forest floor** *Mycological Research* **103**: 811–816 [*Forestry and Forest Products Research Institute, PO Box 16, Tsukuba Norin Kenkyu Danchi Nai, Ibaraki, Osaka 3058687, Japan]
Rillig M C* and Allen M F. 1999	**What is the role of arbuscular mycorrhizal fungi in plant-to-ecosystem responses to elevated atmospheric CO_2?** *Mycorrhiza* **9**(1): 1–8 [*Carnegie Institute of Washington, Department of Plant Biology, 260 Panama Street, Stanford, CA 94305, USA]
Wallander H* and Wickman T. 1999	**Biotite and microcline as potassium sources in ectomycorrhizal and non-mycorrhizal *Pinus sylvestris* seedlings** *Mycorrhiza* **9**(1): 25–32 [*University of Lund, Dept of Microbial Ecology, Solvegatan 23, S-22362 Lund, Sweden]
Imhof S*. 1999	**Root morphology, anatomy and mycotrophy of the achlorophyllous *Voyria aphylla* (Jacq.) Pers. (Gentianaceae)** *Mycorrhiza* **9**(1): 33–39 [*University of Marburg, Fachbereich Biology, D-35032 Marburg, Germany]
Hawkins H J*, Cramer M D, and George E. 1999	**Root respiratory quotient and nitrate uptake in hydroponically grown non-mycorrhizal and mycorrhizal wheat** *Mycorrhiza* **9**(1): 57–60 [*University of Hohenheim, Institute of Plant Nutrition 330, D-70593, Stuttgart, Germany]
Chelius M K and Triplett E W*. 1999	**Rapid detection of arbuscular mycorrhizae in roots and soil of an intensively managed turfgrass system by PCR amplification of small subunit rDNA** *Mycorrhiza* **9**(1): 61–64 [*University of Wisconsin, Dept of Anatomy, 1575 Linden Dr, Madison, WI 53706, USA]
Wells J M*, Harris M J, and Boddy L. 1999	**Dynamics of mycelial growth and phosphorus partitioning in developing mycelial cord systems of *Phanerochaete velutina*: dependence on carbon availability** *New Phytologist* **142**(2): 325–334 [*University of Wales, School of Bioscience, PO Box 915, Cardiff CF1 3TL, S Glam, Wales]

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FIRST ANNOUNCEMENT

Fifth National Conference On Mycorrhiza

Relevance of mycorrhiza in dryland agriculture and forestry

16–18 November 2000

Organized by
Central Arid Zone Research Institute
Jodhpur, Rajasthan

Under the auspices of
Mycorrhiza Network
Tata Energy Research Institute, New Delhi

Scope Food production in the arid and semi-arid regions in a tropical climate is highly dependent on rainfall and soil characteristics. The soils in these regions have very low inherent productivity due to physico-chemical and nutritional constraints and are highly vulnerable to various forces of degradation. Using only chemical fertilizers to enhance soil productivity does not seem to be a viable proposition. Thus, an eco-friendly alternative – mycorrhizal fungi – can partially replace chemical fertilizers and can also help trees to establish on nutrient-deficient, or eroded sites.

The Fifth National Conference on Mycorrhiza is an effort towards developing liaison among mycorrhizologists working in different areas. It hopes to (1) promote networking for exchange of ideas and literature; (2) discuss topics of mutual interest; and (3) take stock of the latest developments in mycorrhizal research for sustainable development of dry areas. Recommendations on promoting mycorrhizal fungi on a commercial scale will be provided to extension agencies and government departments.

Topics The conference will focus on the following.

- Biology, ecology, management and establishment of mycorrhizae, and mycorrhizal dependency of plant species under different edapho climatic conditions
- Inoculum production and biotechnology, mycorrhizal biodiversity, and conservation and maintenance
- Rehabilitation of waste lands including coastal sands, sand dunes, mine spoils, and saline-alkaline soils
- Use of molecular tools in taxonomy and other aspects of mycorrhiza research
- Interactions among soil microflora, microfauna, and mycorrhizal fungi

Call for papers

Extended summaries on original research work covering one of the aforesaid in the field of mycorrhizae are invited. Papers not exceeding 5–6 typed pages (A-4) must include title of the work followed by author(s), abstracts, introduction, materials, methods, results and discussion, and 3 or 4 important references.

Last date for the receipt of papers will be 20 June 2000. Papers may be submitted by post, fax or e-mail to the Organizing Secretary.

Venue
Central Arid Zone Research Institute, Jodhpur, Rajasthan, India

Registration
Registration fee for the participants must be paid on or before 20 August 2000.
Participants – Rs 700/- (Rs 800/- for late registration)
Students – Rs 400/- (Rs 450/- for late registration)
Foreign delegates – US $50 or equivalent in rupees.
Payments are to be made by demand draft favouring 'Jodhpur Chapter of Indian Society of Soil Science' payable at Jodhpur.

All correspondence and further enquiries should be addressed to:

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Erratum: See Volume 11, Number 1, p.15, column 2, line 7: '*Expercentra* **50**: 999–925, 1994' should read '*Expercentia* **50**: 919–925, 1994'.

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