About TERI

TERI is an autonomous not-for-profit, research institute established in 1974 and is involved in research activities in the fields of energy, environment, biotechnology, forestry, and the whole range of sustainable development issues. More specifically, its activities are geared to promoting large-scale use of renewable forms of energy, protecting the earth's ozone layer, mitigating the threat of climate change, and reversing the loss of forest cover and biodiversity, all of which transcend national boundaries and require solutions through global cooperation.

About the Bioresources and Biotechnology Division

The Biotechnology Division seeks to achieve sustainable development through wide-ranging research, from microbes on the one hand to giant forest trees on the other. The Division has four areas: Microbial Biotechnology, Plant Molecular Biology, Plant Tissue Culture, and Forestry/Biodiversity.

The Division also incorporates the Asian Network on Mycorrhizae which coordinates research activities in the field in Asia. A National Facility on Germplasm of Mycorrhizal Fungi has also been established. It has been demonstrated that these organisms are efficient tools for growth enhancers and reclamation of barren sites overburdened with fly ash.

About Mycorrhiza Network and CMCC

The Mycorrhiza Network, located at the Tata Energy Research Institute (TERI), New Delhi, was set up in 1988 with an important component—the Mycorrhiza Information Centre (MIC). With effect from December 1993, a germplasm bank facility named Centre for Mycorrhizal Culture Collection (CMCC) started functioning as a composite project with the Mycorrhiza Network. The general objectives of the Mycorrhiza Network are to strengthen research, encourage cooperation, promote exchange of information, and publish a quarterly newsletter, Mycorrhiza News. The MIC is primarily responsible for establishing an information network in the region that makes available to the researchers the growing literature on mycorrhiza and facilitates information sharing among the members. A database on mycorrhizal literature is operational for information retrieval and supply to researchers, 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 at CMCC and provide starter cultures on request. Cultures from CMCC are available on an exchange basis or on specific requests at nominal costs for spore extraction/handling.

Contents

Role of mycorrhiza in tree nurseries—Part III. Comparative performance of mycorrhizal fungi[1]

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Comparative root colonization and growth response

Tree roots are colonized by mycorrhizal fungi mostly on the basis of their specificity and dependence on a particular mycorrhizal fungus. Percentage of root colonization does not, however, always reflect the corresponding increase in growth parameters of the infected host. Comparative root colonization by mycorrhizal fungi on conifers and hardwoods is discussed.

Comparative root colonization and growth response in conifers

With ectomycorrhizal fungi

Studies conducted at the University of Calgary, Canada, on Jack pine seedlings grown for 20 weeks in a peat-vermiculite medium and inoculated with solid carrier mycelial inoculum showed that the use of low amounts of fertilizer resulted in seedling size below standards for planting out. This low fertilizer amount, however, permitted infection of more than 90% short roots when inoculated with *Thelephora terrestris, Laccaria proxima, Hebeloma* sp. or E-strain fungus (a white spruce mycorrhiza forming fungus), about 50% root colonization when inoculated with *Cenococcum geophilum, Pisolithus tinctorius,* 32% by *Lactarius paradoxus,* and 17% by *Sphaerosporella brunnea.* Inoculation with *Amphenema byssoides, Hydnum immbricatum,* and *Tricholoma flavovirens* resulted in no infection (Danielson, Visser, Parkinson 1984).

In studies conducted at the University of Agricultural Sciences, Agricultural Research Station, Arsekera, Karnataka, *Pinus nigra* var. *Corsicana* seedlings were grown for seven days under sterile conditions and then planted singly in containers in sterile, brown acidic nursery soil which was inoculated with one each of the three isolates of *Laccaria laccata* or one isolate of *L. bicolor.* The plants were then grown for fifteen weeks in a glass house at 22–31 °C with a 16-hour photoperiod.

Within two to three months, short roots became mycorrhizal. However, percentages of mycorrhizal short roots were not significantly different between treatments (43%–55%) as compared to control with 29% infection. 20%–25% of non-inoculated controls were colonized by *Thelephora terrestris* rather than *Laccaria* spp. Seedling growth (shoot lengths, and shoot and root dry weights) were significantly greater with one (and sometimes two) of the *L. laccata* isolates and with *L. bicolor* than with other two *L. laccata* isolates (Ramaiah, Perrin 1990).

In studies conducted at the Forest Research Institute, Hanoi, Vietnam, out of six pure strains of mycorrhizal fungi tested on *Pinus merkusii,* three showed good symbiotic effect (stem volume increasing by 150%–350% by the ninth month) and two strains had average symbiotic effect and one strain showed symbiotic capability (Giao, Nham 1988).

In studies conducted at the Madras University, Tamil Nadu, India, *Pinus patula* seedlings were raised from surface sterilized seeds sown on stem-sterilized shola soil and inoculated with vegetative inocula of early stage fungi, *Thelephora terrestris* and *Laccaria laccata.* The inoculation gave superior growth in shoot height, mycorrhizal development, root collar diameter, and dry matter production when compared to controls. For the first seven months, growth parameters were greater in *T. terrestris*

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[1] Compiled from TERI database—Riza

inoculated plants but from the eighth month onwards, *L. laccata* plants grew better. There was a significant difference in growth between *T. terrestris* and *L. laccata* inoculated seedlings and also between sterilized and unsterilized soil types. *L. laccata* seemed to be better suited for *P. patula* nurseries than *T. terrestris* under south Indian conditions (Natarajan, Reddy 1992).

Studies conducted at the Forest and Range Experiment Station, United States Department of Agriculture, Forest Service, Berkeley, USA, on *Abies mangifica, A. concolor, Pseudotsuga menziesii, Pinus lambartiana,* and *P. ponderosa* inoculated with *Rhizopogon vulgaris, Hebeloma crustuliniforme, Pisolithus tinctorius* (Oregon and California isolates), *Laccaria laccata,* and *Amanita muscaria* showed that in stem caliper, shoot and root length, and dry weight and per cent mycorrhizal colonization, *P. tinctorius* (California isolate) was the most promising fungus after one year. After two years, *P. tinctorius* (California) was dominant with *A. magnifica,* and *A. concolor; A. muscaria* with *P. menziesii; R. vulgaris* and uninoculated treatment with *P. lambartiana; R. vulgaris, L. laccata* and uninoculated *with P. ponderosa. H. crustuliniforme* and *P. tinctorius* (California) had a depressing effect on *P. ponderosa* (Bega 1979).

Studies conducted at the Forest Faculty, Stellenbosch University, South Africa, showed that differences in growth in pines caused by inoculation of soil with ground sporophores of *Rhizopogon luteolus* or spores of *Pisolithus tinctorius* were minor and inoculation with either fungus increased mycorrhizal infection of roots and seedling growth when compared with controls in two trials. There was no difference in other two trials also (Donald D G M 1979).

Studies conducted at the Department of Forest Sciences, University of Alberta, Edmonton, Canada, on containerized seedlings of *Larix laricina* representing four provenances and 17 open pollinated families showed that during an 18-week period after inoculation with vegetative inocula of *Laccaria laccata, Cenococcum geophilum* and *Pisolithus tinctorius* formed ectomycorrhizae with 60%, 7%, and 12% of the total short roots, respectively. *Suillus granulatis* failed to form any mycorrhizae. For the *L. laccata* inoculated seedlings, greatest difference in mycorrhizal formation was 20% among provenances and 32% among families. Significant provenance effects were found in shoot height and root variables. Overall best growth was found with *L. laccata* inoculation (Zhu, Navratil 1987).

Studies at the Department of forestry, University of Wisconsin, USA, on one-year old *Pinus resinosa* and *P. ponderosa* inoculated with *Conococcum graniforme*

or *Thelephora terrestris* and additionally inoculated with *Coprinus ephimerus* along with each mycorrhizal fungus showed that *C. ephimerus* did not reduce the growth or enzymatic activity of feeder roots. Several seedlings showed sinuous morphology or serpentinosis of tap root which probably resulted from antibiotic secretions by *T. terrestris; C. ephimerus* is commonly used in the production of composted fertilizers (Iyer 1981).

Studies conducted at the Natchez Forest Research Centre, International Paper Company, Natchez, Mississippi, USA, on *Pinus taeda* in two nurseries inoculated with ecotypically different isolates of *Pisolithus tinctorius* by incorporating vegetative mycelia of each isolate in nursery soil showed that certain isolates were superior to others in enhancing seedling growth in terms of height, diameter, biomass, and ectomycorrhizal infection throughout the growing season. However, the seedling growth enhancement varied with isolates, with time and type of nursery soil (France et al. 1981).

Studies conducted at the Wageningen University of Agriculture, Biological Station, Kampsweg, The Netherlands, on *Pinus sylvestris* seedlings showed that after nine months' growth on peat and primary stand humus, ectomycorrhizal development with *Suillus bovinus* was significantly greater than that on secondary stand humus or podsolic sand. With *Rhizopogon luteolus*, the reverse was true (growth on secondary stand humus was higher than the growth on primary stand humus). Ectomycorrhizal development with *Laccaria bicolor* in podsolic sandy soil did not differ from that in primary stand humus (Baar, Elferink 1996).

Comparative root colonization and growth response in hardwoods

With ectomycorrhizal fungi

In studies conducted at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Soils, Queensland, Australia, seeds of *Acacia mangium* were germinated axenically and transferred to 150 mm diameter petridishes containing Melin Norkrans Modified (MNM) agar medium and inoculated with cultures of putative ectomycorrhizal fungi isolated from sporocarps of species of *Pisolithus* (two isolates), *Scleroderma, Tilopilus, Laccaria, Labrinthomyces, Boletus, Hysterangium,* and *Melajczukia*. Seedlings were then transferred to a mist chamber in nursery tubes containing 200 g of fumigated granitic sand and inoculated with highly effective strains of Bradyrhizobium and provided with a low phosphorus slow release fertilizer. Five months after transplanting, species of *Boletus, Hysterangium,*

and *Melajczukia* failed to initiate ectomycorrhiza. *Scleroderma*, one isolate of *Pisolithus* and *Laccaria* formed ectomycorrhiza and increased seedling growth by 50%–100% when compared to uninoculated controls. With second isolates of *Pisolithus*, roots were well colonized but there was no growth response. The remaining two fungi behaved erratically and colonized roots of only some individual seedlings which tended to have higher dry weights (Rodell *et al.* 1992).

In studies conducted at the Pusat Penelitian dan Pengembangan, Hutan, Bogor, Indonesia, 45-day old seedlings of *Hopea odorata, Vatica sumattrana, Shorea stenoptera, S. compressa,* and *S. pinanga* were grown in pots with fumigated red yellow podzolic soil and incorporated with fresh inocula of *Russula* sp., *Scleroderma* sp., and *Boletus* sp. After six months' growth, shoot-root ratios were increased in all species except *S. compressa*. Growth responses of *H. odorata, V. sumatrana, S. stenopetera,* and *S. compressa* were best when inoculated with *Scleroderma* sp. while with *S. pinenga*, the best inoculum was *Russula* sp. (Santoso 1988).

With vesicular–arbuscular mycorrhizal fungi

Studies conducted at the National Institute of Biotechnology and Applied Microbiology, Los Banos, Philippines, on *Acacia auriculaeformis* grown in pots on fumigated soil and inoculated by either of the four vesicular–arbuscular mycorrhizal (VAM) fungi by placing 50 spores one inch below pregerminated seeds showed that *Glomus etunicatum* and *G. macrocarpum* were more effective than *G. fasciculatum* and *G. mosseae* in increasing height, biomass, diameter, and phosphorus uptake after nine months' growth. All inoculations, however, increased these parameters significantly over noninoculated plants. The former two fungi also promoted a much greater module weight than the latter two although per cent infection was similar in all the treatments (59%–64%) compared with 16% in controls (Aggangan *et al.* 1990).

Studies conducted at the school of Forestry, Fisheries and Wild Life, University of Missouri, Columbia, USA, on sugar maple (*Acer saccharum*) inoculated with any one of the four VAM fungi namely *Glomus clarum*, *G. epigaeum*, *G. macrocarpum,* and *G. mosseae* showed that colonization by VAM increased mean leaf number per seedling from 2.8 to 3.7 and mean lateral root number from 34 to 43 but had no effect on various other growth parameters. *G. macrocarpum* inoculum most strongly affected seedling variables. Maximum VAM production (44% of the root length colonized) was with *G. macrocarpum*

and added magnesium hydroxide. Only *G. clarum* produced mycorrhizae at low pH but it had little effect on seedling variables during a 10-week growth period (Reid *et al.* 1988).

Studies conducted at the Department of Agricultural Microbiology, University of Agricultural Sciences, GKVK Campus, Bangalore, India, on two Hawaiian giant cultivars (K_8, K_{28}) of *Leucaena leucocephala* showed that out of seven VAM fungi, three showed promise from a preliminary screening trial with fungi obtained from *L. leucocephala* rhizosphere. *Glomus mosseae*, a local isolate, was the best that could be used to obtain healthy, vigorously growing seedlings of *L. leucocephala* both on oxisols and vertisols (Byra Reddy, Bagyaraj 1988).

Comparative efficiency of native versus exotic mycorrhizal fungi

Ectomycorrhizal fungi
In studies conducted at the Centro de Pesquisa Agropecuarea dos Cerrados, Planaltina, Brazil, *Pinus caribaea* seedlings were grown in pots supplied with 30 ppm phosphorus (producing 2.72 ppm extractable phosphorus and showing the maximum effect of mycorrhizal infection) and inoculated with seven fungal isolates. After 60 days, an exotic *Pisolithus tinctorius* isolate (299) produced 84% ectomycorrhizal colonization of root systems, compared with 52%, 67%, and 44% produced by isolates VP8640, VP8618 (*Rhizopogon nigriscens*), and VP8648 (*P. tinctorius*) collected from cerrado soils. The other isolates (including one *Suillus* sp.) produced few or no mycorrhizal roots (Vieira, Peres 1990).

Studies conducted at the Departmento Biologica Geral and Department de Fitopatologia, Universidate Federal de Vicosa, Brazil, on *Eucalyptus* sp. inoculated or uninoculated with indigenous *Pisolithus tinctorius* or introduced *Paxillus involutus* showed that percentage of colonization by both fungi was highest when inoculation was done at 45 days on plants and after that there was a slight decrease. The last sampling date showed percentages that were equal to the first date for *P. tinctorius* but were 15% greater for *P. involutus* (Muchovej et al. 1990).

Studies conducted at the Forest Research Institute, Seoul, South Korea, on *Pinus rigida* seedlings grown in fumigated soil, inoculated with US and Korean strains of *Pisolithus tinctorius* and then transplanted in exposed mineral soil showed that height and root collar diameter with the US strain were 53% and 83% higher than those inoculated with the Korean strain and uninoculated seedlings

(grown on non-fumigated soil), respectively. Survival percentage was 90% in the US strain inoculated seedlings compared to 83% in control. Dry weight in the US strain inoculated seedlings was 20% higher and height 31% higher than in control (Lee *et al.* 1988).

Vesicular–arbuscular mycorrhizal fungi

Studies were conducted at the Instituto Venezolano de Investigaciones Cientificas, Caracas-A, Venezuela, to see the effects of VAM inoculation on the growth of cacao seedlings in nursery soils treated with either copper oxychloride or methyl bromide. Cacao seedlings responded well to indigenous VAM fungi which included *Scutellospora calospora* as a dominant species, resulting in significant increases in height, dry weight, and concentration of phosphorus, copper, and zinc in leaves in relation to sterile controls. The introduced VAM fungi, *Glomus occultum* and *Acaulospora appendiculata,* also increased height but not statistically significantly. *Scutellospora pellucida*, another introduced fungus, and *A. appendiculata* doubled phosphorus uptake of seedlings. Previous methyl bromide soil sterilization resulted in the lowest copper and zinc uptake in seedlings but this effect was ameleorated by VAM inoculation. Copper oxychloride treatment depressed growth to the same level as the sterile control although its residual effect did not kill VAM. It could change the competitive relations among VAM species, and, in this case, seemed to affect the more efficient native fungi adversely (Cuenca *et al.* 1990).

Comparative tolerance of mycorrhizal fungi to drought

In studies conducted at the Department des Sciences, Forestieres, Universite Laval, Quebec, Canada, Jack pine (*Pinus banksiana*) and black spruce (*Picea mariana*) seedlings were inoculated with five mycorrhizal fungi and mycorrhizal seedlings were then subjected to known water stress by exposing their roots to a solution of polyethylene glycol or planted into a specially designed system which allowed simulation of a drought cycle in forest soil. The fungi that grew in pure culture under low water potential in a simultaneous experiment also increased the drought resistance of black spruce. The ability of some fungi to form rhizomorphs extending into the mineral soil layer or to stimulate root growth also correlated with increased drought tolerance of black spruce. In contrast, the fungi had little effect on the drought tolerance of jack pine seedlings which showed relatively higher ability to tolerate water stress independent of their mycorrhizal status (Boyle 1990).

In studies conducted at the College of Forest Resources, University of Washington, Seattle, USA, the ability of 55 isolates of 18 species of ecto-mycorrhizal fungi to tolerate imposed water stress adjusted with polyethylene glycol applied to the petridish units was examined. For 87% of the isolates, growth rate was inhibited by the initial water potential treatment applied, and with the remaining seven isolates, growth rates increased with initial water potential treatment. No growth was evident under the imposed stress treatments for isolates of *Laccaria bicolor*, *L. laccata*, and *Lactarius controversus*; growth occurred only in controls. Drought tolerant species demonstrated by an ability to grow at a water potential of −3 mega Pascal (MPa) included *Boletus edulis, Cenococcum geophilum, Rhizopogon vinicolor,* and five out of eight *Suillus* spp. Species intolerant of −1 MPa included *Hebeloma crustuliniforme, L. bicolor, L. laccata,* and *Suillus caerulascens.* Fungal drought tolerance was poorly correlated with estimates of annual precipitation for collection locations. Re-isolation of *L. bicolor* increased growth rate and water stress tolerance when compared with the same fungus prior to re-isolation (Coleman *et al*. 1989).

Studies conducted at the Division of Forestry and Forest Products, CSIRO, Wimbley, Australia, on seedlings of Karri (*Eucalyptus diversicolor*) raised on a yellow sand with a moisture gradient of −4.5 kPa (above field capacity) to −0.14 kPa (near waterlogged) and inoculated with *Descolea maculata, Pisolithus tinctorius,* and *Laccaria laccata* showed that all fungi enhanced seedling growth above that of uninoculated seedlings. In soil near saturation, however, there was no response to inoculation. Reduced mycorrhizal formation in relation to increasing soil moisture occurred, to various degrees, for all fungi, particularly in *P. tinctorius. L. laccata* maintained a relatively high number of mycorrhizal roots at all moisture levels except at the wettest soil treatment. An isolate of *D. maculata* from a swamp environment did not produce a greater number of mycorrhizal roots at high soil moisture than an isolate of this species from a forest environment (Bougher, Melajczuk 1990)

Comparative performance of mycorrhizal fungi in photosynthesis and water use efficiency

In studies conducted at the Department of Soil Science, Oregon State University, Corvallis, Oregon, potted seedlings of Douglas fir (*Pseudotsuga menziesii*), inoculated with three ectomycorrhizal fungi (*Rhizopogon vinicolor* — FSL788-5, *Laccaria*

laccata — S238-A, or *Hebeloma crustuliniforme* — HeCr2), were grown in a greenhouse for six months under well-watered conditions and then transferred to a growth chamber where measurements were made as the soil dried. *R. vinicolor* enhanced both net photosynthetic rate and stomatal conductance compared to non-mycorrhizal controls in the soil-water potential range of –0.05 to –0.50 MPa, despite 0.2 to 0.3 MPa lower leaf water potential. *H. crustuliniforme* tended to enhance while *Laccaria* decreased net photosynthesis rate and stomata conductance of host seedlings in this range of soil water potential but neither fungus affected leaf water potential (Dosskey *et al*. 1991).

Studies conducted at the Institute National de la Recherche Agronomique (INRA), Nancy, Laboratoire de Bioclimato Pogie et J'Ecophysiologie Forestrieres, Champenoux, France, on Douglas fir (*Pseudotsuga menziesii*) seedlings inoculated with *Laccaria laccata* or *Thelephora terrestris* and grown at 10 mg and 40 mg phosphorus per litre levels showed that *L. laccata* was more efficient than *T. terrestris* in increasing water use efficiency and photosynthesis, partly due to improved phosphorus nutrition. Phosphorus deficiency reduced both the above parameters (Guehl, Garbaye 1990).

In studies conducted at the School of Forestry, Auburn University, Auburn, USA, *Eucalyptus camaldulensis* seedlings inoculated with *Pisolithus tinctorius* and *Thelephora terrestris* were grown in well-watered soil or were subjected to long-term soil water stress of up to 1.0 MPa over a 13-week period in a glass house. After the 13th week, all seedling containers were watered to field capacity and then water was withheld to induce a short-term drought. Diurnal measurements of seedling photosynthesis rate, leaf stomatal conductance, and leaf water potential completed before, during, and after short-term drought were similar both in larger seedlings colonized by *P. tinctorius* and smaller *T. terrestris* seedlings during the short-term drought period although they were growing in equal soil volume. *P. tinctorius* seedlings maintained higher photosynthesis rates over the course of the short-term drought (Dixon, Hiol-Hiol 1992).

Studies conducted at the Forest Research Institute, Nigeria, Ibadon, Nigeria, on *Pinus contorta* seedlings exposed to three levels of irradiance and supplied with three levels of nitrogen fertilizer and inoculated with either *Pisolithus tinctorius* or *Suillus granulatus* showed that the photosynthetic rates with *P. tinctorius* were 1.87 mg CO_2.contdot.dm^{-2}. Cntdot.h^{-1}. These rates were marginally greater than 1.41 mg CO_2.cntdot.dm^{-2} in non-mycorrhizal plants (Ekwebelem, Reid 1983).

In studies conducted at the Department of Forest Science, Oregon State University, Corvallis, USA, on *Pinus ponderosa* seedlings grown in root observation chambers and inoculated or uninoculated with *Hebeloma crustuliniforme* or *Laccaria bicolor*, root-tips initiated during 8–12 months of the growing period were classified monthly as light, intermediate or dark. *H. crustuliniforme*, and to a lesser extent *L. bicolor*, retarded progression of root-tips from light to dark and finally black as compared to controls. The amount of 14C (estimated by labeled $14CO_2$) in light *L. bicolor* and *H. crustuliniforme* mycorrhizae was 2.3 and 1.8 times greater as compared to light control root-tips (Durall *et al*. 1994).

Comparative tolerance of mycorrhizal fungi to heavy metals

Studies conducted at the Department of Botany, University of Toronto, Ontario, Canada, on birch (*Betula papyrifera*) seedlings inoculated with either nickel tolerant *Scleroderma flavidum* or *Lactarius rufus* (which does not increase nickel tolerance) and exposed to 85 µM nickel showed that *L. rufus* provided some initial protection against nickel toxicity. Water uptake (taken as an indicator of the progression of nickel toxicity) in *S. flavidum* infected seedlings was least affected by nickel and was significantly higher than that in *L. rufus* infected or uninoculated plants after week 10. Total dry weight of *S. flavidum* tissue per root was significantly greater than that of *S. rufus* in both nickel treated and control seedlings and this amount increased with time (Jones, Hutchinson 1988). In studies conducted at the Department of Botany, University of Toronto, Ontario, Canada, isolates of *Hebeloma crustuliniforme*, *Rhizopogon rubescens*, and *Suillus tomentosus* obtained from basidiocarps collected from different age *Pinus banksiana* plantations were grown individually for four weeks in nutrient solution containing 37, 150, 370 or 740 µM aluminium (Al) combined in factorial design with 25, 125, 250, or 500 µM calcium (Ca) and maintained at pH 3.8. Growth of all fungi was reduced at 370 µM Al. Increment in external Al concentrations resulted in reduced mycelial concentrations of calcium, magnesium, and potassium and increased mycelial concentrations of Al, phosphorus, and iron in *H. crustuliniforme*. High external Al concentrations resulted in reduced myceliae concentrations of all elements except Al and phosphorus in *R. rubescens* and increased mycelial concentration of all elements except calcium for *S. tomentosus*. Growth of *H. crustuliniforme* was stimulated by step-wise increment in external calcium concentration from 25 to 500 µM while increments

in calcium had no effect on the growth of *R. rubescens*. High external levels of calcium acted synergistically with high external Al concentrations to reduce growth of *S. tomentosus*. Thus, alterations in calcium and Al ratios of soils may influence the succession of ectomycorrhizal fungi (Browning, Hutchinson 1991).

Studies conducted at the School of Environmental Biology, Curtin University of Technology, Perth, Western Australia, on three isolates of *Pisolithus tinctorius*, collected from three sites (a 30-year old abandoned coal mine—pH 4.3, Al: 164 ppm; a 10-year old rehabilitated site—pH 5.1, Al: 6 ppm, and a forest site—pH 5.3, Al: 2 ppm) and grown in pure culture on MNM medium for Al tolerance showed that abandoned mine site isolate demonstrated mycelial growth on up to 2000 ppm Al with a threshold of 90 ppm before Al accumulation occurred. In contrast, growth of the rehabilitated and forest site isolates was limited by 22 ppm and 12 ppm Al, respectively, with significant metal accumulation at low (1–4 ppm) substrate Al. Electron microprobe analysis of *Eucalyptus* seedlings inoculated or not with Al tolerant (mine site) or Al-sensitive (forest site) isolates and grown in Al-contaminated soil demonstrated that Al accumulation within hyphal wall and metal presence within the cytoplasm affected the degree of Al tolerance in the host plant. The presence of Al in the cytoplasm coincided with significant accumulations of sulphur indicating a role for phytochelatins as a biochemical basis for tolerance to Al in mine site isolates. Retention of Al within the hyphal mantle led to decreased Al levels across the root proper. In contrast, non-mycorrhizal plants demonstrated consistently high Al levels in all root tissues with negligible quantities of calcium and magnesium. Dry weight analysis confirmed Al accumulation within roots of seedlings inoculated with Al-tolerant isolates and limited metal tolerance to the shoot but forest site isolate and non-inoculated plants contained as much Al in shoots as in roots. Plants with Al-tolerant isolates were taller with greater root-shoot dry mass and increased mycorrhizal infection and had double the amount of total nitrogen, phosphorous, and potassium than that of forest site isolate plants (Egerton-Warburton *et al.* 1992).

Comparative tolerance of mycorrhizal fungi to pH

Studies conducted at the Department of Soil Science, Oregon State University, Corvallis, USA, on *Liquidambar styraciflua* seedlings raised on surface soil and sub-surface soil with organic matter 8.87 and 0.10, respectively, and adjusted to a range of pH from 5.1 to 8.1 by liming with increments in CaCO$_3$

showed that two VAM species, i.e., *Glomus fasciculatum* and *G. mosseae* strikingly enhance seedling growth (stem, height, collar diameter, leaf number, and area and tissue dry weight) to different degrees depending upon their pH tolerance. *G. fasciculatum,* with about 40% root colonization, stimulated the earliest (within four to six weeks) and longest growth response at the lower pH values (5.1 and 5.9). Conversely, *G. mosseae* with 15% colonization stimulated equivalent, although later, growth (beginning at about three months) but at higher pH values (6–8). It did not enhance growth at pH 5.1 although it colonized seedlings (Davis *et al.* 1983).

Studies conducted at the Department of Microbial Ecology, University of Lund, Sweden, on five ectomycorrhizal isolates and two unidentified isolates showed that *Paxillus involutus* was the only fungus affected both by the pH increase and by different treatments in relation to growth and survival when these fungi were grown in unsterilized humus collected from *Pinus sylvestris* forests that had been treated with varying amounts of wood ash (3 and 7.5 tonnes per ha) and dolomite lime (2 and 5 tonnes per ha). No other fungus grew saprophytically. But when four-week old *P. sylvestris* seedlings were introduced into the system, all fungi showed similar changes in infection potential in response to pH irrespective of the fact whether lime or ash had been used (Erland, Soderstrom 1991).

Studies conducted at the CSIRO, Division of Forestry, Wembley, Australia, on *Eucalyptus globulus* inoculated with one of six fungal isolates (*Laccaria laccata* isolates A and B, *Descolea maculata, Setchelliogeaster* sp., *Pisolithus tinctorius* A and B) and grown in pots in phosphorous-deficient soil in temperature controlled glass house at two levels of pH (pH 5 and pH 6) showed that inoculation increased the uptake of phosphorous and growth of plants from all isolates at both levels of pH, though greater at pH 6 particularly for two *L. laccata* isolates. Isolates that colonized roots most extensively increased plant growth to the greatest extent. *D. maculata* was most effective fungal isolate at pH 5 and both the *D. maculata* and *L. laccata* A isolates were most effective at pH 6. The *L. laccata* isolates formed more hyphae in soil (on a per port, per m of fine root and per m of colonized fine root basis) than other fungal isolates but were not always more effective in increasing plant growth (Thomson et al. 1996).

Comparative performance of mycorrhizal fungi on fumigated soil

Studies conducted at the Centre National de Recherches Forestieres (CNRF), Champenoux,

Seichamps, France, on Douglas fir and Norway spruce grown under normal nursery conditions, with or without fumigation at different levels of fertility and inoculated with pure cultures of *Hebeloma cylindrosporum, Boletus granulatus,* and *B. luteus* showed that tree species only benefitted from *H. cylindrosporum* at any level of fertility and that also only on fumigated soil. *H. cylindrosporum* gave 35% better growth and 43% better survival in Douglas fir than other normal mycorrhizal fungi. For Norway spruce, growth increase was 64%. In fumigated soil, after two years without transplantation, *H. cylindrosporum* mycorrhizae had almost completely disappeared. Without fumigation, however, *H. cylindrosporum* continued to give better growth (49%) in Douglas fir and 110% in Norway spruce than normal mycorrhizal fungi (Tacon le 1981).

Comparative growth depressing effect by mycorrhizal fungi

Some mycorrhizal fungi have growth depressing effect at least in initial stages on their hosts. Studies were conducted at the Pacific South West, Forest and Range Experiment Station, Forest Service, United States Department of Agriculture, Berkeley, California, to determine growth depressant effect (GDE) on *Abies magnifica, A. concolor, Pseudotsuga menziesii, Pinus lambartiana,* and *Pinus ponderosa* when inoculated with *Cenococcum graniforme* A-167, *Amanita muscaria* S-179, *Laccaria laccata* S-184, *Hebeloma crustuliniforme* S166-B or *Pisolithus tinctorius* S-216 or S-360. On the basis of stem diameter and root and shoot dry weights GDE was found on *A. magnifica,* none on *A. concolor* by A-167, S-184, S-216, S-360; on *P. lambartiana* by S-79, S-360; and on *P. ponderosa* by S-179, S-360 (Bega 1981).

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Research findings...

Under this column appear short notes on important breakthroughs/significant achievements in original research of high calibre in the field of mycorrhizae, which have not yet been published.

A modified procedure for mounting spores of arbuscular mycorrhizal fungi

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Introduction
Perfect preparation and preservation of microscopic mounts is an essential prerequisite for mycologists. The semi-permanent mounts of spores of arbuscular mycorrhizal (AM) fungi of coastal sand dunes of west coast of India (Kulkarni, Raviraja, Sridhar 1997) in polyvinyl alcohol-lacto-glycerol (PVLG) mountant (Koske, Tessier 1983; Schenck, Perez 1990) did not last long. After observing under oil immersion objective, wiping the oil from the surface of the cover glass without disturbing the specimen/ nail polish seal was difficult. The remaining traces of oil on the cover glass reduced the photographic quality of the specimen. In addition, the slides were spoiled due to high humidity of coastal weather particularly during wet season by fungal growth on the slides and cover glass. Hence, a modified approach was employed to prepare permanent slides of AM spores. The modified procedure is a combination of techniques outlined for AM fungi (Koske, Tessier 1983; Schenck, Perez 1990) and marine fungi (Kohlmeyer, Kohlmeyer 1979). This article consists of the details of the modified procedure.

Materials and method
Following are the materials and steps involved in the modified procedure.
- A large square cover glass (22 mm^2) was attached to the microscope slide by the addition of a drop of distilled water.
- A drop of PVLG (polyvinyl alcohol, 8.33 g; distilled water, 50 ml; lactic acid, 50 ml; glycerine, 5 ml) (Koske, Tessier 1983) was placed at the centre of the cover glass.
- Selected AM spores were transferred to the drop of PVLG.
- The PVLG drop with spores was covered with a small square cover glass (18 mm^2).
- The slide thus prepared was then heated in an oven at 50–70 °C overnight (which hardens the PVLG).
- The edges of the mount were sealed with a thin layer of Canada balsam and allowed to dry for 30–60 minutes (DPX mountant also serves as a substitute to Canada balsam).
- A drop of Canada balsam was placed on the small cover glass.
- The double cover glass was then turned over and placed on a clean slide (the mountant spread and surrounded the small cover glass).
- The slide was preserved horizontally till the mountant hardened.
- Later, the excess mountant at the edges of the large cover glass was pealed out with the help of a needle.

For the purpose of observation of AM spore walls, preruptured spores from other slides may be transferred to PVLG on large cover glass at Step 3. The spores can also be ruptured after applying the small cover glass over PVLG at step 4.

Results and discussion
The present modified method of permanent mount preparation of AM fungal spores is ideal, particularly for tropical regions with high humidity and/or long wet season which spoils the semi-permanent slides very quickly. Repeated observations of the permanent slides under oil immersion objective and wiping the oil with xylene did not cause any disturbance or damage to the specimen and seal. Semi-permanent PVLG mounts should be preserved horizontally since PVLG does not solidify completely (Schenck, Perez 1990), but the slides prepared by the modified procedure owing to hardened PVLG and permanent seal could be preserved vertically. Though this method is time consuming, the results are far better than the semi-permanent slide. In addition, to facilitate easy transport, the permanent mounts become good voucher specimens for deposition in herbaria.

Acknowledgements

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Growth response of carrot (*Daucus carota* L.) to a selective VA mycorrhizal inoculant in an unsterile soil

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Introduction

Application of an efficient vesicular–arbuscular mycorrhizal (VAM) fungus is amply proved to be an effective biofertilizer in improving the efficiency of phosphorous uptake and increase in crop production without the application of high levels of phosphate fertilizer (Hayman 1980). However, the selection of an efficient VAM fungal species, which can help to enhance phosphorous supply and the choice of the genotype, which can get maximum benefit of the VAM association, are the two important factors which may improve the existing VAM-plant association (Menge 1983; Krikun *et al.* 1987).

There are only a few reports on the response of VAM inoculations in tuber crops like potato (Black, Tinker 1977; Potty 1988; Rai 1990), cassava (Potty 1988) and sweet potato (Potty, Indira 1990) from India. The response of carrot to mycorrhizal inoculation has not been fully investigated except that it is found to be highly dependent on mycorrhizae (Plenchette 1982). For those plants having coarse root system as in tuber crops, the mycorrhizae is of special importance since extramatrical mycelium can only supplement the absorbing area.

In the present study after preliminary trials, *Glomus mosseae* was selected and tested on two varieties of carrot (*Daucus carota* L.) to study its efficiency on growth and yield in unsterile soil.

Materials and methods

Two carrot varieties, Local and SKG, were raised in 32 cm pots containing unsterilized soil-sand mixture (1:1) having high pH and low available phosphorous (Table 1). Ten seeds of each variety were sown in each pot with an addition of *Glomus mosseae* inoculum at the rate of 50 ml/pot (a mixture of root pieves and extramatrical chlamydospores and soil) at a depth of 3–5 cm in the pot. Carrot seeds were sown just above the inoculum layer and later covered with the soil. Appropriate controls without inoculum were maintained. There were three replicates for each variety.

Table 1. Physico-chemical characteristics of the soil sample used

Composition	Per cent
Coarse sand	67.04
Fine sand	9.20
Silt	4.20
Clay	19.56
Total organic content	5.20
Organic carbon	0.42
P_2O_5	0.00113
K_2O	0.012
E C	0.43 mmhos/cm
pH	8.9

After 45 days growth the plants were thinned out retaining only four healthy plants per pot. After 90 days of establishment the plants were harvested carefully and the roots were washed free of the adhering soil for taking measurements. The per cent mycorrhizal infection was determined by observing the roots after staining (Phillips, Hayman 1970) and by using the method of Read *et al.* (1976), i.e.,

$$\% \text{ VA infection} = \frac{\text{No. of infected segments}}{\text{Total no. of segments examined}} \times 100$$

The fresh weights of both the root and shoot systems were recorded separately. Dry weight of shoots and roots were recorded after drying to constant weight at 70 °C.

Results

The percentage mycorrhizal infection of carrot roots, both inoculated and uninoculated (control),

are presented in Table 2. Although, the native mycorrhiza in unsterile soil caused 20% and 15% infection in the var. Local and SKG, respectively, inoculation with *Glomus mosseae* increased per cent infection (Table 2) substantially (significant at 0.01% level). The proliferation of fibrous roots in inoculated plants was very high. The mycorrhizal association was found confined only to lateral fibrous roots and the rootlets with quite abundant intrametrical mycelium and formation of arbuscules spreading almost throughout the cortex. The vesicles, though occasional, were found to be very conspicuous. The fleshy tap root was found completely free from mycorrhizal infection.

Table 2. Per cent mycorrhizal infection of roots of carrot in unsterile soil inoculated with *Glomus mosseae*

	Per cent infection*	
Variety	Control	Inoculated
Local	20.00	70.00
SKG	15.00	50.00
*P=0.01	4.80	6.50

The dry weight and fresh weight of both root and shoot system were found increased due to inoculation with *Glomus mosseae* and was significantly high in the variety Local when compared to SKG. The yield was found increased nearly by 270% in Local and 42% in SKG over non-inoculated control plants (Table 3).

Discussion
Plenchette (1982) has reported that at 100 µg/g available P the relative mycorrhiza dependency of carrot (*Daucus carota* var. Nantaise) is 99.2%. Schenck et al. (1975) have reported that different cultivars of the single plant species differ in harbouring VAM in their root system. Similarly, in the present study both the varieties (Local and SKG)

differed in their response to native inoculum and/or to the inoculant both in terms of per cent root colonization (Table 2) and vegetative growth and tuber yield (Table 3). Mosse (1974) pointed out that if the introduced endophytes can be more beneficial to plant growth than the indigenous ones, the present findings have important practical application. Similar observations were reported in unsterile soils with efficient strains of VAM (Mosse, Hayman 1971; Khan 1972; Bagyaraj, Manjunath 1977) and the plants infected with VA mycorrhizae taking more phosphate from P-deficient soils is well documented (Tinker 1975). Black, Tinker (1980) have also observed positive response of potato to VAM application in its growth and yield under natural conditions in soils having low available phosphorous. Thus, keeping in view the improved plant growth and yield to the extent recorded in this study, it is quite likely that inoculation with efficient VAM fungus in spite of the presence of native ones could be beneficial to practical agriculture.

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Table 3. Growth response of carrot as influenced by *Glomus mosseae* inoculations in unsterile soil

Variety	Treatment	Root length (cm)	Shoot length (cm)	Fresh weight (g)		Dry weight (g)		% yield increase over control
				Root	Shoot	Root	Shoot	
Local	Control	18.50	15.75	1.301	0.825	0.1125	0.105	—
	Inoculated	27.25	23.00	4.832	1.917	0.4025	0.225	270%
SKG	Control	12.40	13.20	0.637	0.285	0.017	0.050	—
	Inoculated	13.40	16.00	0.919	0.736	0.065	0.127	42%
CD at 5% level		4.84	4.85	0.82	6.620	6.440	6.210	—	—

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VAM fungi associations in a protected grassland

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Introduction

The vesicular–arbuscular mycorrhizal (VAM) fungi are ubiquitous in both natural and man-made ecosystems (Hayman 1982). It is now well known that VAM fungi play a vital role in plant growth, particularly in drier areas with nutrient-deficient soils. Since naturally occurring VAM fungi are well adapted to the conditions of their natural occurrence due to their long process of evolution, they can be of immense use for various plants as compared to exotic VAM. Screening of VAM fungal species is essential in areas hitherto not studied to prepare a calendar of existing VAM fungi with their distribution. Though looking at their importance and role in terrestrial ecosystems, a large number of such reports of VAM are available for different areas, more areas are to be surveyed to complete the task to prepare a database on a national level including different geographic and agro-climatic zones.

In view of the above, the present survey was undertaken in a protected grassland of tropical deciduous forest region in Sagar, Madhya Pradesh, to furnish the information on the occurrence and association of VAM with different dominant and common grassland plants.

Materials and method

After selection and identification of dominant and common species of the grassland vegetation, root samples of grasses were collected in the month of August and forbs in the month of October. The root samples were washed thoroughly in tap water and cut into 1 cm long pieces. Roots were stained with 0.1% acid fuchsin. Improved procedure of Phillips, Hayman (1970) was followed to determined the VAM colonization in roots.

The percentage colonization of VAM was calculated by using the following formula:

$$\% \text{ colonization} = \frac{\text{Total no. of colonized root pieces}}{\text{Total no. of root pieces examined}} \times 100$$

The manual for the identification of VAM given by Schenck, Perez (1990) was followed for the identification of chlamydospores and intact VAM spores.

Conclusion

It is evident from Table 1 that all plant species are colonized with VAM fungi. The root colonization ranges from 46% to 100%. Comparatively higher colonization was found in grasses than in forbs. Among the different VAM fungi, *Glomus aggregatum*, *G. fasciculatum,* and *G. intraradix* were the most dominant species found associated with almost all the grasses. Other species were *Acaulospora* sp., *Gigaspora* sp., and *Scutellospora* sp.

The heavily colonized plant species can easily be harvested and could be of immense use for isolation and mass multiplication of VAM.

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Table 1. Percentage colonization and VAM species distribution in grasses and forbs

Name of plant species	% Coloni-zation	G. aggre-gatem	G. fascicu-latum	G. intra-radix	Acaulo-spora sp.	Giga-spora sp.	Scutello-spora sp.
Grass							
Chloris barbata Sw.	100%	+	+	+	—	—	—
Cymbopogon martinii (Roxb) Wats.	78%	+	+	—	—	—	—
Digitaria sanguinalis (Linn) Scop.	100%	+	+	+	—	—	—
Heteropogon contortus (Linn) P. Beauty	82%	+	+	—	—	—	—
Paspelum distichum Linn.	100%	+	+	+	—	—	—
Setaria glauca (Linn) P. Beauv.	100%	+	+	+	—	—	—
Sporobouls diander (Retz.) P. Beauv.	100%	+	+	+	—	—	—
Forbs							
Ageratum conyzoides (Linn).	90%		+	—	+	—	—
Dicliptera verticillata Nees.	96%	+	+	—	—	—	—
Eclipta erecta (Linn)	52%	—	—	—	—	—	—
Euphorbia geniculata Orteg.	90%	+	+	—	—	—	—
Euphorbia hirta Linn.	88%	—	—	—	—	+	—
Justicia quinqueangularis Keon.	80%	+	—	—	—	—	—
Lantana camara Linn.	74%	+	—	—	—	—	—
Lagascea mollis cav.	62%	—	+	—	—	—	—
Malvastrum coromandelianum (Linn) Garcke	82%	+	—	—	—	—	—
Peristrophe bicalyculata (Retz) Nees	52%	+	—	—	—	—	—
Rungia parviflora (Retz) Nees.	60%	—	—	—	—	—	—
Sonchus arvensis Linn.	94%	—	—	—	—	—	+
Vernonia cinerea (Linn.) Less	84%	+	+	—	—	—	—
Vicoa indica (Linn.) DC	46%	—	—	—	—	—	—

New approaches...

Under this column appear brief accounts of new techniques, modifications of available techniques, and new applications of other known techniques, etc., in mycorrhiza research that have been published in reputed journals during the last two or three years.

Determination of chitin in fungi and mycorrhizal roots by HPLC

A method to measure chitin content in fungi and ectomycorrhizal roots with high performance liquid chromotography (HPLC) was developed by Ekblad A, Nasholm T, 1996 (*Plant and Soil* **178**(1): 29–35, 1996). Measurement of fluorescence of 9-fluorenyl methyl chloroformate (FMOC-Cl) derivatives of glucosamine were made on acid hydrolysates of pure

chitin, chitin-root mixtures, and fungal-root mixtures. The method was applied on five isolates of ectomycorrhizal fungi and ectomycorrhizal and non-ectomycorrhizal *Pinus sylvestris* roots. Interference from amino acids was removed by pretreatment of samples with 0.2 NaOH. This pretreatment did not reduce the recovery of chitin. The HPLC method was compared with colorimetric chitin method by measurement on root-fungal mixtures with known fungal content. The HPLC method gave the estimate of fungal biomass which was equal to the expected while the colorimetric method showed values significantly by lower (PL0.001) than the expected . The present chitin method offers a sensitive and specific tool for the quantification of chitin in fungi and in ectomycorrhizal roots.

Assessment of mycorrhizal colonization by fungal specific sterols

The extent of mycorrhizal colonization in plants is generally assessed by microscopic counting or by determination of fungal cell wall chitin. According to Bothe H, Klingner A, Kaldorf M, Schmitz H, Hundeshagen B, Kernebeck H (*Expercentra* **50**: 999–925, 1994), the chitin method is of limited values as prior to HPLC analysis, the heavy salt load in the samples to be assessed has to be removed and this step cannot easily be performed quantitatively. The authors have found that the degree of mycorrhizal colonization can be measured conveniently by determining fungal-specific sterols. Plants colonized by VA mycorrhizal fungi show a specific synthesis of 24-methylene cholesterol and an enhanced level of campesterol (= 24 methyl cholesterol).

Forthcoming events...

23–28 May 1999
Tropical Restoration for the New Millennium. San Juan, Puerto Rico
For further information, please contact:
John Parrota,
Restoration Conference Program Chair, IITF
USDA Forest Service
PO Box 25000, Rio Piedras
PR 00928-5000, USA
Fax: 1-787-766 6263
E-mail: j-parrotta@uprl.upr.clu.edu

14–16 June 1999
The Role of National Forest Programs to Ensure Sustainable Forest Management. Joensuu, Finland
For further information, please contact:
Ms Brita Pajari
European Forest Institute
Torikatu 34, FIN-80 100 Joensuu
Finland
Fax: 358-13 124 393
E-mail: anssi.niskanen@efi.fi

28–30 June 1999
Forest Engineering for Tomorrow. Edinburgh, Scotland
For further information, please contact:
Geoff Freedman
Forestry Engineering
Greenside, Peebles
Scotland, UK
Fax: 44-1721 732 448
E-mail: geoff.freedman@forestry.gov.uk

11–16 July 1999
Forest Biotechnology: Into the Next Millennium. Oxford, UK
For further information, please contact:
Malcolm Campbell
Department of Plant Sciences
University of Oxford
South Parks Road
Oxford OXI 3RB, UK
Fax: 44-1865-275074
E-mail: malcolm.campbell@plants.ox.ac.uk

12–16 July 1999
Off-forest Tree Resources of Africa Workshop. Arusha, Tanzania
For further information, please contact:
Prof. Roger Malimbwi
Faculty of Foresty
Sokoine University of Agriculture
PO Box 3009 Chuo Kikuu
Morogoro, Tanzania
Fax: 255-56-4648
E-mail: forestry@sua.ac.tz

22–25 August 1999
International Conifer Conference. Wye College, England
For further information, please contact:
Lisa von Schlippe
The Royal Botanic Gardens, Kew
Richmond, Surrey, UK
Fax: 44-181-332 5197
E-mail: L.von.schlippe@rbgkew.org.uk

23–25 August 1999
International Teak Conference: Teak Beyond Year 2000. Chiang Mai, Thailand
For further information, please contact:
Director,
Forest Tree Seed Centre
Muak-Lek
Saraburi
Thailand
Fax: 66-36-341 859

September 1999
New Approaches to Integrated Management of Primary and Secondary Forests for the 21ˢᵗ Century. Belem, Brazil
For further information, please contact:
Natalion Silva
Brazilian Agricultural Research Corporation
CP 48, CEP 66240
Belem, Para
Brazil
Fax: 55-91-226 9845
E-mail: natalino@cpatu.embrapa.br

1–7 September 1999
Seminar on Sustainability of Plantations. Curitiba, Brazil
For further information, please contact:
Dr Carlos Ferreira
National Center of Forest Research
EMBRAPA, XX
Fax: 55-41 766 1276
E-mail: bellote@cnpf.embrapa.br

9–23 September 1999
27ᵗʰ International Forestry Students Symposium: Forest History — the Link to Our Future. Gottingen, Germany
For further information, please contact:
IFSS 99 Organising Team
IFSA Secritariat, Buesgenweg 2
37077 Gottingen
Germany
Fax: 49 551 3796992
E-mail: ifss@ifsa.net

18–22 October 1999
Impact of Logging on Biodiversity. Hanoi, Vietnam
For further information, please contact:
Titiek Setyawati
Research Fellow
CIFOR, PO Box 6596
JKPWB Jakarta 10065
Indonesia
Fax: 55-41 766 1276
E-mail: t.setyawati@cgnet.com

18–23 October 1999
II Latin American Symposium on Advances in the Production of Forest Seeds. Santo Domingo, Dominican Republic.
For further information, please contact:
Rodolfo Salazar
CATIE , Turriable
Costa Rica
Fax: 506-556-556 7766
E-mail: rsalazar@catie.ac.cr

News from members ...

UAS professor honoured

Dr D J Bagyaraj, Professor and Head, Department of Agricultural Microbiology of the University of Agricultural Sciences, Bangalore, was honoured with the Professor S R Vyas Memorial Award. This award, instituted by the Association of Microbiologists of India, is conferred biennially on a scientist for his outstanding contributions to microbiology. This award is in recognition of his research work on mycorrhizal fungi and their role in agriculture, horticulture, and forestry. Dr R S Paroda, Director General, Indian Council of Agricultural Research presented the award.

Prof. Bagyaraj has also been conferred with an honorary appointment to Research Board of Advisors by the American Biographical Institute, USA.

A new species of VAM fungus honouring Prof. Bagyaraj

A new species of VA mycorrhizal fungus isolated from Allahabad has been named as *Glomus bagyarajii*, in recognition of the contribution of Prof. D J Bagyaraj, University of Agricultural Sciences, Bangalore, to the field of mycorrhizal research. The fungus produces abundant bright yellow to yellow brown spores with four wall layers, subtending hypha hyaline to pale yellow, cylindrical or funnel shaped. Germination is by regrowth of the subtending hypha. This research publication has appeared in the recent issue of *the Philippine Journal of Sciences* **126**: 233–242.

Recent references · · ·

Latest additions to the Network's database on mycorrhiza are published here for information of the members. The Mycorrhiza Network will be pleased to supply any of the available documents to bonafide researchers at a nominal charge.

This list consists of papers from the following journals, which are arranged in alphabetical order.

- *American Journal of Botany*
- *Annals of Botany*
- *Applied and Environmental Microbiology*
- *Applied Soil Ecology*
- *Biologia*
- *Biology and Fertility of Soils*
- *Biotropica*
- *Canadian Journal of Botany*
- *Environmental and Experimental Botany*
- *FEMS Microbiology Letters Forest Ecology and Management*

- *Hortscience*
- *Journal of Ecology*
- *Journal of Plant Physiology Mycorrhiza*
- *New Phytologist*
- *Oecologia*
- *Plant Journal*
- *Planta*
- *Texas Journal of Science*
- *Tree Physiology*

Copies of papers published by mycorrhizologists during this quarter may please be sent to the Network for inclusion in the next issue.

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Bryla D R, Koide R T (University of Nevada, Department of Environment and Resource Science, Reno, NV 89557 USA). Mycorrhizal response of two tomato genotypes relates to their ability to acquire and utilize phosphorus, 849–857

Tarhanen S (University of Kuopio, Department of Ecology and Environmental Science, POB 1627, FIN-70211 Kuopio, Finland). Ultrastructural responses of the lichen *Bryoria fuscescens* to simulated acid rain and heavy metal deposition, 735–746

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Wilson G W T, Hartnett D C (Kansas State University, Division of Biology, 232 Ackert Hall, Manhattan, KS 66506 USA). Interspecific variation in plant responses to mycorrhizal colonization in tallgrass prairie, 1732–1738

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Vierheilig H, Coughlan A P, Wyss U, Piche Y (University of Laval, Centre Recherches Biologie Forestiere, Pavillon CE Marchand, St Foy, PQ G1K 7P4, Canada). Ink and vinegar, a simple staining technique for arbuscular–mycorrhizal fungi, 5004–5007

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Hanel L (Academy of Science Czech Republic, Institute of Soil Biology, Na Sadkach 7, CZ-37005 Ceske Budejovice, Czech Republic). Distribution of nematodes in soil, mycorrhizal soil, mycorrhizae and roots of spruce forests at the Boubin Mount, Czech Republic, 593–603

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Illmer P, Schinner F (Innsbruck University , Institute of Microbiology NF, Technikerstr 25, A-6020 Innsbruck, Austria). Influence of nutrient solution on Al-tolerance of Pseudomonas sp., 187–190

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Skene K R (University of Dundee, Department of Biological Sciences, Dundee DD1 4HN, Scotland). Cluster roots: some ecological considerations, 1060–1064

Journal of Plant Physiology 153(5-6), 1998
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Van Auken O W, Brown S C (University of Texas, Division of Life Sciences, San Antonio,TX 78249 USA). Importance of arbuscular mycorrhizae to drymass production of a native Texas C-3 and C-4 grass, 291–304

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Jentschke G, Winter S, Godbold D L (University of Wales, School of Agriculture & Forest Science, Bangor LL57 2UW, Gwynedd, WALES). Ectomycorrhizas and cadmium toxicity in Norway spruce seedlings, 23–30

Centre for Mycorrhizal Culture Collection (CMCC)

List of cultures available for circulation

S No.	Germplasm bank code	Fungus name	Host	Source person/place of origin
Ectomycorrhizae				
1.	EM-1232	*Rhizopogon vulgaris*	—	—
2.	EM-1231	*Rhizopogon subrerolatus*	Douglas	Girona
3.	EM-1230	*Rizopogon rubescens*	Pine	France
4.	EM-1012	*Rhizopogon ochraceorubens*	*Pinus contorta Abies lasiocarpa*	Oregon, USA
5.	EM-1140	*Rhizopogon ochraceisporus*	*Pinus ponderosa pseudotsuga*	Canada
6.	EM-1132	*Sarcodon scabrosus*	*Alnus sinnata*	California, USA
7.	EM-1273	*Scleroderma aurantium*	—	USA
8.	EM-1235	*Scleroderma flavidum*	*E. camaldulencis*	Australia
9.	EM-1233	*Scleroderma cepa*	*Eucalyptus sp.*	—
10.	EM-1240	*Suillus granultus*	*Pinus sylvetris*	—