

**SELECTION OF EFFICIENT VA MYCORRHIZAL
FUNGI FOR MANGO, ACID LIME AND PAPAYA**

BALAKRISHNA REDDY

Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the Degree of
MASTER OF SCIENCE
in
AGRICULTURAL MICROBIOLOGY

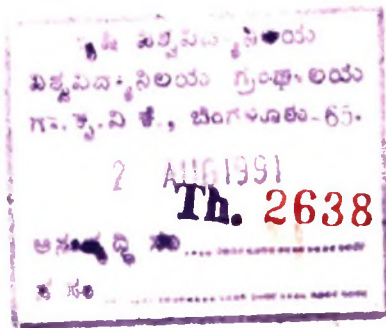
BANGALORE

MAY 3, 1991

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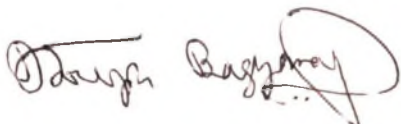
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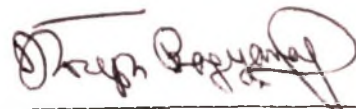
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"SELECTION OF EFFICIENT VA MYCORRHIZAL FUNGI FOR
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requirements for the degree of MASTER OF SCIENCE in
AGRICULTURAL MICROBIOLOGY to the University of
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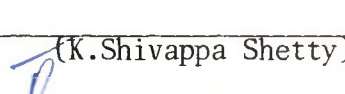
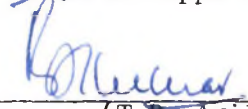

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ACKNOWLEDGMENT

I express my deepest gratitude to Dr. D.J. Bagyaraj, Professor, Department of Agricultural Microbiology, U.A.S. Bangalore, for giving me an opportunity to work under him and introducing me to the science of mycorrhizae. My heartfelt thanks for his excellent guidance, both for carrying out research and write up this dissertation.

I thank Dr. K. Shivappa Shetty, Professor of Agricultural Microbiology, Dr. T.B. Anilkumar, Associate Professor, Department of Plant Pathology and Dr. V. Nache Gowda, Assistant Professor, Department of Horticulture, for their valuable suggestions and guidance as members of my Advisory Committee.

My sincere thanks to Mr. Subbarayappa, Soil Chemist, M/s. Rallis India Ltd., for his help in Zn analysis.

I thank my parents and family members for their encouragement and blessings throughout my studies.

My thanks goes to my friends, fellow graduates and staff members of the Department of Agricultural Microbiology for their help rendered during my research work.

Last but not the least I acknowledge Mr. S.B. Jayadev for his neat typing of this thesis.

May , 1991


BALAKRISHNA REDDY

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INTRODUCTION

I. INTRODUCTION

Scientists in recent years have demonstrated the beneficial role of mycorrhizal fungi in the lives of many plants of horticultural interest. Vesicular-arbuscular mycorrhizal (VAM) fungi are a group of zygomycetous fungi, which are found in association with roots of most crop plants. It is conclusively proved that VAM fungi improve plant growth and productivity, mainly through phosphorus nutrition. In addition to phosphorus, they also help in the uptake of other nutrient elements such as K, Zn, Mg, Fe, Cu, etc. Mycorrhizal fungi appear to be extremely advantageous to crops grown in low fertility soils. They improve the water uptake and induce drought resistance in several grasses and field crops. They improve beneficial rhizospheric microbial activity and suppress plant pathogenic microbes. Nutrients absorption by fungal symbionts is due to the extramatricular hyphae of the fungus proliferating beyond the root nutrient depletion zone and reaching the source of nutrients.

Positive response to inoculation with VAM fungi are well established for a wide variety of field crops. Among the horticultural crops, studies carried out so far mainly dealt with the annuals grown in soils devoid

of indigenous VAM fungi. Information in perennial fruit crops is scanty. Most of these fruit plants are first grown in pots or polythene bags before grafting/budding and then planted in the main field. Of the perennial fruit crops grown in India mango occupies an area of 1.02 million hectares with an annual production of 8.85 million tonnes. Nekkare is the most popular polyembryonic mango root stock used in India. Among the fruit crops, citrus ranks second in terms of cultivated area, being cultivated over one lakh hectares. Citrus being a mycotrophic plant due to its magnoloid root system, lacking fine root hairs, does not survive without the mycorrhizal inoculation. Papaya is another heavy yielding fruit crop covering an area of about 7000 hectares in the country.

Nekkare mango and acid lime are slow growers. It was presumed that inoculation with efficient VAM fungi may hasten their growth rate. This will make them ready for grafting and or transplanting in a much shorter period. Further inoculation with VAM fungi at nursery would safeguard against moisture and nutrient stress when planted in the main field. Hence, the investigation was undertaken to screen and select efficient VAM fungi for inoculating

1. Mango var. Nekkare in order to increase growth rate and make them ready for grafting in a shorter period and
2. Papaya and acid lime in order to produce healthy vigorously growing seedlings.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Importance of VA mycorrhiza

Mycorrhiza, the fungal and plant associations are naturally found in several crop plants, horticultural plants and other perennial woody plants. It is very well documented that VAM fungi improve plant growth mainly through increased uptake of phosphorus from soil. There are indications that VAM fungi are also involved in the translocation of other elements including calcium, zinc, copper and sulphur. VAM also help the plant to resist water stress. They interact synergistically with beneficial soil microbes such as Azotobacter, Rhizobium, etc. and are antagonistic to soil-borne plant pathogens such as Phytophthora, Rhizoctonia, Sclerotium, Meloidogyne, Radopholus, etc.

Occurrence

VAM fungi are ubiquitous in nature. Fossil records suggest their presence in subterranean parts of earlier land plants (Butler, 1939). Geographically VAM occur in diverse ecological and agronomic habitats as they are believed to have occurred in 'Gondwana land' even before the continental drift 125 million years ago. Hence, their occurrence is obvious in association with plants grown in cultivated soils, sand dunes, coal mines and aquatic environments (Hayman, 1980).

Growth response

The effect of VAM fungi on plant growth was reported by several workers. Increase in plant height, shoot and root biomass in inoculated apple leaf-bud cuttings (Mosse, 1957), tobacco, tomato and maize (Daft and Nicolson, 1966) was reported. An increase in growth and yield of soybean grown in fumigated soils in field inoculated with Endogone species was reported by Rose and Harper (1970). Improved growth in potato (Graham *et al.*, 1976), maize, beans, grapevine and olive (Hayman *et al.*, 1976), were also reported. Menge *et al.* (1978a) reported that avocados inoculated with Glomus fasciculatum had up to 250 per cent greater growth than the non-mycorrhizal plants. Manjunath and Bagyaraj (1984) reported an improved growth in blackgram, chickpea and mungbean.

Uptake of phosphorus and other nutrients

Gray and Gerdemann (1969) reported high phosphorus uptake in mycorrhizal onion compared to non-mycorrhizal onion. Hayman and Mosse (1971) observed that mycorrhizal onion plants, grown in a range of soils labelled with ^{32}P had taken up more phosphorus and grew larger, but the proportion of ^{32}P to total P (specific activity) taken up by mycorrhizal plants after ten weeks

was not significantly different. They concluded that the mycorrhizal plant roots used the same source of labile P but explored a greater volume of soil beyond the depletion zone.

Mosse (1957) showed that mycorrhizal apples absorbed more P, K, Fe and Cu than non-mycorrhizal controls. Rose (1971) showed that mycorrhizal soybean grown in low, medium and high phosphates in soil had higher concentrations of leaf N, P, Cu and Ca. Increased P uptake by mycorrhizal plants has been reported in tomatoes (Sanni, 1975, Daft and Nicolson, 1969), onions (Hayman and Mosse, 1971), strawberries (Holevas, 1966), avocados (Menge *et al.*, 1978a), grapes (Possingham and Obbink, 1971) and other crops.

Gray and Gerdemann (1973) showed increased uptake of sulphur by mycorrhizal red clover and maize than non-mycorrhizal plants using ^{35}S . The uptake and transfer of ^{32}P , ^{65}Zn and ^{35}S by mycorrhizal white clover and onion was investigated by Cooper and Tinker (1978). They observed a lag phase of 23 days in the appearance of ^{32}P in the shoot was caused by the delay in the uptake and translocation of P by hyphae from soil rather than from fungus to host. They concluded that molar

amounts of P, S and Zn translocated were in ratio of 35:5:1. Lambert et al. (1979) studying the role of VAM in the interactions of phosphorus with K, Zn, Cu, Fe, Mn and Mg found that phosphorus fertilization significantly reduced Zn and Cu concentrations in mycorrhizal soybeans and not in nonmycorrhizal plants. Jackson (1970) observed increased concentrations of Strontium 90 by soybean infected with Endogone mosseae.

Water uptake

Safir et al. (1971) reported that Endogone mosseae decreased the resistance to water transport in Glycine max, which was attributed to increase in shoot biomass. They showed increased conductivity in mycorrhizal plants and related it to increased nutritional status. Hardie and Leyton (1981) found that mycorrhizal clover roots had higher hydraulic conductivities than non-mycorrhizal clover roots on a per unit root length basis. They also showed higher transpiration rates and lower diffusion resistances in mycorrhizal plants.

Interaction with soil microorganisms

Beneficial organisms : VAM synergistically interact with beneficial microbes like Rhizobium, Azotobacter. P-solubilisers, etc. Legumes in general are nodular

and mycorrhizal in nature. Inoculation with selected efficient strains of rhizobia and VAM fungi improved nodulation, N fixation, growth and P nutrition in some forage and grain legumes (Bagyaraj et al., 1979; Munns and Mossae, 1980; Redente and Reeves, 1981), pigeonpea and cowpea (Manjunath and Bagyaraj, 1984) and *Leucaena* (Nalini et al., 1986).

Bagyaraj and Menge (1978) observed larger populations of bacteria and actinomycetes in the rhizosphere of tomato plants inoculated with the mycorrhizal fungi G. fasciculatum and Azotobacter chroococum together. The fungus population remained unaffected in Glomus inoculated plants but reduced by inoculation with Azotobacter. Inoculation of tomato with G. fasciculatum increased the Azotobacter chroococum population in the rhizosphere at high level for longer time. On the other hand Azotobacter enhanced infection and spore produced by Glomus.

Mohandas (1987) reported that when G. fasciculatum and A. vinelandi were inoculated to tomato plants, leaf area, shoot dry weight, nitrogen content, phosphorus content and yield increased significantly compared to uninoculated control

Azcon (1989) observed that when tomato plants were inoculated with A. vinelandi, and enterobacterial strain and VAM in a sand vermiculite medium, they found that the bacterial inoculations increased the growth of mycorrhizal plants. Germination, hyphal growth and vegetative spore production of Glomus mosseae were increased in the presence of Azotobacter and enterobacteria.

Plant pathogens: VAM are known to reducing the activity of root pathogens like Fusarium in tomato (Dehne and Schoenbeck, 1979), Verticillium on cotton (Davis et al., 1979), Phytophthora in citrus (Davis and Menge, 1981), Phytophthora in avocado (Matore, 1978) Pythium ultimum and Rhizoctonia solani in Poinsettia (Stewart and Pflegar, 1977), Sclerotium rolfsii in groundnut (Krishna and Bagyaraj, 1985), etc. VAM reducing the root gall caused by nematodes Meloidogyne incognita and Meloidogyne javanica have also been reported (Suresh, and Bagyaraj 1984). Lee and Bagyaraj (1986) studied the interaction between VAM and a phosphate dissolving bacterium and also Thiobacillus reported a synergistic interaction between the phosphate solubilising bacterium and VAM with a consequential improvement in tomato growth, while the combined inoculation of VAM and Thiobacillus did not cause any significant increase in

the shoot dry matter of tomato. Umesh et al. (1988)) reported that the burrowing nematode Radopholus similis was suppressed when mycorrhiza was applied to banana plants.

Occurrence of mycorrhiza in citrus

Mycorrhizae are the normal condition of citrus trees, whereas the non-mycorrhizal condition is described abnormal and is a consequence of normal horticultural practices such as over-use of fertilizers, pesticides, soil sterilisation procedures and plant production in sterile soil less media (Graham, 1986). Presence of mycorrhiza in Citrus sinensis and Citrus aurantium grown in orchards of southern California was reported by Rayner (1933). The factors that influenced the formation and development of mycorrhizal associations in citrus roots was reported by Reed and Fremont (1935). Muller (1936) reported the changes in cytology, metabolism and their beneficial role in citrus and also stated that infections by endophytes may be detrimental to normal root metabolism. However, Neill (1944) who observed natural occurrence of endomycorrhizae in varieties of citrus in New Zealand argued that VAM were neither harmful nor beneficial to citrus.

Growth response of citrus to mycorrhizal fungi

Mycorrhizal fungi improve the growth of citrus in fumigated, steamed or autoclaved soils. Soil fumigation and soil sterilisation in nurseries is a common practice in citriculture. This leads to stunting or death of citrus plants. Kleinschmidt and Gerdemann (1972) found that stunted and chlorotic seedlings in fumigated nurseries were non-mycorrhizal and normal seedlings found scattered were mycorrhizal. They showed that stunted seedlings grew well after inoculation with Endogone mosseae. They also reported that mycorrhizal plants accumulated greater dry matter and higher phosphorus content.

Survey by Timmer and Leyden (1973) of Texas citrus, showed the presence of VAM in field grown nurseries and established orchards, but its absence in stunted seedlings and nursery stock grown in sterile potting media and fumigated soils. They also showed that addition of P to soil previously fumigated with sodium N-methyl dithiocarbamate stimulated the growth of sour orange seedlings and compensated for temporary absence of mycorrhiza. Addition of P in fumigated seed bed soil at 24 to 70g per m² increased growth of sour orange seedlings over controls receiving no P. However,

application of 196g per m² of P to fumigated soil significantly reduced the per cent mycorrhizal roots and uptake of copper. Milne (1974, 1979) reported the failure of citrus to grow in nursery soils treated with methyl bromide due to absence of mycorrhiza which affected the nutrient uptake of phosphorus.

Schenck and Tucker (1974) reported that addition of E. calospora to fumigated soil significantly increased shoot and root growth of citrus seedlings in the green house but not in the field. The addition of E. macrocarpa significantly increased growth of seedlings in non-fumigated and in methyl bromide and dichloropropene fumigated field soil. However, this beneficial effect was not seen in soils aerated by disking after fumigation. Partial substitution of mycorrhizal fungi for phosphorus fertilization in green house culture of citrus was studied by Menge et al. (1978b). They reported that mycorrhizal sour orange seedlings which received zero fertilizer P were similar to nonmycorrhizal sour orange fertilized with 258 ppm P. Mycorrhizal citrange seedling which received zero fertilizer P were similar in size to non-mycorrhizal citrange fertilised with 56 ppm.

Mohoney and Nemec (1978) outlined the role of mycorrhizae in plant nutrition, including improved root system and enhanced water and P uptake in citrus seedlings inoculated with Glomus etunicatus. Seedlings inoculated in the green house and transplanted to the field grew 1.9 times taller than the non-inoculated plants in methyl bromide treated sites.

Inserra et al. (1980) identified several species of Glomus in Italian sour orange nurseries and reported mycorrhizal absence in several samples due to the common use of fumigant nematicides. McGraw and Schenck (1980) reported that mycorrhizal plants inducing citrus, tomato, peach and chrysanthemum showed increase in the total shoot height and dry weight.

Weir et al. (1980) showed that growth of Citrus jumberi in unheated soil was greater than in heated soil at low P rates. They also reported that growth in the unheated soil was positively correlated with the percentage VAM colonisation (76.0%), while colonisation was absent in roots from heated soil.

Shanmugam et al. (1981) reported that six month old acid lime seedlings inoculated with Glomus mosseae or Glomus etunicatus significantly increased shoot length, shoot

Vinayak and Bagyaraj (1990a,b) reported that the plant height, number of leaves, stem girth, shoot and root biomass and spore numbers in the root zone of troyer citrange and trifoliate orange inoculated with different mycorrhizal fungi were more compared to uninoculated controls.

According to Gerdemann (1975) mycorrhizal dependency (MD) is the ratio of dry weight of a mycorrhizal plant to dry weight of non-mycorrhizal plant of the same species expressed as percentage. MD is affected by plant species, soil type, etc. Baylis (1975) hypothesised that plants with magnoloid roots are more dependent upon mycorrhizae for phosphorus uptake than plants with graminoid roots. The mycorrhizal dependency of plants reflect the degree to which a plant relies upon mycorrhizal condition to produce maximum growth or yield at a given level of soil fertility (Gerdemann, 1975).

Anatomical studies also suggested high mycorrhizal dependency in citrus. Earlier, citrus was believed to be devoid of root hairs. Cossman (1939) reported the presence of short (30-50 μ m) root hairs. The final direct evidence of citrus mycorrhizal dependency was shown in high fumigated soils, when the stunted plants were treated by G. fasciculatum by Hattingh and Gerdemann (1975).

Mehraveran (1977) studied soil and plant factors involved in mycorrhizal dependency of various citrus cultivars. He reported that dependency of cultivars is inversely related to efficiency of cultivars in phosphate uptake and translocation to the leaves. Cultivars with lower degree of dependency on mycorrhiza produced more roots and generally had higher root/shoot or root/leaf ratios of had thinner roots.

Ojala et al. (1983) predicted MD of citrus using different P extraction techniques in response to the mycorrhizal fungus G. fasciculatum by regression models. Of the five methods, saturation extract -P (PSE), an ion exchange resin P and 1:10 soil to water extract were acceptable for predicting mycorrhizal response. Bicarbonate extractable P (PBIC) and ammonium fluoride P (PAF) were less acceptable.

Menge et al. (1978c) observed that citrus root stock exhibited the greatest mycorrhizal dependency at medium fertilizer regime. Mycorrhizal dependency is also affected by soil type (Baylis, 1967). Manjunath et al. (1983) studied the response of citrus to inoculation with the endomycorrhizal fungus G. fasciculatum in four soil types - sandy, acidic sandy loam, black clayey and laterite soils. They also proved that mycorrhizal inoculation is beneficial to citrus even in unsterile soils inspite of the presence of native endophytes.

Growth response of papaya to mycorrhizal fungi

Ramirez et al. (1975) reported that 15 day-old seedlings of papaya cv. Solo inoculated with Gigaspora calospora, Gigaspora heterogana, Glomus macrocarpum were significantly taller 40 days after inoculation compared to uninoculated controls.

Mohandas (1987) reported that the papaya cv. Coorg honeydew seedlings inoculated with Glomus mosseae increased the plant height by 50 per cent, leaf and root dry weight by 20 per cent compared to uninoculated plants. She also reported that the P content in the leaves of inoculated plants was increased by 20 per cent and 22 per cent respectively by the two fungi. The uptake of N, K, Ca, Zn and Mg was also more in inoculated plants compared to uninoculated plants.

Growth response of other fruit trees to mycorrhizal fungi

The growth of fruit trees in rooting media or soils lacking VAM fungi can often be improved by VAM inoculation. However, the potential for inoculation in non-disinfected soils depends on the infectivity and effectiveness of indigenous VAM population (Gianinaazzi *et al.*, 1987). Otto (1970) studied the influence of VAM on per cent infection of apple clones. He found that infection was 89 per cent in the first year and 97 per cent in the second year. Possingham and Obbink (1971) showed the presence of VAM in the root of grapevines collected from number of localities throughout Australia. They also showed that the shoots of seedlings grown in non-sterile soil or sterile soil inoculated with mycorrhiza had a significantly higher P content than non-infected seedlings.

Gilmore (1971) found that a zinc deficiency could be corrected by inoculating peach plants growing in sterilised Zn deficient medium with an endomycorrhizal fungus. However, the effectiveness in correcting Zn deficiency varied among the fungal species used. Inoculation of apple seedlings with the VAM fungus, Glomus mosseae or Glomus fasciculatum increased shoot weight and Zn concentration (Benson and Covery, 1976).

Rooted cuttings of grapevine cv. Aris inoculated with endotrophic mycorrhiza promoted shoot growth and stimulated phosphate uptake (Gebbing et al., 1977).

Lambert et al. (1979) studied the stunting of peach seedlings in soil fumigated with methyl bromide at 275 kg/ha indicating that poor growth was associated with a major deficiency of P. They also stated that the mycorrhizal root colonization was very poor and viable inoculum was very less in fumigated soil. These results indicated that elimination of mycorrhizal fungi is the primary factor in fumigation induced stunting of peach.

Menge et al. (1978a) showed that avocado seedlings inoculated with Glomus fasciculatum increased plant growth and reduced transplant injury. They found 80 per cent transplant injury with more wilting symptoms in case of non-mycorrhizal plants whereas the transplant injury was only 20 per cent in mycorrhizal plants.

Plenchette et al. (1981) reported that apple seedlings germinated and grown under greenhouse conditions, inoculated with VAM fungi increased the root shoot length, leaf surface, root volume, stem diameter and dry mass. They also reported that the levels of N, P, Cu and possibly K were higher in the roots of inoculated plants compared to uninoculated plants.

Dharmaraj and Irulappam (1982) studied the response of avocado seedlings to Glomus fasciculatum. They found that mycorrhizal inoculum at 2.5 g per plant placed 2.5 or 5.0 cm below the soil level showed the greatest seedling height, number of leaves per seedling and leaf area.

Koch et al. (1982) studied the response of apple seedlings in fumigated soil to phosphorus and VAM. They found that incorporation of P into fumigated soil at planting increased the height, dry weight and P level in apple seedlings. Non-mycorrhizal plants exhibited a 25 fold growth response to P and obtained maximum size at 200 mg additional P/kg soil, whereas plants inoculated with Glomus mosseae showed a smaller growth response to P but had greater maximum height (78.0 cm) than non-mycorrhizal plants (67.9 cm).

Graner et al. (1983) studied the response of Glomus epigeus on the growth and mineral content of two apple clones propagated in vitro. They found that 15 weeks after inoculation mycorrhizal plants were 1.7 times greater than that of control plants, while the total area and leaf dry weight of mycorrhizal plants were both 1.9 times greater. They also found that the inoculated roots of clones were heavily colonised by the fungus and the fungus significantly increased P and copper in both rootstocks.

Geddeda et al. (1983) studied the VAM associated with apples grown in Oregon. They found that Gigaspora margarita, Glomus fasciculatum and Glomus mosseae are the most competitive species in colonising apple roots.

Nappi et al. (1985) studied the distribution of grape vine roots and mycorrhizal fungi in six vine yards in Piedmont, Italy. They found that mycorrhizal spore numbers were positively related to the weight of thin roots and also declined with the profile depth. The percentage mycorrhizal colonization was high and did not decrease in deeper soil layers. They also reported that the spores were most abundant in soil where the vine yard was covered with a grass or bark mulch, while the greatest mycorrhizal colonization occurred in soils with the lowest contents of nutrients and organic matter.

Schmidt and Scow (1986) found that VAM spore numbers and levels of infection were more in the moist regions of Galapagos Island. In the moist zones plants such as Cinchona succirubra and Psidium guajava had higher levels of VAM colonization.

Lin and Chang (1987) studied the effect of Glomus mosseae, Glomus fasciculatum and Glomus etunicatum on the growth of micro-propagated banana. They found that

inoculated plants showed an increase in plant height, total dry weight and pseudostem diameter compared to non-inoculated plants.

Selection of effective strains of VAM for fruit trees

Nemec (1977) showed that combined growth of citrus root stocks increased 21, 8 and 6 fold by G. etunicatus, G. mosseae and G. fasciculatum respectively at 12-0-6 NPK fertilization, while the increase was 1.8 fold at 12-6-6 dosage. This clearly indicated that citrus root stocks differed in their response to different mycorrhizal fungi.

Growth stimulation of sour orange by selected mycorrhizal fungi was studied by McGraw and Schenck (1980). They found increased plant height up to 100 per cent by Glomus mosseae and 50 per cent by G. epigeus and G. etunicatus hinting host preference by the fungal isolates.

Carbohydrate status and cytokinin levels of mycorrhizal citrus

Nemec and Guy (1982) analysed the carbohydrate status of citrus root stocks. They reported that the leaves of VAM inoculated seedlings contained greater amounts of total soluble sugars, sucrose, reducing sugars like glucose and fructose, starch and total non-structural carbohydrates per g of tissue than the

uninoculated controls in low P soil (9-12 ppm). Increased photosynthesis in Citrus aurantium was shown in mycorrhizal plants by Johnson (1984).

Edriss et al. (1984) reported greater cytokinin levels in mycorrhizal sour orange leaves compared to non-
 mycorrhizal controls of similar dry weights and P concentrations in roots and leaves of axenically grown citrus limon. This was attributed to the fungal cytokinin production and its translocation into the plant. Increase in cytokinins such as zeatin, zeatinriboside and dihydrozeatin levels in VAM seedlings were correlated with significant increase in total dry weight and improved P nutrition.

Effect of VAM on water uptake in citrus

Carrizo citrange and sour orange seedlings grown in a low phosphorus sandy soil inoculated with G. intraradices had more than twice root hydraulic conductivity per unit root length than non-mycorrhizal seedlings under well watered conditions. Mycorrhizal plants also had significantly higher transpiration rates (Syversten and Graham, 1985). Graham et al. (1987) reported that under well watered conditions carrizo citrange and sour orange plants inoculated with G. intraradices had similar whole plant transpiration, leaf

water status and root hydraulic conductivity compared to non-mycorrhizal plants. However, their data do not support the hypothesis that mycorrhiza significantly enhance water relations of citrus under drought conditions.

Role of VAM in biocontrol

Davis and Menge (1981) observed increased tolerance to Phytophthora parasitica of sweet orange inoculated with Glomus fasciculatum which they attributed to the indirect effect of mycorrhiza on host P nutrition. Radopholus spp. infection was reduced in banana inoculated with mycorrhiza (Umesh et al., 1988).

Geddeda et al. (1984) studied the response of apple to three VAM fungi Glomus fasciculatus, Glomus mosseae and Gigaspora margarita. They showed that Glomus fasciculatus was the most effective in promoting growth of apple seedlings and Gigaspora margarita the least.

Schubert et al. (1987) studied the response of grape vine to 5 VAM fungi G. caledonicum, G. velum, G. constrictum, G. acultum and G. versiforme with P at 0, 20 or 40 ppm. They showed that at 20 ppm P, G. acultum was the most effective endophyte in promoting growth.

Mohandas (1987) studied the response of papaya to VAM fungi G. fasciculatum and G. mosseae. She showed that G. mosseae was more beneficial than G. fasciculatum in improving seedling growth and nutrient uptake.

Reich (1988) studied the response of apple to four VAM fungi G. macrocarpum, G. intraradices, G. mosseae and G. fasciculatum. He showed that G. intraradices and G. mosseae caused most rapid and highest level of root infection, dry weight and P uptake compared to plants inoculated with other fungi.

Introduction and method of application of VAM inoculum to fruit trees

Menge et al. (1978d) proposed a scheme of commercial production of VAM using Sudangrass as host after screening the efficient mycorrhizal strain. He also gave the method of mycorrhizal application to the seedlings grown in nursery trays and then transplanting the seedlings to the main field.

Nemec and Ferguson (1985) devised an apparatus a fluid drilling applicator to apply mycorrhizal inocula along with seed in a slurry to rows in a field plot. They used the fungus G. deserticola in citrus seedlings which exhibited a good response to

this method of inoculum application. Recently Sreenivas and Bagyaraj (1988a), after screening several grasses, found Rhodes grass to be the best for mass production of G. fasciculatum. They also found that maximum number of infective propagules was produced when soilrite:perlite (1:1) mix was used as the substrate.

MATERIAL AND METHODS

III. MATERIALS AND METHODS

The present study was taken up to screen and select efficient VAM fungi for three important tropical and subtropical fruit crops viz., mango (Mangifera indica var. Nekkare), acid lime (Citrus aurantifolia) and papaya Carica papaya var. Solo. Screening and selection of the efficient VAM fungi was done in pot culture in a glass house.

The seeds of above fruit crops were procured from the Department of Horticulture, GKVK, Bangalore. Fully matured mango fruits of Nekkare variety were harvested from mango orchard and allowed to ripe. Stones were separated from the fully ripened fruits and sown in raised sand (Sterilised) beds of 120 x 90 x 30 cm. The seeds of papaya and acid lime were extracted from matured fruits and washed till they were free from pulp and mucilage. The moisture was removed with blotting paper, dried in shade and sown in autoclaved sand in battery boxes.

Substrate and transplanting

Pure sand autoclaved at 121°C for 15 minutes at 1.1 kg cm² was used as the substrate in the nursery. The seeds of mango and citrus germinated in about 25 to 30 days, whereas seeds of papaya took about 10 to 15 days. Fifty day-old uniform, healthy, disease and pest free seedlings were transplanted to 8 inch pots of 4 kg capacity filled with laterite

alfisol soil:sand mix (1:1) amended with two per cent organic matter. Physical and chemical characteristics of the soil used in the study are shown in table 1. The soil had natural VAM population of 35 spores per 50ml and an inoculum potential of 0.03 per g of soil.

Table 1: Physical and chemical properties of the soil in pot culture

Sl. No.	Characteristics	Magnitude	Method of determination
1	a. Texture	Sandy loam	
	b. Mechanical analysis		
	i) Coarse sand	24.33 %	Bouyocos hydrometer (Piper, 1966)
	ii) Fine sand	48.25 %	
	iii) Silt	4.40 %	
	iv) Clay	22.76 %	
2	Physico-chemical analysis		
	a. EC at 25°C	0.20 mmhos/cm	Conductivity meter (Jackson, 1973)
	b. pH	4.8	Beckman pH meter (Piper, 1966)
	c. CEC	4.2 mEq/100g	Microkjeldal distillation method (Jackson, 1973)
	d. Organic matter	0.41 %	Walkely and Black method (Jackson, 1973)
	e. Organic carbon	0.20 %	(Jackson, 1973)
	f. Available N	0.14 %	Alkaline permanganate method. (Subbaiah and Asiga, 1956; Jackson, 1973)
	g. Available P	0.00088 %	Bray's method (Jackson, 1973)
	h. Available K	0.0024 %	Flame photometer method (Jackson, 1973)

VA mycorrhizal fungi: pot cultures of different VAM species were maintained in sterilised sand:soil (1:1 by volume) mixture on guinea grass (Panicum maximum Jacq.) in the glass house of the Department of Agricultural Microbiology, GKVK, University of Agricultural Sciences, Bangalore.

The following mycorrhizal fungi were used in the experiment:

Fungus	Source
1 <u>Acaulospora laevis</u>	Invermay Research Station, New Zealand
2 <u>Gigaspora margarita</u>	ICRISAT, INDIA
3 <u>Gigaspora margarita</u>	Ruakura Research Station, New Zealand
4 <u>Glomus caledonicum</u>	University of Western Australia, Nedlands
5 <u>Glomus fasciculatum</u>	University of California, Riverside, USA
6 <u>Glomus leptotichum</u>	University of Agricultural Sciences, Bangalore
7 <u>Glomus macrocarpum</u>	University of Agricultural Sciences, Bangalore
8 <u>Glomus merredum</u>	University of Western Australia, Nedlands
9 <u>Glomus monosporum</u>	University of Western Australia, Nedlands
10 <u>Glomus mosseae</u>	ICRISAT, INDIA
11 <u>Glomus mosseae</u>	University of Agricultural Sciences, Bangalore
12 <u>Glomus velum</u>	University of Western Australia, Nedlands
13 <u>Glomus versiforme</u>	University of Agricultural Sciences, Bangalore

Inoculum potential of VAM cultures

Diamond and Horsfall (1960) defined inoculum potential (IP) as the potential of specific amount of inoculum to cause root infection under standard set of conditions i.e., the infectivity of inoculum. Inoculum potential contains hyphae, chlamydospores and root bits

with vesicles and arbuscles. The inoculum potential varies with the mycorrhizal species. Hence, in plant response studies, comparing several mycorrhizal fungi, it is essential to add inocula with the same number of infective propagules. The inoculum potential of the cultures was determined earlier by the most probable number (MPN) method outlined by Porter (1979). The methodology used for determining MPN is described later in this chapter. In the present study 12,500 infective propagules were given to each planting hole before transplantation. The inoculum potential of different fungi is given below.

	Fungi	Inoculum potential	Amount of inoculum used
		I.P $\times 10^4/g$	to give 12,500 IP per planting hole (g)
1	<u>Acaulospora laevis</u>	0.20	12.50
2	<u>Gigaspora margarita</u> (I)	0.093	26.88
3	<u>Gigaspora margarita</u> (R)	0.120	20.83
4	<u>Glomus caledonium</u>	1.800	1.085
5	<u>Glomus fasciculatum</u>	0.08	31.25
6	<u>Glomus leptotichum</u>	0.093	26.88
7	<u>Glomus macrocarpum</u>	0.14	17.85
8	<u>Glomus merredum</u>	0.13	19.23
9	<u>Glomus monosporum</u>	0.95	6.785
10	<u>Glomus mosseae</u> (I)	1.70	1.40
11	<u>Glomus mosseae</u> (L)	0.27	9.25
12	<u>Glomus velum</u>	0.07	35.71
13	<u>Glomus versiforme</u>	1.70	1.40
I	ICRISAT, INDIA		
R	Ruakura Research Station, New Zealand		
L	Local i.e., University of Agricultural Sciences, Bangalore, India.		

Maintenance of experimental plants

The experiment was carried out in the glasshouse of the Department of Agricultural Microbiology, GKVK, University of Agricultural Sciences, Bangalore with 13 treatments and five replications in acid lime and papaya. For mango inoculation was done with only 9 mycorrhizal fungi [fungi listed above except Gigaspora margarita (ICRISAT), Glomus merredum, Glomus mosseae (ICRISAT) and Glomus velum] thus there were 10 treatments including uninoculated control with five replications. Plants were kept in a glasshouse, with a temperature range of 29° to 32°C, in a random fashion. The position of pots were changed once in a month. The plants were watered whenever necessary.

Plant nutrition: Fifty ml of Ruakura plant nutrient solution without phosphorus was given to each pot (Appendix 1 for composition) once in 45 days.

Observations on plant growth parameters

The following plant growth parameters were recorded once in 45 days, for all the three plant species, from the 50th day after sowing or transplanting until harvest.

Plant height: Height of the main shoot was measured from the soil level to the base of the top most fully opened leaf.

Number of leaves: The number of fully opened green leaves were counted per plant.

Stem girth: The stem girth of mango was measured 1 cm and 10 cm above the soil level and 10 cm below from the base of top most fully opened leaf. The stem girth of acid lime and papaya was measured 1 cm above the soil surface. For all the three plants measurements were taken using Vernier callipers.

Leaf area: Fresh green leaves were removed before harvest and their area measured using leaf area meter.

The following post-harvest observations were also recorded.

Plant biomass: The plants were harvested and the samples were dried in an oven at 60°C to a constant weight and the biomass of shoot and root were recorded. Mango and acid lime were harvested 225 days after sowing or transplanting respectively and papaya was harvested 90 days after transplanting.

Estimation of mycorrhizal spores

Extramatricular chlamydospores produced by the mycorrhizal fungus in soil was estimated by wet sieving and decantation method (Gerdemann and Nicolson, 1963).

Thirty ml of representative soil samples drawn from pots after harvest was suspended in sufficient quantity of water and stirred thoroughly. The suspension was passed through sieves of 1mm, 450, 250, 105 and 45 μ m kept one below the other in the same order. the spores on the bottom two sieves were transferred on to a nylon mesh with a pore size of 45 μ m. The nylon mesh with spores on it was placed in a petriplate and the spores were counted under a stereomicroscope.

Percentage VAM root colonisation

The percentage mycorrhizal colonisation of the plant roots was determined according to Phillips and Hayman (1970). Root samples were cut into one cm pieces, fixed in FAA (Formalin:Acetic acid:Alcohol 5:5:90) for two hours. Roots were then cleared by autoclaving with 10 per cent KOH at 1.1 kg. cm² pressure for 15 minutes. The alkalinity due to KOH was neutralised by one per cent HCl for five minutes. Staining was done by simmering the roots in 0.5 per cent trypan blue in lactoglycerol (Lactic acid 400 ml:glycerol 500 ml and distilled water 100ml) for 10 minutes. Excess stain was removed and roots were kept in lactoglycerol. The stained root bits were arranged on slides, covered with coverslips and observed under a microscope for VAM mycelium, vesicles

and arbuscules. The percentage mycorrhizal colonization was calculated as follows.

$$\text{Per cent mycorrhizal colonisation} = \frac{\text{Number of root bits positive for colonisation}}{\text{Number of root bits observed}} \times 100$$

Modifications followed for staining root segments of mango

Mango roots were more pigmented and hard and hence, difficult to clear and stain. Certain extra steps were necessary to clear and stain these roots. The treatment with KOH was done for 30 minutes and repeated twice later with fresh KOH solution. The root bits were then treated with sodium hypochlorite (3%) for one hour followed by treatment with ammonical hydrogen peroxide (H_2O_2 : H_2O : NH_3 :: 50:50:3) for one hour and later HCl. Simmering with trypan blue was done for 10 minutes instead of normal five minutes.

Most probable number of infective propagules

The number of infective propagules of mycorrhiza was determined, using the most probable number (MPN) method adapted from Porter (1979). All the replicate soils from each treatment were pooled and 30 g of each treatment air dried, soil diluted up to 10^{-7} using 270g sterilised sand:soil (1:1 by volume) per dilution. The

diluent culture from 10^{-3} to 10^7 were filled to plant tubes (15 x 2.5 cm) at the rate of 50g per tube for each dilution. Onion seeds (Chikkaballapura Red variety) were sown in the plant tube at the rate of five seeds per tube. Onion seedlings were grown for six weeks in a glass house. Roots were washed and stained with trypan blue in lactoglycerol (Phillips and Hayman, 1970). The presence or absence of VAM colonisation was examined microscopically in all the replications in each dilution and scored. The most probable number of VAM propagules was then calculated, using three appropriate dilutions and referring to MPN table (Alexander, 1965).

Phosphorus content of the plant

Plant established by vanadomolybdate phosphoric yellow colour method (Jackson, 1967). The dried shoot and root samples of each treatments were powdered in a grinder. The powdered material (500 mg) was digested using 10 ml of triacid mixture (nitric acid:perchloric acid:sulphuric acid 10:4:1) in 100 ml conical flasks. The flasks were kept on hot plate till no more white fumes were produced. The flasks were then cooled and a few ml of distilled water was added. The volume was made up to 100 ml in volumetric flasks. Ten ml of the solution was taken in 50ml volumetric flasks and 10 ml

of vanadomolybdic acid (Appendix 2) was added to this solution and volume made up to 50 ml with distilled water. The yellow colour developed was read calorimetrically at 420nm in a Spectronic 20 colorimeter. P content was estimated by comparing the absorbance with a standard curve.

Estimation of zinc: Suitable aliquot from digested, diluted residue were taken and read in Sp. 9 Atomic absorption spectrophotometer with zinc^c hollow cathode lamp set to a wave length of 3138 Å. The quantity of Zn in the sample was estimated after comparing with the standard and expressed as μg per plant sample. Standard curve was prepared by feeding known strengths of analar grade ZnSO_4 (0.5, 1.0, 1.5 and 2.0 μg /ml).

Statistical analysis was carried out for each plant growth and mycorrhizal parameters using one-way analysis of variance. The fungi were ranked for each character and compared pairwise using Student Newman-Keul's test at the five per cent significance level (Zar, 1974).

RESULTS

IV. RESULTS

The present study was carried out to screen and select efficient VAM fungi for inoculating mango root stock (Mangifera indica var. Nekkare), acid lime (Citrus aurantifolia) and papaya (Carica papaya var. Solo). Thirteen different VAM fungi were used for screening. The experiment was conducted as pot cultures in a glasshouse. The results are given in this chapter.

Selection of efficient VAM fungi for Nekkere mango

Effect of different VAM fungi on plant height: The differences in plant height due to inoculation with different VAM fungi was significant on 90th, 135th and 225th days after transplanting. Table 2 shows the increase in plant height due to mycorrhizal treatments were on par with each other. The top three fungi which attained maximum plant height were G. monosporum, G. versiforme and Gi. margarita (Ruakura).

On 225th day the height of plants inoculated with G. monosporum, G. versiforme, Gi. margarita (Ruakura), G. fasciculatum, G. macrocarpum and G. mosseae (local) were best and statistically on par with each other.

Effect of different VAM fungi on leaf number: Inoculated plants though had markedly more number of leaves when compared to uninoculated plants on days 45, 90 and 135,

Table 2: Effect of different VAM fungi on height of nekkare mango (cm)

Sl. No.	VAM fungi	Days after transplanting				
		45d	90d	135d	180d	225d
1.	Control	22.02	27.55	28.85	36.00	22.25
2.	<u>A. laevis</u>	23.87	32.32	34.15	37.62	43.75
3.	<u>Gi. margarita</u> (Ruakura)	25.65	38.22	43.70	47.12	60.15
4.	<u>G. caledonicum</u>	28.02	33.92	29.85	44.35	50.87
5.	<u>G. fasciculatum</u>	23.75	34.97	38.20	46.12	55.87
6.	<u>G. leptotichum</u>	21.47	28.38	29.02	38.50	49.25
7.	<u>G. macrocarpum</u>	28.25	37.27	39.37	45.00	55.75
8.	<u>G. monosporum</u>	30.62	43.65	48.90	49.75	75.62
9.	<u>G. mosseae</u> (local)	27.00	35.52	38.10	63.55	55.00
10.	<u>G. versiforme</u>	26.25	43.65	44.77	53.25	62.75
	F-test	NS	**	**	NS	**
	CV	16.99	18.88	19.26	17.47	17.80
	SEm ±	2.18	3.344	3.7082	3.85	4.8451
Summary of comparison based on Student Newman-Keul's test at 5% significance level		90 days	1 6 2 4 5 9 7 3 8 10			
		135 days	1 6 2 9 5 7 4 3 10 8			
		225 days	1 2 6 4 9 7 5 3 10 8			

Table 3: Effect of different VAM fungi on number of leaves of nekkare mango

Sl. No.	VAM fungi	Days after transplanting				
		45d	90d	135d	180d	225d
1.	Control	6.75	8.75	12.50	13.25	14.00
2.	<u>A. laevis</u>	8.11	11.00	13.75	16.25	19.75
3.	<u>Gi. margarita</u> (Ruakura))	8.75	12.75	14.50	20.75	23.50
4.	<u>G. caledonicum</u>	9.00	12.25	13.25	16.25	20.25
5.	<u>G. fasciculatum</u>	8.00	12.75	16.25	19.50	22.25
6.	<u>G. leptotichum</u>	6.75	8.25	9.50	15.00	21.25
7.	<u>G. macrocarpum</u>	9.00	13.25	13.25	15.25	22.75
8.	<u>G. monosporum</u>	8.25	12.25	13.50	18.75	22.00
9.	<u>G. mosseae</u> (local)	9.25	13.25	14.00	15.50	24.00
10.	<u>G. versiforme</u>	6.25	11.75	13.00	23.75	26.25
	F-test	NS	NS	NS	**	**
	CV	0.8229	1.47	1.4804	1.96	1.79
	SEm ±	19.88	25.34	22.51	22.55	16.63
Summary of comparison based on Student newman- Keul's test at 5% significance level		180 days	1	6 7 9 2 4 8 5 3 10		
		225 days	1	2 4 6 8 5 7 3 9 10		

the differences were not statistically significant. On 180th day and 225th day all the inoculated plants were statistically on par with each other. The top three fungi which attained maximum number of leaves were G. versiforme, G. mosseae (local) and Gi. margarita (Ruakura).

Effect of different VAM fungi on stem girth: The difference in stem girth due to the inoculation with different VAM fungi were not significant on 135th and 180th days after transplanting, although it was higher in most of the mycorrhizal treated plants. Control plants had the least stem girth. Table 4, Fig.. 1 and 2 shows the increase in stem girth (1 cm above ground, 10 cm above ground and 10 cm below the tip) due to mycorrhizal inoculations. On the last day of observation i.e., 225th day after transplanting, girth of mango plants from 1 cm above ground was 1.5 cm with G. versiforme inoculation, 1.09 cm with G. monosporum and 1.05 cm with G. macrocarpum and Gi. macrocarpum and Gi. margarita (Ruakura) treatments. Uninoculated plants had stem girth of 0.88 cm.

At 10 cm above ground, girth of mango plants treated with Gi. margarita (Ruakura) was 1.01 cm. With G. macrocarpum it was 0.94 cm, G. leptotichum 0.88 cm,

Table 4: Effect of differnt VAM fungi on stem girth of nekkare mango (cm)

Sl. No.	VAM gungi	Days after transplanting					
		1 cm above ground			10 cm above ground		10 cm below the tip
		135d	180d	225d	180d	225d	225d
1.	Control	0.80	0.81	0.88	0.60	0.62	0.40
2.	<u>A. laevis</u>	0.95	0.97	1.05	0.75	0.87	0.55
3.	<u>Gi. margarita</u> (Ruakura)	0.85	0.94	1.03	0.76	1.01	0.63
4.	<u>G. caledonicum</u>	0.93	0.95	0.99	0.80	0.85	0.52
5.	<u>G. fasciculatum</u>	0.90	0.95	0.96	0.68	0.86	0.63
6.	<u>G. leptotichum</u>	0.89	0.91	0.97	0.60	0.88	0.54
7.	<u>G. macrocarpum</u>	0.83	0.95	1.05	0.77	0.94	0.56
8.	<u>G. monosporum</u>	0.91	1.02	1.09	0.80	0.80	0.54
9.	<u>G. mosseae</u> (local)	0.94	0.96	1.03	0.67	0.87	0.66
10.	<u>G. versiforme</u>	1.03	1.09	1.15	0.79	0.72	0.52
	F - test	NS	NS	NS	NS	**	**
	CV	0.0481	0.0541	0.0707	0.0673	0.0366	0.0178
	SEm ±	10.64	11.42	13.79	18.63	8.69	6.42
Summary of comparison based on 10 cm above ground		1 10 8 4 5 2 9 6 7 3					
Student Newman-Kaul's test at (at 225 days)							
5% significance level		1 4 10 6 8 2 7 3 5 9					
		10 cm below the tip (at 225 days)					

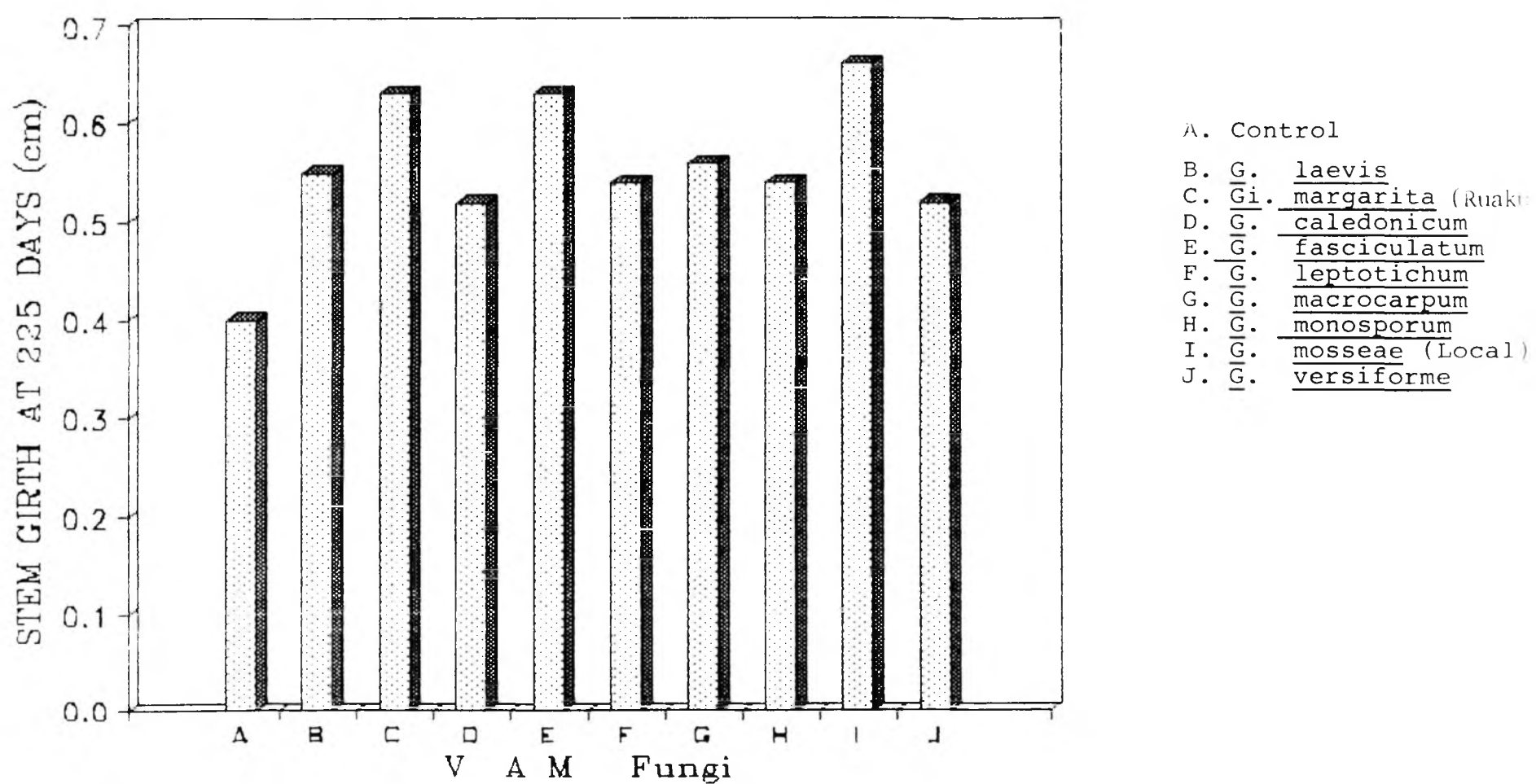


Fig. 2. Effect of different VAM fungi on stem girth of Nekkare mango, 10 cm below tip.

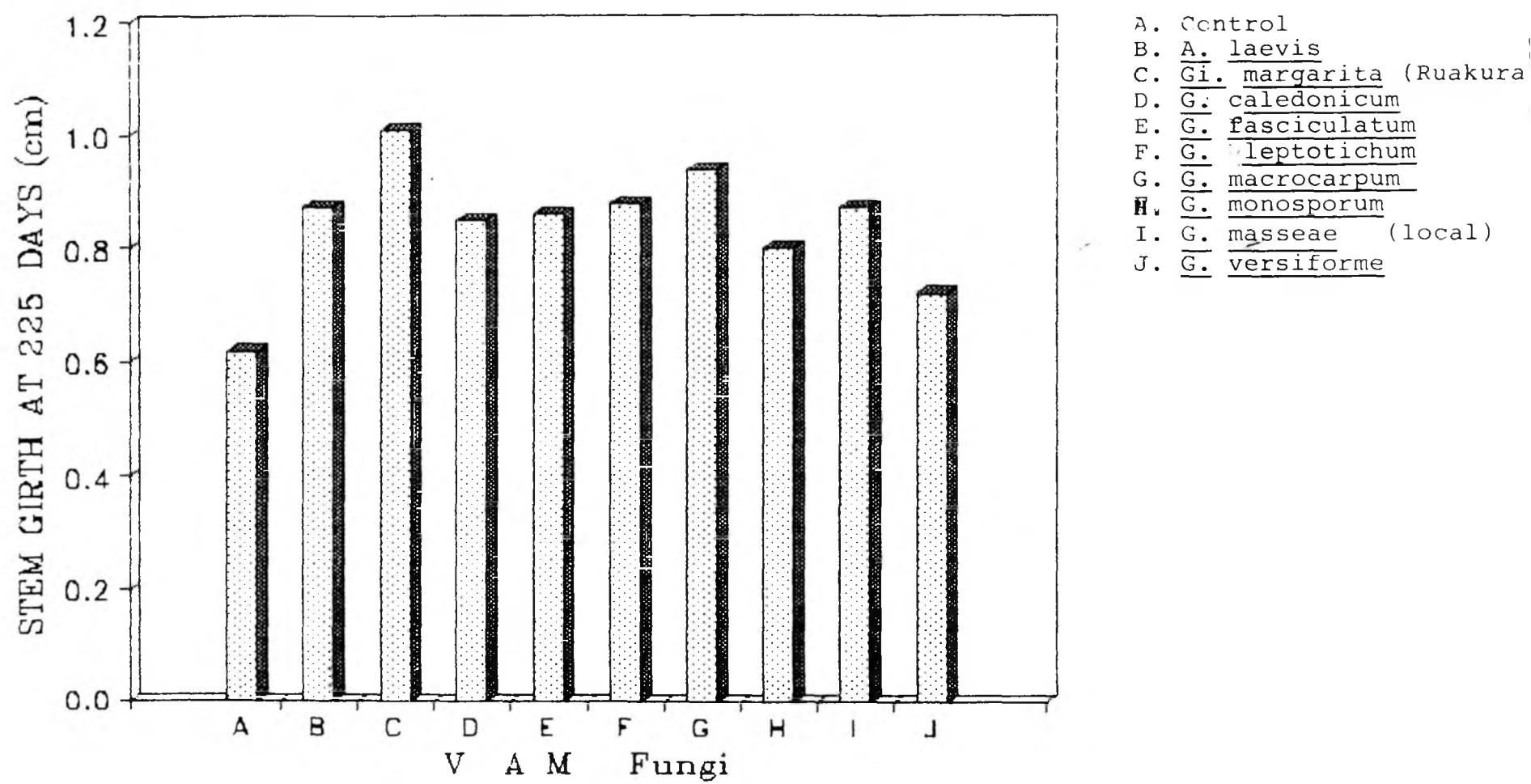


Fig. 1. Effect of different VAM fungi on stem girth of Nekkare mango, 10 cm above ground.

Plate 2: Stem girth of Nekkare mango due to inoculation with
G. mosseae

T 10 cm below tip

M 10 cm above ground

B 1 cm above ground

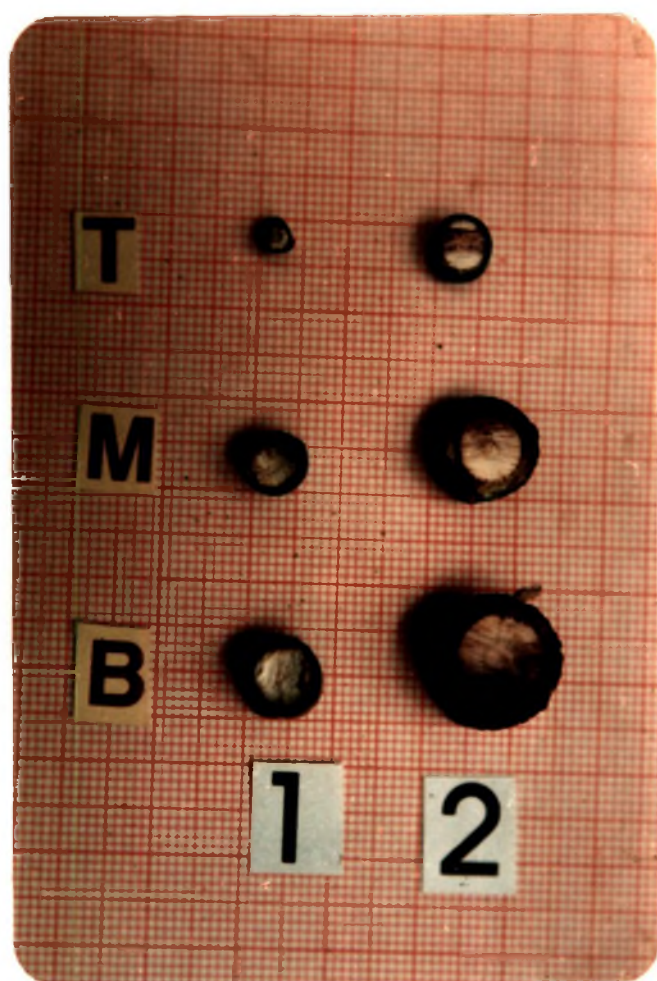


Plate 2

G. mosseae (local) 0.87, A. laevis 0.86 cm, G. fasciculatum 0.86 cm and G. caledonicum 0.85 cm. All the above fungi were statistically on par with each other. Uninoculated plants had a stem girth of 0.62 cm. At 10 cm below the tip the girth of plants treated with G. mosseae (local) was 0.66 cm, G. fasciculatum 0.63 cm and Gi. margarita (Ruakura) 0.63 cm. These were statistically on par with each other. In uninoculated plants it was 0.40cm. The three fungi G. mosseae (local) (Plate 2), G. fasciculatum and Gi. margarita (Ruakura) can be chosen as the best fungi for inoculating nekkere mango as they produced the desired stem girth for soft wood grafting (10cm below the tip) as well as wedge and veneer grafting (10 cm above the ground) in a shorter time.

Effect of different VAM fungi on total leaf area: The total leaf area was determined on the day of harvest i.e., 225 days after transplanting. Plants inoculated with different VAM fungi did not vary significantly with respect to leaf area. However, maximum total leaf area was recorded in plants treated with G. monosporum (1615 cm²), G. mosseae (local) (1470.27 cm²), Gi. margarita (Ruakura) (145 cm²) and G. versiforme (1410.45 cm²). It was 639.87 cm² in uninoculated control plants.

Table 5: Effect of different VAM fungi on leaf area (cm²) of nekkare mango

Sl. No.	VAM fungi	Leaf area (cm ²)
1.	Control	639.87
2.	<u>A. laevis</u>	943.50
3.	<u>Gi. margarita</u> (Ruakura)	1415.00
4.	<u>G. caledonicum</u>	1000.00
5.	<u>G. fasciculatum</u>	1175.00
6.	<u>G. leptotichum</u>	1066.25
7.	<u>G. macrocarpum</u>	1615.00
8.	<u>G. monosporum</u>	1177.90
9.	<u>G. mosseae</u> (local)	1470.27
10.	<u>G. versiforme</u>	1410.45
F - test		NS

Effect of different VAM fungi on plant biomass

Shoot: Plants inoculated with different VAM fungi varied significantly with respect to shoot biomass. Table 6 and Fig. 3, illustrate the variation in shoot biomass due to mycorrhizal inoculation. The shoot biomass of all mycorrhizal plants were statistically on par with each other. Maximum shoot biomass was recorded in plants treated with G. monosporum (24.46g), G. versiforme (23.61g) and Gi. margarita (Ruakura) (21.42 g)(Plate 1a). The shoot biomass of uninoculated plants was only 11.06g.

Root: Table 6, Plate 1b illustrate the variation in root biomass due to mycorrhizal inoculation. However, the variations were not statistically significant.

Effect of different VAM fungi on P content

Shoot: Plants inoculated with different VAM fungi varied significantly with respect to shoot P content (Table 7, Fig. 4a). It was highest in plants inoculated with Gi. margarita (Ruakura) followed by G. monosporum, G. macrocarpum, G. fasciculatum, A. laevis, G. caledonicum, G. versiforme, G. leptotichum and G. mosseae (local). It was least in uninoculated control plants.

Table 6: Effect of differnt VAM fungi on plant biomass of nekkare mango (g/plant)

Sl. No.	VAM fungi	Shoot	Root
1.	Control	11.06	9.64
2.	<u>A. laevis</u>	16.90	14.50
3.	<u>Gi. margarita</u> (Ruakura)	21.42	12.01
4.	<u>G. caledonicum</u>	17.58	16.18
5.	<u>G. fasciculatum</u>	15.65	11.93
6.	<u>G. leptotichum</u>	15.73	13.43
7.	<u>G. macrocarpum</u>	19.48	17.81
8.	<u>G. monosporum</u>	24.46	12.71
9.	<u>G. mosseae</u> (local)	16.07	13.80
10.	<u>G. versiforme</u>	23.61	13.37
	F - test	**	NS
	CV	29.39	27.34
	SEm ±	2.675	1.852

Summary of comparison based on
Student Newman-Keul's test at
5% significance level
Shoot biomass: 1 5 6 9 2 4 7 3 10 8

Table 7: Effect of different VAM fungi on the P content (mg/plant) of nekkare mango

Sl. No.	VAM fungi	Shoot	Root
1.	Control	33.90	62.86
2.	<u>A. laevis</u>	98.65	119.75
3.	<u>Gi. margarita</u> (Ruakura)	174.30	110.09
4.	<u>G. caledonicum</u>	96.01	125.37
5.	<u>G. fasciculatum</u>	98.95	95.47
6.	<u>G. leptotichum</u>	89.34	109.16
7.	<u>G. macrocarpum</u>	110.74	131.09
8.	<u>G. monosporum</u>	123.40	120.07
9.	<u>G. mosseae</u> (local)	84.75	106.14
10.	<u>G. versiforme</u>	91.66	135.00
	F - test	**	NS
	CV	32.94	33.02
	SEm ±	12.32	13.39

Summary of comparison based on
Student Newman-Keul's test at
5% significance level

Shoot P: 1 9 6 10 4 2 5 7 8 3

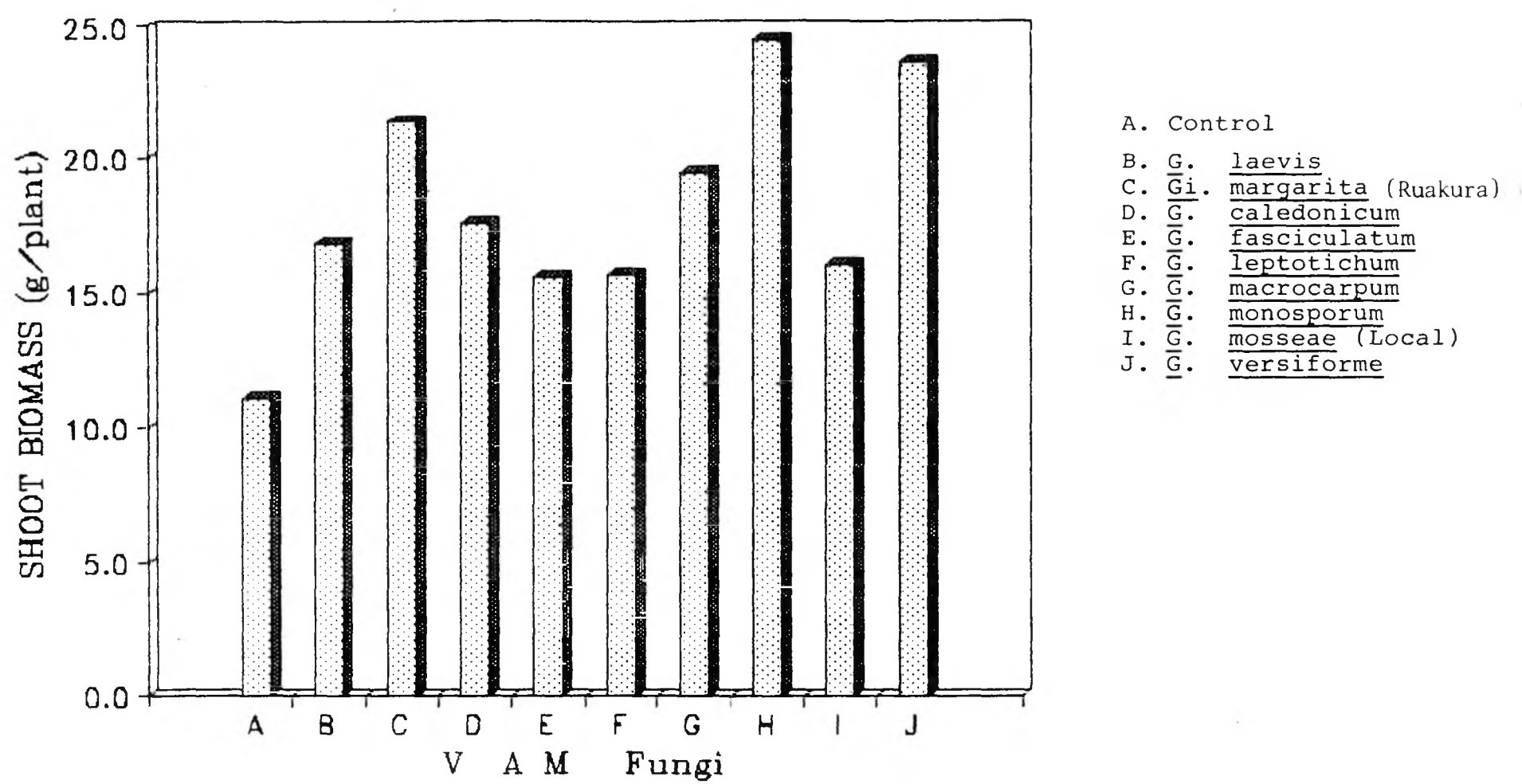


Fig. 3. Effect of different VAM fungi on shoot biomass of Nekkare mango.

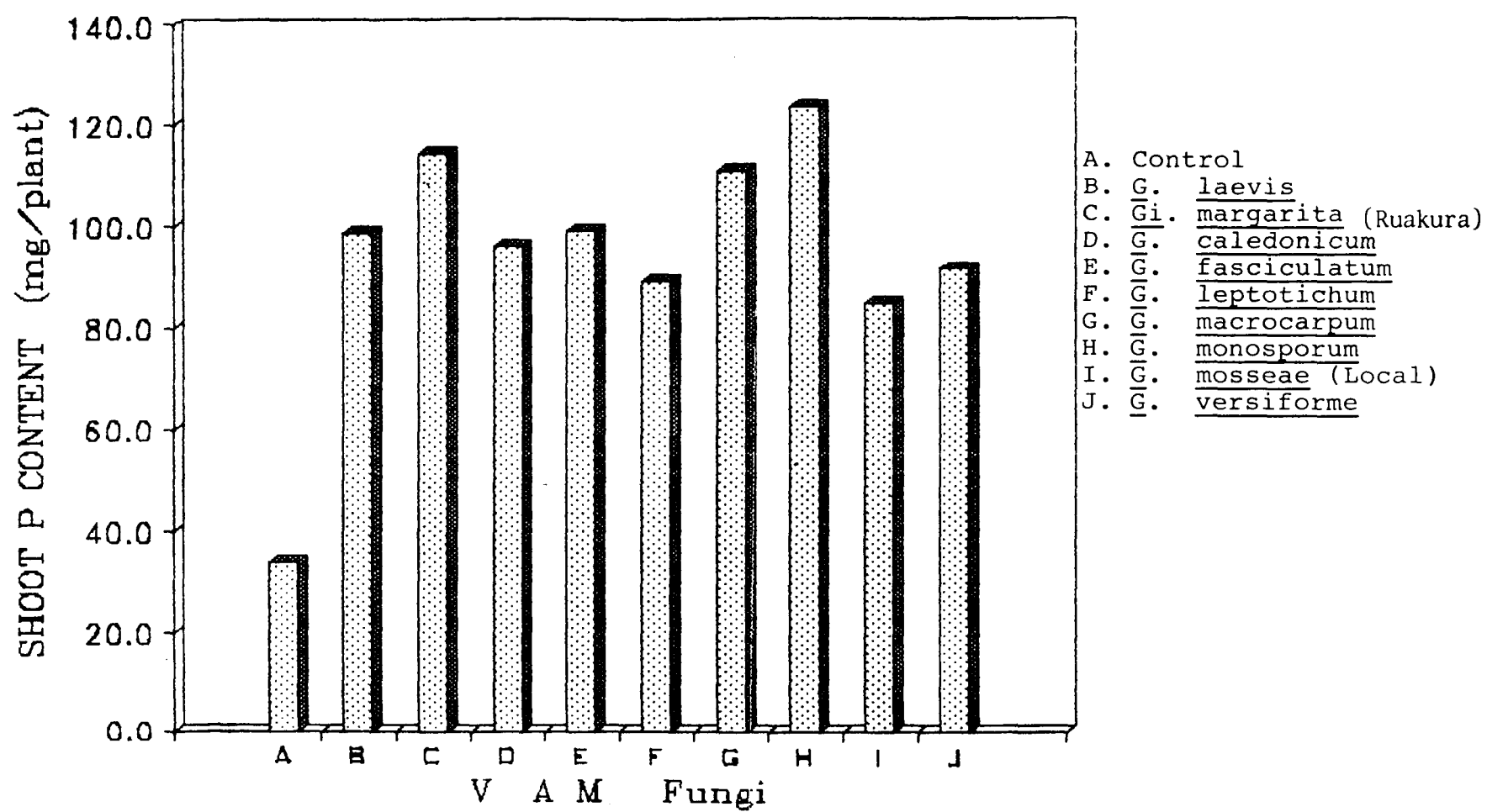


Fig. 4a. Effect different VAM fungi on shoot P content of Nekkare mango.

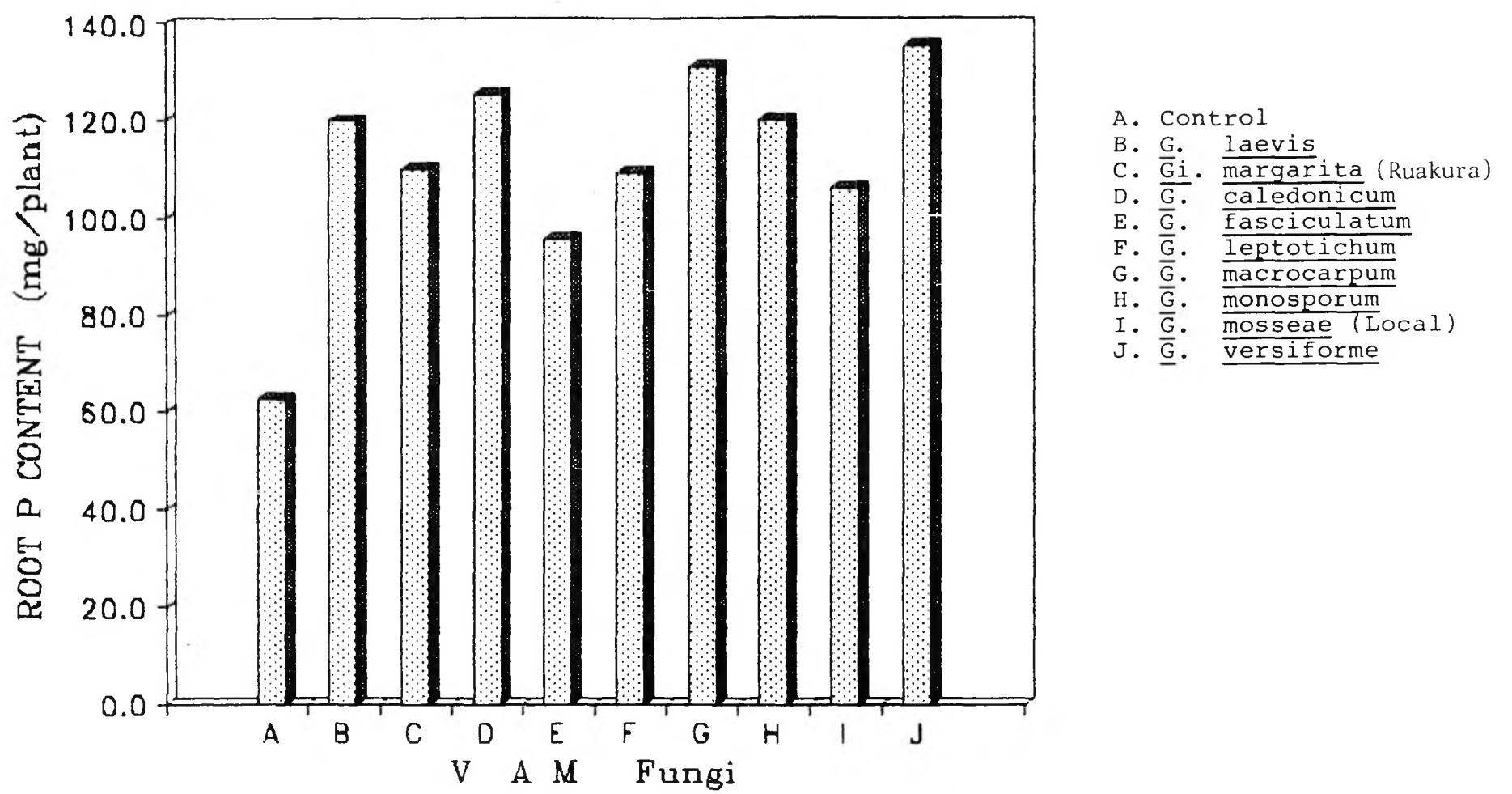


Fig 4b. Effect of different VAM fungi on root P content of Nekkare mango.

Plate 1a & b: Response of Nekkare mango to different VAM fungi

a. Shoot b. Root

1. Control
2. Gi. margarita (Ruakura)
3. G. fasciculatum



Plate 1a.



Plate 1b.

Root: Plants inoculated with various VAM fungi did not differ significantly with respect to root phosphorus content. However, it was highest in plants inoculated with G. versiforme (Fig. 4b) and least in uninoculated plants.

Effect of different VAM fungi on Zn content: Table 8 shows that the Zn content of the shoot and root did not differ significantly, because of mycorrhizal inoculum although higher Zn content was recorded in all the inoculated plants.

Mycorrhizal spore count in soil: Table 9 and Fig. 5 illustrate the mycorrhizal spore count in soil as influenced by mycorrhizal inoculation with different VAM fungi. The differences were highly significant. Maximum spore count was encountered due to inoculation with G. fasciculatum, A. laevis and G. versiforme, all the three being statistically on par with each other. This was followed by G. macrocarpum, G. monosporum, G. mosseae (local) and Gi. margarita (Ruakura), again all the four being statistically on par with each other. Uninoculated plants showed the least spore count.

Table 8: Effect of different VAM fungi on Zn content (μg /plant) of nekkare mango

Sl. No.	VAM fungi	Shoot	Root
1.	Control	314.00	221.90
2.	<u>A. laevis</u>	548.00	439.00
3.	<u>Gi. margarita</u> (Ruakura)	442.85	355.50
4.	<u>G. caledonicum</u>	322.10	425.35
5.	<u>G. fasciculatum</u>	475.60	346.20
6.	<u>G. leptotichum</u>	403.36	413.15
7.	<u>G. macrocarpum</u>	415.30	440.10
8.	<u>G. monosporum</u>	527.55	370.35
9.	<u>G. mosseae</u> (local)	514.65	366.55
10.	<u>G. versiforme</u>	367.10	373.45
	F - test	NS	NS

Table 9: Effect of differnt VAM fungi on spore count and number of infective propagules in soil and per cent root colonization of nekkare mango

Sl. No.	VAM fungi	Spore count/ 30 g soil	% mycorrhizal colonization	infective propagule number x 10 ⁶
1.	Control	86	11.00	0.068
2.	<u>A. laevis</u>	300	24.00	1.20
3.	<u>Gi. margarita</u> (Ruakura)	190	32.00	0.17
4.	<u>G. caledonicum</u>	150	28.00	1.70
5.	<u>G. fasciculatum</u>	321	35.00	5.40
6.	<u>G. leptotichum</u>	162	45.50	0.14
7.	<u>G. macrocarpum</u>	235	38.50	0.11
8.	<u>G. monosporum</u>	206	37.00	1.70
9.	<u>G. mosseae</u> (local)	199	41.00	1.21
10.	<u>G. versiforme</u>	205	34.00	1.70
	F - test	**	**	
	CV	17.52	40.13	
	SEm ±	21.17	6.62	

Summary of comparison based on Student Newman-Keuls test at 5% significance level

% Colonization - 1 2 4 3 10 5 7 8 9 6
Spore count 1 4 6 3 9 8 7 10 2 5

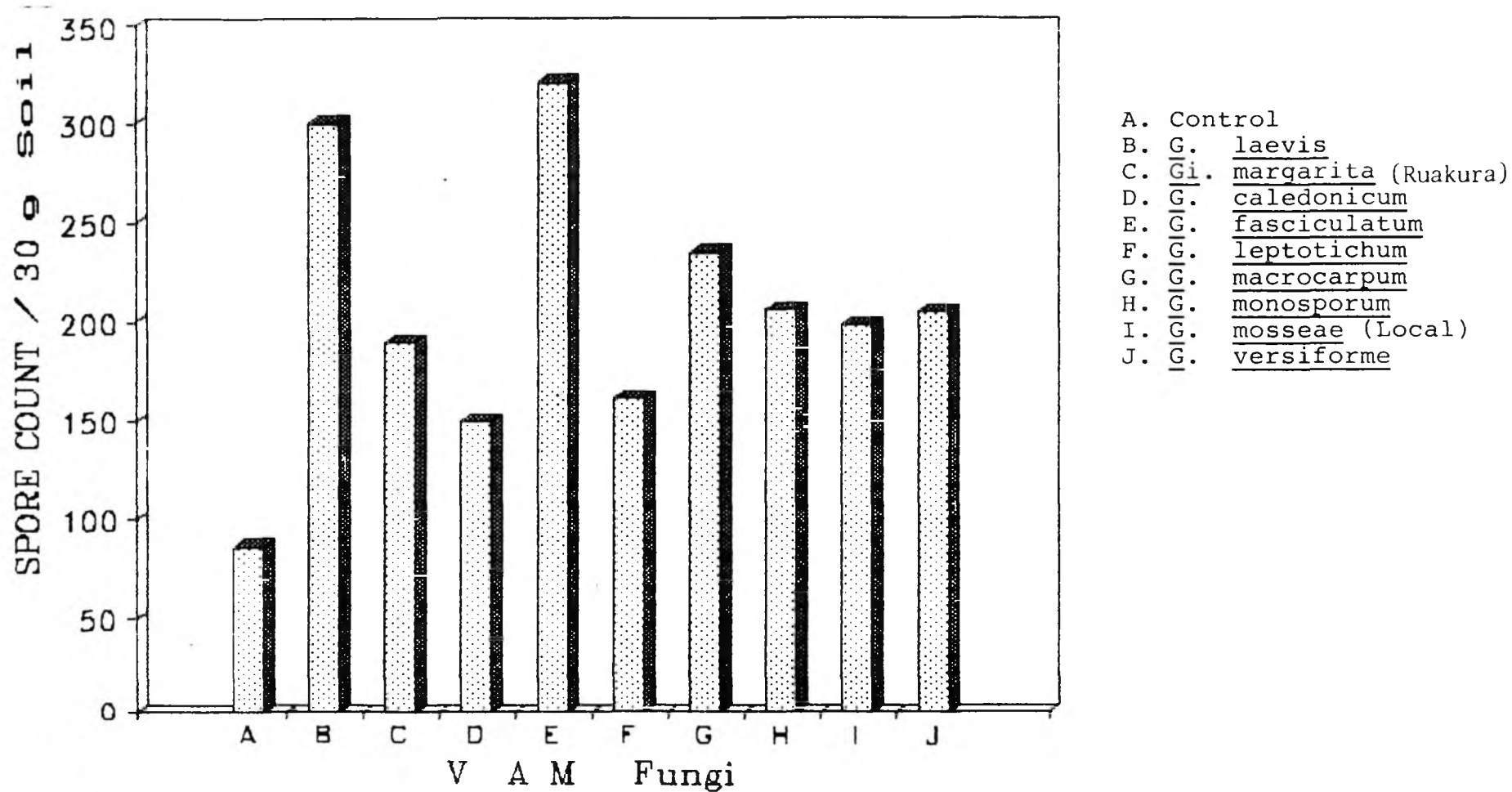


Fig. 5. Effect of different VAM fungi on the mycorrhizal spore count in the root zone soil of Nekkare mango.

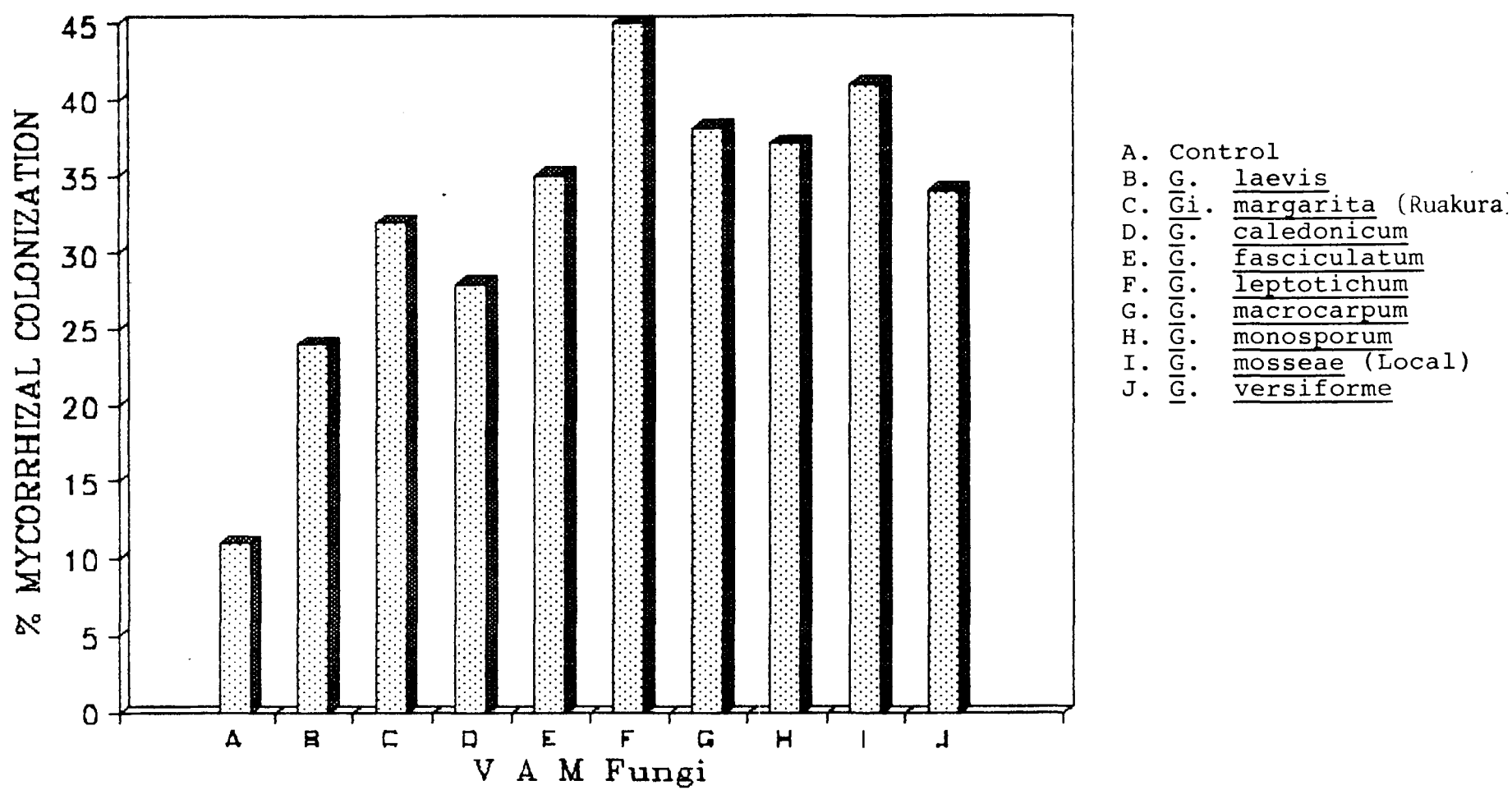


Fig. 6. Effect of different VAM fungi on mycorrhizal root colonization of Nekkare mango.

Per cent mycorrhizal colonization of the root

Statistically par highest per cent mycorrhizal root colonization was recorded in plants treated with G. leptotichum, G. mosseae (local) and G. monosporum (Table 9 and Fig.6). This was followed by G. macrocarpum, G. fasciculatum, G. versiforme and Gi. margarita (Ruakura), all the four being statistically equivalent. Uninocualted plants showed the least mycorrhizal colonization of 11 per cent.

Number of infective propagules in soil

The number of infective propagules produced in soil because of different treatments is given in table 9. Treatment with G. fasciculatum, G. caledonicum, G. monosporum, G. versiforme and G. mosseae (local) had infective propagule numbers of 5.4, 1.7, 1.7, 1.7 and 1.21×10^6 per g respectively. Uninoculated treatment had 0.068×10^6 infective propagules per g of soil.

Selection of efficient VAM fungi for acid lime

Symbiotic response of acid lime to inoculation with 14 different VAM isolates was studied. The effect of inoculation on different plant and soil parameters studied are given below.

Effect of different VAM fungi on plant height: The variations in plant height due to inoculation with different VAM fungi was significant on 90, 135 and 225 days after sowing. It was consistently higher in plants treated with G. macrocarpum, G. mosseae (local) and A. laevis on all the days of observations. On 225th day all the inoculated plants were statistically on par with each other. The top three fungi which attained maximum plant height were G. macrocarpum (74.68 cm), G. mosseae (local) (70.33 cm) and A. laevis (62.8 cm). Control plants had a height of 40.9 cm.

Effect of different VAM fungi on leaf number: Inoculated plants had markedly more leaves when compared to uninoculated plants (Table 11). Statistically significant differences were obtained only on days 90, 135 and 225. On 225th day after sowing the number of leaves were statistically on par with each other in all the inoculated treatments. However, maximum number of leaves was recorded in plants treated with G. monosporum, G. macrocarpum, G. mosseae (local) and A. laevis.

Effect of different VAM fungi on stem girth: The difference in stem girth due to inoculation with several VAM fungi was significant on days 135, 180 and 225 days after sowing. Table 12 and Fig. 7. shows the increase in stem girth due to mycorrhizal inoculation which was significant on all the three intervals of observation.

Table 10: Effect of different VAM fungi on plant height (cm) of acid lime

Sl. No.	VAM fungi	Days after sowing				
		45d	90d	135d	180d	225d
1.	Control	10.45	23.28	28.27	36.45	40.90
2.	<u>A. laevis</u>	15.25	33.23	41.50	54.31	62.80
3.	<u>Gi. margarita</u> (ICRISAT)	11.41	21.05	21.05	41.00	52.00
4.	<u>Gi. margarita</u> (Ruakura)	11.03	27.78	21.98	47.21	57.00
5.	<u>G. caledonicum</u>	11.81	24.02	32.21	48.13	62.32
6.	<u>G. fasciculatum</u>	13.11	26.56	32.95	46.61	56.78
7.	<u>G. leptotichum</u>	10.48	26.63	31.43	47.83	54.78
8.	<u>G. macrocarpum</u>	15.72	39.05	44.15	65.07	74.68
9.	<u>G. merredum</u>	12.30	19.42	25.96	35.60	46.73
10.	<u>G. monosporum</u>	10.98	20.12	25.81	38.18	48.06
11.	<u>G. mosseae</u> (ICRISAT)	12.42	25.12	29.00	45.23	51.56
12.	<u>G. mosseae</u> (Local)	14.48	33.77	41.63	58.07	70.33
13.	<u>G. velum</u>	12.22	24.11	27.32	40.77	48.37
14.	<u>G. versiforme</u>	10.18	21.57	26.35	42.82	55.62
F - test		NS	**	**	**	**
CV		28.10	26.31	21.29	25.04	22.08
SEm ±		1.72	3.44	3.32	5.76	6.12

Summary of comparison based on Student Newman-Keul's test at 5% significance level

90 days	<u>9 10 3 14 1 5 13</u>	<u>11 6 7 4 2 12 8</u>
135 days	<u>3 10 9 14 13 1 11</u>	<u>4 7 5 6 2 12 8</u>
180 days	<u>9 1 10 13 3 11 14</u>	<u>6 4 7 5 2 12 8</u>
225 days	<u>1 9 10 13 11 3 7 14</u>	<u>6 4 5 2 12 8</u>

Table 11: Effect of differnt VAM fungi on number of leaves of acid lime

Sl. No.	VAM fungi	Days after sowing				
		45d	90d	135d	180d	225d
1.	Control	10.62	18.87	21.75	27.87	35.37
2.	<u>A. laevis</u>	13.37	24.37	32.62	39.12	48.50
3.	<u>Gi. margarita</u> (ICRISAT)	11.62	19.50	23.25	33.50	45.73
4.	<u>Gi. margarita</u> (Ruakura)	11.75	21.25	23.87	31.37	39.50
5.	<u>G. caledonicum</u>	14.12	20.12	25.87	34.00	47.00
6.	<u>G. fasciculatum</u>	14.12	22.75	27.37	34.00	45.25
7.	<u>G. leptotichum</u>	11.62	20.25	23.62	35.00	45.12
8.	<u>G. macrocarpum</u>	16.37	27.87	29.50	41.02	53.37
9.	<u>G. merredum</u>	12.50	19.50	28.25	33.12	43.87
10.	<u>G. monosporum</u>	11.87	20.37	29.75	35.00	53.72
11.	<u>G. mosseae</u> (ICRISAT)	11.25	21.87	23.50	31.50	41.87
12.	<u>G. mosseae</u> (Local)	12.75	26.75	30.50	40.37	50.75
13.	<u>G. velum</u>	12.62	20.50	29.25	33.00	37.35
14.	<u>G. versiforme</u>	10.62	19.50	22.50	34.37	43.20
	F - test	NS	**	**	NS	**
	CV	27.28	15.01	17.13	18.23	22.23
	SEm ±	1.70	1.628	2.27	3.14	3.33

Summary of comparison based on
Student Newman Keul's test at
5% significance level

90 days	1	9	3	14	5	7	10	13	4	11	6	2	12	8
135 days	1	14	3	11	7	4	5	6	9	13	8	10	12	2
225 days	1	13	4	11	14	9	7	6	3	5	2	12	8	10

On the day of harvest i.e., 225 days after sowing maximum stem girth was observed in plants treated with G. macrocarpum (0.7cm) followed by G. mosseae (local) (0.7cm), G. caledonicum (0.64 cm), A. laevis (0.64 cm), G. velum (0.13cm), G. mosseae (ICRISAT) (0.61cm), G. leptotichum (0.61cm) and G. fasciculatum (0.6 cm). All these treatments were statistically on par with each other. Uninoculated plants had a stem girth of 0.48cm (Plate 3).

Effect of different VAM fungi on total leaf area : The total leaf area determined on the day of harvest (225 days after sowing) is given in table 13. Plants inoculated with different VAM fungi varied significantly with respect to leaf area. Maximum total leaf area was recorded in plants treated with G. macrocarpum followed by G. caledonicum, G. mosseae (local) G. leptotichum, G. versiforme, Gi. margarita (ICRISAT), G. fasciculatum, A. laevis and G. mosseae (ICRISAT). All these mycorrhizal treatments were statistically equivalent.

Effect of different VAM fungi on the plant biomass: Plants inoculated with different VAM fungi varied significantly with respect to shoot biomass and all of them were statistically on par with each other (Table 14, Fig. 8a). However, the best fungus showing maximum plant biomass

Table 12: Effect of different VAM fungi on plant girth (cm) of acid lime

Sl. No.	VAM fungi	Days after sowing		
		135d	180d	225d
1.	Control	0.38	0.41	0.48
2.	<u>A. laevis</u>	0.53	0.60	0.63
3.	<u>Gi. margarita</u> (ICRISAT)	0.42	0.56	0.58
4.	<u>Gi. margarita</u> (Ruakura)	0.46	0.55	0.59
5.	<u>G. caledonicum</u>	0.47	0.57	0.64
6.	<u>G. fasciculatum</u>	0.51	0.56	0.60
7.	<u>G. leptotichum</u>	0.50	0.54	0.61
8.	<u>G. macrocarpum</u>	0.58	0.65	0.70
9.	<u>G. merredum</u>	0.47	0.54	0.59
10.	<u>G. monosporum</u>	0.49	0.56	0.58
11.	<u>G. mosseae</u> (ICRISAT)	0.48	0.57	0.61
12.	<u>G. mosseae</u> (Local)	0.54	0.60	0.70
13.	<u>G. velum</u>	0.48	0.54	0.62
14.	<u>G. versiforme</u>	0.46	0.52	0.60
F test		**	**	**
CV		11.02	8.68	7.368
SEm ±		0.0265	0.0241	0.0224

Summary of comparison based on Student Newman-Keul's test at 5% significance level

135 days	1	<u>3 14 4 9 5 11 13 10 7 6 2 12 8</u>
180 days	1	<u>14 9 7 13 4 10 3 6 5 11 2 12 8</u>
225 days	1	<u>3 10 4 9 14 6 7 11 13 2 5 12 8</u>

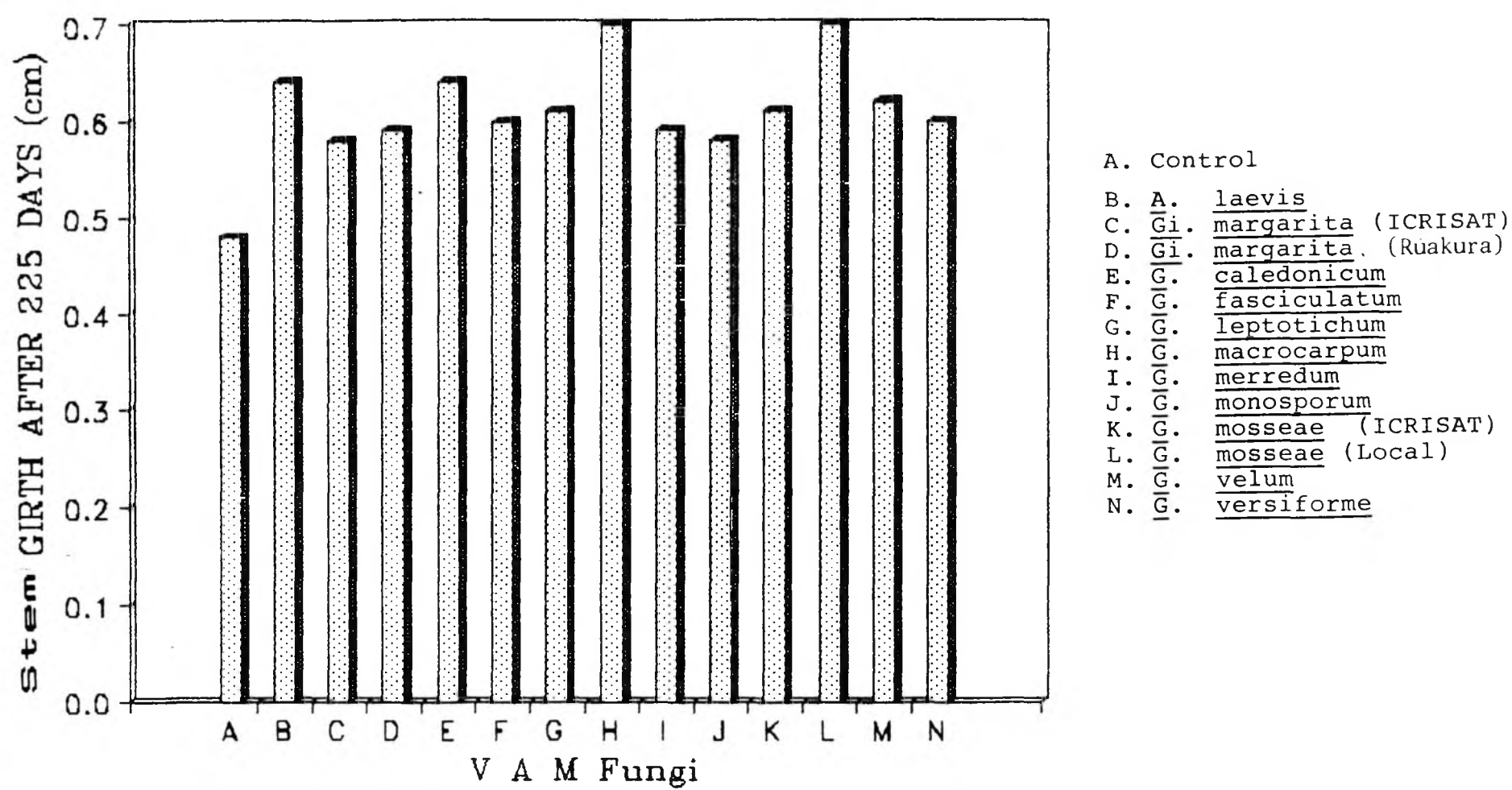


Fig. 7. Effect of different VAM fungi on stem girth of acid lime.

Table 13: Effect of different VAM fungi on leaf area of acid lime (cm²)

Sl. No.	VAM fungi	Leaf area (cm ²)
1.	Control	283.50
2.	<u>A. laevis</u>	373.25
3.	<u>Gi. margarita</u> (ICRISAT)	394.75
4.	<u>Gi. margarita</u> (Ruakura)	253.00
5.	<u>G. caledonicum</u>	559.00
6.	<u>G. fasciculatum</u>	377.25
7.	<u>G. leptotichum</u>	437.75
8.	<u>G. macrocarpum</u>	611.25
9.	<u>G. merredum</u>	275.50
10.	<u>G. monosporum</u>	299.50
11.	<u>G. mosseae</u> (ICRISAT)	347.50
12.	<u>G. mosseae</u> (Local)	439.75
13.	<u>G. velum</u>	302.50
14.	<u>G. versiforme</u>	433.50
	F test	**
	CV	33.41
	SEm ±	62.34

Summary of comparison based on Student Newman-Keul's test at 5% significance level

Leaf area 4 9 1 10 13 11 2 6 3 14 7 12 5 8

Plate 3: Stem girth of acid lime due to inoculation with
different VAM fungi

- 1 Control
- 2 Gi. margarita (Ruakura)
- 3 G. fasciculatum
- 4 G. caledonicum
- 5 G. macrocarpum
- 6 G. mosseae (Local)

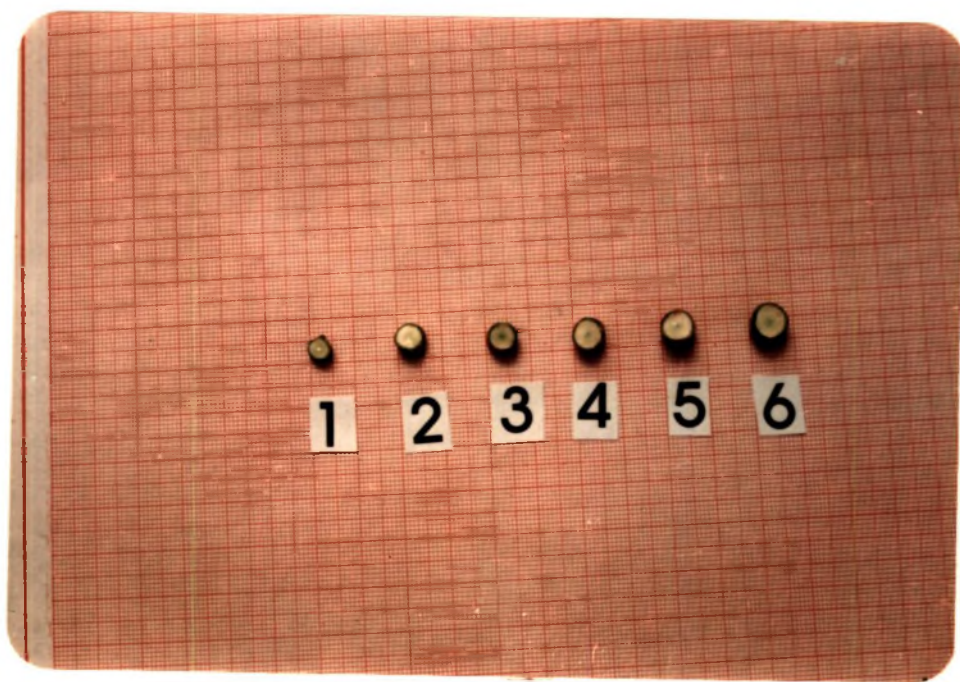


Plate 3

was G. macrocarpum (10.09 g) followed by G. mosseae (local). The shoot biomass of uninoculated plants was 4.63g.

Root: Root biomass in plants inoculated with different VAM fungi varied significantly (Table 14, Fig. 8b). Maximum root biomass was observed in plants treated with G. macrocarpum (5.33g), G. mosseae (local (5.16g), G. mosseae (ICRISAT) (4.30g), A. laevis (4.17g), Gi. margarita (Ruakura) (3.86g), G. leptotichum (3.85g), G. caledonicum (3.60g), G. versiforme (3.37g) and G. fasciculatum (3.30g). These were statistically on par with each other. The root biomass of uninoculated plants was 1.65g. G. macrocarpum and G. moseae (local) ranked 1 and 2 in improving both shoot and root biomass (Plate 4a, 4b).

Effect of differnt VAM fungi on P content

Shoot: Acid lime plants inoculated with different VAM fungi varied significantly from the uninoculated control but were statistically on par with each other in shoot P content (Table 15, Fig. 9a). The top five fungi which showed maximum shoot P were G. mosseae (local), G. macrocarpum, G. leptotichum and G. versiforme. P content was least in uninoculated control plants.

Table 14: Effect of different VAM fungi on plant biomass of acid lime (g/plant)

Sl. No.	VAM fungi	Shoot	Root
1.	Control	4.63	1.65
2.	<u>A. laevis</u>	7.71	4.17
3.	<u>Gi. margarita</u> (ICRISAT)	6.90	2.41
4.	<u>Gi. margarita</u> (Ruakura)	6.40	3.86
5.	<u>G. caledonicum</u>	8.21	3.60
6.	<u>G. fasciculatum</u>	8.26	3.30
7.	<u>G. leptotichum</u>	7.09	3.85
8.	<u>G. macrocarpum</u>	10.09	5.33
9.	<u>G. merredum</u>	7.30	2.60
10.	<u>G. monosporum</u>	6.33	2.20
11.	<u>G. mosseae</u> (ICRISAT)	6.76	4.30
12.	<u>G. mosseae</u> (Local)	9.95	5.18
13.	<u>G. velum</u>	6.67	2.77
14.	<u>G. versiforme</u>	6.73	3.37
	F test	**	**
	CV	23.13	29.98
	SEm ±	0.8514	0.524

Summary of comparison based on Student Newman-Keul's test at 5% significance level

Shoot biomass	1	<u>10 4 13 14 11 3 7 9 2 5 6 12 8</u>	6 12 8
Root biomass	<u>1 10 3 9 13</u>	<u>6 14 5 7 4 2 11 12 8</u>	

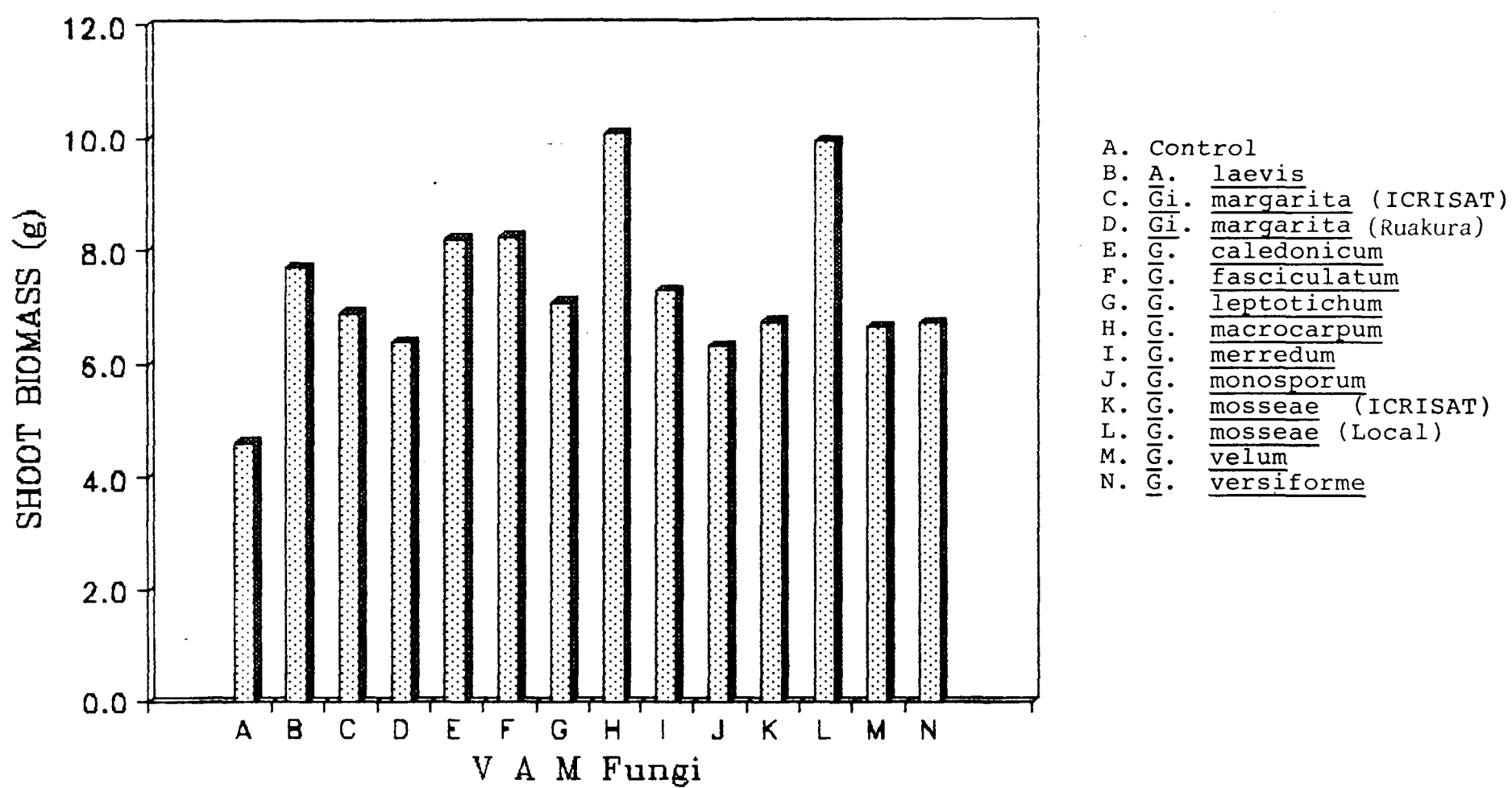


Fig. 8a. Effect of different VAM fungi on shoot biomass of acid lime.

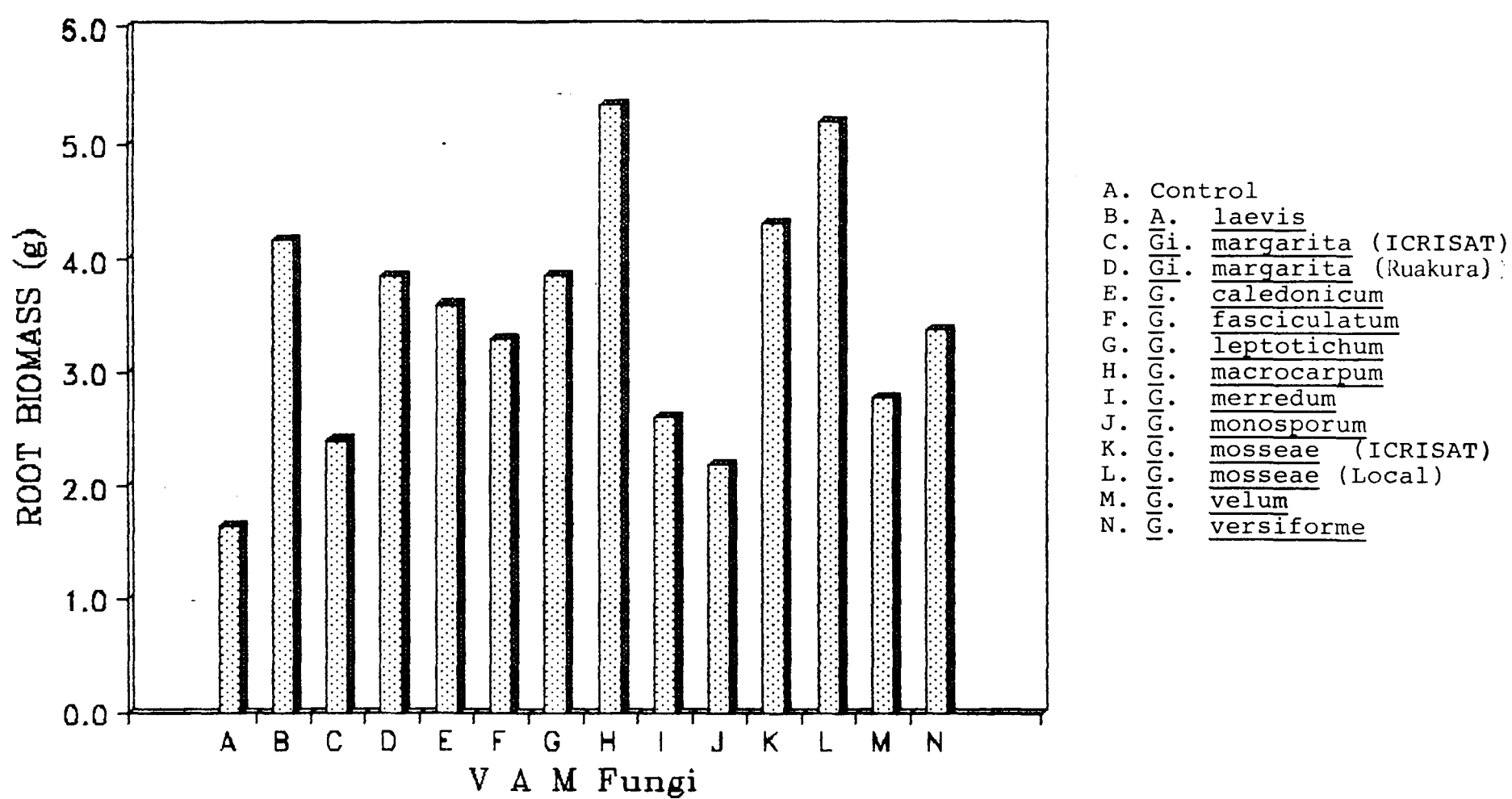


Fig. 8b. Effect of different VAM fungi on root biomass of acid lime.

Table 15: Effect of different VAM fungi on the P content of acid lime (mg/plant)

Sl. No.	VAM fungi	Shoot	Root
1.	Control	15.38	6.30
2.	<u>A. laevis</u>	47.46	38.67
3.	<u>Gi. margarita</u> (ICRISAT)	47.64	14.22
4.	<u>Gi. margarita</u> (Ruakura)	44.07	36.11
5.	<u>G. caledonicum</u>	57.46	26.13
6.	<u>G. fasciculatum</u>	40.58	25.12
7.	<u>G. leptotichum</u>	60.20	24.95
8.	<u>G. macrocarpum</u>	65.90	45.83
9.	<u>G. merredum</u>	44.04	20.28
10.	<u>G. monosporum</u>	47.47	18.44
11.	<u>G. mosseae</u> (ICRISAT)	38.04	32.56
12.	<u>G. mosseae</u> (Local)	76.57	39.19
13.	<u>G. velum</u>	40.14	22.29
14.	<u>G. versiforme</u>	54.74	26.64
	F test	**	**
	CV	33.38	34.48
	SEm ±	9.35	5.70

Summary of comparison based on Student Newman-Keul's test at 5% significance level

Shoot	P	1	11	13	6	9	4	2	10	13	14	5	7	8	12
Root	P	1	3	10	9	13	7	6	5	14	11	4	2	12	8

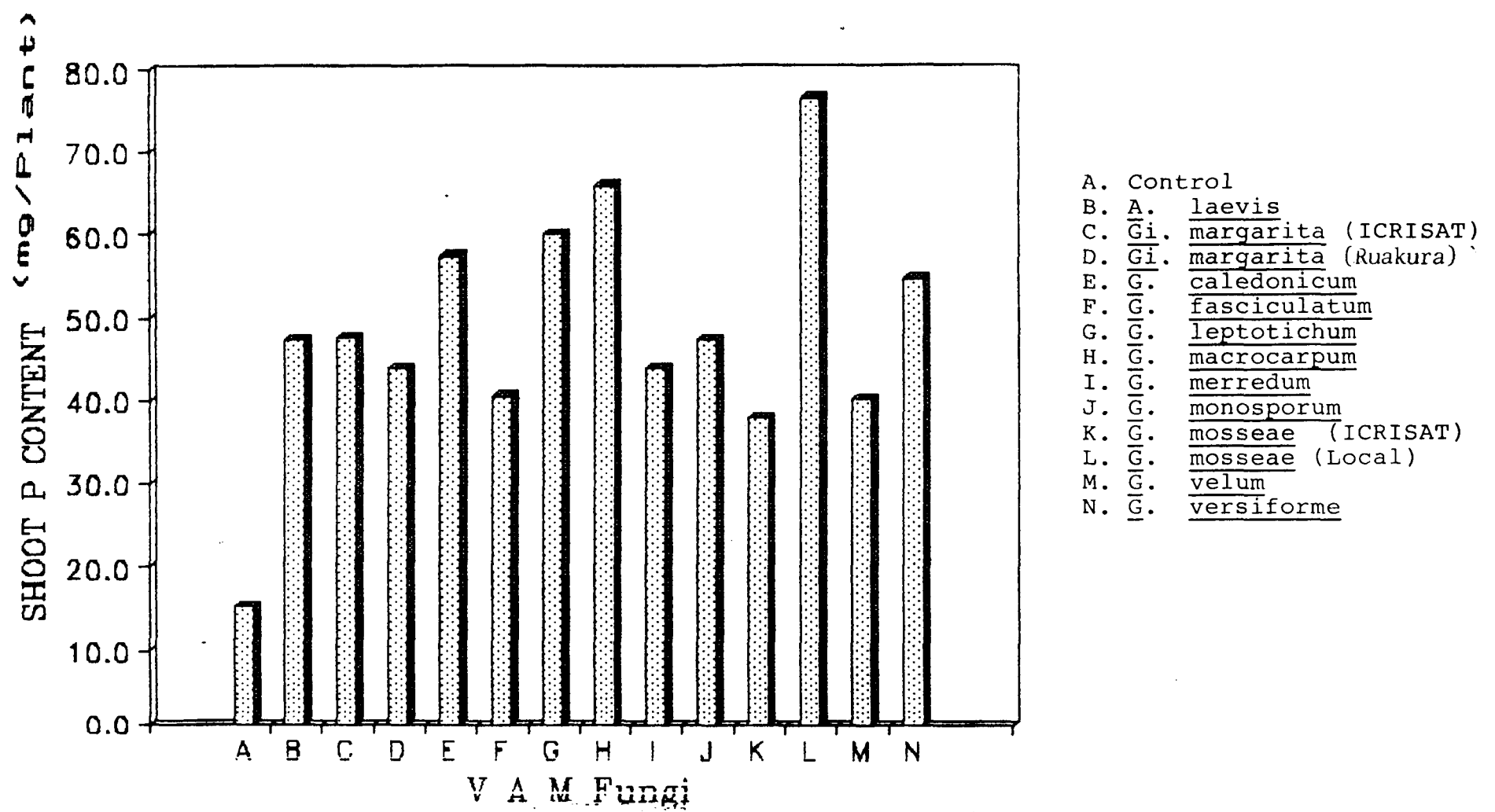
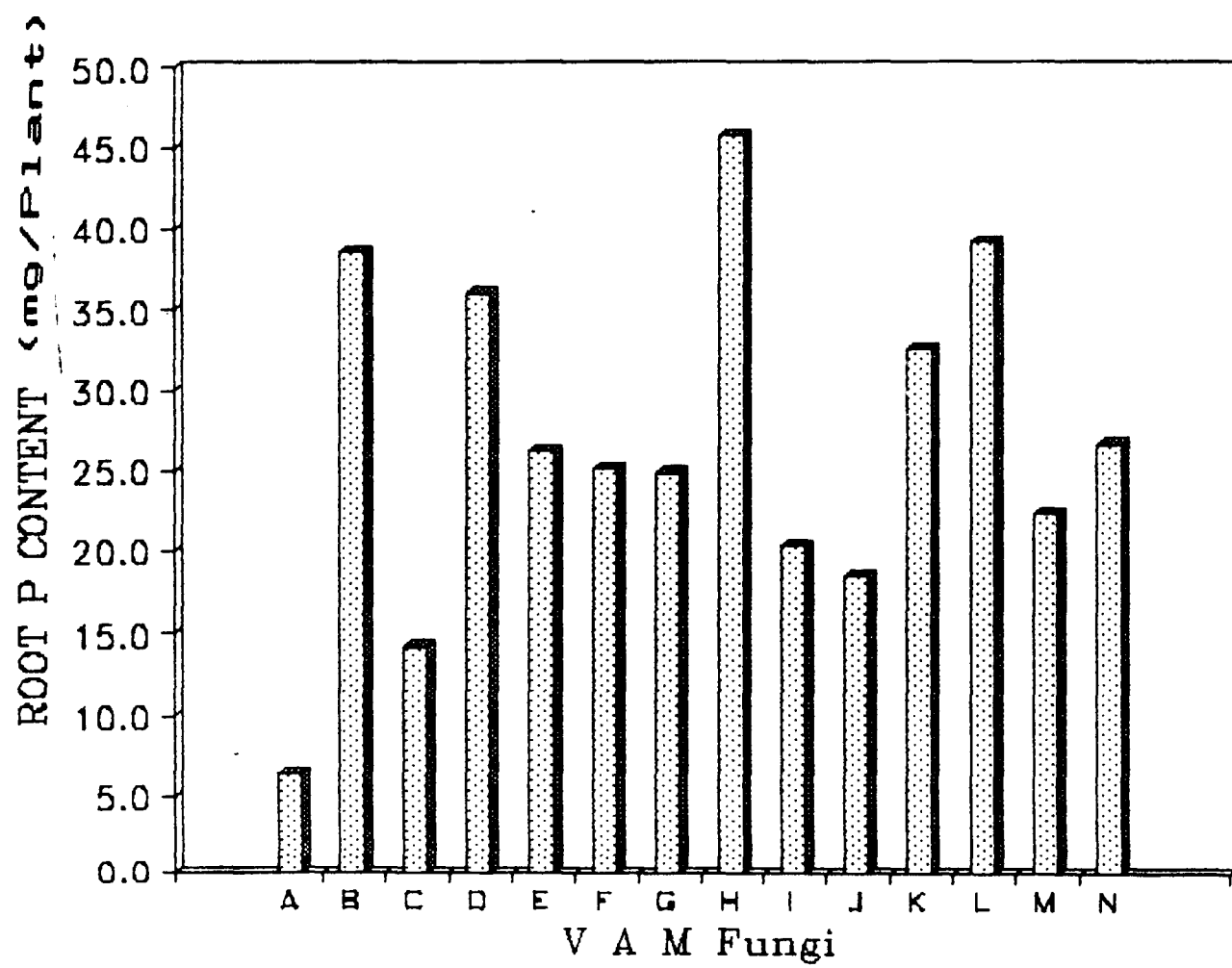


Fig. 9a: Effect of different VAM fungi on shoot P content of acid lime



- A. Control
- B. A. laevis
- C. Gi. margarita (ICRISAT)
- D. Gi. margarita (Ruakura)
- E. G. caledonicum
- F. G. fasciculatum
- G. G. leptotichum
- H. G. macrocarpum
- I. G. merredum
- J. G. monosporum
- K. G. mosseae (ICRISAT)
- L. G. mosseae (Local)
- M. G. velum
- N. G. versiforme

Fig. 9b. Effect of different VAM fungi on root P content of acid lime.

Plate 4a and b: Response of acid lime to inoculation with G.
macrocarpum

	a	Shoot	b	Root
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1	Control
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2	<u>G. macrocarpum</u>
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Plate 4a

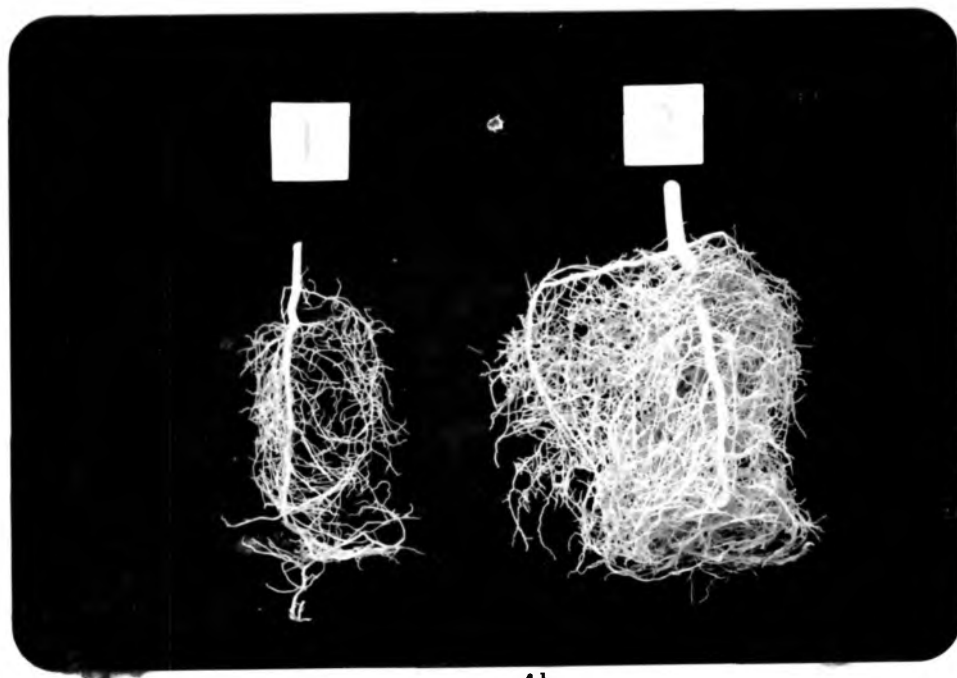


Plate 4b

Root: Different VAM fungi caused a significant variation with respect to root P content (Table 15, Fig. 9b). It was highest in plants inoculated with G. macrocarpum, G. mosseae (local), A. laevis, Gi. margarita (Ruakura), G. mosseae (ICRISAT) and G. versiforme. It was least in uninoculated control plants.

Effect of different VAM fungi on Zn content

Shoot: Plants inoculated with different VAM fungi varied significantly with shoot Zn content (Table 16). Maximum shoot Zn was recorded in plants treated with Gi. margarita (Ruakura), G. macrocarpum, G. leptotichum, G. mosseae (ICRISAT), G. monosporum, G. velum, A. laevis, G. versiforme and Gi. margarita (ICRISAT). These were statistically on par with each other. Uninoculated controls had the least Zn content.

Root: Zn content in roots of acid lime plants inoculated with different VAM fungi were not statistically significant, although higher Zn content was recorded in inoculated plants compared to uninoculated plants.

Mycorrhizal spore count in soil: Maximum spore count was encountered in the root zone soil of plants inoculated with G. mosseae (local) and Gi. margarita (Ruakura) the two being statistically on par with each other (Table 17, Fig. 10). Root zone of uninoculated plants had the least spore count.

Table 16: Effect of different VAM fungi on the Zn content (µg/plant) of acid lime

S1. No.	VAM fungi	Shoot	Root
1.	Control	249.30	285.46
2.	<u>A. laevis</u>	405.30	339.20
3.	<u>Gi. margarita</u> (ICRISAT)	388.00	392.06
4.	<u>Gi. margarita</u> (Ruakura)	727.60	447.66
5.	<u>G. caledonicum</u>	346.30	282.73
6.	<u>G. fasciculatum</u>	353.13	412.96
7.	<u>G. leptotichum</u>	493.60	481.33
8.	<u>G. macrocarpum</u>	500.00	502.20
9.	<u>G. merredum</u>	386.33	425.40
10.	<u>G. monosporum</u>	407.80	504.56
11.	<u>G. mosseae</u> (ICRISAT)	438.93	319.06
12.	<u>G. mosseae</u> (Local)	277.60	335.86
13.	<u>G. velum</u>	407.00	360.66
14.	<u>G. versiforme</u>	397.00	580.73
	F test	**	NS
	CV	30.16	37.58
	SEm ±	71.82	91.16

Summary of comparison based on
Student Newman-Keul's test at
5% significance level

Shoot Zinc 1 12 5 6 9 3 14 2 13 10 11 7 8 4

Table 17: Effect of different VAM fungi on spore count and number of infective propagules in soil and per cent root colonization of acid lime

Sl. No.	VAM fungi	Spore count/ 30 g soil	% mycorrhizal colonization	Infective propagule number x 10 ⁶
1.	Control	46	27.00	0.063
2.	<u>A. laevis</u>	160	54.50	0.20
3.	<u>Gi. margarita</u> (ICRISAT)	194	38.00	0.22
4.	<u>Gi. margarita</u> (Ruakura)	206	44.00	0.22
5.	<u>G. caledonicum</u>	154	51.00	2.80
6.	<u>G. fasciculatum</u>	124	62.00	0.21
7.	<u>G. leptotichum</u>	150	38.00	2.60
8.	<u>G. macrocarpum</u>	155	82.00	0.14
9.	<u>G. merredum</u>	148	59.00	0.039
10.	<u>G. monosporum</u>	158	55.00	0.22
11.	<u>G. mosseae</u> (ICRISAT)	139	55.25	0.18
12.	<u>G. mosseae</u> (Local)	230	76.00	0.14
13.	<u>G. velum</u>	198	41.00	0.20
14.	<u>G. versiforme</u>	201	57.75	0.21
	F test	**	**	
	CV		16.95	
	SEm ±		4.48	

Summary of comparison based on Student Newman-Keul's test at 5% significance level

Spore count: 1 11 9 7 5 8 10 2 6 3 13 14 4 12
 % colonization: 1 3 7 13 4 5 2 10 11 14 9 6 12 8

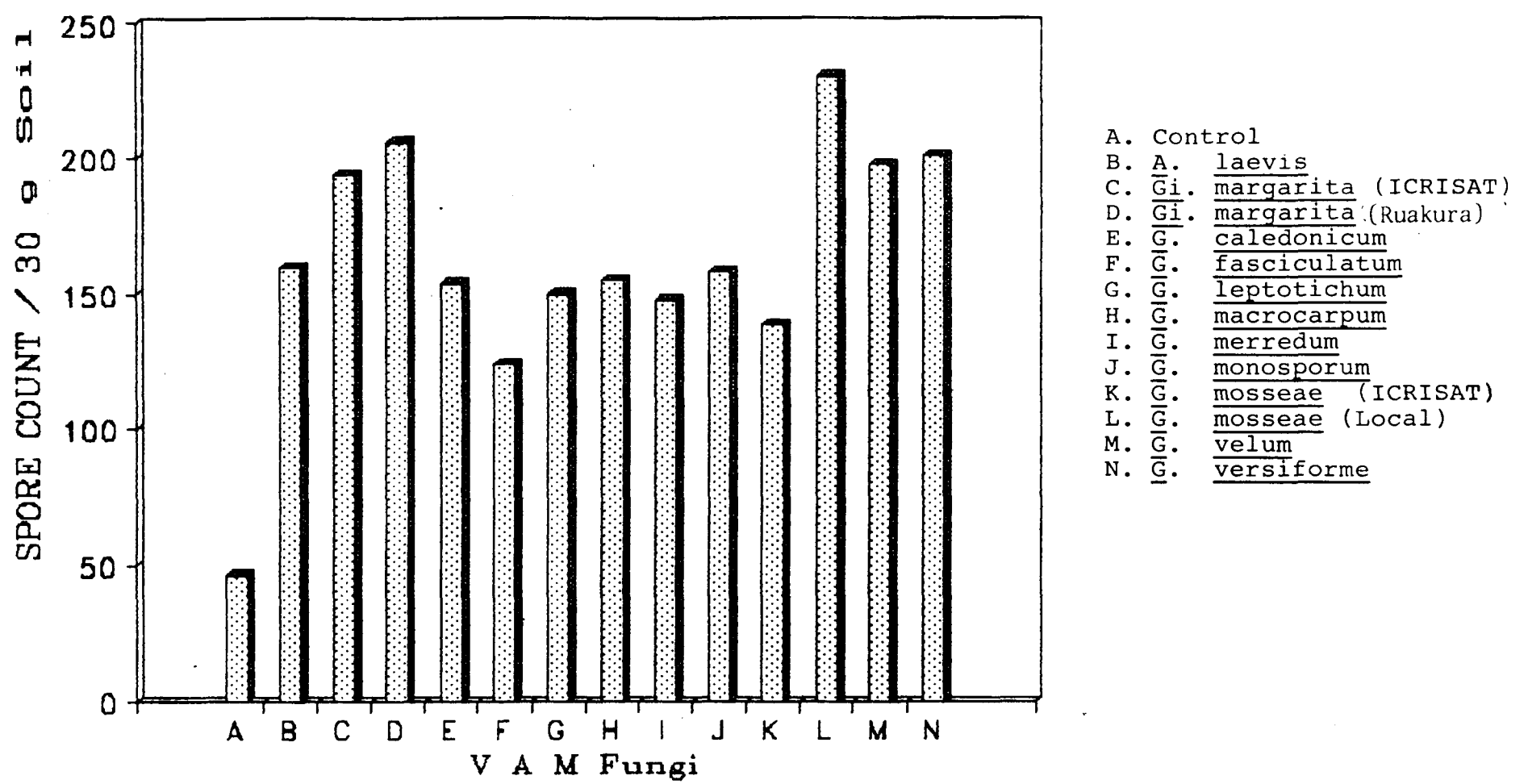


Fig. 10. Effect of different VAM fungi on the mycorrhizal spore count in the root zone soil of acid lime.

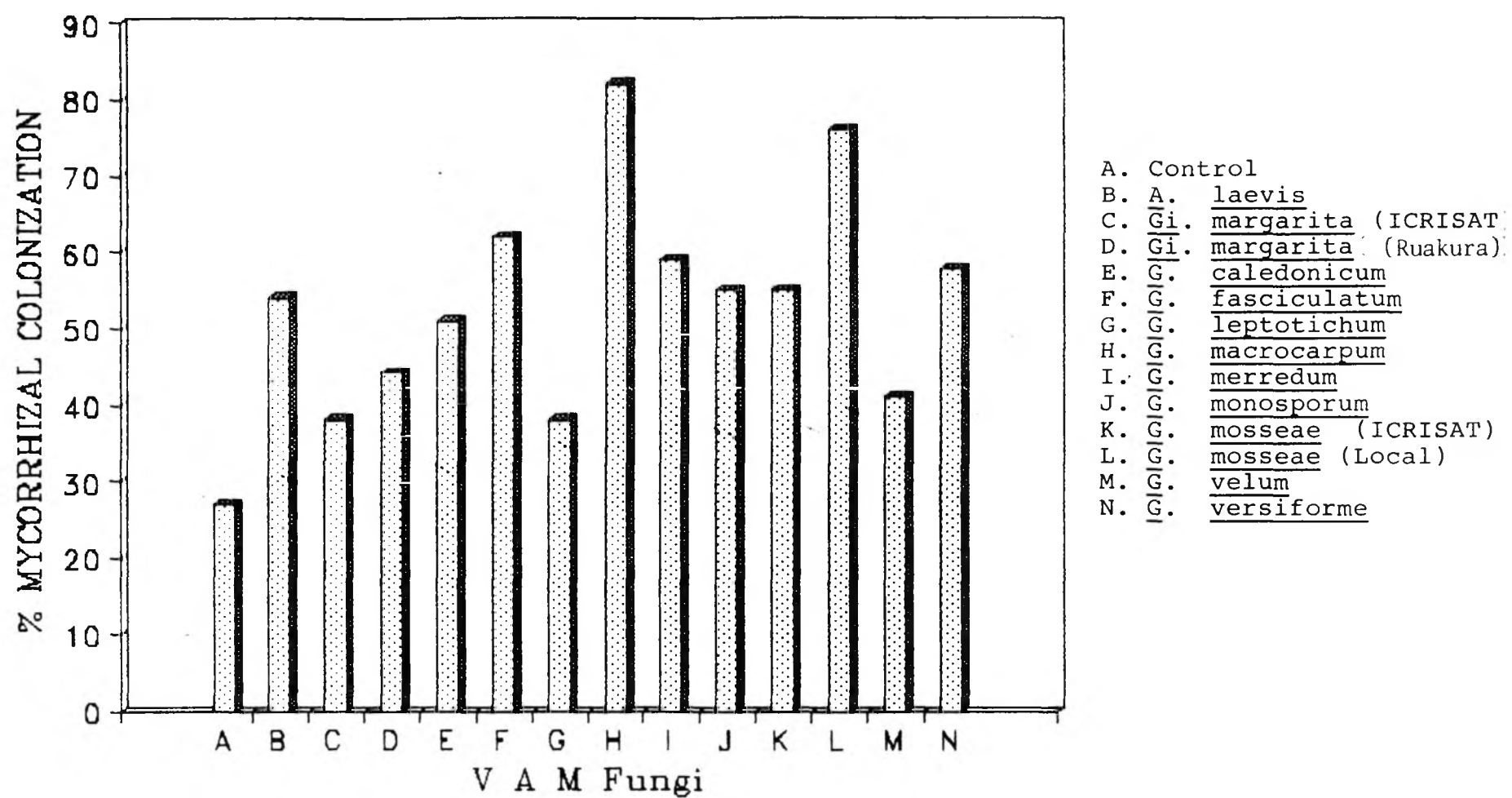


Fig. 11. Effect of different VAM fungi on the mycorrhizal root colonization of acid lime.

Per cent mycorrhizal colonization of the root: The per cent mycorrhizal root colonization significantly varied among the treatment (Table 17, Fig. 11). Highest root colonization was seen in plants inoculated with G. macrocarpum (82%) and G. mosseae (local) (76%) the two being statistically on par with each other. Uninoculated plants had 27 per cent root colonization.

Number of mycorrhizal infective propagules in soil: The number of infective propagules produced in soil by different mycorrhizal treatments is given in Table 17. Root zone soil of plants inoculated with G. caledonicum, G. leptotichum, Gi. margarita (Ruakura), Gi. margarita (ICRISAT), G. monosporum and G. fasciculatum had 2.8, 2.6, 0.22, 0.22, 0.22 and 0.21 x 10⁶ infective propagules per g of soil, respectively.

Selection of efficient VAM fungi for papaya

Symbiotic response of papaya var. solo to inoculation with 13 different VAM fungi was studied. The effect of inoculation on different plant and soil parameters studied are given below.

Effect of different VAM fungi on height of papaya: Though there was considerable increase due to inoculation with different VAM fungi, 45 days after transplanting the

differences were not statistically significant. On the 90th day all the inoculated treatments were significantly on par with each other but different from the uninoculated plants. However, the top five fungi which gave maximum plant height were G. mosseae (local), G. fasciculatum, G. versiforme, G. monosporum and G. mosseae (ICRISAT). Height of uninoculated plants was least.

Effect of different VAM fungi on number of leaves: Table 19 shows the effect of different mycorrhizal fungi on the number of leaves of papaya. The differences were not significant on the 45th day although it was more in most of the plants treated with mycorrhizal fungi. The differences were significant on 90th day after transplanting. Uninoculated plants had more number of leaves compared to some mycorrhiza treated plants which were bigger. Shedding of leaves as the plant grows is common in papaya.

Effect of different VAM fungi on total leaf area: The total leaf area was determined on the day of harvest i.e., 90 days after transplanting is given in table 19. Plants inoculated with different VAM fungi did not vary significantly with respect to leaf area. However, maximum total leaf area recorded in plants treated with G. mosseae (ICRISAT), G. caledonium, G. fasciculatum, G. mosseae

Table 18: Effect of different VAM fungi on plant height (cm) of papaya

Sl. No.	VAM fungi	Days after transplanting	
		45d	90d
1.	Control	23.87	37.00
2.	<u>A. laevis</u>	31.63	47.00
3.	<u>Gi. margarita</u> (ICRISAT)	28.00	42.00
4.	<u>Gi. margarita</u> (Ruakura)	24.00	47.75
5.	<u>G. caledonicum</u>	27.37	44.25
6.	<u>G. fasciculatum</u>	32.37	49.50
7.	<u>G. leptotichum</u>	26.00	42.50
8.	<u>G. macrocarpum</u>	30.37	45.62
9.	<u>G. merredum</u>	27.50	38.25
10.	<u>G. monosporum</u>	27.25	49.25
11.	<u>G. mosseae</u> (ICRISAT)	36.00	56.00
12.	<u>G. mosseae</u> (Local)	26.25	48.50
13.	<u>G. velum</u>	25.25	43.25
14.	<u>G. versiforme</u>	26.25	49.25
F test		NS	**
CV			12.26
SEm ±			0.6954

Summary of comparison based on Student Newman-Keul's test at 5% significance level

90 days: 1 9 3 7 13 5 8 2 4 12 14 6 11

Table 19: Effect of different VAM fungi on number of leaves and leaf area(cm²) of papaya

Sl. No.	VAM fungi	Days after transplanting		Leaf area (cm ²)
		Number of leaves		
		45d	90d	90d
1.	Control	10.75	11.00	324.00
2.	<u>A. laevis</u>	10.75	7.75	333.25
3.	<u>Gi. margarita</u> (ICRISAT)	11.50	9.25	456.75
4.	<u>Gi. margarita</u> (Ruakura)	10.50	9.25	455.25
5.	<u>G. caledonicum</u>	11.25	9.75	591.25
6.	<u>G. fasciculatum</u>	11.50	10.00	541.50
7.	<u>G. leptotichum</u>	11.25	11.25	505.50
8.	<u>G. macrocarpum</u>	13.00	9.50	396.25
9.	<u>G. merredum</u>	10.50	8.00	375.50
10.	<u>G. monosporum</u>	11.25	10.25	412.75
11.	<u>G. mosseae</u> (ICRISAT)	12.50	10.75	607.70
12.	<u>G. mosseae</u> (Local)	11.25	8.25	523.75
13.	<u>G. velum</u>	11.25	11.00	465.00
14.	<u>G. versiforme</u>	11.50	10.00	491.00
	F test	NS	**	NS
	CV	12.26	4.11	31.24
	SEm ±	0.6954	0.6857	72.31

Summary of comparison based on Student Newman-Keul's test at 5% significance level

90 days : 2 9 12 13 4 8 5 6 14 10 11 1 13 7

(local) and G. leptotichum. Eventhough the number of leaves were more in control plants the leaf area was least in uninoculated control plants.

Effect of different VAM fungi on stem girth: The effect of mycorrhizal inoculation on improving stem girth of papaya was significant only on 90th day of observation (Table 20). Significantly more stem girth was observed only in plants inoculated with G. mosseae (ICRISAT) and G. mosseae (local) both being statistically on par with each other.

Effect of different VAM fungi on shoot and root biomass:

Shoot: Plants inoculated with different VAM fungi varied significantly with respect to shoot biomass. Table 21 and Fig. 12a illustrate the variation in shoot biomass due to mycorrhizal inoculation. The best significant response was obtained in plants inoculated with G. mosseae (ICRISAT). The next best significant response was obtained with G. caledonicum. This was followed by G. fasciculatum, G. mosseae (local), G. macrocarpum, G. versiforme, Gi. margarita (Ruakura) and G. monosporum. These six fungi were statistically on par with each other. It was least in uninoculated control plants.

Table 20: Effect of different VAM fungi on stem girth (cm) of papaya

Sl. No.	VAM fungi	Days after transplanting	
		45d	90d
1.	Control	0.79	1.02
2.	<u>A. laevis</u>	0.99	1.23
3.	<u>Gi. margarita</u> (ICRISAT)	0.82	1.16
4.	<u>Gi. margarita</u> (Ruakura)	0.72	1.10
5.	<u>G. caledonicum</u>	0.78	1.15
6.	<u>G. fasciculatum</u>	0.74	1.22
7.	<u>G. leptotichum</u>	0.84	1.31
8.	<u>G. macrocarpum</u>	0.91	1.18
9.	<u>G. merredum</u>	0.71	1.00
10.	<u>G. monosporum</u>	0.86	1.20
11.	<u>G. mosseae</u> (ICRISAT)	1.09	1.60
12.	<u>G. mosseae</u> (Local)	0.74	1.41
13.	<u>G. velum</u>	0.72	1.13
14.	<u>G. versiforme</u>	0.83	1.18
	F test	NS	**
	CV	26.12	11.39
	SEm ±	0.1080	0.0639

Summary of comparison based on Student Newman-Keul's test at 5% significance level

90 days: 9 1 4 13 5 3 8 14 10 6 2 7 12 11

Table 21: Effect of different VAM fungi on plant biomass (g/plant) of papaya

Sl. No.	VAM fungi	Shoot	Root
1.	Control	3.43	0.47
2.	<u>A. laevis</u>	4.05	1.22
3.	<u>Gi. margarita</u> (ICRISAT)	4.50	2.12
4.	<u>Gi. margarita</u> (Ruakura)	4.60	1.55
5.	<u>G. caledonicum</u>	6.07	1.72
6.	<u>G. fasciculatum</u>	5.17	1.40
7.	<u>G. leptotichum</u>	3.92	1.22
8.	<u>G. macrocarpum</u>	4.85	1.40
9.	<u>G. merredum</u>	4.05	0.80
10.	<u>G. monosporum</u>	4.55	1.37
11.	<u>G. mosseae</u> (ICRISAT)	7.50	2.37
12.	<u>G. mosseae</u> (Local)	4.85	1.77
13.	<u>G. velum</u>	3.50	0.85
14.	<u>G. versiforme</u>	4.75	2.00
	F test	**	**
	CV	9.9031	48.59
	SEm ±	6.234	0.3527

Summary of comparison based on Student Newman-Keul's test at 5% significance level

Shoot biomass: 1 13 7 2 9 3 10 4 14 8 12 6 5 11
Root biomass: 1 9 13 7 2 10 6 8 4 5 12 14 3 11

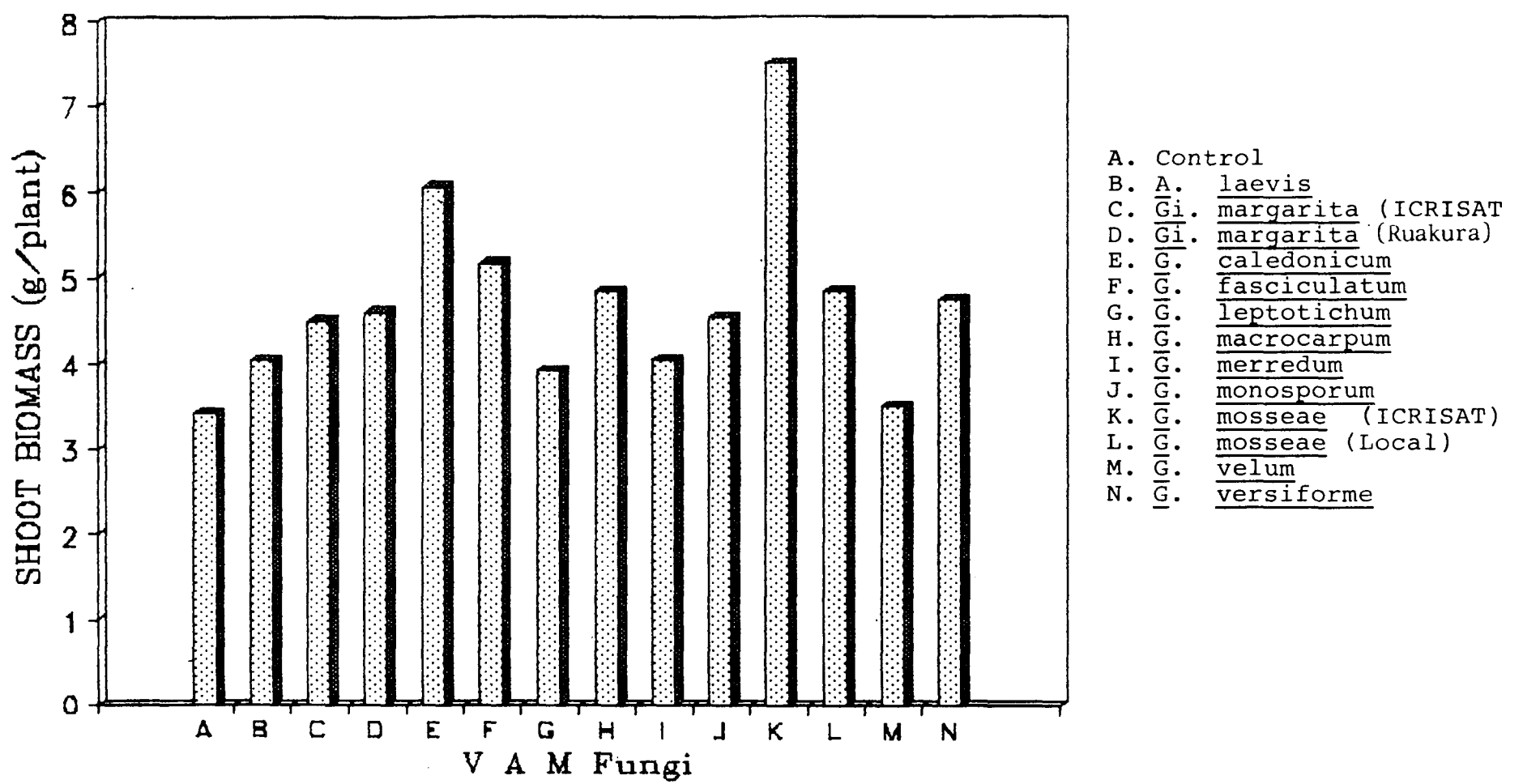


Fig. 12a. Effect of different VAM fungi on shoot biomass of Papaya.

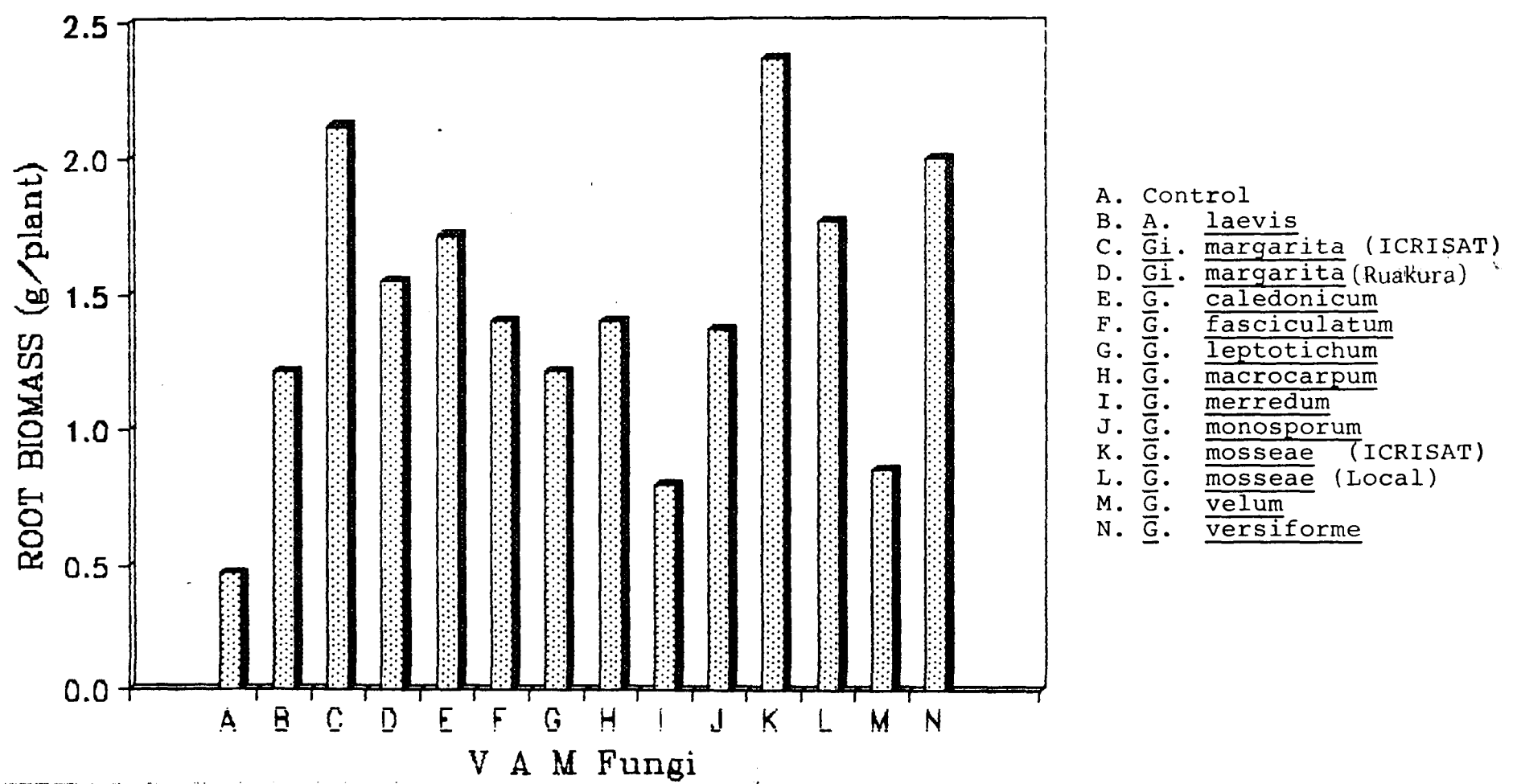


Fig. 12b. Effect of different VAM fungi on root biomass of Papaya.

Plate 5a and b: Response of papaya to inoculation with G. mosseae (ICRISAT)

	a Shoot	b Root
1	Control	
2	<u>G. mosseae</u>	



Plate 5a



Plate 5b

Root: Inoculation with all the mycorrhizal fungi significantly increased root biomass and all of them were statistically on par with each other (Table 21, Fig. 12b). Based on these results it can be concluded that G. mosseae (ICRISAT) is the best fungus for inoculating papaya, the next best being G. caledonicum (Plate 5a and 5b).

Effect of different VAM fungi on P content

Shoot: Differences in shoot P content because of inoculation with various VAM fungi were statistically significant (Table 22, Fig. 13a). The top five fungi which recorded maximum shoot P were G. macrocarpum, Gi. margarita (ICRISAT), G. mosseae (local), G. fasciculatum, and G. mosseae (ICRISAT). It was least in uninoculated control plants.

Root: Root P content varied significantly due to inoculation with different VAM fungi (Table 22, Fig. 13b). Except G. merredum and A. leavis all the other fungi significantly improved root P content. Maximum P content was however recorded in plants inoculated with G. versiforme, G. mosseae (ICRISAT), Gi. margarita (ICRISAT) and G. caledonicum.

Effect of different VAM fungi on Zn content

Shoot: Zinc content of the shoot varied significantly due to mycorrhizal inoculation (Table 23, Fig. 14a). Except A. leavis and G. caledonicum inoculation with all the

Table 22: Effect of different VAM fungi on 'P' content (mg/plant) of papaya

Sl. No.	VAM fungi	Shoot	Root
1.	Control	18.33	3.49
2.	<u>A. laevis</u>	55.00	11.00
3.	<u>Gi. margarita</u> (ICRISAT)	73.00	29.05
4.	<u>Gi. margarita</u> (Ruakura)	63.00	21.34
5.	<u>G. caledonicum</u>	61.67	26.27
6.	<u>G. fasciculatum</u>	46.00	14.95
7.	<u>G. leptotichum</u>	61.67	16.21
8.	<u>G. macrocarpum</u>	74.00	18.69
9.	<u>G. merredum</u>	39.33	9.24
10.	<u>G. monosporum</u>	56.67	18.60
11.	<u>G. mosseae</u> (ICRISAT)	69.00	30.44
12.	<u>G. mosseae</u> (Local)	71.67	15.40
13.	<u>G. velum</u>	56.67	16.79
14.	<u>G. versiforme</u>	65.00	38.42
	F test	**	**
	CV	28.0283	51.40
	SEm ±	9.4319	3.6089

Summary of comparison based on Student Newman-Keul's test at 5% significance level

Shoot P	<u>1 9 5</u>	<u>2 13</u>	<u>10 7 4 14 11 6 12 3 8</u>
Root P	<u>1 9 2</u>	<u>6 12 7 13 10 8 4 5 3 11 14</u>	

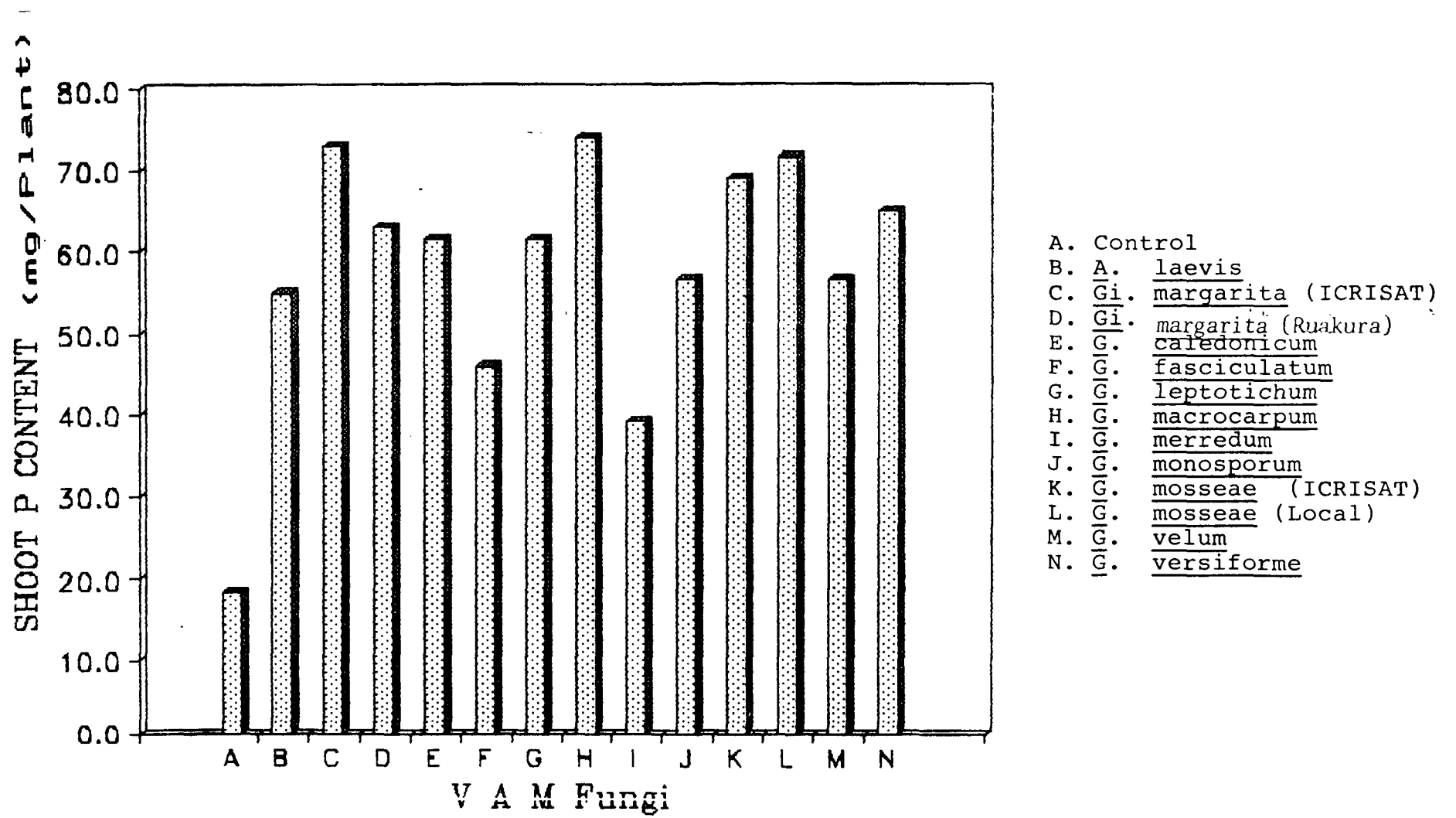


Fig. 13a. Effect of different VAM fungi on shoot P content of Papaya.

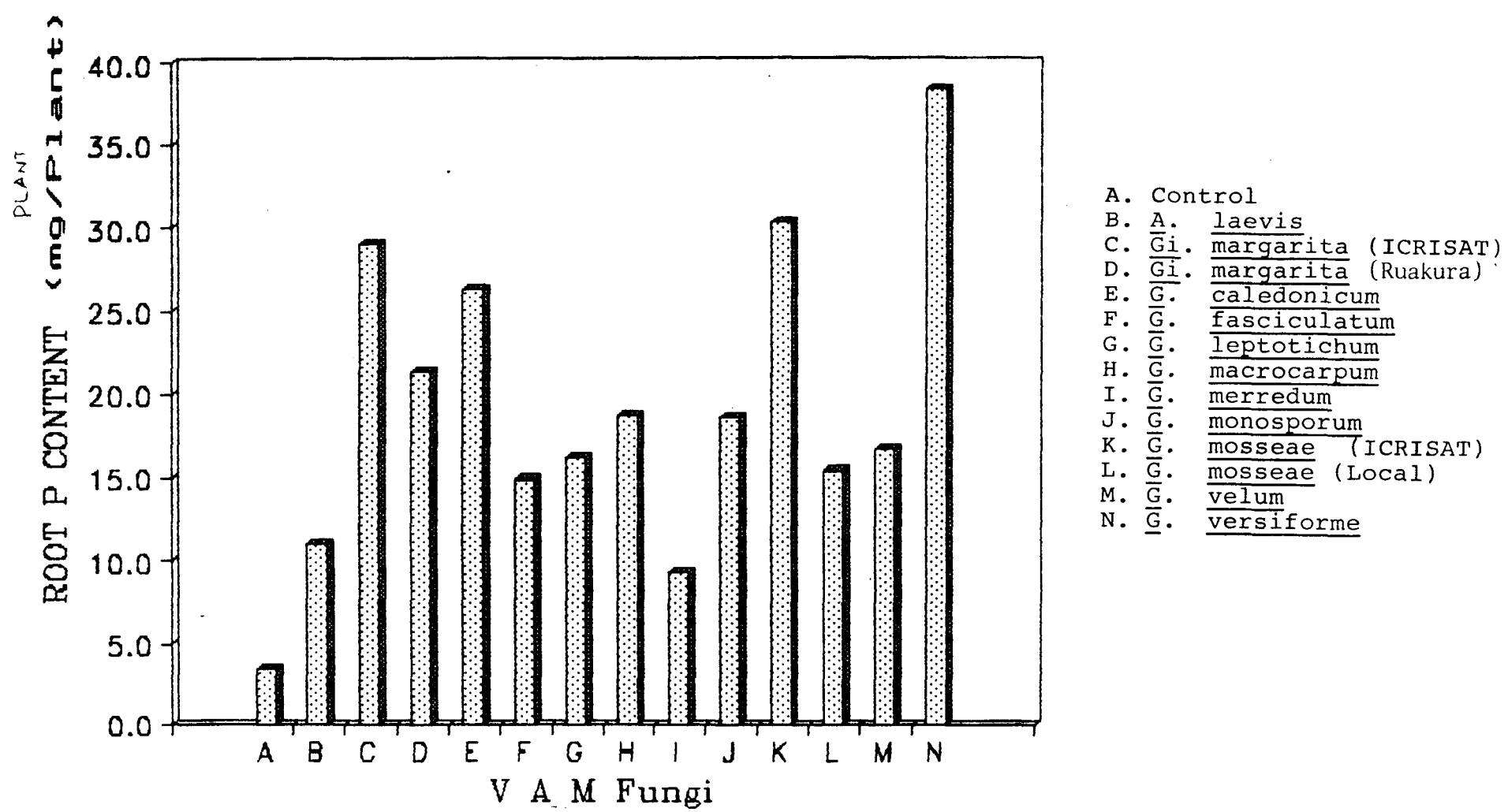


Fig. 13b. Effect of different VAM fungi on root P content of Papaya.

Table 23: Effect of different VAM fungi on Zn content (µg/plant) of papaya

Sl. No.	VAM fungi	Shoot	Root
1.	Control	233.90	355.83
2.	<u>A. laevis</u>	250.80	490.33
3.	<u>Gi. margarita</u> (ICRISAT)	580.60	530.29
4.	<u>Gi. margarita</u> (Ruakura)	257.90	549.40
5.	<u>G. caledonicum</u>	262.40	388.20
6.	<u>G. fasciculatum</u>	556.50	438.67
7.	<u>G. leptotichum</u>	683.80	455.67
8.	<u>G. macrocarpum</u>	553.06	511.87
9.	<u>G. merredum</u>	853.06	320.13
10.	<u>G. monosporum</u>	543.46	487.50
11.	<u>G. mosseae</u> (ICRISAT)	606.80	644.93
12.	<u>G. mosseae</u> (Local)	599.00	659.06
13.	<u>G. velum</u>	654.00	540.33
14.	<u>G. versiforme</u>	611.33	540.53
	F test	**	**
	CV	15.952	16.31
	SEm ±	47.61	46.345

Summary of comparison based on Student Newman-Keul's test at 5% significance level

Shoot Zn : 1 2 5 4 10 8 6 9 3 12 11 14 13 7
Root Zn : 9 1 5 6 7 10 2 8 3 13 14 4 11 12

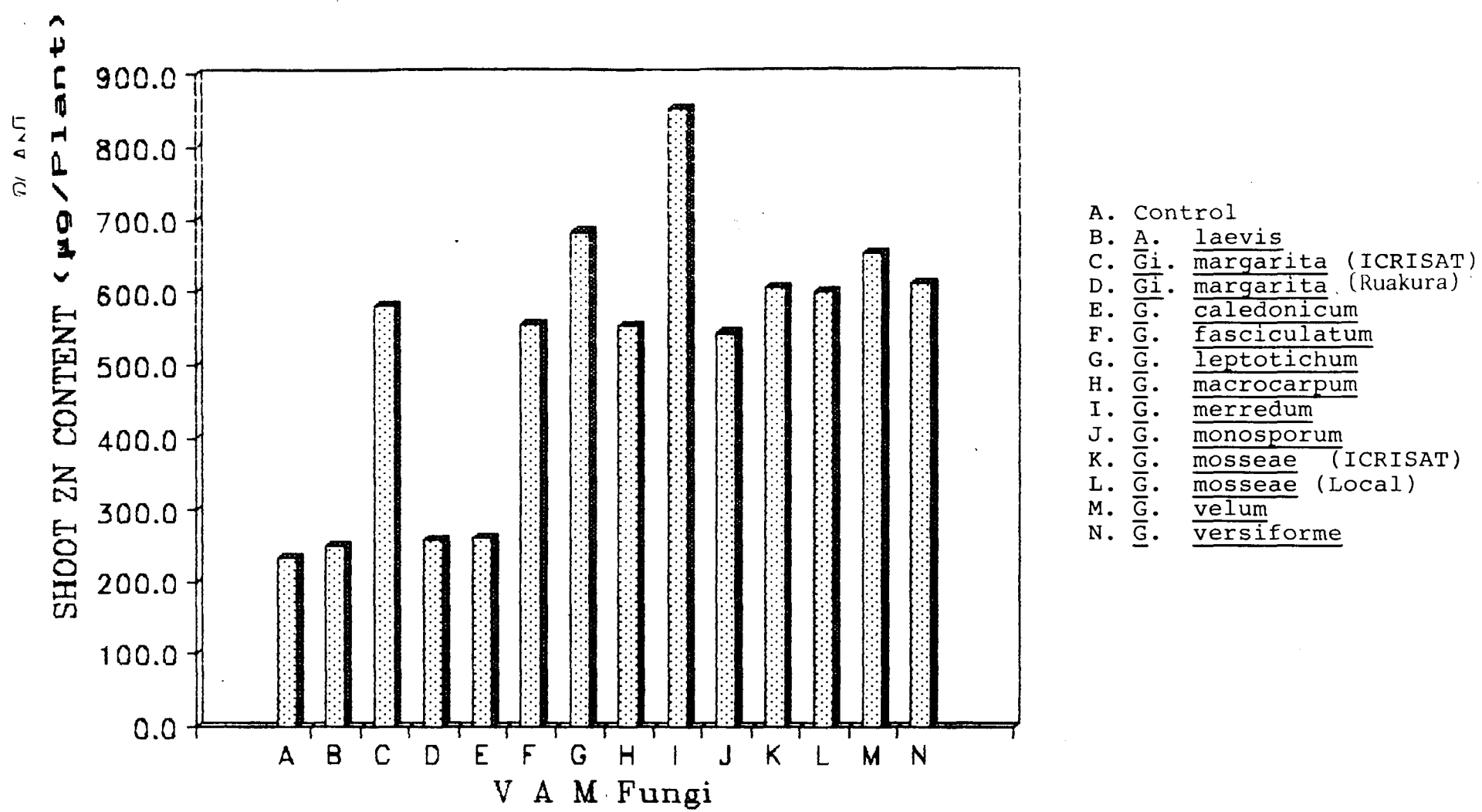


Fig. 14a. Effect of different VAM fungi on shoot Zn content of Papaya.

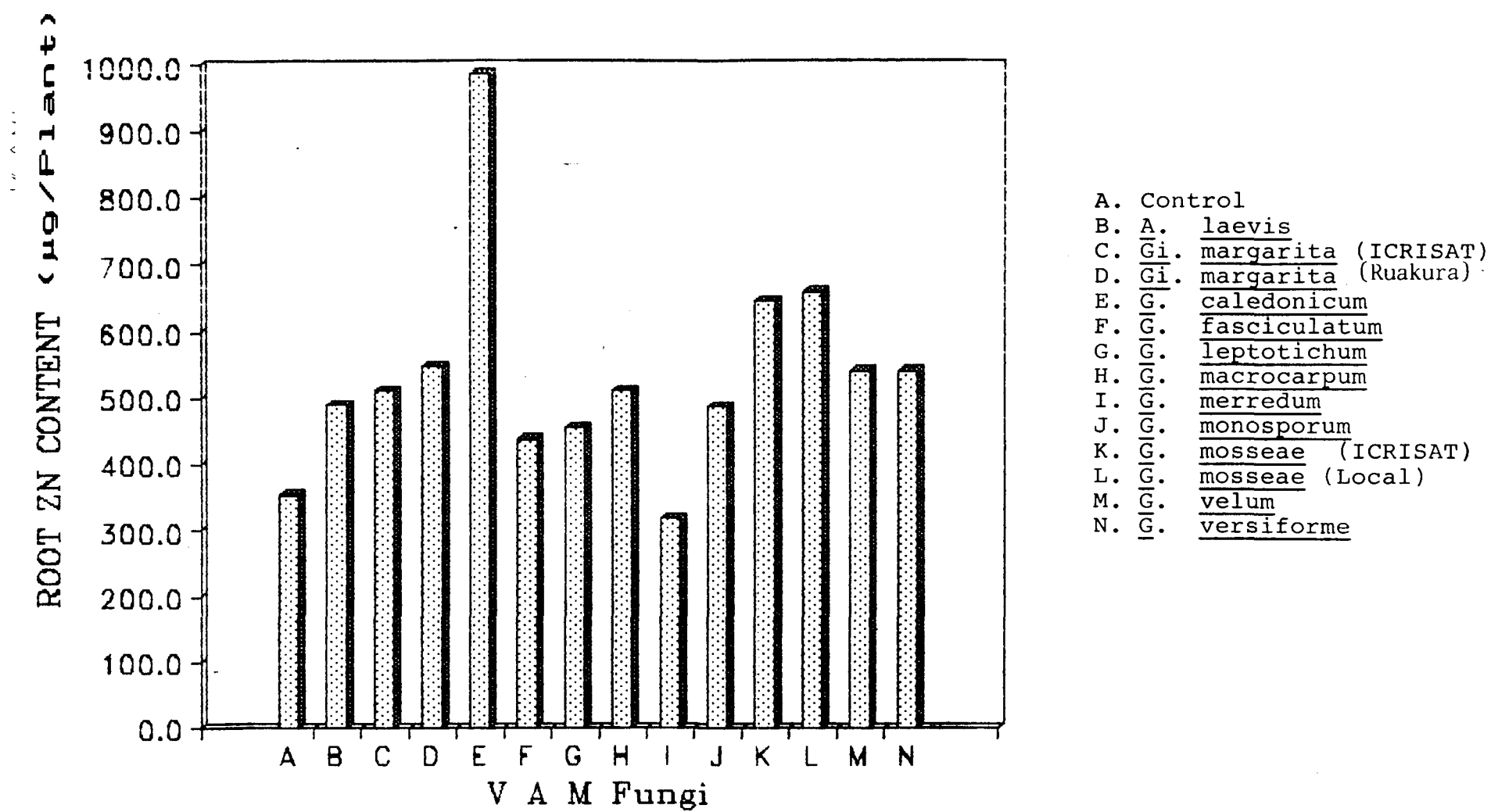


Fig. 14b. Effect of different VAM fungi on root Zn content of Papaya.

other fungi significantly improved the shoot Zn content. More Zn content was recorded in plants inoculated with G. leptotichum, G. velum, G. versiforme and G. mosseae (ICRISAT).

Root: Root Zn content varied significantly due to mycorrhizal inoculations (Table 23, Fig. 14b). Except three fungi (G. merredum, G. caledonium and G. fasciculatum), all the others significantly increased root Zn content. More Zn content was recorded in plants inoculated with G. mosseae (local), G. mosseae (ICRISAT), Gi. versiforme.

Mycorrhizal spore count in soil: Table 24 and Fig. 15 illustrates the mycorrhizal spore count in root zone soil as influenced by inoculation with different VAM fungi. Maximum counts were recorded in G. leptotichum, followed by G. mosseae (ICRISAT), G. versiforme, G. merredum, G. velum, G. macrocarpum and G. fasciculatum which were all statistically on par with each other.

Mycorrhizal root colonisation of papaya

Maximum colonisation was seen in plants treated with G. mosseae (ICRISAT) (77%) and G. mosseae (local) (76%) the two being statistically equivalent (Table 24, Fig.16). The next higher colonization was seen with plants inoculated with G. leptotichum (54%). Uninoculated plants had only 14 per cent colonisation.

Table 24: Effect of different VAM fungi on spore count and number of infective propagules in soil and per cent root colonization of papaya

Sl. No.	VAM fungi	Spore count/ 30 g soil	% mycorrhizal colonization	infective propagule Number x10 ⁶
1.	Control	36	14.00	0.004
2.	<u>A. laevis</u>	129	34.00	0.14
3.	<u>Gi. margarita</u> (ICRISAT)	130	38.50	0.014
4.	<u>Gi. margarita</u> (Ruakura)	140	33.00	0.20
5.	<u>G. caledonicum</u>	133	38.50	0.20
6.	<u>G. fasciculatum</u>	169	40.00	1.30
7.	<u>G. leptotichum</u>	255	53.50	0.49
8.	<u>G. macrocarpum</u>	181	22.00	0.02
9.	<u>G. merredum</u>	212	40.00	0.11
10.	<u>G. monosporum</u>	130	31.00	0.21
11.	<u>G. mosseae</u> (ICRISAT)	249	76.00	0.20
12.	<u>G. mosseae</u> (Local)	156	77.00	1.70
13.	<u>G. velum</u>	182	33.00	0.24
14.	<u>G. versiforme</u>	243	40.00	0.70
	F test	**	**	
	CV	21.46	14.85	
	SEm ±	20.79	3.0326	

Summary of comparison based on
Student Newman-Keul's test at
5% significance level

Spore count : 1 2 3 10 5 4 12 6 8 13 9 14 117
% colonization : 1 8 10 4 13 2 5 3 6 9 14 7 11 12

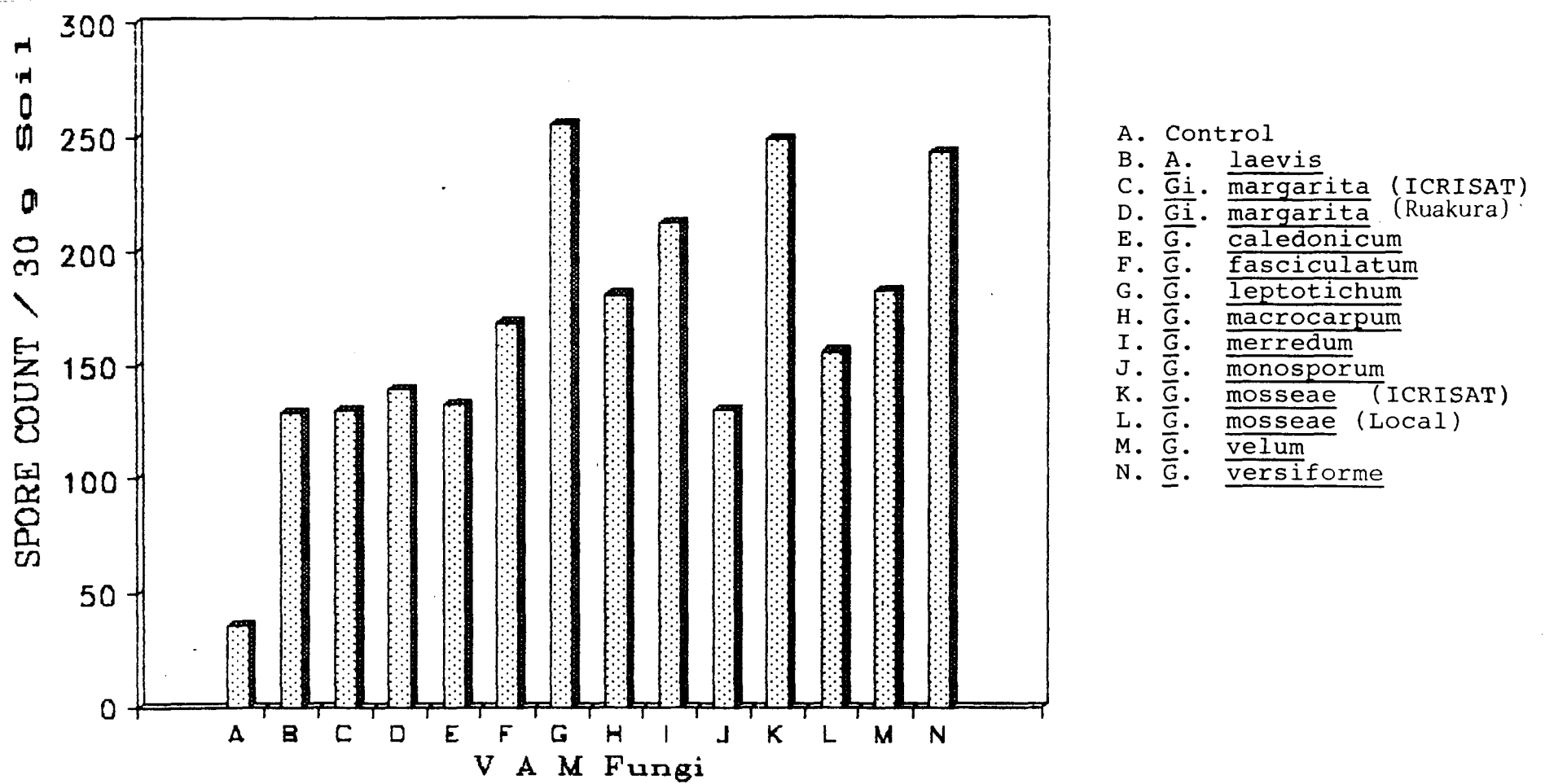


Fig. 15. Effect of different VAM fungi on the mycorrhizal spore count in the root zone soil of Papaya.

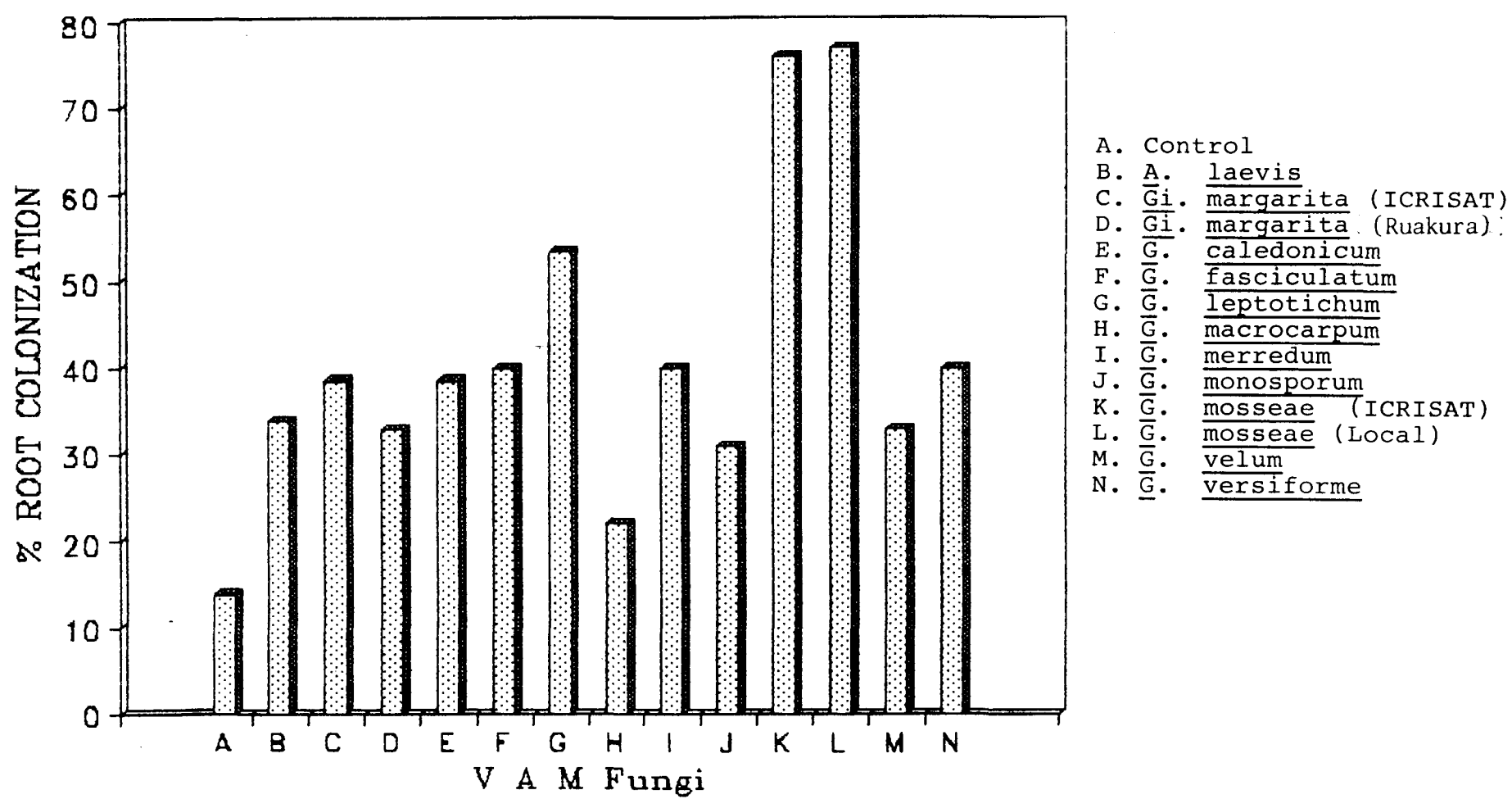


Fig. 16. Effect of different VAM fungi on the mycorrhizal root colonization of Papaya.

Number of mycorrhizal infective propagules in soil: The number of infective propagules produced in soil by different mycorrhizal treatments are given in table 24. Plants inoculated with G. mosseae (local), G. monosporum had 1.70, 1.30, 1.70, 0.24 and 0.21 x 10⁶ infective propagules per g root zone soil. In the uninoculated treatment, the number of infective proagules was 0.004 x 10⁶ per g soil.

DISCUSSION

V. DISCUSSION

Fruit crops are usually high value crops and their production often involves expensive practices such as soil fumigation, sophisticated fertilizer application, plant protection measure etc. Enhanced growth due to inoculation with mycorrhizal fungi is desirable because of more rapid turnover and thus greater productivity, decreased labour, fertilizer and water per plant.

Scientists in recent years have demonstrated the beneficial or essential role of VAM fungi in the lives of many plants of horticultural interest. The growth improvement is mainly through phosphorus nutrition..

Mango, acid lime and papaya are three important fruit crops grown in the tropics. The first two are slow growers. The present study attempted at selecting efficient VAM fungi for inoculating these three fruit crops, so that healthy vigorously growing seedlings are produced.

Mango

Mango is propagated by grafting. Nekkare is one of the important root stocks used for different types of grafting. This mango was reported as polyembryonic (Rai et al., 1970) and a slow grower.

The results of the present study clearly revealed that mango root stock Nekkare responds well to inoculation with VAM fungi. Generally inoculated plants had greater height, stem diameter and leaf area compared to uninoculated plants. Plants inoculated with VAM fungi also had more plant biomass compared to uninoculated controls. Best response in terms of biomass was obtained in plants inoculated with G. monosporum, G. versiforme and Gi. margarita (Ruakura) producing 2.2 folds increase over uninoculated controls.

There is no published information on response of mango to mycorrhizal inoculation. The only paper on mycorrhizal association in mango is monitoring the mycorrhizal spore production in its rhizosphere in different seasons (Harinikumar and Bagyaraj, 1988). But information is available on response of other fruits trees to mycorrhizal inoculation. Plenchette et al. (1981) reported apple seedlings, inoculated with VAM fungi increased shoot length, root volume and dry mass. Graner et al. (1983) studying the response of apple clones propagated in vitro to mycorrhizal inoculation found that 15 weeks after inoculation total leaf area and leaf dry weight increased 1.9 time over control.

The VAM fungi improving plant biomass were also good in increasing the P content of the host. Inoculated plants contained significantly higher amounts of P in their shoot and root than uninoculated plants. Maximum P content was observed when plants inoculated with Gi. margarita (Ruakura) followed by G. monosporum, G. macrocarpum, G. fasciculatum and A. laevis. Increased uptake of P in apples because of mycorrhizal inoculation has been reported by Mosse (1957) and Plenchette et al. (1981). Such improved P nutrition due to mycorrhizal inoculation has also been observed in strawberries (Holevas, 1966) and avocados (Menge et al., 1978a). This increased P uptake is attributed to increased absorbing surface area due to the extensive network of mycelium produced by the VAM fungi in association with the host root system (Howeler, et al., 1981).

Increased uptake of other nutrients especially Zn in mycorrhizal plants has been reported by some workers. Gilmore (1971) noticed that peach seedlings inoculated with mycorrhiza had two to three times more Zn than the uninoculated plants. The present study in mango supported the above findings.

The most important characteristic expected of a mango root stock is its fast growth to reach a stem girth of 0.8 to 1.0 cm at 10 cm above ground for wedge and

Veneer grafting and 0.5 to 0.6 cm at 10.0 cm below the tip for soft wood grafting (Mitra and Bose, 1986). The present study clearly brought out that the best fungi increasing stem girth at different levels are G. mosseae (local), G. fasciculatum and Gi. margarita (Ruakura). Such increase in stem girth because of mycorrhizal inoculation has been observed in apple (Plenchette et al., 1981) and citrus (Vinayak and Bagyaraj, 1990). Increase in stem ~~girth~~ because of mycorrhizal inoculation has also been reported in banana (Lin and Chang, 1987).

The mycorrhizal parameters like per cent root colonization, extra matricular spore count were considerably higher in all the inoculated treatments. These mycorrhizal parameters varied with different VAM fungi. In the present study G. monosporum and G. mosseae (local) inoculated mango root stock Nekkare had highest mycorrhizal colonization and spore count. Higher root colonization and sporulation makes more fungal host contact and more exchange of nutrients and hence, better plant growth (Daft and Nicolson, 1972).

Giving more importance to the stem girth character and considering other characters like plant biomass and P nutrition, the most useful mycorrhizal symbionts for

Nekkare mango are Gi. margarita (Ruakura), G. fasciculatum and G. mosseae (local). The improvements in plant growth parameters induced by these fungi were statistically equivalent, suggesting that the three fungi are equally efficient.

Acid lime

Citrus being a mycotrophic plant, due to its magnoloid root system, lacking fine root hair, does not survive without the mycorrhizal association unlike mango. Considerable amount of research has been done on response of citrus to mycorrhizal inoculation. But the work on acid lime is less and no systematic study has been done to screen and select on efficient VAM symbiont for inoculating this crop.

The present study clearly revealed that acid lime responds well to inoculation with VAM fungi. Generally inoculated plants had greater height, stem girth and leaf area compared to uninoculated plants.

For acid lime G. macrocarpum, G. mosseae (local), A. laevis, G. caledonicum and Gi. margarita were the top five fungi, all statistically equivalent in improving plant height. These fungi were also found to be good in improving other parameters such as leaf number, leaf area

and stem girth. Increased leaf number and total leaf area perhaps enhanced the photosynthetic activity of these plants. Chandrababu et al. (1983) reported that the plant height and stem girth of nine month-old seedlings of Citrus aurantifolia, Italian lemon, mandarin, rough lemon Rangapur lime were appreciably greater in plants inoculated with G. mosseae or G. etunicatus. Enhanced plant height, number of leaves, leaf area and stem girth because of mycorrhizal inoculation has been observed in trifoliate orange and troyer citrange (Vinayak and Bagyaraj, 1990a,b).

Plant inoculated with VAM fungi also had more plant biomass compared to uninoculated controls. G. macrocarpum, G. mosseae (local), G. caledonicum and Gi. margarita were the top five fungi which were all statistically equivalent in improving plant biomass. More or less the same fungi also enhanced P and Zn nutrition of acid lime. Earlier scientists have observed increased plant biomass and P and Zn content of different citrus varieties to inoculation with VAM fungi (Schenck and Tucker, 1974; Mohoney and Nemec, 1979; Shanmugum et al., 1981; Manjunath et al., 1983; Vinayak and Bagyaraj, 1990,a,b).

The mycorrhizal parameters like per cent root colonization and extra matricular spore count were higher in plants inoculated with G. macrocarpum, G. mosseae (local) and Gi. margarita (Ruakura) thus bringing out a correlation between intensity of mycorrhization and plant response (Gerdemann, 1964).

Giving more weightage to plant biomass and P nutrition but not neglecting the other characteristics the two best VAM fungi for inoculating acid lime appear to be G. macrocarpum and G. mosseae (local).

Papaya

The amount of information available on the possibility of improving growth of papaya through VAM inoculation is scanty. a literature research revealed only two reports (Ramirez et al., 1975, Mohandas, 1987). No attempt has been made so far to systematically screen and select an efficient inoculant VAM fungus for papaya. The present study which attempted on this aspect revealed that papaya responds well to inoculation with VAM fungi. Generally inoculated plants had greater height, stem girth and leaf area compared to uninoculated plants.

For papaya G. mosseae (local), G. fasciculatum, G. versiforme, G. monosporum and G. mosseae (ICRISAT) were the top best fungi, all being statistically equivalent

in improving plant height. These fungi also improved other parameters such as leaf number, leaf area, stem girth, etc. Mohandas (1987) reported that the papaya seedlings inoculated with G. fasciculatum and G. mosseae increased plant height by 50 per cent. Ramirez et al. (1975) reported that papaya plants inoculated with G. calospora and G. macrocarpum were significantly taller than those of uninoculated plants 40 days after sowing.

Plants inoculated with VAM fungi also had more plant biomass compared to uninoculated controls. Best significant response was obtained in plants inoculated with G. mosseae (ICRISAT). The next best significant response was obtained with G. caledonicum. The VAM fungi improving plant biomass were also good in increasing P and Zn content of the host. Mohandas (1987) reported nearly 20 per cent increase in the plant biomass and leaf P content of papaya inoculated with G. fasciculatum and G. mosseae. The mycorrhizal parameters like per cent root colonization, extramatricular spore count and number of infective propagules were considerably higher in all the inoculated treatments. In the present study G. mosseae (local), G. mosseae (ICRISAT) and G. leptotichum inoculated plants showed highest values of the mycorrhizal parameters studied.

For papaya var. Solo the best VAM fungus for inoculation is G. mosseae (ICRISAT) and the next best is G. caledonicum.

It is well known that VAM fungi are not host-specific. Any VAM plant species can be colonized by any VAM fungal species, but the degree of colonization and its effects can differ with different host endophyte combinations (Mosse, 1973). The present study also upholds this view. Since the early endophyte screening trials of Mosse (1972) it has become more and more obvious that VAM fungi differ greatly in their symbiotic effectiveness. Though a particular VAM fungus can infect and colonize many host plants, it has a preferred host which exhibits maximum symbiotic response when colonized by that particular VAM fungus. This lead to the concept of 'host preference' in VAM fungi. Several recent studies uphold the the existence of host preference by VAM fungi (Nemec,1977; Bagyaraj et al., 1988; Reena and Bagyaraj, 1990a,b; Vinayak and Bagyaraj, 1990a,b). The results of the present study also supports this view.

The present investigation also revealed that species and strains of VAM fungi differ to the extent by which they increase nutrient uptake and plant growth. Powell (1982) describing a procedure for selection and screening VAM fungi in pot and field trial, reported that fungi isolated from different soil sources caused

different responses with rye grass. He stressed that long term ability of the fungi to absorb P from the soil should be the most important criterion for selecting an efficient fungus and hence, plants should be harvested over a long period to ensure that selection for long term P uptake ability is achieved. The 'efficient fungus' refers to ability of the fungus to increase the plant growth in a phosphate deficient soil. This depends on the ability to form extensive and well distributed hyphae in soil, ability to absorb phosphorus from soil solution and the longevity of the transport mechanism along the hyphae and into the root (Abbott and Robson, 1982).

There have been a few attempts recently to select efficient VAM fungi for inoculating economically important forest tree species like Leucaena leucocephala (Bagyaraj et al., 1989), Tamarindus indica (Reena and Bagyaraj, 1990a), Acacia nilotica and Calliandra calothyrsus (Reena and Bagyaraj, 1990b) and root stocks of citrus (Vinayak and Bagyaraj, 1990a,b). Inoculation of citrus root stocks with efficient fungi made them ready for budding 4 to 6 months early, which had an impact in citriculture. Similarly in the present study inoculation with efficient VAM fungi made the mango root stock Nekkare to grow fast. For mango rootstocks one of the most desirable

characteristics is the speed in reaching a stem girth of 0.8 to 1.0cm (10 cm above ground) so that they are ready for wedge and veneer grafting or a stem girth of 0.5 to 0.6cm (at 10 cm below the tip) for softwood grafting. Being a slow grower, Nekkere is ready for softwood grafting 9 to 10 months after sowing and 12 to 14 months for wedge and veneer grafting. The present study shows that inoculation with any one of the three efficient fungi selected can make Nekkare mango ready for grafting in about eight months, thus saving about 1 to 2 months time for soft wood grafting and 4 to 6 months time for wedge and veneer grafting.

From the present study it can be concluded that the best fungi for inoculating Nekkare mango are Gi. margarita (Ruakura), G. fasciculatum and G. mosseae. For acid lime the two best fungi are G. macrocarpum and G. mosseae (local). For papaya the best VAM symbiont is G. mosseae (ICRISAT), the next best being G. caledonicum. The increase in plant biomass compared to uninoculated plants was 53, 48 and 51 per cent respectively in mango, acid lime and papaya. The simple method of inoculating nursery beds or polythene bags with small quantities of mycorrhizal inoculum before sowing these fruit crops can easily be followed by growers or nurserymen in order to

produce healthy, vigorously growing seedlings. The present study also emphasises the need to screen and select efficient VAM fungi for different fruit crops, at least for the mycotrophic species.

SUMMARY

VI. SUMMARY

The main objective of the present investigation was to screen and select efficient mycorrhizal fungi for three important fruit crops viz., mango root stock Nekkare, acid lime and papaya. The experiment was conducted in the alfisol soil:sand (1:1) mix with 13 different VAM fungal isolates. The fungi used were A. laevis, Gi. margarita, (ICRISAT), Gi. margarita (Ruakura), G. caledonicum, G. fasciculatum, G. leptotichum, G. macrocarpum, G. merredum, G. monosporum, G. mosseae (ICRISAT), G. mosseae (local), G. velum and G. versiforme.

For the mango only nine mycorrhizal fungi were used [except Gi. margarita (ICRISAT), G. merredum, G. mosseae (ICRISAT) and G. velum in the list above]. The various growth parameters studied were plant height, number of leaves, stem girth, leaf area, plant biomass, and P and Zn content. The mycorrhizal parameters studied were per cent root mycorrhizal colonization, number of spores and infective propagules in soil. These studies showed that 1) inoculation with VA mycorrhizal fungi generally improved plant biomass, stem girth, P and Zn nutrition. 2) the fungal isolates differed in their efficiency in improving plant growth. There was direct correlation between per cent root colonization and plant response.

Giving more weightage to the stem girth character and also considering other characters like plant biomass and P nutrition, it was found that the three best fungi for inoculating mango root stock Nekkare are G. mosseae (local), G. fasciculatum and Gi. margarita (Ruakura). The three fungi were equally efficient. Inoculation with any one of these fungi made the root stock Nekkare ready for grafting in about eight months, thus saving about one to two months time for soft wood grafting and four to six months for wedge and veneer grafting.

For acid lime the two best mycorrhizal fungi for improving plant growth and P nutrition were G. macrocarpum and G. mosseae (local). For papaya the best VAM symbiont was G. mosseae (ICRISAT) the next best was G. caledonicum. This increase in plant biomass compared to uninoculated plants was 48 per cent in acid lime and 51 per cent in papaya. These fungi can be used for routine inoculation in fruit nurseries to produce healthy, vigorously growing seedlings which can establish better in the field.

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APPENDICES

APPENDIX - I

RUAKURA PLANT NUTRIENT SOLUTION

1. MAJOR ELEMENTS

Solution A: $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	22.25
$\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$	75.50
NH_4NO_3	38.40
KNO_3	10.25
Solution B: NaCl	1.50
KH_2PO_4	12.00
K_2HPO_4	7.40
K_2SO_4	29.783
Na_2SO_4	2.691

2a. MINOR ELEMENTS

g/500ml

a. Boric acid	N_3BO_3	6.3831	Dissolve in 500ml water
b. Manganese	$\text{MnO}_2 \cdot 4\text{H}_2\text{O}$	20.2647	Dissolve in 20.26ml of Dil.N.HCl. make up to 500 ml with water.
c. Zinc	ZnCl_2	5.864	Dissolve on 117.3ml of 0.1 NHC1 and make up to 500ml with water.
d. Copper	$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$	1.2073	Dissolve in 12.07ml of 0.1 NHC1 and make up to 500 ml with water..
e. Molybdenum	$(\text{NH}_4)_6\text{MO}_7$ $0_{24}4\text{H}_2\text{O}$	0.2070	Dissolve in 500ml water.
f. Cobalt	$(\text{CoCl}_2 \cdot \text{H}_2)$	0.4088	Dissolve in 500ml Water.

Place 5ml of a,b,c,d,e and f in bottle and dilute to 2.5 liters with water.

APPENDIX -I
continued

3. Iron

13.5 g Ferric citrate ($\text{FeC}_6\text{H}_5\text{O}_7 \cdot 5\text{H}_2\text{O}$) is dissolved in 119ml of 1N HCl and diluted to 2.5 litres with water.

To make up the final nutrient solution:

Added 3200ml of solution A, 300 ml of solution B, 150 ml of solution containing minor elements 2 (diluted) and 22.5 ml of Ferric citrate solution and made up to 4.5 litres with water.

* For mycorrhizal plants

K_2HPO_4 and KH_2PO_4 were omitted.

APPENDIX - II
**^D
VANADOMOLYB_AIC ACID**

Solution A was prepared by dissolution of 25g of ammonium molybdate in 400ml of water. Solution B was prepared by dissolving 1.25 g of ammonium metavanadate in 300 ml of boiling water. Solution B was cooled and then 250ml of concentrated HNO_3 was added and the solution was again cooled to room temperature. Finally solution A was poured into solution B and the mixture diluted to one litre.

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