EFFECT OF VAM FUNGI ON GROWTH, YIELD AND DROUGHT TOLERANCE OF PAPAYA

NAGARAJAPPA ADIVAPPAR

DEPARTMENT OF POMOLOGY
KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE,
ARABHAVI – 591 310
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005

AUGUST 2001

EFFECT OF VAM FUNGI ON GROWTH, YIELD AND DROUGHT TOLERANCE OF PAPAYA

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the

Degree of

MASTER OF SCIENCE (HORTICULTURE)

in

POMOLOGY

By

NAGARAJAPPA ADIVAPPAR

DEPARTMENT OF POMOLOGY
KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE,
ARABHAVI – 591 310
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005

AUGUST 2001

DEPARTMENT OF POMOLOGY
Kittur Rani Channamma College of Horticulture, Arabhavi - 591 310
University of Agricultural Sciences, Dharwad - 580 005

CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF VAM FUNGI ON GROWTH, YIELD AND DROUGHT TOLERANCE OF PAPAYA**" *submitted by* **NAGARAJAPPA ADIVAPPAR** for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **POMOLOGY** of the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Place: Arabhavi
Date: August 2001

(P.B. PATIL)
Major Advisor
Professor and Head
Department of Pomology
K.R.C. College of Horticulture,
Arabhavi-591 310

16.10.01

Approved by
Chairman: ______________________
(P.B. Patil)

Members: 1. ______________________
(A.K. Rokhade)

2. ______________________
(C.P. Patil)

3. ______________________
(G.S.K. Swamy)

ACKNOWLEDGEMENT

It is indeed an immense pleasure to express my deep sense of gratitude and indebtedness to **DR. P.B. Patil**, *Professor and Head, Department of Pomology, Kittur Rani Channamma College of Horticulture, Arabhavi and Chairman of my advisory committee for his invaluable guidance, kind encouragement and constant advise throughout the period of this investigation and sustained interest and help in compilation of the thesis.*

I deeply indebted to members of my advisory committee **Dr. A.K. Rokhade**, *Professor and Head, Department of Post-harvest Technology,* **Dr.(Mrs.) C.P. Patil**, *Assistant Professor, Department of Agricultural Microbiology and* **Dr. G.S.K. Swamy**, *Assistant Professor, Department of Pomology, Kittur Rani Channamma College of Horticulture, Arabhavi. Their constructive criticism, valuable suggestions and overwhelming support to pursue my research programme is deeply acknowledged with due respect.*

I avail this opportunity to express my profound thanks to Dr. S.I. Athani, *Associate Professor, Department of Pomology,* Dr. P.L. Patil, *Associate Professor, Department of Soil Science,* Dr. N.K. Hegde, *Assistant Professor, Department of Spices and Plantation Crops and* Dr. Ravindra Mulge, *Assistant Professor, Department of Olericulture, Kittur Rani Channamma College of Horticulture, Arabhavi for their constant support and help during the course of my study.*

I deeply indebted to Dr. P.W. Basarkar, Professor and Head, Department of Biochemistry, University of Agricultural Sciences, Dharwad for his valuable suggestions given during this research programme.

I take this opportunity to offer sincere thanks to my friends Aravindakumar, Mohammadali, Gajanan, Shivaling, Lakkond, Patil, Prabhuraj, Anil, Nagaraju, Kiran, Vishu, Devaraju, Kale, Kamble, Vijay, Shailendra, Ashok, Shrinivas, Benal, Basanagouda, Divakar and other friends for their help and suggestions on various occasions during my study.

I specially thank Mr. Shashidhar Hiremath and Mr. Ashok Angadi for their timely help and encouragement during my study.

I express my sincere gratitude and heartfelt regards to my parents and I owe all my success to loving sisters Nirmala, Neela and Neelaganga. No diction would fulfill to express their sacrifice towards my development.

Finally, I thank **Mr. Shripad Majali** *for his excellent, neat and timely computer service.*

Arabhavi
August 2001

NAGARAJAPPA ADIVAPPAR

CONTENTS

LIST OF TABLES

Tables. Continued...

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

INTRODUCTION

I. INTRODUCTION

Papaya (*Carica papaya* L.) is one of the important tropical and subtropical commercial fruit crops being grown in almost all states in India. It is known for its high nutritive and medicinal values throughout the world. It is rich source of carbohydrates, minerals, vitamins (carotene, riboflavin and vitamin C). Papaya is also known to contain high amounts of proteolytic enzymes, pectin and alkaloids (carpaine), which have many industrial uses (Chadha, 1992). In India, papaya is grown in an area of about 67.70 thousand hectares with the production of 1582 thousand tonnes, while in Karnataka, it is grown on 5.70 thousand hectares with productivity of 87 tonnes per hectare (Anon., 2001).

The nutritional requirement of papaya is unique compared to other fruit crops, because of its continuous vegetative growth, flowering and fruiting behaviour. It is estimated that for production of one tonne of papaya fruits, plants remove 1770 g N, 200 g P, 2120 g K, 1847 mg Mn, 8 mg Mo and 1385 mg Zn (Chadha, 1992). Modern agriculture largely depends on the use of high cost inputs such as chemical fertilizers, pesticides, herbicides, improved seeds, assured irrigation, scientific management and labour saving but energy intensive farm machinery. The application of such high input technologies has undoubtedly increased the production but there is growing concern over the adverse effects of the use of chemicals on soil productivity, microbial community and environmental quality (Motsara, 2000).

The uptake of inorganic nutrients by plants is influenced by microorganisms in the rhizosphere. Symbiotic entophytes such as mycorrhizae are examples of microorganisms that are involved in the uptake of vital plant nutrient elements. There are evidences that most of the plants that belong to taxonomically higher order, are infected with mycorrhizal fungi, which assist in the uptake of nutrients like P, S, K and other micronutrients like Zn, Cu, Mn, Fe, etc. (Sreenivasa *et al.*, 1992).

Vesicular Arbuscular Mycorrhizae (VAM), being mutualistic symbionts having association with plant roots, play an unquestionable role in P-cycling and in the uptake of phosphate by the plant. With the foresight that the known resources of world 'P' could be depleted in few decades (Rhodes, 1980), the contribution of this symbiosis to the reduction of phosphatic fertilizer requirements is receiving more scope with increasing interest.

Plant response to VAM fungi is conditioned mainly by root morphology and soil phosphorus content. Consequently VAM biotechnology is highly feasible for transplanted crops, as in the case with many horticultural crops (Azcon and Barea, 1997). Nevertheless, positive interactions of VAM fungi are well established in variety of crops. Earlier studies on horticultural crops mainly deal with seasonal crops like brinjal (Kandaswamy *et al.*, 1985), okra (Senapati *et al.*, 1987), tomato (Krishnaprasad, 1990) and chilli (Sreenivasa *et al.*, 1992), which were grown in soils devoid of indigenous VAM fungi. Some work has also been done in fruit crops like acid lime (Shanmugam *et al.*, 1981), sour orange (Johnson, 1984), apple (Granger *et al.*, 1983), strawberry (Silva *et al.*, 1996) and papaya (Shrinivas, 1998 and Manjunath, 2000). The literature survey reveals very less work on papaya in relation to VAM fungi.

Securing food and water and maintaining ecological balance in the semi-arid tropics would be a major research and development challenge for Indian agriculture for the years ahead. Unprecedential increase in population, large withdrawals of ground water resources, land degradation, deforestation, establishment of industries and the movement of capital to these high climatic risk areas which are exposed to periodic droughts as witnessed in recent years have contributed to unsustainable agricultural and horticultural production leading to recurrent economic losses. Therefore judicious management of nutrients, especially water for sustainable horticultural production is important. Application of VAM fungi in abiotic stress management is well known and it has to be exploited for drought tolerance.

In papaya, cv. Solo VAM fungi such as *Gigaspora calaspora* and *Glomus macrocarpus* were efficient than *Gigrapora heterogama*

(Ramirez *et al.*, 1975), whereas in Coorg Honey Dew papaya, inoculation with *Glomus mosseae* and *G. fasciculatum* in sterilised nursery soil proved better with respect to growth of papaya plants (Sukhada, 1992). Shrinivas (1998) reported almost same effect of *G. fasciculatum* combined with 75 per cent recommended level of 'P' on plant growth and yield characters of papaya compared to that of 100 per cent 'P' without VAM treatment and these findings are also supported by Manjunath (2000).

However, the earlier findings have not thrown much light on host-fungus interaction in ratoon crop of papaya and influence of VAM on drought tolerance of papaya. Therefore the present study was undertaken to find out the effect of VAM fungi on drought tolerance, growth and yield of papaya cv. Sunset Solo with the following well-defined objectives:

1. To find out the effect of VAM fungi on growth, yield and quality of papaya.
2. To find out effect of VAM on the drought tolerance capacity of papaya plants.
3. To evaluate the efficiency of different mycorrhizal species for drought tolerance capacity.
4. To evaluate the efficiency of different mycorrhizal species for uptake of phosphorus in papaya.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Fruit crops like most horticultural plants, commonly develop vesicular-arbuscular Mycorrhizal (VAM) relationships and exhibit a high degree of dependence on this symbiosis. VAM improves plant growth through increased uptake of P (Nemec, *1986)*, increases plant vigour and reduced transplant injury (Menge, 1982), *reduces the soil* borne diseases (Maronek *et al.*, 1981) for transplanted crops.

Growth benefits by vesicular arbuscular mycorrhizal VAM fungi have been described on numerous host plants (Allen *et al.*, 1980). High 'P' levels in leaf tissue of VAM infected host plants have been suggested as a primary reason for high photosynthetic rates (Johnson *et al.*, 1982).

In many arid and semiarid regions, the major factor limiting plant production and nutrient uptake happens to be water availability. However, the information on the use of VAM fungi in drought hit perennial fruit crops is very scanty. Therefore, information pertaining to other fruit crops has been reviewed.

2.1 Drought in plants

Safir *et al.* (1972) observed 40 per cent less water transport in control soyabean plants than in mycorrhizally infected soyabean plants. However, stem plus leaf resistances were similar in Mycorrhizal and non-mycorrhizal plants.

Allen *et al.* (1981) reported that *Bouteloua gracilis* inoculated with *Glomus fasciculatum* did not affect biomass or gross plant morphology after 30 weeks of growth, but increased chlorophyll and phosphate concentrations by 28 per cent and 70 per cent, respectively.

Busse and Ellis (1985) studied the influence of *Glomus fasciculatum* on soyabean drought tolerance in high 'P' soils and observed that soil water content in stressed columns was slightly less for inoculated plants. Further, he stated that the reduction in soil water was not due to enhanced stomatal functioning during the stress period.

Johnson and Hummel (1985) found that *Poncirus x Citrus* seedlings inoculated with *Glomus intraradices* adapted to conditions of drought stress and low to moderate phosphorus availability better than non-VAM seedlings.

Simpson and Daft (1990) observed that water-stress had significant effect on drought induced maize and sorghum. Stress decreased total dry weight by 27 per cent in maize and 37 per cent in sorghum, halved total root length in sorghum.

Shrestha *et al.* (1996) studied the effect of VAM fungi (*Glomus ambisporum, G. fasciculatum, G. mosseae* and *Gigaspora ramisporophora*) on Satsuma cv. Okitsuwase trees on *Poncirus trifoliata* rootstock with low 'P' application level. The tolerances of trees to 10 days water stress was greater in VAM trees than in uninoculated trees.

Thippeswamy and Sreenivasa (1998) observed that the relative leaf water content (rwc) and chlorophyll contents were significantly highest in the plants inoculated with *Glomus fasciculatum* while proline content was lowest. There was several fold increase in proline content with the age of crop and maximum proline accumulation was observed in uninoculated plants at all the stages of crop growth as compared to inoculated plants.

2.2 VA mycorrhizae in relation to plant nutrient uptake, crop growth and yield

2.2.1 Fruit crops

2.2.1.1 Papaya

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

Padma (1988) observed significant increase in plant height of papaya when VAM was inoculated along with the application of 75 per cent of recommended level of phosphorus. She also observed 69 per cent increase in 'N' content in papaya cv. CO-3 when inoculated with *Glomus fasciculatum.*

Sukhada (1988) reported that the papaya cv. Coorg Honey Dew seedlings inoculated with *Glomus mosseae* had increased plant height by 50 per cent. Leaf and root dry weight increased by 20 per cent compared to uninoculated plants. She also reported that the 'P' content in the leaves of inoculated plants increased by 20 per cent and 22 per cent, respectively, by two fungi, *viz.*, *Glomus mosseae* and *Glomus fasciculatum*. The uptake of N, K, Cu, Zn and Mg was also more in the inoculated plants than that of uninoculated plants.

Among the 13 different VAM fungi inoculated to papaya cv. Solo, *Glomus mosseae* (ICRISAT), *G. fasciculatum, G. versiformae, G. monosporum* and *G. mosseae* (Local) were found to be top five fungi to increase the plant height after 90 days of planting (Reddy, 1991).

Sukhada (1992) showed that papaya cv. Coorg Honey Dew plants inoculated with *G. mosseae* and *G. fasciculatum* in sterilised nursery soil improved the plant height, dry matter as well as P, N and Zn concentration at zero or low levels of phosphorus application.

Weber and De Amorim (1994) conducted an experiment to know the effect of 'P' fertilization and inoculation with VAM fungi in Solo pawpaws plants growing in 10 litre capacity polythene bags in a greenhouse which received triple-superphosphate at four levels equivalent to 0, 20, 40 or 60 ppm P_2O_5 and were inoculated with two VAM fungi, *viz.*, *Glomus etunicatus* and *Entrospora colombiana*. Plants inoculated with *G. etunicatus* showed maximum height, shoot and root dry weight nutrient content at 20 ppm P_2O_5, whereas plants inoculated with *E. colombiana* showed maximum root dry weight and Fe content receiving 20 and 40 ppm P_2O_5.

Jaizme-Vega and Azcon (1995) showed that papaya was highly responsible to *Glomus fasciculatum* VAM fungi and least responsive to inoculation with *Acaulospora* sp.

Shrinivas (1998) reported that inoculation of VAM (*Glomus fasciculatum*) fungi to papaya along with application of 75 per cent recommended dose of 'P' was as good as applying 100 per cent recommended dose of 'P' alone, thereby saving 25 per cent recommended dose of phosphorus.

2.2.1.2 Citrus

Timmer and Leydan (1978) observed that inoculation of sour orange seedlings with *Glomus fasciculatum* stimulated growth over the non-inoculated controls except in the P-fertilized sandy loam soil. Addition of P, Cu or both before planting did not stimulate the growth of the non-mycorrhizal seedlings in sand and showed 'P' deficiency symptoms, whereas inoculated seedlings greatly increased growth and addition of P, Cu or both increased growth further.

Shanmugam *et al.* (1981) observed that both the VAM fungi *Glomus mosseae* and *Glomus etunicatus* have significantly increased shoot height, stem thickness, number of leaves, root length, root weight, besides shoot weight when inoculated on one year old acid lime seedlings. The fungi in combination with phosphorus were also found to significantly enhance the growth and vigour of acid lime seedlings when compared to control seedlings and phosphorus treatment alone. Another important finding by these workers was that between the two methods of VAM application, *viz.*, bottom method (root zone) and top application (1-2 cm below the surface soil), top inoculation was better than the bottom inoculation.

Manjunath *et al.* (1982) reported that VAM fungus *G. fasciculatum* in sandy and black clayey soils responded better for citrus seedlings and had higher shoot and root dry weight, nutrient content compared to uninoculated plants.

Nemec (1982) observed that total soluble sugars, reducing sugars, starch and total non-structural carbohydrates were significantly greater in leaves of Cleopatra mandarin inoculated with *Glomus macrocarpus* compared to uninoculated control.

Nemec and Guly (1982) analysed the carbohydrates of Mycorrhizal and non-mycorrhizal citrus rootstock seedlings under greenhouse conditions having low P soils. Inoculated plants grew taller and weighed more and their leaves contained greater amount of total soluble sugar, sucrose, reducing sugar, starch and total non-structural carbohydrates than uninoculated control. There was slight increase in reducing sugars, fructose and glucose. Uninoculated seedlings grown in high P soil were about the same height and their leaves contained similar levels of total soluble and reducing sugars as that of inoculated rootstocks grown in low P soil.

Edriss *et al.* (1984) found that enhancement of cytokinin production seemed to be associated with Mycorrhizal infection rather than with increased 'P' uptake.

Johnson (1984) in a pot culture experiment observed lower Mycorrhizal colonisation of roots of sour orange (*Citrus aurantium*) seedlings after first nine weeks of inoculation. However, P content of leaf tissue levels was higher with VAM colonisation and high fertilization. Further, in addition to improved 'P' nutrition VAM influenced photosynthetic rates of plants.

The Mycorrhizal infection improved the establishment of Carrizo citrange seedlings after transplanting by improving 'P' uptake and thus reducing the plant stress for 'P' (Johnson and Hummel, 1985).

Graham (1986) found that VAM fungi are slow colonisers of roots compared to most pathogens; hence, potential benefit could be pre-empted if roots are exposed to the VAM fungus and to pathogens at the same time.

Palazzo *et al.* (1992) in their experiment on effect of soil sterilisation on vesicular arbuscular mycorrhiza on growth of sour orange (*C. aurantium* L.) seedlings showed that the roots of plants in fresh (unsterile) soil were colonised well by Mycorrhizal fungi than in steam sterilised soil.

Onkarayya and Sukhada (1993) reported that the inoculation of *Glomus fasciculatum* increased the leaf, shoot and root phosphorus, nitrogen and zinc than in uninoculated rootstocks of citrus, *viz.*, Rough lemon, Rangpur lime, Trifoliate orange, Troyer citrange, Carrizo citrange, Citrumelo and Cleopatra mandarin.

Rocha *et al.* (1995) found that the inoculation of *Acaulospora morrowae, Glomus clarum* and *G. etunicatum* promoted better plant growth, but recorded lower contents of Co, Mg, Cu and Mn in Cleopatra mandarin before transplanting. The addition of increasing doses of simple super phosphate increased the contents of P, Ca and S and reduced contents of Mg.

The response of Satsuma cv. Okitsuwase on *Pomirus trifoliate* rootstocks to inoculation with VAM fungi such as *Glomus ambisporum* was studied under conditions of low P supply and higher air temperature stress conditions. The photosynthesis and transpiration rates of VAM inoculated trees were greater than those of uninoculated ones. In general, VAM inoculated trees had longer leaf area, higher leaf P concentration and more vigorous tree growth than uninoculated plants (Shrestha *et al.*, 1995).

The VAM fungi *Glomus intraradices* increased root and shoot growth of sour orange and Carrizo citrange rootstocks and the application of IBA to VAM plants significantly increased the mean root dry mass (Dutra *et al.*, 1996).

Reddy *et al.* (1996) used 13 species of VA Mycorrhizal fungi and screened for their symbiotic effect on acid lime in pot experiments. Inoculation of pots with *Glomus macrocarpum, Glomus mosseae, Acaulospora laevis, Glomus catedomicum* and *Gigaspora margarita* resulted in greater plant biomass, plant height, plant girth, leaf number, leaf area and leaf P and Zn concentrations. They concluded that the best VAM fungi for lime were considered to be *Glomus macrocarpum* and *Glomus mosseae.*

2.2.1.3 Banana

Umesh *et al.* (1988) observed that the contents of reducing sugars, total sugars, total phenols and total amino acids in the roots of banana were influenced by mycorrhiza and nematodes. Plants having Mycorrhizal treatment alone or with nematodes had higher content of these biochemicals than plants with nematode alone.

Lin and Fox (1992) found that application of *Glomus aggregatum* increased the plant dry weight of banana (*Musa paradisiaca*0 when plants were fertilized with insoluble rock phosphate compared to superphosphate.

Declerck *et al.* (1994) inoculated micropropagated banana plants cv. AAA Giant Cavendish with *Glomus mosseae* and *G.*

geosporum and recorded greater fresh weight and dry weight of shoots and higher 'P' and 'K' contents, particularly with *G. mosseae*.

Alonso *et al.* (1995) reported that the plant height of *in-vitro* derived plants of banana cv. Parocido al Rey grown in soil inoculated with VAM (*Glomus fasciculatum*) at planting and/or with a phosphate mobilising bacterium (*Pseudomonas flurescens*) was significantly greeter than that of the control. Dry weight was also greeter in the inoculated plants.

Among the different fruit crops tested by Jaizme-Vega and Azcon (1995), banana was highly responded to inoculation of VAM fungus *Glomus fasciculatum*.

2.2.1.4 Grape

Grape vines grown on calcareous soils get benefited the combined application of vesicular-arbuscular mycorrhizal (VAM) fungus and siderophore producing pseudomonades (Bavaresco and Fogher, 1992).

Bavaresco and Fogher (1996) related the VAM inoculation in grapevine for increased chlorosis resistance of the susceptible graft combination by improving the nutritional status of the stressed plants, especially for N, P, K and Fe.

2.2.1.5 Pineapple

Micropropagated pineapple plants cv. Queen Tahiti and smooth cayenne were inoculated with *Glomus* sp. before planting in soils with or without high levels of salinity. Mycorrhizal infection was higher in Queen Tahiti compared to smooth cayenne at higher concentrations of Nall. Shoot 'P' concentration was higher in Mycorrhizal treated plants (Guillemin *et al.*, 1995).

Jaizme-Vega and Azcon (1995) investigated the effects of four VAM fungi on growth and nutrition of pineapple. Among the four, *Glomus fasciculatum* was found to be highly responsive while *Acaulospora* sp. was ineffective.

2.2.1.6 Strawberry

In a strawberry breeding programme by Larson and Shaw (1995), increased growth was obtained by inoculating transplants with mycorrhizae. Further, low vegetative vigour was observed during plantation establishments of non-fumigated soils by the same authors.

Silva *et al.* (1996) found that inoculated strawberry plants had significantly more leaves, larger leaf area and more runners per plant than the controls. The concentrations of major and most of the minor nutrients in leaves were similar for inoculated and control plants.

2.2.1.7 Ber

Mathur and Vyas (1995) found that VAM inoculation resulted in a significant increase in net photosynthesis, total chlorophyll, carotenoid, sugar and starch content of *Ziziphus mauritiana*. The VAM mycorrhizae also increased stomatal resistance, thereby reducing rate of transpiration.

Shirsath *et al.* (1998) found that ber crop was highly dependent on Mycorrhizal inoculation and that the VA Mycorrhizal association was necessary to increase growth, dry mater accumulation and nutrient uptake of ber seedlings.

2.2.1.8 Avocado

Inoculation of *Glomus fasciculatum* in avocado influenced significantly the seedling height, seedling girth, number of leaves, leaf area, dry weight of the shoot compared to controlled plants (Dharmaraj and Irulappan, 1982).

Vidal *et al.* (1992) reported that inoculation of micropropagated avocado plantlets with *Glomus fasciculatum* improved and led to formation of a well-developed root system that was converted into a Mycorrhizal system. Further, introduction of the Mycorrhizal fungus to the plantlets where they were transferred from *in-vitro* conditions to *ex-vitro* conditions improved shoot and root growth; enhanced the shoot; root ratio; increased the concentration and/or content of N, P and K in plant tissues and helped plants to tolerate environmental stress at transplanting.

2.2.1.9 Apple

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

Plenchette *et al.* (1981) reported that VAM fungi inoculated apple seedlings germinated and grown under greenhouse conditions had increased the root volume, shoot length, leaf surface, 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.

Koch *et al.* (1982) studied the response of apple seedlings in fumigated soil to the application of phosphorus and VAM fungi. They found that incorporation of P into fumigated soil at planting increased the height and P level in apple seedlings. Mycorrhizal plants exhibited a twenty five fold increased growth response to P and obtained maximum size at 200 mg additional P per kg of soil.

Uosukainen and Vestberg (1994) noticed increase in the mean shoot height of established plants of *Malus* due to VAM inoculation. After the rooting and weaning stage, many uninoculated plants lapsed into arrest of growth, whereas this phenomenon was less frequent in VAM inoculated plants.

Sbrana *et al.* (1995) studied the effect of mycorrhizal infection in survival and growth renewal of micropropagated apple rootstocks. They found that inoculations of VAM fungi during transplanting from *in-vitro* to *in-vivo* culture enhanced the survival rate and growth of plants after transplanting.

Fortuna *et al.* (1996) conducted an experiment to study the effect of vesicular-arbuscular mycorrhizae and phosphate fertilization on shoot apical growth of micropropagated rootstocks. They noticed that in the absence of P, non-mycorrhizal plantlets were similar to those of plantlets given P. They concluded that mycorrhizal inoculation could be used as biotechnological tool to overcome blocked apical growth and to reduce chemical inputs, especially P inputs to micropropagated fruit trees.

2.2.1.10 Other temperate fruits

Gilmore (1971) found that the mycorrhizal peach plants had two to three times more Zn as compared to the non-mycorrhizal peach plants. So, he concluded that Zn deficiency in the peach could be corrected by mycorrhizal inoculation.

La-Rue *et al.* (1975) compared the inoculation of mycorrhizae and standard practice of side dressing of P and Zn at planting time on the growth of peach seedlings. They found that mycorrhizal fungi helped peach seedlings to extract P and Zn from the soil and the seedlings were more efficient in overcoming nutrient deficiency caused due to soil fumigation. Mycorrhizal inoculated plants had higher stem diameter, plant height and N, P, Cu and Zn concentration than control but were on par with fertilization treatment.

Rapparini *et al.* (1994) reported that there was a three fold increase in shoot length of *Glomus* sp. inoculated micropropagated peach plantlets at the end of vegetative phase. Sbrana *et al.* (1995) reported that inoculation of VAM fungi at the time of transplanting from *in-vitro* to *in-vivo* culture enhanced the survivability and improved the growth of micropropagated peach rootstocks after transplanting.

Gardiner and Christensen (1991) studied the effect of P fumigation and mycorrhizal inoculation on the growth and nutrient content of pear cv. Barley (*Pyrus communis*) seedlings and reported that *Glomus intraradices* increased the plant growth at low to medium level of P application and the growth was maximum in plants with *Glomus deserticola* at the highest level of P.

Rapparini *et al.* (1994) reported a three fold increase in shoot length of micropropagated plantlets of pear after inoculation with *Glomus* species compared to non-mycorrhizal plants.

Survivability and growth rates of micropropagated *plum* rootstocks increased by mycorrhizal inoculation during transplanting from *in-vitro* to *in-vivo* culture (Sbrana *et al.*, 1995).

Fortuna *et al.* (1996) proposed mycorrhizal inoculation to plum rootstocks as a biotechnological tool to overcome blocked apical growth and to chemical inputs especially phosphorus.

2.3 Plant mineral nutrition and VAM

Sanders and Tinker (1973) reported that only within the last few years that VAM importance has been widely appreciated. The value of these mycorrhizae for the phosphate nutrition of plants in deficient environments may rival that of *Rhizobium* in nitrogen.

Mosse (1973) indicated that the VA mycorrhizae usually stimulate host growth more in infertile soils than in fertile soils.

Hayman (1980) found that in legumes, nodulation and nitrogen fixation were greatly increased by mycorrhizal inoculation, sometimes beyond that achieved by phosphatic fertilizer alone.

Sreenivasa *et al.* (1992) while studying the response of chilli to the inoculation of efficient VAM fungi observed that inoculation of *G. macrocarpum* increased the shoot dry weight, yield and nutrient status of chilli mainly P, Zn, Cu, Mn and Fe at 50 per cent of recommended dose of added phosphorus than with the application of recommended dose of phosphorus.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigation was carried out at the Department of Pomology, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Agricultural Sciences, Dharwad during 2000-2001 to study the response of papaya (*Carica papaya* cv. Sunset Solo) for the inoculation of vesicular arbuscular mycorrhizal (VAM) fungi at different 'P' levels. The material used, techniques adopted and observations recorded during the course of study are furnished in this chapter.

3.1 Geographical location of the experimental site

Arabhavi is situated in northern dry zone (Zone-3) of Karnataka state. It lies between 16°15' north latitude and 74°45' East longitude with an altitude of 612 m above mean sea level.

3.2 Climate

Arabhavi is considered to have the benefit of both south-west and north-east monsoons. The mean annual rainfall of this area is about 530 mm, distributed over a period of five to six months (June to November) with prominent peaks during July and October. The meteorological data obtained from meteorological observatory of the Agricultural Research Station, Arabhavi situated 3 kilometres away from the experimental site, are presented in Appendix-I.

3.3 Vesicular-arbuscular mycorrhizal inoculum

The starter cultures of vesicular-arbuscular mycorrhizae (*Glomus fasciculatum, Sclerocystis dussii* and *Acaulospora laevis*) were obtained from Department of Agricultural Microbiology, Kittur Rani Channamma College of Horticulture, Arabhavi. The inoculum was further multiplied in sterilised potting mixture using Punjab Napier Grass as host in the nursery of the Department of Pomology, Kittur Rani Channamma College of Horticulture, Arabhavi.

The inoculum used consisted of a mixture of sand : soil in 1 : 1 proportion and root segments of Punjab Napier Grass comprising of hyphae, vesicles, arbuscules and chlamydospores of the VAM fungi. Inoculation of VAM to papaya was done in the nursery.

3.4 Experimental details

Two experiments were conducted in this investigation, *viz.*,

(1) Effect of VAM on growth and yield of papaya.

(2) Effect of VAM on drought tolerance of papaya.

3.4.1 Effect of VAM on growth and yield of papaya

3.4.1.1 Climate, geographical location and VAM multiplication

The data collection, material used and procedure followed for climatic conditions, geographical location chosen and VAM multiplication were same as that of pot culture experiment.

3.4.1.2 Soil properties

The experiment was continued on the existing orchard, which was laid out on medium black soil.

3.4.2 Experimental details

3.4.2.1 Design of the experiment and layout

The design of the experiment adopted was split plot with VAM fungi as main treatment and 'P' levels as sub-treatments with three replications. The treatments in each replication were allotted randomly. The layout plan is illustrated in Fig.-1.

3.4.2.2 Treatment details

A. Main treatments (VAM fungi)

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

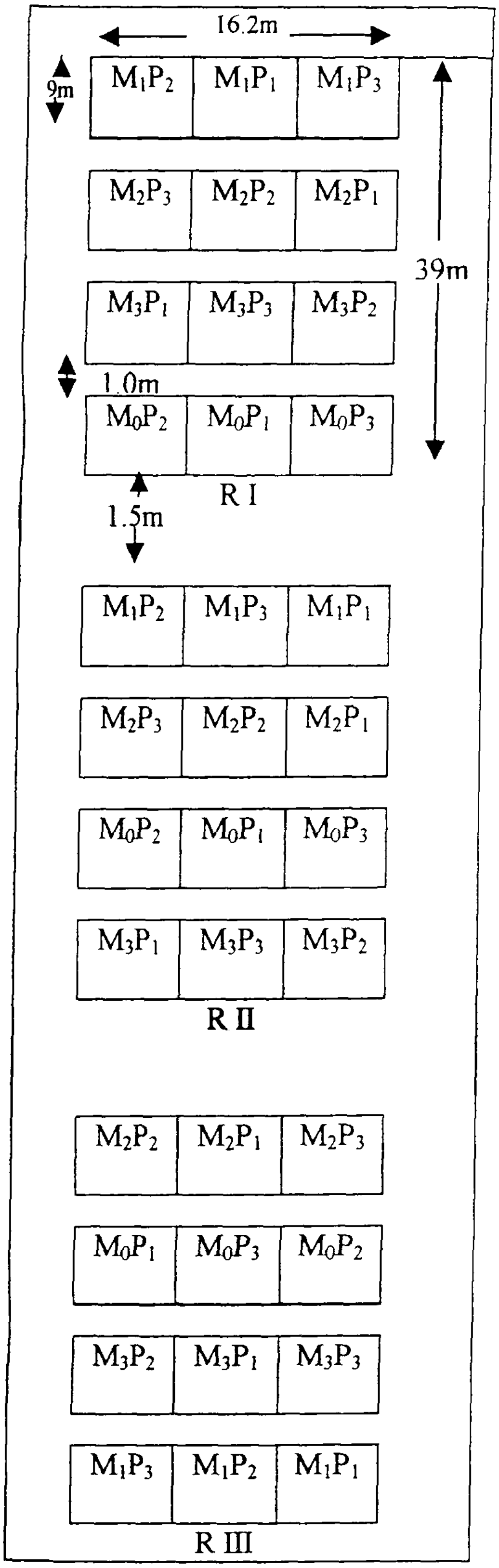
M_3 = *Acaulospora laevis*

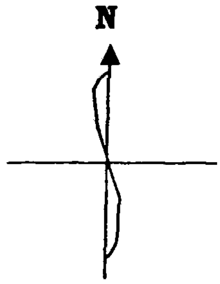
B. Sub-treatments ('P' levels)

P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)

P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)

P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)





M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

P_1 = 312.50 kg P_2O_5 per ha (50% RDP)

P_2 = 468.75 kg P_2O_5 per ha (75% RDP)

P_3 = 625.00 kg P_2O_5 per ha (100% RDP)

Fig.1. Plan of layout

Treatment combinations

1.	M_0P_1	4.	M_1P_1	7.	M_2P_1	10.	M_3P_1
2.	M_0P_2	5.	M_1P_2	8.	M_2P_2	11.	M_3P_2
3.	M_0P_3	6.	M_1P_3	9.	M_2P_3	12.	M_3P_3

Plot size

Gross : 48.6 m^2

Net : 9.72 m^2

Spacing : 1.8 m x 1.8 m

3.4.2.3 Number of experimental plants

There were 45 plants in each sub-treatment.

3.4.3 Cultural operations

3.4.3.1 Fertilizer application

Nitrogen and potassium were applied in the form of urea and muriate of potash, respectively. 'P' was applied according to the treatment levels in the form of single super phosphate. The university recommendation of fertilizer dose 625 : 625 : 1250 kg N : P : K per ha was adopted for experimentation (Anon., 1997). Total quantity of nitrogen and potassium and full quantity of phosphorus as per the treatments were given in three equal split doses at bimonthly intervals. The fertilizers were applied in the basin and mixed into the soil.

3.4.3.2 Weeding and irrigation

The experimental plot was kept free from weeds by periodical hand weeding. Irrigation was given at an interval of eight to ten days throughout the period of experimentation.

3.4.3.3 Plant protection

Timely and suitable plant protection measures were taken to protect the experimental plants from the attack of insect pests and diseases.

3.4.3.4 Observations recorded

Three plants were labelled randomly in the individual treatment for analysing the growth behaviour of the crop. Observations were recorded periodically at monthly intervals on the labelled (tagged) plants.

3.4.3.4.1 Plant height

The plant height was recorded at bimonthly intervals on the tagged plants starting from October 2000 to April 2001. The plant height was recorded in meter from marked point just above the ground level to the growing tip.

3.4.3.4.2 Stem girth

The stem girth of the plant was recorded periodically at the trunk five cm above the ground on the marked position and was expressed in centimetres.

3.4.3.4.3 Number of leaves

The number of leaves (fully opened) were counted on the labelled plants and average was worked out periodically.

3.4.3.4.4 Petiole length

Freshly matured fully expanded leaf (third from top) was tagged for taking petiole length. The petiole length was observed periodically until it was dried.

3.4.3.4.5 Number of fruits per plant

The number of fruits obtained from the individual plants were counted and recorded as and when they were harvested. The total number of fruits per plant at the end were totalled to get the total number of fruits per plant.

3.4.3.4.6 Length and circumference of the fruit

The length and circumference of 10 fruits in each treatment under each replication were recorded with the help of thread. The length of the fruit was measured from the proximal end to distal end and recorded in centimetre. The circumference of the fruit was also measured by thread at the maximum width point (centre of the fruit) and recorded in centimetres.

3.4.3.4.7 Mean weight of fruit

The total fruit weight and number of fruits per plant were recorded and the average fruit weight was calculated.

3.4.3.4.8 Total soluble solids of fruits

The total soluble solids (TSS) of the nine fruits under each treatment was recorded by using hand-refractometer (Erma make) and expressed in °Brix.

3.4.3.4.9 Vitamin C

The vitamin C content of fruits under each treatment was undertaken by volumetric method as given by Sadasivam and Manickam (1997). The vitamin C in mg per 100 g sample was calculated as:

$$\text{Vitamin C}/100\text{ g} = \frac{0.5\text{ mg}}{V_1\text{ ml}} \times \frac{V_2}{5\text{ ml}} \times \frac{100\text{ ml}}{\text{Weight of sample}} \times 100$$

where,

V_1 = 10 ml of 4 per cent oxalic acid

V_2 = 5 ml supernatant, and 10 ml of 4 per cent oxalic acid

3.4.3.4.10 Reducing sugars

Reducing sugars in the fresh ripe fruit pulp were estimated as per Dinitrosalicylic acid method (Miller, 1972). The values obtained were expressed on fresh weight basis as per cent.

3.4.3.4.11 Total sugars

The total sugars in the ripe fruits were estimated following the procedure used for reducing sugars after inversion of the non-reducing sugars using dilute hydrochloric acid (Anon., 1984). The values were expressed as per cent sugars on fresh weight basis.

3.4.3.4.12 Non-reducing sugars

The per cent of non-reducing sugars were obtained by subtracting the values of reducing sugars from that of per cent total sugars and multiplied by 0.95.

Non-reducing sugar (%)=[Total sugar (%) – Reducing sugar (%)] x 0.95

3.4.3.4.13 Shelf life of fruits

Ripe papaya fruits were weighed initially (W_1) and kept for 4 days at ambient condition and final weight was recorded (W_2). The loss in weight was calculated and expressed as per cent physiological loss in weight (PLW).

$$\text{Per cent PLW} = \frac{W_1 - W_2}{W_1} \times 100$$

3.5 Effect of VAM on drought tolerance of papaya (Pot culture)

3.5.1 Design of the experiment

The design of the experiment adopted was completely randomised block design. There were five replications with an additional replication for destructive sampling.

3.5.2 Treatment details

M_0 = Uninoculated control
M_1 = *Glomus fasciculatum*
M_2 = *Sclerocystis dussii*
M_3 = *Acaulospora laevis*

3.5.3 Number of experimental plants per replication

There were three plants in each replication under each treatment.

3.5.4 Pot size

Pot size having 20 cm x 20 cm was selected for the experiment.

3.5.5 Potting mixture

Soil and sand was mixed in the ratio of 1 : 1 and used as potting mixture.

3.6 Nursery

The seedlings were raised in polyethylene bags of 18 cm x 12 cm size. The polyethylene bags of respective treatments were labelled and kept apart from each other to avoid contamination after filling with soil : sand in the ratio of 1 : 1. Mycorrhizal inoculation was done by placing VAM inoculum uniformly @ five grams per bag at five centimetres depth and seeds were sown during first week of January 2000. The polyethylene bags were watered daily, weeding was done as and when required. Forty five days old, uniform, healthy, disease and pest free seedlings were transplanted to the pots, filled with 1 : 1 soil : sand mixture or to the main field depending on the experiment.

3.7 Aftercare

After transplanting to the pots watering was done with rose-can regularly till the imposition of drought. The pots were kept free from weeds by periodical hand weeding throughout the period of experimentation.

Imposition of drought was done two months after transplanting in the pots withdrawing application of water.

3.8 Observations recorded

Randomly selected two plants were labelled per treatment per replication for following periodic observations.

3.8.1 Plant height

Plant height was recorded at weekly interval after transplanting to the pots. Plant height was recorded from marked point just above crown region upto the tip and was expressed in centimetres.

3.8.2 Stem girth

Stem girth of the plant was recorded at weekly intervals on the marked point and was expressed in centimetre.

3.8.3 Number of leaves

The number of leaves per plant were counted and recorded at weekly interval.

3.8.4 Fresh weight and dry weight of shoot

Two plants fresh weight was noted and kept in hot air oven for three days at 60°C to attain a constant dry weight. Dry weight was recorded after three days and expressed in grams.

Fresh weight and dry weight of shoot was also recorded after imposing the drought.

3.8.5 Fresh weight and dry weight of root

Roots of two plants were collected and fresh weight was taken. They were kept in hot air oven at 60°C for three days and dry weight was recorded in gram.

Fresh weight and dry weight of root was also recorded after imposing the drought.

3.8.6 Fresh and dry weight of leaf

Two plants leaf fresh weight was taken and dry weight was recorded after drying in hot air oven at 60°C for three days.

3.8.7 Chlorophyll content

Chlorophyll 'a', 'b' and total chlorophyll content of leaves were recorded before and after 10 days of the drought. Chlorophyll estimation was done by acetone extract method *(Arnon, 1949) and* calculated by using the formulae:

$$\text{mg chlorophyll 'a'/g tissue} = [12.7(A_{663}) - 2.69(A_{645})] \times \frac{V}{1000 \times W}$$

$$\text{mg chlorophyll 'b'/g tissue} = [22.9(A_{645}) - 4.68(A_{663})] \times \frac{V}{1000 \times W}$$

$$\text{mg total chlorophyll/g tissue} = [20.2(A_{645}) + 8.02(A_{663})] \times \frac{V}{1000 \times W}$$

where,

A = Absorbance of specific wave lengths (645 and 663 nm)

V = Final volume of chlorophyll extractant in 80 per cent acetone in 100 ml.

W = Fresh weight of leaf sample, i.e., one g.

3.8.8 Per cent relative water content

The relative leaf water content was estimated according to the standard method developed by Barrs and Weatherly (1962) before drought imposition. It was calculated by using the formula:

$$\text{Per cent RWC} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

3.8.9 Soil moisture

A known quantity of soil was taken and kept in hot air oven for three days at 60°C to attain a constant weight. The final constant weight was recorded to calculate soil moisture before and at the end of the drought imposition. Soil moisture percentage was calculated by following formula:

$$\text{Per cent moisture} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

3.8.10 Proline

Proline content of the leaf was estimated prior to and after imposition of drought by the method given by Bates *et al.* (1973). Proline was calculated by using the formula (on fresh weight basis):

$$\mu \text{ moles of proline/g tissue} = \frac{\mu \text{ g proline/ml x ml of toluene}}{115.5} \times \frac{5}{\text{g. of sample}}$$

where,
115.5 = Molecular weight of proline
Toluene = Extractant

3.8.11 Leaf and soil analysis for nutrient

3.8.11.1 Estimation of leaf 'N'

The estimation of nitrogen was done by modified micro-kjeldahl's method as outlined by Jackson (1967) and expressed in terms of per cent on dry weight basis.

3.8.11.2 Estimation of leaf 'P'

The phosphorus content in petiole was estimated by the procedure given by Jackson (1967) and expressed in terms of per cent on dry weight basis.

3.8.11.3 Estimation of leaf potassium

The potassium content was estimated by the triacid wet digestion method (Jackson, 1967) using flame-photometer. The results were expressed as per cent on dry weight basis.

3.8.11.4 Leaf micronutrients

Micronutrients, *viz.*, Cu, Mn and Zn in leaf sample digest were estimated by Atomic Absorption Spectroscopy (AAS) and expressed in ppm. Micronutrients were calculated by using the formula:

$$\begin{array}{c}\text{ppm of micronutrients}\\ \text{on dry weight basis}\end{array} = \text{AAS reading (ppm)} \times \frac{\text{Volume made up (v)}}{\text{Weight of sample (w)}}$$

3.8.11.5 Soil micronutrient analysis

Micronutrients, *viz.*, Fe, Cu, Mn and Zn of soil sample were estimated by using Atomic Absorption Spectroscopy (AAS) and expressed in ppm. Micronutrients were calculated by using the formula:

$$\text{ppm of micronutrient in soil} = \text{AAS reading} \times \frac{\text{Volume of extractant (20 ml)}}{\text{Weight of soil sample (10 g)}}$$

3.8.12 Microbiological parameters

3.8.12.1 Number of chlamydospores per 50 g soil

Extrametrical chlamydospores produced by VAM fungi were determined by using wet sieving and decanting method as given by Gerdemann and Nicolson (1963).

Fifty grams of representative soil sample drawn from each treatment in each replication was suspended in sufficient quantity of water and stirred thoroughly. It was allowed to stand for one minute undisturbed before decanting onto the sieves. The suspension was passed through a set of sieves with mesh size, 850, 300, 250, 150 and 37 μ, which were arranged in descending order. The spores collected in the 850, 250 and 37 μ were transferred to watch glass. Spore count was done by using stereomicroscope and expressed as number of chlamydospores per 50 g of soil.

3.8.12.2 Per cent root colonisation

Per cent root colonisation was determined by using the method as detailed by Phillips and Hayman (1970).

Root samples were cut into one cm pieces and fixed in FAA (Formalin : Acetic acid : Alcohol in the ratio of 5 : 5 : 90) for 24 hours. The roots were then cleared by auto-claving with 10 per cent KOH at 15 lbs pressure for 15 minutes. The alkalinity due to KOH was neutralised by adding one per cent HCl for five minutes. Staining was done by simmering the roots in 0.05 per cent tryphan blue in lactophenol for 10 minutes. Excess stain was decanted and stained roots were stored in lactophenol. The root bits were arranged on slides covered with cover slips and observed under microscope for the presence of VAM mycelium, vesicles and arbuscules. The per cent root colonisation was calculated by using the formula:

$$\text{Per cent root colonisation} = \frac{\text{Numger of root bits positive for colonisation}}{\text{Total number of root bits observed}} \times 100$$

3.8.12.3 Number of vesicles

Number of vesicles were counted in each treatment in each replication while observing for the per cent root colonisation.

3.9 Statistical analysis

The data recorded on various characters in both the experiments were subjected to Fischer's method of analysis of variance and interpretations of data as given by Panse and Sukhatme (1967). The level of significance used in 'F' test and 't' test was 0.05. Critical difference (CD) values were calculated whenever the 'F' test was significant.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results obtained from the investigations on influence of VAM fungi on growth, physiology and yield of papaya are presented as under, experimentwise.

4.1 Experiment-I: Effect of VAM and different levels of phosphorus on growth and yield of papaya

4.1.1 Growth parameters

4.1.1.1 Plant height

The data on plant height as influenced by VAM fungi at different phosphorus levels are presented in Table-1.

The perusal of the data indicated that the influence of VAM fungi on plant height was non-significant at all the stages of growth except at the last stage of growth, i.e., 970 days after planting (DAT). *G. fasciculatum* recorded significantly highest height (2.88 m) when compared to uninoculated control (2.62 m), which had recorded significantly lowerst value. However, the height recorded in all VAM inoculated plants was on par with each other.

Application of phosphorus showed non-significant differences in the height of plant at all the stages of plant growth. The interaction effects were also found to be non-significant during all the stages of growth.

Table 1. Effect of different VAM fungi and phosphorus levels on plant height (m) at different stages of growth in papaya

Treatment	Plant height (m)							
	I stage 790 DAT		II stage 850 DAT		III stage 910 DAT		IV stage 970 DAT	
M_0P_1	1.89		2.08		2.44		2.64	
M_0P_2	1.91		2.19		2.49		2.67	
M_0P_3	1.74		2.05		2.40		2.54	
Mean for M_0	1.84		2.11		2.44		2.62	
M_1P_1	1.98		2.25		2.72		2.92	
M_1P_2	1.83		2.14		2.54		2.74	
M_1P_3	2.14		2.40		2.74		2.98	
Mean for M_1	1.98		2.26		2.66		2.88	
M_2P_1	1.63		1.98		2.47		2.66	
M_2P_2	2.01		2.22		2.53		2.80	
M_2P_3	2.00		2.34		2.68		2.87	
Mean for M_2	1.88		2.18		2.56		2.77	
M_3P_1	1.85		2.17		2.58		2.81	
M_3P_2	1.79		2.10		2.34		2.59	
M_3P_3	1.84		2.16		2.70		2.92	
Mean for M_3	1.83		2.14		2.54		2.77	
P_1	1.84		2.12		2.55		2.75	
P_2	1.88		2.16		2.47		2.70	
P_3	1.93		2.23		2.63		2.83	
For comparing the mean of	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)
VAM	0.070	NS	0.049	NS	0.059	NS	0.049	0.168
P	0.054	NS	0.045	NS	0.059	NS	0.054	NS
VAM x P	0.113	NS	0.089	NS	0.113	NS	0.101	NS

M_0 = Uninoculated control M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii* M_3 = *Acaulospora laevis*

P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)

P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)

P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)

NS = Non-significant DAT = Days after transplanting

4.1.1.2 Plant girth

The data on plant girth as influenced by VAM fungi at different phosphorus levels are presented in Table-2.

The influence of VAM fungi on plant girth was non-significant at all the stages of growth. Application of phosphorus did not influence the plant girth significantly at all the stages of growth.

The interaction effects were significant only in first two stages of growth. Significantly highest plant girth was found in the interactions M_2P_2 (10.09 cm), which was significantly superior over M_2P_1 (9.34 cm), M_3P_1 (9.79 cm), M_0P_2 (10.22 cm) M_3P_3 (10.18 cm) and M_0P_3 (10.01 cm). In II stage (850 days DAT) of growth, M_2P_3 (11.34 cm) was significantly superior over M_2P_1 (9.57 cm), M_2P_2 (11.01 cm), M_3P_2 (9.94 cm) only.

4.1.1.3 Number of leaves

The data on number of leaves per plant influenced by VAM fungi at different levels of 'P' are presented in Table-3.

The influence of VAM fungi on number of leaves per plant was significant at all the stages of growth except I stage. In II stage, i.e,. 850 DAT, plants inoculated with *G. fasciculatum* recorded significantly higher number of leaves (25.77) compared to *S. dussii* (24.99), *A. laevis* (23.48) and significantly lowest number of leaves were recorded in uninoculated control (22.94). Plants inoculated with

Table 2. Effect of different VAM fungi and phosphorus levels on plant girth (cm) at different stages of growth in papaya

Treatment	Days after planting							
	I stage 790 DAT		II stage 850 DAT		III stage 910 DAT		IV stage 970 DAT	
M_0P_1	10.29		10.46		10.65		10.84	
M_0P_2	10.22		10.45		10.45		10.89	
M_0P_3	10.01		10.26		10.42		10.73	
Mean for M_0	10.17		10.39		10.51		10.82	
M_1P_1	10.71		11.01		11.41		11.50	
M_1P_2	10.77		11.14		11.47		11.82	
M_1P_3	10.45		10.65		11.13		11.55	
Mean for M_1	10.65		10.93		11.34		11.63	
M_2P_1	9.34		9.57		10.27		10.63	
M_2P_2	10.09		11.01		11.24		11.47	
M_2P_3	10.97		11.34		11.41		11.72	
Mean for M_2	10.46		10.64		10.97		11.27	
M_3P_1	9.79		10.27		9.96		10.36	
M_3P_2	9.72		9.94		9.87		10.70	
M_3P_3	10.18		10.35		10.94		10.81	
Mean for M_3	9.89		10.19		10.26		10.63	
P_1	10.03		10.33		10.57		10.83	
P_2	10.45		10.63		10.75		11.22	
P_3	10.40		10.65		10.98		10.20	
For comparing the mean of	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)
VAM	0.191	NS	0.244	NS	0.357	NS	0.346	NS
P	0.125	NS	0.109	NS	0.137	NS	0.161	NS
VAM x P	0.280	0.838	0.302	0.906	0.422	NS	0.434	NS

M_0 = Uninoculated control M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii* M_3 = *Acaulospora laevis*

P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)

P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)

P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)

NS = Non-significant DAT = Days after transplanting

Table 3. Effect of different VAM fungi and phosphorus levels on number of leaves per plant at different stages of growth in papaya

Treatment	Number of leaves per plant							
	I stage 790 DAT		II stage 850 DAT		III stage 910 DAT		IV stage 970 DAT	
M_0P_1	15.67		25.27		22.55		24.67	
M_0P_2	21.00		22.99		21.55		25.33	
M_0P_3	19.55		20.55		24.22		27.44	
Mean for M_0	18.74		22.94		22.77		25.81	
M_1P_1	24.11		28.11		30.55		33.33	
M_1P_2	18.44		26.55		29.88		31.78	
M_1P_3	15.33		22.66		26.12		27.11	
Mean for M_1	19.29		25.77		28.85		30.74	
M_2P_1	15.67		20.66		23.22		25.66	
M_2P_2	15.89		25.89		26.77		24.11	
M_2P_3	20.55		28.44		27.11		28.22	
Mean for M_2	17.37		24.99		25.70		25.99	
M_3P_1	20.55		25.33		25.55		27.44	
M_3P_2	17.10		20.67		20.44		25.11	
M_3P_3	14.55		24.44		20.88		23.00	
Mean for M_3	17.40		23.48		22.29		25.18	
P_1	19.00		24.84		25.47		27.78	
P_2	18.11		24.02		24.66		26.58	
P_3	17.50		24.02		24.58		26.44	
For comparing the mean of	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)
VAM	0.506	NS	0.245	0.849	0.420	1.453	0.328	1.136
P	0.257	0.770	0.177	0.529	0.313	NS	0.369	1.107
VAM x P	0.657	1.969	0.379	1.134	0.661	1.981	0.687	2.058

M_0 = Uninoculated control M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii* M_3 = *Acaulospora laevis*

P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)

P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)

P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)

NS = Non-significant DAT = Days after transplanting

G. fasciculatum and *S. dussii* were statistically on par with each other. Similarly plants inoculated with *A. laevis* and uninoculated showed only numerical differences. Significantly higher number of leaves were recorded in plants inoculated with *G. fasciculatum* (28.85) followed by *S. dussii* (25.70), uninoculated control (22.77) and lowest in plants inoculated with *A. laevis* (22.29) at III stage of growth (910 DAT). Similar trend was observed during the last stage of growth.

Influence of 'P' levels on number of leaves was found to be significant at all the growth stages except at 910 DAT.

Significantly higher number of leaves were recorded in plants supplied with 50 per cent RDP (19.00) followed by 75 per cent RDP (18.11) and 100 per cent RDP (17.50) during 790 DAT. Similar trend was followed during 850 and 970 DAT.

Interaction effects were found to be significant at all the growth stages. In 790 days after planting significantly higher number of leaves were recorded in plants inoculated with *G. fasciculatum* and supplied with 50 per cent RDP followed by plants supplied with 75 per cent RDP without VAM inoculations. During 850 DAT, significantly higher number of leaves were recorded in plants inoculated with *S. dussii* and supplied with 100 per cent RDP (28.44) followed by plants inoculated with *G. fasciculatum* and with 50 per cent RDP (28.11). However, these two treatments were statistically on par with each other. Significantly lower number of leaves were recorded in plants supplied with 100 per cent RDP (20.55) without VAM inoculation. At 910 DAT, highest number of leaves were recorded in plants treated with *G. fasciculatum* and with 50 per cent RDP. Significantly lowest leaves were recorded in plants inoculated with *A. laevis* applied with 75 per cent RDP. During the last stage of growth (970 DAT), higher number of leaves were recorded in plants inoculated with *G. fasciculatum* and applied with 50 per cent RDP (33.33) and least was recorded in plants treated with *A. laevis* and 100 per cent RDP (23.00).

4.1.1.4 Petiole length

The data on petiole length (cm) as influenced by VAM fungi at different levels of 'P' are presented in Table-4.

Effect of VAM on leaf petiole length was found significant during both observations. Plants inoculated with *G. fasciculatum* recorded significantly higher petiole length (70.74 cm) followed by *S. dussii* (69.14 cm), *A. laevis* (62.45 cm) and least petiole length was recorded in uninoculated control (60.59 cm) at 790 DAT. The petiole length in the plants inoculated with *G. fasciculatum* and *S. dussii* showed only numerical difference in them. Similar trend was observed during 850 DAT.

Influences of different 'P' levels were found significant. At 790 DAT, significant highest petiole length was observed in plants which

Table 4. Effect of different VAM fungi and phosphorus levels on petiole length (cm) at different stages of growth in papaya

Treatment	Petiole length (cm)			
	I stage 790 DAT		II stage 850 DAT	
M_0P_1	54.48		66.59	
M_0P_2	63.25		66.17	
M_0P_3	64.03		70.87	
Mean for M_0	60.59		67.87	
M_1P_1	69.36		73.34	
M_1P_2	76.02		78.45	
M_1P_3	66.84		82.78	
Mean for M_1	70.74		78.19	
M_2P_1	67.17		69.71	
M_2P_2	73.67		77.23	
M_2P_3	66.57		81.26	
Mean for M_2	69.14		76.06	
M_3P_1	64.08		67.41	
M_3P_2	72.16		77.92	
M_3P_3	55.11		78.41	
Mean for M_3	62.45		74.58	
P_1	63.77		69.26	
P_2	71.27		74.94	
P_3	62.14		78.33	
For comparing the means of	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)
VAM	0.899	3.111	0.580	2.009
P	1.456	4.362	0.570	1.708
VAM x P	2.541	7.615	1.097	3.287

M_0 = Uninoculated control; M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*; M_3 = *Acaulospora laevis*

P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)

P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)

P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)

DAT = Days after transplanting

received 75 per cent RDP (71.27 cm) followed by 50 per cent RDP (63.77 cm) and least was noticed in 100 per cent RDP (62.14 cm). During 850 DAT, significantly higher petiole length was recorded in plants supplied with 100 per cent RDP (78.33 cm) followed by 75 per cent RDP (74.94 cm) and lowest was observed in 50 per cent RDP (69.26 cm).

Interaction effects were found significant with respect to leaf petiole length. During 790 DAT, highest petiole length was recorded in plants inoculated with *G. fasciculatum* and supplied with 75 per cent RDP (76.02 cm), whereas, significantly lower petiole length was noted in plants receiving only 50 per cent RDP (54.48 cm) in control plots. Higher petiole length was observed in 850 days old plants inoculated with *G. fasciculatum* and supplied with 100 per cent RDP (82.78 cm) and significantly lower values were registered in plants uninoculated and supplied with 50 per cent RDP (66.59 cm).

4.1.2 Yield parameters

4.1.2.1 Fruit length, circumference and mean fruit weight

The data on fruit length, circumference and mean fruit weight as influenced by VAM fungi at different levels of 'P' are presented in Table-5.

The data reveals that the effect of VAM fungi on fruit length was non-significant. However the effect of different levels of 'P' were found

Table 5. Effect of different VAM fungi and phosphorus levels on fruit length (cm), fruit circumference (cm) and mean fruit weight (g)

Treatment	Fruit length (cm)		Fruit circumference (cm)		Mean fruit weight (g)	
M_0P_1	16.05		21.27		465.00	
M_0P_2	18.00		26.63		508.33	
M_0P_3	20.75		28.72		526.67	
Mean for M_0	18.27		25.54		500.00	
M_1P_1	16.70		28.68		590.00	
M_1P_2	19.24		32.31		509.00	
M_1P_3	19.83		32.91		560.00	
Mean for M_1	18.59		31.30		553.00	
M_2P_1	15.27		27.93		543.33	
M_2P_2	16.88		31.26		530.00	
M_2P_3	20.34		32.20		568.33	
Mean for M_2	17.50		30.46		547.22	
M_3P_1	15.21		22.81		488.33	
M_3P_2	17.56		30.80		511.67	
M_3P_3	19.82		31.23		553.33	
Mean for M_3	17.53		28.28		517.78	
P_1	15.81		25.17		521.67	
P_2	17.92		30.25		514.75	
P_3	20.19		31.26		552.08	
For comparing the mean of	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)
VAM	0.464	NS	0.676	2.341	13.337	NS
P	0.482	1.445	0.255	0.765	17.093	52.611
VAM x P	0.914	NS	0.794	2.381	19.304	57.848

M_0 = Uninoculated control; M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*; M_3 = *Acaulospora laevis*

P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)

P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)

P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)

NS = Non-significant

to be significant. Significantly higher fruit length was recorded in the plants supplied with 100 per cent RDP (20.19 cm) followed by 75 per cent RDP (17.92 cm) and least was observed in 50 per cent RDP (15.81 cm).

The interaction effects for this character were non-significant.

Effect of VAM fungi on fruit circumference was found to be significant. Significantly higher fruit circumference was recorded in plants inoculated with *G. fasciculatum* (31.30 cm) followed by *S. dussii* (30.46 cm), *A. laevis* (28.28 cm) and lowest in the plants without inoculation (25.54 cm). Plants inoculated with *S. dussii* and *A. laevis* registered statistically on par differences.

Effect of 'P' was also found to be significant. Significantly highest fruit circumference was recorded in plants receiving 100 per cent RDP (31.26 cm) followed by 75 per cent RDP (30.25 cm) and 50 per cent RDP (25.17 cm).

Interaction effects were also found to be significant with respect to this trait. Significantly highest fruit circumference was recorded in plants inoculated with *G. fasciculatum* along with 100 per cent RDP (32.91 cm) followed by *G. fasciculatum* along with 50 per cent RDP (32.31 cm). However, these two treatments were on par with each other. Significantly lower values for fruit circumference were noticed in control plants applied with 50 per cent RDP (21.27 cm).

Effect of VAM fungi on mean fruit weight was found to be non-significant. However, effect of different levels of 'P' on fruit weight was found to be significant. Significantly higher fruit weight was recorded in plants supplied with higher dose of 'P' (552.08 g) followed by 50 per cent RDP (521.67 g) and 75 per cent RDP (514.75 g). However, the plants supplied with 75 per cent RDP and 50 per cent RDP were found to be on par.

Interaction effects were also found to be significant. Significantly higher fruit weight was recorded in plants inoculated with *G. fasciculatum* with 50 per cent RDP (590.00 g) followed by plants inoculated with *S. dussii* and supplied with 50 per cent RDP (543.33 g) and same organism with 100 per cent RDP (568.33 g). Significantly lowest fruit weight was noticed in control plants supplied with 50 per cent RDP.

4.1.2.2 Number of fruits per plant

Data on number of fruits per plant is presented in Table-6 and Fig-2.

Influence of VAM fungi on number of fruits per plant was found significant. Significantly higher number of fruits per plant were recorded in plants treated with *G. fasciculatum* (31.58) followed by *S. dussii* (24.56), *A. laevis* (19.23) and least was recorded in control plants (19.00).

Table 6. Effect of different VAM fungi and phosphorus levels on number of fruits per plant, fruit yield per plant (kg) and fruit yield per hectare (t)

Treatment	No. of fruits per plant		Fruit yield per plant (kg)		Fruit yield per hectare (t)	
M_0P_1	15.33		7.12		21.97	
M_0P_2	18.47		9.39		28.96	
M_0P_3	23.22		12.17		37.54	
Mean for M_0	19.00		9.56		29.49	
M_1P_1	27.17		14.11		43.55	
M_1P_2	35.31		17.95		55.41	
M_1P_3	32.25		18.09		55.79	
Mean for M_1	31.58		16.72		51.58	
M_2P_1	16.01		8.71		26.84	
M_2P_2	31.50		16.65		51.36	
M_2P_3	26.16		14.86		45.85	
Mean for M_2	24.56		13.41		41.35	
M_3P_1	24.23		11.78		36.35	
M_3P_2	22.01		11.25		34.72	
M_3P_3	22.45		12.42		38.31	
Mean for M_3	19.23		9.77		30.14	
P_1	20.67		10.43		32.18	
P_2	26.82		13.81		42.61	
P_3	23.27		12.85		39.65	
For comparing the mean of	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)	S.Em±	C.D. (5%)
VAM	0.426	1.474	0.518	1.793	1.593	5.513
P	0.434	1.301	0.308	0.922	0.952	2.854
VAM x P	0.827	2.478	0.722	2.163	2.226	6.671

M_0 = Uninoculated control M_1 = *Glomus fasciculatum*
M_2 = *Sclerocystis dussii* M_3 = *Acaulospora laevis*
P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)
P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)
P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)
NS = Non-significant

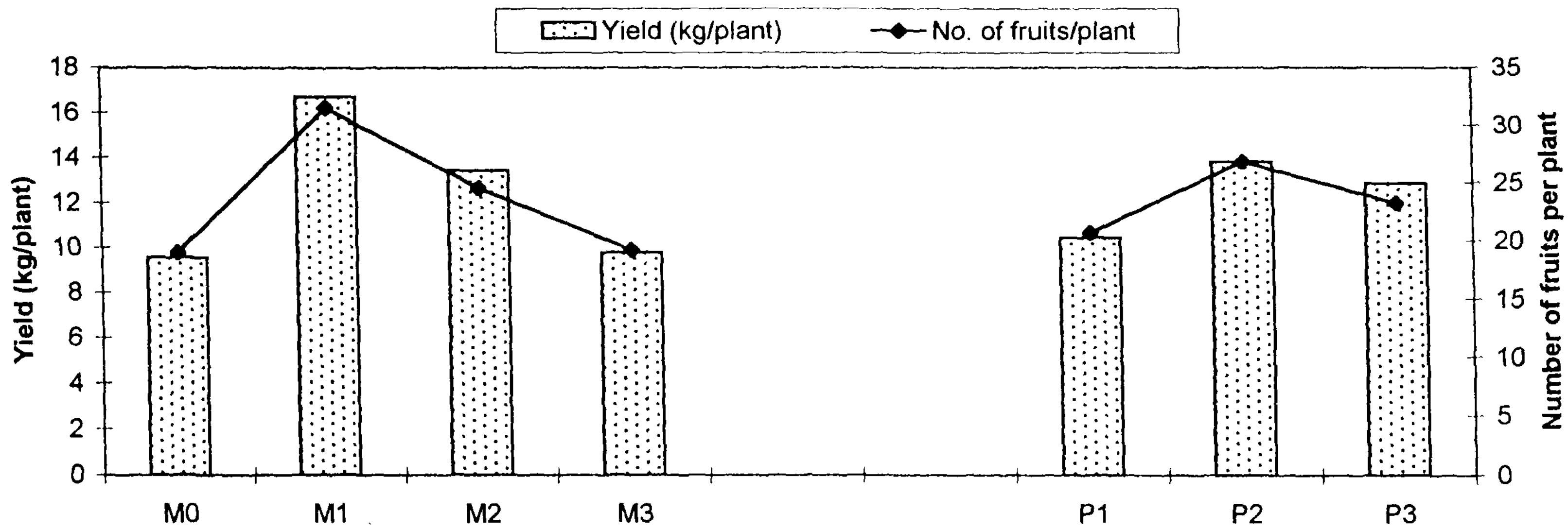


Fig.2. Effect of different VAM fungi and phosphorus levels on number of fruits per plant and fruit yield per plant (kg)

M_0 = Uninoculated control M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii* M_3 = *Acaulospora laevis*

P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)

P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)

P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)

Influence of different levels of 'P' was found significant. Significantly highest number of fruits per plant was seen in plants which had received 75 per cent RDP (26.82) followed by 100 per cent RDP (23.27) and least was seen in 50 per cent RDP (20.67).

Interaction effects were also found to be significant. Significantly higher number of fruits were recorded in plants inoculated with *G. fasciculatum* and supplied with 75 per cent RDP (35.31) and least was recorded in plants inoculated with *A. laevis* and supplied with 100 per cent RDP (11.45).

4.1.2.3 Yield per plant

The data on yield per plant as influenced by VAM fungi at different phosphorus levels are presented in Table-6 and illustrated in Fig-2.

The influence of VAM fungi on fruit yield per plant was found to be significant, recording significantly highest yield per plant in plants inoculated with *G. fasciculatum* (16.72 kg) followed by *S. dussii* (13.41 kg), *A. laevis* (9.77 kg) and uninoculated control. Plants treated with *A. laevis* and uninoculated control was found to be statistically on par.

The effect of different levels of phosphorus on fruit yield per plant was significant. Significantly highest fruit yield was recorded in plants which received 75 per cent RDP (13.81 kg) followed by 100 per cent RDP (12.85 kg) and least was seen in 50 per cent RDP (10.43 kg).

The interaction effects were also found to be significant. Highest fruit yield per plant was recorded in plants inoculated with *G. fasciculatum* with 100 per cent RDP (18.09 kg). Significantly lowest fruit yield was noted in plants inoculated with *A. laevis* and supplied with 100 per cent RDP (6.27 kg/plant).

4.1.2.4 Yield per hectare

The data on yield per hectare as influenced by VAM fungi at different levels are presented in Table-6

Influence of VAM fungi on fruit yield per hectare was significant. Highest fruit yield was recorded in plants inoculated with *G. fasciculatum* (51.58 t/ha) followed by *S. dussii* (41.35 t/ha), *A. laevis* (30.14 t/ha) and least was recorded in uninoculated plants (29.49 t/ha).

Effect of 'P' levels on fruit yield per hectare was significant. Highest fruit yield was recorded in plants supplied with 75 per cent RDP (42.61 t/ha) followed by 100 per cent RDP (39.65 t/ha) and least was recorded in 50 per cent RDP (32.18 t/ha).

Interaction effects were also found to be significant. Significantly highest fruit yield per hectare was recorded in plants treated with *G. fasciculatum* and supplemented with 100 per cent

RDP (55.79 t/ha), while significantly lower values were recorded in plants with 100 per cent RDP.

4.1.3 Quality parameters

4.1.3.1 TSS

Effect of different VAM fungi and 'P' levels on TSS (°Brix) is presented in Table-7.

The perusal of data in Table-7 clearly indicates that the influence of VAM fungi on TSS was significant. Plants inoculated with *G. fasciculatum* (11.90°Brix) were found to be superior over plants inoculated with *A. laevis* (10.29°Brix), *S. dussii* (10.18°Brix). Differences between the plants inoculated with *A. laevis* (10.29°Brix) and control (9.77°Brix) plants were statistically similar.

The influence of different levels of 'P' on TSS was found significant. Significantly higher TSS was recorded in plants supplied with 75 per cent RDP (10.77°Brix) followed by 50 pre cent RDP (10.46°Brix) and least was recorded in 100 per cent RDP (10.38°Brix).

The interaction effects were found non-significant.

4.1.3.2 Vitamin C

The data on vitamin C content as influenced by different VAM fungi and levels of 'P' are presented in Table-7.

Table 7. Effect of different VAM fungi and phosphorus levels on total soluble solids, vitamin C, sugars and physiological loss in weight

Treatment	TSS (°Brix)	Vitamin C (mg/100g)	Sugars (%)			Per cent physiological loss in weight
			Reducing	Non-reducing	Total	
M_0P_1	9.67	33.41	9.82	2.46	12.43	9.02
M_0P_2	10.03	33.17	10.41	2.40	13.02	11.37
M_0P_3	9.63	33.46	11.08	2.41	13.44	11.23
Mean for M_0	9.77	33.35	10.43	2.42	12.95	10.54
M_1P_1	11.47	35.67	12.31	2.06	14.43	8.11
M_1P_2	12.47	37.07	11.66	2.20	13.93	9.22
M_1P_3	11.77	36.27	11.69	2.40	13.74	9.68
Mean for M_1	11.90	36.34	11.89	2.23	14.03	9.00
M_2P_1	10.40	33.61	11.15	2.20	13.43	9.76
M_2P_2	10.43	35.32	11.36	2.18	13.66	9.20
M_2P_3	9.73	33.91	10.97	2.19	13.40	10.53
Mean for M_2	10.18	34.28	11.16	2.19	13.50	9.83
M_3P_1	10.30	34.33	11.38	2.27	13.52	8.25
M_3P_2	10.17	34.58	11.47	2.17	13.80	10.34
M_3P_3	10.40	34.43	10.23	2.33	12.92	9.73
Mean for M_3	10.29	34.45	11.03	2.26	13.41	9.44
P_1	10.46	34.25	11.16	2.25	13.45	8.79
P_2	10.77	35.04	11.23	2.23	13.60	10.03
P_3	10.38	34.52	10.99	2.34	13.38	10.29

For comparing the means of	TSS S.Em±	TSS C.D. (5%)	Vitamin C S.Em±	Vitamin C C.D. (5%)	Reducing S.Em±	Reducing C.D. (5%)	Non-reducing S.Em±	Non-reducing C.D. (5%)	Total S.Em±	Total C.D. (5%)	PLW S.Em±	PLW C.D. (5%)
VAM	0.111	0.383	0.137	0.476	0.183	0.632	0.114	NS	0.151	0.522	0.882	NS
P	0.107	0.321	0.182	0.545	0.094	NS	0.092	NS	0.080	NS	0.541	NS
VAM x P	0.207	NS	0.327	NS	0.239	0.716	0.188	NS	0.200	0.599	1.248	NS

M_0 = Uninoculated control M_1 = *Glomus fasciculatum*
M_2 = *Sclerocystis dussii* M_3 = *Acaulospora laevis*
P_1 = 50 per cent of the recommended dose of 'P' (312.5 kg P_2O_5 per ha)
P_2 = 75 per cent of the recommended dose of 'P' (468.75 kg P_2O_5 per ha)
P_3 = 100 per cent of the recommended dose of 'P' (625 kg P_2O_5 per ha)
NS = Non-significant

The effect of different VAM fungi on vitamin C content was found significant. Higher vitamin C content was recorded in plants inoculated with *G. fasciculatum* (36.34 mg) followed by *A. laevis* (34.45 mg), *S. dussii* (34.28 mg) and lowest was recorded in uninoculated control (33.35 mg). Plants inoculated with *A. laevis* and *S. dussii* were on par.

The influence of different levels of phosphorus was found significant. Highest vitamin C content was observed in plants supplied with 75 per cent RDP (35.04 mg) followed by plants supplied with 100 per cent RDP (34.52 mg) and 50 per cent RDP (34.25 mg). The values in the plants supplied with 50 per cent RDP and 100 per cent RDP were found on par with each other.

The interaction effects were found to be non-significant.

4.1.3.3 Reducing sugars

The data on per cent reducing, non-reducing and total sugars as influenced by different VAM fungi and 'P' levels are presented in Table-7.

The effect of VAM fungi on per cent reducing sugars was found significant. Significantly higher reducing sugars were observed in the fruits of plants which were treated with *G. fasciculatum* (11.89%) followed by *S. dussii* (11.16%), *A. laevis* (11.03%) and uninoculated control (10.43%) plants inoculated with *S. dussii* and *A. laevis* were on par. Similarly, plants inoculated with *A. laevis* and control plants were on par.

Effect of different 'P' levels on reducing sugar content was found non-significant, whereas interaction effects were found to be significant. Significantly higher reducing sugar content was observed in plants inoculated with *G. fasciculatum* along with 50 per cent RDP and significantly lowest percentage was observed in controlled plants applied with 50 per cent RDP.

4.1.3.4 Non-reducing sugars

Effect of different VAM fungi phosphorus levels and interaction effects on the content of non-reducing sugars were found to be non-significant (Table-7).

4.1.3.5 Total sugars

The effect of different VAM fungi on the content of total sugars was found to be significant. Significantly higher total sugar content was observed in plants inoculated with *G. fasciculatum* (14.03%) followed by *S. dussii* (13.50%), *A. laevis* (13.41%) and least was recorded in plants uninoculated control plants (12.95%). Plants inoculated with *S. dussii* and *A. laevis* were on par.

Influence of different levels of phosphorus was found non-significant, whereas interaction effects were found significant. Significantly higher per cent total sugars were recorded in plants inoculated with *G. fasciculatum* and supplied with 50 per cent RDP (14.43%) followed by similar organism with 75 pre cent RDP and was observed in control plants supplied with 50 per cent RDP (12.43%).

4.1.4 Per cent physiological loss in weight

The data on per cent physiological loss in weight (PLW) as influenced by different VAM fungi and 'P' levels are presented in Table-7.

The influence of different VAM fungi, different levels of phosphorus and their interaction effects were found to be non-significant.

4.2 Experiment-II: Effect of VAM on drought tolerance of papaya

4.2.1 Growth parameters

4.2.1.1 Plant height

The data on the plant height as influenced by different VAM fungi are presented in Table-8.

The study of data indicated that the influence of VAM fungi on plant height of papaya was significant at all the stages of growth. In first week, the plants inoculated with *Sclerocystis dussii* (16.75 cm) recorded significantly higher plant height than the plants inoculated with *Glomus fasciculatum* (14.55 cm), *Acaulospora laevis* (14.30 cm) and uninoculated control (8.65 cm). The plant height recorded with different VAM fungi and uninoculated control at II, III, IV, V and VI

Table 8. Effect of different VAM fungi on plant height (cm) at weekly interval of papaya 45 DAT

Sl. No.	Treatment	Plant height (cm)					
		I week	II week	III week	IV week	V week	VI week
1.	M_0	8.65	9.95	11.80	15.16	17.75	19.93
2.	M_1	14.55	15.80	18.50	22.60	25.05	25.85
3.	M_2	16.75	17.91	19.15	23.60	26.20	28.15
4.	M_3	14.30	16.37	17.85	22.20	24.30	26.37
Comparing the means of							
S.Em±		0.386	0.313	0.246	0.382	0.312	0.289
C.D. at 5%		1.191	0.964	0.758	1.178	0.963	0.892

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

weeks followed similar trend. The plant height recorded with the inoculation of *Sclerocystis dussii* and *Glomus fasciculatum* in I, II and VI weeks were significantly different, whereas in III, IV and V weeks the plant heights of the plants inoculated with *Sclerocystis dussii*, *Glomus fasciculatum* and *Acaulospora laevis* were on par with each other.

The plants inoculated with *Sclerocystis dussii*, *Acaulospora laevis* in II, III, IV, V and VI weeks recorded significant differences among the treatments. There was significant difference between treated and uninoculated controlled plants.

4.2.1.2 Stem girth

The perusal of data on the plant girth as influenced by different VAM fungi are presented in Table-9.

The data indicated that the influence of VAM fungi on girth of papaya was significant at all the stages of growth with respect to treated and uninoculated control.

There was significant difference among the treatments, *viz.*, *Glomus fasciculatum*, *Sclerocystis dussii*, *Acaulospora laevis* and uninoculated control at I, II and III week. However, the effect of inoculation of three strains of VAM fungi on stem girth of papaya was found to be on par at IV, V and VI week.

Table 9. Effect of different VAM fungi on stem girth (cm) at weekly interval of papaya 45 DAT

Sl. No.	Treatment	Plant girth (cm)					
		I week	II week	III week	IV week	V week	VI week
1.	M_0	0.34	0.41	0.48	0.61	0.68	0.80
2.	M_1	0.73	0.79	0.89	0.97	1.13	1.26
3.	M_2	0.65	0.72	0.81	0.97	1.12	1.25
4.	M_3	0.57	0.65	0.76	0.92	1.07	1.18
Comparing the means of							
S.Em±		0.017	0.020	0.014	0.022	0.019	0.035
C.D. at 5%		0.053	0.063	0.042	0.068	0.060	0.109

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

4.2.1.3 Number of leaves per plant

The data on number of leaves per plants influenced by different VAM fungi are presented in Table-10.

The influence of VAM fungi on number of leaves at different growth stages were found to be significant.

In first week, highest number of leaves per plant were recorded in plants treated with *G. fasciculatum* (8.10) and least was observed in uninoculated control (5.90). Similar trend was seen in II, III, IV, V and VI week after transplanting to pots. Plants inoculated with *S. dussii* and *A. laevis* were found to be on par in I, III, IV, V, VI weeks after transplanting except in II week. In II week, there was significant difference between plants inoculated with *S. dussii* (7.70), *A. laevis* (7.20) and *G. fasciculatum* (8.20).

4.2.1.4 Fresh weight of shoot, root and leaf before drought imposition

The results on the shoot, root and leaf fresh weight (g) as influenced by different VAM fungi are tabulated in Table-11 and illustrated in Fig.-3. These parameters were recorded before the imposition of drought.

The data reveals that the influence of VAM fungi on shoot, root and leaf fresh weight was significant. Significantly higher fresh shoot weight of 23.80 g was noticed in the plants inoculated with *Glomus fasciculatum* than the plants inoculated with *Sclerocystis dussii, Acaulospora laevis* and uninoculated control. Plants inoculated with

Table 10. Effect of different VAM fungi on number of leaves per plant at weekly interval 45 DAT

Sl. No.	Treatment	Number of leaves					
		I week	II week	III week	IV week	V week	VI week
1.	M_0	5.90	6.90	7.20	8.20	9.00	9.60
2.	M_1	8.10	8.20	9.30	10.10	10.70	11.50
3.	M_2	6.80	7.70	8.30	8.80	9.40	10.10
4.	M_3	6.20	7.20	8.20	9.20	9.70	10.10
Comparing the means of							
S.Em±		0.270	0.112	0.207	0.339	0.269	0.336
C.D. at 5%		0.832	0.346	0.639	1.045	0.830	1.036

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

Plate 1. Effect of VAM on growth of papaya before imposition of drought

Table 11. Effect of different VAM fungi on fresh weight and dry weight (g) of root, shoot and leaf before imposition of drought

Sl. No.	Treatment	Fresh weight			Dry weight		
		Root	Shoot	Leaf	Root	Shoot	Leaf
1.	M_0	13.95	14.00	6.40	1.65	1.93	1.28
2.	M_1	18.70	23.80	14.00	2.31	2.70	2.50
3.	M_2	15.46	15.40	8.20	2.15	1.94	1.56
4.	M_3	12.30	14.58	7.26	1.84	2.04	1.34
Comparing the means of							
S.Em±		0.676	0.680	0.404	0.050	0.075	0.034
C.D. at 5%		2.084	2.095	1.244	0.153	0.237	0.105

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

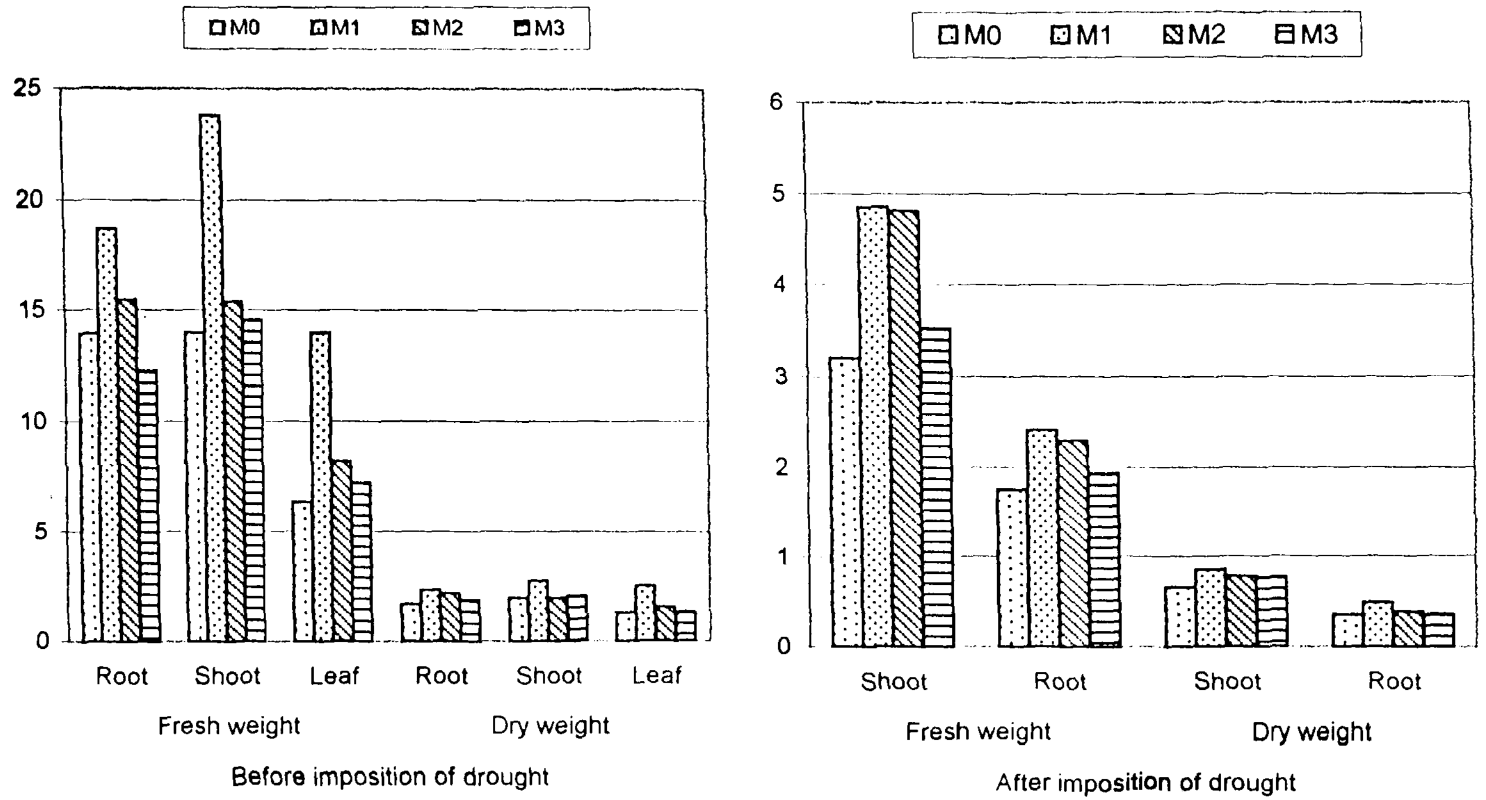


Fig.3. Effect of different VAM fungi on fresh weight (g) and dry weight **(g) of** root, shoot and leaf before and after imposition of drought

M_0 = Uninoculated control M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii* M_3 = *Acaulospora laevis*

Sclerocystis dussii, Acaulospora laevis and uninoculated control were on par with each other.

In case of fresh weight of root (g), there were significant differences among the treatments. Highest fresh root weight was recorded in the plants inoculated with *Glomus fasciculatum* (18.70 g) followed by *Sclerocystis dussii*, uninoculated control and *Acaulospora laevis*. However, the plants treated with *Acaulospora laevis and* uninoculated control was on par.

With respect to fresh weight of leaf, there was significant difference between the treatments. Highest fresh weight of leaf (14.00 g) was observed in the plants treated with *Glomus fasciculatum* and least was recorded in the uninoculated plants. However, the plants treated with *Sclerocystis dussii* and *Acaulospora laevis* were on par. Similar trend was seen in the plants treated with *Acaulospora laevis* and uninoculated control.

4.2.1.5 Dry weight of shoot, root and leaf before drought imposition

The data on the shoot, root and leaf dry weight (g) as influenced by different VAM fungi are presented in Table-11. These parameters were recorded before the imposition of drought.

The data indicates that the influence of VAM fungi on root weight was significant. Significantly higher root dry weight was recorded in the plants treated with *Glomus fasciculatum* (2.31 g) followed by *Sclerocystis dussii*, *Acaulospora laevis* and least was noticed in uninoculated control (1.65 g).

The influence of VAM fungi on shoot dry weight was significant. There were significant differences between the plants inoculated with *G. fasciculatum* (2.70 g) and *Sclerocystis dussii* (1.94), whereas plants treated with *S. dussii* and *A. laevis* and uninoculated control were on par.

Plants inoculated with *G. fasciculatum* recorded highest leaf dry weight (2.50 g) followed by *S. dussii* (1.56 g) and *A. laevis* (1.34 g). There was significant difference between the plants treated with *G. fasciculatum*, *S. dussii* and *A. laevis*. However, plants treated with *A. laevis* and uninoculated control were on par.

4.2.1.6 Fresh weight of stem and root after drought imposition

The data on fresh weight of stem and roots are presented in Table-12 and illustrated in Fig.-3.

The influence of VAM fungi on fresh weight of stem and root were significant. Plants inoculated with *G. fasciculatum* (4.86 g) and *S. dussii* (4.82 g) were recorded significantly higher fresh weight than plants inoculated with *A. laevis* (3.53 g) and uninoculated control (3.20 g). Plants inoculated with *G. fasciculatum* and *S. dussii* were on par. With respect to root fresh weight, highest root fresh weight was recorded in plants inoculated with *G. fasciculatum* (2.41 g) followed

Table 12. Effect of different VAM fungi on fresh weight and dry weight (g) of root and shoot after imposition of drought

Sl. No.	Treatment	Fresh weight		Dry weight (g)	
		Shoot	Root	Shoot	Root
1.	M_0	3.20	1.76	0.66	0.35
2.	M_1	4.86	2.41	0.85	0.49
3.	M_2	4.82	2.29	0.78	0.39
4.	M_3	3.53	1.94	0.77	0.36
Comparing the means of					
S.Em±		0.083	0.018	0.034	0.010
C.D. at 5%		0.254	0.057	0.104	0.030

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

by *S. dussii* (2.29 g), *A. laevis* (1.94 g) and uninoculated control (1.76 g). Plants treated with *G. fasciculatum* and *S. dussii* were found superior over plants inoculated with *A. laevis* and uninoculated control.

4.2.1.7 Dry weight of stem and root after drought imposition

The data on dry weight (g) of stem and root were found significant.

Significantly higher stem dry weight was observed in plants inoculated with *G. fasciculatum* (0.85 g) followed by *S. dussii* (0.78 g) followed by *A. laevis* (0.77 g) and uninoculated control (0.66 g). However, plants inoculated with *G. fasciculatum* and *S. dussii* were on par. Similarly plants inoculated with *A. laevis* and uninoculated control were on par. with respect to root dry weight, similar trend was observed. Plants inoculated with *G. fasciculatum* (0.49 g) and *S. dussii* (0.39 g) were on par. Likewise, plants inoculated with *A. laevis* (0.36 g) and uninoculated control (0.35 g) were on par.

4.2.2 Physiological parameters

4.2.2.1 Chlorophyll content before drought imposition

Chlorophyll content (mg/g fresh weight basis) as influenced by different VAM fungi before drought imposition was recorded and are presented in Table-13.

Table 13. Effect of different VAM fungi on chlorophyll content (mg/g fresh weight basis) before imposition of drought and 10 days after imposition of drought

Sl. No.	Treatment	Before drought imposition			10 days after drought imposition		
		Chloro phyll 'a'	Chloro phyll 'b'	Total chloro phyll	Chloro phyll 'a'	Chloro phyll 'b'	Total chloro phyll
1.	M_0	1.27	1.00	2.27	1.11	0.88	1.99
2.	M_1	1.43	1.21	2.64	1.36	1.19	2.55
3.	M_2	1.37	1.26	2.63	1.36	1.08	2.44
4.	M_3	1.22	0.97	2.20	1.15	0.89	2.04
Comparing the means of							
S.Em±		0.007	0.005	0.008	0.005	0.011	0.006
C.D. at 5%		0.022	0.015	0.025	0.016	0.034	0.019

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

Chlorophyll 'a'

The influence of different VAM fungi on chlorophyll 'a' content was found to be significant. Significantly highest chlorophyll 'a' was observed in the plants treated with *G. fasciculatum* (1.43 mg) and least was recorded in *A. laevis* treated plants (1.22 mg).

Chlorophyll 'b'

The influence of different VAM fungi on chlorophyll 'b' content was found to be significant. Highest chlorophyll 'b' was recorded in *S. dussii* followed by *G. fasciculatum* and least was noticed in *A. laevis* treated plants.

Total chlorophyll

The effect of three species of VAM fungi on total chlorophyll content was found to be significant. The content of total chlorophyll in the plants inoculated with *G. fasciculatum* and *S. dussii* were found to be on par, whereas there were significant differences between the plants treated with *G. fasciculatum*, *A. laevis* and uninoculated control.

4.2.2.2 Chlorophyll content after 10 days of drought imposition

Chlorophyll content (mg/g fresh weight basis) as influenced by different VAM fungi 10 days after drought imposition is presented in Table-13.

Chlorophyll 'a'

Influence of VA mycorrhizal inoculation on chlorophyll 'a' content was found to be significant. Chlorophyll 'a' content of the plants inoculated with *G. fasciculatum* was found to be on par with plants inoculated with *S. dussii*. However, there were significant differences observed between the plants inoculated with *G. fasciculatum*, *A. laevis* and uninoculated control.

Chlorophyll 'b'

Influence of VAM fungi on chlorophyll 'b' content was found to be significant. There were significant differences between plants inoculated with *G. fasciculatum* (1.19 mg), *S. dussii* (1.08 mg) and *A. laevis* (0.89), whereas plants inoculated with *A. laevis* and uninoculated control were on par.

Total chlorophyll

Influence of VAM fungi on total chlorophyll content was found to be significant. Highest total chlorophyll content was recorded in plants inoculated with *G. fasciculatum* (2.55 mg) and least was recorded in case of uninoculated (1.99 mg) plants. There was significant difference among the treatments.

4.2.2.3 Per cent relative water content of leaf

Data recorded on per cent relative water content (r.w.c.) of leaf as influenced by different VAM fungi are presented in Table-14.

Table 14. Effect of different VAM fungi on per cent relative water content (r.w.c.) of leaf before drought and per cent soil moisture content before and after imposition of drought

Sl. No.	Treatment	Per cent relative water content	Per cent soil moisture	
			Before drought	After drought
1.	M_0	61.39	4.80	0.33
2.	M_1	66.75	8.80	0.43
3.	M_2	64.72	7.20	0.43
4.	M_3	62.49	5.20	0.30
Comparing the means of				
S.Em±		0.772	0.503	0.020
C.D. at 5%		2.378	1.551	0.061

Highest per cent r.w.c. was observed in *G. fasciculatum* inoculated plants (66.75%) compared to *S. dussii* (64.72%), *A. laevis* (62.49%) and least in control (61.39%). However, plants treated with *G. fasciculatum* (66.75%) and *S. dussii* (64.72%) were on par.

4.2.2.4 Soil moisture content

The data on soil moisture content (%) before and after drought imposition are presented in Table-14.

The influence of VAM fungi on soil moisture per cent before drought was found to be significant. Significantly higher soil moisture per cent was recorded in *G. fasciculatum* (8.80%) treated pots followed by *S. dussii* (7.20%) and *A. laevis* (5.20%). However, the treatments *A. laevis* and uninoculated control were on par.

The influence of VAM fungi on per cent soil moisture content after drought imposition was found to be significant. Soil treated with *G. fasciculatum* (0.43%) and *S. dussii* (0.43%) recorded significantly higher soil moisture content when compared to soils treated with *A. laevis* and uninoculated control. However, soil treated with *A. laevis* (0.30%) and uninoculated control (0.33%) was found to be on par with each other.

4.2.2.5 Proline content

The data on proline content as influenced by different VAM fungi on 10 days and 20 days after drought imposition are presented in Table-15.

Table 15. Effect of different VAM fungi on proline content (μ moles/g) 10 days and 20 days after imposition of drought and days taken for permanent wilting

Sl.No.	Treatment	Proline content (μ moles/g of fresh weight)		Days taken for permanent wilting
		10 DAD	20 DAD	
1.	M_0	12.65	35.01	25
2.	M_1	8.17	27.00	30
3.	M_2	10.14	32.01	28
4.	M_3	9.32	22.54	25
For comparing the means of				
S.Em±		0.272	0.103	0.145
C.D. at 5%		0.840	0.318	0.440

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

DAD = Days after drought

Plate 2. Effect of VAM on growth of papaya after imposition of drought

The significant differences in the proline content were noticed both at 10 days and 20 days after drought due to the inoculation of *Glomus fasciculatum*, *Sclerocystis dussii* and *Acaulospora laevis*.

Ten days after drought, highest proline content was recorded in uninoculated plants (12.65 μ moles) and least was recorded in plants treated with *G. fasciculatum* (8.17 μ moles) followed by plants treated with *A. laevis* (9.32 μ moles). The plants treated with *S. dussii* and *A. laevis* were on par.

Twenty days after drought, highest proline content was recorded again in uninoculated plants (35.01 μ moles) and least was recorded in plants treated with *A. laevis* (22.54 μ moles) followed by plants treated with *G. fasciculatum* (27.00 μ moles). There was significant difference among the treatments.

4.2.3 Nutritional parameters

4.2.3.1 Leaf nutrients

Significant variations were observed due to inoculation of VAM fungi on leaf nutrient contents. The data are presented in Table-16 and illustrated in Fig.-4.

There were significant differences among the treatments with respect to per cent leaf N, P and K and micronutrients. The influence of VAM fungi on leaf 'N' was significant. Highest leaf 'N' content was recorded in plants treated with *S. dussii* (0.93%) followed by *G. fasciculatum* (0.92%), *A. laevis* (0.74%) and least was observed in

Table 16. Effect of different VAM fungi on leaf nutrient content (dry weight basis) of papaya

Sl. No.	Treatment	Nutrients (dry weight basis)					
		N	P	K	Micronutrients (ppm)		
					Zn	Cu	*Mn*
1.	M_0	0.57	0.04	0.37	57.00	43.00	86.40
2.	M_1	0.92	0.07	0.52	62.20	40.41	183.40
3.	M_2	0.93	0.07	0.42	67.10	53.60	108.66
4.	M_3	0.74	0.06	0.38	60.90	25.00	91.10
For comparing the means of							
S.Em±		0.030	0.001	0.028	1.123	5.393	8.291
C.D. at 5%		0.092	0.003	0.086	3.460	16.622	25.556

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

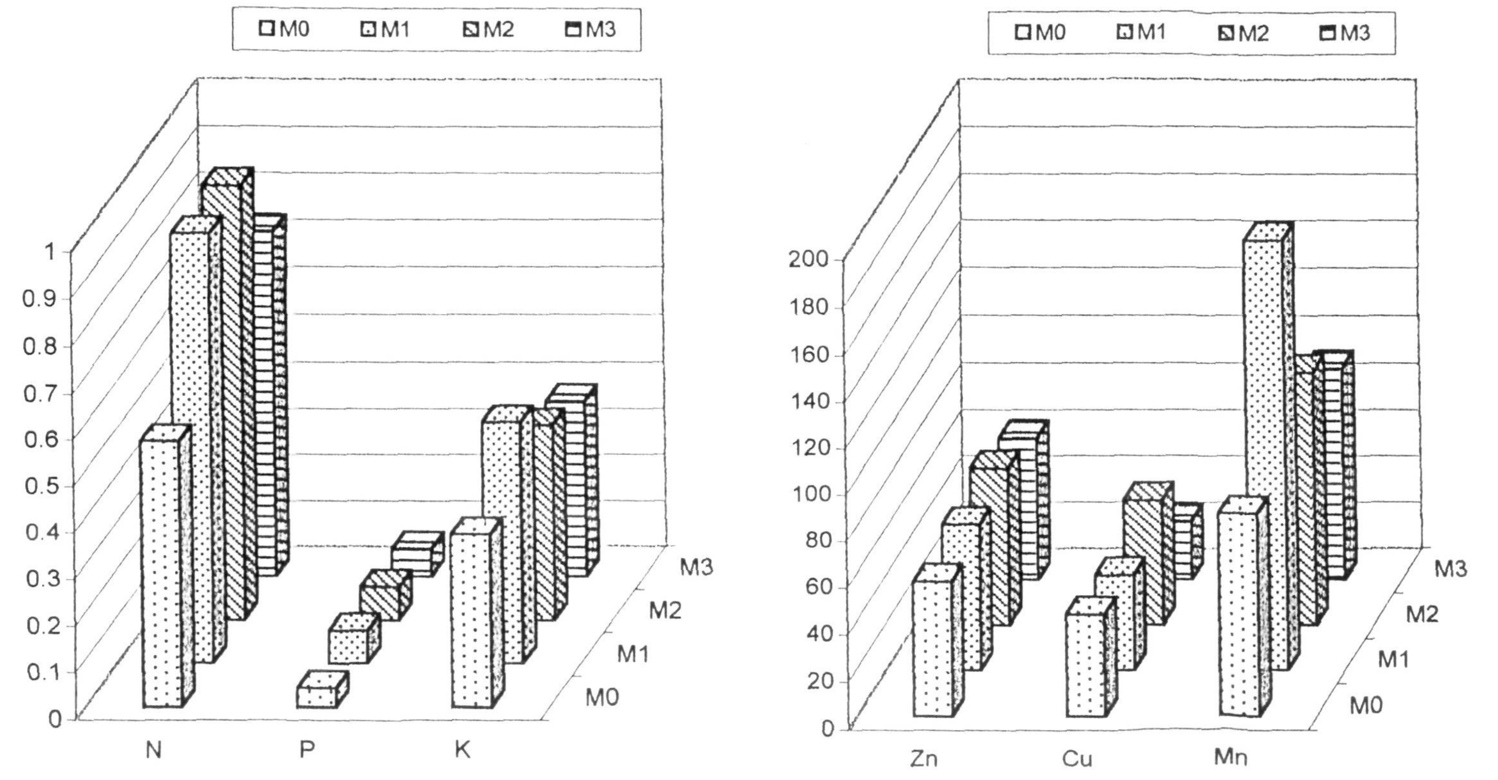


Fig.4. Effect of different VAM fungi on N, P, K content (%) and Zn, Cu, Mn (ppm) (dry weight basis) of papaya

M_0 = Uninoculated control M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii* M_3 = *Acaulospora laevis* uninoculated plants (0.57%). The plants treated with *G. fasciculatum* (0.92%) and *S. dussii* (0.93%) were on par. Significantly highest plant 'P' was recorded in *G. fasciculatum* (0.07%) treated plants and least was recorded in uninoculated control (0.04%). Similar trend was followed in leaf 'K' content. In leaf 'P' content, plants treated with *G. fasciculatum* and *S. dussii* were on par. In case of leaf 'K' content, highest 'K' was recorded in plants inoculated with *G. fasciculatum* (0.52%) followed by *S. dussii* and least was noticed in uninoculated control.

With respect to micronutrient Zn, significantly higher value was recorded in plants treated with *S. dussii* (67.10 ppm) followed by *G. fasciculatum* (62.20 ppm) and *A. laevis* (60.90 ppm). However, plants treated with *G. fasciculatum* (62.20 ppm) and *A. laevis* (60.90 ppm) were on par with each other. In case of leaf Cu content, highest value was recorded in plants treated with *S. dussii* (53.60 ppm) followed by uninoculated control (43.00 ppm). Plants treated with *G. fasciculatum* (40.41 ppm), *S. dussii* (53.60 ppm) and uninoculated control were on par. Significantly lower values were recorded in *A. laevis* treated plants (25.00 ppm). Significantly higher leaf Mn content was recorded in plants treated with *G. fasciculatum* (183.40 ppm) followed by *S. dussii* (108.66 ppm). Plants treated with *A. laevis* and uninoculated control were on par.

4.2.3.2 Soil micronutrients

Influence of different VAM fungi on soil micronutrients are presented in Table-17.

Significant variation was observed due to the inoculation of VAM fungi on soil micronutrient content.

The soil containing *G. fasciculatum* had significantly highest Cu content (2.59 ppm) compared to the soil of plants inoculated with *Sclerocystis dussii* (2.05 ppm), *A. laevis* (1.67 ppm) and uninoculated control (1.48 ppm). Similar trend was seen in Mn content of soil. *G. fasciculatum* inoculated soils had significantly highest Mn content (75.96 ppm) compared to soil analysed from inoculation with *S. dussii* (52.96 ppm), *A. laevis* (38.82 ppm) and uninoculated control (32.14 ppm).

With respect to Fe content, significantly highest concentration was recorded in soil inoculated with *A. laevis* (20.64 ppm) and comparatively least was noticed in uninoculated control (17.60 ppm), whereas Fe content in soils of plants inoculated with *G. fasciculatum* and *S. dussii* were on par.

Significantly highest concentration of soil Zn was recorded in treatment with *S. dussii* (2.05 ppm) compared to *G. fasciculatum* (1.82 ppm), *A. laevis* (1.78 ppm) and uninoculated control (1.57 ppm), whereas treatment *G. fasciculatum* and *A. laevis* were on par.

Table 17. Effect of different VAM fungi on soil micronutrient content

Sl. No.	Treatment	Micronutrients (ppm)			
		Cu	Fe	Mn	Zn
1.	M_0	1.48	17.60	32.14	1.57
2.	M_1	2.59	19.22	75.96	1.82
3.	M_2	2.05	19.78	52.96	2.05
4.	M_3	1.67	20.64	38.82	1.78
Comparing the means of					
S.Em±		0.015	0.225	1.18	0.020
C.D. at 5%		0.045	0.695	3.638	0.060

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

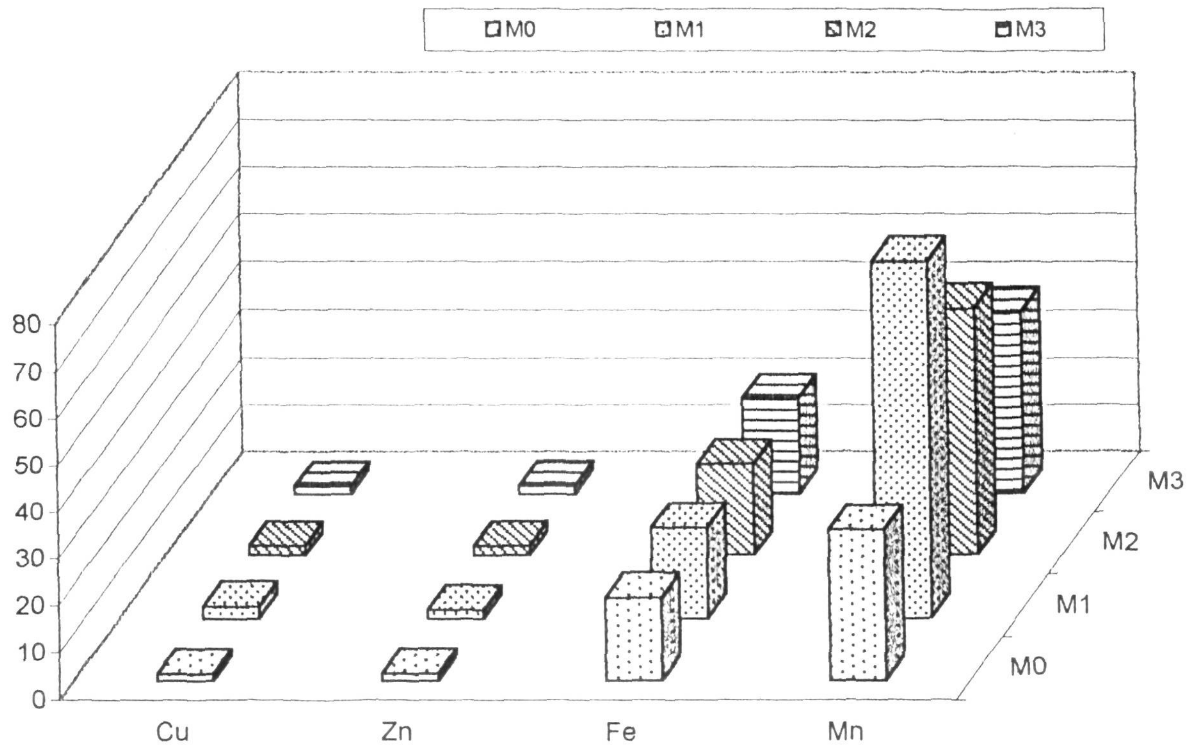


Fig.5. Effect of different VAM fungi on soil micronutrient content (ppm)

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

4.2.4 Mycorrhizal parameters

4.2.4.1 Number of chlamydospores per 50 g soil

The data on spore count as influenced by different VAM fungi are presented in Table-18.

The influence of VAM mycorrhizal fungi on spore count was significant. Inoculation of *Glomus fasciculatum* recorded significantly higher spore count (383.20) than the plants inoculated with *S. dussii* (367.80), *A. laevis* (360.60) and uninoculated control (134.40).

4.2.4.2 Per cent root colonisation

Effect of VAM inoculation on per cent root colonisation is presented in Table-18.

The influence of VAM fungi on per cent root colonisation was significant. Numerically highest per cent root colonisation was recorded in plant roots with *G. fasciculatum* (70.20%) and least was recorded in uninoculated control (28.60%). However, the plants inoculated with *G. fasciculatum* (70.20%), *S. dussii* (69.80%) and *A. laevis* (68.40%) were on par with each other.

4.2.4.3 Number of vesicles

Effect of different VAM fungi on number of vesicles formed is presented in Table-18.

Table 18. Effect of different VAM fungi on spore count, per cent root colonisation and number of vesicles

Sl. No.	Treatment	Spore count per 50 g of soil	Per cent root colonisation	Number of vesicles
1.	M_0	134.40	28.60	30.80
2.	M_1	383.20	70.20	92.80
3.	M_2	367.80	69.80	79.60
4.	M_3	360.60	68.40	60.80
Comparing the means of				
S.Em±		3.231	2.027	4.717
C.D. at 5%		9.960	6.247	14.539

M_0 = Uninoculated control

M_1 = *Glomus fasciculatum*

M_2 = *Sclerocystis dussii*

M_3 = *Acaulospora laevis*

The influence of VA mycorrhizal fungi on number of vesicles formed was found to be significant. *G. fasciculatum* recorded significantly higher number of vesicles (92.80) than *S. dussii* (79.60), *A. laevis* (60.80) and uninoculated control (30.80).

DISCUSSION

V. DISCUSSION

India is endowed with varied agroclimatic conditions, which offer immense scope for the cultivation of various kinds of horticultural crops. This has provided an excellent platform for the country to emerge as a leading producer of horticultural crops. The horticultural sector has established its credibility by way of improving technologies like use of improved fertilizers, pesticides, water management, greenhouse technology, breeding for abiotic and biotic stresses, etc. (Parvathareddy, 2000). The high productivity of papaya in Karnataka is a result of these improved technologies. At the same pace, on the side of this prosperity in near future, the country is likely to face the problems related to supply of fertilizers as the reserves of some of the fertilizers are getting diminished day by day. Besides, well-recognised adverse effects due to intensified use, inorganic chemical fertilizers are polluting soil, water and environment. Therefore, it is high time to go back to the *nature and* search for the alternative resources of ecofriendly technologies for sustainable horticultural production. Of the many ways in sustainable production technologies, exploitation of soil microbial community, particularly which are having symbiotic association with roots of crop plants, is of top most priority.

The effects of Arbuscular Mycorrhizal Fungi on the growth and development of horticultural crops have been studied and described in many research papers (Ramirez *et al.*, 1975; Maronek, 1981; Johnson and Hummel, 1985; Sukhada, 1988; Weber and De-Amurim, 1994; Jaizme-Vega and Azcon, 1995 and Shrinivas, 1998) since it is highly feasible in inoculation of transplanted crops than field crops. Obviously, the interest of pomologists in Arbuscular Mycorrhizal technology is due to the ability of Arbuscular Mycorrhizal Fungi to increase the uptake of nutrients and increase resistance to biotic and abiotic stresses (Azcon-Aguilan and Barea, 1997).

With discovery of different vesicular arbuscular mycorrhizae, the question of specificity in VAM fungi have been reinvestigated, both with regard to host range and to specific interactions between particular endophytes and their hosts. Mycorrhizae are symbiotic associations between plant roots and certain soil fungi, which play a key role in nutrient cycling in the ecosystem and also protect plants against environmental and cultural stress. Further, it is reported that VAM fungi also play a vital role in primary and secondary succession of plant species, especially in low nutrient ecosystems, increase nutrient supply, reduced abiotic stresses (Beena *et al.*, 2000).

Water is one of the primary inputs of horticulture, and water plays an important role in growth and development of plant. In semi-arid tropics, highly erratic rainfall distribution in terms of space and time causes very low productivity. Even irrigated perennial fruit crops encounters a situation during growing season where the plant has to face the water stress. The occurrence of drought particularly in these areas is a common feature. So, a viable technology, which gives plant to tolerate this abiotic stress, is most urgently needed. Interestingly, mycorrhizal associations with all types of plant roots are so prevalent that the non-mycorrhizal plant is more of an exception (Gerdemann, 1968). A role of VAM fungi in this respect has been documented in few crops. Hence, the present investigation was undertaken to find out an efficient VAM fungus for growth, development and drought tolerance capacity to papaya plants at Kittur Rani Channamma College of Horticulture, Arabhavi during 2000-2001. The results obtained from this investigation are discussed hereunder.

Inoculation of VAM fungi increased the fruit yield significantly over uninoculated control in ratoon crop in the present investigation (Table-6). Similar increase in the yield of papaya with inoculation of mycorrhizae has been reported by Pande and Mishra *(1975)*, Shrinivas (1998) and Manjunath (2000). The host specificity of VAM has been brought by many workers [Nicolson and Gerdemann (1968) in onion, pea, apple and strawberry; Marx *et al.* (1971), Kleinschmidt and Gerdemann (1972) in citrus; Khan (1972) in maize; Sukhada (1988) Shrinivas (1998) and Manjunath (2000) in papaya]. It is also very clear from the previous work that the papaya responds to *G. fasciculatum*. The present investigation also falls in line with earlier workers in recording higher yield in *G. fasciculatum* inoculated plants compared to *S. dussii* and *A. laevis*. This host specificity can be attributed to the different segregations and genetic make up, as certain plants react positively to one VAM strain while others do not (Granger *et al.*, 1983). Further, this specificity may be related to the plant genotypes that control the amount of root tissue, which would be mycorrhizal. That is, it follows certain type of specificity for the symbiosis in which plant root and arbuscular mycorrhizae participate. It is here that the concept of 'compatibility' arises that is the symbiotic effectiveness to establish functional compatibility, which involves fungus plant recognition process at several stages such as (i) cell to cell contact (ii) certain morphological and structural changes within the fungus mainly with the fungal cell wall organisation (iii) integration of the physiology of both symbionts for the re-distribution of enzymatic activity for nutrient exchange between symbionts.

Fruit yield is a manifestation of yield contributing characters like number of fruits, mean fruit weight and fruit circumference. In the present investigation, inoculation of *G. fasciculatum* had higher number of fruits per plant and also the high values of other yield contributing characters (Table-5) over uninoculated control. Shrinivas (1998) and Manjunath (2000) observed increased number of fruits per plant, mean weight of fruit and fruit circumference with inoculation of VAM fungi in papaya. The differences in these yield components could be traced back to the physiological characters both in vegetative and reproductive phase of crop growth.

The results given in Table-5 showed the increased mean fruit weight, which will result in the formation of higher sink capacity by retention of more number of fruits. Formation of higher number of fruits can be achieved by the plant only when the plants have sufficient carbohydrates and other required metabolites. The increase in fruit weight along with increase in number of fruits can also be attributed to higher translocation of carbohydrates from other parts to reproductive parts during development. The source to sink translocation can be more effective only when the rates of photosynthesis are high (Johnson, 1984). Further, the photosynthetic capacity of a plant depends upon chlorophyll content in leaves (Mathur and Vyas, 1995). Interestingly, in the present investigation, the chlorophyll content was high in the *G. fasciculatum* inoculated plants (Table-13). Similar high content of chlorophyll in *G. fasciculatum* plants of papaya was reported by Shrinivas (1998). Photosynthetic rates might be an indirect effect of 'P' on ATP and ADP ratio or a direct action on RuBP carboxylase activity (Johnson, 1984). Accordingly, further improvement of photosynthesis by VAM inoculated plants could be related to higher tissue levels of 'P' (Table-16). Similar higher content of 'P' in papaya plants inoculated with

VAM was reported by Shrinivas (1998) and Manjunath (2000). In experiments, using ^{32}P, it was found that VAM inoculated plants accumulate and store 'P' (Harley and Briverley, 1955). Further, Sanders and Tinker (1973) observed that the rate of inflow of 'P' into mycorrhizal roots was much higher than that of non-mycorrhizal plants. This increase in absorption of 'P' by mycorrhizal plants could be brought about by increased physical exploration *of the soil*, thereby making positionally unavailable nutrients available which can be achieved by decreasing the distance for diffusion of phosphate ions and by increased surface area and absorption. It has also been shown that extensive hyphal growth of mycorrhiza effectively short circuits, the distance for diffusion and thereby increases in the uptake (Sanders and Tinker, 1973). Abbott and Robson (1977), Sanders and Tinker (1973) have attributed the increased absorption of 'P' by mycorrhizal plants to increase in surface area of absorption, while Bolan (1991) had studied mycorrhizal roots on a unit weight basis and observed much higher amounts of 'P' in mycorrhizal plants, which suggested that fungal hyphae have higher affinity for phosphate ions. However, in the present investigation, the reason for higher 'P' absorption could not be pinpointed, as the relative parameters were not studied.

Inoculation of VAM fungi has significant influence on the production of leaf, which is the photosynthetic site. In the present investigation, plants inoculated with VAM recorded higher number of leaves both in ratoon as well as potted plants. Undoubtedly, the vegetative growth depends on the availability of nutrients and water, which is also stated by Nemec and Vu (1990).

Increase in the N content of plants inoculated with *G. fasciculatum* has been reported by Sukhada (1988), *Shrinivas* (1998) and Manjunath (2000) and also in the present investigation.

Using ^{15}N labelled ammonium sulphate, Kessel *et al.* (1985) had shown increased content of N in VAM inoculated maize plants than uninoculated. Those workers, who have found increased N in mycorrhizal plants have ascribed it to the improved nutrition and not to fungal activity. Further, it was reported that the mycorrhiza may improve N-nutrition not as a result of their extension of absorbing surface, but by the mechanism, which accelerates other parts of N-uptake process (Hughes *et al.*, 1978).

Leaf micronutrients, *viz.*, Zn, Mn were significantly higher in inoculated plants compared to uninoculated plants. Surprisingly, the Cu uptake was found on par in the treated and uninoculated plants.

Soil micronutrients, *viz.*, Cu, Fe, Mn and Zn were significantly higher over uninoculated control. Significantly higher micronutrients recorded in the present investigation either in leaf or in soil could be explained in the light of well known fact that root volume and root biomass will increase with VAM inoculation. Mycorrhizal hyphae with

2 to 5 μm diameter can explore large soil volume and absorb nutrients and water which is inaccessible to root hairs and thus enhance nutrient and water uptake (Thippeswamy and Sreenivasa, 1998). Similar increase in soil and plant nutrients was also reported by Hayman (1980), Umesh *et al.* (1988), Granger *et al.* (1983) and Vidal *et al.* (1992).

The transfer of nutrients P, Zn and sulphur from the soil to the cells of the root cortex is mediated by intracellular obligate fungal endosymbionts of genera *Glomus, Acaulospora* and *Sclerocystis* which possess vesicles for storage of nutrients and arbuscule for funnelling these nutrients into the root system (Kannaiyan, 2000). Vesicular arbuscular mycorrhizal fungi increase the efficiency of plants in nutrient absorption, leading to increasing vegetative growth (Johnson and Hummel, 1985; Nemec and Vu, 1990; Vinayak and Bagyaraj, 1990 and An *et al.*, 1993). The similar increase in the nutrients observed in the present investigation might have increased the vegetative parameters, *viz.*, leaf number (Table-3), leaf petiole length (Table-4), height (Table-8) and girth (Table-9), both in field and potted plants. The findings of Shrinivas (1998) and Manjunath (2000) also support the above findings.

Increase in photosynthetic activity in VAM fungi inoculated plants might have also resulted increase in the biomass production, which was evident both from the fresh and dry weight of plants

Plate 3. Influence of VAM on root development of papaya

(Table-11 and 12). Similar increase in biomass production in terms of fresh weight and dry weight was reported by Busse and Ellis (1985); Johnson and Hummel (1985) and Rapparini *et al.* (1994).

The increase in growth and productivity of plant can also be attributed to the synthesis of growth hormones and vitamins by the mycorrhizal fungi. Miller (1967), Crafts and Miller (1974) reported that VAM fungi produce these hormones and vitamins. According to Sheldraki (1973) and Torrey (1976), these compounds have pronounced effect on plant growth and development, which has been confirmed by Ries *et al.* (1977) and Jacobs (1979).

Water is one of the important component of photosynthesis. It is reported that under water stress condition, the photosynthetic activity of plant suffers affecting the productivity of the plant (Boyer, 1968; Cailloux, 1972 and Sung and Kreig, 1979).

In the present investigation, the productivity and growth was higher in *G. fasciculatum* inoculated plants in the semi-arid tropical regions (Table-6), where abiotic stress is a common feature. The study on influence of mycorrhizal plants for stress tolerance capacity indicated that these plants had better ability than non-mycorrhizal plants under water-stress situation. This is evident from the Table-15 on days taken on initiation of drought symptoms and complete wilting of plant. In mycorrhizal plants initiation of water stress symptoms that is curling of leaves took maximum days as compared to non-mycorrhizal plants. Similar findings have also been reported by Busse and Ellis (1985) and Johnson and Hummel (1985).

It is reported that a lower content of proline is an indication of better tolerance to drought (Ruiz-Lozano *et al.*, 1995).

The lower content of proline in *G. fasciculatum* inoculated plants both at 10 DAD and 20 DAD when compared to non-mycorrhizal plants clearly indicated the ability of mycorrhizal plants to withstand its drought. Similar results were reported that the proline content will be having lower values in drought tolerant plants. Even the per cent soil moisture was more in the soil before drought and after drought in mycorrhizal inoculated soil when compared to non-mycorrhizal soil. The higher per cent of soil moisture before drought may be due to lower rates of transpiration and lower rates of water utilisation.

The protection of mycorrhizal plants against water stress could be related to the facts that endophytes had an increasing leaf conductance and transpiration (Ruiz-Lozano *et al.*, 1995) as well as 'P' and 'K' (Table-16) uptake. Potassium plays a key role in plant-water stress and has been found to be the cat-ionic solute, which is responsible for stomatal movement on response to change in leaf water status (Ruiz-Lozano *et al.*, 1995). Accordingly, the response of *Glomus* infected plants and 'K' contents are closely related.

The adjustment of leaf osmotic potential requires inter-cellular osmotic balance. Proline when accumulated in the leaves enhances osmotic adjustment (Ruiz-Lozano *et al.*, 1995). In the present study, the proline content was greater (Table-15) in more drought stressed plants (20 DAD) than in low drought stressed plants (in 10 DAD) (Table-14).

The term mycorrhiza refers to the association of fungi and roots and this association was usually considered to be mutualistic symbiosis because of high interdependent relationship established between both the partners when the host plant receives mineral nutrients via fungal mycelium (mycotropism), while heterotrophic fungus obtains carbon compounds from the host synthesis (Harley and Smith, 1983 and Azcon and Bago, 1994). Auxins, cytokinins and gibberellins and vitamins have been shown to be produced by mycorrhizal fungi in pure culture Crafts and Miller (1974) and Slankis (1975). Effects of these compounds on plant growth and development have been well documented (Torrey, 1976). The type and quantity of growth substances produced by both partners could affect their association and subsequently overall crop responses. Increase in the growth of crop as observed in the present investigation may be attributed to the beneficial synthesis of these hormones by VAM fungi through increasing cell multiplication and cell division (Azcon and Bago, 1994). Further, for the growth and development of the plants, nutrients are also required at optimum levels and it is stated that one of the functions of mycorrhizal fungi particularly relevant to the world wide production of horticultural plants is increase in the mineral nutrients of the plants. Increase in mineral uptake as a result of mycorrhizal association are often reflected in increased plant growth and yield as well as optimum and required nutrition.

It is noteworthy that the VAM fungi influenced the chemical composition of the fruits, *viz.*, total soluble solids, vitamin C content, reducing sugars, non-reducing sugars and total sugars (Table-7). The increase in chemical composition of fruits may be mainly due to increase in CO_2 incorporation rate with increase in leaf chlorophyll and RuBP case activity and increase in number of leaves per plant in plants inoculated with VAM fungi. Table-7 suggested that carbohydrate balance changes during VAM fungi infection. A higher carbohydrate concentration generally coincided with active growth by VAM fungi in plants, which might have helped in increasing these metabolites in fruits.

5.2 Response of papaya to graded levels of phosphorus

Application of phosphorus registered significant linear increase in yield upto 75 per cent of RDP only. Lal and Pundrik (1971), Chougule and Mahajan (1979) and Singh and Srivastava (1988) had also observed similar linear increase on the fruit yield with increase in the levels of phosphorus. Further, in the present investigation, yield components, *viz.*, number of fruits (Table-6), mean weight of fruit (Table-5), length and circumference of the fruit (Table-5) also increased with increased levels of phosphorus. Similar results with respect to increase in yield and yield components have been reported by Chougule and Mahajan (1979), Singh and Srivastava (1988), Shrinivas (1998) and Manjunath (2000).

The differences in the yield components can be traced back to the physiological characters both in vegetative and reproductive phases of growth. Differences in the growth parameters with the application of phosphorus may be mainly responsible for the differences in the fruit yield. Increased yield due to 'P' application was also shown by Sreeramulu (1981), Srinivas (1983), Prabhakar *et al.* (1987), Babu *et al.* (1988), Singh and Srivastava (1988), Shrinivas (1998) and Manjunath (2000).

5.3 Interaction effects of VAM and phosphorus on papaya

The treatment combination of *G. fasciculatum* and 100 per cent of RDP and *G. fasciculatum* with 75 per cent RDP in the present investigation recorded higher growth parameters like number of leaves per plant. These treatment combinations also recorded higher yield contributing characters, *viz.*, mean fruit weight, fruit circumference and number of fruits per plant and yield. Experiments conducted using labelled 'P' have confirmed that VAM fungi are capable of increasing 'P' uptake (Gray and Gerdemann, 1969).

Further, it has also been reported that higher 'P' levels in leaf tissue (Table-16) could be expected to increase the rate of photosynthesis. Improvement of photosynthesis by VAM was suggested to be the result of higher 'P' tissue levels after infection (Losel and Cooper, 1979 and Johnson *et al.*, 1982), leading to higher growth and yield.

5.4 Economics of inoculation of VAM fungi at different levels of phosphorus

The plants inoculated with *G. fasciculatum* and applied with 75 per cent RDP recorded maximum net return of Rs. 71807.00 per hectare. Similarly, plants inoculated with *S. dussii* applied with 75 per cent RDP recorded the net return of Rs. 63707.00. The returns of all the treatments involving fungi were higher when compared to 100 per cent RDP in uninoculated control plants.

Maximum benefit : cost ratio of 2.84 was noticed in *G. fasciculatum* inoculated plants coupled with 75 per cent RDP (Appendix-II).

5.5 Practical utility

Papaya being a heavy nutrient feeder, application of nutrients for profuse growth and fruiting is very essential. In the present scenario of energy crises, fertilizer has become one of the costliest input of Indian Agriculture. Hence, this costliest input should be used more judiciously. There is a vast scope to increase papaya production by inoculating with VA mycorrhizae to increase the efficiency of nutrient uptake. From this point of view, the present investigation is worthful and following results of practical importance are noted.

1. *G. fasciculatum* was found superior over other two fungi.
2. Inoculation of VAM along with application of 75 per cent RDP was as good as 100 per cent RDP alone, thereby saving 25 per cent RDP.
3. VAM inoculation imparts drought tolerance capacity to the plants.
4. Several fold increase in nutrients and fresh and dry weight of VAM inoculated plants compared to control plants.

Future line of work

1. Establishment of host-fungus relationship.
2. Effect of VAM in management of biotic and abiotic stresses should be studied in detail.

SUMMARY

VI. SUMMARY

In order to study the effect of VAM and graded levels of 'P' on papaya, following two experiments were conducted at the Department of Pomology, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Agricultural Sciences, Dharwad during June 2000 to May 2001:

1. To know the effect of VAM on growth and yield of ratoon crop of papaya
2. to know the effect of VAM on drought tolerance of papaya.

There were twelve treatment combinations laid out in split plot design with three replications in the field experiment and four treatments with five replications in completely randomised block design (CRBD) in pot culture experiment.

The inoculation of VAM fungi resulted in significantly higher values with the characters, *viz.*, number of leaves, petiole length, fruit circumference, number of fruits, fruit yield and chemical parameters studied, whereas non-significant differences with respect to the characters plant height, stem girth, fruit length, mean fruit weight, per cent PLW and non-reducing sugars.

Number of leaves and petiole length were respectively 19 per cent higher (970 DAT) and 15.20 per cent higher in *G. fasciculatum* inoculated plants over uninoculated control.

Number of fruits per plant and fruit yield were higher in *G. fasciculatum* inoculated plants to the tune of 66.20 per cent and 24.90 per cent over control.

Total soluble solids, vitamin C and total sugars were respectively 21.80 per cent, 8.90 per cent and 8.30 per cent higher in *G. fasciculatum* inoculated plants over uninoculated plants.

Application of 50 per cent RDP produced significantly higher number of leaves and 75 per cent RDP produced higher petiole length. Application of 100 per cent RDP produced significantly higher fruit length, fruit circumference and mean fruit weight, whereas fruit yield, TSS, vitamin C, reducing sugar and total sugar were higher in 75 per cent RDP.

Inoculation of VAM fungi *G. fasciculatum* coupled with 75 per cent RDP (55.41 t/ha) was found to be statistically equal to *G. fasciculatum* coupled with 100 per cent RDP (55.79 t/ha) and these were higher when compared to 75 per cent RDP (42.61 t/ha) alone.

In pot culture experiment plants inoculated with *G. fasciculatum* found to be superior over other two fungi with respect to the characters, *viz.*, plant girth, plant fresh weight and dry weight before and after drought imposition, chlorophyll content, except plant height, which was more influenced by *S. dussii* rather than *G. fasciculatum*.

Similarly, leaf micro and macronutrients were higher in *G. fasciculatum* inoculated plants than other two fungi and control, whereas relative water content of leaf was found higher in *G. fasciculatum* and *S. dussii* inoculated plants than *A. laevis* and control plants. Proline content was influenced by VAM fungi and relatively lower content was recorded in inoculated plants compared to uninoculated plants. *G. fasciculatum* inoculated soils have higher soil moisture before drought, whereas soils inoculated with *G. fasciculatum* and *S. dussii* were statistically equal after drought imposition.

REFERENCES

VII. REFERENCES

ABBOTT, L.K. AND ROBSON, A.D., 1977, Growth stimulation of subterranean clover with vesicular-arbuscular mycorrhiza. *Australian Journal of Agricultural Research*, **28**: 639-649.

ALLEN, M.F., MOORE, T.S. JR. AND CHRISTENSEN, M., 1980, Phytohormone changes in *Bouteloua gracillis* infected by vesicular-arbuscular mycorrhizae. I. Cytokinin increase in the host plant. *Canadian Journal of Botany*, **58**: 371-374.

ALLEN, M.F., SMITH, W.K., MOORE, T.S. JR. AND CHRISTENSEN, M., 1981, Comparative water relations and photosynthesis of mycorrhizal and non-mycorrhizal *Bouteloua gracilis*. *New Phytologist*, **88**: 683-686.

ALONSO, R.R., GONZALEZ, P.M., EXPOSITO, G.L., CRUBELO, R.R., ROQUE, M.L. AND PAZOS, G.M., 1995, The influence of mycorrhizae and phosphate solubilizing bacteria on the growth and development of banana *vitro* plants. *Infomusa*, **4**: 9-10.

AN, Z.Q., SHEN, T. AND WANG, H.G., 1993, Mycorrhizal fungi in relation to growth and mineral nutrition of apple seedlings. *Scientia Horticulturae*, **54**: 275-285.

ANONYMOUS, 1984, Official methods of analysis. Edn. Sioney Williams, Association Official Analytic Inc. Virginia, 14th Ed. pp. 423-462.

ANONYMOUS, 1997, *Improved Package of Practices for Horticulture Crops.* Published by University of Agricultural Sciences, Dharwad, p. 46.

ANONYMOUS, 2001, HTTP://hortibizindia.nic.in. A official web site of National Horticulture Board, Gurgoan, Area and production.

ARNON, D.I., 1949, Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiology*, **24**: 1-15.

AZCON, A. AND BAGO, B., 1994, Physiological characteristics of the host plant promoting an undisturbed functioning of the mycorrhizal symbiosis. In *Impact of Arbuscular Mycorrhizas on Sustainable Agriculture and Natural Ecosystems.* Ed. Gianinazzi, S. and Schuepp, H., ALS, Birkhanser, Basel, pp. 47-60.

AZCON-AGUILAN, C. AND BAREA, J.M., 1997, Applying mycorrhiza biotechnology to horticulture: Significance and potentials. *Scientia Horticulturae*, **68**: 1-24.

BABU, S.H.R., LOKESHWAR, D., RAO, N.S. AND BHASKAR RAO, B.R., 1988, The response of chilli (*Capsicum annuum* L.) plants to early inoculation with mycorrhizal fungi at different levels of phosphorus. *Journal of Horticultural Science*, **63**: 315-320.

BARRS, H.D. AND WEATHERLY, P.E., 1962, A re-examination of relative turgidity for estimating water deficits in leaves. *Australian Journal of Biological Sciences*, **15**: 413-428.

BATES, L.S., WALDER, R.P. AND TEARE, I.D., 1973, Rapid determination of free proline in water stress studies. *Plant and Soil*, **39**: 205-208.

BAVARESCO, L. AND FOGHER, C., 1992, Effect of root infection with *Pseudomonas fluorescens* and *Glomus mosseae* in improving Fe-efficiency of grapevine ungrafted rootstocks. *Vitis*, **31**: 163-168.

BAVARESCO, L. AND FOGHER, C., 1996, Lime induced chlorosis of grapevine as affected by rootstock and root infection with arbuscular mycorrhiza and *Pseudomonas fluorescens*. *Vitis*, **35**(3): 119-123.

BEENA, K.R., RAVIRAJA, N.S., ARUN, A.B. AND SRIDHAR, K.R., 2000, Diversity of arbuscular mycorrhizal fungi on the coastal sand dunes of the west coast of India. *Current Science*, **79**: 550-555

BOLAN, N.S., 1991, A critical review on the role of mycorrhizal fungi in the uptake of phosphorus by plants. *Plant and Soil*, **134**: 189-207.

BOYER, J.S., 1968, Relationship of water potential to growth of leaves. *Plant Physiology*, **43**: 1056-1062.

BUSSE, M.D. AND ELLIS, J.R., 1985, Vesicular-arbuscular mycorrhizal (*Glomus fasciculatum*) influene on soybean drought tolerance in high phosphorus soil. *Canadian Journal of Botany*, **63**: 2290-2294.

CAILLOUX, M., 1972, Metabolism and absorption of water by root hairs. *Canadian Journal of Botany*, **50**: 557-573.

CHADHA, K.L., 1992, Scenario of papaya production and utilisation in India. *Indian Journal of Horticulture*, **49**(2): 97-119.

CHOUGULE, A.B. AND MAHAJAN, P.R., 1979, Effect of varying levels of plant population, nitrogen, phosphorus and potash on growth and yield of chilli (*Capsicum annuum* L.). *Vegetable Science*, **4**: 72-79.

CRAFTS, C.B. AND MILLER, C.O., 1974, Detection and identification of cytokinins produced by mycorrhizal fungi. *Plant Physiology*, **54**: 586-588.

DECLERCK, S., DEVOS, B., DELVAUX, B. AND PLENCHETTE, C., 1994, Growth response of micropropagated banana plants to VAM inoculation. *Fruits* (Paris), **49**(2): 103-109.

DHARMARAJ, G. AND IRULAPPAN, I., 1982, Response of avocado seedlings to *Glomus fasciculatum*, a mycorrhizal fungus. *South Indian Horticulture*, **30**: 139-141.

DUTRA, P.V., ABAD, M., ALMELA, V. AND AGUSTI, M., 1996, Auxin interaction with the vesicular-arbuscular mycorrhizal fungus *Glomus intraradices* Schenck and Smith improves vegetative growth of two citrus rootstocks. *Scientia Horticulturae*, **66**: 77-83.

EDRISS, M.H., DAVIS, R.M. AND BURGER, D.W., 1984, Influence of mycorrhizal fungi on cytokinin production in sour orange. *Journal of American Society for Horticultural Science*, **109**(4): 587-590.

FORTUNA, P., CITERNESI, A.S., MORINI, S., VITAGLIANO, C. AND GIOVANNETTI, M., 1996, Influence of arbuscular mycorrhizae and phosphate fertilization on shoot apical growth of micropropagated apple and plum rootstocks. *Tree Physiology*, **16**: 757-763.

GARDINER, D. AND CHRISTENSEN, N.W., 1991, Pear seedling responses to phosphorus fumigation and mycorrhizal inoculation. *Journal of Horticultural Science*, **66**: 775-780.

GERDEMANN, J.W., 1968, Vesicular-arbuscular mycorrhiza and plant growth. *Annual Review of Phytopathology*, **6**: 397-418.

GERDEMANN, J.W. AND NICOLSON, J.H., 1963, Spores of mycorrhiza *Endogone* species extracted from soil by wet sieving and decanting. *Transactions, British Mycological Society*, **46**: 235-244.

GILMORE, A.E., 1971, The influence of endophytic mycorrhiza on growth of peach seedlings. *Journal of American Society for Horticultural Science*, **96**: 35-38.

GRAHAM, J.H., 1986, Citrus mycorrhizae: Potential benefits and interactions with pathogens. *Journal of Horticultural Science*, **21**(6): 1302-1306.

GRANGER, R.L., PLENCHETTE, C. AND FORTIN, J.A., 1983, Effect of vesicular arbuscular (VA) endomycorrhizal fungus (*Glomus epigaeum*) on the growth and leaf mineral content of two apple clones propagated *in-vitro*. *Canadian Journal of Plant Science*, **63**: 551-555.

GRAY, L.E. AND GERDEMANN, J.W., 1969, Uptake of phosphorus-32 by vesicular-arbuscular mycorrhiza. *Plant and Soil*, **30**: 415-422.

GUILLEMIN, J.P., GIANINAZZI, S., GIANINAZZIPEARSON, V. AND MARCHAL, J., 1995, Effects of arbuscular endomycorrhizae on growth and mineral nutrition of pineapple *vitro* plants in a soil with high salinity. *Fruits* (Paris), **50**(5): 334-341.

HARLEY, J.L. AND BRIVERLEY, J.K., 1955, Uptake of phosphate by excised mycorrhizal roots of the beech VII. Active transport of ^{32}P from fungus to host during uptake of phosphate from solution. *New Phytologist*, **54**: 296-301.

HARLEY, J.L. AND SMITH, S.E., 1983, *Mycorrhizal Symbiosis*. Academic Press, New York, pp. 483.

HAYMAN, D.S., 1980, Mycorrhiza and crop production. *Nature*, **287**: 487-488.

HUGHES, M., MARTIN, L.W. AND BREEN, P.J., 1978, Mycorrhizal influence on the nutrition of strawberries. *Journal of American Society for Horticultural Science*, **103**(2): 179-181.

JACKSON, M.L., 1967, *Soil Chemical Analysis*. Prentice Hall of Indian Private Limited, New Delhi, pp. 38-82.

JACOBS, W.P., 1979, *Plant Hormones and Plant Development.* Cambridge University Press, Cambridge.

JAIZME-VEGA, M.C. AND AZCON, A., 1995, Response of some tropical and subtropical crops to endomycorrhizal fungi. *Mycorrhiza*, **5**(3): 213-217.

JOHNSON, C.R., 1984, Phosphorus nutrition on mycorrhizal colonization, photosynthesis, growth and nutrient composition of *Citrus aurantium*. *Plant and Soil*, **80**: 35-42.

JOHNSON, C.R. AND HUMMEL, R.L., 1985, Influence of mycorrhizae and drought stress on growth of *Poncirus* x *Citrus* seedlings. *HortScience*, **20**: 754-755.

JOHNSON, C.R., MENGE, J.A., SCHWAB, S. AND TING, I.P., 1982, Interaction of photoperiod and vesicular-arbuscular mycorrhizae on growth and metabolism of sweet orange. *New Phytologist*, **90**: 665-669.

KANDASWAMY, D., MOHANRAJ, S.G. AND OBLISAMI, G., 1985, Influence of VA mycorrhizae and phosphobacteria on the growth of brinjal and chillies in nursery. *South Indian Horticulture*, **33**: 172-176.

KANNAIYAN, S., 2000, Biofertilizers: Key factor in organic farming. *The Hindu Survey of Indian Agriculture*, pp. 169.

KESSEL, C., PAUL, W.S. AND HEINZ, J.H., 1985, Enhanced N-transfer from a soybean to maize by vesicular-arbuscular mycorrhizal fungi. *Plant Physiology*, **79**: 562-563.

KHAN, A.G., 1972, The effect of vesicular-arbuscular mycorrhizal associations on growth of cereals. I. Effects on maize growth. *New Phytologist*, **71**: 613-619.

KLEINSCHMIDT, G.D. AND GERDEMANN, J.W., 1972, Stunting of citrus seedlings in fumigated nursery soils related to the absence of endomycorrhizae. *Phytopathology*, **62**: 1447-1453.

KOCH, B.L., COVEY, R.P. AND LARSEN, H.J., 1982, Response of apple seedlings in fumigated soil to phosphorus and vesicular-arbuscular mycorrhiza. *HortScience*, **17**: 232-233.

KRISHNAPRASAD, S., 1990, Interaction effect of *Azatobactr chroococcum, Glomus fasciculatum, Aspergillus niger and Fusarium oxysporum* f.sp. *Lycopersici* on growth of tomato (*Lycopersicon esculentum* Mill.). *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Bangalore.

LAL, N. AND PUNDRIK, K.C., 1971, Effect of nitrogen, phosphorus and potassium on the growth and yield of chilli (*Capsicum frutescens* L.). *Punjab Horticultural Journal*, **11**: 82-86.

LARSON, K. AND SHAW, D.V., 1995, Relative performance of strawberry genotypes on fumigated and non-fumigated soils. *Journal of American Society for Horticultural Science*, **120**: 274-277.

*LA-RUE, J.H., MCCLELLEN, W.D. AND PEACOCK, W.L., 1975, mycorrhizal fungi and peach nursery nutrition. *California Agriculture,* **29**: 6-7.

LIN, M.R. AND FOX, R.L., 1992, The comparative agronomic effectiveness of rock phosphate and super phosphate for banana. *Journal of Fertilizer Technology,* **31**: 131-135.

LOSEL, D.M. AND COOPER, K.M., 1979, Incorporation of 14C-labelled substrates by uninfected and VA mycorrhizal roots of onion. *New Phytologist,* **83**: 415-426.

MANJUNATH, H., MOHAN, R. AND BAGYARAJ, D.J., 1982, Response of citrus to vesicular-arbuscular mycorrhizal inoculation in unsterile soils. *Canadian Journal of Botany,* **61**: 2729-2732.

MANJUNATH, V.G., 2000, Effect of vesicular arbuscular mycorrhizal species and phosphorus levels on growth and yield of papaya, cv. Sunset Solo. *M.Sc.(Hort.) Thesis,* University of Agricultural Sciences, Dharwad.

MARONEK, D.M., 1981, Mycorrhizal fungi and their importance in horticultural crop production. *Horticultural Reviews,* **3**: 173-213.

MARONEK, D.M., HENDRIX, J.W. AND KIERNAM, J., 1981, Mycorrhizal fungi and their importance in horticultural crop production. *Horticulture Reviews*, **3**: 172-213.

MARX, D.H., BRYAN, W.C. AND CAMPBELL, W.A., 1971, Effect of endomycorrhiza by *Endogone mosseae* on growth of citrus. *Mycologia*, **63**: 1222-1226.

MATHUR, N. AND VYAS, A., 1995, Influence of VA mycorrhizae on net photosynthesis and transpiration of *Ziziphus mauritiana*. *Journal of Plant Physiology*, **147**: 328-330.

MENGE, J.A., 1982, Utilization of vesicular-arbuscular mycorrhizal fungi in agriculture. *Canadian Journal of Botany*, **61**: 1015-1024.

MILLER, C.O., 1967, Zeatin and Zeatin riboside from a mycorrhizal fungus. *Science*, **15**: 1055-1057.

MILLER, G.L., 1972, Use of Dinitrosalicylic acid reagent for determination of reducing sugars. *Annual of Chemistry*, **31**: 426-428.

MOSSE, B., 1973, Plant growth responses to vesicular-arbuscular mycorrhiza. IV. In soil given additional phosphate. *New Phytologist*, **72**: 127-136.

MOTSARA, M.R., 2000, Plant nutrients: Role of micronutrients. *The Hindu Survey of Indian Agriculture*, pp. 175.

*NEMEC, S., 1982, Carbohydrate status of mycorrhizal and non-mycorrhizal citrus rootstocks. *Journal of American Society for Horticultural Science*, **107**(2): 177-180.

NEMEC, S., 1986, VA mycorrhizae in horticultural systems. In *Ecophysiology of VA Mycorrhizal Plants*. Ed. Safir, G.R., CRC, Boca Raton, FL, pp. 193-211.

NEMEC, S. AND GULY, C., 1982, Carbohydrate status of mycorrhizal and non-mycorrhizal citrus rootstocks. *Journal of American Society for Horticultural Science*, **107**: 177-180.

NEMEC, S. AND VU, J.C.V., 1990, Effect of soil phosphorus and *Glomus intraradices* on growth, non-structural carbohydrates and photosynthetic activity of *Citrus aurantium*. *Plant and Soil*, **128**: 257-263.

NICOLSON, T.H. AND GERDEMANN, J.W., 1968, Mycorrhizal *Endogone* species. *Mycologia*, **60**: 313-325.

ONKARAYYA, H. AND SUKHADA, M., 1993, Studies on dependency of citrus rootstocks to VAM inoculation in Alfisol soil. *Advances in Horticulture and Forestry*, **3**: 81-91.

PADMA, T.M.R., 1988, Effect of interaction between VA mycorrhizae and graded levels of phosphorus on the growth of papaya (*Carica papaya). M.Sc.(Agri.) Thesis*, Tamil Nadu Agricultural University, Coimbatore.

PALAZZO, D., POMMERENING, B. AND VANADIA, S., 1992, Effect of soil sterilization and vesicular-arbuscular mycorrhiza on growth of sour orange (*Citrus aurantium* L.) seedlings. In *Proceedings of the International Society of Citriculture*, **2**: 621-623.

PANDE, S.P. AND MISHRA, A.P., 1975, Mycorrhizae in relation to growth and fruiting of *Litchi chinensis*. *Journal of Indian Botanical Survey*, **54**: 280-293.

PANSE, V.G. AND SUKHATME, P.V., 1967, *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.

PARVATHAREDDY, P., 2000, Horticulture: Rich export potential. *The Hindu Survey of Indian Agriculture*, pp. 141.

PHILLIPS J.M. AND HAYMAN, D.S., 1970, Improved procedure for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. *Transactions, British Mycological Society*, **55**: 158-161.

PLENCHETTE, C., FURLAN, V. AND FORTIN, J.A., 1981, Growth stimulation of apple trees in unsterilised soil under field conditions with VA mycorrhizal inoculation. *Canadian Journal of Botany*, **59**: 2003-2008.

PRABHAKAR, B.S., SRINIVAS, K. AND VISHNU SHUKLA, 1987, Growth and yield response of green chilli to nitrogen and phosphorus fertilization. *Indian Cocoa Arecanut and Spices Journal*, **11**: 12-14.

RAMIREZ, B.N., MITCHELL, D.J. AND SCHENCK, N.C., 1975, Establishment and growth effects of three vesicular-arbuscular fungi on papaya. *Mycologia*, **67**: 1039-1041.

RAPPARINI, F., BARALD, R., BERTAZZA, G., BRANZANTI, B. AND PREDIERI, S., 1994, Vesicular-arbuscular mycorrhizal inoculation of micropropagated fruit trees. *Journal of Horticultural Science*, **69**: 1101-1109.

REDDY, B.M.S., 1991, Selection of efficient VA mycorrhizal fungi for mango, acid lime and papaya. *M.Sc.(Agri.) Thesis*, University of Agricultural Sciences, Bangalore.

REDDY, B.M.S., BAGYARAJ, D.J. AND MALLESHA, B.C., 1996, Selection of efficient VA mycorrhizal fungi for acid lime. *Indian Journal of Microbiology*, **36**(1): 13-16.

RHODES, L.H., 1980, *Outlook Agriculture*, **10**: 275-281 (cited in Shrinivas, M., 1998).

RIES, S.K., WERT, V., SWEELEY, C.C. AND LEAVITT, R.A., 1977, Triacontanol: a new naturally occurring plant growth regulator. *Science*, **195**: 1339-1341.

*ROCHA, M.R.DA., CORREA, G.C. AND OLIVEIRA, E.DE., 1995, Effect of vesicular-arbuscular mycorrhizal infection and phosphorus fertilzation on Cleopatra mandarin rootstock. *Pesquisa-Agropecuaria Brasileria*, **30**(10): 1253-1258.

RUIZ-LOZANO, J.M., AZCON, R. AND GOMEZ, M., 1995, Effects of arbuscular-mycorrhizal *Glomus* species on drought tolerance: Physiological and nutritional plant responses. *Applied and Environmental Microbiology*, **61**: (2): 456-460.

SADASIVAM, S. AND MANICKAM, A., 1997, *Biochemical Methods*, New Age International (P) Limited Publishers, New Delhi and Tamil Nadu Agricultural University, Coimbatore, pp. 184-185.

SAFIR, G.R., BOYER, J.S. AND GERDEMANN, 1972, Nutrient status and mycorrhizal enhancement of water transport in soyabean. *Plant Physiology*, **49**: 700-703.

SANDERS, F.E. AND TINKER, B.P., 1973, Phosphate flow into mycorrhizal roots. *Pesticide Science*, **4**: 385-395.

SBRANA, C., GIOVANNETTI, M. AND VITAGLIANO, C., 1995, The effect of mycorrhizal infection on survival and growth renewal of micropropagated fruit rootstocks. *Mycorrhiza*, **5**(2): 153-156.

SENAPATI, H.K., PAL, A.K. AND SWAIN, S.K., 1987, Effect of mycorrhiza on the growth characteristics of okra in lateritic soil. *Indian Journal of Horticulture*, **44**: 93-95.

SHANMUGAM, N., CHANDRABABU, R. AND THALAMUTHU, C., 1981, Studies on the response of acid lime (*Citrus aurantifolia*) to vesicular arbuscular mycorrhizae. *Current Science*, **50**(17): 772-773.

SHELDRAKI, A.R., 1973, The production of hormones in higher plants. *Biological Reviews*, **48**: 509-559.

SHIRSATH, K.S., WANI, P.V. AND KONDE, B.K., 1998, Development and performance of mycorrhizal seedlings in ber (*Zizypus mauritiana* L.). *Journal of Maharashtra Agricultural Universities,* **23**(1): 4-6.

SHRESTHA, Y.H., ISHII, T. AND KADOYA, K., 1995, Effect of vesicular-arbuscular mycorrhizal fungi on the growth, photosynthesis, transpiration and the distribution of photosynthates of bearing Satsuma mandarin trees. *Journal of the Japanese Society for Horticultural Science*, **64**: 517-525.

SHRESTHA, Y.H., ISHII, T., MATSUMOTO, I. AND KADOYA, K., 1996, Effects of vesicular-arbuscular mycorrhizal fungi on Satsuma mandarin tree growth and water stress tolerance and fruit development and quality. *Journal of the Japanese Society for Horticultural Science*, **64**: 801-807.

SHRINIVAS, M., 1998, Response of papaya to vesicular arbuscular mycorrhizal fungi at graded levels of phosphorus. *M.Sc.(Agri.) Thesis,* University of Agricultural Sciences, Dharwad.

SILVA, A.DE., PATTERSON, K. AND MITCHELL, J., 1996, Endomycorrhizae and growth of 'Sweet heart' strawberry seedlings. *HortScience*, **31**(6): 951-954.

SIMPSON, D. AND DAFT, M.J., 1990, Interactions between water-stress and different mycorrhizal inocula on plant growth and mycorrhizal development in maize and sorghum. *Plant and Soil*, **121**: 179-186.

SINGH, K. AND SRIVASTAVA, B.K., 1988, Effect of various levels of nitrogen and phosphorus on growth and yield of chilli (*Capsicum annuum* L.). *Indian Journal of Horticulture*, **45**: 319-324.

SLANKIS, V., 1975, Hormonal relationships in mycorrhizal development. In *Ectomycorrhizae*, Ed. Marx. G.C. and Kozlowski, T.T., Academic Press, New York, pp. 231-298.

SREENIVASA, M.N., KRISHNARAJ, P.U., GANGADHARA, G.A. AND MANJUNATHAIAH, H.M., 1992, Response of chilli (*Capsicum annuum* L.) to the inoculation of efficient vesicular-arbuscular mycorrhizal fungus. *Scientia Horticulturae*, **53**: 45-52.

SREERAMULU, K.R., 1981, Response of chillies to VA mycorrhiza under field conditions. *M.Sc.(Agri.) Thesis*, University of Agricultural Sciences, Bangalore.

SRINIVAS, K., 1983, Response of green chilli to nitrogen and phosphorus fertilization. *South Indian Horticulture*, **31**: 37-39.

SUKHADA, M., 1988, Response of papaya (*Carica papaya*) to VAM fungal inoculation. In *Mycorrhizae for Green Asia*. First Asian conference on Mycorrhizae. Eds. Mahadevan, N., Raman and Natarajan, H., Madras, p. 260.

SUKHADA, M., 1992, Effect of VAM inoculation on plant growth, nutrient level and root phosphatase activity in papaya (*Carica papaya*, cv. Coorg Honey Dew). *Researcher*, **31**: 263-267.

SUNG, F.J.M. AND KREIG, D.R., 1979, Relative sensitivity of photosynthetic assimilation and translocation of carbon to water stress. *Plant Physiology*, **64**: 852-856.

THIPPESWAMY, R. AND SREENIVASA, M.N., 1998, Physiolgoical nutritional and yield responses of tomato to the inoculation of *Glomus fasciculatum* under water stress condition. *Journal of Maharastra Agricultural Universities*, **23**(3): 265-268.

TIMMER, L.W. AND LEYDAN, R.F., 1978, Stunting of citrus seedlings in texas and its correction by phosphorus fertilization and inoculation with mycorrhizal fungi. *Journal of American Society for Horticultural Science*, **103**: 533-537.

TORREY, J.A., 1976, Root hormones and plant growth. *Annual Review of Plant Physiology*, **27**: 435-459.

UMESH, K.C., KRISHNAPPA, K. AND BAGYARAJ, D.J., 1988, Interaction of burrowing nematode, *Radopholus similis* (Cobb, 1893) Throne 1949 and VA Mycorrhiza, *Glomus fasciculatum* (Thaxt.) Gerd. and Troppe in banana (*Musa acuminata* Colla.). *Indian Journal of Nematology*, **18**(1): 6-11.

*UOSUKAINEN, M. AND VESTBERG, M., 1994, Effect of inoculation with arbuscular mycorrhizas on rooting, weaning and subsequent growth of micropropagated *Malus* (L.) Moench. *Agricultural Science in Finland*, **3**(3): 269-279.

VIDAL, M.T., AZCON, A. AND BAREA, J.M., 1992, Mycorrhizal inoculation enhances growth and development of micropropagated plants of avocado. *HortScience*, **27**(7): 785-787.

VINAYAK, K. AND BAGYARAJ, D.J., 1990, Selection of efficient VAM mycorrhizal fungi for Trifoliate orange. *South Indian Horticulture,* **6**: 305-311.

*WEBER, O.B. AND DE-AMORIM, S.M.C., 1994, Phosphorus fertilization and inoculation with vesicular-arbuscular mycorrhizal fungi in Solo Pawpaws. *Revista-Brasileira-de-Ciencia-do-Solo*, **18**: 187-191.

---

* Originals not seen

APPENDICES

APPENDIX-I

Meteorological data during the period (2000-2001) of experimentation collected at Agricultural Research Station, Arabhavi

Month	Temperature (°C)		Rainfall (mm)	Relative humidity (%)
	Minimun	Maximum		
Jun 2000	24.48	29.46	56.90	75.14
Jul 2000	22.40	27.30	29.70	79.10
Aug 2000	23.00	28.10	53.90	78.60
Sep 2000	22.50	29.30	226.10	74.80
Oct 2000	22.30	30.00	166.80	57.00
Nov 2000	18.60	30.00	-	65.70
Dec 2000	11.80	26.10	-	61.40
Jan 2001	13.04	27.73	-	72.45
Feb 2001	14.56	32.10	-	64.07
Mar 2001	19.41	34.22	-	53.70
Apr 2001	25.46	34.10	-	61.00

APPENDIX-II

Effect of inoculation with VAM fungi and phosphorus levels on cost of cultivation, gross returns (Rs/ha) and benefit : cost ratio

Sl. No.	Particulars	Uninoculated control			*Glomus fasciculatum*			*Sclerocystis dussii*			*Acaulospora laevis*		
		50% (P_1)	75% (P_2)	100% (P_3)	50% (P_1)	75% (P_2)	100% (P_3)	50% (P_1)	75% (P_2)	100% (P_3)	50% (P_1)	75% (P_2)	100% (P_3)
1.	Fixed cost	29790	29790	29790	29790	29790	29790	29790	29790	29790	29790	29790	29790
2.	Variable cost	6412	9193	11975	6442	9223	12005	6442	9223	12005	6442	9223	12005
3.	Total cost	36202	38483	41765	36232	39013	41795	36232	39013	41795	36232	39013	41795
4.	Yield (t/ha)	21.97	28.96	37.54	43.55	55.41	55.79	26.84	51.36	45.85	36.35	34.72	38.31
5.	Gross returns	43940	57920	75080	87100	110820	111580	53680	102720	91700	72700	69440	76620
6.	Net returns	7738	18937	38848	50868	71807	69785	17448	63707	49905	36468	30427	34825
7.	Benefit : Cost ratio	1.21	1.48	1.80	2.40	2.84	2.66	1.48	2.63	2.19	2.00	1.77	1.83

EFFECT OF VAM FUNGI ON GROWTH, YIELD AND DROUGHT TOLERANCE OF PAPAYA

NAGARAJAPPA ADIVAPPAR **2001** **DR. P.B. PATIL**
Major Advisor

ABSTRACT

A field experiment was conducted at Kittur Rani Channamma College of Horticulture, Arabhavi during 2000-2001 to study the effect of vesicular arbuscular mycorrhizal (VAM) fungi and graded levels of 'P' on growth, yield and quality of papaya (cv. Sunset Solo).

The inoculation of VAM fungi in the nursery resulted in significantly higher number of leaves, petiole length, number of fruits, fruit circumference and fruit yield over control. The fruit yield was highest in *Glomus fasciculatum* (51.58 t/ha) followed by *Sclerocystis dussii* (41.35 t/ha) as compared to control (29.49 t/ha) during second year after planting. Application of 75 per cent of recommended dose of 'P' along with inoculation of *G. fasciculatum* was found to be on par with 100 per cent recommended dose of 'P' alone, thereby reducing 25 per cent of recommended dose of 'P'.

The quality of the fruits obtained from the plants inoculated with VAM was superior to control in terms of TSS, sugars and vitamin C content.

In a pot experiment study, inoculation of VAM fungi, *viz.*, *G. fasciculatum* and *S. dussii* recorded higher N, P, K and micronutrients, *viz.*, Zn, Cu and Mn in leaf compared to *A. laevis* and uninoculated control apart from enhancing the drought tolerance capacity of the seedling.