ROLE OF ARBUSCULAR MYCORRHIZAL (AM) FUNGI ON GROWTH AND NUTRIENT UPTAKE OF SOME LEGUMES

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CERTIFICATE

This is to certify that the thesis entitled **"ROLE OF ARBUSCULAR MYCORRHIZAL (AM) FUNGI ON GROWTH AND NUTRIENT UPTAKE OF SOME LEGUMES"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in PLANT PATHOLOGY,** embodies the results of a piece of bona fide research work carried out by **MD. SAIFUL ALAM, REGISTRATION NO. 26277 / 00560,** under my supervision and guidance. No part of this thesis has been submitted for any other degree in any other institutions.

I further certify that any help or sources of information received during the course of this investigation have been duly acknowledged.

Dated: 30.12.2006

Dhaka, Bangladesh

Dr. F. M. Aminuzzaman
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Dedicated to

My

Beloved Parents

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ABSTRACT

A pot experiment was conducted in the net house of the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka during the period from May 2006 to December 2006 with a view to study the role of Arbuscular Mycorrhizal (AM) fungi on growth and nutrient uptake of some legumes. A positive growth response to AM was observed in all the selected legumes. The seedling emergence, plant height, shoot length and root length of inoculated legumes were comparatively higher then that of uninoculated control. The mycorrhizal inoculation suppressed root rot, damping off and leaf blight disease of BARI Mungbean and suppressed root rot, damping off, leaf blight and leaf spot disease of Lentil and Chickpea. The inoculated plants showed early flowering and fruiting in comparison to uninoculated control. Mycorrhizal root colonization differed among the crops ranging from 20.00 to 49.75% and mycorrhizal dependency varied from 8.85 to 55.22%. Increased nutrient (N, P, K, S, B and Zn) uptake was recorded with the inoculated plants. Among the inoculated legumes comparatively higher N, P and K nutrient uptake was observed in Pigeonpea, Cowpea and Chickpea respectively; where as S in Pigeonpea, B in Cowpea and Zn in Soybean.

Chapter 1
Introduction

1. INTRODUCTION

Mycorrhizae are highly evolved, mutualistic associations between soil fungi and plant roots. The partners in this association are members of the fungus kingdom (Basidiomycetes, Ascomycetes and Zygomycetes) and most vascular plants (Harley and Smith, 1983; Brundrett, 1991). Mycorrhiza which literary means 'fungus root', comprise two Greek words 'Mykes' means fungus and 'Rhiza' means root. A German Forest Pathologist Albert Bernard Frank first coined this in 1885. AMF (Arbuscular Mycorrhizal Fungi), which are microscopic soil fungi, simultaneously colonize the roots and their rhizosphere and spread out over several centimetres in the form of ramified filaments. This filamentous network dispersed inside as well as outside the roots allows the plant to have access to a greater quantity of water and soil minerals required for its nutrition. In return, the plant provides the fungus with sugars, amino acids and vitamins essential to its growth (Harley and Smith, 1983). As a result of its improved nourishment, a mycorrhiza-colonized plant has better growth. It fructifies abundantly and, above all, acquires increased resistance to environmental stresses such as drought, cold and root pathogens (Sylvia and Williams, 1992). The AMF mycelium increase the total absorption surface of infected plants and thus improves its access of immobile elements such as P, S, Zn, Cu and Cd in areas beyond the root's depletion zone. These fungi could help improve plant productivity through increased absorption of mineral nutrients from soil, including P.

Arbuscular Mycorrhizal (AM) fungi are distributed worldwide and their occurrence varies with environmental conditions. In spite of immense importance, much less is known about the associations of these fungi with legume crops in field soils of Bangladesh (Khan *et al.*, 1994; Solaiman *et al.*, 2005). A better understanding is needed because of their involvement in systems of sustainable agriculture. The selection of the most specific and appropriate plant-fungus association for each specific environmental and ecological situation is one of the main challenges in current research of arbuscular mycorrhizae. A first step in using the indigenous community of arbuscular mycorrhizal fungi at a site is to understand more thoroughly the community structures and effectiveness with the existing legume crops. Diversification of arbuscular mycorrhizal association in various legume crops is currently of great interest because of the important role played by various legume crops in enriching soil fertility (Mridha, 2002). Arbuscular Mycorrhiza (AM) is known to play an important role in promoting and sustaining grain legumes productivity even under adverse environmental conditions (Smith and Read, 1997). The external fungal hyphae act as a bridge transporting slow diffusing nutrients like P more effectively than those of non mycorrhizal ones. They help increase grain legumes production in several ways through improvement in nutrient uptake, plant resistance to diseases. They also help in conserving soil productivity for the future. Given that the majority of cultivated plants used for human and animal food purposes are colonized by mycorrhizae. This symbiosis can be considered for the benefit of agriculture, by selecting the best plant-fungus combinations (Abbott and Robson, 1991). It is then possible to promote healthier cropping systems and to reduce the use of chemical inputs (pesticides, fertilizers), while ensuring crop profitability and environmental quality. This symbiosis association contributes to the success of the plant establishment and survival, increasing uptake of water and osmotic adjustment under drought stress (Masri, 1997) and also improves soil-plant –water relationship (Jastrow *et al.*, 1998).

Many reports have indicated that VAM (Vesicular Arbuscular Mycorrhiza) can decrease the severity of diseases caused by root pathogenic fungi, bacteria, and nematodes. VAM fungi suppress the incidence of wilt caused by *Fusarium oxysporum* spp. *ciceri* of chickpea plants (Jalali and Thareja, 1981). Reduction of the effects of pathogenic root infecting fungi like *Macrophomina phaseolina*, *Rhizoctonia solani*, *Fusarium solani* on soybean plants by this fungus, *Glomus mosseae* (Zambolim and Schenck, 1983). This fungus reduced the number of sclerotia produced by *Sclerotium rolfsii* while the root pathogen reduced the percentage of root infection and chlamydospore production by *Glomus mosseae* (Krishna and Bagyaraj, 1983). It also appears to decrease plant susceptibility to disease or increase tolerance against the attack of root pathogens (Jalali and Chand, 1988). Simultaneous inoculation of VAM fungi reduced the *Fusarium* wilt incidence in the wilt susceptible JG62 chickpea variety (Reddy *et al.*1988). Introduction of mycorrhizal fungi 15 days before the nematode adversely affected root penetration to a greater extent than simultaneous inoculations (Jain and Sethi, 1989). Plants with VAM were more resistant to *Meloidogyne incognita* than without VAM fungi (Santhi and Sundarababu, 1995).

In Bangladesh lentil, grasspea, chickpea, cowpea, gardenpea, groundnut, blackgram, mungbean, soybean, and bushbean are mainly cultivated as leguminous crop. It is an important component of cropping systems in South Asia, West Asia and North Africa (Saxena, 1990). Grain legumes cultivable land is decreasing day by day and it is now 420933 ha, fifth crops position in area and yield around 0.791 t per ha in Bangladesh (BBS 2004). The importance of AM fungal associations in agricultural crops, especially legumes and their significance in nodulating nitrogen fixing plants are well documented (Barea and Azcon-Aguilar 1983). Mycorrhizal dependency (MD) is an essential property of plant species. Mycorrhizal dependency has been defined by Gerdemann (1975) as "the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility". Legume crops may obligatory or facultative be dependent on arbuscular mycorrhiza. Arbuscular mycorrhizae and legume crops have an obligate nutritional dependency. The extent of AM root colonization affects the symbiosis and depends on the interaction between the macrosymbiont, AM, edaphic conditions and the environments (Mukerji *et al.*, 1996). Differences in the relative mycorrhizal dependency between crop species, or even cultivars are also related to other plant microorganisms in the rhizosphere that could affect the demand for phosphorus (Xie *et al.*, 1995). Systematic research on mycorrhiza has recently been initiated in the mycorrhizal laboratory of Chittagong University (Mridha *et al.*, 1990). The aim is to develop suitable laboratory based technology for inoculation of the crops grown in Bangladesh, with soils and seeds collected from Bangladesh. A little work has been reported on mycorrhizal dependency of legume crops in Bangladesh. The present study was carried out to evaluate the effect of AM on growth, nutrient uptake ability, flowering and fruiting of legumes with the following objectives:

Objectives:

- ❖ To evaluate the effect of arbuscular mycorrhizal (AM) fungi on growth of some legumes.
- ❖ To assess mycorrhizal dependency and nutrient uptake of these crops.

Chapter 2
Review of literature

2. REVIEW OF LITERATURE

2.1 Mungbean (*Vigna radiata*)

Mungbean is an important pulse crop in Bangladesh. Mathew and Johri (1988) investigated in details of a NFT system for multiplication of *Glomus caledonium, G. fasciculatum, Gigaspora margarita* and *Gigaspora calospora* on *V. radiata*. The effects of NFT grown *V. radiata* inoculum on pot grown maize plants were recorded, *G. fasciculatum* was the most effective in producing mycorrhizal infection and *G. calospora* the least. The infection percentage obtained on *Vigna radiata* was not critical in determining the subsequent efficiently of the AM fungi in infecting maize. Mathew and Johri (1989) were also worked with the indigenous vesicular-arbuscular mycorrhizal fungi recovered from soil at the crop research centre of G. B. Plant. Introduced *Glomus caledonium* was effective in improving plant growth and dual inoculation with *G. caledonium* and indigenous AM fungi was most effective. The tripartite system indigenous AM *G. caledonium* and (*Rhizobium phaseoli*) improved plant growth and also resulted in increased nodulation and nitrogenase activity.

Seed inoculation of potted Soybeans, Pigeon peas, *Vigna mungo*, *Vigna radiata* and Cow peas with yeast (*Saccharomyces cerevisiae*) increased root colonization by native AM fungi (Singh and Kapoor, 1989). The highest AM colonization, both in the presence and absence of yeast, was recorded in pusa 78 Pigeon peas. Growth (nodule number, DW of shoot and root) of the crops was also increased due to yeast inoculation. Bajwa (1991) reviewed the occurrence of AM fungi in agricultural production systems. The role of AM fungi in improving the growth of plants by increasing the absorption of phosphorus and micronutrients and enhancing tolerance to drought is reviewed. The potential for commercial use of AM is described along with the most recent advances in inoculum production technology. New approaches to the identification of AM fungi, including ELISA with polyclonal and monoclonal antibodies, isoenzyme analysis and restriction fragment length polymorphism are discussed in the context of a model for research and development of AM fungus inoculation.

Khadge *et al.* (1992) studied in a field condition, maize grain yields on soil inoculated with the vesicular arbuscular mycorrhiza (VAM) *Glomus mosseae* and not fumigated was 1.61 t/ha compared with 1.23 t on uninoculated soil. On soil fumigated with formaldehyde, grain yields of inoculated and uninoculated maize were 1.31 and 1.25 t respectively. Maize inoculation failed to carry over effective inoculum to the mung bean sown immediately after maize harvest. Fresh soil inoculation with *G. mosseae* increased mungbean seed yield from 0.57 to 0.66 t and 0.58 to 0.67 t on fumigated and non-fumigated soil, respectively. Thakur and Panwar (199[illegible]) conducted a field trial with *Vigna radiata* cv. Pusa-105 and PS-16 giving the following treatments; seed inoculation with *Bradyrhizobium*, soil inoculation with AM fungus (*Glomus fasciculatum*) or a combination of both. Inoculation, either singly or combined, increased plant height, leaf area, photosynthetic rate and total dry matter (DM) production compared with no inoculation. A combination of the 2 inoculants gave higher DM production and seed yield compared with either single inoculant's. Pusa-105 had higher leaf area, photosynthetic rate, total DM production, pod number, seed number/pod, seed size and seed yield than PS-16.

2.2 Cowpea (*Vigna unguiculata* var *unguiculata*)

Cowpea is one of the important agricultural crops in Bangladesh especially the crop is growing in Chittagong and coastal zones of the country. Not much work has been done for the improvement of the crop using mycorrhizal fungi. Godse *et al.* (1978) reported that the inoculation of Cowpea with VA mycorrhiza increased nodulation and root and shoot development. The increased shoot and root development were presumably due to increased phosphorus uptake. Islam *et al.* (1980) examined in pot and field for 4 different soil series, inoculation with vesicular arbuscular mycorrhizal fungi caused root infection. A higher infection was maintained during subsequent plant growth in the field. Rock phosphate (RP) application reduced infection without affecting plant growth. Nodulation, N-fixation and RP utilization were increased by mycorrhizae in the pot but not in the field experiments. In pots inoculated plants supplied with RP flowered earlier and took up more P than either uninoculated plants or those inoculated but without RP. The highest response to inoculation in terms of shoot dry matter, nodule yield and N content of the shoots was obtained in Alagba soil under both pot and field conditions. Islam and Ayanaba (1981) from the Nigeria divulged that inoculation by placing seed and inoculum into the planting hole, increased root infection, shoot yield, P content and grain yield in the Cowpea plants. Root infection was temporarily decreased and grain yield increased when the soil was sterilized with formalin. VA mycorrhizas were studied in 2 Cow pea cultivars by Ollivier *et al.* (1983). *Glomus* E_3 and *G. mosseae* stimulated growth of both cultivars, *G. epigaeus* only one and to a lesser extent. Growth stimulation was accompanied by the appearance of additional soluble alkaline phosphatases in mycorrhizal root extracts. The number and the electrophoretic mobility of these enzymes varied with the VA fungus involved, suggesting that they were of fugal origin.

The effect of *Glomus fasciculatum* or *Glomus epigaeus* on growth of Cowpea (*Vigna unguiculata*) var. Pusa Dofasli in concomitant occurrence was largely independent of each other and the organisms did not modify the effect of each other to any considerable extent. However, an increase in nematode inoculum invariably resulted in reduced root infection and spore production by the mycorrhizal fungi. The presence of *Glomus fasciculatum* showed a profound adverse effect on cyst production and nematode multiplication, while *Glomus epigaeum* tended to exhibit a reverse trend (Jain and Sethi, 1987). Jain and Sethi (1989) studied the effect of early establishment of *Glomus fasciculatum* or *Glomus epigaeus* on the penetration and development of *Heterodera cajani* in Cowpea

(*Vigna unguiculata*) in pots. Introduction of mycorrhizal fungi 15 days before the nematode, adversely affected root penetration to a greater extent than simultaneous inoculations. Over 60% colonization of the root system by AM fungi considerably hampered root invasion. However, the endophytes did not further influence the development of penetrated juveniles or the fecundity of the nematode.

In a greenhouse experiment, the effectiveness of three species of vesicular-arbuscular (VA) mycorrhizal fungi was determined in an oxisol subjected to simulated erosion, using *Vigna unguiculata* cv. California Black Eye as an indicator most. Inoculation of the eroded soil resulted in increased VA mycorrhizal colonization of roots without enhancing shoot P concentration and DM (Dry Matter) yields. Inoculation of the uneroded soil, however, significantly improved infection level and symbiotic effectiveness. The lack of expression of mycorrhizal effectiveness in the eroded soil appeared to be a result of nutrient deficiency. The importance of restoring nutrients before the benefits of VA mycorrhizal inoculation can be effectively exploited for successful establishment of mycorrhizal Cowpeas in eroded soils is stressed (Aziz and Habte, 1989).

Aziz and Habte (1990) conducted a greenhouse experiment to determine the combined effects of lime, nitrogen and phosphorus on mycorrhizal activity in an oxisol subjected to imposed erosion using *Vigna unguiculata* cv. California Black eye no. 5 (cow pea) as a test plant. Cowpea was grown in the soil in the presence or absence of the vesicular-arbuscular mycorrhizal fungus *Glomus aggregatum* with or without a basal nutrient consisting of K, Mg, S, Zn, Cu and B; and with basal nutrients plus lime, N and P. The extent of mycorrhizal colonization of roots as well as mycorrhizal effectiveness measured in terms of leaf disc. P content increased significantly when the eroded soil was amended with a combination of all of the nutrients and inoculated with *Glomus aggregatum*.

Vesicular-arbuscular mycorrhizal inoculation and nutrient amendment was also accompanied by a significant increase in shoot P, Cu, Zn and N content and nodule, shoot and root dry matter yield. The findings of this study demonstrate the importance of an adequate nutrient supply to legumes on highly weathered eroded soils inoculated with vesicular-arbuscular mycorrhizal fungi.

Pai *et al.* (1994) studied the role of vesicular arbuscular mycorrhizal (VAM) colonization on the uptake of calcium by Cow pea plants under different levels of moisture stress. Cow peas were sown in pots containing soil inoculated with *Glomus fasciculatum*. The soil maintained at different moisture levels, received known amounts of radioactive calcium (^{45}Ca). The radioactivity present in various parts of the plants was assessed after 60h. High ^{45}Ca levels were present in all parts of AM inoculated plants compared with non-mycorrhizal plants at all levels of moisture stress. The effect of VA mycorrhization of maize plants by *Glomus* spp. on phosphorus metabolism was investigated (Shnyreva and Kulaev, 1994). Phosphorus content in the VA-mycorrhizal root tissues increased by 35% for the species *G. mosseae* and by 98% for *G. fasciculatum*. Phosphorus was accumulated in the root tissues as low molecular organophosphorus compounds of the acid soluble fraction and high molecular compounds of the acid insoluble fraction (RNAs). Daily dynamics of phosphorus transfer to the above ground parts of the mycorrhizal plants depended on the plant developmental stage by the 60th day phosphorus carry over was predominantly as orthophosphates, whereas the 70 days old plants showed a significant increase of the organophosphorus content in the daily root exudates. Root infection by AM fungi significantly improved phosphorus uptake, translocation and its subsequent transfer through the host plant.

Santhi and Sundarababu (1995) conducted a pot experiment to study the effect of different levels of phosphorus (0, 50 and 100 kg/g soil) against

Meloidogyne incognita, VAM fungi and the nematode and fungal interaction. All the differences among the growth parameters of Cowpea of different phosphorus levels were significant. Plant with AM were more resistant to *M. incognita* than those without. Plants treated with phosphorus resulted in increased total phosphorus content. Positive correlation was observed between the phosphorus levels and the nematode population, whereas negative correlation occurred between phosphorus level and the AM spore population and colonization.

2.3 Chickpea (*Cicer arietinum)*

Very few workers did growth improvement study with mycorrhizal fungi. Jalali and Thareja (1981) revealed that inoculation of pot-grown *Cicer arietinum* plants with VA mycorrhiza resulted in extensive root colonization by the endophyte and an accompanying reduction in the incidence of wilt caused by *F. oxysporum fsp. ciceri* (26.6% in mycorrhizal plants, 80% in non-mycorrhizal). No inhibitory effects were found the test organism *Glomus fasciculatum* in the rhizosphere of *Cicer arietinum* in pot experiments (Poi *et al.* 1989). Inoculation also resulted in significantly greater dry matter production and phosphate uptake than uninoculated one. The results suggested that *G. fasciculatum* could greatly assist symbiotic N fixation as well as phosphate uptake by *C. arietinum* particularly when the crop is grown in soils containing insoluble phosphate. Use of inoculation was suggested for establishing leguminous crops with minimum supplies of N and P fertilizers.

Reddy *et al.* (1988) found that simultaneous inoculation of *Cicer arietinum* with vesicular arbuscular mycorrhizal fungi (*Glomus mosseae, G. constrictum*) and *Fusrium oxysporum* f.sp. *ciceri* had no effect on wilt incidence in the succeptible JG 62 and resistant WR 315 genotypes. However, the wilt-tolerant genotype, K 850 had 25% wilt in soil with *Fusarium* +VAM, less than with *Fusarium* alone (35%). Champawat (1990) demonstrated that the interactions between vesicular-arbuscular myconrrhiza and *Rhizobium* in chickpea and dual inoculation with AM fungi *Gigaspora calospora* and *Rhizobium* bacteria considerably enhanced the plant growth, uptake of phosphorus and nitrogen and root nodulation.

Chaturvedi and Kumar (1991) observed that nodulation and nitrogenase activity in Chickpea cultivars plant G-114 and BG-209 raised in P deficient unsterilized soil and inoculated with *Rhizobium* and *Glomus caledonium* were maximum compared with plants inoculated with either in inoculum alone. Uninoculated cultivars formed poor nodules and had lower levels of nitrogenase activity. Tilak and Dwivedi (1991) reported that the Yields per plant were higher in micro plots inoculated with *Glomus versiforme* than in noninoculated ones at all N levels. A non inoculated micro plot at 50 kg N/ha yield almost as much as a AM inoculated one receiving only 25 kg N/ha in the presence of *Rhizobium*.

Exposure of *Rhizobium* sp. to a low strength (5×10^{-3}T) electromagnetic field before inoculation to mycorrhizal chickpea seedlings in pots increased nodulation, VAM infection and top growth (Bajwa *et al*1995). Bajwa *et al.*(1995) were also observed that an increase in number of nodules, status of AM infection and top growth was obtained in plants raised from electromagnetised seeds.

2.4 Blackgram (*Vigna* mungo)

Black gram is very important crop in Bangladesh. Very few people has conducted experiments for growth improvement of the crop with mycorrhizal inoculation. Devi and Sitaramaiah (1991) showed that Plants of *Vigna mungo* grown in field soil inoculated with *Glomus fasciculatum, G. constrictum, G. epigaeum. Acaulospora morroweae* increased mycorrhizal root colonization and had greater root volume and greater dry wt. of shoots and roots than non-inoculated plants. The rhizosphere microbial population was reduced in inoculated plants.

Sullia and Chandranath (1991) studied that AM in *Vigna radiata*, Chickpeas and *Vigna unguiculata* with preference to plant age. Root samples were screened for hyphae, vesicles and arbuscules and all 3-plant species were colonized by 15 days after sowing in field plots. There was an increase in the number of vesicles and arbuscules up to 30-45 days followed by a decline to almost zero after 120 days. In the early days of growth, arbuscules were predominant but later, vesicles were more abundant. In chickpeas and *Vigna unguiculata* there were 2 peaks of vesicle appearance whereas in *Vigna radiata* there was only 1 peak. VAM mycelium persisted up to 135 days after sowing but vesicles and arbuscules were not present. The increase in the number of vesicles and arbuscules did not conform to the reproductive cycle of the plants i.e. there was no increase or decrease of these structures with either flowering or fruiting. The mycelium of *Rhizoctonia* sp. was seen in the roots of all 3 legumes. As the VAM mycelium degenerated, *Rhizoctonia mycelium* became more dense, forming large cushions of beded mycelium. The fungus was a symbiont and not a pathogen as it did not produce any pathogenic symptoms.

2.5 Fieldpea (*Pisum sativum*)

Dual inoculation of pea plants with *Gigaspora calospora* and *Rhizobium* resulted in greater increases in shoot and root dry weight, P and N uptake, nodulation and mycorrhizal infection than single inoculations (Champawat, 1990). Sdobnikova *et al.* (1991) studied the effect of artificial inoculation with *Glomus* sp. N race I, *Glomus mosseae* N8 race II and *Glomus mosseae* on meadow clover, Lucerne and Spring Vetch (*Vicia* sp). The results demonstrated that inoculation with AM fungi improved growth and development of plants, increased P assimilation and N fixation.

In an experiment by Boovaraghan *et al.* (1995) transformed root cultures were established from the nonmycorrhizal and mycorrhizal (Myc^+) pea mutants to study the biochemical factors necessary for initiating and maintaining the arbuscular mycorrhizal (AM) Symbiosis. Root exudates produced by both the Myc^- and Myc^+ mutants inhibited the hyphal growth of *Gigaspora margarita*, whereas root volatiles from the mutants stimulated the hyphal growth significantly in the precolonization stage. Carbon dioxide is the principal volatile compound necessary for the elongation of hyphae from both the Myc^- and the Myc^+ transformed roots. The addition of quercetin, a flavonol compound, to the medium with a Myc^- mutant enriched with an optimum CO_2 improved hyphal elongation and spreading as previously reported but did not cause Myc^- roots to become mycorrhizal. It is suggested that the root factors may stimulate or inhibit AM fungal growth and that they do not determine the mycorrhizal nature of pea mutants.

2.6 Soybean (*Glycine max*)

Soybean is not only important in Bangladesh but also important all over the World. Many scientists have done lot of work with this crop for the growth improvement. Bagyaraj *et al.* (1979) from India demonstrated the results of dual inoculations on plants in a phosphorus deficient sandy loam soil which suggested that *Glomus fasciculatum* can greatly assist nodulation and nitrogen fixation in field grown Soybean with *Rhizobium japonicum*. Carling *et al.* (1979) reported that dually infected (AM fungi and nitrogen fixing bacteria) nodulating Soybean plants showed increases in total dry wt. and nodule dry wt., as well as higher levels of nitrogenase and nitrate reductase activities over singly of uninfected plants. When phosphorus was substituted for mycorrhizal infection, similar growth and enzyme activity increases were observed. This suggests that VA endomycorrhizal fungi, which can assist legumes in the uptake of phosphorus, do not interact directly with nitrogen fixing bacteria.

Barley and Safir (1978) observed that Benomyl prevented increased plant growth due to the vesicular arbuscular mycorrhizal even with fungal colonization of the root system as high as 48%. The two Canadian Pathologist observed that root and shoot development of Soybean was significantly inhibited on adding *Glomus* sp+*Aphelenchus avenae* to root zone soil and poor fungal sporulation was shown to be due to nematode (Salawu and Estey, 1979). Carling *et al.* (1979) from USA divulged Soybean seedlings remained free from mycorrhizal infection in the early stages of development. First infection units appeared 10-12 days after plants, which was also the approximate time, that *Rhizobium* root nodule and tertiary roots were first observed. The response to colonization by VA mycorrhizal fungi was evident as early as 6 weeks after planting.

Skipper and Smith (1979) examined the response of Soybean endomycorrhiza symbiosis depended on soil pH. In unlimed soil (pH 5.1) were greater for *Gigaspora gigantea* than *G. mosseae* and limed soil (pH 6.2), the larger responses were obtained with *Gigaspora mosseae*. The cv. Bossier and *G. gigantea* combination was particularly responsive in unlimed soil, showing a 10% increase in shoot length, 35% in shoot dry wt., 75% in root dry wt. and 397% in nodule dry wt. over uninoculated controls and little cv. Response was observed with *G. mosseae* in unlimed soil. Plants of 2 cvs. infected with *G. mosseae* were physiologically stressed by top removal and harvested at 7 bi-weekly intervals. Removing tops stopped root growth, stimulated branching delayed plant growth stages by c. 2. weeks but did not affect spore production. Spore numbers were significantly related only to time of harvest. Harvest, cv. and cutting effect were highly significant for root and shoot wts. and root/shoot ratios (Luedders *et al.*1979).

In glasshouse tests, roots of cv. Pickett Soybean plants were inoculated with chlamydospores of *Glomus macrocarpus* and or eggs of *Meloidogyne incognita* by using an aluminium foil funnel technique. They were inoculated with 1 organism 10 days before the other or with both simultaneously, either at or 10 days after planting. After 14 weeks plants infected with both organisms had significantly fewer galls/g of root, greater root and higher yields than those with the nematode alone yield. Chlamydospores production and the number of mycorrhizal roots were not significantly different in the presence or absence of nematodes. A typical hyphae, vesicles and arbuscules of the fungus were observer in galled tissue and 57% of the galls examined were not associated with mycorrhizal roots. The presence of *G. macrocarpus* reduced the number of galls produced by *M. incognita;* the nematode affected mycorrhizal development in the immediate area of the gall, but had little effect on the mean number of mycorrhizal roots or the number of chlamydospores (Kellam and Schenck, 1980).

Asimi *et al.* (1980) recorded the beneficial effects of inoculating nodulated plants, growing in unamended sterile soil, with *Glomus mosseae* improved P uptake, lower root: shoot ratio and better nodulation with higher nitrogenase activity. Addition of 0.25 g KH_2PO_4 / kg to the soil eliminated the mycorrhizal effect on plant growth but not on nodule formation and nitrogenase activity. Effect on nodulation however eliminated with 0.5g KH_2PO_4 and on nitrogenase activity with 1 g / kg. These higher levels of phosphate fertilization considerably diminished infection and in particular fungal spread within the roots. Specific activity of vesicular arbuscular mycorrhizal (with *Glomus mossae* or E_3) and non-mycorrhizal soybeans in a $^{32}PO_4$ labeled soil was the same and identical to that of the PO_4-ions in the soil solution. Analysis of the isotopic dilution kinetics of the soils after harvest showed that mycorrhizal Soybeans had essentially absorbed P from the soil solution. Insoluble tricalcium phosphate added to soil was not used as a P source by mycorrhizal or non mycorrhizal plants. Calcium phosphate was hydrolysed by both plants and PO_4 ion accumulation in the solution was grater in the presence of mycorrhizas. The results confirmed that the principal role of mycorrhizas is a more efficient utilization of soil phosphates. (Gianinazzi-Pearson *et al.*, 1981).

Carling and Brown (1980) found that the growth and yield response of glasshouse-grown plants to colonization by 19 isolates (including 6 *Glomus* and 13 *Gigaspora* spp.) of VA mycorrhizal fungi. Each isolate was evaluated in a high (169 kg/ha Bray-1 P_2O_5) and low (50 kg/ha) fertility soil. Colonization by most *Glomus* isolates significantly increased plant top dry wt. and seed yields and of these isolates most produced larger increases in dry weight in low fertility soil. colonization by 5 of the *Gigaspora* isolates did not significantly affect top dry wt. and seed yield in either soil.

Bethlenfalvay *et al.* (1982) studied with *Glomus fusciculatus*, the amount of total fungal biomass relative to that of the host plant varied throughout the lifespan of the association, reaching a max. 2.3%, 10 week after planting. The amount of intraradical mycelium increased throughout the host lifespan. Extraradical fungal structures attained max. wt. at the onset of logarithmic growth of the Soybean pods but there after decreased. Cessation of rapid growth in the fungus logged behind that in the host but appeared related to pod development. The fungus: root dry wt. ratio was 12.3% at senescence. The ratio of extra to intraradical mycelium decreased throughout the association. Since the Extraradical hyphae are the organs responsible for enhancing nutrient uptake. This ration is proposed as an index of the endophytes usefulness to the host. High values coincided with significant growth enhancement of the host. Source sink relationships in the host appear to be a determining factor in the growth of the fungal endoplyte.

The Taiwani Patnologists, Cheng and Tu (1982) investigated the endomycorrhizal fungi (*Glomus clarus*) and their relation with parasitic nematode and divulged inoculation of Soybean with chlamydospore of *Glomus clarus* significantly increased growth and pod production. Yost and Fox (1982) reported that silicon percentages in mycorrhizal soybean plants were higher than those in non-mycorrhizal plants (grown in fumigated soil) at all levels of soil P. Silicon content of cowpea however, was not altered by the presence or absence of mycorrhiza.

Zambolim and Schenck (1983) studied Soybean growth responses to *Glomus mosseae* in combination with either *Macrophomina phaseolina, Rhizoctonia solani* or *Fusarium solani* using autoclaved and / or nonautoclaved field soil (91 ppm P and pH 6.8) in a glasshouse with air temperatures of 25-35°C. After 45 days, plants in autoclaved soil containing any one of the 3 pathogens had fewer roots and shoot weight and were shorter than control plants in soil without *G. mosseae* or the pathogens. Plants exposed to the pathogens in autoclaved and nonautoclaved soil had 20-30% and 10-16% less seed weight, respectively than controls. *G. mosseae* did not affect the incidence of pathogenic infection but the pathogens significantly reduced (av. 38%) root colonization by *G. mosseae* in autoclaved soil. The addition of *G. mosseae* to autoclaved soil with and without the pathogens significantly improved plant growth. *G. mosseae* increased seed yields by 50 and 15% in autoclave and nonautoclaved soil, respectively, over that of control without *G. mosseae*. Significant correlations occurred between the percentage of root colonized by *G. mosseae* and weight of roots and shoots and plant height. The correlation between seed weight and plant growth responses at 45 days was also significant. Although the incidence of infection by the pathogens was the same in mycorrhizal and nonmycorrhizal plants, plants colonized by *G. mosseae* appeared to tolerate this infection better than mycorrhizal plants.

The fungi, each at 500 spores/kg of pasteurized soil, were compared in a repeated greenhouse experiment. Generally the 5 spp. were categorized into 2 groups; those in group I (*Glomus mosseae, G. intraradices* and *Gigaspora* *heterogama*) had higher spore germination, root penetration percentage, root colonization values and fungal growth rates in the roots than those in group II (*Glomus etunicatum, Gigaspora margarita,* and *Entrophospora* sp.). However when the fungal growth rate (cm/day) / penetration point was calculated on Smith and Walker's equation applied, the highest values were assigned to group II. Fungal growth rate/penetration point was inversely proportional to the number of penetration points, indicating growth interference, among hyphae originating from different penetration points in the root. The number of penetration points was correlated significantly with root length but not with percentage of root colonization. Dry root wt. was significantly correlated with length of colonized roots in both experiments, shoot wt. with colonized root length in only 1 experiment. *G. mosseae* was the only sp. which induced a significant increase in both dry shoot wt. and number of *Rhizobium* nodules. (Nuffelen and schenck, 1984).

Soybean plants were cultivated in knop nutrient medium containing 4.6 ppm phosphorus and 17.6 ppm nitrogen. Inoculation of Soybean root by VA mycorrhizal fungi positively influenced nitrogenase activity of nodules, biomass production and shoot: root ratios in nodulating plants. Phosphorus was accumulated in higher amounts in shoots of mycorrhizal plants, resulting better growth with respect to nodulating plants without mycorrhiza. In spite of the fact that nodulating mycorrhizal and non mycorrhizal plants did not differ in their nitrogen content, the total nitrogen production by the biomass was higher in mycorrhizal treatments, though significant differences were only found in plants with *Glomus fasciculatum.* Bethlenfalvay and Franson (1989) examined that soybean plants inoculated with *Bradyrhizobium japonicum* strain Nitragin 61A118 were grown with or without the vesicular arbuscular mycorrhizal fungus *Glomus mosseae* in pot cultures in soil high in available Mn (40.4 mg/g). Leaves of the non AM plants showed severe symptoms of Mn toxicity and had toxic Mn conc.

(314 mg/g) in the foliage. Non AM plants had significantly lower DW (Dry weight) and nodule wt. than AM plants. Mn conc. in the AM plants were significantly lowers that in the non AM plants and there were no symptoms of Mn toxicity. Both AM and non AM plants had a significant negative correlation between shoot DW and leaf Mn conc.

Aliette (fosetyl aluminium), a fungicide known to increase VAM infection and aminooxyacetic acid (AOA), a herbicide which inhibits phenylalanine ammonialyase were applied to Soybeans inoculated or not with *Glomus intraradices*. Effects on AM infection were positive with fosetyl aluminium and negative with AOA. Conc. of the isoflavonoids glyceollin, coumestrol and daidzein were significantly decreased by AOA but remained unchanged with fosetyl aluminium. These results suggest that phytoalexins do not control AM development and show that biocides can modify the physiological state of the root system and the plant AM fungus interaction (Morandi, 1990). An attempt to formulate a preliminary version of a mathematical model could represent the dependence of Soybean growth on the symbiotically mediated uptake of nutrient is presented (Prikryl *et at.*, 1990). The model involves a growing plant, a phosphorus source, nitrogen, AM fungi, and rhizobia and serves to study mutual interrelations among these components.

Sasai (1991) investigated in field tests on Maize, Soybean, Tomato, Carrot and *Arctium lappa* for the application of phosphorus fertilizers increased after shoot dry weight, increased shoot phosphorus content after the second cropping (86 days after sowing) and decreased mycorrhizal infection rate to varying degrees. Mycorrhizal spore number in rhizosphere soil (Soybean, Tomato and Maize) was much higher in soil without added phosphorus. It is concluded that AM fungi promote phosphate uptake in low phosphate soils during the early stages of plant growth.

Maize and Soybeans (either inoculated with *Glomus versiforme* or not) were grown together in pots of sterilized sand. Soybean plants were enriched with ^{15}N before transplanting into the pots. The root systems of the two plants were not separated or were separated by barriers of permeabilities 0.22 µm or 0.60 µm. Transfer of ^{15}N from Soybeans to Maize was facilitated by root and hyphal contact and by inoculation with *G. versiforme*. When the hyphae were restricted by a 0.22 pm barrier, the level of ^{15}N transfer was small and similar to non-inoculated plants separated by 0.22 or 0.60 µm barriers in the rooting zone. This suggested that root and hyphal contacts played a role in N-transfer from Soybean to Maize plants, and that nitrogenous exudates diffusion in sand was not a significant route for N transfer. Transport of ^{15}N from the host plant to *G. versiforme* was extremely low, suggesting that the fungus is independent of its host for its N nutrition and that the role of hyphal bridges is insignificant. Uptake by the receiver plant (Maize) of the N excreted by the donor plant (Soybean) appeared to be the mechanism of N-transfer between plants. The presence of the endomycorrhizal fungus in plants roots reduced ^{15}N loss from soybeans, but at the same time its extensive hyphal network improved the efficiency of the maize root system for the recovery of ^{15}N excreted by Soybeans. The transfer of N between mycorrhizal plants was particularly enhanced by the death of the Soybean plants (Hamel, *et al.* 1991).

Brown *et al.* (1992) reported that Soybean (*Glycine max* cv. clark) plants associated with Maize (*Zea mays*) by AM hyphae had greater nodule activity (C_2H_2 reduction) than plants of the nonassociated comparison treatment. In associated Maize plants, Cob dry mass and VAM colonization were significantly smaller than in nonassociated plants. Conc. of N in associated Soybeans and P in nonassociated ones, were significantly greater than in their respective nonassociated or associated counterparts. Nutrient balance was better in the associated than in the nonassociated plants. Transport of products of photosynthesis was investigated by exposing maize plants to $^{13}CO_2$ and later evaluating the distribution of the C among plants and soil. All the data suggest that nutrient distribution is modified in plant associations that include AM hyphae. Implications of this phenomenon for agro-ecosystem management are discussed.

The diversity of AM fungi in a crop-rotation system in Nebraska, USA, was examined and the effect of Soybean-Sorghum crop rotation, fertilizer-N and manure application on AM fungal colonization and root development of soybean and grain sorghum was determined. Rooting densities correlated with previous crop, AM fungal colonization and soil NO_3, while root colonization by AM fungi was affected by previous crop, rooting density, N-fertilization, soil-P and soil water content. Root colonization by AM fungi varied from 93% at 15 cm to 15% at 120 cm soil depth. Root density and AM fungi colonization were least when Soybean had been grown the previous year and when manure was applied. In continuous Soybean plots, the percentage root colonization by AM fungi was 54, 53 and 30% for control, N and manure treatments, while in Soybean from rotation plots, colonization was 61, 55 and 44% respectively. A total of 26 VAM fungal species, belonging to 7 genera (*Acaulospora, Endogone entrophospora, Gigaspora, Glomus, Sclerocystis* and *Scutellospora*) were isolated from rotation plots. Colonization by VAM fungi was greater on plants stressed due to cropping system or fertilizer practice. It is concluded that the diversity of VAM fungi in these soils may contributes to the high productivity of soils of this area by supplying a VAM fungal population capable of responding to varying environmental conditions and stresses (Ellis *et al.*, 1992).

Khalil *et al.* (1992) investigated in 15 soils in Iowa, USA to extent of root colonization by mycorrhizal fungi, the distribution of mycorrhizal fungal spores in the rhizosphere and the mycorrhizal fungal genera associated with Soybeans. Roots from most soils, including those with high soil test P levels, were extensively colonized (60-100%) by AM fungi, with an average colonization (determined by evaluation of the percentage of root segments with AM fungi) for all soils of 89% AM fungal spores were quite common in all rhizosphere soils sampled and ranged from 66 to 998 spores/100 soil. Total spore counts were significantly different among soil series and within soil series. A negative correlation was found between soil organic matter, P and AM fungal colonization. Four fungal genera, *Glomus, Gigaspora, Acaulospora* and *Scutellospora* were found associated with Soybean rhizosphere soil with *Glomus* spp. most common.

In microplot trials on grey forest soil in 1988-89, Soybeans cv. Mageva were given PK+ 40 kg N/ha at sowing, with N mixed with the 0-15 cm soil layer or banded in the middle of the plot at 15 cm depth. Seeds were uninoculated or inoculated with *Bradyrhizobium japonicum* alone or with *Pseudomonas fluorescens* or *Glomus mosseae* (Shabaev and Smolin, 1992). When N was broadcast dual inoculation increased seed yields by 18-34% and aboveground dry matter (DM) yield by 13-27% compared with inoculation with *B. japonicum* alone. Inoculation with *B. japonicum* + *G. mosseae* gave the highest yield and N uptake. Banded N application increased seed yield by 17-19% and aboveground DM yield by 13-16% compared with broadcast N and increased the uptake of soil and ^{15}N-labelled fertilizer N by 37-50%. Dual inoculation increased N fixation and uptake of soil and fertilizer N but had little effect on their proportions in the total N content of inoculated plants.

In microplot trials on grey forest soil in 1988, Soybeans were given PK+40 kg N/ha at sowing with N mixed with the 0-15 cm soil layer or banded in the middle of the plot at 15 cm depth, seed were uninoculated or inoculated with *Bradyrhizobium japonicum* alone or with *Pseudomonas fluorescens* or *Glomus mosseae.* Effect on plant N, P, K, Ca, Mg, Fe, Zn, Cu, Mn, Mo and Co contents were determined. Soil inoculation and location N application did not cause significant changes in the concentration of most of the elements in seed or straw at harvest, compared with values obtained when only *B. japonicum* and broadcast N were used. The increased yield produced by dual inoculation or localized N-application occurred as a result of increased uptake of major and trace elements. This uptake depended on the species of microorganism and the method of N application. Dual inoculation and localized N application significantly reduced Fe concentration and uptake in straw and total biomass. *P. fluorescens* increased K, Zn, and Mn uptake by aboveground plant parts (Smolin and Shabaev, 1992).

Two wild legume plants, *Glycine soja* and *Cassia mimosoides* var. *nomame* and a cultivated plant, Soybean (*Glycine max*), employed for a study of triple symbiosis with an inoculum of *Scutellospora heterogama* harvested from natural soil and an inoculum of their own rhizobial cells. The dry weight (DW) colonization of arbuscular mycorrhizal (AM) fungus nodule formation and N_2 fixation activity were estimated as parameters of triple symbiosis. The 2 wild legume plants showed greater growth with colonization of AM fungi than with nodulation, whereas the cultivation legume showed more growth with nodulation than colonization of AM fungi, *S. heterogama* appeared to stimulate the triple symbiosis for the wild legume plants. It is suggested that spores of *S. heterogama* are important in disturbed soils in the Korea Republic (Eom *et al.*, 1994).

Cabello (1992) observed the interaction between the indigenous AM fungus, *Glomus epigaeus* (*G. versiforme*) produced in pots and *Bradyrhizobium japonicum* improved growth of Soybean plants and increased the size and number of nodules compared with uninoculated plants. N and P contents increased by 102 and 233%, respectively as a result of the tripartite interactions. Isobe *et al.* (1993) divulged that vesicular-arbuscular mycorrhizal infection increased phosphoric acid content of soybeans at 50 days after emergence. Application of superphosphate fertilizer decreased mycorrhizal infection.

Kumutha and Santhanakrishnan (1994) conducted a pot experiment in Madras of Soybean plants. Soybeans cv. Co. 1 was seed inoculated with *Bradyrhizobium japonicum* or not inoculated and grown in pots soil inoculated with *Glomus fasciculatum* or not inoculated. Dual inoculation approximately doubled N fixation compared with *Rhizobium* alone. In a field experiment in 1993 at Dharwad, Karnataka, Soybeans CV. MACS-58 were sown in plots inoculated with *Glomus fasciculatum or Gigaspora margarita* and were given 80, 60 or 40 kg P_2P_5/ha as single super phosphate. Plots not inoculated with mycorrhizas received 80kg P_2O_2 seed yield was highest in plots inoculated with *G. margarita* and supplied with 80 kg p_2o_5 (1413 kg/ha). Soil inoculation with *Glomus fasciculatum* + 80 kg P_2O_5 gave seed yield of 1405 kg. Soil inoculation with the mycorrhizas + 60 kg P_2O_5 gave similar seed yields as no inoculation + 80 kg P_2O_5 (Lingaraju *et al.* 1994).

Price *et al.* (1995) studied the effects of *Glomus intraradices* and the Soybean cyst nematode (SCN) *Heterodera glycines* singly and in combination on 2 Soybean cultivars. Bragg (Nematode intolerant) and Wright (moderately tolerant) grown in the greenhouse in soils with low (35 µg/g) and high (70 µg/g) phosphorus (p). Cultivar wrights grew better than Bragg, showing a greater response to P and VAM, and was damaged less by SCN. These differences were not apparent or reversed when the same cultivars were grown in growth chambers where lighting was sub-opt. Wright had a larger shoot: root ratio than Bragg. It is concluded that Wright has a more efficient root system than Bragg which is the basis of both the greater response to VAM and a greater nematode tolerance.

Cheng Yung Hsiung and Tu chinchyu (1995) conducted a pot experiments, inoculation of 5 days old Soybean cv. Taiwan No.15 seedlings with *Glomus clarum* spores increased plant growth, with pod number per plant highest with inoculation with 100-200 spores/pot. The process of mycorrhizal colonization and infection of plant roots, and the subsequent development of external mycelium and spores, are described for Soybeans and watermelons using staining and microscopic examination. *Paspalum notatum* is suggested as a suitable host plant for increasing *G. clarum* inoculum, giving up to a 13 fold increase within 8 weeks.

A controlled environment experiment was conducted to examine the effect of root zone temperatures (RZT_s) on vesicular arbuscular mycorrhizal colonization, nutrient uptake, nodulation and nitrogen fixation and plant growth and development in Soybeans cv. Maple Glen. The experiment was organized as a randomized complete block split plot design, the main plot units consisting of 4 RZT_s:15, 18.2, 21.6 or 25°C, and the 4 harvest stages and inoculation (or not) with mycorrhizal fungi formed the sub plot units. The optimal RZT for mycorrhizal infection of *Glomus versiforme* was 21-22°C. Above and below this range, mycorrhizal colonization (MC) was inhibited. MC increased until flowering colonization (the 3rd harvest), but decreased there after at all tested RZT_s. In addition, MC had a negative effect on nodule establishment (nodule number) at lower RZT_s and a positive effect at higher RZT_s. However the lower nodule number at lower RZT_s was compensated for by an increased mass per nodule such that mycorrhizal infection stimulated N_2 fixation at lower RZT_s (Zhang *et al.*, 1995).

Eranna and Parama (1994) carried out a pot experiment with Soybeans using an acid (pH 5.1) soil, 0 or 2.64 g lime/kg soil and 0, 10, 20 or 40 g rock phosphate/kg soil were applied and the soil was inoculated with *Glomus mosseae*. Liming had no significant effects on Soybean DW (Dry Matter) but it decreased P uptake. Mycorrhizal inoculation increased both DW and P uptake. Shoot DW increased with rate of P application whereas root DW was highest with the lowest rate of P. Shoot P uptake increase with up to 20 g P/kg soil whereas root P uptake increased with up to 40g P/kg soil. Root extracts of leek and soybean showed trehalase activity which was inhibited by phloridzin and was several times higher than the activity of general α-glucosidase (Schubert and Wyss, 1995). The activity had an acidic optimum. Trehalase activity in extracts of sporocarps and extraradical mycelium of the arbuscular mycorrhizal fungus *Glomus mosseae* was higher than in root extracts and had an optimum at pH 7. Following inoculation with *G. mosseae* trehalase activity increased in mycorrhizal roots above the levels observed in nonmycorrhizal roots. Irrespective of fungal colonization, root trehalase activity increased in the presence of Mg^{+2}, deceased in the presence of Mn^{+2} and Zn^{2+} and was unaffected by Na_2EDTA.

Lussenhop (1996) observed that collembola affect rhizobia and mycorrhizas of Soybean (*Glycine max*) and thus indirectly change leaf tissue nutrient concentration was studied in pot and field experiments. When a high density of the collembolan species *Folsomia candida*, was added to pots, the number of nodules per plant increased 52%. When moderate densities of two collembolan species, *Folsomia candida* and *Tullbergia granulata*, were added in factorial combinations to cylinders sunk in the soil around Soybean in fields, the following responses were observed: 40% grater mycorrhizal root length, and 5% higher leaf tissue N, but no changes in leaf P., nodule number or root mass. Collembola density in the field was too low to increase nodule number per plants as observe in pot experiments: there was no mechanism to explain the 5% increase in leaf tissue N associated with collembola in the field. In the field, intermediate densities of collembola were associated with greater mycorrhizal root length, but since available soil P concentrations were high, longer mycorrhizal root length was not associated with higher leaf tissue P. A path model showed that if mycorrhizas were positively associated with higher leaf P, the indirect effect of collembola would have been significantly higher leaf tissue P. This study showed that both available soil P and collembola density determine mycorrhizal benefits.

In natural habitats, intermediate collembola density and low soil P are expected to maximize benefits of mycorrhizas to plants.

Singh *et al.* (1995) conducted a greenhouse experiment to study the effects of vesicular arbuscular mycorrhizal fungi, phosphate solubilizing microbes and *Bradyrhizobium japonicum* on nodulation and Dry Matter accumulation at 45 days in Soybeans cv. Bragg. Inoculation with mycorrhizal fungi caused about 56% root infection. Addition of rock phosphate (RP) and inoculation with *B. japonicum* or PSM stimulated root infection by native as well as exotic mycorrhizal fungi. Addition of RP and inoculation with *B. japonicum*, mycorrhizal fungi and PSM individually increased the number and DW of nodules / plant and shoot DM accumulation. The number and DW of nodules / plant were significantly higher than the control due to RP × *B. japonium*, RP × mycorrhizas, *B. japonicum* × *PSM*, mycorrhizas × *B. japonicum*, *B. japonicum* × mycorrhizas and RP × PSM interactions. Among the 4 factor interactions, the number and DW of nodules / plant were highest with RP × *B. japonicum* × *mycorrhizas* × *P. straite* (*Pseudomonas striata*).

Plenehette and Morel (1996) conducted an experiment under greenhouse conditions to evaluate the effects of vesicular-arbuscular mycorrhizal (VAM) fungi on the external P requirement of Barley and Soybeans. The plants were grown in pots containing a P-deficient soil. Adding 0, 20, 30, 40, 50, 60, 70, 110, 160 or 310 mg P/kg as NaH2PO4.2H2O obtained a range of 10 P levels. Half of the pots were inoculated with the VAM fungus *Glomus intraradices*. The P concentration in the soil solution was determined using an adsorption isotherm and plotted against the relative yield. Barley did not respond to mycorrhizal inoculation and it was concluded that P nutrition was not the limiting factor on the growth of this low mycotrophic plant. In contrast, mycorrhizal inoculation stimulated the growth of soybean. The external P requirements were 0.110 µg/ml for mycorrhizal and 0.148 μg/ml for non-mycorrhizal Soybeans to obtain 80% of the maximum yield. In terms of P fertilization this corresponds to a saving of 222 kg P_2O_5/ha. The mycorrhizal dependency of the Soybean was highly correlated with the P concentration in the soil solution and it is proposed that both values should be displayed together.

2.7 Groundnut *(Arachis hypogea)*

Germani *et al.* (1980) reported that DBCP (dibromo-3-chloropropane) fumigation of a typical sandy soil in central Senegal, on which Groundnut is commonly cultivated, favoured inter alia early infection by endomycorrhizal in 2 of the 3 cvs. The results indicated that the nematode *Scutellonema cavenessi* alters the physiology of the groundnut plant by affecting the establishment and functioning of the symbiosis between the plant and endomycorrhizae. Krishna and Bagyaraj (1982) recorded that inoculation with *Glomus fasciculatum* increased dry wt. of Groundnut plants and resulted in greater absorption of nutrients, especially P. Uptake of K, Ca, and Cu was unaffected. A time course experiment showed that during the early stages (up to 20 days) growth rates of mycorrhizal and control plants were similar but in the former growth and dry matter were stimulated after 25 days.

Krishna and Bagyaraj (1983), the Indian pathologist observed in a Groundnut pot test, the mycorrhizal fungus reduced the number of sclerotia produced by *S. rolfsii* while the root pathogen reduced the percentage of root infection and chlamydospore production by *Glomus fasciculatum*. Root and shoot dry wt. of the host and their P content were highest in plants inoculated with mycorrhizal only and lowest in plants inoculated with the pathogen only. Simultaneous addition of mycorrhizal inoculum and the pathogen reduced disease severity. Roots of mycorrhizal (*Glomus fasciculatum*) Groundnut plants had higher amounts of phenols than non-mycorrhizal roots (Krishna and Bagyaraj, 1984).

The Indian researchers established this mycorrhizal fungus (*Glomus mosseae*) in a nutrient solution containing 0.25 mM P and inoculated with powdered infected Groundnut roots or resting spores. Initiation of mycelial growth in roots was observed after 8 days of contact with the inoculum. In a second experiment intial P conc. in the range 0.25-1 mM resulted in maximum colonization by *G. mosseae* and increased production of the plant biomass. Plant growth and VAM development was slightly less in a pot culture without the addition of P to the soil. It is suggested that the static solution culture method can be successfully adopted to determine the requirement of initial levels of essential elements in culture solutions for investigating similar mycorrhizal associations of crop plants (Parvathi *et al.*, 1984).

Krishna and Bagyaraj (1985) found that in sterilized soil, acid and alkaline phosphatase activities in the rhizospheres of mycorrhizal and non mycorrhizal plants were higher than in non-rhizosphere soil. No significant differences were noted between mycorrhizal and non-mycorrhizal plants. In unsterile soil, differences in alkaline phosphatase activity among the 3 treatments were not significant. With acid phosphatase, the activity was highest in the rhizosphere of mycorrhizal plants followed by uninoculated rhizosphere and then non-rhizosphere soil. Santhanakrishnan and Oblisami (1990) revealed that colonization of the roots by vesicular arbuscular mycorrhizal fungi significantly increased due to inoculation with AM fungi alone over the uninoculated control at 3 stages of growth. There was an increase in colonization of AM fungi up to 150 kg/ha gypsum with a decrease in AM colonization with further increase up to 450 kg/ha gypsum. The magnitude of increase of growth, AM colonization and nutrient content in Groundnut plants was maximum with AM inoculation together with 150 kg /ha gypsum.

Simpson and Daft (1991) worked in order to evaluate of two genotypes of Groundnut (TMV 2, Robut 33-1), grown with or without the mycorrhizal fungus *Glomus clarum*, Genotype TMV 2 responded much more to mycorrhizal infection than the genotype Robut 33-1. Control plants of R 33-1 were bigger than controls of TMV2, but mycorrhizal TMV2 plants were larger than those of R 33-1. Acetylene reduction was greater in mycorrhizal than non-mycorrhizal plants in both genotypes. There was virtually no acetylene reduction in non-mycorrhizal TMV2. A 23-day period of water stress reduced growth of both genotypes. Mycorrhizal infection had no significant effects on the response of the hosts to water stress. Mane *et al.* (1993) conducted an experiment in the field during the monsoon season of 1989/90 at Parbhani, Maharashtra, Groundnuts cv. LG-19 plants inoculated either with vesicular-arbuscular mycorrhiza *Glomus fasciculatum* or *Rhizobium* increased root length, root weight, biomass production, nodulation, N_2 fixation, P uptake and seed yield (by 235 - 330 kg/ha).

Venkateswarlu *et al.* (1995) studied the influence of soil application of carbofuran on the growth response of Groundnut and both mycorrhizal colonization and sporulation of *Glomus clarum* in a pot culture experiment under controlled conditions. Carbofuran application with or without mycorrhizal inoculation increased the height of the potted plants measured 8 weeks after sowing. Mycorrhizal plants were significantly taller than nonmycorrhizal plants of the final harvest time (14 weeks). Carbofuran, at the recommended field dose of up to 2 kg/ha greatly increased shoot dry matter and pod yield in mycorrhizal Groundnut. Colonization and sporulation by this vesicular-arbuscular mycorrhizal fungus were also enhanced significantly at these dose levels. The application of carbofuran at 5 kg/ha inhibited both growth and mycorrhizal status of groundnut.

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Ibrahim *et al.* (1995) studied nine cultivars of Groundnut (*Arachis hypogaea*), earlier shown to respond to arbuscular mycorrhiza (AM) in a soil poor in available N or P in the same soil over three subsequent seasons for response to AM (*Glomus fasciculatum*) and *Bradyrhizobium* (R) singly or in combination (AM+R). The responses were measured for six traits, namely percentage of root length colonized by AM (AMC), root P, biomass (BM), carbon dioxide exchange rate (CER), leaf nitrogen and pod yield. Differences in the traits under 4 treatments, namely control, AM alone, R alone and AM+R, were statistically evaluated across cultivars and seasons. High improvements over the control were consistently recoded under AM+R in experimental plots of 75 m^2, particularly for yield though responses were generally genotype and season dependent. The most responsive to combined inoculation were cultivars 1441A1, NFP104, 1423VB and RB15. A basis for explaining improved yield sustenance by dual inoculation with arbuscular mycorrhiza and *Bradyrhizobium* was provided by the significant correlation between AMC and root P and of yield with them, in addition to the desirable correlations between CER, BM and root P. The results provide ample reason for integrating AM schedules into breeding and agronomic approaches in programmes on stabilizing Groundnut yields.

Khan *et al.* (1995) observed the response of Groundnut (*Arachis hypogaea*) inoculation with vesicular-arbuscular mycorrhizal (VAM) fungi (*Glomus etunicatum*) and *Bradyrhizobium* sp. in pots by the acetylene reduction activity (ARA) and 'A-value, methods. A light-coloured Andosol was used and the treatments consisted of the inoculation of AM fungi only inoculation of *Bradyrhizobium* only, dual inoculation of AM fungi and *Bradyrhizobium* and control, under non-sterilized and sterilized soil conditions. In the non-sterilized soil the ARA and nitrogen fixation determined by the 'A-value' method increased significantly only by dual inoculation of AM fungi and *Bradyrhizobium* at 100 days after planting (DAP), but no significant difference was observed at 70 DAP. In the case of dual inoculation 175% of the nitrogen of the plant was derived from fixation whereas the plants inoculated only with *Bradyrhizobium* derived 68% of their nitrogen from fixation and the control plants, 64%. P conc. in plants increased significantly only by dual inoculation with VAM fungi and *Bradyrhizobium*. In the sterilized soil an increase in the ARA was observed of the dual inoculation at all the sampling times. Nitrogen fixation determined by the 'A-value' technique and N and P contents in plants also increased significantly by dual inoculation. Results obtained by the 'A-value' method showed that plants with dual inoculation derived 68% of their nitrogen from fixation while the plants inoculated only with *Bradyrhizobium*, 38%. It was concluded that nitrogen fixation as well as N and P contents in Groundnut increased only by dual inoculation with AM fungi and *Bradyrhizobium*.

2.8 Pigeonpea (*Cajanus cajan*)

Manjunath and Bagyaraj (1984) studied the response of two crops (Pigeonpea and cowpea) to dual inoculation with *Glomus fasciculatum* and/or *Rhizobium* sp. in a P deficient non-sterile soil. Application of P (22 kg/ha) increased nodulation and the number of endomycorrhizal spores in the root zone of the both legumes. Plants inoculated with both organisms and supplemented with P recorded the highest shoot dry weights and N and P contents, indicating the need for the addition of a small amount of P to drive max. benefit from dual inoculation with *Rhizobium* and vesicular-arbuscular mycorrhiza. The Indian Pathologists were examined 25 legumes from the university campus, 18 showed mycorrhizas; *Glomus mosseae* was present in all of them. The most heavily infected spp. were groundnut, pigeonpea, *Crotalaria juncea*, *Dolichos* spp. *Phaseolus* spp and *Rhynchosia* minima (Parvathi *et al.*, 1984).

Diederichs (1990) was reported that *Cajanus cajan* plants grown under greenhouse conditions in a dark red latosol were fertilized with soluble simple super phosphate and scarcely soluble rock phosphate and inoculated with 3 VA mycorrhizal fungi [(a) *Gigaspora margarita* (b) *Scutellospora verrucosa*. (c)

Acaulospora rehmii] from the cerrado ecosystem, Brazil. Only with rock phosphate the plant growth significantly increased by all fungi with enhanced P uptake corresponded with higher yields and proved to be a characteristic of the VA mycorrhizas. No definite relationship between infection intensity and efficiency of VA mycorrhizas was detected. Spore production was generally more pronounced in the treatment with rock phosphate especially with (a) and (b). Nodulation of *Cajanus cajan* was greatly improved by all fungi in the treatment with rock phosphate. It was suggested that the increased plant development and nodulation was due to improved uptake of P by mycorrhiza.

Sivaprasad and Rai (1991) conducted an experiment in a field trial and a greenhouse trial in 1984 with Pigeonpeas on P-deficient tropical soil, soil inoculation with *G. fasciculatum* and *Rhizobium* sp increased nodulation by 178%, nitrogenase activity by 185%, growth and N and P contents compared with inoculation with *Rhizobium* alone. The association with *G. fasciculatum* increased nodulation due to native rhizobia. The response of dual inoculation was less in the field than in the greenhouse. In the field dual inoculation gave 15.2% more yield than inoculation with *Rhizobium* alone.

2.9 Hyacinthbean (*Lablab niger* var *typicus*)

When beans were inoculated with *Glomus mosseae, G. fasciculatum* and *G. vesiculifer* at sowing the roots were already infected after 7 days. Acid and alkaline phosphatases were found in the arbuscules, mostly in active or collapsed ones when the mycorrhiza was established. Supporting hyphae attached to collapsed arbuscules showed no enzyme activity. No reaction was observed in the intracellular hyphae. Enzyme activity in the vesicles was weak. It is suggested that the arbuscules are important for phosphate metabolism of the mycorrhiza (Chen and Chang, 1981). The numbers of endomycorrhizal spores in root zone soil as influenced by cultivars of *Lablab purpurens* are tabulated (Manjunath and

Bagyaraj, 1982). Mosse and Thompson (1984) described a system in which typical VA mycorrhizal infections were produced by *Glomus mosseae* and E_3. *G. fasciculatum* in plants grown in trays in which the roots were bathed in a shallow layer of recirculating nutrient solution (nutrient film technique, NFT). Infections were compared in solutions containing 1, 3, and 8 mg /liter p, bone meal, and rock phosphate. The infectivity of the NFT-grown mycorrhizal roots was tested using 1, 2, 0.24 and 0.05 g of fresh root inoculum on bean seedlings. The inoculum had good infectivity and even 0.05 g produced 5-10% infection in test seedlings after 6 weeks.

Reeves (1992) reported that ^{15}N-enriched soil (with 0.28% N) was used to distinguish between the uptake of soil and atmospherically derived N in Maize grown with *Phaseolus vulgaris* in the presence or absence of vesicular-arbuscular mycorrhizal (VAM) fungi. AM infection did not result in transfer of fixed N or soil N from *Phaseolus vulgaris* to Maize, despite a AM-stimulated increased in N fixation in *P. vulgaris*. *P. vulgaris* was more competitive for soil N when mycorrhizal N content in *P. vulgaris* increased by 75% with a concomitant 22% decrease in mg N per maize plant. The competitive effect may have resulted from a VAM-mediated shift in C allocation in *P. vulgaris* (but not maize) from shoots to roots.

Chapter 3
Materials and methods

3. MATERIALS AND METHODS

3.1 Experimental site

The experiment was carried out in the net house and in laboratory, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka-1207.

3.2 Experimental period

The experiment was conducted during the period from May, 2006 to December, 2006.

3.3 Selection of Crops

Important available leguminous crops grow in different areas of Bangladesh were assessed for their dependency to AM.

List of the crops included in the present experiment:

Common Name	Scientific name	Family
BARI Mung bean	(*Vigna radiata* L.Wilczek)	Fabaceae
Cowpea	(*Vigna unguiculata* L.)	Leguminosae
Chick pea	(*Cicer arietinum* L. Wilczek)	Leguminosae
Black gram	(*Vigna mungo* L.)	Leguminosae
Lentil	(*Lens esculentum* L.)	Leguminosae
Soybean	(*Glycine max* L. Merr.)	Fabaceae
Groundnut	(*Arachis hypogaea* L.)	Leguminosae
Pegion pea	(*Cajanus cajan* L. Millsp.)	Leguminosae
Hyacinth Bean	(*Lablab niger* var *typicus* L.)	Fabaceae
Dhaincha	(*Sesbania rostrata*)	Leguminosae

3.4 Mycorrhizal assessment:

Inoculum of Mycorrhizal fungi from natural condition was used for conducting the experiment. For this reason, a survey programme was conducted in the Agronomy farm field of Sher-e-Bangla Agricultural University during May 2006. Root samples of 21 plants species (both crops and weeds) growing under natural condition in different places of the Agronomy field were collected for the observation of occurrence of vesicular arbuscular mycorrhizal (VAM) association with the root systems.

List of plants:

Common name	Scientific Name	Family
White eclipta	*Eclipta prostrate* L.	Composite
Goat weed	*Ageratum conyzoides* L.	Composite
Harkuch	*Enhydra fluctuans* Lour.	Composite
Zirakata ful	*Spilanthes acmella* L.	Composite
Garden spurge	*Euphorbia hirta* L.	Euphorbiaceae
Prostute spurge	*Euphorbia parviflora* F.B.I.	Euphorbiaceae
Croton plant	*Croton sparsiflorus* L.	Euphorbiaceae
Spider wort	*Commelina benghalensis* L.	Commelinaceae
Kanainala	*Cyanotis axillaries* Roem and schutt	Commelinaceae
Sensitive plant	*Misosa pudica* L.	Leguminosae
Araich	*Cassia tora* L.	Leguminosae
Wild lentil	*Vicia sativa* L.	Leguminosae
Wild mustard	*Brassica kaber (DC)* L. *E. wheeler*	Cruciferae
Block night shade	*Solanum nigrum* L.	Solanaceae
Horse nettle	*Salarum carolinense* L.	Solanaceae
Bondhunia	*Seroparua dulcis* L.	Scrophulariaceae
Spiny pig weed	*Amaranthus spinosus* L.	Amaranthaceae
Pig weed	*Amaranthus Viridis* L.	Amaranthaceae
Alligator weed	*Alternanthera philoxeroides*	Amaranthaceae
Wild clary	*Heliotropium indicum* L.	Boraginaceae
Soybean	*Glycine max*	Leguminosae

Plant roots were dugout, washed thoroughly with water to remove the adhering soil particles and then cut into 1 cm long segment. The root samples were then preserved in screw cap test tubes with 50% ethanol for future use.

3.5 Staining of roots:

The roots of each plant species were stained according to Koske and Gemma (1989) with some modifications (Mridha *et al.*, 1999) and it was conducted in the Plant Pathology laboratory, Sher-e-Bangla Agricultural University Dhaka. The root pieces were boiled in 2.5% KOH solution for 30 minutes at 90°C temperature. Later on, the root segments were washed in water several times and acidified with 1% HCl solution for 24 hours. Heavily pigmented roots were bleached by 10% H_2O_2 for 20 to 60 minutes. Again these segments were boiled for 30 minutes in 0.05% aniline blue at a temperature of 90°C. Subsequently the roots were destined at room temperature in acidic glycerol.

3.6 Staining of indicator plants:

The stained root segments were mounted in glycerol solution on glass slides and the cover slip was gently pressed to facilitate the observation of different type of structures present in the whole root segment. A root segment was considered to be infected if it showed mycelium, arbuscular vesicles or any other combination of these structural characteristics of AM fungi. When any of these were found in sample, the intensity of infection of VAM fungi was estimated as: Low (*) if only mycelium were present; moderate-(**) if mycelium and vesicles or arbuscules were present and High (***) if mycelium, vesicles and arbuscules were present (Mridha and Mohammed, 1989). Out of 21 plant species studied, abundant amount of infections (hundred percent root segments infected) were found with only two plant species *Cassia tora* L. and *Croton sparsiflorus* L. (weeds). For this study the *Cassia tora* weed roots were used as a natural inoculum. The soils of this plant collection sites were sandy loam type. This rhizosphere soils also used as natural inoculum.

3.7 Collection of soils:

Soil was collected from the Agronomy field of Sher-e-Bangla Agricultural University Campus from a depth of 5 to 10 inch. After collecting the soil, clods were broken and weeds, stones, gravels, roots, and other unwanted materials were removed.

3.8 Collection of seeds:

Seeds of 10 different legume plants namely Soybean, Lentil, BARI Mungbean, Groundnut, Hyacinthbean, Chickpea, Blackgram, Pigeonpea, Dhaincha and Cowpea were collected from BARI (Bangladesh Agricultural Research Institute).

3.9 Preparation of inoculum:

Cassia tora roots were collected from Agronomy field along with rhizosphere soil. The presence of AM fungi within the root sample was confirmed using the staining procedure of Koske and Gemma (1979). Collected root samples were cut into small pieces by the help of chopper. Half of rhizosphere soils and root samples were sterilized in the autoclave at 121°C at 15 PSI for 45 minutes and used it as base materials for control pots.

3.10 Preparation of seedling bags:

The polythene bags of 8"×12" size were bought from the market which have the capacity to filled with 2 kg soil. The bags were perforated at the bottom portion by the perforator to remove excess water. Before preparation of substratum, soil was sterilized by formaldehyde (0.05%) and used it as base soil. Then base soil and cow dung were mixed properly with a ratio of 19:1. Substratum was taken into the perforated seedling bags of 8"×12" size. At first $\frac{2}{3}$ rd portion of the seedling bags were filled with substratum. Then a layer of both inoculum i.e. root inoculum 25 g and soil inoculum 100 g, were placed in each treated bag. For each crop 10 replications i.e., 10 for inoculated and 10 for non-inoculated were prepared. Both 25 g roots and 100 g soil (rhizosphere) of sterilized inoculum were used in non-inoculated bags to maintain the same nutrient status between the inoculated and non-inoculated bags. The inoculum layer (both sterilized and non-sterilized) of each bag was covered with a thin soil (substratum) layer of 2 cm below the surface in which seed were sown. 200 polythene bags (10 × 2 × 10) were prepared for ten crops in the present study.

3.11 Sowing of seeds:

For each crop 10 replications were maintained and in each replication consists same number of seed of same crop plant. For different crops different number of seeds was sown in the bags based on seed size. For Soybean 10 seeds/bag; Lentil 20 seeds/bag; Mungbean 15 seeds/bag; Groundnut 10 seeds/bag; Hayacinth bean 5 seeds/bag; Chick pea 10 seeds/bag; Black gram 15 seeds/bag; Pigeon pea 10 seeds/bag and Dhaincha 10 seeds/bag were sown. After 15 days, 5 seedlings in each bag were retained and other seedlings were removed. To avoid the chance of contamination a space of 30 cm was maintained between the inoculated and non-inoculated replications.

3.12 Intercultural operation:

The pots were irrigated whenever necessary to maintain field moisture. Intercultural operations (weeding, mulching, thinning) were done when necessary to ensure the normal growth of the crops. The pots were carefully observed regularly to record any change of plant growth.

3.13 Harvesting:

When the seedlings were 40 DAS and 60 DAS old then those were harvested. In this case 3 seedlings bags from inoculated and 3 seedlings bags from non-inoculated were harvested randomly for each crop. Shoots and roots of 10 different crops plants were collected. At first polythene bags were removed very carefully with sharp knife. The roots were washed with tap water to remove the adhering soil. Roots and shoots were separated with the help of sharp scissors and were preserved after necessary processing for determining root mass and shoot mass. Then roots and shoots were dried in an oven for 72 hours at 70°C until the samples gave constant weight.

3.14 Data recording:

Data on different plant variables were recorded. Data were recorded on seedling emergence (%) (7 DAS, 10 DAS, 15 DAS), plant height (cm) (20 DAS, 40 DAS, 60 DAS), shoot fresh and dry weight (g) (40 DAS, 60 DAS), root fresh and dry weight (g) (40 DAS, 60 DAS), shoot and root length (cm), 1st branching and flowering, number of branches plant^{-1}, number of flowers plant^{-1} and disease incedence.

3.14.1 Seedling emergence:

The seedling bags were observed carefully regularly after seed sowing and the seedlings emergences were measured by percent at 7 DAS, 10 DAS, 15 DAS and data were recorded.

3.14.2 Growth and biomass:

Plant height: Plant height was measured by a meter scale (cm) at 20 DAS, 40 DAS and 60 DAS and data was recorded.

Root length: Root length was measured by a meter scale (cm) after washing and data was recorded.

Shoot length: Shoot length was measured by a meter scale (cm) and data was recorded.

Root fresh weight: Roots were taken in polythene bag and marked. There after, it was brought to the laboratory, fresh weight of roots was measured with an electric balance, and data was recorded. Some roots were taken from each seedling and preserved in a vial with 5% formalin for future mycorrhizal study.

Shoot fresh weight: Shoots were taken in another polythene bag and marked. There after, they were brought to the laboratory and fresh weight of shoots recorded.

Root dry weight: After taking the roots for mycorrhizal study, the rest were weighted again and recorded. Then those were taken separately in brown envelop for drying. There after roots were dried in the oven at 70°C for 70 hours and dry weight was recorded.

Shoot dry weight: Shoots were taken in brown envelope and dried in the oven as same process of roots. Then dry weight was measured and recorded.

3.14.3 Flowering fruiting and branching

After sowing of seeds, the experimental pots were observed regularly. First flowering date of crop was recorded. Two or three days after first flowering, the number of flowers plant^{-1} were recorded. The data of branching was recorded for some of the crops only.

3.14.4 Disease incidence

Disease data were recorded for some selected crops. It is only done for determining % affected plants between two treatments (Mycorrhiza and Control).

3.15 Mycorrhizal dependency (MD):

Mycorrhizal dependency was calculated according to Plenchette *et al.*(1983).

$$MD\ (\%) = \frac{Dry\ wt.of\ Mycorrhizal\ plant - Dry\ wt.of\ non\ mycorrhizal\ plant}{Dry\ wt.of\ mycorrhizal\ plant} \times 100$$

3.16 Assessment of root colonization

Preserved root samples were assessed. Roots were taken out of the vial and washed 2-3 times with clear water and cut into small segments of approximately 1 cm length for the determination of percent of AM colonization. The root pieces were stained according to Koske and Gamma (1989) with some modifications (Mridha and Xu, 2001). The percentage of AM colonization was estimated by root slide technique (Read *et al.*, 1976). One hundred root segments were examined for each sample. The stained root pieces were mounted in acidic glycerol on slides and the cover slip was place and slightly pressed. The roots were observed under a microscope. A root segment was considered as positively colonized when it showed mycelium, arbuscules and vesicles or any other combination of these structural characteristics of AM colonization. The presence or absence of infection in colonization was calculated as follows:

$$\%\ Root\ colonization = \frac{Number\ of\ AM\ positive\ segments}{Total\ number\ of\ segments} \times 100$$

3.17 Nutrient analysis:

3.17.1 Preparation of plant sample

Plant (shoot) samples were dried in oven at 70°C for 72 hours and then ground the samples and sufficient amount of sample for each treatment was kept in a desiccators for chemical analysis.

3.17.2 Sample analysis

3.17.2.1 N, P, K nutrient uptake

The shoot samples were oven dried at 70°C for 72 hours. Dried plant materials were ground and processed for determination of N, P and K.

3.17.2.2 Total Nitrogen

Total nitrogen content in plants samples (shoot) were determined by micro Kjeldahl method (Bremner, 1965).

3.17.2.3 Total phosphorus and potassium

Dried plant materials were digested with concentrated HNO_3 and $HCLO_4$ mixture as described by Piper (1950) for determination of total phosphorus and potassium contents.

Total phosphorus content in the extract was determined by Vanado-Molybdate Yellow colour methods as described by Jackson (1973).

Total potassium content was determined by Atomic Absorption Spectrophotometer.

NPK uptake was computed using N, P and K contents and yield data (shoot). Nutrient uptake was calculated by using the following formula:

$$\text{Nutrient uptake} = \frac{\textit{Nutrient content}\ (\%) \times \textit{yield}}{100}$$

Available other elements like S, B, Zn, were determined following ASI method (Hunter, 1984).

3.18 Statistical analysis

All data were analyzed in the computer using SP SS Program for T-test.

Chapter 4
Results

4. RESULTS

4.1. BARI Mungbean

Seedling emergence:

The emergence of seedlings of BARI Mungbean is presented in Table 1 significantlyh higher seedling emergence was found in case of inoculated BARI Mungbean than non-inoculated. The seedling emergences were calculated in three different times. With the elapse of time, the seedling emergence was increased in both treatments. The per cent seedling emergence increased over control in mycorrhiza inoculated pots were 29.08, 23.37and 16.24 at 7, 10 and 15 days after sowing respectively. The lowest seedling emergence was 57.33% in control at 7 days after sowing and the highest seedling emergence (90.67%) was counted in mycorrhiza treated pots at 15 days after sowing.

Plant height:

The influence of inoculation of arbuscular mycorrhizal fungi on plant height of BARI Mungbean recorded at different growth periods is presented in Table 2. With the increase of growth period the plant height was increased both mycorrhizal inoculated and non-inoculated plants. The per cent plant height increased over control in mycorrhiza inoculated pots were 4.63, 21.93 and 13.58 at 20, 40 and 60 days after sowing, respectively. The trend of overall growth increment (plant height) among different periods of growth for both mycorrhizal and non mycorrhizal plant was more or less similar. In both the cases, at first 20 days (20 DAS) and 3rd 20 days (40 to 60 days) after sowing, the growth increment was higher than the 2nd 20 days (20 to 40 days) and the rate of growth was also higher in 1st and 3rd 20 days also. In case of (%) growth increment for mycorrhizal and non mycorrhizal plants, it was observed that the (%) increase was minimum (62.13% in inoculated and 54.74% non inoculated) in 3rd 20 days (40 to 60 days) and it was maximum (83.79% in inoculated and 89.55% in non inoculated) in 2nd

20 days (20 to 40 days). In the mycorrhizal plants the rate of growth increment in 3rd 20 days (40 to 60 days) was significantly higher (62.13%) in comparison to non mycorrhizal plants (54.74%) but in 2nd 20 days (20 to 40 days) it was slightly less than non mycorrhizal plants. It was also observed that the per cent growth increase over control in mycorrhizal plant was less in 2nd 20 days (20 to 40 days) than in 3rd (40 to 60 days) or 1st (20 DAS) 20 days.

Table 1. Influence of Arbuscular Mycorrhizal Fungi(AMF) inoculation on seedling emergence (%) of BARI Mungbean at different growth periods

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (control)	57.33 b	71.33 b	78.00 b	---	---	---
Inoculated Mycorrhiza	74.00 a	88.00 a	90.67 a	29.08	23.37	16.24

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 2. Influence of AMF inoculation on plant height of BARI Mungbean at different periods

Treatment	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (control)	24.18 b	30.09 b	75.06 b	---	---	---
Inoculated Mycorrhiza	25.30 a	36.69 a	85.25 a	4.63	21.93	13.58

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Influence of AM inoculation on root length and root weight is presented in Table 3. The root length of mycorrhizal plants in both harvested period (40 DAS and 60 DAS) was significantly higher in comparison to non mycorrhizal plants. It is also observed that the rate of root length increment at 40 days after sowing was higher than in 60 days after sowing in both treatment, respectively. Because last 20 days (40 to 60 days) the increase of root length was only 3.87 cm in control and 1.75 cm in mycorrhizal plant. With the increase of growth period the root weight was increased both mycorrhizal inoculated plant and non mycorrhizal control. In case of AM inoculation, the root weight of BARI Mungbean was significantly higher than the non inoculated plants. The per cent root weight increase over control in mycorrhizal plant was38.33, 45.35 (fresh) and 106.67, 225 (dry) after 40 and 60 days sowing respectively.

Shoot growth:

Influences of AM inoculation on shoot growth of BARI Mungbean harvested at different period have been shown in Table 4. Mycorrhizal inoculation enhanced plant shoot growth in comparison to non inoculated plant. Among the mycorrhizal plants, the rate of shoot length increment in 20 days duration (40 to 60 days) was significantly higher (34.68 %) in comparison to non mycorrhizal plants (7.33 %). The per cent shoot weight increased over control in mycorrhizal plants was 6.41, 33.53 (fresh) and 3.63, 20.79 (dry) after 40 and 60 days sowing, respectively.In every growth period, some variation in shoot length of BARI Mungbean was significantly found and the maximum variation (12 cm) was found at 60 days after sowing between mycorrhizal and non mycorrhizal plant.

Table 3. Influence of AM inoculation on root growth of BARI Mungbean at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (control)	18.95b	22.82b	0.60b	0.86b	0.15b	0.16b	---	---	---	---
Inoculated Mycorrhiza	22.50a	28.25a	0.83a	1.25a	0.31a	0.52a	38.33	45.35	106.67	225.00

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 4. Influence of AM inoculation on shoot growth of BARI Mungbean at different growth periods

Treatment	Shoot length (cm)		Shoot weight (g)				%Shoot weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (control)	51.86b	80.25b	10.92b	11.72b	1.93b	2.02b	---	---	---	---
Inoculated Mycorrhiza	56.90a	92.25a	11.62a	15.65a	2.00a	2.44a	6.41	33.53	3.63	20.79

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Disease suspression:

Inoculation of pot grown BARI Mungbean plants with VA mycorrhiza resulted by the endophyte and accompanying reduction in the incidence of diseases of seedling stage presented in Table 5. The percentage root rot disease was 2.83 in control and 2.27 in inoculated pots. Damping off disease was found in uninoculated control (3.77%) but it was absented in inoculated plants. Leaf blight disease was 5.66% in control plants but in inoculated plants it was only 0.76%. For all diseases (Root rot, Damping off and Leaf blight) the incidence was always significantly higher in uninoculated control plants in compare to inoculated mycorrhizal plants.

Flowering and fruiting:

It was observed that both flowering and fruiting of inoculated mycorrhizal plant (26 DAS and 29 DAS) has become earlier than the non inoculated control plant (28 DAS and 31 DAS).

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency. The mycorrhizal dependency of BARI Mungbean was 26.35%.

Root colonization:

The highest per cent root colonization (42.60%) of mycorrhiza inoculated plants was recorded at 60 DAS and the lowest (21.75%) at 20 DAS. On the other hand no root colonization was found in untreated control plants.

Nutrient uptake:

Inoculation of arbuscular mycorrhizal fungi responsed to nutrients uptake (N, P, K, S, B, and Zn) by BARI Mungbean are presented in Table 6. It is evident from the study that mycorrhizal inoculation significantly enhanced nutrient uptake in shoot with comparison to control plant. These results of the study indicate that the per cent nutrient uptake increase over control for N, P, K, S, B and Zn were 11.57%, 14.43%, 21.90%, 12.18%, 13.33% and 5.22%, respectively. The highest percent increased was obtained with K which was followed by S, P, B, N and lowest was found with Zn.

Table 5. Effect of AM inoculation of BARI Mungbean in suppression of different diseases at seedling stage

Treatment	Infected plant (%)		
	Root rot	Damping off	Leaf blight
Non inoculated (control)	2.83a	3.77 a	5.66 a
Inoculated (Mycorrhiza)	2.27 b	0.00 b	0.76 b

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 6. Effect of AM inoculation on nutrient uptake by BARI Mungbean shoot

Treatment	Nutrient uptake by shoot					
	Total N (%)	P (%)	K (%)	S (%)	B (µg/g)	Zn (µg/g)
Non-inoculated (control)	2.022 b	0.305 b	1.973 b	0.238 b	45 b	74.70b
Inoculated (mycorrhizal)	2.256 a	0.349 a	2.405 a	0.267 a	51 a	78.60 a
% increase over control	11.57	14.43	21.90	12.18	13.33	5.22

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

MYCORRHIZA INOCULATED CONTROL

Fig.1. Influence of mycorrhizal inoculation on growth of BARI Mungbean

4.2. COWPEA

Seedling emergence:

The emergence of seedling of Cowpea is presented in Table 7. Higher seedling emergence was significantly found in case of inoculated pots than non-inoculated. The seedling emergences were calculated in three different times. With the elapse of time, the seedling emergence was increased in both treatments. The per cent seedling emergence increased over control in mycorrhiza inoculated pots was 16, 8.95 and 0.00 at 7, 10 and 15 days after sowing, respectively. The lowest seedling emergence was (50%) in control at 7 days after sowing and the highest seedling emergence (80%) was counted in both treated and control pots at 15 days after sowing.

Plant height:

The influence of inoculation of Arbuscular Mycorrhizal Fungi on plant height of Cowpea recorded at different growth periods are presented in Table 8. With the increase of growth period the plant height was increased both mycorrhizal inoculated and non-inoculated plants. The per cent plant height increased over control in mycorrhiza inoculated pots was 21.70, 10.85 and 9.68 at 20, 40 and 60 days after sowing, respectively. The trend of overall growth increment (plant height) among different periods of growth for both mycorrhizal and non mycorrhizal plant was not similar. In both the cases, at first 20 days (20 DAS) and 2nd 20 days (20 to 40 days) after sowing the growth increment was higher than the 3rd 20 days (40 to 60 days) and the rate of growth was also higher in 1st and 2nd 20 days also. In case of (%) growth increment for mycorrhizal and non mycorrhizal plants it was observed that the (%) increased was minimum (2.96% in inoculated and 4.06% in non inoculated) in 3rd 20 days (40 to 60 days) and it was maximum (65.55 % in inoculated and 81.76% in non inoculated) in 2nd 20 days (20 to 40 days). Among the mycorrhizal plants the rate of growth increment in 2nd 20 days (20 to 40 days) was less (65.55%) in comparison to non mycorrhizal plants (81.76%) but in 3rd 20 days (40 to 60 days) it was slightly less than non mycorrhizal plants. It was also observed that the per cent growth increased over control in mycorrhizal plant was less in 3rd 20 days (40 to 60 days) than in 1st (20 DAS) or 2nd (20 to 40 days) 20 days.

Table 7. Influence of AMF inoculation on seedling emergence (%) of Cowpea at different growth stages

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (control)	50.00b	71.59b	80.00a	---	---	---
Inoculated Mycorrhiza	58.00a	78.00a	80.00a	16	8.95	0.00

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 8. Influence of AMF inoculation on plant height of Cowpea at different growth periods.

Treatment	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (control)	68.47b	124.45b	129.50b	---	---	---
Inoculated Mycorrhiza	83.33a	137.95a	142.03a	21.70	10.85	9.68

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Influence of AM inoculation on root length and root weight is presented in Table 9. In the mycorrhizal plants the root length in both harvested period (40 DAS and 60 DAS) was significantly higher in comparison to non mycorrhizal plants. It is also observed that the rate of root length increment at 40 days after sowing was higher than in 60 days after sowing in both treatments, respectively. In last 20 days (40 to 60 days), the increase of root length was only 8.67cm in control and 11.90cm in mycorrhizal plant. With the increase of growth period the root weight was increased both mycorrhizal inoculated plant and non mycorrhizal control. In case of AM inoculation, the root weight of Cowpea was significantly higher than the non inoculated plants. Among the mycorrhizal plant, the per cent root growth increment was significantly higher (181.25%) in comparison to non mycorrhizal control plant (168.38%). The per cent root weight increase over control in mycorrhizal plant was 17.65. 23.29 (fresh) and 2.56, 49.02 (dry) after 40 and 60 days sowing, respectively.

Shoot growth:

Influence of AM inoculation on shoot growth of Cowpea harvested at different period has been presented in Table 10. Mycorrhizal inoculation significantly enhanced plant shoot growth in comparison to non inoculated plant. Among the mycorrhizal plants, the rate of shoot growth increment in 20 days duration (40 to 60 days) was higher (30.44%) in comparison to non mycorrhizal plants (20.36%). Every growth period, the shoot length was always higher in inoculated plants than in non inoculated plants. Some variation in shoot length of Cowpea always was found in every growth period and the maximum variation (13.5cm) was found at 40 days after sowing between mycorrhizal and non mycorrhizal plant. The per cent shoot weight increased over control in mycorrhizal plants was 16.62, 26.39 (fresh) and 6.10, 26.33 (dry) after 40 and 60 days sowing, respectively.

Table 9. Influence of AMF inoculation on root growth of Cowpea at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (control)	18.63b	27.30b	1.36b	3.65b	0.39b	1.02b	---	---	---	---
Inoculated Mycorrhiza	20.70a	32.60a	1.60a	4.50a	0.40a	1.52a	17.65	23.29	2.56	49.02

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 10. Influence of AMF inoculation on shoot growth of Cowpea at different growth periods.

Treatment	Shoot length (cm)		Shoot weight (g)				% Shoot weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (control)	124.45b	129.50b	19.55b	23.53b	2.95b	4.71b	---	---	---	---
Inoculated Mycorrhiza	137.95a	142.03a	22.80a	29.74a	3.13a	5.95aa	16.62	26.39	6.10	26.33

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Flowering and fruiting:

Both the flowering and fruiting has become earlier in inoculated mycorrhizal plant with comparison to non mycorrhizal (control) plant. After 33 days after sowing, inoculated plant has got flower and it has been delayed 3 days in control plants. Fruiting also delayed 3 days in control plants in compared to inoculated mycorrhizal plants.

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency.The intermediate mycorrhizal dependency (MD) was found in cowpea and it was 23.29%.

Root colonization:

The highest per cent root colonization (49.75%) was found at 60 DAS old plants and lowest (32.25%) at 20 DAS old seedlings.

Nutrient uptake:

Mycorrhizal inoculation significantly enhanced nutrient uptake (N, P, K, S, B and Zn) compared to control in Cowpea plants (Table 11). The per cent nutrient uptake increased over control for N, P, K, S, B and Zn was 5.73%, 64.21%, 4.43%, 6.67%, 5.88% and 1.70%, respectively. The maximum nutrient uptake increased in inoculated plant was recorded P (64.21%) and the minimum was Zn (1.70%).

Table 11. Effect of AMF inoculation on nutrient uptake by Cowpea shoot

Treatment	Nutrient uptake					
	Total N (%)	P (%)	K (%)	S (%)	B (μg/g)	Zn (μg/g)
Non-inoculated (control)	2.426b	0.285b	1.804b	0.315b	51b	70.50b
Inoculated (mycorrhizal)	2.565a	0.468a	1.884a	0.336a	54a	71.70a
% increase over control	5.73	64.21	4.43	6.67	5.88	1.70

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

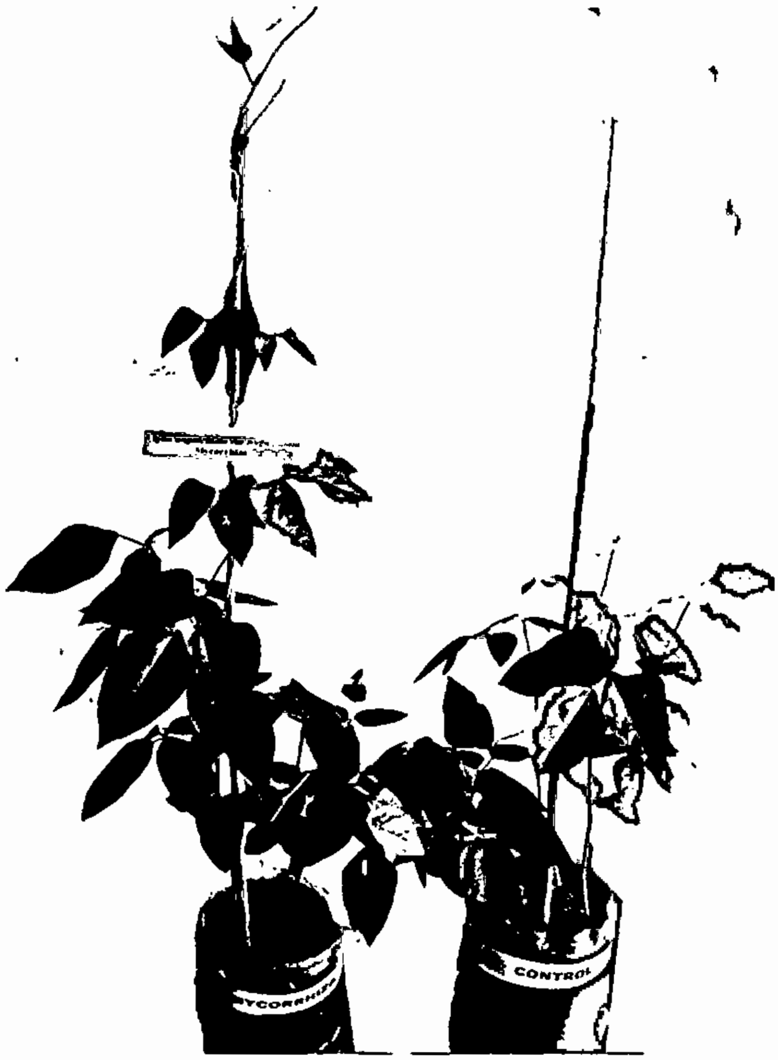


Fig. 2. Influence of mycorrhizal inoculation on growth of Cowpea

4.3. CHICKPEA

Seedling emergence:

The emergence of seedlings of Chickpea is presented in Table 12. Significantly higher seedling emergence was found in case of inoculated Chick pea than non-inoculated. The seedling emergences were calculated in three different times. With the elapse of time, the seedling emergence was increased in both treatments. The per cent seedling emergence increased over control in mycorrhiza inoculated pots was 27.87, 13.89 and 15.07 at 7, 10 and 15 days after sowing, respectively. The lowest seedling emergence was 61% in control at 7 days after sowing and the highest seedling emergence (84%) was counted in mycorrhiza treated pots at 15 days after sowing.

Plant height:

The influence of inoculation of Arbuscular Mycorrhizal fungi on plant height of Chickpea recorded at different growth periods are presented in Table 13. With the increase of growth period the plant height was increased both mycorrhiza inoculated and non-inoculated plants. The per cent plant height increased over control in mycorrhiza inoculated pots was 13.98, 15.79 and 9.17 at 20, 40 and 60 days after sowing, respectively. The trend of overall growth increment (plant height) among different periods of growth for both mycorrhizal and non mycorrhizal plant was more or less similar. In both the cases, at first 20 days (20 DAS) and 3rd 20 days (40 to 60 days) after sowing the growth increment was higher than the 2nd 20 days (20 to 40 days) and the rate of growth was also higher in 1st and 3rd 20 days also. In case of per cent growth increment for mycorrhizal and non mycorrhizal plants it was observed that the per cent increase was minimum (25.03% in inoculated and 23.07% non inoculated) in 2nd 20 days (20 to 40 days) and it was maximum (44.08 % in inoculated and 52.83% in non inoculated) in 3rd 20 days (40 to 60 days). Among the mycorrhizal plants, the rate of growth increment in 2nd 20 days (20 to 40 days) was slightly higher (25.03%) in comparison to non mycorrhizal plants (23.07%) but in 3rd 20 days (40 to 60 days) it was slightly less than non mycorrhizal plants. It was also observed that the per cent growth increased over control in mycorrhizal plant was less in 3rd 20 days (40 to 60 days) than in 1st (20 DAS) or 2nd (20 to 40 days) 20 days.

Table 12. Influence of AMF inoculation on seedling emergence (%) of Chickpea at different growth stages.

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	61.00 b	72.00 b	73.00 b	---	---	---
Inoculated Mycorrhiza	78.00 a	82.00 a	84.00 a	27.87	13.89	15.07

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 13. Influence of AMF inoculation on plant height of Chickpea at different periods.

Treatment	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	15.95 b	19.63 b	30.00 b	---	---	---
Inoculated Mycorrhiza	18.18 b	22.73 b	32.75 b	13.98	15.79	9.17

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Root length and root weight (fresh and dry) of Chickpea is presented Table 14. The root length of the mycorrhizal plants in both harvested period (40 DAS and 60 DAS) was significantly higher in comparison to non mycorrhizal plants. It is also observed that the rate of root length increment at 40 days after sowing was higher than in 60 days after sowing in both treatments, respectively. In last 20 days (40 to 60 days), the increase of root length was only 2.83cm in control and 6.18cm in mycorrhizal plant. With the increase of growth period the root weight was increased both mycorrhizal inoculated plant and non mycorrhizal control. In case of AM inoculation, the root weight of Chickpea was significantly higher than the non inoculated plants. The per cent root weight increased over control in mycorrhizal plant was 38.81, 20.00 (fresh) and 44.44, 21.43 (dry) after 40 and 60 days after sowing, respectively.

Shoot growth:

Influence of AM inoculation on shoot growth of Chickpea harvested at different period has been presented in Table 15. Mycorrhizal inoculation significantly enhanced plant shoot length in comparison to non inoculated plant. Among the mycorrhizal plants the rate of shoot weight increment in 20 days duration (40 to 60 days) was less (88.99%) in comparison to non mycorrhizal plants (140%). But in every growth period, the shoot growth was always significantly higher in inoculated plants than in non inoculated plants. The per cent shoot weight increased over control in mycorrhizal plants was 81.60, 43.00 (fresh) and 51.61, 31.03 (dry) after 40 and 60 days sowing, respectively. In every growth period, some variation in shoot length of Chickpea always was found and the maximum variation (3.1cm) was found at 40 days after sowing between mycorrhizal and non mycorrhizal plant.

Table 14. Influence of AMF inoculation on root growth of Chickpea at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	10.67b	13.50b	0.67b	1.00b	0.09b	0.14b	---	---	---	---
Inoculated Mycorrhiza	12.57a	18.75a	0.93a	1.20a	0.13a	0.17a	38.81	20.00	44.44	21.43

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 15. Influence of AMF inoculation on shoot growth of Chickpea at different growth periods

Treatment	Shoot length (cm)		Shoot weight (g)				% Shoot weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	19.63b	30.00b	1.25bb	3.00bb	0.31bb	0.58b	---	---	---	---
Inoculated Mycorrhiza	22.73a	32.75a	2.27a	4.29a	0.47a	0.76a	81.60	43.00	51.61	31.03

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Disease suspression:

The diseases recorded of Chickpea plant are presented in Table 16. The 25 days old Chick pea plant was affected by various diseases like Damping off, root rot, leaf blight and leaf spot. The damping off disease incidence was 12.33% in uninoculated and 8.33% in inoculated mycorrhizal plant. Incidence of root rot, leaf blight and leaf spot diseases were 4.11%, 13.70% and 4.11% in uninoculated control plants and 2.38%, 3.57% and 1.19% in inoculated mycorrhizal plants. The disease incidence was always significantly higher in uninoculated control plant in compare to inoculated mycorrhizal plant.

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency. The intermediate mycorrhizal dependency (MD) was found in Chickpea and it was 22.58%.

Root colonization:

The highest per cent root colonization (43.75%) in mycorrhizal inoculated plants was found at 60 DAS and the lowest (22.75%) at 20 DAS.

Nutrient uptake:

Inoculation of arbuscular mycorrhizal fungi responsed to nutrients uptake (N, P, K, S, B, and Zn) by Chickpea presented in Table 17. It is evident that mycorrhizal inoculation enhanced nutrient uptake in shoot with comparison to control plant. The per cent nutrient uptake increased over control for N, P, K, S, B and Zn was 12.44%, 11.79%,30.45%, 5.70%, 5.88%, and 4.37%, respectively.The highest percent increased was obtained with K which was followed by N, P, B, S and the lowest was found with Zn.

Table 16. Effect of AMF inoculation of Chickpea in suppression of different diseases at vegetative stage

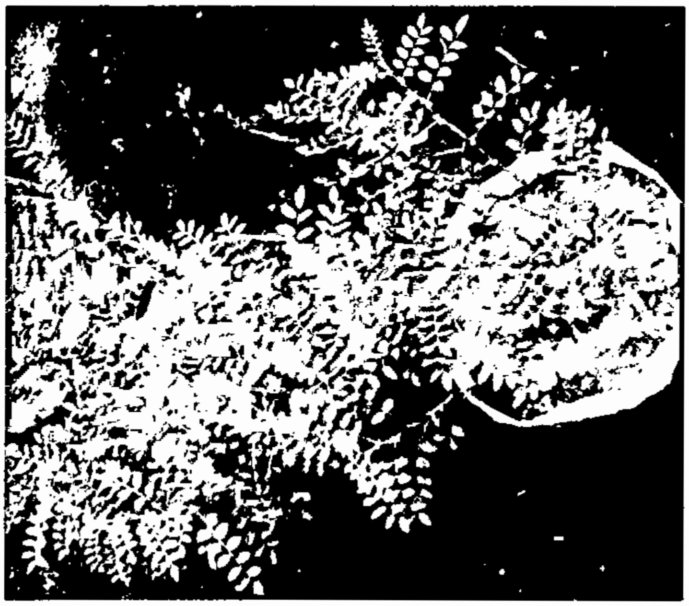
Treatment	Infected plant (%)			
	Damping off	Root rot	Leaf blight	Leaf spot
Non inoculated (Control)	12.33 a	4.11 a	13.70 a	4.11 a
Inoculated (Mycorrhiza)	8.33 b	2.38 b	3.57 b	1.19 b

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 17. Effect of AMF inoculation on nutrient uptake by Chickpea shoot

Treatment	Nutrient uptake					
	Total N (%)	P (%)	K (%)	S (%)	B (µg/g)	Zn (µg/g)
Non-inoculated (Control)	2.042 b	0.390 b	1.980 b	0.316 b	51 b	61.80 b
Inoculated (mycorrhizal)	2.296 a	0.436 a	2.583 a	0.334 a	54 a	64.50 a
% increased over control	12.44	11.79	30.45	5.70	5.88	4.37

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.



MYCORRHIZA

CONTROL

Fig.3. Influence of mycorrhizal inoculation on growth of Chickpea

4.4. BLACKGRAM

Seedling emergence:

The emergence of seedling of Blackgram is presented in Table 18. significantly higher seedling emergence was found in case of inoculated Blackgram than non-inoculated. The seedling emergences were calculated in three different times and the highest differences was found at 15 days after sowing which was the 12.66% between inoculated mycorrhiza and non-inoculated control. With the elapse of time, the seedling emergence was increased in both treatments. The per cent seedling emergence increased over control in mycorrhiza inoculated pots was 24.98, 12.61 and 16.95 at 7, 10 and 15 days after sowing, respectively. The lowest seedling emergence was 42.67% in control at 7 days after sowing and highest seedling emergence (87.33%) was counted in mycorrhiza treated pots at 15 days after sowing.

Plant height:

The influence of inoculation of Arbuscular Mycorrhizal fungi on plant height of Black-gram recorded at different growth periods is presented in table 19. With the increase of growth period the plant height was increased both mycorrhizal inoculated and non-inoculated plants. The per cent plant heights increased over control in mycorrhiza inoculated pots were 5.44, 8.22 and 3.27 at 20, 40 and 60 days after sowing, respectively. The trend of overall growth increment (plant height) among different periods of growth for both mycorrhizal and non mycorrhizal plant was more or less similar. In the control plant, at 1st 20 days (20 DAS) and 3rd 20 days (40 to 60 days) after sowing the growth increment was higher than the 2nd 20 days (20 to 40 days) but in the mycorrhizal plant, at 1st 20 days and 2nd 20 days after sowing the growth increment was higher than the 3rd 20 days and the rate of growth was also higher in that responsible days. In case of (%) growth increment for mycorrhizal and non mycorrhizal plants it was observed that the (%) increased was minimum (39.17% in inoculated and 45.84% in non inoculated) in 3^{rd} 20 days (40 to 60 days) and it was maximum (83.28% in inoculated and 78.57% in non inoculated) in 2^{nd} 20 days (20 to 40 days). Among the mycorrhizal plants the rate of growth increment in 2^{nd} 20 days (20 to 40 days) was slightly higher (83.28%) in comparison to non mycorrhizal plants (78.57%) but in 3^{rd} 20 days (40 to 60 days) it was slightly less than non mycorrhizal plants. It was also observed that the per cent growth increased over control in mycorrhizal plant was less in 3^{rd} 20 days (40 to 60 days) than in 1^{st} (20 DAS) or 2^{nd} (20 to 40 days) 20 days.

Table 18. Influence of AMF inoculation on seedling emergence (%) of Blackgram at different growth stages

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	42.67 b	68.67 b	74.67 b	---	---	---
Inoculated Mycorrhiza	53.33 a	77.33 a	87.33 a	24.98	12.61	16.95

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 19. Influence of AMF inoculation on plant height of Blackgram at different growth periods

Treatment	Plant height (cm)			% increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	25.01 b	44.66 b	65.13 b	---	---	---
Inoculated Mycorrhiza	26.37 a	48.33 a	67.26 a	5.44	8.22	3.27

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Root length and root weight (fresh and dry) of Black gram is presented in Table 20. In mycorrhizal plants the root length in the 1st harvested period (40 DAS) was significantly higher and in the 2nd harvested period (60 DAS) was less in comparison to non mycorrhizal plants. It is also observed that the rate of root length increment at 40 days after sowing was higher than in 60 days after sowing in inoculated treatment but the root length increment was about same in non inoculated plant in both harvested periods, respectively. In 3rd 20 days (40 to 60 days) the increase of root length was only 1.60cm in mycorrhizal plant but in control plant it was 9.60cm. With the increase of growth period the root weight was increased both mycorrhizal inoculated plant and non mycorrhizal control. The per cent root weight increased over control in mycorrhizal plant was 65.29 (fresh) after 40 days of sowing but the per cent root weight decrease over control in mycorrhizal plant was 21.93 (fresh) after 60 days sowing, respectively.

Shoot growth:

The influence of AM inoculation on shoot length and shoot weight of Black gram harvested at different period have been shown in Table 21. Mycorrhizal inoculation significantly enhanced plant shoot length in comparison to non inoculated plant. After 1st harvested (40 DAS) period the shoot weight was 14.21g in control and 15.57g in mycorrhizal plant and 2nd harvested period (60 DAS) the shoot weight was 16.93g in control and 18.74g in mycorrhizal plant. Among the mycorrhizal plants the rate of shoot growth increment in 20 days duration (40 to 60 days) was higher (20.36%) in comparison to non mycorrhizal plants (19.14%). The per cent shoot weight increased over control in mycorrhizal plants was 9.57, 10.69 (fresh) and 14.06, 16.11 (dry) after 40 and 60 days sowing, respectively. Some variation in shoot length of black gram always was found and the maximum variation (3.67cm) was found every growth period at 40 days after sowing between mycorrhizal and non mycorrhizal plant.

Table 20. Influence of AMF inoculation on root growth of Blackgram at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	11.20b	20.80b	1.21b	2.69b	0.39b	0.73a	---	---	---	---
Inoculated Mycorrhiza	14.60a	16.20a	2.00a	2.10a	0.58a	0.61b	65.29	21.93	48.72	16.44

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 21. Influence of AM inoculation on shoot growth of Blackgram at different harvested periods.

Treatment	Shoot length (cm)		Shoot weight (g)				% Shoot weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	44.66b	65.13b	14.21b	16.93b	2.49b	2.98b	---	---	---	---
Inoculated Mycorrhiza	48.33a	67.26a	15.57aa	18.74a	2.84a	3.46a	9.57	10.69	14.06	16.11

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Flowering:

The first flowering in inoculated mycorrhizal plant was found at 45 days after sowing and in control plant it was found at 47 days after sowing .

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency. The lowest mycorrhizal dependency (MD) was found in Black gram and it was 8.85%.

Root colonization:

The highest per cent root colonization (35.75%) was observed at 60 DAS old plants and lowest (20.00%) at 20 DAS old seedlings. No root colonization was found in untreated control plants.

Nutrient uptake:

Mycorrhizal inoculation significantly enhanced nutrient uptake (N, P, K, S, B and Zn) compare to control in Blackgram plants (Table 22). The per cent nutrient uptake increased over control for N, P, K, S, B and Zn was 3.27%, 18.51%, 18.06%, 6.23%, 16.67% and 2.59%, respectively. The maximum nutrient uptake increase in inoculated plant was recorded with P (18.51%) and the minimum was with Zn (2.59%).

Table 22. Effect of AMF inoculation on nutrient uptake by Blackgram shoot

Treatment	Nutrient uptake					
	Total N (%)	P (%)	K (%)	S (%)	B (μg/g)	Zn (μg/g)
Non-inoculated (Control)	2.143 b	0.389 b	1.456 b	0.353 b	36 b	77.49 b
Inoculated (mycorrhizal)	2.213 a	0.461a	1.719 a	0.375 a	42 a	79.50 a
% Increased over control	3.27	18.51	18.06	6.23	16.67	2.59

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

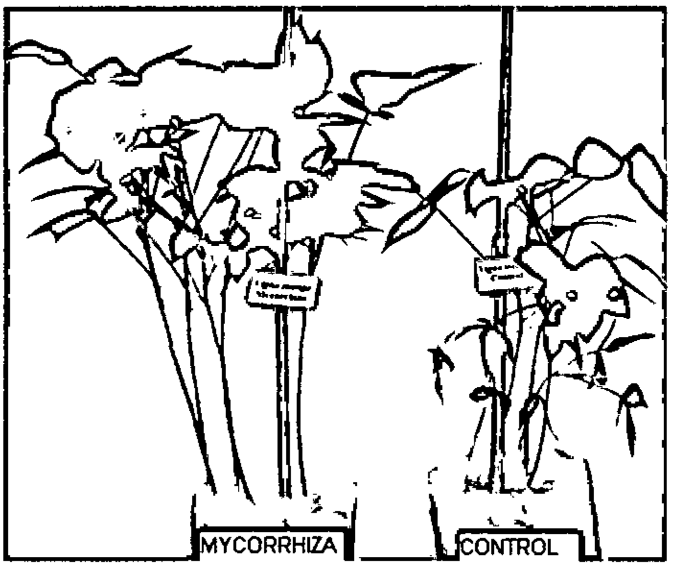


Fig.4. Influence of mycorrhizal inoculation on growth of Blackgram

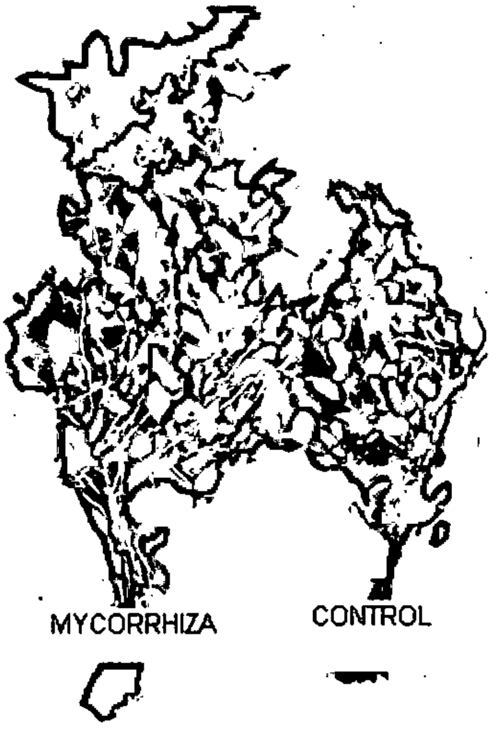


Fig.5. Influence of mycorrhizal inoculation on growth of Blackgram

4.5. LENTIL

Seedling emergence:

The influence of inoculation of Arbuscular mycorrhizal fungi on seeding emergence of Lentil recorded at different period is presented in Table 23. Higher seedling emergence was significantly found in case of inoculated lentil than non inoculated control. At three different times, seedlings emergence were recorded and the highest difference was found at 15 days after sowing which was 13.50 % between inoculated mycorrhiza and non inoculated control. With the elapse of time the seedlings emergence were increased in both treatments. The highest seeding emergence was 89.50% in mycorrhiza treated pots at 15 days after sowing and the lowest was 61.50 % in control at 7 days after sowing. The per cent seedling emergence increased over control in mycorrhiza fungi inoculated pots were 16.26, 15.79 and 17.76 at 7, 10 and 15 days after sowing, respectively.

Plant height:

In case of Arbuscular Mycorrhizal (AM) fungi inoculation the measurements of plant height of Lentil at different growth period given in Table 24. The plant height was recorded at 20, 40 and 60 days after sowing and with increase of growth period the plant height was increased both mycorrhizal inoculated and non inoculated control. In 1^{st} (20 DAS) and 2^{nd} 20 (20 to 40 days) days after sowing the growth increment was higher than the 3^{rd} 20 days (40 to 60 days). The per cent increased was minimum (25.79% in non inoculated and 27.25% in inoculated) in 3^{rd} 20 days (40 to 60 days) and it was maximum (72.73% in non inoculated and 54.93% in inoculated) in 2^{nd} 20 days (20 to 40 days). The per cent growth increased over control in mycorrhiza fungi inoculated plant was 28.09, 14.88 and 16.21 after 20, 40 and 60 days after sowing, respectively. Among the mycorrhizal plants the rate of growth increment in 2^{nd} 20 days (20 to 40days) was less (54.93%) in comparison to non mycorrhizal plants (72.73%) but in 3^{rd} 20 days (40 to 60 days) it was slightly higher (27.25%) than non mycorrhizal plants

(25.79%). It also observed that the per cent growth increased over control in mycorrhizal plant was less (14.88%) in 2nd 20 days (20 to 40 days) than in 1st and 3rd 20 days (40 to 60 days).

Table 23. Influence of AMF inoculation on seedling emergence (%) of Lentil at different stages

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	61.50 b	76.00 b	76.00 b	---	---	---
Inoculated Mycorrhiza	71.50 a	88.00 a	89.50 a	16.26	15.79	17.76

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 24. Influence of AMF **inoculation on plant height of Lentil at different growth periods**

Treatment	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	10.93 b	18.88 b	23.75 b	---	---	---
Inoculated Mycorrhiza	14.00 a	21.69 a	27.60 a	28.09	14.88	16.21

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Disease suspression:

The influence of inoculation of arbuscular mycorrhizal fungi on plant diseases of Lentil recorded at different growth stages are presented in Table 25. In the seedling stage, the highest incidence of damping off disease was found in non-inoculated control plant (14.47%) and the lowest (5.68%) in inoculated plants. Root rot incidence was less in seedling stage but higher in the vegetative stage and leaf blight incidence was higher in seedling stage but less in vegetative stage. Leaf spot disease was found in vegetative stage. In all growth stages, the disease incidence was significantly higher in uninoculated control plants in comparison to inoculated mycorrhizal plants

Table 25. Effect of AMF inoculation of Lentil in suppression of different diseases at different growth stages

Treatment	Infected plants (%)							
	Seedling stages				Vegetative stages			
	Damping off	Root rot	Leaf blight	Leaf spot	Damping off	Root rot	Leaf blight	Leaf spot
Non inoculated (Control)	14.47 a	3.29 b	5.26 a	---	---	10.53 a	1.31 b	10.53a
Inoculated (Mycorrhiza)	5.68 b	3.98 a	1.14 b	---	---	5.03 b	1.68 a	3.91 b

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

4.2 SOYBEAN

Seedling emergence:

The influence of inoculation of Arbuscular mycorrhizal fungi on seeding emergence of Soybean recorded at different period are presented in Table 26. Higher seeding emergence was significantly found in case of inoculated soybean than non inoculated control. At three different times, seedlings emergence were recorded and the highest difference was found at 10 days after sowing which was the 12 % between inoculated mycorrhiza and non inoculated control. With the increase of seedling emergence period the emergence were increased in both treatments. The highest seedling emergence was 83% in mycorrhiza treated pots at 10 days after sowing and the lowest seedling emergence was 64 % in control at 7 days after sowing. The per cent seedling emergence increased over control in mycorrhiza fungi inoculated pots were 20.31, 16.90 and 9.21 at 7, 10 and 15 days after sowing respectively.

Plant height:

The measurements of plant height of Soybean at different growth period due toArbuscular Mycorrhizal (AM) fungus inoculation was given in Table 27. The plant height was recorded at 20, 40 and 60 days after sowing and with increase of growth period the plant height was increased both mycorrhizal inoculated and non inoculated control. The per cent plant height increased over control in mycorrhiza inoculated pots was 6.27, 7.52 and 7.36 at 20, 40 and 60 days after sowing, respectively. In 1st (20 DAS) and 2nd 20 (20 to 40 days) days after sowing growth increment was significantly higher than the 3rd 20 days (40 to 60 days). The per cent increase was minimum (9.54% in non inoculated and 9.37% in inoculated) in 3rd 20 days (40 to 60 days) and it was maximum (110.14% in non inoculated and 112.61% in inoculated) in 2nd 20 days (20 to 40 days). The per cent growth increased over control in inoculated plant was 6.27, 7.52 and 7.36 after 20, 40 and 60 days sowing, respectively. Among the mycorrhizal plants the rate of growth increment in 2nd 20 days (20 to 40 days) was significantly higher (112.61%) in comparison to non mycorrhizal plants but in 3rd 20 days (40 to 60 days) it was slightly less than non mycorrhizal plants. It also observed that the per cent growth increased over control in mycorrhizal plants was less (6.27%) in 1st 20 days (20 DAS) than in 2nd (40 DAS) and 3rd 20 days (60 DAS).

Table 26. Influence of AMF inoculation on seedling emergence (%) of Soybean at different growth stages

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	64.00 b	71.00 b	76 b	---	---	---
Inoculated Mycorrhiza	77.00 a	83.00 a	83.00 a	20.31	16.90	9.21

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 27. Influence of AMF inoculation on plant height of Soybean at different growth periods

Treatment	Plant height (cm)			% increase over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	39.86 b	83.76 b	91.75 b	---	---	---
Inoculated Mycorrhiza	42.36 a	90.06 a	98.50 a	6.27	7.52	7.36

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Root length and weight of Soybean grown in mycorrhiza inoculated and non inoculated condition are described in Table 28. With the increase of growth period the root length and weight of soybean were increased both mycorrhiza inoculated plant and non mycorrhizal control. Mycorrhizal inoculation significantly enhanced the root growth in comparison to non inoculated control. In the mycorrhizal plants the root length in both harvested period (40 DAS and 60 DAS) was significantly higher in comparison to non mycorrhizal plants. It was also observed that the rate of root growth increment in 40 days after sowing was higher than in 60 days after sowing. The root weight in control plant was 2.56 g and 0.74 g (fresh) and in mycorrhizal inoculated plant it was 2.58 g and 1.75 g (fresh) at 40 and 60 days after sowing respectively. The per cent root weight increased over control in mycorrhizal plants 11.32, 136.46 (fresh) and 36.17, 174.67 (dry) after 40 and 60 days of sowing.

Shoot growth:

Mostly Arbuscular mycorrhiza fungal inoculation increased plant shoot growth. The results of Soybean shoot growth (weight and length) harvested at different periods have been presented in Table 29. The shoot length in both harvested period (40 DAS and 60 DAS) was significantly higher in mycorrhizal plant than in non mycorrhizal plant.The shoot fresh weight in control plant was 10.06 g and 11.25 g and in mycorrhiza inoculated plant it was 13.29 g and 26.83 g at 40 and 60 days after sowing, respectively. Among the mycorrhizal plants the rate of shoot growth increment in 20 days duration (40 to 60 days) was significantly higher (101.88%) than non mycorrhizal control plant (11.83%). The per cent shoot weight increased over control in mycorrhizal plant was 32.11, 138.49 (fresh) and 31.94, 118.64 (dry) at 40 and 60 days after sowing, respectively.

Table 28. Influence of AMF inoculation on root growth of Soybean at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	31.75b	18.64b	2.56b	0.74b	0.47b	0.27b	---	---	---	---
Inoculated Mycorrhiza	35.25a	23.75a	2.85a	1.75a	0.64a	0.74a	11.32	136.49	36.17	174.07

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 29. Influence of AMF inoculation on shoot growth of Soybean at different growth periods

Treatment	Shoot length (cm)		Shoot weight (g)				% Shoot weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	83.76b	91.75b	10.06b	11.25b	2.16b	2.95b	---	---	---	---
Inoculated Mycorrhiza	90.06a	98.50a	13.29a	26.83a	2.85aa	6.45a	32.11	138.99	31.94	118.64

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Flowering and fruiting:

The first flowering in inoculated mycorrhizal plants and non inoculated control plants were found at 42 and 46 days after sowing, respectively. Fruiting also delayed 4 days in control plants (48 DAS) in comparison to inoculated mycorrhizal plants (44 DAS).

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency. Soybean showed the highest mycorrhizal dependency (55.22%).

Root colonization:

The maximum per cent root colonization (48.53%) was recorded at 60 DAS plants and lowest (25.50%) at 20 DAS host plants. No root colonization was found in untreated control plant.

Nutrient uptake:

Data presented in Table 30 show that mycorrhizal inoculation significantly enhanced nutrient uptake (N, P, K, S, B and Zn) compared to control in Soybean plants. The per cent nutrient uptake increased over control for N, P, K, S, B and Zn was 33.03%, 26.75%, 8.19%, 9.70%, 30.77% and 5.53%, respectively. The maximum nutrient uptake increased in inoculated plant was recorded with N (33.01%) and the minimum was with Zn (5.53%).

Table 30. Effect of AMF inoculation on nutrient uptake by Soybean

Treatment	Nutrient uptake					
	Total N (%)	P (%)	K (%)	S (%)	B (µg/g)	Zn (µg/g)
Non-inoculated (Control)	2.092 b	0.314 b	1.672 b	0.134 b	39 b	75.90 b
Inoculated (Mycorrhizal)	2.783 a	0.398 a	1.809 a	0.147 a	51 a	80.10 a
% Increased over control	33.03	26.75	8.19	9.70	30.77	5.53

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Fig.6. Influence of mycorrhizal inoculation on growth of Soybean

4.1 GROUNDNUT

Seedling emergence:

The emergence of seedling of Groundnut is presented in Table 31. Higher seedling emergence was found in case of inoculated groundnut than non-inoculated. The seedling emergences were calculated in three different times and significantly the highest differences was found at 10 days after sowing which was the 6% between inoculated mycorrhiza and non-inoculated control. With the elapse of time, the seedling emergence was increased in both treatments. The per cent seedling emergences increased over control in mycorrhiza inoculated pots were 1.41, 6.90 and 5.56 at 7, 10 and 15 days after sowing, respectively. The lowest seedling emergence was 71% in control at 7 days after sowing and the highest seedling emergence (95%) was counted in mycorrhiza treated pots at 15 days after sowing.

Plant height:

The influence of inoculation of Arbuscular mycorrhizal fungi on plant height of Groundnut recorded at different growth periods are presented in Table 32. With the increase of growth period the plant height was increased both mycorrhizal inoculated and non-inoculated plants. The per cent plant height increased over control in mycorrhiza inoculated pots was 4.63, 21.93 and 13.58 at 20, 40 and 60 days after sowing, respectively. The trend of overall growth increment (plant height) among different periods of growth for both mycorrhizal and non mycorrhizal plant was more or less similar. In both the cases, at first 20 days (20 DAS) and 3rd 20 days (60 DAS) after sowing the growth increment was significantly higher than the 2nd 20 days (40 DAS) and the rate of growth was also significantly higher in 1st and 3rd 20 days also. In case of (%) growth increment for mycorrhizal and non mycorrhizal plants, it was observed that the % increase was minimum (45.02% in inoculated and 24.44% in non inoculated) in 2nd 20 days (20 to 40 days) and it was maximum (132.35% in inoculated and 149.45% in non inoculated) in 3rd 20 days (40 to 60 days). Among the mycorrhizal plants, the rate of growth increment in 2nd 20 days (20 to 40 days) was significantly higher (45.02%) in comparison to non mycorrhizal plants but in third 20 days (40 to 60 days) it was slightly less than non mycorrhizal plants.

Table 31. Influence of AMF inoculation on seedling emergence (%) of Groundnut at different growth stages

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	71b	87b	90b	---	---	---
Inoculated Mycorrhiza	72a	93a	95a	1.41	6.90	5.56

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 32. Influence of AMF inoculation on plant height of Groundnut at different growth periods

Treatment	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	24.18 b	30.09 b	75.06 b	---	---	---
Inoculated Mycorrhiza	25.30 a	36.69 a	85.25 a	4.63	21.93	13.58

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Root length and root weight (fresh and dry) of Groundnut is presented in Table 33. In the mycorrhizal plants, the root length in both harvested period (40 DAS and 60 DAS) was significantly higher in comparison to non mycorrhizal plants. It is also observed that the rate of root growth increment in 40 days after sowing was higher than that of 60 days after sowing in both treatments, respectively. In last 20 days (40 to 60 days) the increase of root length was only 2.20 cm in control and 1.26 cm in mycorrhizal plant. With the increase of growth period the root weight was increased both mycorrhizal inoculated plant and non mycorrhizal control. In case of AM inoculation, the root weight of groundnut was higher than the non inoculated plants. The per cent root weight increased over control in mycorrhizal plant was 21.00, 41.87 (fresh) and 8.00, 46.50 (dry) after 40 and 60 days sowing, respectively.

Shoot growth:

The data of influence of AM inoculation on shoot growth of Groundnut harvested at different period have been presented in Table 34. Mycorrhizal inoculation enhances plant shoot length in comparison to non inoculated plant. In every growth period some variation in shoot length of groundnut was always found and the maximum variation (10.19 cm) was found at 60 days after sowing. Among the mycorrhizal plants the rate of shoot growth increment in 20 days duration (40 to 60 days) was less (13.25%) in comparison to non mycorrhizal plants (14.28%). But in every growth period, the shoot growth was significantly higher in inoculated plants than in non-inoculated plants. The per cent shoot weight increased over control in mycorrhizal plants was 41.10, 39.83 (fresh) and 39.83, 51.39 (dry) after 40 and 60 days of sowing, respectively.

Table 33. Influence of AMF inoculation on root growth of Groundnut at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	21.70b	23.90b	4.38b	5.78b	0.75b	1.89b	---	---	---	---
Inoculated Mycorrhiza	24.50a	25.76a	5.30a	8.20a	0.81a	2.77a	21.00	41.87	8.00	46.56

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 34. Influence of AMF inoculation on shoot growth of Groundnut at different growth periods

Treatment	Shoot length (cm)		Shoot weight (g)				% Shoot weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (control)	30.09b	75.06b	30.12b	34.42b	5.02b	8.39b	---	---	---	---
Inoculated Mycorrhiza	36.69a	85.25a	42.50a	48.13a	7.60a	14.10a	41.10	39.83	51.39	68.05

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Flowering and branching:

Results presented in Table 35 show that inoculated (mycorrhizal) Groundnut plant produced significantly higher number of branches and flowers plant^{-1}.In the inoculated plant, the number of branching plant^{-1} increased 54.55% and the number of flowering plant^{-1} increased 28.57% over non inoculated control. It is also observed that both branching and flowering of inoculated plant has become earlier than the non inoculated plant.

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency. The mycorrhizal dependency (MD) of Groundnut was 39.06%.

Root colonization:

The maximum per cent root colonization (38.56%) was observed at 60 DAS plants and lowest (20.50%) at 20 DAS old seedlings. No root colonization was recorded in untreated control plants.

Nutrient uptake:

Inoculation of arbuscular mycorrhizal fungi responsed to nutrients uptake (N, P, K, S, B, and Zn) by Groundnut are presented in Table 36. It is evident from the study that mycorrhizal inoculation significantly enhanced nutrient uptake in shoot in comparison to control plant. The per cent nutrient uptake increased over control for N, P, K, S, B and Zn was 13.07%, 17.16%, 55.88 %, 47.01%,15.38% and 1.94%, respectively. The highest percent increased was obtained with K which was followed by S, P, B, N and lowest was found with Zn.

Table 35. Effect of AMF inoculation on flowering and branching of Groundnut

Treatment	Number of flowers/plant	% Increased over control	Number of flowers/plant	% Increased over control
Non- inoculated (Control)	7.00 b	---	4.40 b	---
Inoculated (Mycorrhiza)	9.00 a	28.57	6.80 a	54.55

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 36. Effect of AM inoculation on nutrient uptake by Groundnut shoot

Treatment	Nutrient uptake					
	Total N (%)	P (%)	K (%)	S (%)	B (µg/g)	Zn (µg/g)
Non-inoculated (Control)	2.494 b	0.169 b	1.200 b	0.251 b	39 b	77.40 b
Inoculated (Mycorrhizal)	2.820 a	0.198 a	1.867 a	0.369 a	45 a	78.90 a
% Increased over control	13.07	17.16	55.88	47.01	15.38	1.94

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

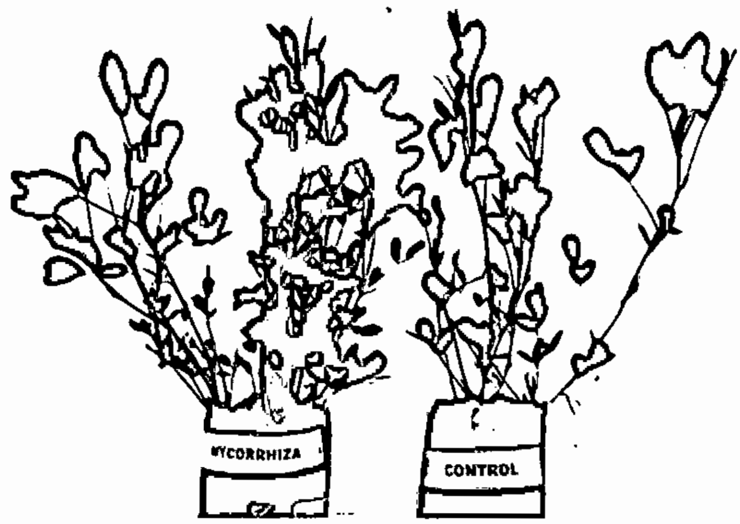


Fig. 7. Influence of mycorrhizal inoculation on growth of Groundnut

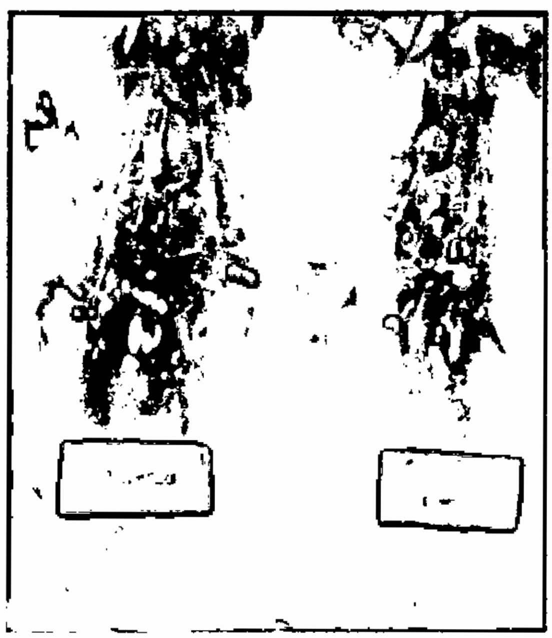


Fig. 8. Influence of mycorrhizal inoculation on growth of Groundnut

4.8. PIGEONPEA

Seedling emergence:

The influence of inoculation of Arbuscular mycorrhizal fungi on seedling emergence of Pigeonpea recorded at different period is presented in Table 37. Higher seeding emergence was significantly found in case of inoculated pigeonpea than non inoculated control. At three different times, seedlings emergence were recorded and the highest difference was found at 15 days after sowing which was the 10 % between inoculated mycorrhiza and non inoculated control. With the increase of seedling time the seedlings emergence were increased in both treatments. The highest seedling emergence was 90 % in mycorrhiza treated pots at 15 days after sowing and the lowest seedling emergence was 62 % in control at 7 days after sowing. The per cent seedling emergence increased over control in mycorrhiza fungi inoculated pots were 12.90, 10.53 and 12.50 at 7, 10 and 15 days after sowing, respectively.

Plant height:

In case of Arbuscular Mycorrhizal (AM) fungus inoculation the measurements of plant height of Pigeon pea at different growth period is given in Table 38. The plant height was recorded at 20, 40 and 60 days after sowing and with increase of growth period the plant height was increased both mycorrhizal inoculated and non inoculated control. In 1st (20 DAS) and 3rd 20 (40 to 60 days) days after sowing growth increment was higher than the 2nd 20 days (20 to 40 days) and the rate of growth was also higher in 1st and 3rd 20 days also. The per cent increase was minimum (43.81% in non inoculated and 45.58% in inoculated) in 2nd 20 days (20 to 40 days) and it was maximum (63.22% in non inoculated and 73.63% in inoculated) in 3rd 20 days (40 to 60 days). The per cent growth increased over control in mycorrhiza inoculated plant was 4.85, 6.14 and 12.91 after 20, 40 and 60 days sowing, respectively. Among the mycorrhizal plants the rate of growth increment (height) in all growth periods was significantly higher in comparison to non mycorrhizal plants. It also observed that the per cent growth increased over control in mycorrhizal plants was less (4.85%) in 1st 20 days (20 DAS) than in 2nd (20 to 40 days) and 3rd 20 days (40 to 60 days).

Table 37. Influence of AMF inoculation on seedling emergence (%) of Pigeon pea at different stages

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	62.00 b	76.00 b	80.00 b	---	---	---
Inoculated Mycorrhiza	70.00 a	84.00 a	90.00 a	12.90	10.53	12.50

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 38. Influence of AMF inoculation on plant height of Pigeon pea at different periods

Treatment	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	36.70a	52.78a	86.15a	---	---	---
Inoculated Mycorrhiza	38.48b	56.02b	97.27b	4.85	6.14	12.91

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Root weight and length of Pigeon pea grown in mycorrhiza inoculated and non inoculated condition are described in Table 39. With the increase of growth period the root weight and length of pigeon pea were increased both mycorrhiza inoculated plant and non mycorrhizal control. Mycorrhizal inoculation significantly enhanced the root growth in comparison to non inoculated control. In the mycorrhizal plants the root length in both harvested period (40 DAS and 60 DAS) were significantly higher in comparison to non mycorrhizal plants. It was also observed that the rate of root length increment in 40 days after sowing was higher than in 60 days after sowing, respectively. The root weight in control plant was 1.62g and 2.40g (fresh) and in mycorrhizal inoculated plant were 3.00g and 3.75g (fresh) at 40 and 60 days after sowing respectively. The per cent root weight increased over control in mycorrhizal plants was 85.19, 56.25 (fresh) and106.25, 48.75 (dry) after 40 and 60 days sowing, respectively.

Shoot growth:

Mostly Arbuscular mycorrhiza fungi inoculation increased plant shoot growth. The results of Pigeonpea shoot growth (weight and length) harvested at different periods have been presented in Table 40. The shoot length in both harvested period (40 DAS and 60 DAS) was significantly higher in mycorrhizal plant than in non mycorrhizal plant. The shoot weight in control plant was 9.23g and 12.10g (fresh) and in mycorrhiza inoculated plant it was 14.33g and 21.71g (fresh) at 40 and 60 days after sowing, respectively. Among the mycorrhizal plants the rate of shoot growth increment in 20 days duration (40 to 60 days) was significantly higher (51.50 %) in comparison to non mycorrhizal control plant (31.09 %). The per cent shoot weight increased over control in mycorrhizal plant was 55.25, 79.42 (fresh) and 54.65, 83.11 (dry) at 40 and 60 days after sowing, respectively.

Table 39. Influence of AMF inoculation on root growth of Pigeonpea at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	19.00b	33.00b	1.62b	2.40b	0.48b	0.80b	---	---	---	---
Inoculated Mycorrhiza	28.00a	46.00a	3.00a	3.75a	0.99a	1.19a	85.1	56.25	106.25	48.75

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 40. Influence of AMF inoculation on shoot growth of Pigeonpea at different growth periods

Treatment	Shoot length (cm)		Shoot weight (g)				% Shoot weight Increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	52.78b	86.15b	9.23b	12.10b	2.58b	4.50b	---	---	---	---
Inoculated Mycorrhiza	56.02a	97.27a	14.33a	21.71a	3.99a	8.24a	55.25	79.42	54.65	83.11

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency. The leguminous crop, pigeon pea showed 43.79 % mycorrhizal dependency (MD).

Root colonization:

The maximum per cent root colonization (32.56%) was recorded at 60 DAS old plants and the lowest (21.75%) at 20 DAS old seedlings.

Nutrient uptake:

Inoculation of arbuscular mycorrhizal fungi responsed to nutrients uptake (N, P, K, S, B, and Zn) by Pigeonpea are presented in Table 41. It is evident from the study that mycorrhizal inoculation significantly enhanced nutrient uptake in shoot in comparison to control plant. These results of the study indicated that the per cent nutrient uptake increased over control for N, P, K, S, B and Zn was 7.69%, 21.24%,. 24.19%, 12.32%, 20% and 1.65%, respectively. The highest percent increased was obtained with K which was followed by S, P, B, N and the lowest was found with Zn.

Table 41. Effect of AMF inoculation on nutrient uptake by Pigeonpea shoot

Treatment	Nutrient uptake					
	Total N (%)	P (%)	K (%)	S (%)	B (µg/g)	Zn (µg/g)
Non-inoculated (Control)	2.834b	0.193b	1.331b	0.487b	30b	72.90b
Inoculated (Mycorrhizal)	3.052a	0.234a	1.653a	0.547a	36a	74.10a
% increased over control	7.69	21.24	24.19	12.32	20	1.65

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

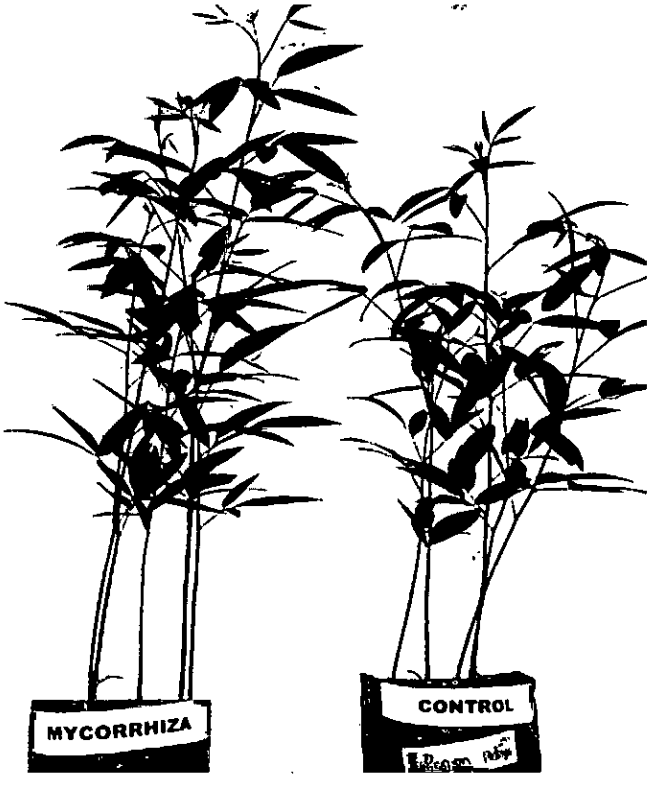


Fig. 9. Influence of mycorrhizal inoculation on growth of Pigeonpea

4.4. HYACINTHBEAN

Seedling emergence:

The influence of inoculation of Arbuscular mycorrhizal fungi on seedling emergence of Hyacinthbean recorded at different period is presented in Table 42. Higher seedling emergence was significantly found in case of inoculated hyacinth bean than non inoculated control. At three different times, seedlings emergence were recorded and the highest difference was significantly found at 10 days after sowing which was the 12 % between inoculated mycorrhiza and non inoculated control. With the increase of time the seedlings emergence were increased in both treatments. The highest seedling emergence was 98 % in mycorrhiza treated pots at 10 days after sowing and the lowest seedling emergence was 76 % in control at 7 days after sowing. The per cent seedling emergences increased over control in mycorrhiza inoculated pots were 10.53, 13.95 and 11.36 at 7, 10 and 15 days after sowing, respectively.

Plant height:

In case of Arbuscular Mycorrhizal (AM) fungi inoculation the measurements of plant height of Hyacinthbean at different growth period has given in Table 43. The plant height was recorded at 20, 40 and 60 days after sowing and with increase of growth period the plant height was increased both mycorrhizal inoculated and non inoculated control. The per cent plant height increased over control in mycorrhiza inoculated pots was 18.42, 9.36 and 13.18 at 20, 40 and 60 days after sowing respectively. In 1st (20 DAS) and 3rd 20 (40 to 60 days) days after sowing growth increment was higher than the 2nd 20 days (20 to 40 days). The per cent increase was minimum (38.47% in non inoculated and 43.30% in inoculated) in 3rd 20 days (40 to 60 days) and it was maximum (65.71% in non inoculated and 53.04% in inoculated) in 2nd 20 days (20 to 40 days). The per cent growth increased over control in mycorrhiza fungus inoculated plant was 18.42, 9.36 and 13.18 after 20, 40 and 60 days sowing respectively. Among the mycorrhizal plants the rate of growth increment in 2nd 20 days (20 to 40days) was less (53.04%) in comparison to non mycorrhizal plants (65.71%) but in 3rd 20 days (40 to 60 days) it was slightly higher (43.30%) than non mycorrhizal plants (38.47%). It also observed that the per cent growth increased over control in mycorrhizal plants was less (9.36%) in 2nd 20 days (20 to 40 days) than in 1st (20 DAS) and 3rd 20 days (40 to 60 days).

Table 42. Influence of AMF inoculation on seedling emergence (%) of Hyacinthbean at different growth periods

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	76.00 b	86.00 b	88.00 b	---	---	---
Inoculated Mycorrhiza	84.00 a	98.00 a	98.00 a	10.53	13.95	11.36

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 43. Influence of AMF inoculation on plant height of Hyacinthbean at different periods

Treatment	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	101.50 b	164.20 b	232.90 b	---	---	---
Inoculated Mycorrhiza	120.20 a	183.95 a	263.60 a	18.42	9.36	13.18

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Root length and root weight of Hyacinthbean grown in mycorrhiza inoculated and non inoculated conditions are described in Table 44. With the increase of growth period the root weight and length of Hyacinth bean were increased both mycorrhiza inoculated plant and non mycorrhizal control. Mycorrhizal inoculation significantly enhanced the root growth in comparison with non inoculated control. In the mycorrhizal plants the root length in both harvested period (40 DAS and 60 DAS) was significantly higher in comparison to non mycorrhizal plants. It was also observed that the rate of root growth increment in 40 days after sowing was higher than in 60 days after sowing. The root weight in control plant was 3.00 g and 4.64 g (fresh) and in mycorrhizal inoculated plant was 23.67g and 5.25g (fresh) at 40 and 60 days after sowing, respectively. The per cent root weight increased over control in mycorrhizal plants 22.33, 13.15 (fresh) and 37.74, 21.78 (dry) after 40 and 60 days sowing.

Shoot growth:

Mostly Arbuscular mycorrhiza fungal inoculation significantly increased plant shoot growth. The results of Hyacinthbean shoot growth (weight and length) harvested at different periods have been presented in Table 45. The shoot length in both harvested period (40 DAS and 60 DAS) was significantly higher in mycorrhizal plant than in non mycorrhizal plant. The shoot weight in control plant was 23.67g and 30.76g (fresh) and in mycorrhiza inoculated plant was 28.43g and 41.50g (fresh) at 40 and 60 days after sowing, respectively. Among the mycorrhizal plants the rate of shoot growth increment in 20 days duration (40 to 60 days) was significantly higher (45.97%) in comparison to non mycorrhizal control plant (29.95%). The per cent shoot weight increased over control in mycorrhizal plant was 20.11, 34.92 (fresh) and 8.13, 14.75 (dry) at 40 and 60 days after sowing, respectively.

Table 44. Influence of AMF inoculation on root growth of Hyacinth bean at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	18.75b	26.37b	3.00b	4.64b	0.53b	1.01b	---	---	---	---
Inoculated Mycorrhiza	25.86a	32.87a	3.67a	5.25a	0.73a	1.23a	22.33	13.15	37.74	21.78

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 45. Influence of AMF inoculation on shoot growth of Hyacinthbean at different growth periods

Treatment	Shoot length (cm)		Shoot weight (g)				% Shoot weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	168.20b	232.90b	23.67b	30.76b	4.18b	5.56b	---	---	---	---
Inoculated Mycorrhiza	183.95a	263.60a	28.43a	41.50a	4.52a	6.38a	20.11	34.92	8.13	14.75

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency. Hyacinth bean showed mycorrhizal dependency (MD) 13.66%.

Root colonization:

The maximum per cent root colonization (40.26%) was found at 60 DAS old plants and minimum (25.73%) at 20 DAS old seedlings.

Nutrient uptake:

Data presented in Table 46 show that mycorrhizal inoculation significantly enhanced nutrient uptake (N, P, K, S, B and Zn) compared to control in Hyacinthbean. The per cent nutrient uptake increased over control for N, P, K, S, B and Zn was 8.44%, 10.88%, 50.00%, 10.844%, 15.38% and 5.40%, respectively. The maximum nutrient uptake increased in inoculated plant was recorded with K (50.00%) and the minimum was Zn (5.40%).

Table 46. Effect of AMF inoculation on nutrient uptake by Hyacinthbean shoot

Treatment	Nutrient uptake					
	Total N (%)	P (%)	K (%)	S (%)	B (μg/g)	Zn (μg/g)
Non-inoculated (Control)	2.629 b	0.331b	1.684b	0.203 b	39 b	66.60 b
Inoculated (Mycorrhizal)	2.851 a	0.367 a	2.526 a	0.225 a	45 a	70.20 a
% increased over control	8.44	10.88	50.00	10.84	15.38	5.40

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

4.10. Dhaincha (*Sesbania rostrata*)

Seedling emergence:

The influence of inoculation of Arbuscular mycorrhizal fungi on seeding emergence of Dhaincha recorded at different period is presented in Table 47. Higher seedling emergence was significantly found in case of inoculated dhaincha than non inoculated control. At three different times, seedlings emergence were recorded and the highest difference was found at 10 days after sowing which was the 9.50 % between inoculated mycorrhiza and non inoculated control. With the increase of seedling emergence period the seedlings emergence were increased in both treatments. The highest seedling emergence was 92% in mycorrhiza treated pots at 15 days after sowing and the lowest seedling emergence was 71.50 % in control at 7 days after sowing. The per cent seedling emergence increased over control in mycorrhiza inoculated pots were 9.79, 11.73 and 8.24 at 7, 10 and 15 days after sowing, respectively.

Plant height:

In case of Arbuscular Mycorrhizal (AM) fungi inoculation the measurements of plant height of Dhaincha at different growth period has given in Table 48. The plant height was recorded at 20, 40 and 60 days after sowing and with the increase of growth period the plant height was increased both mycorrhizal inoculated and non inoculated control. In 1st (20 DAS) and 3rd 20 (40 to 60 days) days after sowing growth increment was higher than the 2nd 20 days (20 to 40 days). The per cent increase was minimum (74.64% in non inoculated and 74.92% in inoculated) in 3rd 20 days (40 to 60 days) and it was maximum (94.51% in non inoculated and 97.61% in inoculated) in 2nd 20 days (20 to 40 days). The per cent growth (height) increased over control in mycorrhiza inoculated plant was 6.12, 7.81 and 8.60 after 20, 40 and 60 days of sowing, respectively. Among the mycorrhizal plants the rate of growth increment in 2nd 20 days (20 to 40days) was significantly higher (97.61%) in comparison to non mycorrhizal plants (94.51%) but in 3rd 20 days (40 to 60 days) it was slightly higher (74.92%) than non mycorrhizal plants (74.64%). It was also observed that the per cent growth increased over control in mycorrhizal plants was less (6.12%) in 1st 20 days (20 DAS) than in 2nd (20 to 40 days) and 3rd 20 days (40 to 60 days).

Table 47. Influence of AMF inoculation on seedling emergence (%) of Dhaincha at different growth stages

Treatment	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	71.50b	81.00b	85.00b	---	---	---
Inoculated Mycorrhiza	78.50a	90.50a	92.00a	9.79	11.73	8.24

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 48. Influence of AMF inoculation on plant height of Dhaincha at different growth periods

Treatment	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	28.77b	55.96b	97.73b	---	---	---
Inoculated Mycorrhiza	30.53a	60.33a	106.13a	6.12	7.81	8.60

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Root growth:

Root length and weight of Dhaincha grown in mycorrhiza inoculated and non-inoculated conditions are described in Table 49. With the increase of growth period the root weight and length of dhaincha were increased both mycorrhiza inoculated plant and non-mycorrhizal control. Mycorrhizal inoculation significantly enhanced the root growth in comparison to non inoculated control. In the mycorrhizal plants the root length in both harvested period (40 DAS and 60 DAS) was significantly higher in comparison to non-mycorrhizal plants. It was also observed that the rate of root length increment in 40 days after sowing was higher than in 60 days after sowing respectively. The root weight in control plant was 2.42g and 2.61g (fresh) and in mycorrhizal inoculated plant was 2.70g and 2.83g (fresh) at 40 and 60 days after sowing, respectively. The per cent root weight increased over control in mycorrhizal plants 11.57, 8.43 (fresh) and 10.61, 19.57 (dry) after 40 and 60 days sowing, respectively.

Shoot growth:

Mostly Arbuscular mycorrhiza fungi inoculation increased plant shoot growth. The results of Dhaincha shoot growth (weight and length) harvested at different periods have been presented in Table 50. The shoot weight in control plant was 11.33g and 14.386g (fresh) and in mycorrhiza inoculated plant was 12.70g and 18.64g (fresh) at 40 and 60 days after sowing, respectively. Among the mycorrhizal plants the rate of shoot growth increment in 20 days duration (40 to 60 days) was significantly higher (46.77%) in comparison to non-mycorrhizal control plant (26.92%). The per cent shoot weight increased over control in mycorrhizal plant was 12.09, 29.26 (fresh) and 8.13, 72.85 (dry) at 40 and 60 days after sowing, respectively. The shoot length in both harvested period (40 DAS and 60 DAS) was higher in mycorrhizal plant than in non-mycorrhizal plant.

Table 49. Influence of AMF inoculation on root growth of Dhaincha at different growth periods

Treatment	Root length (cm)		Root weight (g)				% Root weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	20.00b	32.00b	2.42b	2.61b	0.66b	1.13b	---	---	---	---
Inoculated Mycorrhiza	25.00a	37.00a	2.70a	2.83a	0.73a	1.35a	11.57	8.43	10.61	19.57

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Table 50. Influence of AMF inoculation on shoot growth of Dhaincha at different growth periods

Treatment	Shoot length (cm)		Shoot weight (g)				% Shoot weight increased over control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Non-inoculated (Control)	55.96b	97.73b	11.33b	14.38b	2.09b	2.91b	---	---	---	---
Inoculated Mycorrhiza	60.33a	106.13a	12.70a	18.64a	2.26a	5.03a	12.0	29.62	8.13	72.85

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

Mycorrhizal dependency:

Mycorrhizal dependency is the degree to which a host relies on the mycorrhizal condition to produce maximum growth at a given level of soil fertility. Arbuscular mycorrhiza and legume crops have an obligate nutritional dependency. The mycorrhizal dependency (MD) of Dhaincha was 36.67%.

Root colonization:

The maximum per cent root colonization (45.68%) was recorded at 60 DAS old plants and minimum (25.75%) at 20 DAS old seedlings.

Nutrient uptake:

Inoculation of arbuscular mycorrhizal fungi responsed to nutrients uptake (N, P, K, S, B, and Zn) by Dhaincha are presented in Table 51. It is evident from the study that mycorrhizal inoculation enhanced nutrient uptake in shoot in comparison to control plant. These results indicated that the per cent nutrient uptake increased over control for N, P, K, S, B and Zn was 2.76%, 48.51%, 3.38%, 28.13%, 30.43% and 17.73%, respectively. The highest percent increased was obtained with P which was followed by B, S, Zn, K and lowest was found with N.

Table 51. Effect of AMF inoculation on nutrient uptake by Dhaincha (*Sesbania rostrata*) shoot

Treatment	Nutrient uptake					
	Total N (%)	P (%)	K (%)	S (%)	B (μg/g)	Zn (μg/g)
Non-inoculated (Control)	1.810b	0.202b	1.747b	0.192b	23b	66.00b
Inoculated (Mycorrhizal)	1.860a	0.300a	1.806a	0.246a	30a	77.70a
% increased over control	2.76	48.51	3.38	28.13	30.43	17.73

Means followed by a common letter are not significantly different at the 5% level of significance by T-test.

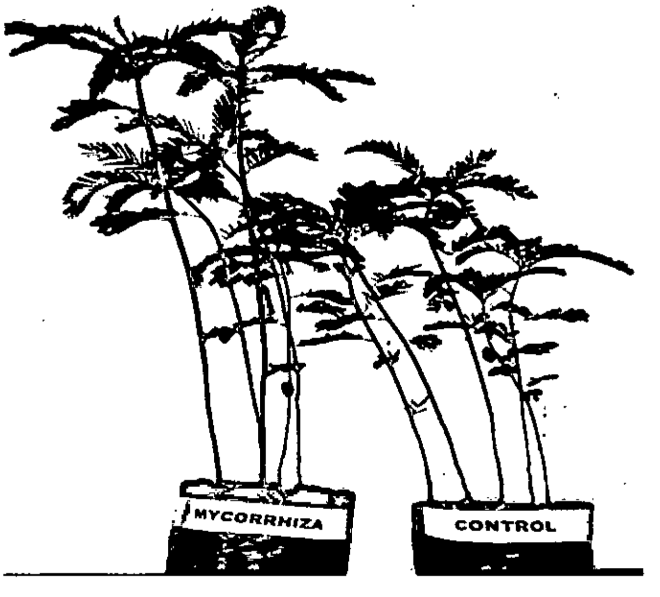


Fig. 10 Influence of mycorrhizal inoculation on growth of Dhaincha

Chapter 5
Discussion

5. DISCUSSION

Bangladesh is one of the most densely populated countries in the world. It is essential to improve crop production for the burgeoning human population and to meet the increasing demands for food. Because of economic and environmental constrains, it is necessary to develop least-expensive and technologically simple methodologies for immediate benefit. Mycorrhizal technology as a nature farming technique can be one of the alternatives to improve crop production, farm profitability and environmental quality (Mridha *et al.*, 1991).

Agricultural research in the last decade has shown that crop production constrains in the tropics are most likely to be circumvented by technologies based biological processes. It is recognized that on a long-term basis only via biological technologies soil productivity can be maintained and increased and that in this way food can be produced at lower costs per unit.

Until about 35 years ago, arbuscular mycorrhizal fungi were virtually ignored by most soil and plant scientists and AM was not considered as a soil microbiological resource for crop production. However, since under controlled conditions it was demonstrated that AM fungi increase phosphorus (P) uptake and that they can play a role in uptake of other plant nutrients as well as in the biological nitrogen fixation of *Rhizobium*, biological control of root pathogens and drought resistance of plants, these microorganisms attracted the interest of scientists from several agricultural disciplines (Powell and Bagyaraj, 1984).

As more efficient technologies become available for the production and use of arbuscular mycorrhizal inoculum, additional applications for these fungi should become commercially feasible. Many scientists tried to produce mass AM inoculum through soil less media, tissue culture, hydroponics and aeroponics system and they were partially or fully succeed by this method but these methods are not suitable for Bangladesh conditions. Mridha (1988) tried to develop more efficient technologies for mass production of AM fungal inoculum, which will be simple, inexpensive and suitable for our environmental condition.

Mycorrhizal fungi are not new, trendy, genetically engineered organisms. These specialized fungi have been fundamental to the survival and growth of plants for over 400 million years. Arbuscular mycorrhizae have potential benefits to host plants by enhancing plant nutrient uptake and increasing tolerance to adverse condition (Smith and Read, 1997).

The present piece of work has been carried out to determine the role of AM fungi on growth, nutrient uptake and disease suppression (some selected crops) of some legumes.

Percent increased in seedling emergence of inoculated plants over control was recorded with all most all the selected legumes. In case of Groundnut, mycorrhizal inoculation increased seedling emergence over control. Inoculated treatment in Soybean came up with the same result that means it perform percent increase in seedling emergence over control. BARI Mungbean did not perform any unusual results. The influence of AM inoculation on seedling emergence of Hyacinthbean, Chickpea and Lentil showed increased (%) seedling emergence. AM inoculation in Lentil struck the highest seedling emergence. Blackgram performed the highest seedling emergence. Blackgram also showed the 3rd highest percentage increase in seedling emergence. The influence of AM inoculation on seedling emergence of Pigeonpea, Cowpea and Dhaincha remarkable over control.

The high MD value suggests that mycorrhizal inoculation would be useful in producing vigorous seedlings in nursery which establish better and withstand some amount of drought and pathogenic infections (Vishwakarma and Singh, 1996). Matsubara *et al.*(1994) were investigated the effects of inoculation with

Vesicular-arbuscular mycorrhizal fungi (VAMF, Species used *Glomus etunicatum* or *Glomus intraradices*) on seedling growth of 17 vegetable crop species. Growth was noticeably enhanced by VAMF inoculation to roots in Welsh onion cv. Green Negi, Asparagus cv. welcome, Pea cv. Sanzyunichi Kinusayaendo, Celery cv. Kornel No.619 and Cucumber cv. Hokushin Kyuri. Bajwa *et al.* (1995) reported mycorrhizal inoculation in pots increased nodulation, VAM infection and top growth in Chickpea seedlings.

Influence of AM inoculation on physical growth of ten different legumes namely Groundnut, Soybean, BARI Mungbean, Hyacinthbean, Chickpea, Lentil, Blackgram, Pigeonpea, Cowpea and Dhaincha were studied. Plant heights of these crops were recorded at 20, 40 and 60 days after sowing. Arbuscular mycorrhizal inoculation significantly increased the plant height of leguminous over uninoculated control plant. Venkateswarlu *et al.*(1995) recorded similar results in plant height of groundnut. They recorded that mycorrhizal plants were significantly taller than nonmycorrhizal plants at the final harvested time (14 weeks). In case of the parameter plant height (cm) of soybean inoculated treatment showed the per cent increase in height over control. Similar results were reported by Skipper and Smith (1979). They recorded the cv. Bossier (Soybean variety) and *Gigaspora gigantea* combination in unlimed soil, showing a 10 % increase in shoot length. Inoculated treatment in BARI Mungbean came up with the same result that means it perform per cent increase in plant height over control. Mathew and Johri (1989) revealed that introduced *Glomus caledonicum* was effective in improving plant growth and dual inoculation with *Glomus caledonicum* and indigenous VAM fungi was most effective. Hyacinthbean did not show any unusual results but highest percentage increase in plant height for AM inoculation over control was recorded. Inoculated chickpea treatment showed the percent increase in height over control and the highest plant height (15.79 %) recorded at 40 DAS followed by 13.98 % at 20 DAS and 9.17 % at 60 DAS. Champawat

(1990) demonstrated that dual inoculation with VAM fungi *Gigaspora calospora* and *Rhizobium* bacteria in Chickpea considerabely enhanced the plant growth. Exposure of *Rhizobium* sp. to a low strength (5×10^{-3} T) electromagnetic field before inoculation to mycorrhizal Chickpea seedling in pots increased nodulation, VAM infection and top growth (Bajwa *et al.*1995). Yields per plant were higher in inoculated with *Glomus versiforme* than in noninoculated ones at all N levels (Tilak and Dwivedi, 1991).

Inoculated treatment in Lentil came up with the same result that means it perform per cent increase in plant height over control Sdobnikova *et al.* (1991) demonstrated the results that inoculation with VAM fungi improved growth and development of plants. In case of the parameter plant height (cm) of Pigeonpea inoculated treatment showed increase in height over control and the highest increase of plant height (12.91 %) recorded at 60 DAS, which was followed by 6.14% at 40 DAS and 4.85 % at 20 DAS. Diederichs (1990) showed that nodulation of *Cajanus cajan* greatly improved by VAM fungi treated with rock phosphate. It was suggested that increased plant development and nodulation was due to improved uptake of P by mycorrhiza. AM inoculation in Cowpea struck the highest plant height (21.70 %) at 20 DAS which was followed by 60 DAS and 40DAS and Cowpea showed the 3rd highest percentage increase in plant height in the crop pool selected for this experiment. Dhaincha performed per cent increase in plant height over control. AM inoculation in Dhaincha showed the highest increase of plant height (8.60 %) at 60 DAS which was followed by 20 DAS and 40 DAS. The lowest percentage increase in inoculation treatment over control was 6.12.

Root length, fresh and dry weight of roots was found higher in all the inoculated plants species. This was probably due to uptake of nutrient, which increased vegetative growth and hence greater translocation of phytosynthates from shoot to root and thereby enhanced root growth and weight. Comparatively higher root lengths were recorded in inoculated treatment over control. Mane *et al.* (1993) reported that groundnut cv. LG-19 plants inoculated with vesicular arbuscular mycorrhiza *Glomus fasciculatum* increased root length, root weight, and biomass production.

Cheng and Tu (1982) divulged inoculation of Soybean with Chlamydospore of *Glomus clarus* significantly increased top growth and pod production. Zambolim and Schenck (1983) reported significant correlations occurred between the percentage of root colonized by *Glomus mosseae* and weight of roots and shoots and plant height. Eranna and parama (1994) observed that mycorrhizal innoculation of Soybean increased both root dry weight and P uptake. Benomyl prevented increased plant growth due to the AM even with fungal colonization of the root system as high as 48% (Barley and Safir, 1978).

This is likely because increase in plant growth over time favored increase in root length. Weight of root significantly increased due to inoculation of AM fungi in Pigeonpea. This might be due to the adequate translocation of nutrient (N, P, K, and Mg) with the help of AM fungi, which increased vegetative growth, and greater translocation of photosynthates and thereby root growth.

Significantly increase in shoot weight over control was recoded with all the crops at 40 DAS and 60 DAS. This was probably due to uptake of nutrient, which increased vegetable growth and hence greater translocation of phytosynthates from leaf to shoot and thereby enhanced shoot growth and weight. Comparatively higher shoot length were recorded in inoculated treatment over control. Santhanakrishnan and Oblisami (1990) observed the magnitude of increase of growth, AM colonization and nutrient content in groundnut plants was maximum with AM inoculation together with 150kg/ ha gypsum.

Carling and Brown (1980) reported that colonization by most *Glomus* isolates significantly increased plant top dry weight and seed yields and of these isolates must produced larger increases in dry weight in low fertility soil. The VA fungus, *Glomus fasciculatum* coincided the high values with significant growth enhancement of the Soybean plant. This fungus also enhanced nutrient uptake in the host (Bethenfavay *et al.* 1982). The maximized benefits of mycorrhizas to plants were observed: 40% grater mycorrhizal root length, 5% higher leaf tissue N and root much (Lussenhop, 1996).

Bajwa (1991) reviewed that the role of VAM fungi in improving the growth of plants by increasing the absorption of phosphorus and micronutrients and enhancing tolerance to drought. Shoot length also increased significantly by inoculation of AM fungi. This is likely because increase in plant growth over time favored increase in shoot length. Inoculation of *Cicer arietinum* plants with VA mycorrhiza (*Glomus fasciculatum*) resulted in significantly greater dry matter production and phosphate uptake than uninoculated one (Poi, *et al.* 1989). Weight of shoot significantly increased due to inoculation of AM fungi in Pigeonpea. This might be due to the adequate translocation of nutrient (N, P, K, and Micro nutrient) with the help of AM fungi, which increased vegetative growth and greater translocation of photosynthates and thereby shoot growth.

Devi and Sitaramaiah (1991) showed that VAM fungi inoculation of *Vigna mungo* increased root colonization, root volume, dry weight of shoot and root than non inoculated plants. AM inoculation displayed higher shoot length over control and comparatively higher shoot length different between treated mycorrhizal plant and non treated control plant was 13.5 cm at 40 DAS old plant. Godse *et al.* (1978) reported that the inoculation of Cowpea with VA mycorrhiza increased nodulation and root and shoot development. The increased shoot and root development were presumably due to increased phosphorus uptake. Vesicular arbuscular mycorrhizal inoculation was significant increase in shoot P, Cu, Zn and N content and nodule, shoot and root dry matter yield (Aziz and Habte, 1990).

Nutrient uptake was increased because of inoculation AM fungi in all selected legumes. Nitrogen uptake was influenced significantly by the inoculation of AM fungi over control in some of the crops but other nutrient was higher amount for different other crops. It is evident from the study that mycorrhizal inoculation enhance nutrient uptake in Cow pea shoot with comparison to control plant. Results of this experiment also show that AM inoculation significantly increased nutrient uptake of Dhaincha shoot over control. Krishna and Bagyaraj (1984) reported that root of mycorrhizal (*Glomus fasciculatum*) groundnut plants had higher amount of phenols than non mycorrhizal roots. Phenols accumulated in the hyphae and arbuscules of the fungus within the host. Khan *et al.* (1995) identified that nitrogen fixation as well as N and P contents in groundnut increased only by dual inoculation with VAM fungi and *Bradyrhizobium*. Nutrient uptake was enhanced significantly in soybean shoot by inoculation of AM fungi. Bagyaraj *et al.* (1978) reported that *Glomus fasciculatum* could greatly assist nodulation and nitrogen fixation in field grown soybean with *Rhizobium japonicum*. Vasicular arbuscular endomycorrhizal fungi can assist legumes in the uptake of phosphorus, do not interact directly with nitrogen fixing bacteria (Carling *et al.*, 1979). Asimi *et al.* (1980) reported the beneficial effects of inoculating nodulated plants, growing in unamended sterile soil, with *Glomus mosseae* improved P uptake, lower root:shoot ratio, and greater nodulation with higher nitrogenase activity. The VAM fungai promote phosphorus uptake in low phosphate soil during the early stages of plant growth (Sasai, 1991). Cabello (1992) observed that interaction between the indigenous VAM fungus, *Glomus epigaeus* (*G. versiforme*) and *Bradyrhizobium japonicum* improved growth of soybean plants and increased the size and number of nodules compared with uninoculated plants. N and P contents increased by 102 and 233 % respectively as a result of the tripartite interactions. Vesicular-arbuscular mycorrhizal infection increased phosphoric acid content of soybeans at 50 days after emergence (Isobe *et al.*1993). Shnyreva and Kulaev (1994) identifyed the effect of VAM mycorrhization of maize plants by *Glomus* spp., phosphorus content in the VA-mycorrhizal root tissues increased by 35 % for the species *G. mosseae* and by 98 % for *G. fasciculatum*.

Phosphorus uptake was influenced significantly by the inoculation of AM fungi over control by many selected crops. Nutrient uptake was enhanced significantly in Pigeonpea shoot by inoculation of AM fungi. Sivaprasad and Rai (1991) recorded that soil inoculation with *Glomus fasciculatum* and *Rhizobium* sp. increased nodulation by 178 %, nitrogease activity by 185 % growth and N and P contents compared with inoculation with *Rhizobium* alone.

Disease suppression data were recorded from some selected legumes of this study. Mycorrhizal fungi inoculation significantly enhanced disease reduction compared to control plant. Germani *et al.*(1980) observed that the nematode *Scutellonema cavenessi* altered the physiology of the Groundnut plant by affecting the establishment and functioning of the symbiosis between the plant and endomycorrhizae. The mycorrhizal fungus reduced the number of sclerotia produced by *Sclerotium rolfsii* while the root pathogen reduced the percentage of root infection and chlamydospore production by *Glomus fasciculatum* (Krishna and Bagyaraj, 1983). They also found that root and shoot dry weight of the host and their P content were highest in plants inoculated with mycorrhiza only and lowest in plants inoculated with the pathogen only. Kellam and Schenck (1980) obtained reduced number of galls produced by *Meloidogyne incogita* in the presence of *Glomus macrocarpus*. Price *et al.* (1995) reported that the *Glomus intradices* has efficient effect on Soybean cyst nematode, *Heterodera glycines* on nematode intolernat variety Bragg. Jalali and Thareja (1981) tested with inoculation of *Cicer arietinum* plants with VA mycorrhiza resulted in extensive root colonization by the endophyte and an accompanying reduction in the incidence of wilt caused by *F oxysporum tsp. ciceri* (26.6% in mycorrhizal plants, 80% in non-mycorrhizal). Simultaneous inoculation of *Cicer arietinum* with vesicular arbuscular mycorrhizal fungi (*Glomus mosseae, G. constrictum*) and *Fusrium oxysporum* f.sp. *ciceris* had no effect on wilt incidence in the susceptible JG 62 and resistant WR 315 genotypes. However, the wilt-tolerant genotype, K 850 had 25% wilt in soil with *Fusarium* +VAM, less than with *Fusarium* alone (35 %) (Reddy *et al.*, 1988). Jain and Sethi (1989) found that over 60 % colonization of the root system by VAM fungi in cowpea considerately hampered root invasion by the *Heterodera cajari* nematode. Santhi and Sundarababu (1995) found that Cowpea plant with VAM were more resistant to *Meloidogyne icognita* than those without.

Mycorrhizal dependency (MD) of these experimental legumes ranged from 8.85 to 55.22 %. The highest mycorrhizal dependency (55.22 %) was observed in Soybean that was superior to all other legume crops. Blackgram showed lowest MD (8.85%). Pigeonpea recorded the second highest MD (43.79 %) which was followed by Groundnut (39.06%), BARI Mungbean (26.35 %), Hyacinthbean (13.60 %), Chickpea (22.58 %), Cowpea (23.29 %) and Dhaincha (36.67 %). Parvathi *et al.* (1984) reported that Pigeonpea is the most heavily infected plant species where Matsubara *et al.* (1994) reported the highest mycorrhizal dependency in the vegetable of Liliaceae. Khalil *et al.* (1994) divulged that Soybean had a higher MD than corn but considerable variation occurred within Soybean cultivars. They also observed that the VAMF colonization of roots ranged from 62 to 87 % for Soybean and 49 to 68 % for corn. *Prosopis cineraria* showed tremendous dependency (226.8%) of *Scutellospora calospora* for biomass production and nutrient uptake (Mathur and Vyas, 1995). Habte (1995) reported that the dependency of *Cassia siamea* on VAMF for dry matter production was 79 % at soil P concentration of .02 mg/L and 46% at the higher P concentration.

Kapulnik and Kushnir (1991) suggested that factors limiting mycorrhizal dependence in wheat are found among the A and B genomes but are epistatic to the more consistency dependent D-genome contributors whereas Rao *et al.* (1990) observed a positive correlation between the ability of a mycorrhizal fungus to infect roots and mycorrhizal dependence in plant cultivars.

Chapter 6
Summary and Conclusion

6. Summary and Conclusion

A pot experiment was carried out to study the effectiveness of inoculation of AM fungi in ten legumes. The selected legumes were Groundnut, Soybean, BARI Mungbean, Hyacinthbean, Blackgram, Pigeonpea, Cowpea and Dhaincha. The studies included the seedling emergence, plant growth and assessment of percent root colonization, Arbuscular mycorrhizal dependency, nutrient uptake of these legumes.

The seedling emergences were influenced by AM inoculation. Seedling emergences were recorded at 7, 10 and15 days after sowing and all recorded period-inoculated Hyacinth bean showed higher seedling emergence. The highest percent seedling emergence increased in BARI Mungbean and Lentil were 29.08% and 17.76% at 7 and 15 days after sowing over control respectively, whereas BARI Mungbean showed the highest seedling emergence at 10 days after sowing.

The treatment AM inoculation recorded the highest plant growth at all growth stages for all legumes. The crops showed the per cent increase of plant height, root weight, shoot weight with AM inoculation over control and the highest plant height stroke (28.09%) increased in lentil at 20 days after sowing which was followed by 21.93% in Groundnut, 15.79% in Chickpea, 10.85% in Cowpea at 40 DAS and 16.21% in Lentil, 14.95% in Mungbean, 13.18% in Hyacinthbean, 12.91% in Pigeonpea increased at 60 days after sowing. The highest percent increased of root weight was recorded in Soybean (133.49%) at 60 DAS and Pigeonpea (85.19%) at 40 DAS whereas the highest shoot growth increased over control was observed in Chickpea (81.60%) at 40 DAS and Soybean (138.49%) at 60 DAS. Data on diseases were recorded in Lentil, BARI Mungbean and Chickpea. Inoculation of pot grown of these crop plants with VA mycorrhiza resulted an accompanying reduction in the per cent affected plants caused by various soil pathogens like *Pythium sp*, *Sclerotium rolfsii*, *Fusarium oxysporum*, *Rhizoctonia solani*, *Stemphylium sp* etc. The percent root colonization of mycorrhizal fungi in all legumes was recorded and it was differed from legume to legume. The highest root colonization was obtained in Cowpea (49.75%) and the lowest in Blackgram (20.00%).

Arbuscular mycorrhizal dependency (MD) of some legumes was studied. Ten legumes grown under the pot experiment were assessed. All inoculated legumes had mycorrhizal colonization percentage (MCP) and dry matter values than their equivalent uninoculated counterparts. The dependency of different legumes ranged from 8.85 to 55.22%. The highest mycorrhizal dependency was found in Soybean (55.22%) and the lowest was found in Blackgram (8.85%). The nutrient uptake (N, P, K, S, B and Zn) was highly influenced by AM inoculation. The highest N, P and k nutrient uptake occurred in Pigeonpea, Cowpea, and Chickpea, respectively whereas S in Pigeonpea, B in Cowpea and Zn in Soybean were found.

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