INFLUENCE OF ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH AND NUTRIENT UPTAKE OF SOME VEGETABLE CROPS

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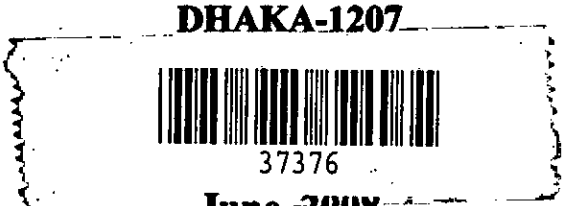

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BY
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CERTIFICATE

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This is to certify that the thesis entitled "*INFLUENCE OF ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH AND NUTRIENT UPTAKE OF SOME VEGETABLE CROPS*" 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 result of a piece of bona fide research work carried out by ***MD. MOMRAZ ALI, Registration No. 27607/00751,*** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

I further certify that any help or sources of information as has been availed of during the course of this inquire have been duly acknowledged and the contents & style of the thesis have been approved and recommended for submission.

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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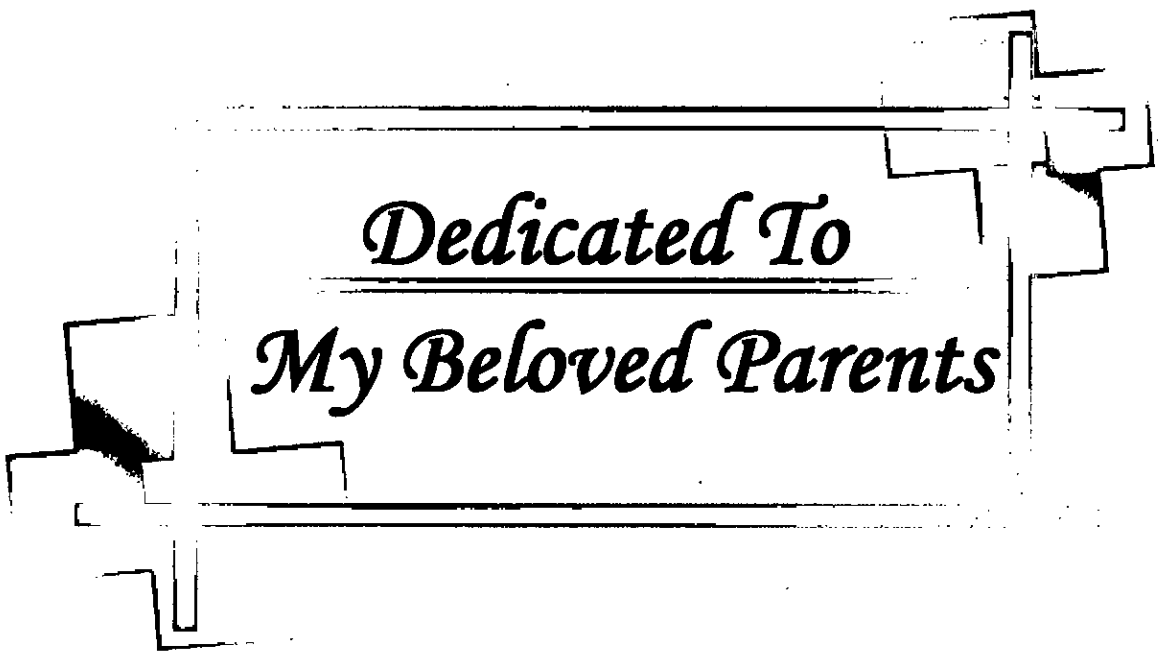
Dedicated To
My Beloved Parents

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The Author

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INFLUENCE OF ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH AND NUTRIENT UPTAKE OF SOME VEGETABLE CROPS

BY

MD. MOMRAZ ALI

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 vegetable crops(Brinjal,Tomato,Chilli,Okra and Data). Significant positive growth response to AM was observed in all the selected vegetables. The seedling emergence, plant height, shoot length and root length of inoculated vegetables were comparatively higher than that of uninoculated control. Mycorrhizal fungi inoculation significantly enhanced disease reduction in all the treatment compared to control plant. In case of Okra the incidence of damping off and foot rot were 10.78% and 6.48% in noninoculated plant whereas 4.52% and 3.24% in inoculated mycorrhizal plant respectively. No leaf spot disease in inoculated plant was found. Mycorrhizal dependency (MD) of the vegetables ranged from 15.58% to 31.38%.Among the vegetable studied the highest mycorrhizal dependency (31.38%) was observed in Brinjal and the lowest MD (15.58%) was observed in Chilli. Okra recorded the second highest MD (26.82%) which was followed by Data (24.79%) and Tomato (18.56 %). N, P, K, Zn and Fe uptake were influenced significantly by the inoculation of AM fungi over control in all the tested vegetables.

Chapter 1

Introduction

INTRODUCTION

Vegetable is a nutritional and culinary term denoting any part of a plant that is commonly consumed by humans as food, but is not regarded as a culinary fruit, nut, herb, or spice. Vegetables constitute a very important group of crops in Bangladesh for their low production cost, short production time and high nutritive value. In 2005-2006 about 191.9 ('000) hectare of land were under vegetable cultivation in Bangladesh and produced 1687.2 ('000) tons of vegetables. Brinjal (*Solanum melongena*), Tomato (*Lycopersicon esculentum* L.), Chilli (*Capsicum frutescens*), Okra (*Abelmoschus esculentus*) and Data (*Amaranthus oleraceus*) are very popular vegetables in our country. It is an important component of cropping systems in south and west Asia. Total areas under cultivation of Brinjal, Tomato, Chilli, Okra and Data are 50.7 thousand ha, 18.8 thousand ha, 142.5 thousand ha, 24.9 thousand ha and 6.8 thousand ha with the annual production of 6.47 tons/ha, 6.98 tons/ha, 1.09 tons/ha, 9.2 tons/ha and 5.83 tons/ha, respectively (BBS, 2007). The country requires a sustainable technology where an agricultural out put can be high as well as minimum residual effects of chemical fertilizer because of per hectare yield of these crops are low and indiscriminate use of fertilizer and pesticides affect our environment.

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. Arbuscular Mycorrhiza (AM) is known to play an important role in promoting and sustaining vegetable productivity even under adverse environmental conditions (Smith and Read, 1997). The external fungal hyphae act as a bridge transporting slow diffusing nutrients like P(phosphorus) more effectively than those of non mycorrhizal ones. They help increase

vegetable production in several ways thorough improvement in nutrient uptake, plant resistance to diseases. They also help in conserving soil productivity for the future. 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 waters relationship (Jastrow *et al.*, 1998).

It has a great opportunity to diversify Arbuscualr mycorrhizal association in various agricultural crops because of the important role played by various vegetable crops in enriching soil fertility (Mridha, 2002). Out of the different types of mycorrhizae, the AM fungi are by far the most widely occurring mycorrhizae and very important in relation to improvement of agricultural and horticultural crops and forest trees in hilly areas (Mridha *et al.*, 2001). The fungus receives sucrose from the plant in exchange for soil solution derived orthophosphate, which is given up by the fungus at the arbuscules in the root cortex (Smith and Gianinajji-pearson, 1998). The AM association can help in higher production of growth regulating substances (Danneberg *et al.*, 1992) and increase plant resistance against pest and diseases (Bethlerfalvay and Linderman, 1992). Arbuscular mycorrhizae increase plant productivity by increasing the rate of photosynthesis (Masri, 1997; Syvertsen and Graham, 1999) and providing protection against toxic metals (Bonifacio *et al.*, 1999). Moreover, it helps in the formation of soil aggregation and aggregate stability (Miller and Jastrow, 1994).

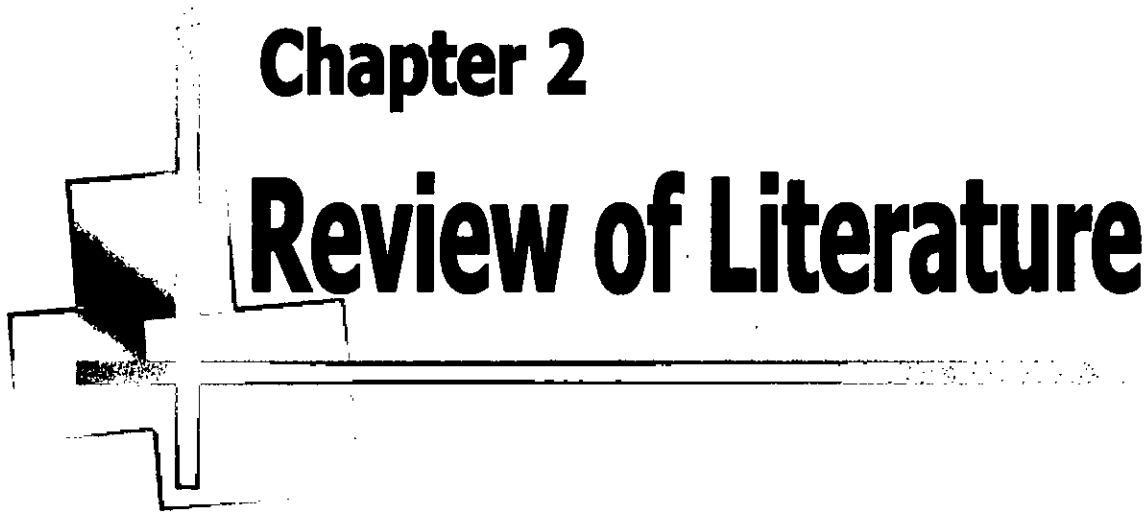
Many researchers have found that VAM (Vesicular Arbuscular Mycorrhiza) can decrease the severity of diseases caused by root pathogenic fungi, bacteria and nematodes. VAM fungi reduced the number of sclrotia produced by *Sclerotium roffsii* while the root pathogen reduced the percentage of root infection and chlamydospore productin by *Glomus mosseae* (Krishna and Bagyaraj, 1983). This fungus suppresses the incidence of wilt caused by *Fusarium oxysporum* (Jalali and Thareja, 1981). 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).

In the tropics many crops are grown in infertile acid soils, where their establishment is frequently limited by low levels of available phosphorus. In such soils, an efficient mycorrhizal association can increase phosphorus uptake and crop yield (Howeler *et al.,* 1987). In addition to enhanced P uptake, VAM fungi often also enhance acquisition of relatively immobile micronutrient cations, particularly Zn and Cu (Lambert *et al.,* 1979; Killham and Firestone, 1983; Gnevow and Marschner, 1989; Swaminathan and Verma, 1983; Gildon and Tinker, 1983 and Pacovsky, 1986). Nutrient uptake was enhanced significantly in soybean shoot by inoculation of AM fungi. The VAM fungai promote phosphorus uptake in low phosphate soil during the early stages of plant growth (Sasai, 1991).

The present study was carried out to evaluate the effect of AM on growth and nutrient uptake ability of vegetables with the following objectives:

1. To evaluate the effect of Arbuscular mycorrhizal (AM) fungus on growth, nutrient uptake and disease suppression of some selected vegetable crops.
2. To determine the effect of Arbuscular mycorrhizal (AM) fungi on yield of some selected vegetable crops.



Chapter 2

Review of Literature

REVIEW OF LITERATURE

The literatures available on VA-mycorrhizal association of different vegetable crops are presented in this chapter.

Krishna and Bagyaraj (1982) reported that mycorrhizal dependency was found to decrease with increase in added soluble P. They also observed that root, shoot and total plant dry weight were significantly greater in mycorrhizal plants than in non-mycorrhizal controls.

Jalali and Chand (1988) found that arbuscular mycorrhizal fungi can increase plant tolerance to salinity (Pond *et al.*, 1984) and it can decrease plant susceptibility to diseases.

Afek *et al.*, (1990) studied the percent root colonization of AM fungi on onion, cotton and capsicum inoculated with *Glomus deserticola, Dlomus intraracices* and *Glomus spp.* They recorded 50%, 37% and 20% colonization after 12 days of inoculation and 60%, 13% and 10% colonization after 21 days of inoculation in onion, cotton and capsicum, respectively. They found that length of time was an important factor for root colonization. Wani and Konde (1996) recorded AM colonization in garlic root ranging from 39 to 62%.

Morton and Benny (1990) reported that arbuscular mycorrhizal fungi colonize or infect the roots of most species of vascular plants except for a few belonging to the families Chenopodiecea, Crucifereae, Cyperaceae, Juncaceae and Caryo-phyllaceae (Richardson *et al.*, 2000; Sramek *et al.*, 2000).

Masri (1997) informed that the AM association contributes to the success of the plant establishment, survival and increasing uptake of water and osmotic adjustment under drought stress.

Rosendahl and Rosendahl (1991) examined the interactions between *Pythium ultimum* and two strains of vesicular-arbuscular mycorrhizal (VAM) fungi (*Glomus* spp.) with Cucumber (*Cucumis sativus* L.) plants.VAM inoculation

before or simultaneous with the inoculation of the pathogen increased survival of the seedlings. Inoculation with *P. ultimum* 14 days after sowing did not kill the plants, but reduced the leaf area. This reduction was almost eliminated by one of the VAM isolates.

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.

Christensen and Jakobsen (1993)conducted on experiment on Cucumber, grown in a partially sterilized sand-soil mixture with the vesicular-arbuscular mycorrhizal (VAM) fungus *Glomus fasciculatum* or left uninoculated. The presence of VAM decreased the rate of bacterial DNA synthesis, decreased the bacterial biomass, and changed the spatial pattern of bacterial growth compared to non-mycorrhizal cucumbers.

Edathii *et al.,* (1994) assessed the VAM status of tomato, brinjal and chilli (Capsicum) during the initial establishment period in natural field conditions and in pot culture using non sterile soil. The soil had a low nutrient status and no manorial application was made during the 60-d study. VAM colonization in roots was maximized at 45, 50 and 60 days after germination of brinjal, tomato and capsicum seeds, respectively under field conditions and on the 60^{th} day in pot culture.

Matsubara *et al.,* (1994) reported the effects of vesicular-arbuscular mycorrhizal fungus (VAMF) inoculation on seedling growth in 17 species of vegetable crops. Growth was noticeably enhanced by VAMF inoculation to roots in Welsh onion, asparagus, pea, celery, and cucumber. The degree of

growth enhancement varied with the host-fungus combination. VAMF inoculation caused both leaf sheaths and leaf blades to thicken in Welsh onion and enhanced the formation of shoots and crowns in asparagus. Fresh weights of shoot and root increased when the plants were inoculated with VAMF. In most vegetables, the increase in fresh weight of roots was caused by an increase of the number of roots, They also reported that mycorrhizal dependency (ratio of total dry weight of 10 VAMF-inoculated plants to total dry weight of 10 non-inoculated plants) was maximum in Liliaceae (Welsh onion and asparagus) among 7 families with VAM fungus infection.

Joner and Jakobsen (1994) investigated the role of arbuscular mycorrhiza (AM) in utilization of P from organic matter during mineralization in soil. Cucumber (*Cucumis sativus L.*) inoculated with one of two AM fungi or left uninoculated were grown for 30 days in cross-shaped PVC pots. The experiment confirms that AM fungi differ in P uptake characteristics, and that mycorrhizal hyphae can intercept some P immobilization by other microorganisms and P-sorbing clay minerals.

Trimble and Knowles (1995) divulged the growth response of greenhouse cucumber (*Cucumis sativus* L.) to infection by vesicular-arbuscular mycorrhizal (VAM) fungi. Plants were highly receptive to colonization by *Glomus mosseae*, *G. dimorphicum* and *G. intraradices*. Growth rates of primary yield components (e.g., stem and leaf dry weights, leaf area) of VAM-infected plants were greater than those of noninfected plants at all levels of P nutrition. The VAM-enhanced growth was similar to that induced by increases in P nutrition.

Sreeramulu *et al.*, (1996) examined the growth of *Amaranthus viridis* and *Trigonella foenuni* in an unsterlized sandy loam soil in response to P fertilizers application (0 or 25, 50 or 100% of the recommended rate of 50 kg P_2O_5/ha) in a pot experiment. They recorded significantly greater higher and leaf number of plants when inoculated with *Glomus fasciculatum*. Inoculated plants also had

significantly higher shoot and root biomass than corresponding uninoculated plants. Shoot weight with 50% of the recommended P rate + AM inoculation was comparable that with 100% of the recommended P rate without mycorrhizal inoculation. Inoculation of AM in *Amaranthus viridis* and *Trigonella foenuni* reduced the P requirement to obtain maximum leaf yields. Phosphorus uptake in both shoot and root was significantly higher in inoculated plants over control.

Sreeramulu *et al.*, (1996) noted a greater number of AM spores with root zones of inoculated *Amaranthus viridis* and *Trigonella foenuni* than that of un-inoculated plants. Mridha *et al.* (1999) recorded spore density in some vegetable crops viz *Amaranthus gangeticus, Coriandrum sativum, Curcubita moschata, Cucumis sativus, Capsicum frutescens* and *Lablab purpureus*. They observed a larger number of spore populations in the rhizosphere zone of these crops.

Tarafdar and Praveen (1996) studied the effect of different vesicular arbuscular mycorrhizal fungi (VAMF) on crops (*Vigna aconitifoli*) under field conditions. Plants growth and nutrient uptake of non-inoculated plants were compared with the growth and nutrient uptake of VAMF-inoculated plants. Percent root infection increased 29-fold in inoculated plants after 8 weeks of growth. At maturity of crop, shoot biomass, N, P, K, Zn and Cu concentration were significantly improved in all cases of inoculated plants.

Eltrop and Marschner (1996) examined on the growth, nitrogen uptake and mineral nutrient concentrations in the plant tissues in non-mycorrhizal and mycorrhizal seedlings grown under controlled condition. The concentrations of N, P, K, Ca and Mg tended to be higher in the smaller mycorrhizal than in the larger non-mycorrhizal plants. A significant increase in mineral nutrient concentration in mycorrhizal compared with non-mycorrhizal plants was found.

Nedumpara and Mercy (1996) studied the Vesicular Arbuscular Mycorrhizal (VAM) association with many vesicular plant species and the contribution of VAM fungi on uptake N, P, K by crop plants. Colonization by VAM fungi significantly enhanced P uptake and plant growth. There was no effect of VAM fungi on plant growth in high P soil. In low P soil the positive effects of VAM fungi on plant growth due to enhanced P uptake were more important than any negative.

Arriola (1997) reported that Arbuscular mycorrhizal root colonization in all the Amaranthaceae species, positively correlated with maximum border cell production. Commercially available forms of the arbuscular mycorrhizal fungus *Glomus intraradices* and *Trichoderma harzianum* investigated as biocontrol agents of *Fusarium oxysporum f. sp. asparagi* inoculated (at high and low concentrations) asparagus. Death rates of biocontrol treated plants were less than half those of plants inoculated only with *F. oxysporum*. Shoot height, weight and number of shoots produced were greater in biocontrol treated plants than in plants inoculated only with *F. oxysporum*.

Osonubi *et al.*, (1998) evaluated the effect of root exudates from non-mycorrhizal and mycorrhizal cucumber (*Cucumis sativus* L.) plants colonized by one of three arbuscular mycorrhizal fungi (*Gigaspora rosea*), *Glomus intraradices* or *Glomus mosseae* on hyphal growth of *G. rosea* and *G. intraradices* in axenic culture and on root colonization by *G. mosseae* in soil. Root exudates from non-mycorrhizal cucumber plants clearly stimulated hyphal growth, whereas root exudates from all mycorrhizal cucumber plants tested showed no stimulation of the hyphal growth of *G. rosea* and only a slight stimulation of the hyphal growth of *G. intraradices*. These results suggest that plants colonized by AM fungi regulate further mycorrhization via their root exudates (Pinior *et al.*, 1999).

Mridha *et al.*, (1999) studied AM colonization in some crops of Bangladesh. They observed high levels of colonization in the members of Leguminosae family and no colonization in Amaranthaceae, Chenopodiaeae and Cruciferae.

Mahmud *et al.*, (1999) studied different agricultural crops of Bangladesh and the relationship with Vesicular Arbuscular Mycorrhizal (VAM) fungi. They identified *Acaulospora, Entrophosphora, Gigaspora, Glomus* and *Scutellospora. Glomus* species were the most common followed by *Gigaspora* and *Scutellospora* in vegetables and rice.

Gaur and Adholeya (2000) carried out an experiment on onion, potato and garlic inoculated with AM fungi. They reported that inoculation response in terms of yield increase was maximized in onion (70%) whereas garlic and potato showed 30% and 48% increases, respectively.

George (2000) worked with the colonization of plant roots by arbuscular mycorrhizal (AM) fungi can greatly affect the plant uptake of mineral nutrients. It may also protect plants from harmful elements in soil. The contribution of AM fungi to plant nutrient uptake is mainly due to the acquisition of nutrients by the extraradical mycorrhizal hyphae. Many mycorrhizal fungi can transport nitrogen, phosphorus, zinc, and copper to the host plant, but other nutrients can also be taken up and translocated by the hyphae. Among the nutrients, phosphorus is often the key element for increased growth or fitness of mycorrhizal plants because phosphorus is transported in hyphae in large amounts compared to the plant phosphorus demand. The evidence for distinct differences between nonmycorrhizal and mycorrhizal plants in the use of non-soluble nutrient sources in soil is contradictory.

Bagayoko *et al.,* (2000) found positive effects of Vesicular Arbuscular Mycorrhizae (VAM) on plant growth in temperate soils. A pot experiment conducted with local genotypes of pearl millet (*Pennisetum glaucum* L.), sorghum (*Sorghum bicolor* L. *Moench*) and cowpea (*Vigna unguiculata*) with and without phosphorus (P) application in a sterilized sandy soil from a

farmer's field in Niger shelved large growth-enhancing effects of VAM. Phosphorus application led to 18- and 24-fold increases in pearl millet root and shoot dry matter independently of VAM, whereas the shout and root dry matter of sorghum and cowpea depended largely on the interaction between P application and VAM. With P, VAM increased total uptake of P, K, Ca, Mg and Zn by 2.5- to 6-fold in sorghum and cowpea. On severely P deficient West African soils P application can lead to large increases in early root growth, a prerequisite for early mycorrhizal infection and a subsequent significant contribution of VAM to enhanced plant growth and nutrient uptake.

Mridha and Xu (2001) studied the genus diversity of AM fungi in some vegetable crops in Bangladesh. They identified *Acaulospora, Entrophosphora* and *Glomus* abundantly. But *Gigaspora* and *Sclerocystis* were poor in number.

Estrada-Luna and Davies (2001) evaluated the effects of a mixed Mexican Arbuscular Mycorrhizal (AM) fungal inoculum (composed of *Glomus albidum, G. diaphanum*, and *G. claroides*) and low phosphate supply on growth and nutrient uptake of micropropagated prickly-pear cactus (*Opuntia albicarpa Scheinvar Reyna*) plantlets. Poorest growth occurred with uninoculated plantlets that lacked supplementary P supply. In contrast, the combination of mycorrhizal colonization and supplementary P significantly increased shoot length, shoot and root DM and surface area of the plantlets. AM fungi enhanced concentration of P and Zn and increased nutrient uptake of P, B and Zn in the cladodes. They conclude that AM fungi can be used as a biotechnological tool that allows more efficient, low P input to enhance ex vitro transplantation of *O. albicarpa*.

Karagiannidis *et al.,* (2002) studied the effect of the arbuscular mycorrhizal fungus (AMF) *Glomus mossecte* and the soil-borne *Verticillium dahliae* and their interaction on root colonization, plant growth and nutrient uptake in eggplant and tomato seedlings grown in pots. Root colonization by the AMF as well as spore formation was higher (34.6 and 30.5%, respectively) in the

eggplant than in tomato. The mycorrhiza treatments increased fresh and dry weight and mean plant height in tomato by 96, 114 and 21% compared to controls. The beneficial effect of the AMF supersedes the pathogenic effect of *V. dahliae*; P and N uptake were higher in mycorrhizal treatments than in controls.

Phiri *et al.,* (2003) found AM root infection in both coarse and fine roots was significantly greater in plants established from plantlets than those established from stakes with differences of 21 and 31%, respectively. Nutrient uptake efficiency (mug of shoot nutrient uptake per in of root length) and use efficiency (g of shoot biomass produced per g of shoot nutrient uptake) for N, P, K, Ca, and Mg were also greater with plants established from plantlets than those established from stakes. Improved nutrient acquisition could be attributed to relief from P stress and possibly uptake of some essential micronutrients resulting from AM association.

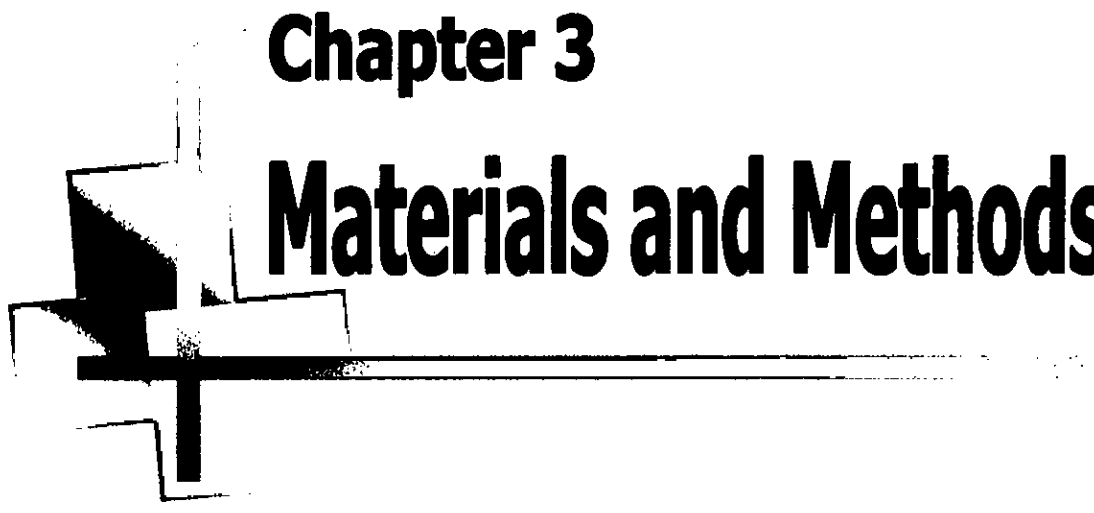
Kubota *et al.*, (2005) studied the colonization by arbuscular mycorrhizal (AM) fungi, investigated in cucumber (*Cucumis sativus*), tomato (*Lycopersicon esculentum*) and *Clethra barbinervis* (Ericales) grown in field-collected soil known from previous studies to generate Paris-type arbuscular mycorrhizae in *C. barbinervis* The morphology of colonization is strongly influenced by the selection of fungi to colonize the host plant from among those in the soil environment.

Giri *et al.,* (2005) evaluated the effect of two Arbuscular Mycorrhizal (AM) fungi, *Glomus fasciculatum* and *G. macrocarpum* on shoot and root dry weights and nutrient content of *Cassia siamea* in a semi-arid wasteland soil. Under nursery conditions, mycorrhizal inoculation improved growth of seedlings. Root and shoot dry weights were higher in mycorrhizal than non-mycorrhizal plants. The concentration of P, K, Cu, Zn and Na was significantly higher in AM inoculated seedlings than in non-inoculated seedlings. Mycorrhization led to decrease in alkalinity of the rhizosphere soil from pH 8.5

to 7.4. On transplantation to the field, the survival rate of mycorrhizal seedlings (75%-90%) was higher than that of non-mycorrhizal seedlings (40%). AM inoculation improved the growth performance of seedlings in terms of height and stem diameter. Among the two AM fungi used, the efficiency of *Glomus macrocarpum* was higher than that of *G. fasciculatum* under both nursery and field conditions.

Srivastava *et al.*, (2007) examined the effect of arbuscular mycorrhizal fungi (AMF) and pseudomonads as the microbial inoculants in vegetable based cropping systems under organic farming practices. A significant increase in yield was observed in the inoculated plots over the control. The mycorrhizal inoculation followed by combination of AMF and pseudomonads proved to be better. Present findings indicated that microbial gene pool especially the key helpers for the maintenance of soil health residing in the vicinity of roots, was positively affected by using pseudomonads and AMF.

Arifunnahar (2007) carried out an experiment on role of arbuscular mycorrhizal fungi on growth and nutrient uptake of some vegetable crops. A positive growth response to AM was observed in all the selected vegetables. Increased nutrient (N, P, K, Fe and Zn) uptake was recorded with the inoculated plants. Among the inoculated vegetables comparatively higher N, P and K nutrient uptake was observed in Spinach, Water spinach/ Kalmishak and Cucumber respectively; whereas Zn in Spinach, and Fe in Cucumber.



Chapter 3

Materials and Methods

MATERIALS AND METHODS

3.1 Experimental site

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

3.2 Experimental period

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

3.3 Selection of crops

Different important available vegetable crops were selected for the experiment which grown in different areas of Bangladesh to assess their dependency to AM. The list of the crops included in the experiment is given below.

List of the crops included in the present experiment

Common Name	**Scientific name**	**Family**
Okra	*Abelmoschus esculentus*	Malvaceae
Tomato	*Lycopersicon esculentum*	Solanaceae
Brinjal	*Solanum melongena*	Solanaceae
Chilli	*Capsicum frutescens*	Solanaceae
Data	*Amaranthus oleraceus*	Amaranthaceae

3.4 Collection of roots for mycorrhizal assessment

For conducting the experiment inoculum of Mycorrhizal fungi from natural condition were used. In this condition, a survey programme was conducted in the Agronomy farm of Sher-e-Bangla Agricultural University in May 2006. Root samples of 21 plants species (both crops and weeds) growing under natural condition at a depth of 0 to 15 cm in different places of the Agronomy field were collected for the observation of occurrence of vesicular arbuscular mycorrhizal (VAM) association with the root systems. The list of the plants collected for inoculum preparation is given below.

List of plants

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

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 Cleaning of roots

Collected roots were freed from adhering soil, gently washed with water and fine roots were cut into small segments of approximately 1 cm for determine of percentage of VAM root colonization. For these only 100 segments were randomly selected for staining. The root segments were then preserved in screw cup test tubes with 50% ethanol for future use.

3.6 Staining of roots

According to Koske and Gemma (1989) the roots of each plant species were stained with some modifications (Mridha *et al.*, 1999). The root pieces were boiled in 2.5% KOH solution for 30 minutes at 90 ° C temperatures. 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.

3.7 Mycorrhizal assessment

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 *either* alone 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.

3.8 Collection of soils

For the experiments 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.

3.9 Collection of seeds

For experimental purposes seeds of five different vegetable crops namely Okra, Tomato, Brinjal, Chilli and Data were collected from Bangladesh Agricultural Research Institute (BARI) during March-April 2006.

3.10 Preparation of inoculum

Cassia tora roots were collected from Agronomy field along with rhizosphere soil for inoculum. 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 15 minutes and used it as base materials for control pots.

3.11 Preparation of seedling bags

The polythene bags of 8"×12" size were bought from the market which has the capacity to fill 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. 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 seeds were sown. 200 polythene bags (10 × 2 × 10) were prepared for ten crops in the present study.

3.12 Sowing of seeds

Each bag was considered one replication. There were ten replications for each vegetable and same numbers of seeds were sown in each bag. For Okra 5 seeds/bag, Tomato 30 seeds/bag, Brinjal 30 seeds/bag, Chilli 20 seeds/bag and Data 20 seeds/bag was sown. After 15 days, 5 seedlings in each bag were left 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.

3.13 Intercultural operation

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

3.14 Harvesting

The seedlings were harvested when those were 40 DAS and 60 DAS old. In this case 3 seedlings from inoculated bag and 3 seedlings from non-inoculated bag were harvested randomly for each crop. Shoots and roots of 5 different crops were collected. 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.

3.15 Data recording

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 leaves and branches plant^{-1}, number of flowers plant^{-1} and disease incidence.

3.16 Mycorrhizal dependency (MD)

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

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

3.17 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 placed 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:

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

3.18 Nutrient analysis

3.18.1 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 desiccators for chemical analysis.

3.18.2 Sample analysis

3.18.2.1 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.

3.18.2.2 Total Nitrogen

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

3.18.2.3 Total phosphorus and potassium

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

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).

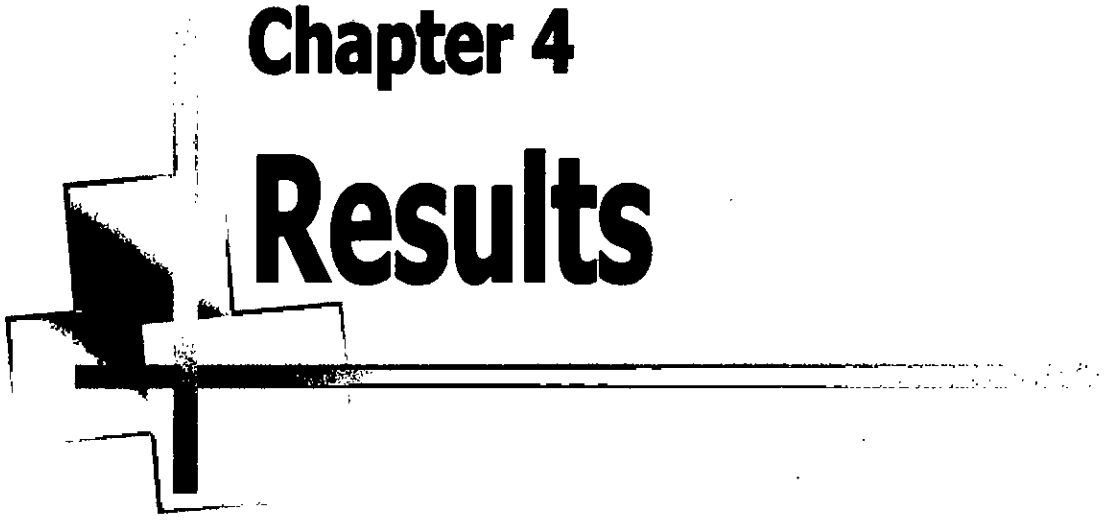
Nutrient uptake was calculated by using the following formula:

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

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

3.19 Statistical analysis

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



Chapter 4
Results

RESULTS

4.1. BRINJAL (*Solanum melongena*)

Seedling emergence

The influence of inoculation of Arbuscular Mycorrhizal (AM) fungi on seedling emergence of Brinjal is presented in Table 1. The seedling emergences were recorded in three different times. Significantly the higher seedling emergence was found in case of inoculated treatment than non-inoculated. The per cent seedling emergences increased over control in mycorrhizal treated pots was 20.38, 19.75 and 51.15 at 7, 10 and 15 days after sowing, respectively. The highest seedling emergence was 70.67% in mycorrhiza treated pot at 15 days after sowing and the lowest (52.33%) was counted in control condition at 7days after sowing.

Plant height

Influence of AM inoculation on plant height of Brinjal seedlings are shown in table 2. It was observed from the table that the plant height was increased both mycorrhizal inoculated and non inoculated plants with the increase of growth period. In both the cases, at 1st 20 days (20 DAS) and 2nd 20 days (20 to 40 DAS) after sowing the growth increment was higher than the 3rd 20 days (40 to 60 DAS) and the rate of growth was also higher in 1st and 2nd 20 days. The percent plant height increased over control in mycorrhiza inoculated pots was 19.85, 9.54 and 18.23 at 20, 40 and 60 days after sowing, respectively.

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

Treatments	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	52.33b	55.67b	58.33b	-	-	-
Inoculated (Mycorrhiza)	63.00a	66.67a	70.67a	20.38	19.75	51.15

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

Table 2. Influence of AMF inoculation on plant height of Brinjal at different growth stages

Treatments	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	8.06b	23.79b	42.66b	-	-	-
Inoculated (Mycorrhiza)	9.66a	26.06a	50.44a	19.85	9.54	18.23

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

Root growth

The root length of mycorrhizal plants in both harvested period (40 and 60 days) was significantly higher in compassion to non mycorrhizal plants (Table 3). 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. With the increase of growth period, the root weight was increased in treated plant, but the percent

root weight increased over control in mycorrhizal plant was 13.11, 66.91(Fresh) and 21.35, 33.33(Dry) after 40 and 60 days sowing, respectively.

Shoot growth

Shoot length and shoot weight (Fresh and dry) of Brinjal is presented in Table 4. Mycorrhizal inoculation significantly enhanced plant shoot length in comparison to non inoculated plant. The percent shoot weight increased over control in mycorrhizal plants was 183.15, 95.59 (Fresh) and 184.67, 78.22 (Dry) after 40 and 60 days sowing, respectively. Some variation in shoot length of Brinjal always was found in every growth period and maximum variation (7.78 cm) was found at 60 days after sowing between mycorrhizal and non mycorrhizal plant.

Table 3. Influence of AMF inoculation on root growth of Brinjal at different growth stages

Treatments	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)	16.38b	22.77b	3.28b	2.66b	0.89b	0.81b	-	-	-	-
Inoculated (Mycorrhiza)	19.67a	28.1a	3.71a	4.44a	1.08a	1.08a	13.11	66.91	21.35	33.33

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

Table 4. Influence of AMF inoculation on shoot growth of Brinjal at different growth stages

Treatments	Shoot length (cm)		Shoot weight (g)				% Shoot weight increased ov control			
			Fresh		Dry		Fresh		Dry	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DA
Non-inoculated (Control)	23.79b	42.66b	6.71b	9.77b	1.37b	2.25b	-	-	-	-
Inoculated (Mycorrhiza)	26.06a	50.44a	19.00a	19.11a	3.90a	4.01a	183.15	95.59	184.67	78.

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

Disease suppression

Inoculation of pot grown Brinjal plants with VA mycorrhizal fungi reduce by the incidence of diseases are presented in Table 5. The root rot disease incidence was 5.70% in non inoculated and 2.50% in inoculated mycorrhizal plants. Damping off disease was 10.05% in control plants, but in inoculated plant, it was only 2.00%. The disease incidence was always significantly higher in uninoculated control plant in compare to inoculated mycorrhizal plant.

Table 5. Effect of AMF inoculation of Brinjal on incidence of different diseases at seedling stage

Treatments	Infected plant (%)	
	Root rot	Damping off
Noninoculated (Control)	5.70a	10.05a
Inoculated (Mycorrhiza)	2.50b	2.00b

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

Number of leaf/ shoot

It was observed that the number of leaf per shoot of inoculated mycorrhizal plant is more than the non inoculated control 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 vegetable crops have an obligate nutritional dependency. The mycorrhizal dependency of Brinjal was 31.38%.

Root colonization

The highest percent root colonization 41.25 of mycorrhiza inoculated plants was recorded at 60 DAS and lowest 20.74 at 20 DAS. On the other hand no root colonization was found in untreated control plants.

Nutrient uptake

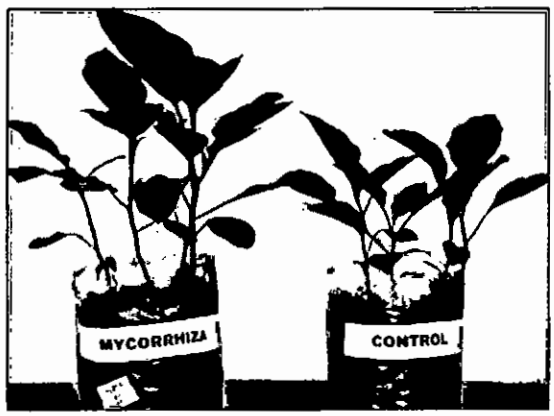
The response to nutrients uptake (N, P, K, Zn and Fe) by Brinjal are presented in Table 6. It is evident from the study that mycorrrhizal inoculation significantly enhanced nutrient uptake in shoot with comparison to control plant. The results of the study indicate that the percent nutrient uptake

increased over control for N, P, K, Zn and Fe were 32.92%, 26.66%, 12.67% 57.14% and 31.5%, respectively. The highest percent increased was obtained with Zn which was followed by N, Fe, P and the lowest was found with K.

Table 6. Effect of AMF inoculation on nutrient uptake by Brinjal shoots

Treatments	Nutrient uptake by shoot				
	Total N (%)	P (%)	K (%)	Zn (%)	Fe (%)
Non-inoculated (Control)	0.82b	0.30b	2.13b	0.007b	0.019b
Inoculated (Mycorrhiza)	1.09a	0.38a	2.40a	0.011a	0.025a
%Increased over control	32.92	26.66	12.67	57.14	31.5

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



A B

Fig.1. Influence of Mycorrhizal fungi inoculation on growth of Brinjal

A = Mycorrhiza inoculated plants

B = Untreated (control) plants

4.2. TOMATO (*Lycopersicon esculentum*)

Seedling emergence

The influence of inoculation of Arbuscular mycorrhizal fungi on seedling emergence of Tomatois presented in Table 7. The seedling emergences were calculated in three different times. With the advancement of time the seedling emergence increased in both treatments.Significantly higher seedling emergence was found in case of inoculated Tomato. The percent seedling emergence increased over control in mycorrhizal treated pot was 16.46, 45.45 and 4.47 at 7, 10 and 15 days after sowing, respectively. The highest seedling emergence was 70% in mycorrhiza treated pot at 15 days after sowing and the lowest (56.67%) was counted in control condition at 7days after sowing.

Plant height

The trend of overall increment of plant height of Tomato among different period of growth for both mycorrhizal and non mycorrhizal plants were more or less similar (Table 8). In both the cases, at first 20 days (20 DAS) and 3rd 20 days (40 to 60 days) after sowing, the growth increment were higher and the rate of growth was also higher at 1st and 3rd 20 days also. In case of percent growth increment for mycorrhizal and non mycorrhizal plant it was observed that the increment was minimum (113.97% in inoculated and 107.87% in non-inoculated) in 3rd 20 days (40 to 60 days) and it was maximum (48.77% in inoculated and 41.57% non inoculated) in 2nd 20 days (20 to 40 days).The percent plant height increased over control in mycorrhiza inoculated pots was 20.36, 23.89 and 19.10 at 20, 40 and 60 days after sowing, respectively.

Table 7. Influence of Arbuscular Mycorrhizal Fungi (AMF) inoculation on seedling emergence (%) of Tomato at different periods

Treatments	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	56.67b	66.00b	67.00b	----	----	----
Inoculated (Mycorrhiza)	66.00a	69.00a	70.00a	16.46	45.45	4.47

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

Table 8. Influence of AMF inoculation on plant height of Tomato at different growth stages

Treatments	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	14.09b	29.29b	45.33b	----	----	----
Inoculated (Mycorrhiza)	16.96a	36.29a	53.99a	20.36	23.89	19.10

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

Root growth

Root length and root weight (Fresh and dry) of Tomato is presented in Table 9. The root length of mycorrhizal plants in both harvested period (40 days and 60 days) was higher in comparison to non mycorrhizal plants. In case of AM inoculation, the root weight of Tomato was significantly higher than the non

inoculated plants. The percent root weight increased over control in mycorrhizal plant was 3.43, 53.33 (Fresh) and 60.00, 2.5 (dry) after 40 and 60 days of sowing, respectively.

Shoot growth

Influence of AM inoculation on shoot growth of Tomato harvested at different periods has been shown in Table 10. In every growth period the shoot weight and shoot length were always higher in inoculated plants than in non inoculated plants. Among the mycorrhizal plants the rate of shoot length increment in 20 days duration (40 to 60 days) was less (48.77%) in comparison to non mycorrhizal plants (54.81%).The percent shoot weight increased over control in mycorrhizal plant was 21.43, 20.83 (Fresh) and 39.22, 41.08 (dry) after 40 and 60 days sowing, respectively.

Table 9. Influence of AMF inoculation on root growth of Tomato at different growth stages

Treatments	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)	9.08b	17.88b	2.33b	2.70b	0.50b	0.80b	----	----	----	----
Inoculated (Mycorrhiza)	10.06a	18.88a	2.41a	4.14a	0.80a	0.82a	3.43	53.33	60.00	2.5

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

Table 10. Influence of AMF inoculation on shoot growth of Tomato at different growth stages

Treatments	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)	29.29b	45.33b	9.33b	9.60b	1.81b	1.85b	----	----	----	----
Inoculated (Mycorrhiza)	36.29a	53.99a	11.33a	11.60a	2.52a	2.61a	21.43	20.83	39.22	41.08

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

Number of leaf/ shoot

It was observed that the number of leaf per shoot of inoculated mycorrhizal plant is more than the non inoculated control 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 vegetable crops have an obligate nutritional dependency. The mycorrhizal dependency of Tomato was 18.56%.

Root colonization

The highest percent root colonization 32.88 of mycorrhiza inoculated plants was recorded at 60 DAS and lowest 17.84 at 20 DAS. On the other hand no root colonization was found in untreated control plants.

mycorrhizal inoculated and non inoculated plants. In both the cases, at 1st 20 days (20 DAS) and 2nd 20 days (20 to 40 DAS) after sowing the growth increment was lower than the 3rd 20 days (40 to 60 DAS) and the rate of growth was also lower 1st and 2nd 20 days. The percent plant height increased over control in mycorrhiza inoculated pots were 14.90, 22.04 and 13.41 at 20, 40 and 60 days after sowing, respectively.

Table 12. Influence of Arbuscular Mycorrhizal Fungi (AMF) inoculation on seedling emergence (%) of Chilli at different periods

Treatments	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	52.00b	58.50b	60.50b	----	----	----
Inoculated (Mycorrhiza)	56.50a	66.50a	71.00a	8.65	13.67	17.35

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

Table 13. Influence of AMF inoculation on plant height of Chilli at different growth stages

Treatments	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	15.63b	29.48b	41.44b	----	----	----
Inoculated (Mycorrhiza)	17.96a	35.98a	47.00a	14.90	22.04	13.41

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

Root growth

Influence of AMF inoculation on root growth is presented in Table 14. The root length of mycorrhizal plants in both harvested period (40 and 60 days) was significantly higher in compassion 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. With the increase of growth period, the root weight was increased in treated plant and in control plant, but the activity of mycorrhiza is reduced due to the effect of continuous flooded condition. The percent root weight increased over control in mycorrhizal plant was 12.27, 8.27 (Fresh) and 40, 33.33 (Dry) after 40 and 60 days sowing, respectively.

Shoot growth

Shoot length and shoot weight (Fresh and dry) of Chilli is presented in Table 15. Mycorrhizal inoculation significantly enhanced plant shoot length in comparison to non inoculated plant. Among the mycorrhizal plant, the rate of shoot weight in 20 days duration (40 to 60 days) was lower (18.52%) in comparison to non mycorrhizal plant (102.88%).Because the activity of mycorrhiza is reduced due to continuous flooded condition. The percent shoot weight increased over control in mycorrhizal plants was 116.34, 26.38 (Fresh) and 148.93, 4.93 (Dry) at 40 and 60 days after sowing, respectively. Some variation in shoot length of Chilli always was found in every growth period and maximum variation (6.5 cm) was found at 40 days after sowing between mycorrhizal and non mycorrhizal plant.

Table 14. Influence of AMF inoculation on root growth of Chilli at different growth stages

Treatments	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)	11.85b	18.67b	1.21b	1.33b	0.125b	0.45b	----	----	----	----
Inoculated (Mycorrhiza)	12.08a	18.77a	2.75a	1.44a	0.175a	0.60a	12.27	8.27	40	33.33

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

Table 15. Influence of AM inoculation on shoot growth of Chilli at different growth stages

Treatments	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)	29.48 b	41.44 b	3.12b	6.33b	0.47 b	1.62 b	---	----	----	----
Inoculated (Mycorrhiza)	35.98a	47.00 a	6.75a	8.00a	1.17a	1.70a	116.34	26.38	148.93	4.93

In a column means followed by a letter not common are 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 vegetable crops have an obligate nutritional dependency. The mycorrhizal dependency of Chilli was 15.58%.

Root colonization

The highest percent root colonization 38.12 of mycorrhiza inoculated plants was recorded at 60 DAS and lowest 17.65 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, Zn and Fe) by Chilli are presented in Table 16. It is evident from the study that mycorrrhizal inoculation significantly enhanced nutrient uptake in shoot with comparison to control plant. The results of the study indicate that the percent nutrient uptake increased over control for N, P and K is 12%, 3.33% and 7.4%, respectively. The highest percent increased was obtained with Fe which was followed by Zn and N whereas the lowest was obtained with P.

Table 16. Effect of AM inoculation on nutrient uptake by Chilli shoots

Treatments	Nutrient uptake by shoot				
	Total N (%)	P (%)	K (%)	Zn (%)	Fe (%)
Non-inoculated (Control)	1.75b	0.30b	2.70b	0.014b	0.017b
Inoculated (Mycorrhizal)	1.96a	0.31a	2.90a	0.019a	0.028a
% Increased over control	12	3.33	7.40	35.71	64.70

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

A B

Fig.3. Influence of Mycorrhizal fungi inoculation on growth of Chilli

A = Mycorrhiza inoculated plants

B = Untreated (control) plants

4.4. Okra (*Abelmoschus esculentus*)

Seedling emergence

The influence of inoculation of Arbuscular mycorrhizal fungi on seedling emergence of Okra is presented in Table 17. The seedling emergence were calculated in three different times. With the past of time the seedling emergence increased in both treatments. Significantly higher seedling emergence was found in case of inoculated Okra than non-inoculated. The percent seedling emergence increased over control in mycorrhizal treated pot were13.79, 17.64 and 23.52 at 7, 10 and 15 days after sowing, respectively. The highest seedling emergence was 84 % in mycorrhiza treated pot at 15 days after sowing and the lowest seedling (58%) was counted in control condition at 7days after sowing.

Plant height

The trend of overall increment of plant height of Okra in different period of growth for both mycorrhizal and non mycorrhizal plants was more or less similar (Table 18). In both the cases, at first 20 days (20 DAS) and 2nd 20 days (20 to 40 days) after sowing, the growth increment were higher and the rate of growth was also higher at 1st and 2nd 20 days also. In case of percent growth increment for mycorrhizal and non mycorrhizal plant it was observed that the increase was minimum (20.69% in inoculated and 17.52% in non-inoculated) in 3rd 20 days (40 to 60 days) and it was maximum (100.95% in inoculated and 95.43% non-inoculated) in 2nd 20 days (20 to 40 days). The percent plant height increased over control in mycorrhiza inoculated pot was 6.09, 9.09 and 12.03 at 20, 40 and 60 days after sowing, respectively.

Table 17. Influence of Arbuscular Mycorrhizal Fungi (AMF) inoculation on seedling emergence (%) of Okra at different periods

Treatments	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	58b	68b	68b	----	----	----
Inoculated (Mycorrhiza)	66a	80a	84a	13.79	17.64	23.52

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

Table 18. Influence of AMF inoculation on plant height of Okra at different growth stages

Treatments	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	38.53b	75.30b	88.50b	----	----	----
Inoculated (Mycorrhiza)	40.88a	82.15a	99.15a	6.09	9.09	12.03

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

Root growth

Root length and root weight (Fresh and dry) of Okra is presented in Table 19. The root length of mycorrhizal plants in both harvested period (40 days and 60 days) was significantly higher in comparison to non mycorrhizal plants. In case of AM inoculation, the root weight of Okra was significantly higher than the non inoculated plants. The percent root weight increased over control in mycorrhizal plant was 21, 13.66 (Fresh) and 50.00, 2.46 (dry) after 40 and 60 days of sowing, respectively.

Shoot growth

Influence of AM inoculation on shoot growth of Okra harvested at different periods has been shown in Table 20. In every growth period the shoot weight and shoot length were always higher in inoculated plants than in non inoculated plants. Among the mycorrhizal plants the rate of shoot length increment in 20 days duration (40 to 60 days) was more (20.69%) in comparison to non mycorrhizal plants (17.52%). The percent shoot weight increased over control in mycorrhizal plant was 18.62, 17.25 (Fresh) and 3.73, 46.91 (dry) after 40 and 60 days sowing, respectively.

Table 19. Influence of AMF inoculation on root growth of Okra at different growth stages

Treatments	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	36.58bb	2.00b	3.66b	0.30b	0.81b	----	----	----	----
Inoculated (Mycorrhiza)	31.16a	46.88a	2.42a	4.16a	0.45a	0.83a	21	13.66	50	2.46

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

Table20. Influence of AMF inoculation on shoot growth of Okra at different growth stages

Treatments	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)	75.30b	88.50b	25.50b	27.00b	4.82b	4.05b	----	----	----	----
Inoculated (Mycorrhiza)	82.15a	99.15a	30.25a	31.66a	5.00a	5.95a	18.62	17.25	3.73	46.91

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

Disease suppression

Inoculation of pot grown Okra plants with VA mycorrhizal plants resulted by the endophyte by the accompany reduction in the incidence of diseases are presented in Table 21. The damping off disease incidence was 10.78% in non inoculated and 4.52% in inoculated mycorrhizal plants. Leaf spot disease was 4.88% in control plants, but in inoculated plant, there was no leaf spot disease in inoculated plant. Root rot disease was 6.48% in control plant and 3.24% in treated plant. The disease incidence was always significantly higher in uninoculated control plant in compare to inoculated mycorrhizal plant.

Table 21. Effect of AMF inoculation of Okra in suppression of different diseases at seedling stage

Treatments	Infected plant (%)		
	Foot rot	Damping off	Mosaic
Noninoculated (Control)	6.48a	10.78a	4.88a
Inoculated (Mycorrhiza)	3.24b	4.52b	3.50b

In a column means followed by a letter not common are 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 vegetable crops have an obligate nutritional dependency. The mycorrhizal dependency of Okra was 26.82%.

Root colonization

The highest percent root colonization 50.64 of mycorrhiza inoculated plants was recorded at 60 DAS and lowest 32.42 at 20 DAS. On the other hand no root colonization was found in untreated control plants.

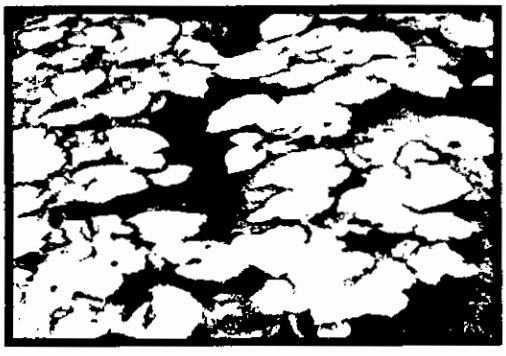
Nutrient Uptake

Mycorrhizal inoculation significantly enhanced nutrient uptake (N, P, K, Zn and Fe) compared to control in Okra plants (Table 22). The percent nutrient uptake increased over control for N, P, K, Zn and Fe was 22.97%, 15.00%, 50.00%, 88.88% and 31.25, respectively. The maximum nutrient uptake increased in inoculated plant was recorded Zn (88.88%) and the minimum was P (15.00%).

Table 22. Effect of AMF inoculation on nutrient uptake by Okra shoots

Treatments	Nutrient uptake by shoot				
	Total N (%)	P (%)	K (%)	Zn (%)	Fe (%)
Non-inoculated (Control)	0.74b	0.40b	1.60b	0.009b	0.016b
Inoculated (Mycorrhizal)	0.91a	0.46a	2.40a	0.017a	0.021a
%Increased over control	22.97	15.00	50.00	88.88	31.25

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



A B

Fig.4. Influence of Mycorrhizal fungi inoculation on growth of Okra

A = Untreated (control) plants Mycorrhiza inoculated plants

B = Mycorrhiza inoculated plants

4.5. DATA (*Amaranthus oleraceus*)

Seedling emergence

The influence of inoculation of Arbuscular mycorrhizal fungi on seedling emergence of Data is presented in Table 23. The seedling emergences were calculated in three different times. With the elapse of time the seedling emergence increased in both treatments. Significantly higher seedling emergence was found in case of inoculated Data than non-inoculated. The percent seedling emergence increased over control in mycorrhizal treated pot where 10.68, 9.58and 7.64 at 7, 10 and 15 days after sowing, respectively. The highest seedling emergence was 85.50% in mycorrhiza treated pot at 15 days after sowing and the lowest (65.5%) was counted in control condition at 7days after sowing.

Plant height

Table 24 showed the effect of Arbuscular mycorrhizal fungi on plant height of Data. With the increase of growth period, the plant height was increased both mycorrhizal inoculated and non inoculated plants. In both the cases, at 1st 20 days (20 DAS) and 3rd 20 days (40 to 60 DAS) after sowing the growth increment was higher than the 2nd 20 days (20 to 40 DAS) and the rate of growth was also higher 1st and 3rd 20 days. The percent plant height increased over control in mycorrhiza inoculated pots was 10.68, 9.58and 7.64 at 20, 40 and 60 days after sowing, respectively.

Table 23. Influence of Arbuscular Mycorrhizal Fungi (AMF) inoculation on seedling emergence (%) of Data at different periods

Treatments	Seedling emergence (%)			% Increased over control		
	7 DAS	10 DAS	15 DAS	7 DAS	10 DAS	15 DAS
Non-inoculated (Control)	65.5b	73.00b	78.5b	----	----	----
Inoculated (Mycorrhiza)	72.5a	80.00a	85.50a	10.68	9.58	7.64

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

Table 24. Influence of AMF inoculation on plant height of Data at different growth stages

Treatments	Plant height (cm)			% Increased over control		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Non-inoculated (Control)	22.00b	50.64b	57.10b	----	----	----
Inoculated (Mycorrhiza)	27.56a	57.56a	63.66a	25.77	14.25	11.48

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

Root growth

Influence of AM inoculation on root growth is presented in Table 25. The root length of mycorrhizal plants in both harvested period (40 and 60 days) was significantly higher in compassion to non mycorrhizal plants. It was also observed that the rate of root length increment at 60 days after sowing was higher than in 40 days after sowing in both treatments, respectively. With the increase of growth period, the root weight was increased in treated plant and control plant, but the percent root weight increased over control in mycorrhizal plant was 71.98, 6.77 (Fresh) and 52.63, 17.5 (Dry) after 40 and 60 days sowing, respectively.

Shoot growth

Shoot length and shoot weight (Fresh and dry) of Data is presented in Table 26. Mycorrhizal inoculation significantly enhanced plant shoot length in comparison to non inoculated plant. Among the mycorrhizal plant, the rate of shoot weight increment in 20 days duration (40 to 60 days) was lower (6.25%) in comparison to non mycorrhizal plant (60.06%). The percent shoot weight increased over control in mycorrhizal plants was 71.98, 6.77 (Fresh) and 52.63, 17.5 (Dry) after 40 and 60 days sowing, respectively. Some variation in shoot length of Data always was found in every growth period and maximum variations (6.56 and 6.46 cm) were found at 40 days after sowing between mycorrhizal and non mycorrhizal plant.

Table 25. Influence of AMF inoculation on root growth of Data at different growth stages

Treatments	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)	17.67b	27.33b	3.57b	4.28b	0.57b	0.80b	----	----	----	----
Inoculated (Mycorrhiza)	18.92a	27.77a	6.14a	4.57a	0.87a	0.94a	71.98	6.77	52.63	17.5

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

Table 26. Influence of AMF inoculation on shoot growth of Data at different growth stages

Treatments	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)	50.64b	57.10b	15.1b	24.17b	1.62b	4.28b	----	----	----	----
Inoculated (Mycorrhiza)	57.86a	63.66a	31.85a	33.85a	3.32a	4.42a	110.9	40.04	64.77	3.27

In a column means followed by a letter not common are 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 vegetable crops have an obligate nutritional dependency. The mycorrhizal dependency of Data was 24.79%.

Root colonization

The highest percent root colonization 42.00 of mycorrhiza inoculated plants was recorded at 60 DAS and lowest 24.00 at 20 DAS. On the other hand no root colonization was found in untreated control plants.

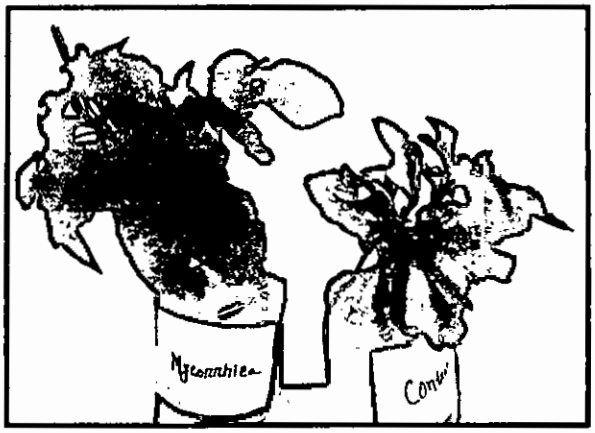
Nutrient uptake

Inoculation of arbuscular mycorrhizal fungi responsed to nutrients uptake (N, P, K, Zn and Fe) by Data are presented in Table 27. It is evident from the study that mycorrrhizal inoculation significantly enhanced nutrient uptake in shoot with comparison to control plant. The results of the study indicate that the percent nutrient uptake increased over control for N, P, K, Zn and Fe were 5.69%, 20%, 22.58%, 190.90% and 112.5%, respectively. The highest percent increased was obtained with Zn which was followed by Fe, K, P and the lowest was found with N.

Table 27. Effect of AMF inoculation on nutrient uptake by Data shoots

Treatments	Nutrient uptake by shoot				
	Total N (%)	P (%)	K (%)	Zn (%)	Fe (%)
Non-inoculated (Control)	1.23b	0.40b	3.10b	0.011b	0.016b
Inoculated (Mycorrhiza)	1.30a	0.48a	3.80a	0.032a	0.034a
%Increased over control	5.69	20	22.58	190.90	112.5

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

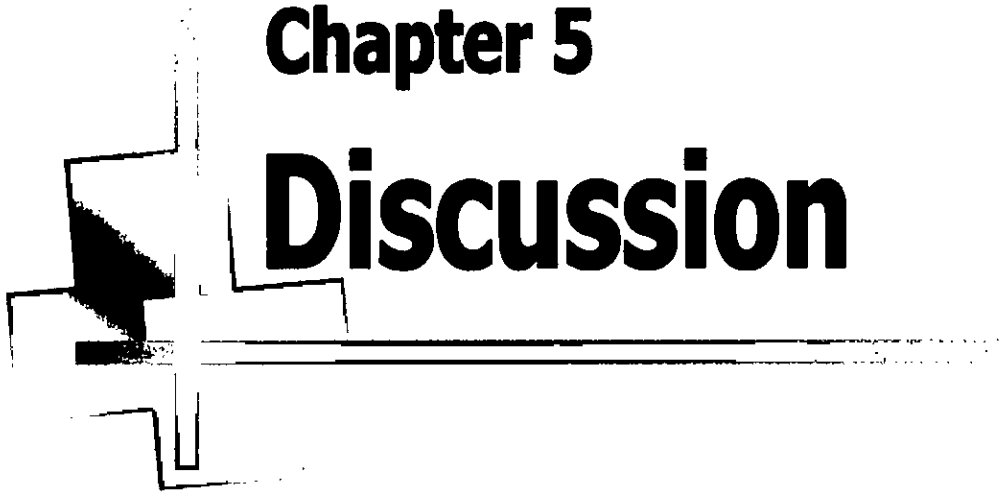


A B

Fig.5. Influence of Mycorrhizal fungi inoculation on growth of Data

A = Mycorrhiza inoculated plants

B = Untreated (control) plants



Chapter 5
Discussion

DISCUSSION

Vegetables constitute a very important group of crops in Bangladesh for their low production cost, short production time and high nutritive value. As Bangladesh is one of the most densely populated countries in the world, it is essential to improve crop production for the burgeoning population and to meet the increasing demands for food. Least-expensive and technologically simple methodologies should be developed for immediate benefit of crop production. 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 technology as a low imputes and nature farming technique can be one of the alternatives to improve crop production, farm profitability and environmental quality (Mridha *et al.*, 1991). The present experiment has been carried out to determine the role of AM fungi on growth and nutrient uptake of five vegetables namely Brinjal, Tomato, Okra, Chilli and Data.

The results of seedling emergence of inoculated pots were increased over control in all the selected vegetable crops. Data (*Amaranthus oleraceus.*) performed the highest seedling emergence which was followed by Okra (*Abelmoschus esculentus*), Chilli (*Capsicum frutescens*), Brinjal (*Solanum melongena*) and the lowest was recorded with Tomato (*Lycopersicon esculentum*).

Influence of AM inoculation on physical growth of five vegetable namely brinjal, tomato, chilli, okra and data 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 vegetable over uninoculated control plant. Between the treatments arbuscular mycorrhizal inoculated tomato showed the highest increase of plant height. The present findings are well supported by Venkateswarlu *et al.* (1995) who reported similar results in plant height of groundnut. They reported that mycorrhizal plants were significantly taller than nonmycorrhizal plants at the final harvested time (14 weeks).

In all the inoculated plants species, higher root length, fresh and dry weight of roots was found. This was probably due to uptake of nutrient, which increased vegetative growth. Comparatively higher root lengths were recorded in inoculated plants Inoculated plants had significantly higher root biomass than corresponding uninoculated plants (Sreeramulu *et al.*, 1996). In inoculated plant, the highest per cent increased of root weight over control were 66.91% in Brinjal, 60.00% in Tomato, 52.62% in Data 50.00% in Okra and 33.33% in Chilli at 40 and 60 days after sowing, respectively. The present findings are supported by Gaur and Adholeya (2000) who reported the higher growth with mycorrhizal inoculation in some other agricultural crops such as onion, potato and garlic.

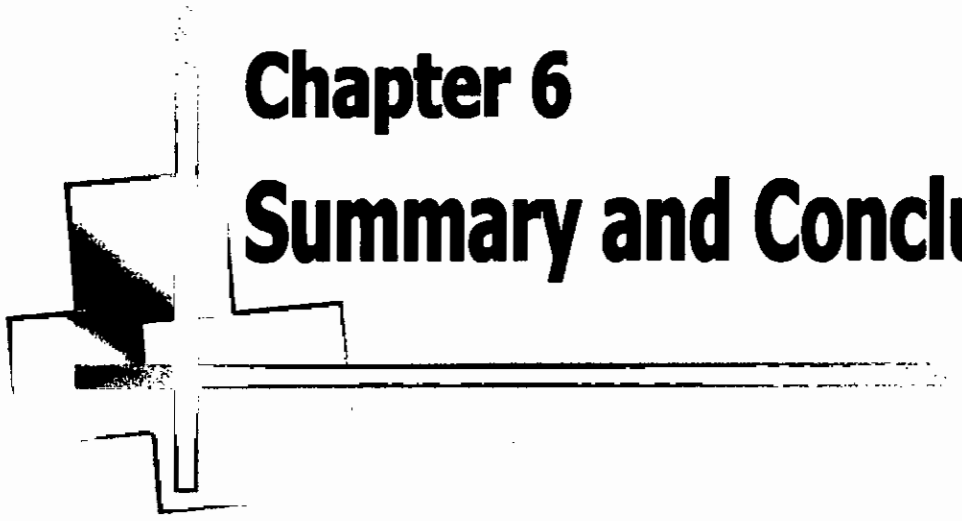
In case of shoot weight, it was significantly increased over untreated control. This was probably due to uptake of nutrient, which increased vegetable growth and hence greater translocation of phytosynthates from leaf to shoot and thereby enhanced shoot growth and weight. Inoculated plants had significantly higher shoot biomass than corresponding uninoculated plants (Sreeramulu *et al.*, 1996). Krishna and Bagyaraj (1982) also reported that root, shoot and total plant dry weight were significantly greater in mycorrhizal plants than in non-mycorrhizal controls in *Abelmoscus esculentus*.

Disease suppression data were recorded from the selected vegetables of this study. Mycorrhizal fungi inoculation significantly enhanced disease reduction compared to control plant. The different plant diseases like root rot and damping off were recorded in Brinjal. In case of Okra the incidence of damping off and foot rot were 10.78% and 6.48% in noninoculated plant whereas 4.52% and 3.24% in inoculated mycorrhizal plant. No leaf spot disease in inoculated plant was found here. More or less similar results were found in other vegetables and agricultural crops. This was reported by many scientists. 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). 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. Death rates of biocontrol (*Glomus intraradices* and *Trichoderma harzianum)* treated plants were less than half those of plants inoculated only with *F. oxysporum* (Arriola, 1997). On transplantation to the field, the survival rate of mycorrhizal seedlings (75%-90%) was higher than that of non-mycorrhizal seedlings (40%) (Giri *et al.*, 2005). Nahar (2007) also reported that the leaf spot disease was completely absent in White Gourd seedlings in mycorrhizal condition.

Mycorrhizal dependency (MD) of these experimental vegetables ranged from 15.58% to 31.38%. The highest mycorrhizal dependency (31.38%) was observed in Brinjal that was superior to all other vegetables. Chilli showed

lowest MD (15.58%). Okra recorded the second highest MD (26.82%) which was followed by Data (24.79%), and Tomato (18.56 %). The present findings are well supported by Khalil *et al.* (1994) who reported that Soybean had a higher MD than corn but considerable variation occurred within Soybean cultivars. Habte (1995) also 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. Mentionable Mycorrhizal dependency was observed in Spinach, White Gourd, Cucumber and Water Spinach (Nahar, 2007).

Uptake of nutrient like N, P, K, Zn and Fe by AM fungi inoculated vegetables was studied. Nutrient uptake was increased because of inoculation of AM fungi in all selected vegetables. Nitrogen uptake was influenced significantly by the inoculation of AM fungi over control in all the tested vegetables. The highest amount of nitrogen was uptake by inoculated Brinjal followed by Okra, Chilli and Tomato. 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. 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*. Furland and Cardon (1989) reported the effect of N, P and K on formation of vesicular arbuscular mycorrhiza growth and mineral content of onion. Mycorrhizal inoculation increased the growth and nutrient uptake of several vegetable crops inoculated under control conditions (Nahar, 2007).



Chapter 6
Summary and Conclusion

Summary and Conclusion

Arbuscular Mycorrhiza (AM) is known to play an important role in promoting and sustaining vegetable productivity even under adverse environmental conditions. A pot experiment was carried out to study the effectiveness of inoculation of AM fungi in five popular vegetables of Bangladesh like Brinjal (*Solanum melongena*), Tomato (*Lycopersicon esculentum* L.), Chilli (*Capsicum frutescens*), Okra (*Abelmoschus esculentus*) and Data (*Amaranthus oleraceus*). The studies included the seedling emergence, plant growth and assessment of percent root colonization, Arbuscular mycorrhizal dependency and nutrient uptake of these vegetables.

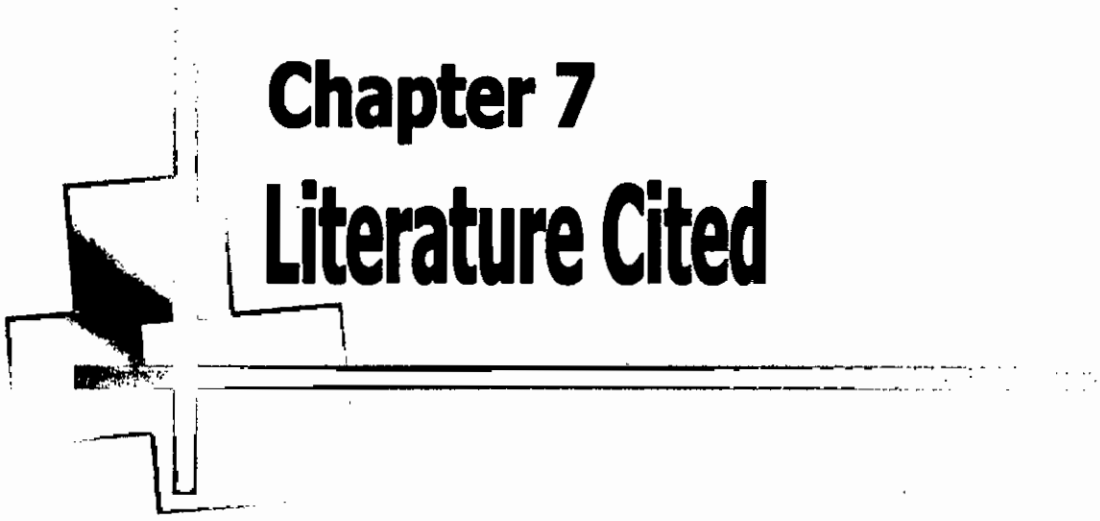
Seedling emergences were recorded at 7, 10 and15 days after sowing. The seedling emergences were influenced by AM inoculation. Data showed higher seedling emergence followed by Okra, Chilli, Brinjal and the lowest was recorded with Tomato in all recorded period after-inoculation.

Arbuscular mycorrhizal inoculation significantly increased the plant height of vegetable over uninoculated control plant. Between the treatment arbuscular mycorrhizal inoculated tomato showed the highest increase of plant height. In inoculated plant, the highest percent increased of root weight over control were 66.91% in Brinjal, 60.00% in Tomato, 52.62% in Data 50.00% in Okra and 33.33% in Chilli at 40 and 60 days after sowing, respectively. In case of shoot weight, it was also significantly increased over untreated control.

Mycorrhizal fungi inoculation significantly enhanced disease reduction compared to control plant. The different plant diseases like root rot and damping off were recorded in Brinjal. In case of Okra the incidence of damping off and foot rot were 10.78% and 6.48% in noninoculated plant whereas 4.52% and 3.24% in inoculated mycorrhizal plant. No leaf spot disease in inoculated plant was found here.

Mycorrhizal dependency (MD) of these experimental vegetables ranged from 15.58% to 31.38%. The highest mycorrhizal dependency (31.38%) was observed in Brinjal that was superior to all other vegetables. Chilli showed lowest MD (15.58%). Okra recorded the second highest MD (26.82%) which was followed by Data (24.79%), and Tomato (18.56 %).

Nutrient uptake was enhanced significantly in all the treated vegetables. The highest amount of nitrogen was uptake by inoculated Brinjal followed by Okra, Chilli and Tomato.



Chapter 7
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