MYCORRHIZAL STATUS OF CROPS GROWN IN ARSENIC AFFECTED AREAS OF MANIKGANJ DISTRICT AND ROLE OF MYCORRHIZAE ON GROWTH OF SELECTED CROPS IN ARSENIC AMENDED SOIL

BY

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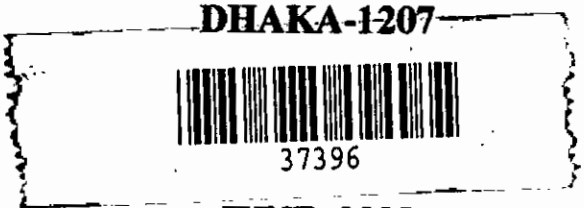

JUNE, 2008

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BY

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CERTIFICATE

This is to certify that the thesis entitled " **MYCORRHIZAL STATUS OF CROPS GROWN IN ARSENIC AFFECTED AREAS OF MANIKGANJ DISTRICT AND ROLE OF MYCORRHIZAE ON GROWTH OF SELECTED CROPS IN ARSENIC AMENDED SOIL**" submitted to the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment 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 **NIBIR KUMAR SAHA, REGISTRATION. NO. 00919,** 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: 30.04.2009
Dhaka, Bangladesh

(Dr. Md. Amin Uddin Mridha)
Vice chancellor
Pabna University of Science and Technology
Supervisor

Dedicated to
My
Beloved parents who laid the foundation of my success

LIST OF ABBREVIATIONS

ABBREVIATION	FULL WORD
%	Percentage
°C	Degree Celsius
AMF	Arbuscular Mycorrhizal Fungi
As	Arsenic
BARI	Bangladesh Agricultural Research Institute
C	Carbon
cm	Centimeter
DAS	Days after sowing
et al.	And others
g	Gram
K	Potassium
Kg	Kilogram
L	Liter
N	Nitrogen
N	Normal
P	Phosphorus
ppb	Parts per billion
ppm	Parts per million
S	Sulphur
VAM	Vesicular Arbuscular Mycorrhiza
µg	Microgram

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June, 2008

Dhaka, Bangladesh *The Author*

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ABSTRACT

Crops are often contaminated with arsenic in Bangladesh. This result from irrigation water contaminated with arsenic and leads to problems in human health. Mycorrhizal fungi have their most significant effect on P uptake and have also been shown to reduce arsenic contamination to the crops. The present experiment was performed to know the mycorrhizal status of different crops root collected from different arsenic affected villages of Manikganj district. This study also determined the role of arbuscular mycorrhizal fungi on crops growth in arsenic amended soil. Three crops (tomato, radish and garlic) were grown in arsenic amended soils with or without mycorrhizal inoculation. Three levels of arsenic concentrations (10ppm, 100ppm and 500ppm) were used. At higher concentration of arsenic, the seed germination was affected more than the other treatments. A positive germination response to AMF inoculation was observed in all the selected crops. In case of garlic, the seed germination, all physical growth was higher at 500ppm treated pots but lower in other two crops. In case of tomato and radish shoot height, root length, number of leaves, both fresh and dry weight of shoots and roots, mycorrhizal root colonization and percent vigor were higher in AMF inoculated pots in comparison to their respective treatments and decreased significantly with the increase rate of arsenic concentrations. Higher nutrient uptake and less arsenic content were recorded in mycorrhiza inoculated plants. The findings indicate that AMF inoculation not only minimize arsenic toxicity but also can increase growth and nutrient uptake of crops.

CHAPTER 1
INTRODUCTION

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INTRODUCTION

Arsenic (As) is one of the major global environmental toxicants. Arsenic is released in to the environment in both inorganic and organic forms. Arsenate [As (V)] and arsenite [As (III)] are the inorganic, phytoavailable forms in soil solution. Inorganic species of As, arsenate, AsO_4^{-3} referred to as As V and arsenite AsO_3^{-3}, referred to as As III, and is carcinogenic. Organic arsenic species are generally considered to be less toxic than inorganic species to a wide range of organisms, plants, animals and humans (Tamaki and Frankenberger, 1992). Groundwater contamination by arsenic (As) has been reported from many countries, with the most severe problems occurring in Asia, particularly Bangladesh (Chowdhury *et al.*, 1999; Dhar *et al.*, 1997; Nickson *et al.*, 1998). Arsenic contamination of groundwater was confirmed in 1993 in Bangladesh (British Geological Survey, 2000; Tondel *et al.*, 1999). In some areas of Bangladesh, arsenic contamination of groundwater reached to 2 mg L^{-1} (British Geological survey, 2000; Tondel *et al.*, 1999), well above the WHO limit of arsenic in drinking water of 0.01 mg L^{-1}.

Manikganj is one of the major arsenic affected areas of Bangladesh. According to National Arsenic Mitigation Information Center in Manikganj district, average 5611.25 tube-wells are affected out of 14705.75. While 1.7% having arsenic above 300 µg/L. (http://www.soesju.org/arsenic/bangladesh.htm)

The people of Bangladesh not only drink the arsenic contaminated groundwater, but also irrigate their crops with this water. It enters the living biota through

biogeochemical and biochemical pathways. Livestock feeding on arsenic contaminated feeds will accumulate this element with potential of arsenic to be transferred to humans. Serious health effects to human including cancer, melanosis, hyperkeratosis, Blackfoot disease, diabetes mellitus and heart disease are caused by chronic exposure to arsenic. Arsenic can be introduced to food through plant uptake from soil contaminated with groundwater or irrigation water. (http://www.umanitoba.ca/.....pdf).

Arsenic also effects in two ways; arsenic is drawn into plants contaminating the plant and arsenic is drawn up instead of phosphorus, which is a major limiting factor in plant growth. As a result, the plants possess a degree of toxicity and are stunted due to lack of phosphorus. Arsenic and phosphorus have a unique relationship in nature. Both are chemically similar and it is well known that arsenate can be taken up and incorporated as phosphorous (Meharg & Macnaie, 1990). Adding phosphorus to arsenic contaminated soil has been shown to alter the fixation of arsenic and phosphorus, as well as decreasing the rate of arsenic accumulation (Woolson *et al.* 1973). Arsenic contamination of irrigation water represents a major constraint to Bangladesh agriculture. When the contaminated water used as irrigation water in lentil field, plant height decreased with increasing concentration of arsenate in irrigation water. Leaf number, pod number, root length and biomass were also decreased but mycorrhizal inoculation with arsenic increased those parameters (Ahmed *et al*, 2006).

Arsenic accumulates in the grains of rice plants grown on arsenic contaminated soil and irrigated with arsenic contaminated water in Bangladesh. These rice plants not only had elevated arsenic concentrations in the tissues, but also had a decreased quantity of protein in the grain. Rice grown in a variety of contaminated water and soil combinations was shown to have elevated levels of arsenic in many of the plant tissues. AMF can reduce arsenic uptake of tomato (*Lycopersicon esculentum*) and they have the potentials to reduce arsenic levels in the food chain (http://www.umanitoba.ca/.....pdf).

Tomato (*Lycopersicon esculentum* Mill.), belonging to the family Solanaceae, is one of the most popular and quality vegetable grown in Bangladesh. It is popular for its test, nutritional status and various uses. The crop is one of the most popular and important vegetables in Bangladesh with a considerable total production of 191000 metric tons produced in an area of 203000 ha (BBS, 2007).

Radish *(Raphanus sativus)* a member of the family Cruciferae is a popular vegetables in Bangladesh. It is a good source of vitamin C (Ascorbic acid) containing 34-40 mg per 100 g of edible portion and supplies a variety of minerals. Trace elements in radish include aluminum, barium, lithium, manganese, silicon titanium, fluorine and iodine (up to 18 μ g /100 g). Besides, tender leaves which are used as green vegetables are rich in vitamin A and C. Roots are also rich in carbohydrate and protein (Gopalan *et al*, 1989). Radish is also the most popular and important vegetables in Bangladesh with a considerable total production of 179000 metric tons produced in an area of 157000 ha (BBS, 2007).

Garlic (*Allium sativum* L.) is a fragrant herbaceous plant and is one of the most important bulb crop belongs to the family Alliaceae. It has been considered as a rich sources of carbohydrate, protein and phosphorus (Augusti, 1977) the average yield of garlic in Bangladesh is only 443 m.ton per acre (BBS, 2007). In Bangladesh area under garlic cultivation is 305000 ha (BBS, 2007).

Mycorrhizae are symbiotic associations that form between the roots of most plant species and fungi. These symbioses are characterized by bi-directional movement of nutrients where carbon flows to the fungus and inorganic nutrients move to the plant, thereby providing a critical linkage between the plant root and soil. In infertile soils, nutrients taken up by the mycorrhizal fungi can lead to improved plant growth and reproduction. As a result, mycorrhizal plants are often more competitive and better able to tolerate environmental stresses than non-mycorrhizal plants (Bethlenfalvay *et al.*, 1992). 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 more effectively than those of non mycorrhizal ones. They help to increase vegetable production in several ways thorough improvement in nutrient uptake and plant resistance to diseases. The positive role of the vesicular-arbuscular mycorrhizal (VAM) fungi in P uptake and plant growth response under P-deficient conditions has been well established for many agricultural systems (Mosse, 1973). 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).

Vesicular-arbuscular mycorrhizas are also important for N uptake to stimulate the growth and nutrition of plants and are of great ecological importance with regards to N-nutrition of plant, especially non-fining species (Barea, 1991).

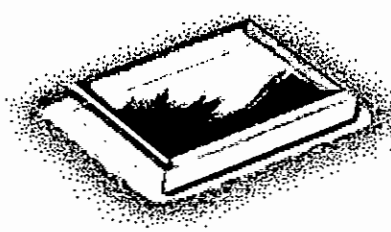
The AMF association can help in higher production of growth regulating substances (Danneberg *et al.*, 1992) and increase plant resistance against pest and diseases (Bethlenfalvay and Linderman, 1992). Moreover, it helps in the formation of soil aggregation and aggregate stability (Miller and Jastrow, 1994). 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). 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* (Jalali and Thareja, 1981).

AM inoculation as well as P application reduced As toxicity symptoms, most clearly so in the +AM–P treatment. Plant growth reported to be the highest in the +AM + P treatment. Shoot As concentrations were slightly reduced by AM inoculation but enhanced by P application. (Ultra *et al.*, 2007). Xia *et al.* (2007) conducted an experiment and found that P application in maize plants may introduce additional environmental risk by increasing soil As mobility but AM

fungal inoculation decreased shoot As concentrations. There is growing evidence that AM fungal infection can exert protective effects on host plants under conditions of trace element/metal/metalloid contamination. When considering the toxicity of arsenic to plants, the role of mycorrhizal associations must also be considered, as one of the principal roles of mycorrhizal fungi is phosphorus uptake (Smith and Read, 1997). This could potentially be a problem on arsenic contaminated substrates because of enhanced acquisition of arsenate. However, there is also growing evidence that mycorrhizal fungi may alleviate metal or metalloid toxicity to the host plant by acting as a barrier to uptake (Leyval *et al.*, 1997). Sharples *et al.* (2000) showed that the ericoid mycorrhizal fungus *Hymenoscyphus ericae* acted as an As and Cu filter to maintain low As concentration in plant tissues, while improving P nutrition of the host plant in an As/Cu contaminated mine site. It has been widely reported that ectomycorrhizal and ericoid mycorrhizal fungi can increase the tolerance of their host plants to heavy metals when the metals are present at toxic levels (Bradley *et al.*, 1981, 1982; Jones and Hutchinson 1988a, b). The underlying mechanism is thought to be the binding capacity of fungal hyphae which immobilize the metals in or near the roots and thus depresses translocation to the shoots (Bradley *et al.*, 1981; Brown and Wilkins 1985; Wassermann *et al.*, 1987).

On view of the above facts, the present study had been undertaken with the following objectives:

- To assess the mycorrhizal status of some standing crops and weeds grown in different arsenic affected area of Manikganj district in Bangladesh
- To assess the effect of arsenic on seed germination and seedling growth and
- To assess the interaction of arsenic and mycorrhiza on different growth parameters of some selected crops.



CHAPTER 2
REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

A number of studies were done to know the role of AMF inoculation on plant growth in many areas of the world. Mycorrhizae are the symbiotic associations that form between the roots of plant species and fungi. This symbiosis can be considered for the benefit of agriculture by selecting the best plant-fungus combinations. Most of the cultivated plants used for human and animal food purposes are colonized by mycorrhiza. Some of the published reports relevant to research topic from various sources of home and abroad have been reviewed in this chapter as follows.

2.1. Role of mycorrhiza in different crops:

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.

Giri *et al.* (2005) assessed 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. 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.

Phiri *et al.* (2003) reported that 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.

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.

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.

George (2000) studied on 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.

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 maximum in onion (70%) whereas garlic and potato showed 30% and 48% increases, respectively.

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) worked with different 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.

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.

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.*

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.

Eltrop and Marschner (1996) studied 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.

Tarafdar and Praveen Kumar (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. After 8 weeks of growth, percent root infection increased 29-fold in inoculated plants. At maturity of crop, shoot biomass, N, P, K, Zn and Cu concentration were significantly improved in all cases of inoculated plants.

Wani and Konde (1996) investigated AM spores with root zones association in garlic. They recorded AM spore ranging from 62 to 242 per 50 g of rhizosphere soil. Loth (1996) recorded spore densities ranging from 31 to 97 per gram of soil.

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.

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.

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 informed 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.

Edathii *et al.* (1994) evaluated the VAM status of tomato, brinjal (aubergenic) 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 max. 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.

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.

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.

Sylvia (1990) reported that the flow of carbon to the soil mediated by mycorrhizae serves several important functions. It can increase plant tolerance to salinity (Pond *et al.*, 1984) and it can decrease plant susceptibility to diseases (Jalali and Chand, 1988). Arbuscular mycorrhizal fungi colonize or infect the roots of most species of vascular plants (Morton and Benny, 1990) except for a few belonging to the families Chenopodiecea, Crucifereae, Cyperaceae, Juncaceae and Caryo-phyllaceae (Richardson *et al.*, 2000; Sramek *et al.*, 2000).

Baath and Hayman (1984) studied on the effect of soil volume and plant density on mycorrhizal infection and growth response of onion. There was a significant negative correlation between percentage vesicular-arbuscular mycorrhizal infection and root density. The growth response due to mycorrhiza decreased when less soil was available for the plant. The root shoot ration decreased with increasing plant density in both mycorrhizal and non-mycorrhizal plants. Pot size did not effect root and shoot ratio.

The effect of VA mycorrhizal and soluble phosphorus on *Abelmoscus esculentus* (L.) was studied by Krishna and Bagyaraj (1982). They reported that root, shoot and total plant dry weight were significantly greater in mycorrhizal plants than in non-mycorrhizal controls. Mycorrhizal dependency was found to decrease with increase in added soluble P.

2.2. Interaction of arsenic and mycorrhiza:

The literatures regarding arsenic and mycorrhizal interaction of Bangladesh are very Spartan. However, some of the published reports relevant to research topic from various sources of home and abroad have been presented in this chapter.

Chen *et al.* (2007) observed that mycorrhizal fungi may play an important role in protecting plants against arsenic contamination. They used a compartmented pot cultivation system to investigate the roles of *Glomus mosseae* in plant phosphorus and As acquisition by *Medicago sativa*, and P-As interactions. The results indicate that fungal colonization increased plant dry weight and also substantially increased both plant P and As contents. The decreased shoot As concentrations were largely due to "dilution effects" that resulted from stimulated growth of AM plants and reduced As partitioning to shoots.

Dong *et al.* (2007) reported that, in a compartmented cultivation system, white clover and ryegrass were grown together in arsenic (As) contaminated soil. The influence of AM inoculation on plant growth, As uptake, phosphorus nutrition, and plant competitions were investigated. Results showed that both plant species highly depended on mycorrhiza for surviving the As contamination.

Xia *et al.* (2007) examined the effects of arbuscular mycorrhizal fungus (*Glomus mosseae*) and phosphorus addition on arsenic uptake by maize plants from an As-contaminated soil. The results indicated that addition of P inhibited root colonization, shoot and root biomass and development of extraradical mycelium. Root length, dry weight and shoot and root As concentrations both increased with mycorrhizal colonization under the zero-P treatments. AM fungal inoculation decreased shoot As concentrations when no P was added. AM colonization therefore appeared to enhance plant tolerance to As in low P soil, and have some potential for the phytostabilization of As-contaminated soil.

Ultra *et al.* (2007) set up an experiment to find out the effects of arbuscular mycorrhiza (AM) and phosphorus application on arsenic toxicity in As-contaminated soil. The treatments consisted of a combination of two levels of AM (*Glomus aggregatum*) inoculation and two levels of P application. AM inoculation as well as P application reduced As toxicity symptoms and increased plant growth. Shoot As concentrations were reduced by AM inoculation but enhanced by P application.

Ahmed *et al.* (2006) reported that Arsenic contamination of irrigation water represents a major constraint to Bangladesh agriculture. This study examined the effects of As and inoculation with an AM fungus, *Glomus mosseae*, on lentil. Plant height, leaf number, pod number, plant biomass and shoot and root P concentration/offtake increased significantly due to mycorrhizal infection. Plant height, leaf/ pod number, plant biomass, root length, shoot P concentration/offtake, root P offtake and mycorrhizal infection decreased significantly with increasing As concentration. However, mycorrhizal inoculation reduced As concentration in roots and shoots. This study shows that growing lentil with compatible AM inoculum can minimize As toxicity and increase growth and P uptake.

Kim *et al.* (2006) were investigated the effects of arbuscular mycorrhizal fungi (*Glomus mosseae*) inoculation on arsenic and phosphorus uptake by *Trifolium repensin* and *Oenothera odorata*. These results indicate that inoculation of AM fungi to host plants obtained high yield and increase arsenic resistance to its toxicity and has a potential applicability to enhance the efficiency of phytostabilization in soils highly contaminated with arsenic.

Leung *et al.* (2006) conducted a greenhouse trial to investigate the role of arbuscular mycorrhiza in aiding arsenic uptake and tolerance by *Pteris vittata* and *Cynodon dactylon*. The infectious percentage of mycorrhizas and the average

biomass of shoots in infected *P. vittata* increased according to the increase of As levels when compared to control. The indigenous mycorrhizas enhanced As accumulation in the As mine populations of *P. vittata* and also sustained its growth by aiding P absorption. For *C. dactylon*, As was mainly accumulated in mycorrhizal roots and translocation to shoots was inhibited.

Trotta *et al.* (2006) studied the effects of arbuscular mycorrhizae on growth and As hyperaccumulation in the Chinese brake fern *Pteris vittata*. The As treatment produced a dramatic increase of As concentration in pinnae and a much lower increase in roots of both mycorrhizal and control plants. Mycorrhization increased pinnae dry weight and leaf area, strongly reduced root As concentration, and increased the As translocation factor. The concentration of phosphorus in pinnae and roots was enhanced by both fungi.

Agely *et al.* (2005) said that Chinese brake fern (*Pteris vittata* L.) is a hyperaccumulator and mycorrhizal symbiosis may be involved in As uptake by this fern. This is because arbuscular mycorrhizal (AM) fungi have a well-documented role in increasing plant phosphorus (P) uptake and ferns are known to be colonized by AM fungi. They found that the AM fungi not only tolerated As amendment, but their presence increased frond dry mass at the highest As application rate. These data indicate that AM fungi have an important role in arsenic accumulation by Chinese brake fern.

Liu *et al.* (2005) conducted a glasshouse experiment to study the effect of arbuscular mycorrhizal (AM) colonization by *Glomus mosseae* on the yield and arsenate uptake of tomato plants in soil experimentally contaminated with five As levels. Mycorrhizal colonization was little affected by As application and declined only in soil amended with 150 mg As kg(-1). Shoot As concentration increased with increasing As addition up to 50 mg kg(-1) but decreased with mycorrhizal colonization. Mycorrhizal plants had higher shoot and root P/As ratios at higher As application rates than did non-mycorrhizal controls. Mycorrhizal colonization may have increased plant resistance to potential As toxicity at the highest level of As contamination.

Gonzalez *et al.* (2002) studied the role of arbuscular mycorrhizal fungi (AMF) in arsenate resistance which was isolated from the arsenate-resistant grass *Holcus lanatus.* Resistant and nonresistant *G. mosseae* both suppressed high-affinity arsenate/phosphate transport into the roots of both resistant and nonresistant *H. lanatus.* Resistant AMF colonization of resistant *H. lanatus* growing in contaminated mine spoil reduced arsenate uptake by the host. They conclude that AMF have evolved arsenate resistance, and conferred enhanced resistance on *H. lanatus.*

CHAPTER 3
MATERIALS AND METHODS

3.1. Study of root colonization:

To investigate the mycorrhizal status different crops and weeds root samples were collected from different arsenic affected locations of Manikganj district.

a. Selection of location:

The present investigation was carried out in eight different arsenic affected locations of Manikganj district. Root samples were collected from different agricultural fields, side of the roads, ponds side and both high and low lands.

b. Period of collection:

Root samples were collected during January-07 to June-07 from all the selected locations to observe the variation of AMF infection and intensity of infection in different crops.

c. Collection of root samples:

Root samples were collected at a depth of 10 cm to 15 cm. During the collection of roots, the soil around the selected plant was loosened, fine roots with some coarse roots were collected with a sharp knife, special care was taken to

separate the fine roots from the soil. The collected roots were put into tagged polyethylene bags and brought to the laboratory for study.

d. Cleaning and preservation of roots:

Collected root samples were freed from adhering soil and washed carefully. Fine roots were cut into small segment of approximately 1 cm for determination of percentage AMF colonization. From these, 100 segments were randomly selected for staining. Some segments were preserved in 50% ethyl alcohol solution in vials and in refrigerator for future use. The roots were stained by the methods of Koske and Gemma (1989)

e. Staining of roots:

The roots of each plant species were stained according to 'Koske and Gemma (1989)' with some modifications as suggested by Mridha *et al.,* (1999) and it was conducted in the Plant Pathology laboratory of Sher-e-Bangla Agricultural University. 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 for 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.

f. Observation of roots:

The stained root segments were mounted in acetic glycerol on slides and the cover slip was placed and slightly pressed. The roots were observed under the microscope. The presence or absence of infection of AMF in the root segments was recorded and the percent infection was calculated using the following formula:

$$\% \text{ of root infection} = \frac{\text{Number of AMF positive segments}}{\text{Total number of segments recorded}} \times 100$$

At least 100 segments were examined for each sample. A root segment was considered to be infected if it showed mycelium, vesicle and arbuscules or any other combination of AM fungi.

g. Estimation of intensity of infection of AMF:

For the estimation of intensity of infection of AMF we used 0-3 scale. 0 indicate that there was no infection. The intensity of infection of AMF was estimated as, 1 if only mycelium were present; 2 mycelium and vesicle were present and 3 mycelium, vesicle and arbuscules were present (Mridha *et al.*,2007).

3.2. Study of spore population in soil:

After confirming mycorrhizal association in the root system, we identify the spore population in soils were isolated and inoculated. Identification was done in the mycorrhiza laboratory of department of Botany, Chittagong University.

3.3. Experiments were conducted in blotter method, plastic tray and poly bag

Sequentially three experiments (blotter method, plastic tray and poly bag) were performed in the Sher-e-Bangla Agricultural University during the period from August 2007 to December 2007 to study the role of mycorrhiza on growth of few crops in arsenic amended soil.

a. Collection of soil:

Soil was collected from the Agronomy field of Sher-e-Bangla Agricultural University campus from a depth of 5 to 10 inch.

b. Preparation of soil:

After collection of soil, clods were broken and weeds, stones, gravels, roots, and other unwanted materials were removed. Soil was prepared for the experiment containing 1% cow dung, 10% sand and 89% soil.

c. Mycorrhizal assessment:

Conducting the experiment necessitated the collection of natural inoculums. For this reason, a survey progamme was conducted in the Agronomy farm field of Sher-e-Bangla Agricultural University during the August 2007. Root samples of different plants species growing under natural condition in different places of the Agronomy field were collected for the observation of occurrence of vesicular arbuscular mycorrhizal (AMF) association with the root systems.

d. Staining of roots:

Same as previous staining procedure of roots of Koske and Gemma (1989).

e. Preparation of inoculums:

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 (1989). Collected root samples were cut into small pieces with 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 sterilized mycorrhiza inoculated pots.

f. Preparation of arsenic solution:

For preparation of 1000 ppm 1liter arsenic solution at first 4g of sodium hydroxide was taken in a 100ml measuring cylinder. Sodium hydroxide was diluted with distilled water and the volume of the cylinder rose up to the 100ml mark. Then 1.32g arsenic powder was taken in another 1000ml measuring cylinder and dilute with that diluted sodium hydroxide. 10% HCL was taken in a beaker. Then HCL was added into the 1000ml measuring cylinder to make it acidic. Finally the volume of the flask rose up to the 1000ml mark with distilled water.

g. Selection of crops:

Different crops like radish, tomato and garlic were selected.

h. Collection of seeds:

Seeds of different plants namely radish, tomato and garlic were collected from Bangladesh Agricultural Development Corporation (BADC).

3.4. Effect of arsenic on seed germination

3.4.1. Blotter method experiment

a. Treatments :

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 100 ppm arsenic solution

T_4 = 500 ppm arsenic solution

b. Preparation of blotter plate:

The 9 cm Petri plates were taken from the Seed Pathology Laboratory of SAU. Petri plates were autoclaved at 121^0C for 15 minutes for sterilization. Then 9cm three layer blotting paper were placed on it. For this study 3 replications and 4 treatments were used for two crops (Tomato and radish). Out of 24 Petri plates, 6 Petri plates were soaked with 10 ppm arsenic solution, 6 Petri plates were soaked with 100 ppm arsenic solution, 6 Petri plates were soaked with 500 ppm arsenic solution and rests of 6 Petri plates were soaked with distilled water.

c. Application of arsenic solution:

Arsenic solution and water was applied for two to three times with an interval of a day in arsenic treated and control Petri plates, respectively.

d. Data recording:

Data were recorded on seedling emergence (%) at 3 DAS, 5 DAS and 7 DAS.

3.5. Role of mycorrhiza on plant growth in arsenic amended soil

3.5.1. In plastic tray experiment

a. Treatments:

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution + mycorrhiza

b. Preparation of plastic tray:

Plastic trays of 18″ × 12″ size were filled with 8 kg soil. At first polythene sheet was placed on it. Before preparation of substratum, soil was sterilized with formaldehyde (0.05%) and used it as base soil. Seven plastic trays were used for

seven treatments and each of them contains 2 replications of the three crops. Two-third of all the plastic tray was filled with the substratum. Then a layer of both root inoculums (150 g) and soil inoculums (600 g) were placed in 3 plastic trays. Then six trays were amended for 2 to 3 times with 10 ppm, 100 ppm and 500 ppm arsenic solution. The rest of each tray was remained untreated control.

c. Sowing of seeds:

Seeds of each crop sown in every tray, maintaining two lines as two replications. For that 20 seeds required for each crop/tray and seed to seed distance was 1 cm.

d. Intercultural operation:

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

e. Harvesting:

When the seedlings were 20 days old then one line of each crop harvested. Next harvest was done at 30 days after sowing.

f. Data collection:

Data on different variables were recorded. Data were recorded on seedling emergence (%) (3 DAS, 5 DAS and 7 DAS), shoot fresh weight (g) (20 DAS and 30 DAS), root fresh weight (g) (20 DAS and 30 DAS), shoot and root length (cm) (20 DAS and 30 DAS). The amount of dry weight of shoot and root were too little to record.

3.5.2. In poly bags experiment

a. Treatments:

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

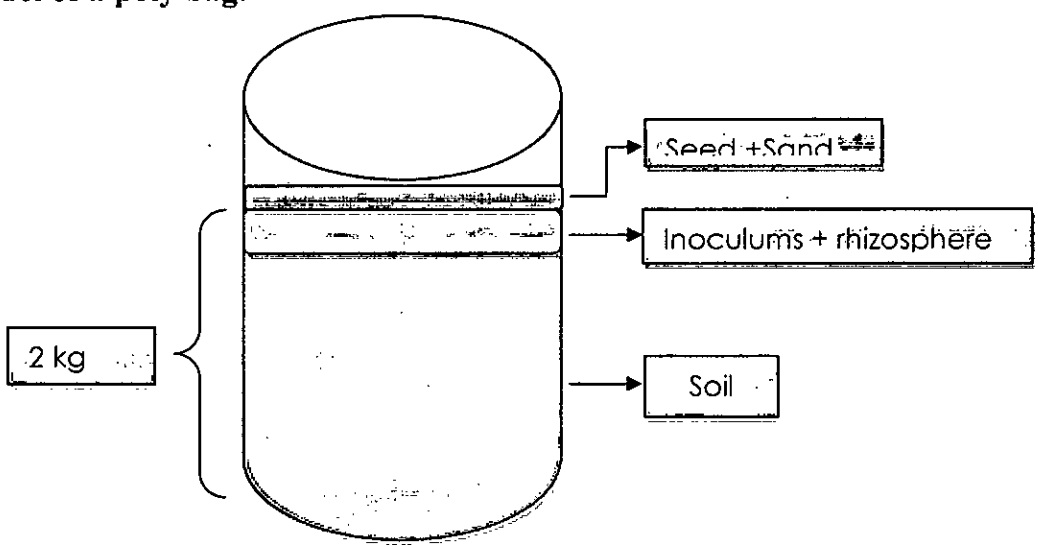
b. Preparation of seedling bags:

The polythene bags of 12"×10" size 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 with 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. At first $\frac{2}{3}$ rd portion of the seedling bags were filled with substratum. Then a layer of both inoculums i.e. root inoculums 25 g and soil inoculums 100 g, were placed in each bag. For each crop 3 replications were taken. Both 25 g roots and 100 g soil (rhizosphere) of sterilized inocula were used in 10 ppm arsenic solution + sterilized mycorrhiza, 100 ppm arsenic solution+ sterilized mycorrhiza and 500 ppm arsenic solution+ sterilized mycorrhiza treated poly bags to maintain the same nutrient status between the mycorrhizal and non-mycorrhizal bags. The inoculum layer (both mycorrhizal and non-mycorrhizal) of each bag was covered with a thin soil (substratum) layer of 2 cm below the surface in which seed were sown. 180 poly bags (2 × 10 × 3) were prepared for two crops for the present study.

Then 27 poly bags of each crop were amended with 10 ppm arsenic solution for 2 to 3 times, another 27 poly bags of each crops were amended with 100 ppm arsenic solution and the next 27 poly bags were amendment with 500

ppm arsenic solution. The rest of 9 poly bags of each crop were maintained as untreated control.

Model of a poly bag:



c. Sowing of seeds:

For each crop 9 poly bags of each treatment contain 10 seeds. . Then each poly bag was covered with a thin layer of sand to protect the seeds from adverse condition. To avoid the chance of contamination a space of 30 cm was maintained between the inoculated and non-inoculated poly bags.

d. Intercultural operation:

The pots were irrigated whenever necessary to maintain field moisture condition. Intercultural operation (weeding and 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.

e. Harvesting:

When the seedlings were 30, 45 and 60 days old then those were harvested. In this case 3 seedlings bags 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. Shoots and roots were separated with the help of sharp scissors and were preserved after necessary processing for determining shoot mass and root mass. Then roots and shoots were dried in an oven for 72 hours at 70°C until the samples gave constant weight.

f. Data recording:

Data on different variables were recorded. Data were recorded on seedling emergence (%) (3 DAS, 5 DAS and 7 DAS), fresh and dry weight of shoot (g) (30 DAS, 45 DAS, 60 DAS), fresh and dry weight of root (g) (30 DAS, 45 DAS, 60 DAS), shoot and root length (cm) (30 DAS, 45 DAS, 60 DAS) and percentage of plant vigor.

➢ **Seedling emergence:**

After sowing of seeds, the seedling bags were observed regularly with care and the seedlings emergences were measured by percentage at 3 DAS, 5 DAS and 7 DAS.

➢ **Growth and biomass:**

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

Root length: After washing, root length was measured by a meter scale.

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

Root fresh weight: Roots were taken in polythene bag and marked. There after, it was brought to the laboratory, 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 dry weight: Shoots were taken in brown envelope and dried in the oven at 70°C for 70 hours. Then weight was measured and 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. Then roots were dried in the oven at 70°C for 70 hours and weight was recorded.

➢ **Vigor index**: Vigor index was calculated by using the fowling formula

Vigor index = (Mean root length + Mean shoot length) × percent germination. (Abdul and Anderson, 1972)

g. 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). Fifty 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:

$$\% \text{ of root infection} = \frac{\text{Number of AMF positive segments}}{\text{Total number of segments recorded}} \times 100$$

h. Chemical analysis of plant sample

i) Nutrient analysis:

- **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.

- **Digestion of plant samples with nitric-perchloric acid mixture**

An amount of 0.5g of sub-sample was taken into a dry clean 100 ml Kjeldahl flask, 10 ml of di-acid mixture (HNO_3, $HClO_4$ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature rising slowly to 200°C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6ml of 6N HCl were added to it. The content of the flask was boiled until they became clear and colorless. This digest was used for determining P, K and S.

- **Phosphorous**

Phosphorous in the digest was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 4049).

- **Potassium**

Potassium content in the digested plant sample was determined by flame photometer.

➢ **Sulphur**

Sulphur content in the digest was determined by turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049).

➢ **Nitrogen**

Plant samples were digested with 30% H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio of 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldahl method. Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982).

ii) Arsenic analysis

➢ **Dilution of digested samples**

After digestion, the samples were diluted individually with deionized water separately in 20 ml calibrated volumetric flask. After dilution, each sample was filtered individually with filter paper (Whatman 42) into correspondingly marked sterile 30ml screw capped sterile glass vials and preserved at 4^0C in a refrigerator until tested for arsenic.

➢ **Detection of arsenic in plant samples**

Arsenic was detected in the ADM Lab, Department of Pharmacology, Bangladesh Agricultural University, Mymensingh with Hydride Generation Atomic Absorption Spectrophotometer (HG-AAS; PG-990, PG Instruments Ltd.

UK; Photograph 1). Arsenic was detected by forming AsH_3 at below p^H 1.0 after the reaction of As with a solution of potassium borohydride (KBH_4 = 53.94, BDH Chemicals Ltd., Poole England, UK.), sodium hydroxide (NaOH, M = 40,000 g/mol, Merck KGaA, Darmstadt, Germany) and 10% HCl. In this test, standard was maintained as As^V ranging from 0 to 12.5 µg/L.

- **Preparation of working solutions**

Trace element grade chemicals were used in the preparation of working solutions.

- **Preparation of carrier liquid**

Carrier liquid consisted of 10% HCl in deionized water. To make this solution, 100ml of concentrated HCl was taken in a 1000ml calibrated volumetric flask and then deionized water was added up to the mark of 1000ml of the flask and thereby the required solution was prepared.

- **Preparation of potassium borohydride solution**

Potassium borohydride solution used in the detection of As in HG-AAS contained 1.5% potassium bromohydride and 0.3% sodium hydroxide in deionized water. This solution was freshly prepared immediately before detection by taking 7.5 g of potassium bromohydride and 1.5 g of sodium hydroxide in a 500ml calibrated volumetric flask and then deionized water was added part by part with frequent gentle shaking the flask for dissolving the solute to the solvent. Addition

of deionized water was continued up to the 500ml mark of the volumetric flask, and thereby potassium borohydride solution was made.

- **Preparation of arsenic standard solutions**

Arsenic standard solutions were prepared with the As concentration of 0, 2.5, 5.0, 7.5, 10.0 and 12.5 µg/L in 10% HCl in separate 25ml calibrated volumetric flasks following proper acid washing and drying from 1000 µg As/L working solution of As_2O_5 (arsenic pentaoxide).

- **Operation of HG-AAS and taking reading**

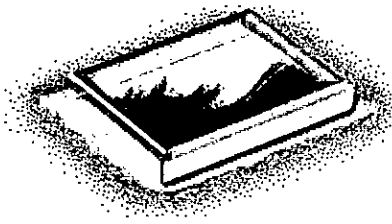
After preparation of samples and all the necessary chemical solutions along with arsenic standard solutions, the HG-AAS was started by switching the power and argon gas was allowed to flow to the hydride generation unit of the HG-AAS with flow rate between 120 to 140 ml/minute by regulating the pressure meter of the gas cylinder. Operation of the hydride generation was started by switching the operation button. Then the HG-AAS was calibrated as per manufacturer's instruction mentioned in the HG-AAS operation manual.

Before the formal determination, for cleaning of water and air in the fluid measurement system, the sample suction tube was inserted first into the carrier liquid. Then the operation process was carried out for two times by switching the hydride generation (HG). The waste liquid in the burette used for cleaning was drained quickly through the gas-liquid separation tube. Respective sucking tubes were inserted into potassium borohydride solutions and the carrier liquid. Then the

blank solution was calibrated before measuring the sample solution. The first two data was ignored. The carrier liquid was carrying the sample solution and the potassium bromohydride began their permanent flow and the reaction was taken place after their convergence. The carrier gas (argon gas) into the gas-liquid separation tube brought along the resultant, and the mixed gas entered the electric quartz absorption tube atomizer. The As in the sample was first ionized into arsine and then atomized. Reading was taken with the help of a computer connected to the HG-AAS by using manufacturer supplied 'AAwin software' (Atomic Absorption Spectrophotometer PC-Software). The reading of the tested sample was displayed on the computer monitor in a pre-customized Microsoft excel sheet provided by the AAWin software as numerical number with giving a peak of As concentration on the respective part of the software displayed sheet on the computer monitor. Readings of As concentrations of the samples were taken in ppb. After finishing the detection of one sample, the waste liquid was driven out automatically through HG outlet and taken into a waste liquid container. The procedures were the same as those of the traditional flow injection method. After the determination was finished, in order to clean every tube, all the three suction tubes were inserted into the distilled water, the operating procedures were carried out twice, taken them out, air was sucked to expel water and the operating procedures were carried out once.

a. Statistical analysis

All data were analyzed using computer by SPSS Program for F-test and mean separations were done by DMRT at 5% level of significance.



CHAPTER 4
RESULTS

CHAPTER 4

RESULTS

4.1. Study of root colonization:

To know the percent root infection and intensity of infection of AMF, different crops root were collected from different villages of Manikganj district.

a. Crops of Diapar village:

The results of the percentage of AM-fungal association in different crops root collected from Diapar village of Manikganj district is shown in Figure 1. Seven different plant species were collected from Diapar village to determine the infection percentage. The percent root infection ranged from 0-32percentage. Among the seven plant species, the highest root infection was observed in *Zea mays* and the lowest root infection was observed in *Ipomoea batatas* (Field- b). No infection was recorded in *Cucumis sativus* and *Raphanus sativius* although both the plants are mycotrophic in nature.

To determine the intensity of infection 0-3 scale was used. Percentage of intensity of infection of AMF on different crops root collected from Diapar village of Manikganj district is presented in Table 1. Intensity of infection was also varied in different scale. Most of the crops showed intensity of infection in scale 0 and 1. *Ipomoea batatas* root collected from the field-a showed 20% intensity of infection in scale 1 whereas, the root sample collected from field-b showed 11% intensity of infection in scale 1 and 3% in scale 2. No Intensity of infection was found in scale-3.

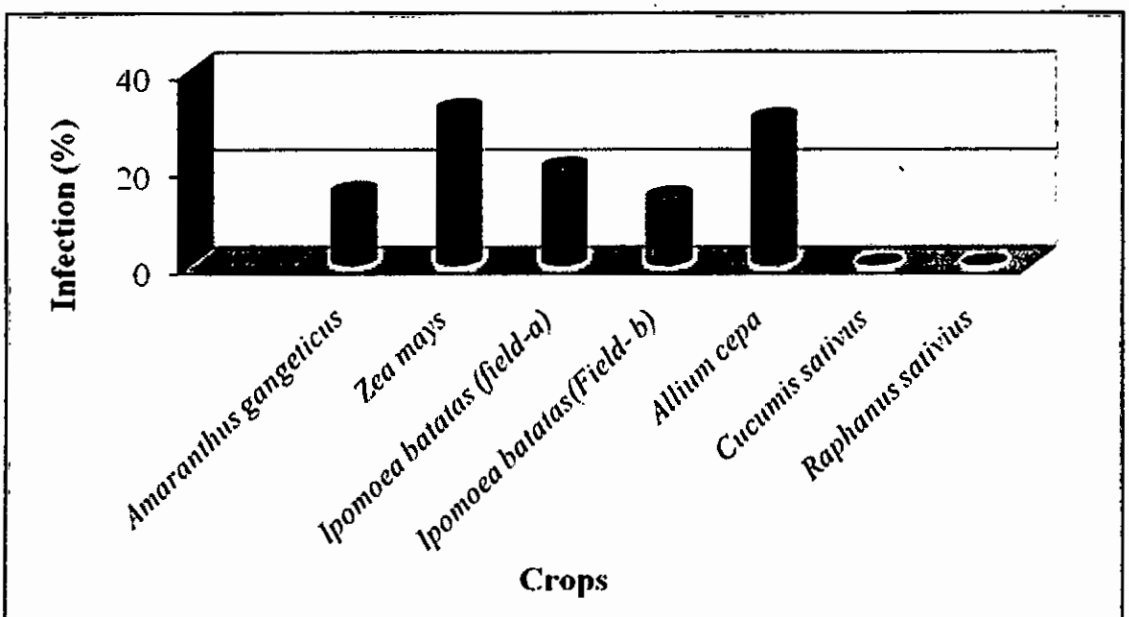


Fig. 1. AMF root infection of different crops root collected from Diapar village of Manikganj district

Table 1. Intensity of infection of AMF on different crops root collected from Diapar village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Amaranthus gangeticus	85	10	5	0
Zea mays	68	13	19	0
Ipomoea batatas (field-a)	80	20	0	0
Ipomoea batatas (Field- b)	86	11	3	0
Allium cepa	70	20	10	0
Cucumis sativus	100	0	0	0
Raphanus sativius	100	0	0	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

b. Crops of Jatrapur village:

The percent AMF root infection of different crops root collected from Jatrapur village of Manikganj district is showed in Figure 2. Six different plant species were collected to determine the infection percentage. The root infection ranges from 0% to 21%. Among the six plant species the highest root infection was recorded in *Zea mays* and that was 21% on the other hand no root infection was recorded in *Corcorus capsularis. Allium cepa, Ipomoea batatas, Amaranthus gangeticu* and *Capsicum frutescens* showed 11%, 15%, 9% and 7% root infection respectively.

Percent intensity of infection of AMF on different crops root is presented in Table 2. Intensity of infection was also varied at different scale. The highest intensity of infection was recorded in *Zea mays* and those were 17% in scale 1 and 4% in scale 2. Intensity of infection was zero in case of *Corcorus capsularis.* In all the six selected crops no intensity of infection was found in scale-3.

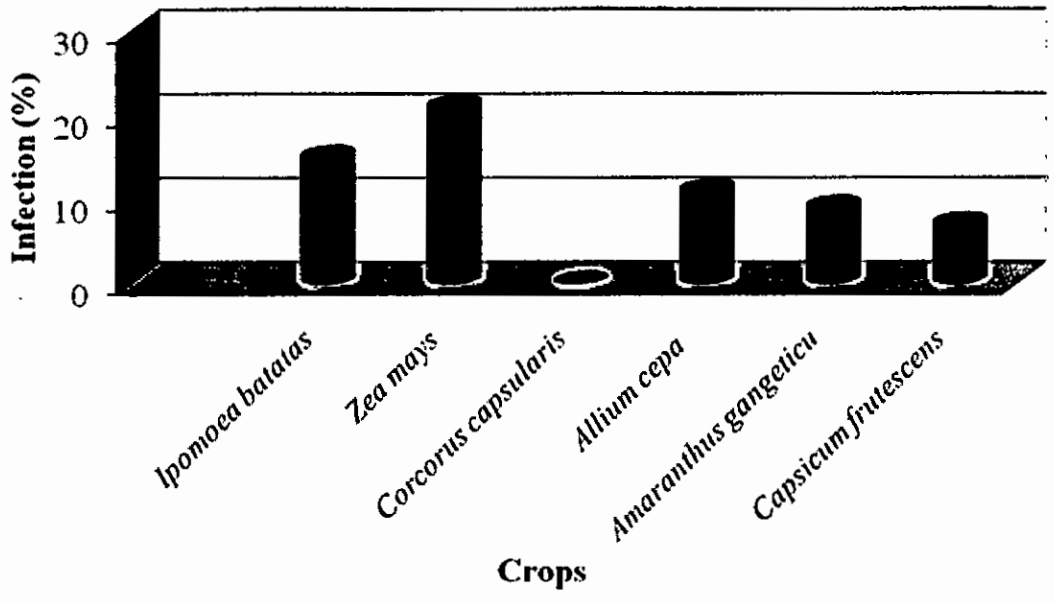


Fig. 2. AMF root infection of different crops root collected from Jatrapur village of Manikganj district

Table 2. Intensity of infection of AMF on different crops root collected from Jatrapur village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Ipomoea batatas	85	9	6	0
Zea mays	79	17	4	0
Corcorus capsularis	100	0	0	0
Allium cepa	89	9	2	0
Amaranthus gangeticu	91	9	0	0
Capsicum frutescens	93	6	1	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

c. Weeds of Jatrapur village:

The percent AMF root infection of different weeds root collected from Jatrapur village of Manikganj district is shown in Figure 3. Nine different weeds were collected from the village. Present investigation reveals that root infection ranged from 0% to 31%. The highest percentage root infection was found in *Croton sparsiflorus* L. and that was 31% followed by *Leucas aspera* WilldLink. (28 %) and *Linderlia antipoda* L. (10%). There was no infection found in *Leeesia hexandra* Swartz, *Amaranthus viridis* L. and *Cyperus rotundus* L.

The percent intensity of infection of AMF of different weeds root is presented in Table 3. The intensity of infection was assessed on a 0-3 scale. Intensity of infection of most of the crops was in scale 0 and scale 1. Intensity of infection varied in different scale. The highest percentage of intensity was found in *Croton sparsiflorus* L. and that was 27 in scale 1 and 4 in scale 2. There was no infection in scale 3.

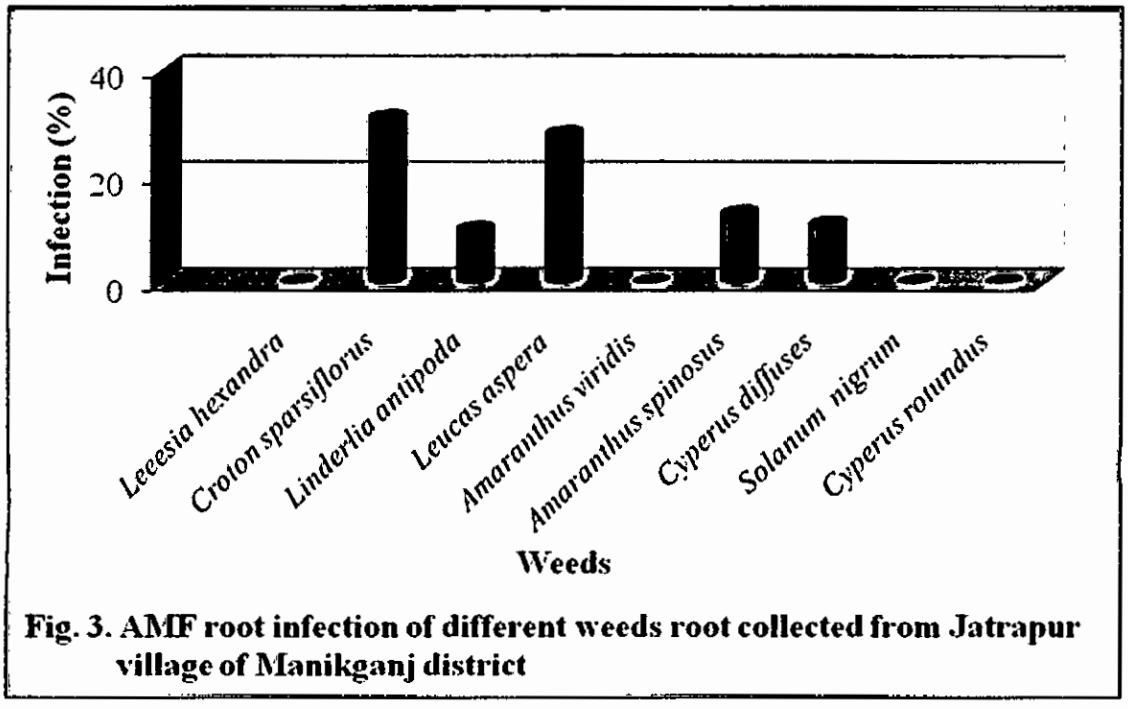


Fig. 3. AMF root infection of different weeds root collected from Jatrapur village of Manikganj district

Table 3. Intensity of infection of AMF on different weeds root collected from Jatrapur village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Leeesia hexandra Swartz.	100	0	0	0
Croton sparsiflorus L.	69	27	4	0
Linderlia antipoda L.	90	10	0	0
Leucas aspera (Willd.) Link.	72	21	7	0
Amaranthus viridis L.	100	0	0	0
Amaranthus spinosus L.	87	12	1	0
Cyperus diffuses L.	89	9	2	0
Solanum nigrum L.	00	0	0	0
Cyperus rotundus L.	100	0	0	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

d. Crops of West Dashora village:

Percent AMF root infection of different crops collected from West Dashora village of Manikganj district are presented in Figure 4. Six different crops were collected from West Dashora village of Manikganj district and percent root infection was investigated. It was observed that root infection varied from location to location. The percent root infection was ranged from 0% to 18%. The highest root infection was observed in *Zea mays* (18%) and the lowest in *Lagenaria vulgaris* and that was 6%. No infection was recorded in *Cucurbita moschata, Lagenaria vulgaris,* and *Solanum melongena.*

The intensity of infection of AMF on different crops root is presented in Table 4. Intensity of infection varied at different scale. Among the six crops most of the time intensity of infection was found in scale 0 and scale 1. No intensity of infection was recorded in scale 3. The highest intensity of infection was found in *Zea mays* and that was 15% in scale 1 and 3% in scale 2. In case of *Amaranthus gangeticus* intensity of infection was found only in scale 1 and that was 9%.

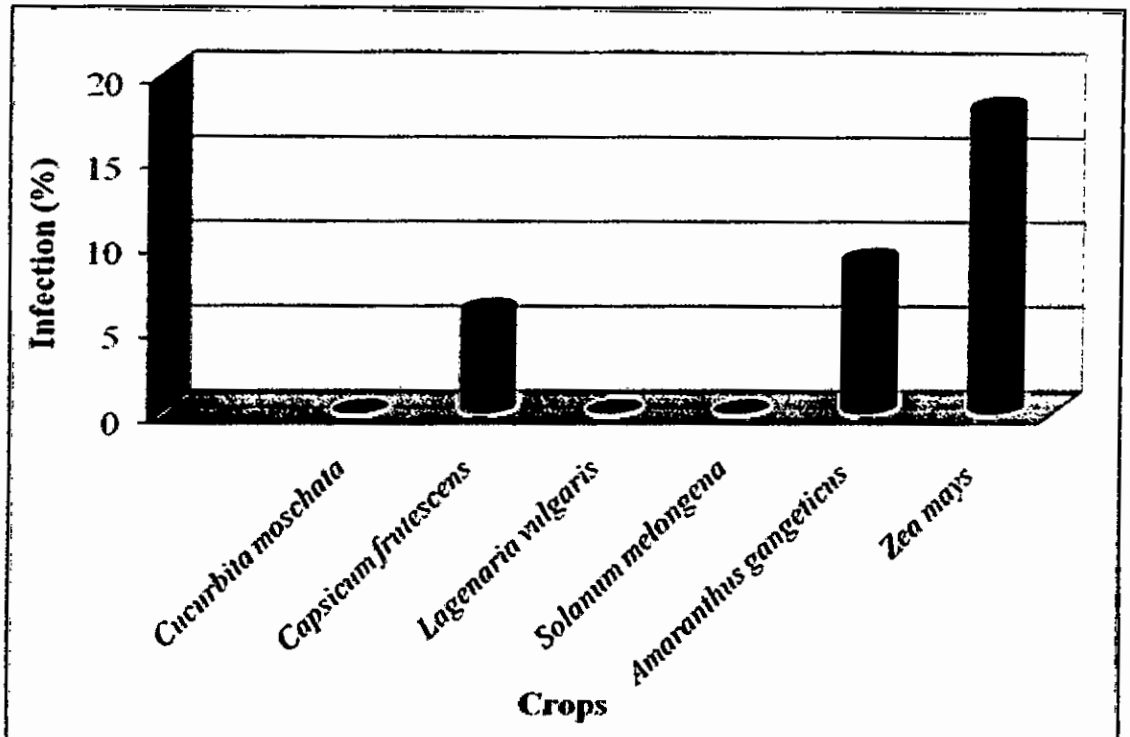


Fig. 4. AMF root infection of different crops root collected from West Dashora village of Manikganj district

Table 4. Intensity of infection of AMF on different crops root collected from West Dashora village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Cucurbita moschata	100	0	0	0
Capsicum frutescens	94	4	2	0
Lagenaria vulgaris	100	0	0	0
Solanum melongena	100	0	0	0
Amaranthus gangeticus	87	9	0	0
Zea mays	82	15	3	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

e. Weeds of West Dashora village:

The data of percent AM-fungal root infection of different weeds root collected from West Dashora village of Mynikgong district are presented in Figure 5. The highest percent root infection was recorded in *Croton sparsiflorus* L. and that was 29% and the lowest percent root infection was recorded in *Solanum carolinense* and that was 10%. No infection was recorded in *Linderlia antipoda* L., *Alternanthera philoxeroides* (Mort.) Griseb., *Amaranthus viridis* L. and *Amaranthus spinosus* L.

Percent intensity of infection of AMF on different weeds root collection from West Dashora village of Manikganj district is presented in Table 5. A scale of 0-3 was used to determine the intensity of infection. In scale 1, intensity of infection was recorded in 4 cases. Among them, the lowest percentage was found in *Solanum carolinense*, that was 7%, and the highest was found in *Leucas aspera* (Willd.) Link. and that was 23%. In scale 2, intensity of infection was recorded in 4 cases. Among them, the lowest percentage was found in *Leucas aspera* (Willd.) Link. and that was 1% and the highest was found in *Croton sparsiflorus* L. and that was10 %. In scale 3 only *Leucas aspera* (Willd.) Link showed 3% intensity of infection.

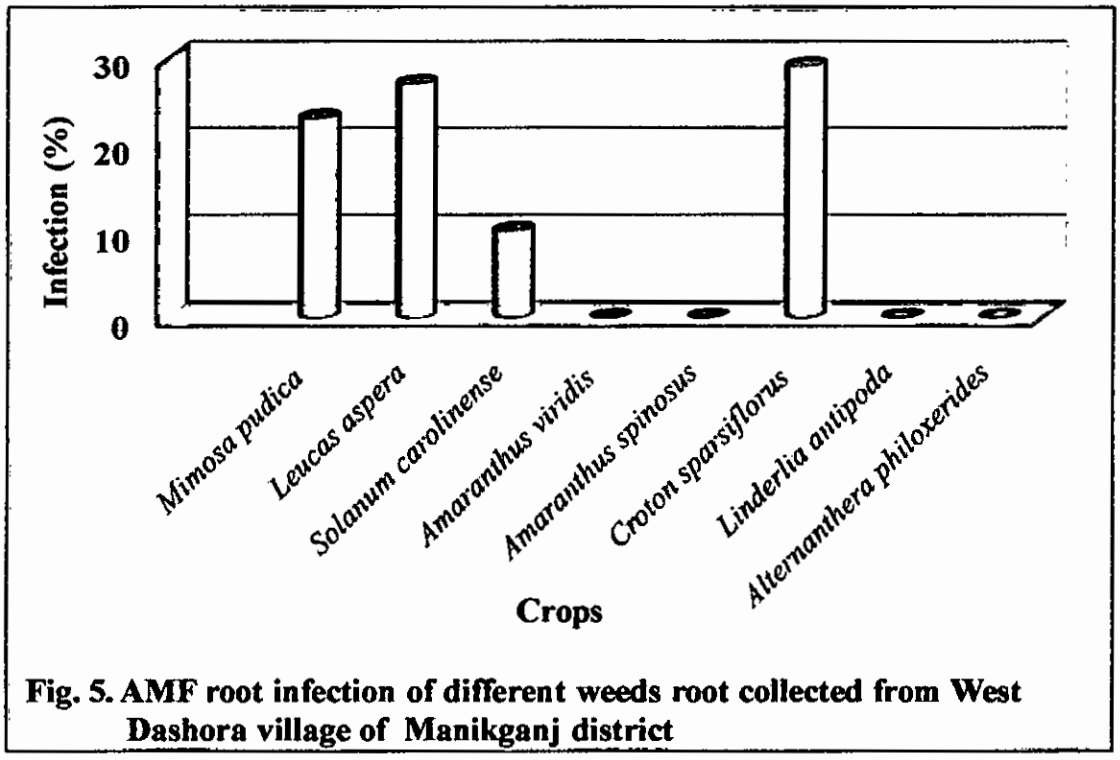


Fig. 5. AMF root infection of different weeds root collected from West Dashora village of Manikganj district

Table 5. Intensity of infection of AMF on different weeds root collected from West Dashora village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Mimosa pudica L.	77	19	4	0
Leucas aspera (Willd.) Link.	73	23	1	3
Solanum carolinense	90	7	3	0
Amaranthus viridis L.	100	0	0	0
Amaranthus spinosus L.	100	0	0	0
Croton sparsiflorus L.	81	19	10	0
Linderlia antipoda L.	100	0	0	0
Alternanthera philoxeroides (Mort.) Griseb.	100	0	0	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

f. Crops of East Dashora village:

The percent AMF root infection of different crops root collection from East Dashora village of Manikganj district are shown in Figure 6. Seven different crops were collected from that district and percent root infection was investigated. The percentage of root infection was found in case of two species out of seven. The root infection was ranged from 0% to 8%. The highest root infection was observed in *Capsicum frutescens* (8%) and the lowest root infection was observed in *Corcorus capsularis* (7%). No infection was recorded from other crops.

Percent intensity of infection of AMF on different weeds root collection from East Dashora village of Manikganj district is presented in Table 6. Intensity of infection was also varied from species to species. Most of the time intensity of infection was recorded in scale 0 and 1. In case of *Capsicum frutescens* 5% intensity of infection was recorded in scale 1 and 3% in scale 2 on the other hand in *Corcorus capsularis* 4% intensity of infection was recorded in scale 1 and 3% in scale 2. In scale 3, no intensity of infection was found.

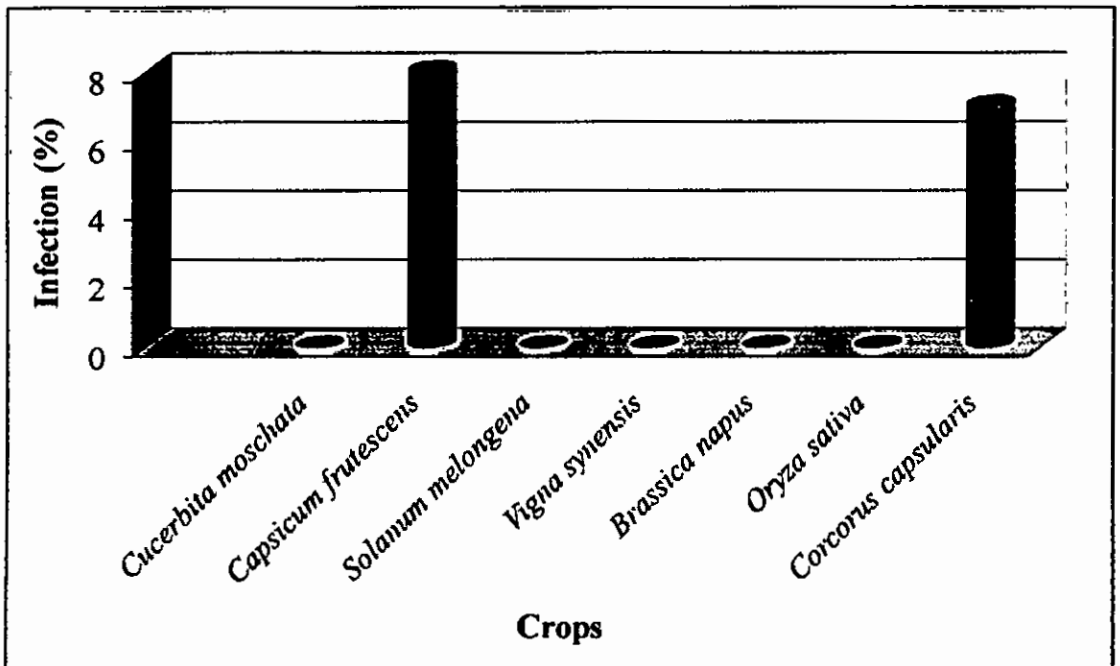


Fig. 6. AMF root infection of different crops root collected from East Dashora village of Manikganj district

Table 6. Intensity of infection of AMF on different crops root collected from East Dashora village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Cucerbita moschata	100	0	0	0
Capsicum frutescens	92	5	3	0
Solanum melongena	100	0	0	0
Vigna synensis	100	0	0	0
Brassica napus	100	0	0	0
Oryza sativa	100	0	0	0
Corcorus capsularis	93	4	3	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

g. Weeds of East Dashora village:

Root samples collected from East Dashora village of Manikganj district were assessed to observe the VAM association. The percent AMF root infection of different weeds root collected from East Dashora village of Manikganj district are presented in Figure 7. The percent root infection was varied from one species to another species. The maximum percent root infection was recorded in *Leucas aspera* (Willd.) Link and that was 23%. The lowest percent root infection was recorded in *Alternanthera sessilis* R. Br and that was 18%.

Percent intensity of infection of AMF on different weeds root collected from East Dashora village of Manikganj district is presented in Table 7. Intensity of infection was also varied at different scale. The highest intensity of infection was recorded in *Leucas aspera* (Willd.) Link and it was11% in scale 1, 9% in scale 2 and 4% in scale 3. Intensity of infection was 0 in case of *Amaranthus viridis* L., *Physalis heterophylla* L., *Linderlia antipoda* L. and *Datura matal* L..

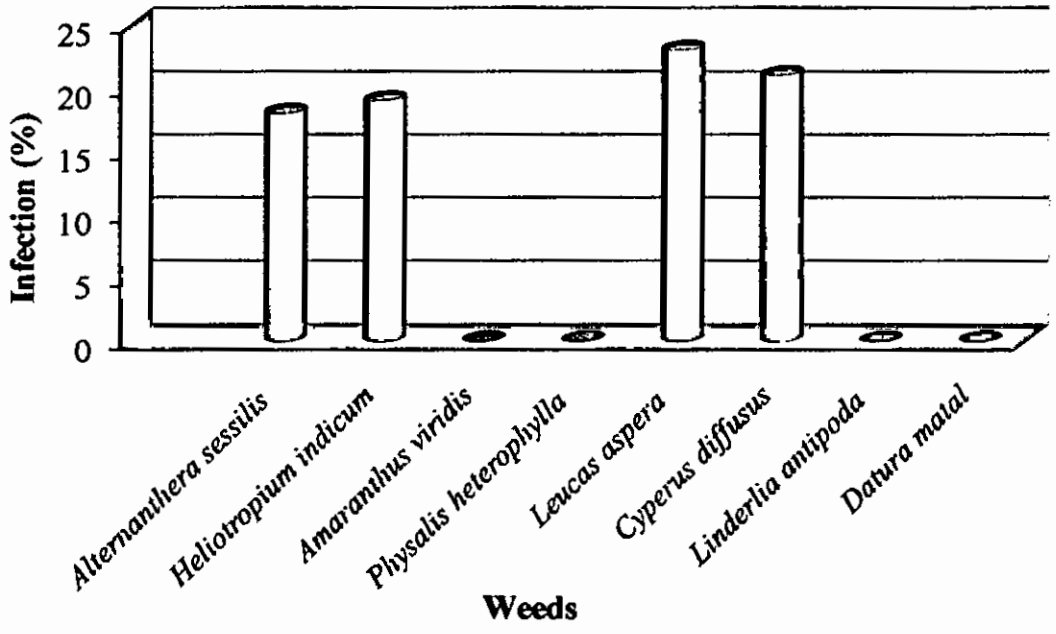


Fig. 7. AMF root infection of different weeds root collected from East Dashora village of Manikganj district

Table 7. Intensity of infection of AMF on different weeds root collected from East Dashora village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Alternanthera sessilis R. Br.	82	13	5	0
Heliotropium indicum L.	81	13	6	0
Amaranthus viridis L.	100	0	0	0
Physalis heterophylla L.	100	0	0	0
Leucas aspera (Willd.) Link.	77	11	9	4
Cyperus diffusus L.	79	16	5	0
Linderlia antipoda L.	100	0	0	0
Datura matal L.	100	0	0	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

h. Crops of Bautha village:

The results of the percentage of AM-fungal association in different crops root collected from Bautha village of Manikganj district are presented in Figure 8. Eight different plant species were collected from the village of to determine the infection percentage. Percent root infection ranged from 0% to 11%. The highest percentage root infection was found in *Zea mays* and that was 11% followed by *Amaranthus gangeticus* (9 %), *Cucerbita moschata* (8%) and *Capsicum frutescens* (4%). No infection found in *Solanum melongena* and *Cicer arietinum.*

Percent intensity of infection of AMF on different weeds root collected from East Dashora village of Manikganj district is presented in Table 8. Intensity of infection was also varied at different scale. The highest intensity of infection was recorded in *Zea mays* and it was10% in scale 1, 1% in scale 2.No intensity of infection was recorded in scale 3.

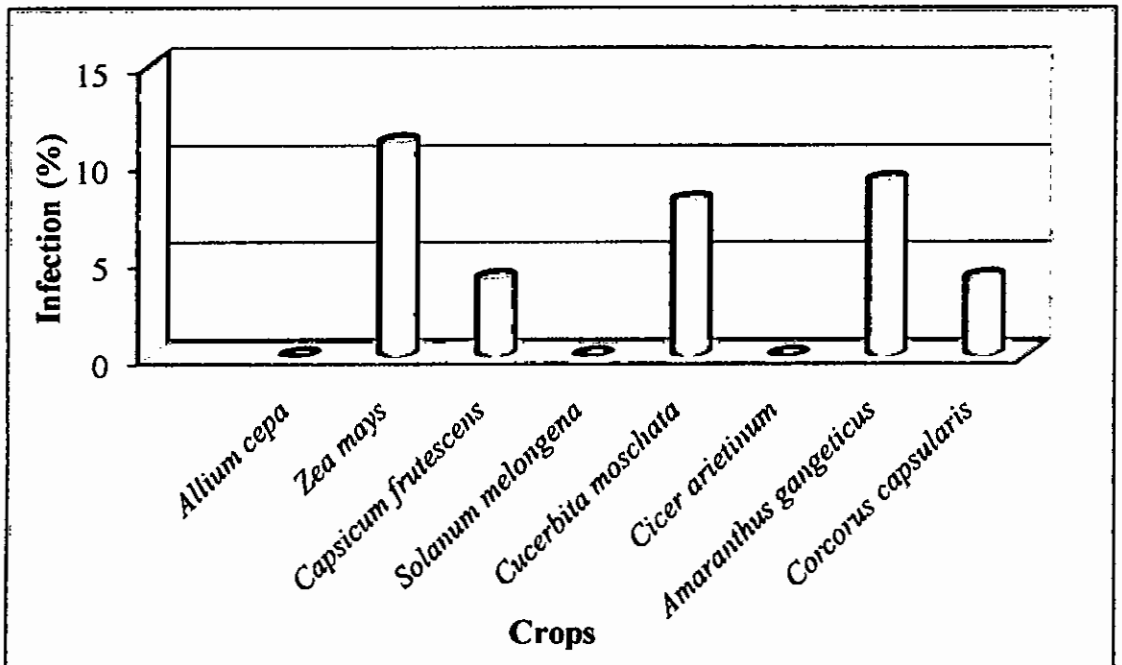


Fig. 8. AMF root infection of different crops root collected from Bautha village of Manikganj district

Table 8. Intensity of infection of AMF on different crops root collected from Bautha village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Allium cepa	100	0	0	0
Zea mays	89	10	1	0
Capsicum frutescens	96	4	0	0
Solanum melongena	100	0	0	0
Cucerbita moschata	92	6	2	0
Cicer arietinum	100	0	0	0
Amaranthus gangeticus	91	7	2	0
Corcorus capsularis	96	4	0	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

i. Crops of North Shauta village:

The data of percent AM-fungal root infection of different plants root collected from North Shauta village of Manikganj district are presented in Figure 9. The highest percent root infection was recorded in *Zea mays* and that was 17% and the lowest percent root infection was recorded in *Amaranthus* (3%). No infection was recorded *Allium cepa, Capsicum frutescens, Oryza sativa, Brassica napus, Vigna unguiculata.*

Percent intensity of infection of AMF on different crops root collected from North Shauta village of Manikganj district is presented in Table 9. 0-3 scale was used to determine the intensity of infection. In scale 1, intensity of infection was recorded in 4 cases. In scale 2 intensity of infection was recorded in two cases. No intensity of infection was recorded in scale 3. In case of *Zea mays* 15% intensity of infection was recorded in scale 1 and 2% in scale 2 on the other hand in *Abelmoscus esculentus* 4% intensity of infection was recorded in scale 1 and 3% in scale 2.

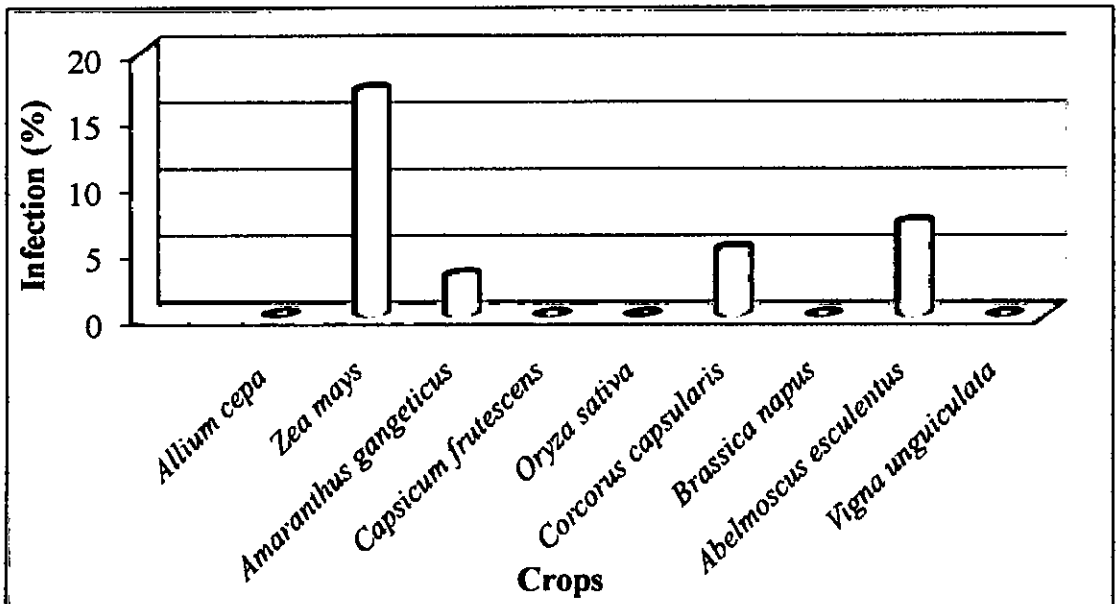


Fig. 9. AMF root infection of different crops root collected from North Shauta village of Manikganj district

Table 9. Intensity of infection of AMF on different crops root collected from North Shauta village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Allium cepa	100	0	0	0
Zea mays	83	15	2	0
Amaranthus gangeticus	97	3	0	0
Capsicum frutescens	100	0	0	0
Oryza sativa	100	0	0	0
Corcorus capsularis	95	5	0	0
Brassica napus	100	0	0	0
Abelmoscus esculentus	93	4	3	0
Vigna unguiculata	100	0	0	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

j. Crops of Gangadhar patti village:

Percent AMF root infection and intensity of infection of different plants root collected from Gangadhar patti village of Manikganj district are shown in Figure 10. Seven plants were collected from Gangadhar patti village. Result revealed that the percent root infection ranged from 0% to 17%. The highest percentage root infection was found in *Zea mays* and that was 17%. No infection was recorded in case of *Corcorus capsularis, Capsicum frutescens, Oryza sativa, Solanum melongena* and *Cicer arietinum.*

Percent intensity of infection of AMF on different crops root collectd from Gangadhar patti village of Manikganj district is presented in Table 10. 0-3 scale was used to determine the intensity of infection. Intensity of infection was also varied at different scale. The highest percentage of intensity was found in *Zea mays* and that was 15% in scale 1 and 2% in scale 2. Most of the cases intensity of infection was recorded in scale 0. There was no intensity of infection was found in scale 3.

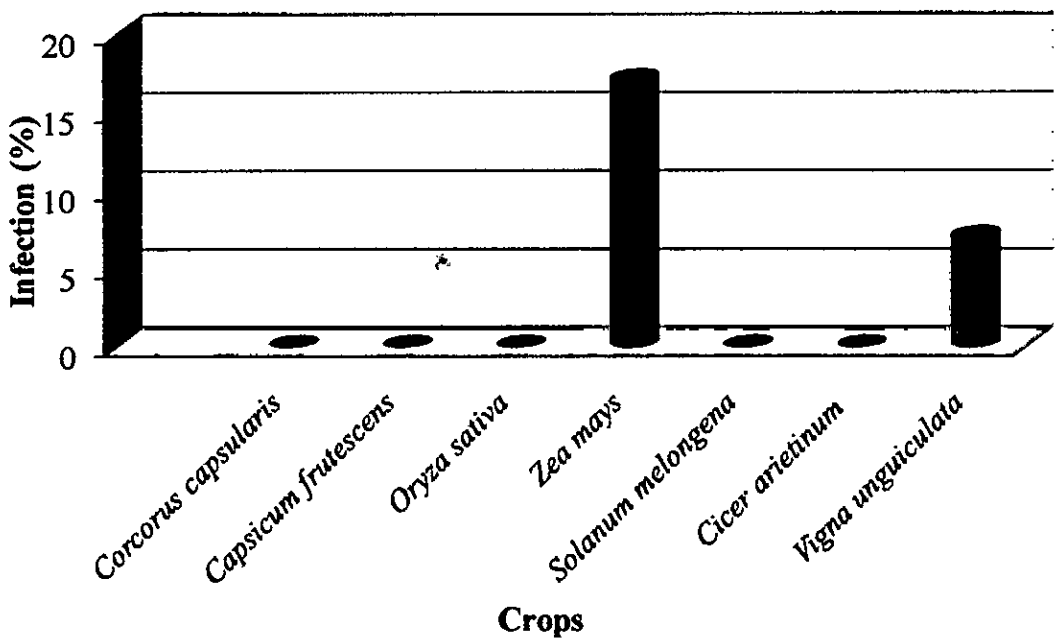


Fig. 10. AMF root infection of different crops root collected from Gangadhar patti village of Manikganj district

Table 10. Intensity of infection of AMF on different crops root collected from Gangadhar patti village of Manikganj district

Name of the plant species	Intensity of infection (%)			
	Scale			
	0	1	2	3
Corcorus capsularis	100	0	0	0
Capsicum frutescens	100	0	0	0
Oryza sativa	100	0	0	0
Zea mays	83	15	2	0
Solanum melongena	100	0	0	0
Cicer arietinum	100	0	0	0
Vigna unguiculata	93	4	3	0

0-3 scale: 0 = no infection, 1 = only mycelium present, 2 = mycelium + vesicle present, 3 = mycelium + vesicle + arbuscule present

K. Comparison

Comparison of AMF infection percentage of different crops among the villages:

Comparison of some crops among the seven villages is presented in Figure 11. The average percent root infection of different crops varied from village to village. The highest value of percent root infection was found from Diapar village and that was 15.86% followed by Jatrapur (9%) and West Dashora (5.5%). The lowest percent root infection was found in East Dashora village and that was 2.14%.

Comparison of AMF infection percentage of crops and weeds root among the villages:

Comparison of some crops with weeds among the three villages is presented in Figure 12. The average percent root infection of different crops and weeds varied from village to village. It was revealed that the average percent root infection was higher in weeds than crops in all the three villages. The highest average percent root infection of crops was found in Jatrapur village and the lowest percent was in West Dashora village whereas in case of weeds the highest average percent root infection was found in West Dashora village and the lowest percent was found in East Dashora village.

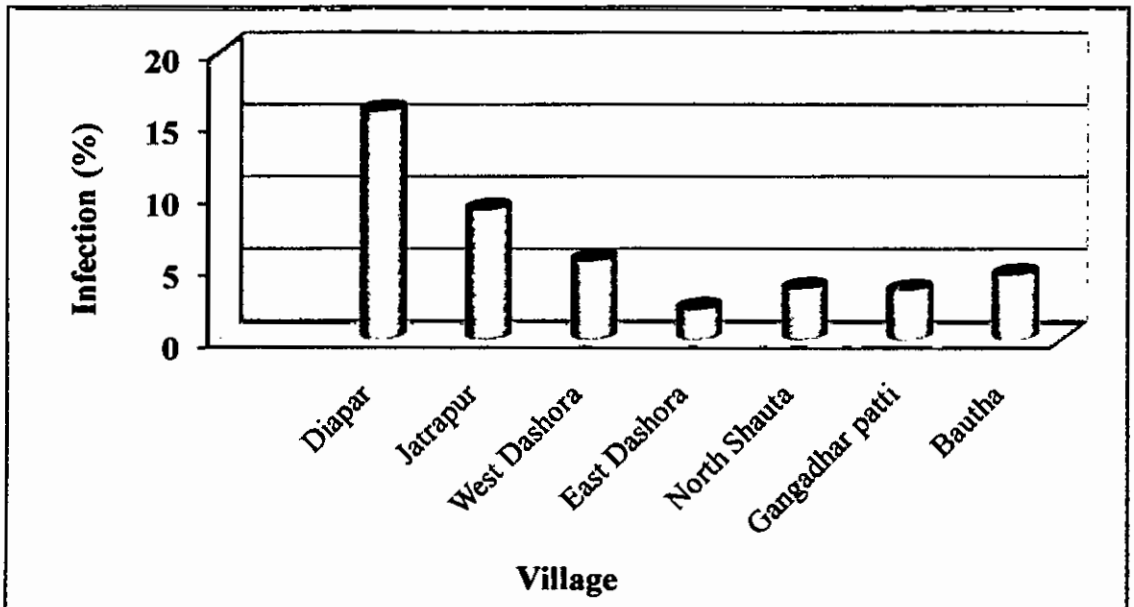


Fig. 11. Comparison of AMF infection percentage of different crops among the seven villages

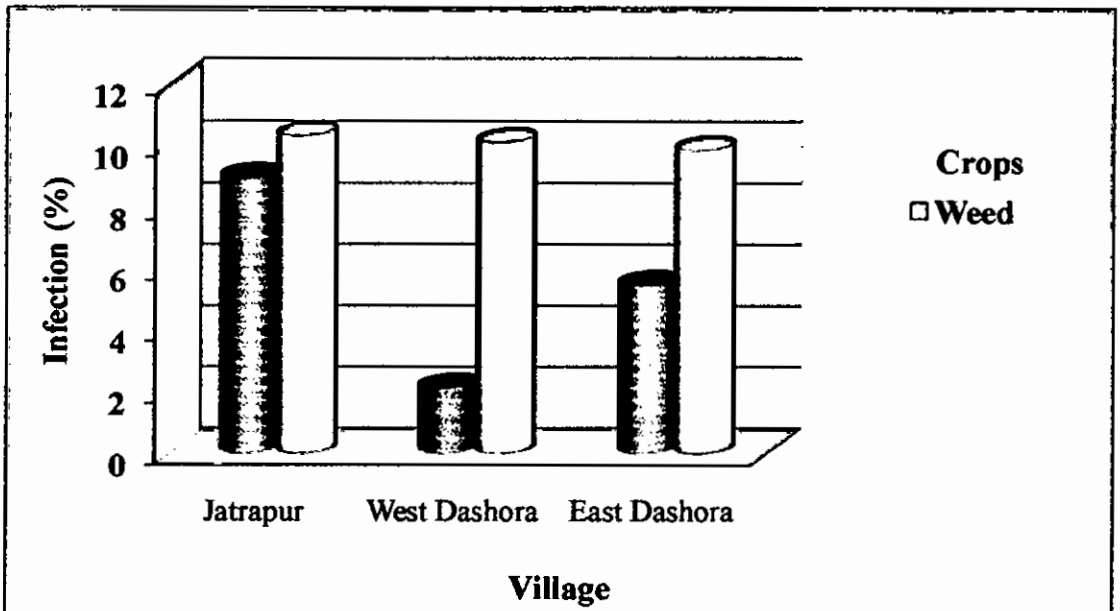


Fig. 12. Comparison of AMF infection percentage of crops and weeds root among the three villages

Comparison of AMF infection percentage of *Zea mays* among the six villages:

Comparison of AMF infection percentage of *Zea mays* among the six villages is presented in Figure 13. The average percent root infection of *Zea mays* varied from village to village. The highest value of percent root infection was found from Diapar village and that was 32% followed by Jatrapur (21%) and West Dashora (5.5%). The lowest percent root infection was found in Bautha village and that was 11%. Same kind of result was found in North Shauta and Gangadhar patti village.

Comparison of AMF infection of weed roots collected from three villages:

Comparison of total infection percentage of weeds among the three villages is presented in Figure 14. The average percent root infection of weeds was varied from village to village. The highest value of percent root infection was found from Jatrapur village and that was 10.33% followed by East Dashora (10.12%). The lowest percent root infection was found in West Dashora village and that was 9.88%.

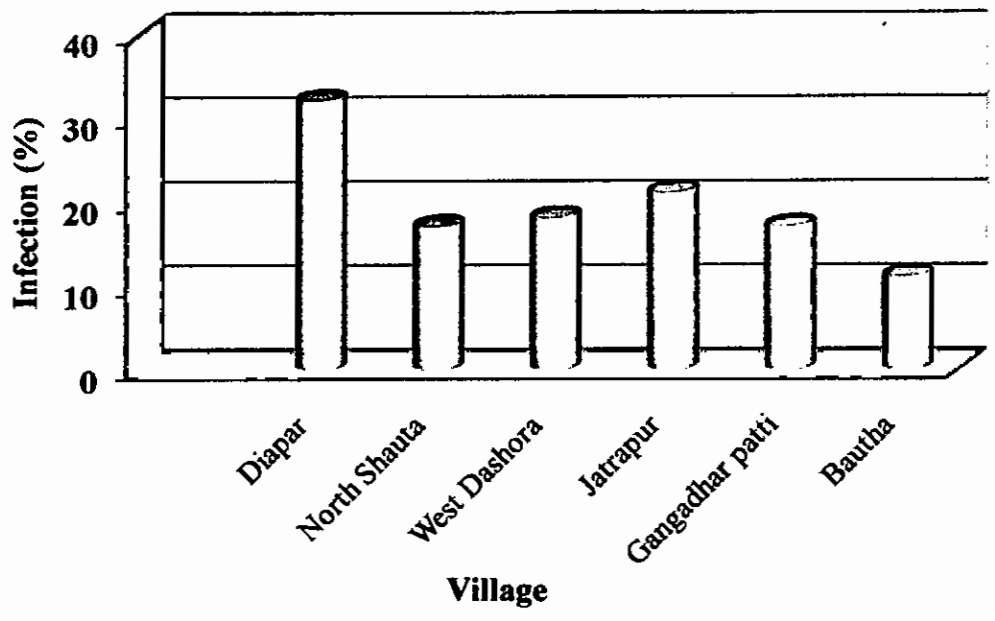


Fig. 13. Comparison of AMF infection percentage of *Zea mays* among the six villages

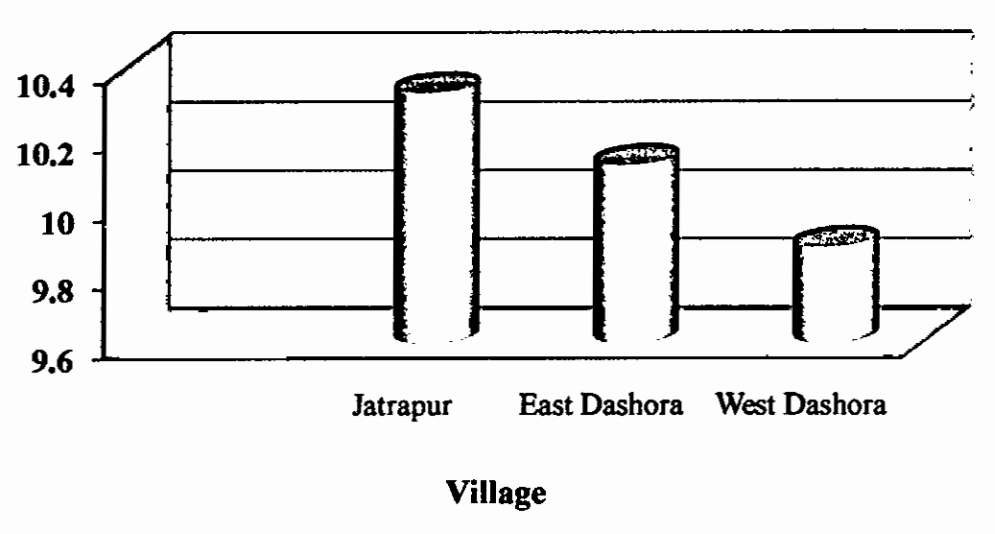


Fig. 14. Comparison of AMF infection of weed roots collected from three villages

Comparison of AMF infection between two weeds collected from three different villages:

Comparison of AMF infection of two weeds (*Leucas aspera* and *Croton sparisiflorus*) among the three villages is presented in Figure 15. The average percent root infection of two weeds varied from village to village. *Leucas aspera* collected from Jatrapur and West Dashora village showed higher percent root infection than *Croton sparisiflorus* on the other hand in East Dashora *Croton sparisiflorus* showed higher percent root infection than *Leucas aspera*.

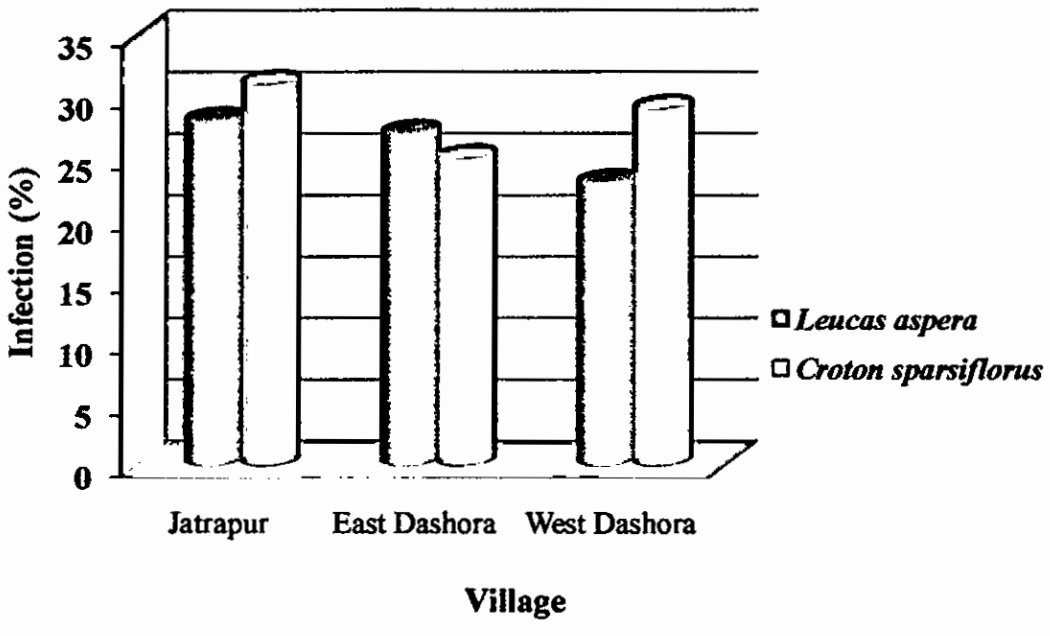


Fig. 15. Comparison of AMF infection between two weeds collected from three villages

4.2. Spore population in soil:

After confirming mycorrhizal association in the root system, we identify the spore population in soils and then isolated. But we obtained a little amount of mycorrhizal spore so that by using that data we cannot not find any variation to make table.

4.3. Effect of arsenic on seed germination:

Effect of arsenic on seed germination of different crops were studied in this section.

4.3.1. Blotter method experiment:

A. Tomato

Four different treatments were taken to evaluate the effect of different concentrations of arsenic solution on seed germination of tomato at different growth periods by using blotter method. It was exposed from the Figure-16 that the performances of the most of the treatment differed significantly from each other. Seed germination of tomato was decreased with the increase of arsenic concentration. With the increase of time the seedlings emergence were increased in every treatment. Result revealed that treatment T_1 (control) gave the highest seed germination and that was 86.66 % at 7 days after sowing which were significantly better in comparison to each of the other treatments. Among the four different treatments, treatment T_4 (500 ppm arsenic solution) gave the lowest result and that was 40 % at 3 days after sowing. Among the treatments T_2, T_3 and T_4, treatment T_2 showed better performance where less concentration of arsenic was used.

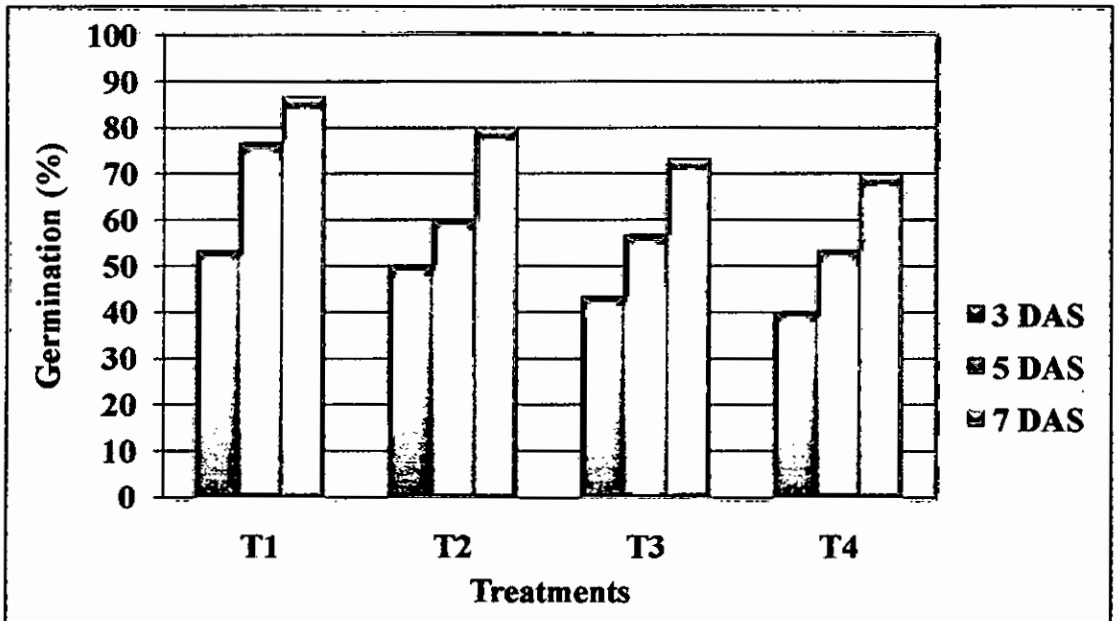


Fig. 16. Effect of different concentrations of arsenic solution on seed germination of tomato at different growth periods

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 =100 ppm arsenic solution

T_4 =500 ppm arsenic solution

B. Radish

Four different treatments were taken to evaluate the effect of different concentrations of arsenic solution on seed germination of radish at different growth periods by using blotter method. It was exposed from the Figure 17 that the performances of most of the treatment differed significantly from each other. Seed germination of radish was decreased with the increase arsenic concentration. With the increase of period the seedlings emergence were increased in every treatment. Result revealed that treatment T_1 (control) gave the highest seed germination and that was 96.66% at 7 days after sowing which were significantly better in comparison to each of the other treatments. Among the four different treatments, treatment T_4 (500 ppm arsenic solution) gave the lowest result and that was 46.66% at 3 days after sowing. Among the treatments T_2, T_3 and T_4, treatment T_2 showed better performance where lower concentration of arsenic was used.

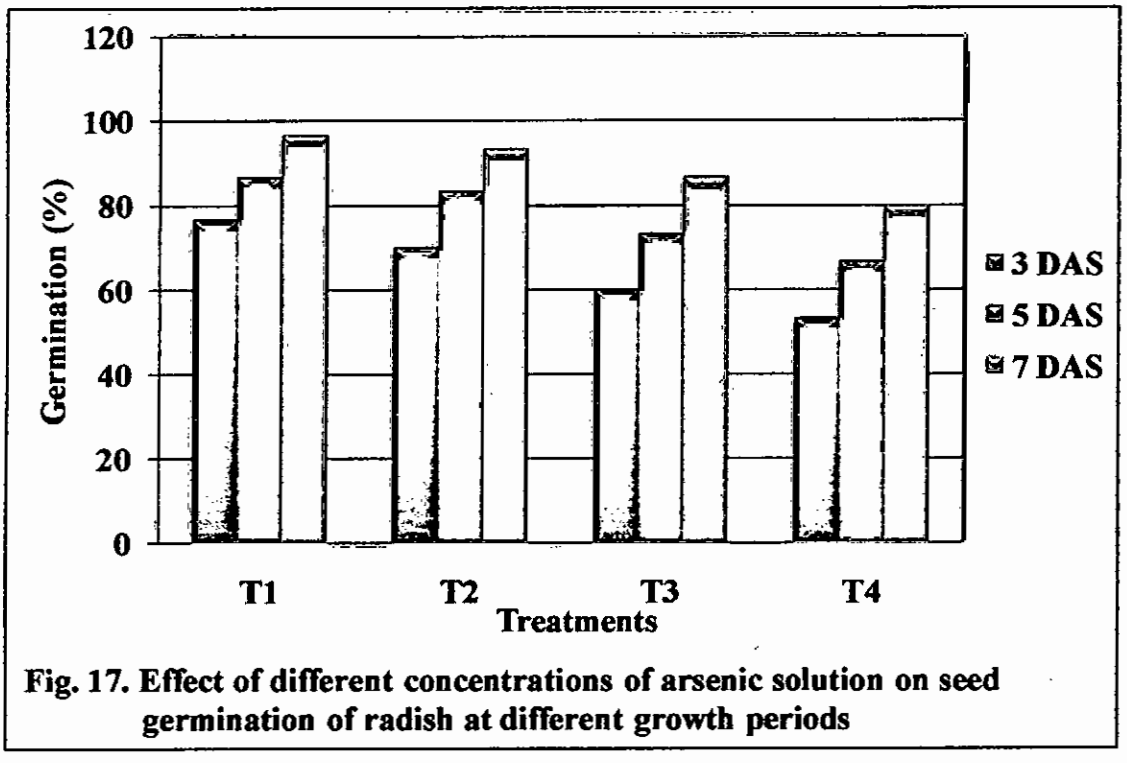


Fig. 17. Effect of different concentrations of arsenic solution on seed germination of radish at different growth periods

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 100 ppm arsenic solution

T_4 = 500 ppm arsenic solution

4.4. Role of mycorrhiza in arsenic amended soil

Role of AMF on plant growth of some crops grown in soil amended with different concentrations of arsenic solution is studied in this section.

4.4.1. Plastic tray experiment:

A. Tomato

- **Seedling emergence:**

The Role of AMF inoculation on seedling emergence of tomato, seeds sown in soil amended with different concentrations of arsenic solution are shown in Figure 18. Seedling emergence of tomato differs significantly due to the application of different concentration of arsenic solution and inoculation of mycorrhiza at 3, 5 and 7 days after sowing. Result revealed that treatment T_3 (10 ppm arsenic solution + mycorrhiza) gave the highest percent seedling emergence and those were 53.33%,70.00% and 90.00 % at 3 DAS, 5 DAS and 7 DAS, respectively which is significantly better in comparison to each of the other treatments. Treatment T_1 (control) showed the second highest percent seedling emergence in case of tomato. The lowest percent seedling emergence was recorded from the treatment T_6, those were 23.33%, 33.33% and 63.33% at 3 DAS, 5 DAS and 7 DAS, respectively, and percent seedling emergence of tomato decreased when the rate of arsenic concentration increased.

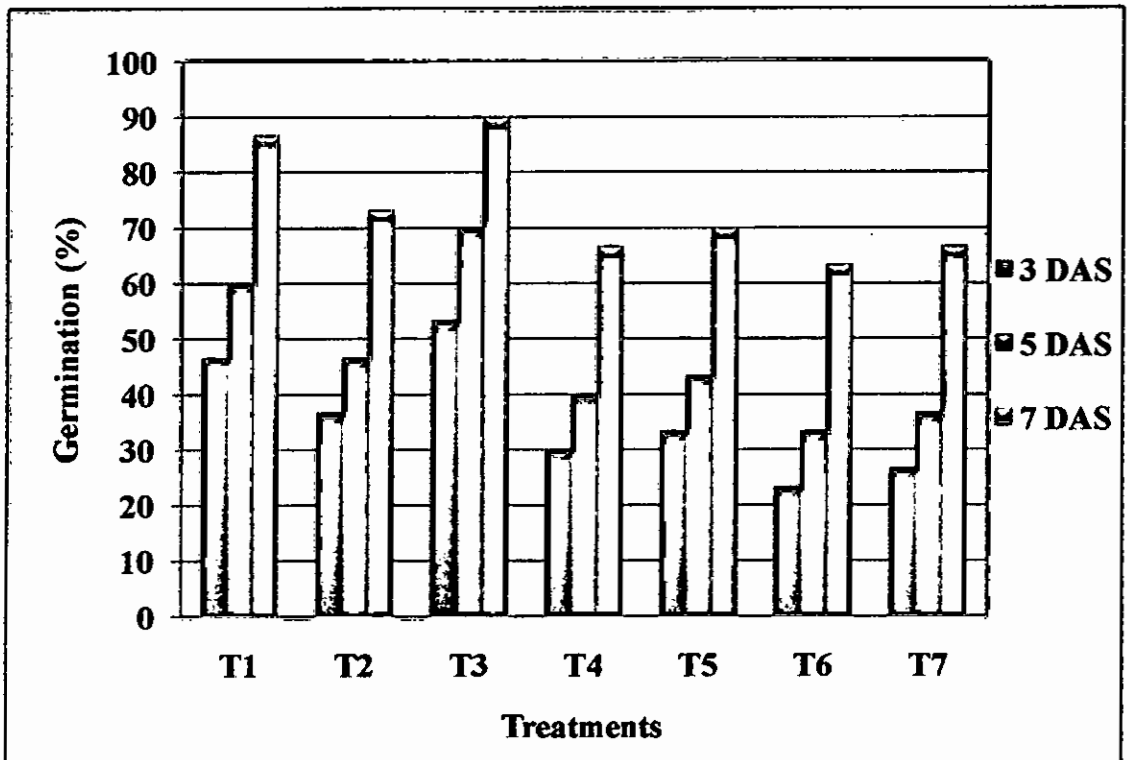


Fig. 18. Role of AMF on seed germination of tomato at different growth periods in soil amended with different concentrations of arsenic solution

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + mycorrhiza

T_4 =100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 =500 ppm arsenic solution

T_7 =500 ppm arsenic solution+ mycorrhiza

➢ **Shoot height:**

The Role of AMF inoculation on shoot height of tomato at different growth periods sown in soil amended with different concentration of arsenic solution are shown in Table 11. Shoot height of tomato differed significantly due to the application of different concentration of arsenic solution and inoculation of mycorrhiza at 20 and 30 days after sowing. Result revealed that treatment T_3 (10 ppm arsenic solution + mycorrhiza) gave the highest shoot height and those were 12.62cm and 15.45cm at 20 DAS and 30 DAS, respectively which is significantly better in comparison to each of the other treatments. Treatment T_1 (Control) showed the second highest shoot height in case of tomato. The lowest shoot height of tomato was recorded from the treatment T_6 and those were 5.12cm and 7.21cm at 20 DAS and30 DAS, respectively and shoot height of tomato decreased when the rate of arsenic concentration increased.

Table 11. Role of AMF on shoot height of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Shoot height (cm)	
	20 DAS	30 DAS
T_1	11.86 e (3.51)	13.99 e (3.80)
T_2	10.34 d (3.29)	12.00 d (3.53)
T_3	**12.62 f (3.62)**	**15.45 f (3.99)**
T_4	7.25 b (2.78)	9.23 b (3.11)
T_5	8.99 c (3.08)	10.88 c (3.37)
T_6	5.12 a (2.37)	7.21 a (2.77)
T_7	6.70 b (2.68)	8.82 b (3.05)

* The values in the parenthesis are the square root transformed value

T_1 = control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + mycorrhiza

T_4 =100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution+ mycorrhiza

➢ **Root length:**

The Role of AMF inoculation on root length of tomato, which was sown in soil, amended with different concentrations of arsenic is shown in Table 12. The root length of tomato was recorded after 20 and 30 days of sowing. The root length of tomato was varied at different concentration. The highest root length of tomato was recorded in treatment T_3 (10 ppm arsenic solution + mycorrhiza) and the lowest root length of tomato was recorded in treatment T_6 (500 ppm arsenic solution) in all the three recorded time. In comparison to all the treatments better result was obtained where mycorrhiza was inoculated than non-inoculated. Among the mycorrhizal treatments T_3 (10 ppm arsenic solution + mycorrhiza), T_5 (100 ppm arsenic solution+ mycorrhiza) and T_7 (500 ppm arsenic solution+ mycorrhiza); T_3 gave the highest root length of tomato and that was 5.98cm and 7.24cm at 20 and 30 days after sowing, respectively.

Table 12. Role of AMF on root length of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Root length (cm)	
	20 DAS	30 DAS
T_1	4.89 f (2.32)	5.98 f (2.54)
T_2	4.01 e (2.12)	5.12 e (2.37)
T_3	**5.98 g (2.54)**	**7.24 g (2.78)**
T_4	2.39 c (1.7)	4.45 d (2.22)
T_5	3.43 d (1.98)	3.87 c (2.09)
T_6	0.99 b (1.22)	2.45 b (1.71)
T_7	1.49 a (1.41)	1.56 a (1.46)

* The values in the parenthesis are the square root transformed value

T_1 = control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + mycorrhiza

T_4 =100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution+ mycorrhiza

➢ **Fresh weight of shoot:**

The Role of AMF inoculation on fresh weight of shoot of tomato, which was sown in soil, amended with different concentrations of arsenic is shown in Table 13. There was a remarkable variation of fresh weight of shoot of tomato among the seven treatments. The highest fresh weight of shoot of tomato was found in case of treatment T_3 (10 ppm arsenic solution + mycorrhiza) and those were 9.87gm and 11.01gm at 20 DAS and 30 DAS respectively which were significantly better in comparison to each of the other treatments. Control T_1 showed the second highest fresh weight of shoot of tomato. The lowest fresh weight of shoot of tomato was recorded from the only arsenic treated pots and due to the increase rate of arsenic concentration fresh weight of shoot of tomato decreased. Fresh weight of shoot of tomato was decreased with the increase of arsenic solution.

Table 13. Role of AMF on fresh weight of shoot of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of shoot (g)	
	20 DAS	30 DAS
T_1	8.22 f (2.95)	9.49 f (3.16)
T_2	7.20 d (2.77)	8.19 d (2.95)
T_3	**9.87 g (3.22)**	**11.01 g (3.39)**
T_4	5.27 c (2.40)	6.38 c (2.62)
T_5	6.59 e (2.66)	7.35e (2.80)
T_6	3.37 a (1.97)	4.24a (2.18)
T_7	4.43 b (2.22)	5.27 b (2.40)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution + mycorrhiza

➢ **Fresh weight of root:**

Role of AMF inoculation on fresh weight of root of tomato sown in soil amended with different concentration of arsenic solution presented in Table 14. The fresh weight of root of tomato was varied significantly at different concentration but with the increase of days, the emergence was increased. The fresh weight of root of tomato was recorded after 20 and 30 days of sowing. Higher fresh weight of root of tomato was recorded in mycorrhizal treatment in all the recorded time. Among the only arsenic treatment T_2, T_4 and T_6, the highest fresh weight of root of tomato was recorded in treatment T_2 (10 ppm arsenic solution) and the lowest fresh weight of root of tomato was found from T_6 (500 PPM arsenic solution) so, with the increase rate of arsenic concentration the fresh weight of root of tomato decreased. In another cases, when we inoculated AMF on those treatments, the Fresh weight of root of tomato increased. The highest Fresh weight of root of tomato was found in treatment T_3 (10 ppm arsenic solution + mycorrhiza).

Table 14. Role of AMF on fresh weight of root of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of root (g)	
	20 DAS	30 DAS
T_1	1.86 f (1.54)	1.99 e (1.58)
T_2	1.58 e (1.44)	1.78 d (1.51)
T_3	**2.12 g (1.62)**	**2.68 f (1.78)**
T_4	1.03 c (1.24)	1.45 c (1.40)
T_5	1.25 d (1.32)	1.32 c (1.35)
T_6	0.56 a (1.03)	0.79 a (1.14)
T_7	0.82 b (1.15)	1.02 b (1.23)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution + mycorrhiza

B. Radish

➢ Seedling emergence:

The Role of AMF inoculation on seedling emergence of radish at different growth periods in soil amended with different concentrations of arsenic solution is presented in Figure 19. It was exposed from the Figure 19 that the performances of the most of the treatments differ significantly from each other. Seedling emergence of radish ranges from 63.33%-86.66%, 70.00%-93.33% and 73.33%-96.66% at 3 DAS, 5 DAS and 7 DAS respectively. The highest seedling emergence of radish was recorded in treatment T_3 followed by treatment T_1, T_2 and the lowest seedling emergence of radish was recorded in treatment T_6 at 3 DAS. Similar results were also obtained at 5 DAS and 7 DAS. In case of treatment T_2, $T_4$and T_6 it was clearly showed that with the increase of arsenic concentration the seedling emergence of radish decreased. In case of only arsenic treatment T_2 (10 ppm arsenic solution) the seedling emergence of radish was 76.66% but it increased to 86.66% when we inoculated mycorrhiza with that 10 ppm arsenic solution.

➢ Shoot height:

The role of AMF inoculation on shoot height of radish in soil amended with different concentrations of arsenic solution is presented in Table 15. Data were recorded after 20 and 30 days of sowing. There was a remarkable variation of shoot height of radish found among the seven treatments. Shoot height of radish ranges from 7.38-16.23cm and 10.12-19.88cm at 20DAS and 30DAS respectively. In comparison to all the treatments mycorrhizal treatment T_3 (10 ppm arsenic solution + mycorrhiza) gave the highest result and those were 16.23cm and 19.88cm at 20DAS and 30DAS respectively and the lowest shoot height of radish was recorded in case of non-mycorrhizal treatment T_6 (500 ppm arsenic solution) and those were 7.38cm and 10.12cm at 20DAS and 30DAS respectively. It was revealed from the table that the shoot height of radish was the lowest in only arsenic treated poly bags but when added mycorrhiza with those treatments the shoot height of radish increased. Among the treatments T_2, T_4 and T_6, treatment T_6 gave the lowest result. Therefore, it was clearly exposed that with the increase of arsenic concentration the shoot height of radish decreased.

Table 15. Role of AMF on shoot height of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Shoot height (cm)	
	20 DAS	30 DAS
T_1	14.34 f (3.72)	16.23 f (4.09)
T_2	12.78 e (3.64)	14.78 e (3.90)
T_3	**16.23 g (4.09)**	**19.88 g (4.51)**
T_4	9.87 c (3.22)	12.23 c (3.56)
T_5	11.67 d (3.48)	13.66 d (3.76)
T_6	7.38 a (2.80)	10.12 a (3.25)
T_7	8.82 b (3.05)	11.88 b (3.51)

* The values in the parenthesis are the square root transformed value

T_1 = control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + mycorrhiza

T_4 =100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 =500 ppm arsenic solution

T_7 =500 ppm arsenic solution+ mycorrhiza

➢ **Root length:**

The Role of AMF inoculation on root length of radish, which was sown in soil, amended with different concentrations of arsenic is shown in Table 16.The root length of radish was recorded after 20 and 30 days of sowing. The root length of radish was varied at different concentration. The highest root length of radish was recorded in treatment T_3 (10 ppm arsenic solution + mycorrhiza) and the lowest root length of radish was recorded in treatment T_6 (500 ppm arsenic solution) in all the three recorded time. In comparison to all the treatments better result was obtained where mycorrhiza was inoculated than non-inoculated. Among the mycorrhizal treatments T_3 (10 ppm arsenic solution + mycorrhiza), T_5 (100 ppm arsenic solution+ mycorrhiza) and T_7 (500 ppm arsenic solution+ mycorrhiza); T_3 gave the highest root length of radish and that was 5.92cm and 7.48cm at 20 and 30 days after sowing respectively.

Table 16. Role of AMF on root length of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Root length (cm)	
	20 DAS	30 DAS
T_1	4.89 e (2.32)	5.99 f (2.54)
T_2	3.98 d (2.11)	5.02 e (2.34)
T_3	**5.92 f (2.53)**	**7.48 g (2.82)**
T_4	2.43 b (1.71)	3.45 c (1.98)
T_5	3.23 c (1.93)	4.54 d (2.24)
T_6	1.42 a (1.38)	1.72 a (1.48)
T_7	2.03 b (1.59)	2.55 b (1.74)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution+ mycorrhiza

➢ **Fresh weight of shoot:**

Table 17 represents the Role of AMF inoculation on fresh weight of shoot of radish, which was sown in soil amended with different concentrations of arsenic solution. The significant variation recorded due to the application of mycorrhizal inoculums against different concentration of arsenic solution on fresh weight of shoot of radish. The fresh weight of shoot of radish ranges from 1.65gm to 7.82g and 3.24g to 9.76g at 20 DAS and 30 DAS respectively. The highest fresh weight of shoot of radish was recorded in case of treatment T_3 (10 ppm arsenic solution + mycorrhiza) and the lowest fresh weight of shoot of radish was found from treatment T_6 (500 ppm arsenic solution) in all the two recorded periods. In comparison to treatment T_2, T_4 and T_6 we can say that the fresh weight of shoot of radish decreased with the increase of arsenic concentration.

Table 17. Role of AMF on fresh weight of shoot of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of shoot (g)	
	20 DAS	30 DAS
T_1	6.80 f (2.70)	8.43 f (2.99)
T_2	5.75 d (2.50)	6.54 e (2.65)
T_3	**7.82 g** (2.88)	**9.76 g** (3.20)
T_4	3.57 c (2.02)	5.39 c (2.43)
T_5	4.58 e (2.25)	6.37 d (2.62)
T_6	1.65 a (1.47)	3.24 a (1.93)
T_7	2.55 b (1.75)	4.38 b (2.21)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution + mycorrhiza

➢ **Fresh weight of root:**

Fresh weight of root of radish influenced by AMF inoculation in soil amended with different concentrations of arsenic solution is presented in Table 18. The fresh weight of root of radish was varied significantly at different concentrations but with the increase of days, the weight increased. The fresh weight of root of radish was recorded after 20 and 30 days of sowing. Higher seed germination was recorded in mycorrhizal treatment in all the recorded time. Among the only arsenic treatment T_2, T_4 and T_6, the highest fresh weight of root of radish was recorded in treatment T_2 (10 ppm arsenic solution) and the lowest fresh weight of root of radish was found from T_6 (500 ppm arsenic solution) so with the increase rate of arsenic concentration the fresh weight of root of radish decreased. In another cases, when we inoculated AMF on those treatments, the fresh weight of root of radish increased. The highest fresh weight of root of radish was found in treatment T_3 (10 ppm arsenic solution + mycorrhiza).

Table 18. Role of AMF on fresh weight of root of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of root (g)	
	20 DAS	30 DAS
T_1	1.33 e (1.35)	1.78 f (1.51)
T_2	0.98 d (1.22)	1.16 e (1.29)
T_3	**1.59 f (1.45)**	**2.08 g (1.61)**
T_4	0.43 b (0.96)	0.68 b (1.09)
T_5	0.78 c (1.13)	0.99 d (1.22)
T_6	0.23 a (0.85)	0.45 a (0.97)
T_7	0.46 b (0.98)	0.77 c (1.13)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution + mycorrhiza

C. Garlic

➢ Seedling emergence:

The role of AMF inoculation on seedling emergence of garlic seeds sown in soil amended with different concentrations of arsenic solution is presented in Figure 20. The seed germination was recorded after 3, 5 and 7 days of sowing. The seedling emergence was varied significantly at different concentrations but with the increase of incubation period, the emergence increased. The highest seedling emergence was recorded in case of treatment T_7 (500 ppm arsenic solution + mycorrhiza) and those were 80.00%, 90.00% and 96.66% at 3DAS, 5DAS and 7DAS respectively and the lowest was recorded in case of treatment T_2 (10 ppm arsenic solution) and those were 63.33% ,66.66% and 70.00% at 3DAS, 5DAS and 7DAS respectively. Among the three mycorrhizal treatments, treatment T_7 (500 ppm arsenic solution + mycorrhiza) gave the best result. On the other hand, among the only arsenic treatments T_2, T_4 and T_6, seedling emergence was the highest in case of treatment T_6 (500 ppm arsenic solution). In all the three recorded periods, it was observed that seedling emergence of garlic increased with the increase of arsenic concentration.

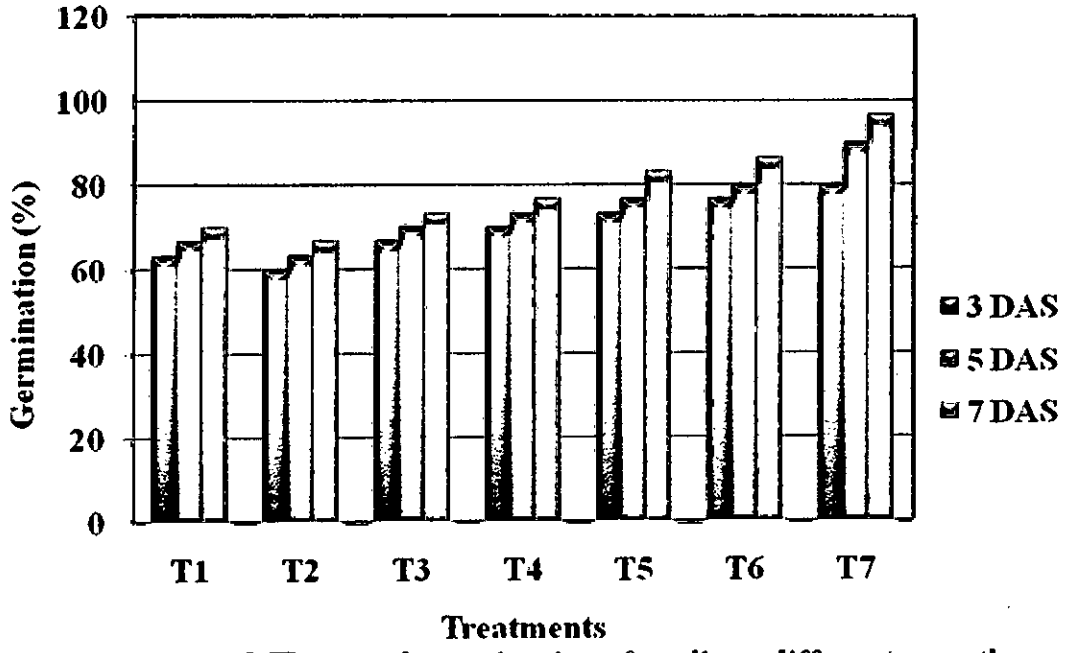


Fig. 20. Role of AMF on seed germination of garlic at different growth periods in soil amended with different concentrations of arsenic solution

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution+ mycorrhiza

➢ **Shoot height:**

Shoot height of garlic influenced by AMF inoculation in soil amended with different concentrations of arsenic solution is presented in Table 19. Different concentrations of arsenic showed significant differences in case of shoot height of garlic. Among the 10 treatments, treatment T_7 (500 ppm arsenic solution+ mycorrhiza) gave the highest result and lowest result was found in case of treatment T_2 (10 ppm arsenic solution). Among the three mycorrhizal treatments, (T_3, T_5 and T_7) T_7 showed better performance and those were 24.21 and 28.89 at 20 and 30 days after sowing. In all the two recorded periods it was observed that the shoot height of garlic increased with the increase of arsenic concentration and shoot height of garlic was higher in mycorrhiza inoculated poly bags than non-inoculated.

Table 19. Role of AMF on shoot height of garlic at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Shoot height (cm)	
	20 DAS	30 DAS
T_1	18.21 b	20.37 b
T_2	17.76 a	19.01 a
T_3	**19.00 c**	**21.02 c**
T_4	20.34 d	22.08 d
T_5	22.95 f	24.78 f
T_6	21.78 e	25.98 e
T_7	24.21 g	28.89 g

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution+ mycorrhiza

➢ **Root length:**

The Role of AMF inoculation on root length of garlic, which was sown in soil amended with different concentration of arsenic, is shown in Table 20. The root length was recorded after 20 and 30 days of sowing. The root length was varied significantly at different concentrations but with the increase of incubation period the root length increased. Root length of garlic differs significantly due to the effect of different concentrations of arsenic solution and mycorrhizal inoculation. Result revealed that treatment T_7 (500 ppm arsenic solution + mycorrhiza) gave the highest percentage of root length of garlic and those were 8.99cm and 10.23cm at 20 DAS and 30 DAS, respectively which is significantly better in comparison to each of the other treatments. The lowest root length of garlic was recorded from treatment T_2 (10 ppm arsenic solution) and root length of garlic increased when the rate of arsenic concentration decreased. It was found that the table, mycorrhiza with arsenic treated treatments gave better performance than the only arsenic treated treatments.

Table 20. Role of AMF on root length of garlic at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Root length (cm)	
	20 DAS	30 DAS
T_1	4.03 b (2.12)	4.98 b (2.34)
T_2	3.12 a (1.90)	4.01 a (2.12)
T_3	4.22 b (2.17)	5.13 b (2.37)
T_4	5.30 c (2.40)	6.24 c (2.59)
T_5	6.32 d (2.61)	7.49 d (2.82)
T_6	7.78 e (2.87)	8.56 e (3.00)
T_7	**8.99 f (3.08)**	**10.23 f (3.24)**

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution+ mycorrhiza

➢ **Fresh weight of shoot:**

Fresh weight of shoot of garlic influenced by AMF inoculation in soil amended with different concentrations of arsenic solution is presented in Table 21. The fresh weight of shoot of garlic varied significantly at different concentrations. The fresh weight of shoot of garlic was recorded after 20 and 30 days of sowing. Higher fresh weight of shoot of garlic was recorded in mycorrhizal treatment in all the recorded time. Among the only arsenic treatment T_2, T_4 and T_6 the highest fresh weight of shoot of garlic was recorded in treatment T_6 (500 ppm arsenic solution) and the lowest fresh weight of shoot of garlic was found from T_2 (10 ppm arsenic solution) so that with the increase rate of arsenic concentrations the fresh weight of shoot of garlic increased. In another cases, when we inoculated AMF on those treatments, the fresh weight of shoot of garlic increased.

Table 21. Role of AMF on fresh weight of shoot of garlic at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of shoot(g)	
	20 DAS	30 DAS
T_1	4.03 b (2.13)	5.21 c (2.39)
T_2	3.01a (1.87)	3.87 a (2.09)
T_3	3.99 b (2.12)	4.77 b (2.30)
T_4	4.98 c (2.34)	5.78 d (2.51)
T_5	5.99 d (2.55)	6.89 e (2.72)
T_6	7.65 e (2.85)	8.72 f (3.04)
T_7	**8.63 f (3.02)**	**10.78 g (3.36)**

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution + mycorrhiza

➢ **Fresh weight of root:**

Fresh weight of root of garlic influenced by AMF inoculation in soil amended with different concentrations of arsenic solution is presented in Table 22. The fresh weight of root of garlic was varied significantly at different concentrations but with the increase of days, the weight increased. The fresh weight of root of garlic was recorded after 20 and 30 days of sowing. Higher fresh weight of root of garlic was recorded in mycorrhizal treatment in all the recorded time. Among the only arsenic treatment T_2, T_4 and T_6, the highest fresh weight of garlic was recorded in treatment T_6 (500 ppm arsenic solution) and the lowest fresh weight of root of garlic was found from T_2 (10 ppm arsenic solution) so that with the increase rate of arsenic concentrations the fresh weight of root of garlic increased. In another cases, when we inoculated AMF on those treatments, the Fresh weight of root of garlic increased. The highest Fresh weight of root of garlic was found in treatment T_7 (500 ppm arsenic solution + mycorrhiza).

Table 22. Role of AMF on fresh weight of root of garlic at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of root (g)	
	20 DAS	30 DAS
T_1	1.69 d (1.48))	1.97 d (1.57)
T_2	1.03 a (1.24)	1.20 a (1.30)
T_3	1.23 b (1.31)	1.56 b (1.43)
T_4	1.45 c (1.40	1.79 c (1.51)
T_5	2.01 e (1.58)	2.54 e (1.74)
T_6	2.13 e (1.62)	2.86 f (1.83)
T_7	**2.56 f (1.75)**	**3.12 g (1.90)**

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution + mycorrhiza

T_6 = 500 ppm arsenic solution

T_7 = 500 ppm arsenic solution + mycorrhiza

highest in case of treatment T_2 (10 ppm arsenic solution). In all the three recorded periods, it was observed that seedling emergence of tomato decreased with the increase of arsenic concentrations. The sterilize mycorrhiza added with 10 PPM,100 PPM and 500 PPM arsenic solution did not differ so much.

- **Number of leaves:**

Ten different treatments were taken to evaluate the role of AMF inoculation on number of leaves of tomato, which was sown in soil, amended with different concentrations of arsenic solution. It was showed from the Table 23 that the performances of the most of the treatment differed significantly from each other. Result revealed that treatment T_4 (10 ppm arsenic solution + mycorrhiza) gave the highest number of leaves of tomato which were significantly better in comparison to each of the other treatments. Among the treatment T_2, T_5 and T_8, treatment T_2 gave the highest result followed by treatment T_5 and T_8. Among the 10 different treatments, treatment T_8 (500 ppm arsenic solution) gave the lowest result in all the three recorded periods. Number of leaves of tomato was decreased with the increase of arsenic solution.

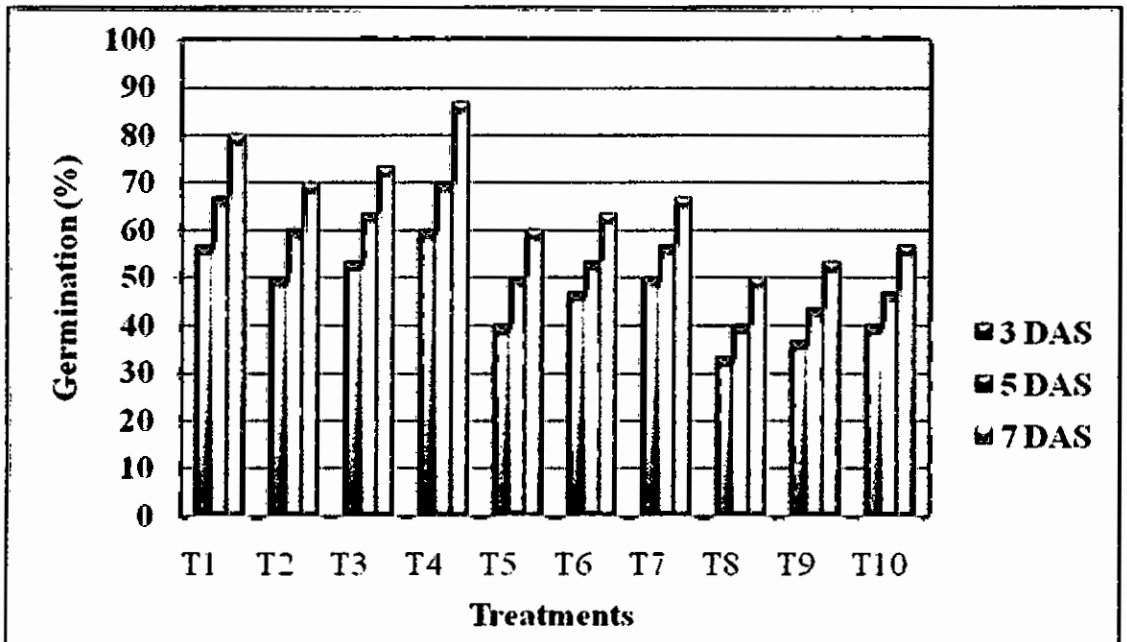


Fig. 21. Role of AMF on seed germination of tomato at different growth periods in soil amended with different concentrations of arsenic solution

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

Table 23. Role of AMF on number of leaves of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Number of leaves		
	20 DAS	30 DAS	45 DAS
T_1	5.23 e (2.39)	5.89 e (2.53)	7.00 e (2.74)
T_2	4.26 d (2.18)	4.65 c (2.67)	5.21 b (2.39)
T_3	4.34 d (2.20)	4.89 c (2.32)	5.67 c (2.48)
T_4	**6.23 f (2.59)**	**6.78 f (2.70)**	**8.21 f (2.94)**
T_5	3.44 c (1.98)	4.01 c (2.12)	4.98 b (2.34)
T_6	3.45 c (1.99)	4.21 c (2.17)	5.12 b (2.37)
T_7	4.03 d (2.13)	5.02 d (2.35)	6.01 d (2.55)
T_8	1.67 a (1.47)	2.45 a (1.72)	3.46 a (1.99)
T_9	1.88 a (1.54)	2.87 b (1.84)	3.78 a (2.07)
T_{10}	2.78 b (1.80)	3.42 b (1.98)	3.89 a (2.09)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ **Shoot height:**

The Role of AMF inoculation on shoot height of tomato, which was sown in soil amended with different concentration of arsenic, is shown in Table 24. The ranges of the shoot height of tomato were 17.60cm-22.10 cm, 19.70cm-25.80cm and 20.33cm-26.60cm. By the reason of high toxicity of arsenic in all the arsenic amended pots i.e. 10 ppm, 100 ppm and 500 ppm, the shoot height of tomato was 19.7cm, 18.70cm and 17.60cm, respectively again the shoot height of tomato increased to 22.10cm, 25.80cm and 26.60cm, respectively due to role of mycorrhizal inoculation. In control condition, shoot height of tomato was 21.23cm, 24.30cm and 25.40cm at 30 DAS, 45 DAS and 60 DAS, respectively. This Figurer reduced to 19.70cm, 22.80cm and 24.33cm, respectively when the soil amended with 10 ppm arsenic solution. Another time by using mycorrhizal inoculums, the figure increased to 22.10cm, 25.80 and 26.60cm, respectively. It was observed from the Plate 7 (T_2) and Plate 8 (T_4); Plate 9 (T_5) and Plate10 (T_7); Plate 11 (T_8) and Plate 12 (T_{10}) that each cases mycorrhizal inoculation helped to increase plant growth in arsenic amended soil.

Table 24. Role of AMF on shoot height of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Shoot height (cm)		
	30 DAS	45 DAS	60 DAS
T_1	21.23 h	24.30 i	25.40 g
T_2	19.70 e	22.80 f	24.33 e
T_3	20.20 f	23.30 g	24.90 f
T_4	**22.10 i**	**25.80 j**	**26.60 h**
T_5	18.70 c	20.80 c	21.90 c
T_6	19.20 d	21.40 d	22.80 d
T_7	20.60 g	23.40 h	24.20 e
T_8	17.60 a	19.70 a	20.33 a
T_9	18.10 b	20.20 b	21.10 b
T_{10}	19.10 d	21.90 e	23.10 d

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

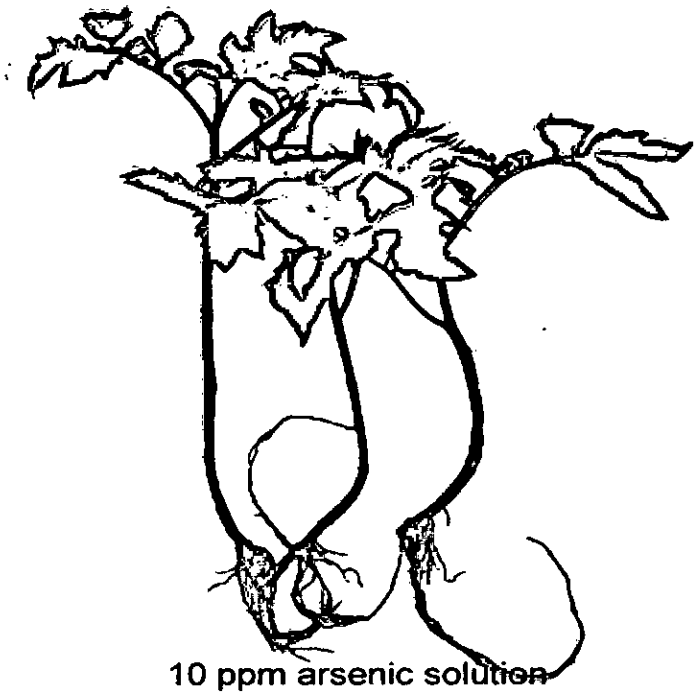


Plate 1. Effect of 10 ppm arsenic solution on growth of tomato at 60 DAS

Plate 2. Influence of AMF inoculation on growth of tomato in 10 ppm arsenic amended soil at 60 DAS

Plate 3. Effect of 100 ppm arsenic solution on growth of tomato at 60 DAS

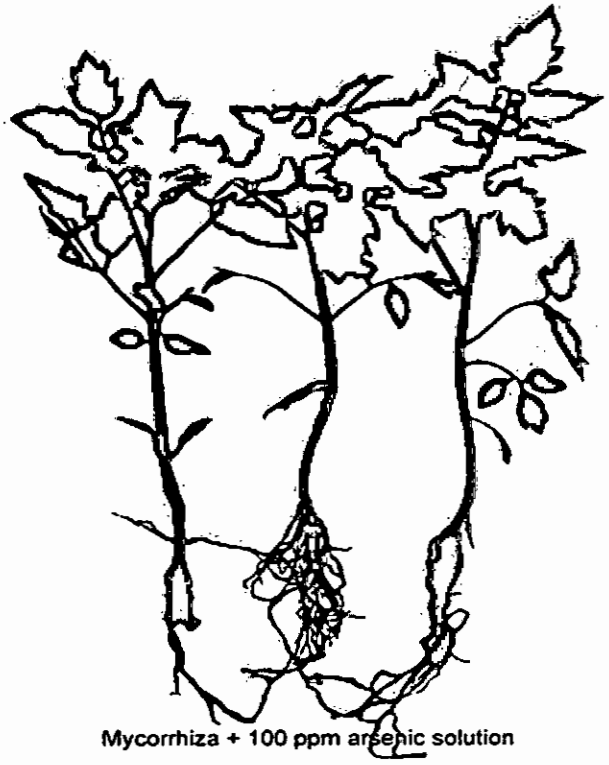


Plate 4. Influence of AMF inoculation on growth of tomato in 100 ppm arsenic amended soil at 60 DAS

Plate 5. Effect of 500 ppm arsenic solution on growth of tomato at 60 DAS

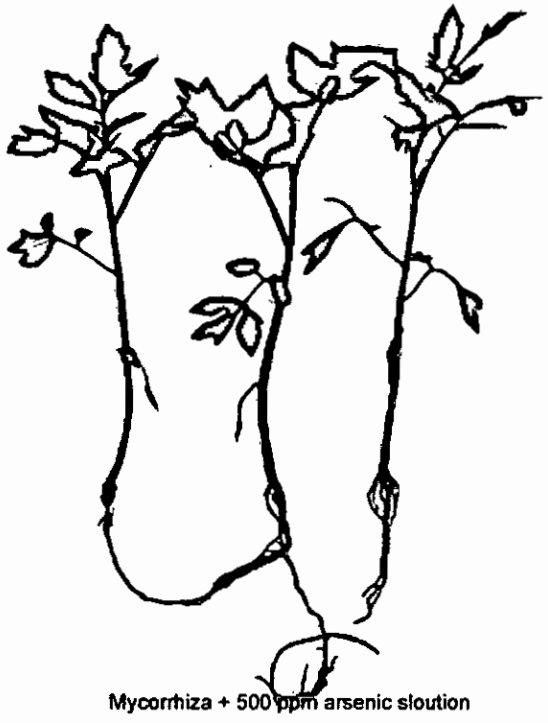


Plate 6. Influence of AMF inoculation on growth of tomato in 500 ppm arsenic amended soil at 60 DAS

➢ **Root length:**

Root length of tomato influenced by AMF inoculation in soil amended with different concentrations of arsenic solution is presented in Table 25. Root length of tomato differed significantly due to the relevance of different concentrations of arsenic solution and inoculation of mycorrhizal fungi at 30, 45 and 60 days after sowing. Among the 10 different treatments, treatment T_4 (10 ppm arsenic +mycorrhiza) gave the highest result and those were 21.97 cm, 23.07 cm and 25.87 cm at 30, 45 and 60 days after sowing. Treatment T_8 (500 ppm arsenic solution) gave the lowest result and those were 14.99 cm,15.65 cm and 16.01 cm at 30, 45 and 60 days after sowing. In all the three recorded periods it was observed that, the root length of tomato decreased with the increase of arsenic concentrations and root length of tomato was higher in mycorrhiza inoculated poly bags than non-inoculated. The sterilize mycorrhiza added with 10 ppm,100 ppm and 500 ppm arsenic solution did not differ so much.

Table 25. Role of AMF on root length of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Root length (cm)		
	30 DAS	45 DAS	60 DAS
T_1	19.58f	21.86f	23.08h
T_2	17.03c	18.96d	19.36e
T_3	17.89d	19.02d	19.65f
T_4	**21.97g**	**23.07g**	**25.87i**
T_5	16.45b	17.54c	18.35c
T_6	17.01c	17.69c	18.43cd
T_7	19.02e	20.87e	21.03g
T_8	14.99a	15.65a	16.01a
T_9	15.11a	15.97b	16.43b
T_{10}	16.89c	17.67c	18.69d

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ Vigor percent:

The Role of AMF inoculation on vigor percent of tomato, seeds sown in soil amended with different concentration of arsenic solution are shown in Table 26. Vigor percent of tomato differed significantly due to the application of different concentrations of arsenic solution and inoculation of mycorrhiza at 30, 45 and 60 days after sowing. Result revealed that treatment T_4 (10 ppm arsenic solution + mycorrhiza) gave the highest vigor percentage and those were 22.91%, 30.06% and 43.55% at 30 DAS, 45 DAS and 60 DAS, respectively which is significantly better in comparison to each of the other treatments. Treatment T_1 (Control) showed the second highest vigor percent. The lowest vigor percent was recorded from the treatment T_8 and those were 12.38%, 19.44% and 22.53% at 30 DAS, 45 DAS and 60 DAS, respectively and vigor percent of tomato decreased when the rate of arsenic concentration increased.

Table 26. Role of AMF inoculation on vigor percent of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Vigor (%)		
	30 DAS	45 DAS	60 DAS
T_1	22.03 h	34.92 f	41.20 h
T_2	16.52 e	25.89 c	31.01 e
T_3	18.66 f	27.50 e	35.64 g
T_4	**22.91 i**	**36.06 g**	**43.55 i**
T_5	14.76 c	23.00 b	26.56 c
T_6	16.29 e	23.84 b	29.27 d
T_7	19.81 g	26.77 d	33.92 f
T_8	12.38 a	19.44 a	22.53 a
T_9	13.28 b	20.61 a	24.39 b
T_{10}	15.83 d	23.34 b	29.25 d

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ **Fresh weight of shoot:**

Ten different treatments were taken to evaluate the role of AMF inoculation on fresh weight of shoot of tomato, which was sown in soil, amended with different concentration of arsenic solution. It was exposed from the Table 27 that the performances of the most of the treatment differ significantly from each other. Result revealed that treatment T_4 (10 ppm arsenic solution + mycorrhiza) gave the highest fresh weight of shoot of tomato 30.90gm, 33.90gm and 35.10gm at 30 DAS, 45 DAS and 60 DAS, respectively which is significantly better in comparison to each of the other treatments. Control T_1 showed the second highest fresh weight of shoot of tomato. The lowest fresh weight of shoot of tomato was recorded from the only arsenic treated treatments (T_2, T_5 and T_8) and fresh weight of shoot of tomato decreased when the rate of arsenic concentrations increased. For a second time the fresh weight of shoot of tomato increased when mycorrhiza inoculated on that arsenic treated treatments.

Table 27. Role of AMF on fresh weight of shoot of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of shoot (gm)		
	30 DAS	45 DAS	60 DAS
T_1	29.00 h	32.00 i	34.60 h
T_2	25.40 e	28.90 e	28.80 e
T_3	27.90 g	29.20 f	30.90 g
T_4	**30.90 i**	**33.90 j**	**35.10 i**
T_5	21.80 b	23.30 a	26.30 b
T_6	24.20 d	26.80 c	27.80 d
T_7	27.80 g	30.80 h	33.80 g
T_8	20.30 a	25.40 b	17.47 a
T_9	23.80 c	27.80 d	29.90 c
T_{10}	25.90 f	29.70 g	31.90 f

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + sterilized mycorrhiza

T_4 =10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 =100 ppm arsenic solution+ sterilized mycorrhiza

T_7 =100 ppm arsenic solution+ mycorrhiza

T_8 =500 ppm arsenic solution

T_9 =500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} =500 ppm arsenic solution+ mycorrhiza

Table 28. Role of AMF on fresh weight of root of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of root (g)		
	30 DAS	45 DAS	60 DAS
T_1	5.80 h (2.51)	6.80 h (2.70)	7.10 h (2.76)
T_2	3.60 e (2.02)	4.90 e (2.32)	5.40 e (5.40)
T_3	4.80 g (2.30)	5.90 g (2.53)	6.30 g (2.61)
T_4	**6.30 i (2.61)**	**7.10 i (2.76)**	**7.90 i (2.90)**
T_5	2.50 c (1.71)	2.80 a (1.82)	3.10 b (1.90)
T_6	2.90 d (1.84)	3.90 c (2.10)	4.20 c (2.17)
T_7	4.60 f (2.26)	5.30 f (2.44)	5.80 f (2.51)
T_8	2.00 a (1.58)	2.90 a (1.84)	2.90 a (1.84)
T_9	2.30 b (1.67)	3.40 b (1.97)	3.20 b (1.92)
T_{10}	3.00 d (1.87)	4.46 d (2.23)	4.90 d (2.32)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ **Fresh weight of root:**

Ten different treatments were taken to evaluate the role of AMF inoculation on fresh weight of root of tomato, which was sown in soil, amended with different concentration of arsenic solution. It was exposed from the Table 28 that the performances of the most of the treatment differ significantly from each other. Result revealed that treatment T_4 (10 PPM Arsenic solution + mycorrhiza) gave the highest fresh weight of root of tomato 6.03g 7.10g and 7.09g at 30 DAS, 45 DAS and 60 DAS respectively which is significantly better in comparison to each of the other treatments. Control T_1 showed the second highest fresh weight of root of tomato. The lowest fresh weight of root of tomato was recorded from the only arsenic treated treatments (T_2, T_5 and T_8) and fresh weight of root of tomato decreased when the rate of arsenic concentration increased. For a second time the fresh weight of root of tomato increased when we inoculated mycorrhiza on that arsenic treated treatments.

➢ Dry weight of shoot:

Ten different treatments were taken to evaluate the role of AMF inoculation on dry weight of shoot of tomato, which was sown in soil, amended with different concentrations of arsenic solution. It was showed from the Table 29 that the performances of the most of the treatment differ significantly from each other. Result revealed that treatment T_4 (10 ppm arsenic solution + mycorrhiza) gave the highest dry weight of shoot of tomato 2.30g, 2.50g and 3.10 g at 30 DAS, 45 DAS and 60 DAS respectively which were significantly better in comparison to each of the other treatments. Among the treatment T_2, T_5 and T_8, treatment T_2 gave the highest result followed by treatment T_5 and T_8. Among the 10 different treatments, treatment T_8 (500 ppm arsenic solution) gave the lowest result and that was 0.20 g, 0.43 g and 0.59 g at 30, 45 and 60 days after sowing. Dry weight of shoot of tomato was decreased with the increase of arsenic solution. The sterilize mycorrhiza added with 10 ppm, 100 ppm and 500 ppm arsenic solution did not differ so much.

Table 29. Role of AMF on dry weight of shoot of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Dry weight of shoot (g)		
	30 DAS	45 DAS	60 DAS
T_1	2.10 f (1.61)	2.30 h (1.67)	2.77 h (1.81)
T_2	0.99 d (1.22)	1.03 e (1.24)	1.21 e (1.31)
T_3	1.40 e (1.38)	1.69 g (1.48)	1.72 g (1.49)
T_4	**2.30 g (1.67)**	**2.50 i (1.73)**	**3.10 i (1.90)**
T_5	0.45 b (0.97)	5.81 c (1.14)	0.90 c (1.18)
T_6	0.80 c (1.14)	0.95 d (1.20)	1.03 d (1.24)
T_7	1.03 d (1.22)	1.21 f (1.31)	1.41 f (1.38)
T_8	0.20 a (0.84)	0.43 a (0.96)	0.59 a (1.04)
T_9	0.48 b (0.99)	0.65 b (1.07)	0.83 b (1.15)
T_{10}	0.82 c (1.14)	0.99 de (1.22)	1.03 d (1.24)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ Dry weight of root:

The Role of AMF inoculation on dry weight of root of tomato, seeds sown in soil amended with different concentrations of arsenic are shown in Table 30. The dry weight of root was ranged from 0.48-1.30 gm, 0.57-1.52 gm and 0.69-1.72 gm at 30 DAS, 45 DAS and 60 DAS respectively. The highest dry weight of root was recorded in case of treatment T_4 (10 ppm arsenic +mycorrhiza) and those were 1.30 gm,1.52 gm and 1.72 gm at 30 DAS, 45 DAS and 60 DAS, respectively. The lowest result was recorded in case of treatment T_8 (500 ppm arsenic solution) and those were 0.48 g, 0.57 g and 0.69 g at 30 DAS, 45 DAS and 60 DAS, respectively. Among the treatment T_2, T_5 and T_8 it was revealed that with the increase of arsenic concentrations the dry weight of root of tomato decreasing. The dry weight of root of tomato was 0.90 gm in treatment T_2 but it was increased to 1.30 gm in treatment T_4 when we inoculated mycorrhiza with 10 ppm arsenic solution. The sterilize mycorrhiza added with 10 ppm, 100 ppm and 500 ppm arsenic solution did not differ so much.

Table 30. Role of AMF on dry weight of root of tomato at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Dry weight of root (g)		
	30 DAS	45 DAS	60 DAS
T_1	0.97 g (1.21)	1.32 i (1.35)	1.31 g (1.35)
T_2	0.90 f (1.18)	0.92 e (1.19)	0.99 d (1.22)
T_3	0.98 g (1.22)	1.02 g (1.23)	1.19 f (1.30)
T_4	**1.30 h (1.34)**	**1.52 j (1.42)**	**1.72 h (1.49)**
T_5	0.78 d (1.28)	0.89 d (1.18)	0.95 c (1.20)
T_6	0.82 e (1.15)	0.97 f (1.21)	1.03 e (1.24)
T_7	0.97 g (1.21)	1.13 h (1.28)	1.21 f (1.31)
T_8	0.48 a (0.99)	0.57 a (1.03)	0.69 a (1.09)
T_9	0.57 b (1.03)	0.61 b (1.05)	0.81 b (1.14)
T_{10}	0.69 c (1.09)	0.80 c (1.14)	0.92 c (1.19)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ Nutrient uptake:

Inoculation of arbuscular mycorrhizal fungi in response to nutrient uptake (N, P, K and S) by tomato shoots, which was sown in soil amended with different concentration of arsenic solution is presented in Table 31. It is clearly exposed from the table that arbuscular mycorrhizal fungi inoculation significantly enhanced nutrient uptake by shoot of tomato than the other treatments. The highest result was found in case of treatment T_4 and T_8 gave the lowest result among the 10 different treatments. Total N percentage, P percentage, K percentage and S percentage ranges from 1.48 to 2.94, 0.41 to 0.78, 1.56 to 3.00and 0.43 to 0.78respectively. Among the treatment T_2, T_5 and T_8 it was clearly revealed that with the increase of arsenic concentration the percentage of nutrient uptake decreasing.

Table 31. Role of AMF on nutrient uptake by shoots of tomato at 60 DAS in soil amended with different concentrations of arsenic solution

Treatments	Nutrient uptake by tomato shoot at 60 DAS			
	Total N %	P %	K %	S %
T_1	2.24 f (1.66)	0.69 f (1.09)	2.97 g (1.86)	0.71 e (1.10)
T_2	1.68 d (1.48)	0.47 b (0.98)	2.54 d (1.74)	0.53 cb (1.01)
T_3	1.82 e (1.52)	0.47 b (0.98)	2.67 e (1.78)	0.54 b (1.02)
T_4	**2.94 g (1.85)**	**0.78 g (1.13)**	**3.00 h (1.87)**	**0.78 e (1.13)**
T_5	1.54 b (1.43)	0.44 b (0.97)	2.34 c (1.69)	0.51 c (1.00)
T_6	1.54 b (1.43)	0.44 b (0.97)	2.56 d (1.75)	0.52 cb (1.01)
T_7	1.61 c (1.45)	0.56 e (1.03)	2.78 f (1.81)	0.61 d (1.05)
T_8	1.48 a (1.41)	0.41 a (0.95)	1.56 a (1.44)	0.43 a (0.96)
T_9	1.48 a (1.41)	0.41 a (0.95)	2.04 b (1.59)	0.46 b (0.98)
T_{10}	1.52 ab (1.42)	0.50 c (1.00)	2.31 c (1.68)	0.52 cb (1.01)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ Arsenic uptake:

Role of AMF inoculation in response to arsenic uptake by shoots of tomato, which was sown in soil, amended with different concentrations of arsenic solution is presented in Table 32. The amount of arsenic uptake by shoots of tomato at 60 DAS differed significantly due to inoculation of AMF and different concentrations of arsenic solution. Due to inoculation of AMF, lower amount of arsenic was found in AMF inoculated pots than non-inoculated ones. The amount of arsenic increased with the increase rate of arsenic concentrations but in all the cases inoculation of AMF the rate of arsenic decreased. The lowest amount of arsenic was found in treatment T_3 (10 ppm arsenic solution + mycorrhiza) and that was 1.29 ppm on the other hand the highest amount was found in treatment T_7 (500 ppm arsenic solution). Among the treatment T_1, T_2 and T_3, the amount of arsenic was higher in treatment T_1 and that was 1.923 ppm but inoculation of mycorrhiza on that treatment the amount significantly decreased to 1.29 ppm. Same sort of result was found from other treatments.

Table 32. Role of AMF on arsenic uptake by shoots of tomato at 60 DAS in soil amended with different concentrations of arsenic solution

Treatments	Arsenic uptake by tomato shoot at 60 DAS (ppm)
T_1	1.923 bc
T_2	1.585 ab
T_3	1.290 a
T_4	2.409 d
T_5	2.046 cd
T_6	1.639 ab
T_7	8.874 g
T_8	5.585 f
T_9	4.012 e

T_1 = 10 ppm arsenic solution

T_2 = 10 ppm arsenic solution + sterilized mycorrhiza

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_6 = 100 ppm arsenic solution+ mycorrhiza

T_7 = 500 ppm arsenic solution

T_8 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_9 = 500 ppm arsenic solution+ mycorrhiza

➢ **Root colonization:**

The highest percent root colonization 48.41 of 10 ppm + mycorrhiza inoculated plants was recorded at 60 DAS and lowest 19.21 of 500 ppm + mycorrhiza inoculated plants were recorded at 30DAS. On the other hand, no root was colonized by the AMF in non-inoculated poly bags.

B. Radish

➢ Seedling emergence:

Seedling emergence of radish influenced by AMF inoculation in soil amended with different concentrations of arsenic solution is presented in Figure 22. The seed germination varied significantly at different concentrations but with the increase of days, the emergence increased. The seedling emergence was recorded after 3, 5 and 7 days of sowing. Among the treatment T_4, T_7 and T_{10}, higher seed germination was recorded in treatment T_4. In another cases, among the treatment T_2, T_5 and T_8, seedling emergence was the highest in treatment T_2 (10 ppm arsenic solution). In all the three-recorded periods it was observed that seedling emergence of radish decreased with the increase of arsenic concentration and seedling emergence was higher in mycorrhiza inoculated poly bags than non-inoculated. The sterilize mycorrhiza added with 10 ppm,100 ppm and 500 ppm arsenic solution did not differ so much.

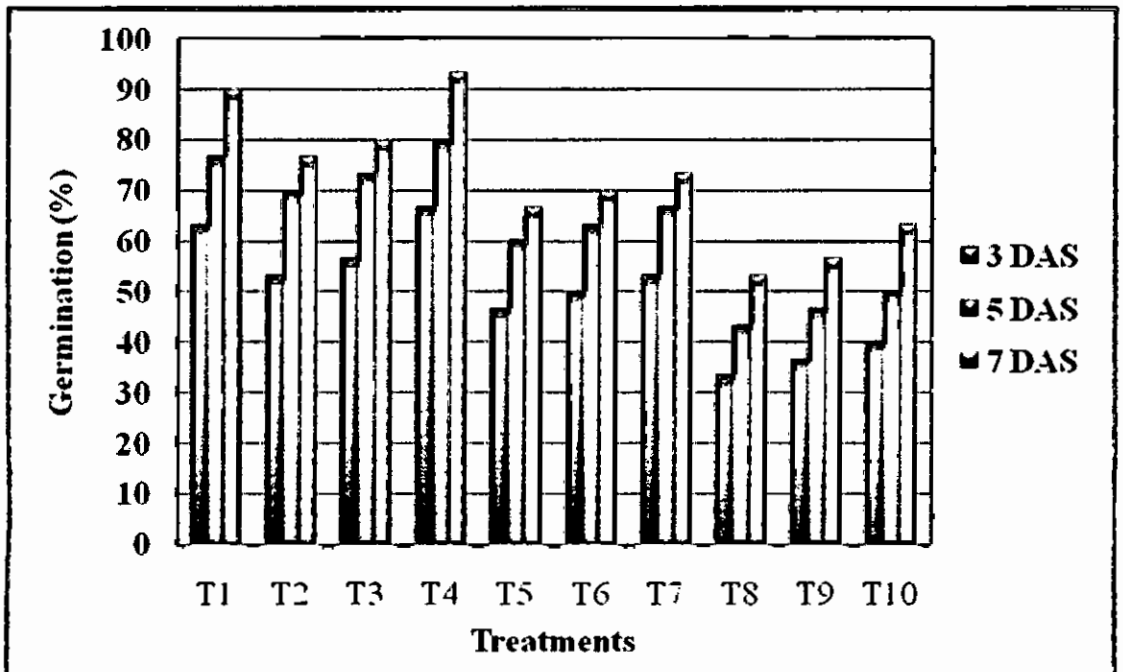


Fig 22. Role of AMF on seed germination of radish at different growth periods in soil amended with different concentrations of arsenic solution

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ **Number of leaves:**

The role of AMF inoculation on number of leaves of radish in soil amended with different concentrations of arsenic solution is presented in Table 33. Data were recorded after 15, 30 and 45 days of sowing. In comparison to all the treatments mycorrhizal treatment T_4 (10 ppm arsenic solution + mycorrhiza) gave the highest result and the lowest number of leaves of radish was recorded in case of treatment T_8 (500 ppm arsenic solution) in all the three recorded time. It was revealed from the table the number of leaves of radish was the lowest in only arsenic treated poly bags but when we added mycorrhiza with those treatments, the number of leaves of radish increased. Among the treatment T_2, T_5 and T_8 treatment T_8 gave the lowest result so it was clearly exposed that with the increase of arsenic concentrations the number of leaves of radish decreased.

Table 33. Role of AMF on number of leaves of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Number of leaves		
	15 DAS	30 DAS	45 DAS
T_1	5.84 h (2.52)	6.12 f (2.57)	6.34 f (2.62)
T_2	4.67 g (2.27)	4.89 e (2.32)	5.00 d (2.34)
T_3	4.73 g (2.29)	4.99 e (2.34)	5.32 de (2.41)
T_4	**6.93 i (2.73)**	**7.56 f (2.84)**	**8.34 g (2.97)**
T_5	3.21 c (1.93)	3.89 c (2.10)	4.12 c (2.15)
T_6	3.82 e (2.08)	4.56 d (2.25)	4.89 d (2.32)
T_7	4.12 f (2.15)	5.02 e (2.35)	5.76 ef (2.50)
T_8	2.13 a (1.62)	2.89 a (1.84)	3.23 a (1.93)
T_9	2.56 b (1.75)	3.02 a (1.88)	3.58 ab (2.02)
T_{10}	3.42 d (1.98)	3.20 b (1.92)	3.98 bc (2.12)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ **Shoot height:**

The Role of AMF inoculation on shoot height of radish, which was sown in soil amended with different concentration of arsenic, is exposed in Table 34. The shoot height was recorded in cm after 30, 45 and 60 days of sowing. The shoot height was significantly varied at different concentrations. The highest shoot height was recorded in treatment T_4 (10 ppm arsenic solution + mycorrhiza) and those were 23.10cm, 25.40cm and 26.90cm at 30, 45 and 60 days of sowing. Among the treatments T_2, T_3 and T_4, higher shoot height was recorded in treatment T_4. In the same way among the treatments T_5, T_6 and T_7 highest shoot height was recorded in treatment T_7 (100 ppm arsenic solution+ mycorrhiza). Among the treatments T_8, T_9 and T_{10} height shoot height was recorded in treatment T_{10} (500 ppm arsenic solution+ mycorrhiza). Therefore, it is clear that in every case mycorrhizal treatment gave the better result than non-mycorrhizal. In comparison to mycorrhizal treatments T_4, T_7 and T_{10} treatment T_4 gave the best performance in all the three recorded time. It was observed from the Plate 7 (T_2) and Plate 8 (T_4); Plate 9 (T_5) and Plate10 (T_7); Plate 11 (T_8) and Plate 12 (T_{10}) that each cases mycorrhizal inoculation helped to increase plant growth in arsenic amended soil. Similar response of AMF treatments were also observed in tomato crops.

Table 34. Role of AMF on shoot height of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Shoot height (cm)		
	30 DAS	45 DAS	60 DAS
T_1	22.26 h	24.90 g	26.00 h
T_2	20.40 e	22.90 e	23.90 e
T_3	21.20 f	23.40 f	24.60 f
T_4	**23.10 i**	**25.40 h**	**26.90 i**
T_5	19.30 b	20.50 b	22.40 c
T_6	20.20 d	21.20 c	22.90 d
T_7	21.90 g	23.30 f	24.90 g
T_8	18.20 a	19.60 a	21.00 a
T_9	19.20 b	20.40 b	21.50 b
T_{10}	20.00 c	21.90 d	22.80 d

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + sterilized mycorrhiza

T_4 =10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 =100 ppm arsenic solution+ sterilized mycorrhiza

T_7 =100 ppm arsenic solution+ mycorrhiza

T_8 =500 ppm arsenic solution

T_9 =500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} =500 ppm arsenic solution+ mycorrhiza

Plate 7. Effect of 10 ppm arsenic solution on growth of radish at 60 DAS

Plate 8. Influence of AMF inoculation on growth of radish in 10 ppm arsenic amended soil at 60 DAS

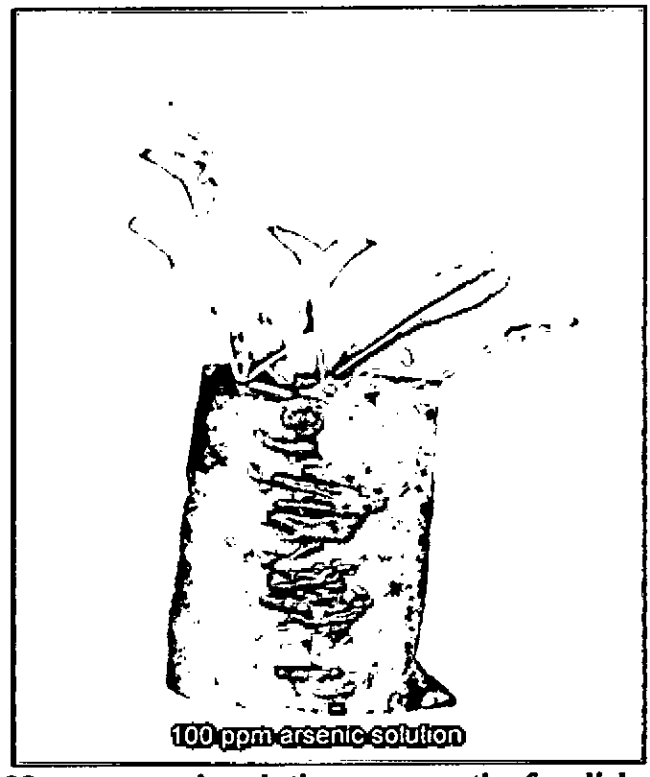


Plate 9. Effect of 100 ppm arsenic solution on growth of radish at 60 DAS

Plate 10. Influence of AMF inoculation on growth of radish in 100 ppm arsenic amended soil at 60 DAS

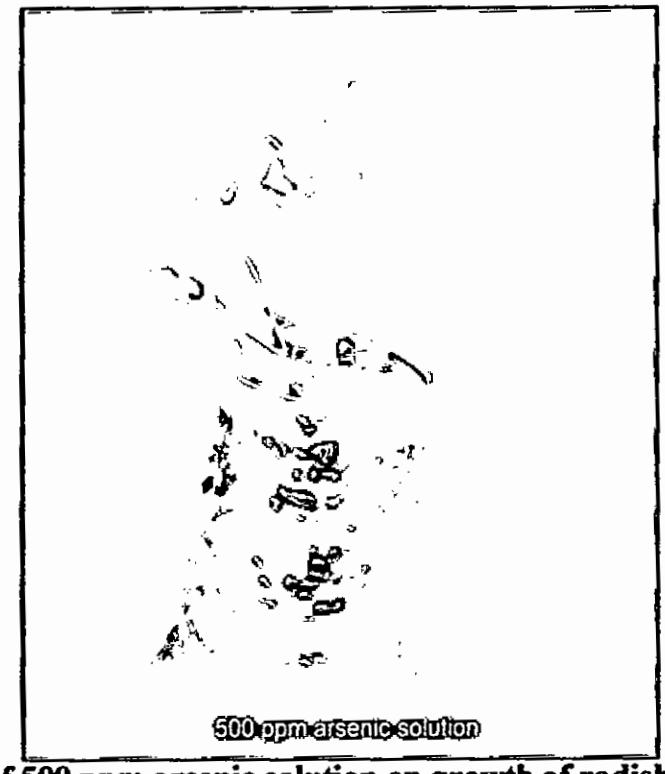


Plate 11. Effect of 500 ppm arsenic solution on growth of radish at 60 DAS

Plate 12. Influence of AMF inoculation on growth of radish in 500 ppm arsenic amended soil at 60 DAS

➢ Root length:

Ten different treatments were taken to evaluate the role of AMF inoculation on root length of radish, sown in soil amended with different concentration of arsenic solution is presented in Table 35. All the treatments varied significantly. With the elapse of time, root length of radish increased but there was not so much difference between the second and last recorded period. Among the 10 treatments, T_4 (10 ppm arsenic +mycorrhiza) gave the best result and that was 23.78cm, 25.60cm and 27.20 cm at 30, 45 and 60 days after sowing respectively. Whereas, treatment T_8 (500 ppm arsenic solution) gave the lowest result in all the three recorded periods. Among the all treatments, mycorrhizal treatments showed better performance than non-mycorrhizal. Mycorrhizal inoculation significantly enhanced radish root length in comparison to non-inoculation. Among the mycorrhizal treatments, treatment T_4 gave the highest result. Among the only arsenic amended treatments (T_2, T_5 and T_8), treatment T_2 gave the best result. Root length of radish decreased with the increase of arsenic concentrations.

Table 35. Role of AMF on root length of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Root length (cm)		
	30 DAS	45 DAS	60 DAS
T_1	22.76 g	24.70 h	26.70 f
T_2	20.60 e	22.50 e	25.26 e
T_3	21.60 f	23.70 g	25.30 e
T_4	**23.78 h**	**25.60 i**	**27.20 g**
T_5	19.30 b	20.70 b	22.50 c
T_6	20.00 c	21.60 d	23.00 c
T_7	21.50 f	23.60 g	24.80 e
T_8	18.70 a	19.70 a	20.10 a
T_9	19.30 b	20.90 c	21.20 b
T_{10}	20.30 d	22.80 f	23.90 d

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ **Vigor percent:**

Ten different treatments were taken to evaluate the role of AMF inoculation on vigor percent of radish, which was sown in soil amended with different concentrations of arsenic solution, is presented in Table 36. There was a remarkable variation of vigor percent of radish among the 10 different treatments. Result revealed that treatment T_4 (10 ppm arsenic solution + mycorrhiza) gave the highest vigor percent of radish and those were 27.19%, 37.74% and 47.06% at 30 DAS, 45 DAS and 60 DAS, respectively which is significantly better in comparison to each of the other treatments. Treatment T_1 (Control) showed the second highest vigor percent. The lowest vigor percent of radish was recorded from the only 500 ppm arsenic treated treatment (T_8) and percent vigor of radish decreased when the rate of arsenic concentrations increased. The variation of vigor percent of radish was recorded due to the combined effect of arsenic concentration and mycorrhizal inoculation.

Table 36. Role of AMF on vigor percent of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Vigor (%)		
	30 DAS	45 DAS	60 DAS
T_1	24.01e	36.00 h	45.43 h
T_2	19.27 c	28.60 d	31.95 d
T_3	22.25 d	31.55 f	37.45 f
T_4	**27.19f**	**37.74 i**	**47.06 i**
T_5	15.44 b	24.72 b	29.18 c
T_6	19.99 c	26.96 c	32.13 e
T_7	22.56d	32.83g	40.75 g
T_8	13.91 a	19.18 a	22.48 a
T_9	16.17 b	25.19 b	26.90 b
T_{10}	19.74 c	29.05 e	32.42 e

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + sterilized mycorrhiza

T_4 =10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 =100 ppm arsenic solution+ sterilized mycorrhiza

T_7 =100 ppm arsenic solution+ mycorrhiza

T_8 =500 ppm arsenic solution

T_9 =500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} =500 ppm arsenic solution+ mycorrhiza

➢ Fresh weight of shoot:

Table 37 represents the role of AMF inoculation on fresh weight of shoot of radish seeds sown in soil amended with different concentrations of arsenic solution. The fresh weight was recorded after 30, 45 and 60 days of sowing. The fresh weight was varied at different concentrations. The rate of increase of fresh weight was higher at 1st 30 days but no significant difference of fresh weight was recorded at next 15 days (30-45 days) and last 15 days (45-60 days). The highest fresh weight was recorded in treatment T_4 (10 ppm arsenic solution + mycorrhiza) and the lowest fresh weight of shoot of radish was recorded in treatment T_8 (500 ppm arsenic solution) in all the three recorded time. In comparison to all the treatments better result was obtained where mycorrhiza was inoculated than non-inoculated. Among the mycorrhizal treatments T_4 (10 ppm arsenic solution + mycorrhiza), T_7 (100 ppm arsenic solution+ mycorrhiza) and T_{10} (500 ppm arsenic solution+ mycorrhiza); T_4 gave the highest fresh weight and that was 33.90gm, 35.90gm and 36.90gm at 30, 45 and 60 days after sowing respectively.

Table 37. Role of AMF on fresh weight of shoot of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of shoot (g)		
	30 DAS	45 DAS	60 DAS
T_1	30.00 f	34.90 g	36.00 g
T_2	28.90 e	30.80 e	32.80 e
T_3	30.10 f	33.10 f	34.20 f
T_4	**33.90 i**	**35.90 h**	**36.90 h**
T_5	25.43 c	26.50 b	29.40 c
T_6	27.30 d	29.30 d	31.80 d
T_7	32.10 h	33.00 f	34.10 f
T_8	24.00 a	26.10 a	27.20 a
T_9	24.90 b	27.80 c	29.00 b
T_{10}	30.70 g	30.90 e	31.80 d

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ Fresh weight of root:

Table 38 represented the role of AMF inoculation on fresh weight of root of radish, seeds sown in soil amended with different concentrations of arsenic solution. Fresh weight of root of radish ranges from 1.50-4.40 gm, 2.00-6.00 gm and 2.40-6.90 gm at 30, 45 and 60 days after sowing. The highest fresh weight was recorded in case of treatment T_4 (10 ppm arsenic solution + mycorrhiza) and those were 4.40 gm, 6.00 gm and 6.90 gm at 30, 45 and 60 days after sowing respectively. The lowest result was recorded in case of treatment T_8(500 ppm arsenic solution) and those were 1.50 g, 2.00 g and 2.40 g at 30, 45 and 60 days after sowing restively. It was revealed from the table the fresh weight of root of radish was the lowest in only arsenic treated poly bags but when we added Mycorrhiza with those treatments, the fresh weight of root of radish increased. Among the treatment T_2, T_5 and T_8 treatment T_8 gave the lowest result so it was clearly revealed that with the increase of arsenic concentration the fresh weight of root of radish decreased.

Table 38. Role of AMF on fresh weight of root of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight of root(g)		
	30 DAS	45 DAS	60 DAS
T_1	2.10 f (1.61)	2.30 h (1.67)	2.77 h (1.81)
T_2	0.99 d (1.22)	1.03 e (1.24)	1.21 e (1.31)
T_3	1.40 e (1.38)	1.69 g (1.48)	1.72 g (1.49)
T_4	**2.30 g (1.67)**	**2.50 i (1.73)**	**3.10 i (1.90)**
T_5	0.45 b (0.97)	5.81 c (1.14)	0.90 c (1.18)
T_6	0.80 c (1.14)	0.95 d (1.20)	1.03 d (1.24)
T_7	1.03 d (1.22)	1.21 f (1.31)	1.41 f (1.38)
T_8	0.20 a (0.84)	0.43 a (0.96)	0.59 a (1.04)
T_9	0.48 b (0.99)	0.65 b (1.07)	0.83 b (1.15)
T_{10}	0.82 c (1.14)	0.99 de (1.22)	1.03 d (1.24)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 =10 ppm arsenic solution + sterilized mycorrhiza

T_4 =10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 =100 ppm arsenic solution+ sterilized mycorrhiza

T_7 =100 ppm arsenic solution+ mycorrhiza

T_8 =500 ppm arsenic solution

T_9 =500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} =500 ppm arsenic solution+ mycorrhiza

➢ **Dry weight of shoot:**

The influence of AMF inoculation on dry weight of shoot of radish at different growth periods, which was sown in soil, amended with different concentration of Arsenic solution is presented in Table 39. It was revealed from the table that the performance of the most of the treatment differ significantly from each other. Result showed that treatment T_4 gave the highest dry weight of shoot of radish and those were 2.50gm, 2.89gm and 3.03gm at 30 DAS, 45 DAS and 60 DAS respectively, which were significantly better in comparison to each of the other treatments. Control T_1 showed the second highest dry weight of shoot of radish. The lowest dry weight of shoot of radish was recorded from the only arsenic treated pots and due to the increase rate of arsenic concentration dry weight of shoot of radish decreased. On the other hand, in comparison to mycorrhiza inoculated pots with non-inoculated pots, combination effect of mycorrhiza with arsenic, mycorrhiza plays a vital role in the point of decrease the effect of arsenic toxicity and increase dry weight of shoot of radish.

Table 39. Role of AMF on dry weight of shoot of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Dry weight of shoot (g)		
	30 DAS	45 DAS	60 DAS
T_1	2.40 g (1.70)	2.63 i (1.46)	2.95 i (1.86)
T_2	0.95 e (1.20)	1.03 e (1.24)	1.21 e (1.31)
T_3	1.03 e (1.24)	1.21 g (1.31)	1.45 g (1.40)
T_4	**2.50 h (1.73)**	**2.89 j (1.84)**	**3.03 j (1.88)**
T_5	0.55 c (1.02)	0.85 b (1.16)	0.99 c (1.22)
T_6	0.83 d (1.15)	0.99 d (1.22)	1.03 d (1.24)
T_7	1.22 f (1.31)	1.45 h (1.40)	1.50 h (1.41)
T_8	0.21 a (0.84)	0.63 a (1.06)	0.75 a (1.12)
T_9	0.43 b (0.96)	0.89 c (1.18)	0.97 b (1.21)
T_{10}	0.99 e (1.22)	1.10 f (1.26)	1.25 f (1.32)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ **Dry weight of root:**

The Role of AMF inoculation on dry weight of root of radish, which was sown in soil amended with different concentrations of arsenic solution, is exposed in Table 40. Data were recorded after 30, 45 and 60 days of sowing. Dry weight of root of radish ranged from 0.10g-0.67g, 0.29g-1.02g and 0.34g-1.36g at 30 DAS, 45DAS and 60DAS respectively. In comparison to all the treatments, mycorrhizal treatment T_4 (10 ppm arsenic solution + mycorrhiza) gave the highest result and those were 0.67g, 1.02g and 1.36g at 30 DAS, 45DAS and 60DAS respectively and the lowest dry weight of root of radish was recorded in case of treatment T_8 (500 ppm arsenic solution) and those were 0.10g, 0.29g and 0.34g at 30 DAS, 45DAS and 60DAS respectively. In control condition, dry weight of root of radish was 0.58g, 0.97g and 1.25g in the three respective recorded times but it decreased to 0.39g, 0.62g and 0.85g when we amended the soil with 10 ppm arsenic solution. Again, when we inoculated mycorrhiza on those pots, the dry weight of root of radish increased to 0.67g, 1.02g and 1.36g at 30 DAS, 45DAS and 60DAS respectively. Same kind of result was observed in case of other mycorrhizal and non-mycorrhizal treatments in all the recorded time.

Table 40. Role of AMF on dry weight of root of radish at different growth periods in soil amended with different concentrations of arsenic solution

Treatments	Dry weight of root (g)		
	30 DAS	45 DAS	60 DAS
T_1	0.58 f (1.04)	0.97 g (1.21)	1.25 i (1.32)
T_2	0.39 d (0.94)	0.62 d (1.06)	0.85 f (1.16)
T_3	0.48 e (0.99)	0.78 e (1.13)	0.92 g (1.19)
T_4	**0.67 g (1.08)**	**1.02 h (1.23)**	**1.36 j (1.36)**
T_5	0.29 c (0.89)	0.48 c (0.99)	0.62 d (1.06)
T_6	0.31 c (0.90)	0.62 d (1.06)	0.71 e (1.10)
T_7	0.46 e (0.98)	0.89 f (1.18)	0.98h (1.22)
T_8	0.10 a (0.77)	0.29 a (0.89)	0.34 a (0.92)
T_9	0.19 b (0.83)	0.39 b (0.94)	0.48 b (0.99)
T_{10}	0.29 c (0.89)	0.48 c (0.99)	0.58 c (1.04)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ **Nutrient uptake:**

Table 41 represented the inoculation of arbuscular mycorrhizal fungi in response to nutrient uptake (N, P, K and S) by radish shoots at 60 DAS. It is revealed from the study that mycorrhizal fungi have a positive role in response to nutrient uptake and mycorrhizal fungi inoculated treatments significantly enhanced nutrient uptake by radish shoots in comparison to other treatment. The highest nutrient uptake was recorded in case of treatment T_4 (10 ppm arsenic solution + mycorrhiza) and those were 2.01 % total N, 0.73 % P, 3.00 % K and 0.66 % S and the lowest result was found in case of treatment T_8 (500 ppm arsenic solution) and those were 1.30 % total N, 0.39 % P, 1.70 % K and 0.34 % S and statistically similar result was found from the treatment T_9 (500 ppm arsenic solution + sterilized mycorrhiza). It was clearly showed from the table that due to toxicity of arsenic the percent nutrient uptake by shoots of radish was the lowest but when we inoculated mycorrhiza we got the highest percentage of nutrient uptake.

Table 41. Role of AMF on nutrient uptake by shoots of radish at 60 DAS in soil amended with different concentrations of arsenic solution

Treatments	Nutrient uptake by radish shoot at 60 DAS			
	Total N %	P %	K %	S %
T_1	1.96 e (1.57)	0.67 f (1.08)	2.92 g (1.85)	0. 64 g (1.04)
T_2	1.68 b (1.48)	0.51 d (1.00)	2.52 f (1.74)	0.44 de (.97)
T_3	1.68 b (1.48)	0.51 d (1.00)	2.71 g (1.79)	0.47 e (.98)
T_4	**2.01 e (1.58)**	**0.73 g (1.11)**	**3.00 i (1.87)**	**0.66 h (1.08)**
T_5	1.40 b (1.38)	0.43 bc (.96)	2.04 d (1.59)	0.40 bc (.95)
T_6	1.45 b (1.40)	0.45 c (.97)	2.41 e (1.71)	0.41 bc (.95)
T_7	1.54 d (1.43)	0.52 e (1.04)	2.48 f (1.73)	0.52 f (1.01)
T_8	1.30 a (1.34)	0.39 a (.94)	1.70 b (1.48)	0.34 a (.92)
T_9	1.34 a (1.35)	0.41 ab (.95)	1.85 c (1.53)	0.38 b (.94)
T_{10}	1.39 c (1.37)	0.49 d (.99)	1.99 a (1.22)	0.42 cd (.96)

* The values in the parenthesis are the square root transformed value

T_1 = Control

T_2 = 10 ppm arsenic solution

T_3 = 10 ppm arsenic solution + sterilized mycorrhiza

T_4 = 10 ppm arsenic solution + mycorrhiza

T_5 = 100 ppm arsenic solution

T_6 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_7 = 100 ppm arsenic solution+ mycorrhiza

T_8 = 500 ppm arsenic solution

T_9 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_{10} = 500 ppm arsenic solution+ mycorrhiza

➢ Arsenic uptake:

Role of AMF inoculation in response to arsenic uptake by shoots of radish, which was sown in soil, amended with different concentrations of arsenic solution is presented in Table 42. The amount of arsenic uptake by shoots of radish at 60 DAS differed significantly due to inoculation of AMF and different concentrations of arsenic solution. Due to inoculation of AMF, lower amount of arsenic was found in AMF inoculated pots than non-inoculated ones. The amount of arsenic increased with the increase rate of arsenic concentrations but in all the cases inoculation of AMF the rate of arsenic decreased. The lowest amount of arsenic was found in treatment T_3 (10 ppm arsenic solution + mycorrhiza) and that was 0.450 ppm on the other hand the highest amount was found in treatment T_7 (500 ppm arsenic solution). Among the treatment T_1, T_2 and T_3, the amount of arsenic was higher in treatment T_1 and that was 0.985 ppm but inoculation of mycorrhiza on that treatment the amount significantly decreased to 0.450 ppm. Same kind of result was found from other treatments. Among the all treatments, treatment T_1 and T_5 are statistically similar with treatment T_2 and T_6 respectively. It was observed from the table that when lower amount of arsenic was used, inoculation of mycorrhizal fungi helps to reduce arsenic uptake up to 54.31% than non-inoculated treatments but at higher amount of arsenic concentration, it helps to reduce only 30.06%.

Table 42. Role of AMF on arsenic uptake by shoots of radish at 60 DAS in soil amended with different concentrations of arsenic solution

Treatments	Arsenic uptake by radish shoots at 60 DAS (ppm)
T_1	0.985 ab
T_2	0.799 ab
T_3	**0.450 a**
T_4	1.847 c
T_5	1.388 bc
T_6	1.256 bc
T_7	4.324 e
T_8	3.548 de
T_9	3.024 d

T_1 = 10 ppm arsenic solution

T_2 = 10 ppm arsenic solution + sterilized mycorrhiza

T_3 = 10 ppm arsenic solution + mycorrhiza

T_4 = 100 ppm arsenic solution

T_5 = 100 ppm arsenic solution+ sterilized mycorrhiza

T_6 = 100 ppm arsenic solution+ mycorrhiza

T_7 = 500 ppm arsenic solution

T_8 = 500 ppm arsenic solution+ sterilized mycorrhiza

T_9 = 500 ppm arsenic solution+ mycorrhiza

➢ **Root colonization:**

The highest percent root colonization 51.48 of 10 ppm + mycorrhiza inoculated plants was recorded at 60 DAS and lowest 21.24 of 500 ppm + mycorrhiza inoculated plants were recorded at 30DAS. On the other hand, no root was colonized by the AMF in non-inoculated poly bags.

CHAPTER 5
DISCUSSIONS

CHAPTER 5

DISCUSSION

Preliminary studies on the occurrence of the AM fungi association in the roots of different crops and weeds species collected from different arsenic affected village of Manikganj district are reported here. It was revealed that the infection percentage and intensity of infection differed from crop to crop and location to location. The extent of infection also varied from species to species and within the same species from location to location. Some of the selected plant species both crops and weeds collected from different field of same location showed a wide range of variation.

The compared value of percent root infection of some crops among the seven villages, the highest value was found from Diapar village and that was 15.86% followed by Jatrapur (9%). The lowest percent root infection was found in East Dashora village and that was 2.14%.

It was observed from the comparison of some crops with weeds that the average percent root infection was higher in weeds than crops. The highest average percent root infection of crops was found in Jatrapur village and the lowest percent was in West Dashora village. In case of weeds the highest average percent root infection was found in West Dashora village and the lowest percent was found in East Dashora village.

Zea mays was collected from six different villages and it was observed that the highest value of percent root infection was found from Diapar village and that was 32% followed by Jatrapur village (21%). The lowest percent root infection was found in Bautha village and that was 11%.

The compared value of percent root infection of weeds among the three villages that the highest value of percent root infection was found from Jatrapur village and that was 10.33% followed by East Dashora (10.12%). The lowest percent root infection was found in West Dashora village and that was 9.88%.

It was observed from the comparison of total infection percentage of two weeds (*Leucas aspera* and *Croton sparisiflorus*) among the three villages that *Leucas aspera* collected from Jatrapur and West Dashora village showed higher percent root infection than *Croton sparisiflorus* on the other hand in East Dashora *Croton sparisiflorus* showed higher percent root infection then *Leucas aspera.*

Results of the present study are consistent with Saif (1977).There was a lack of definite correlation between percentage infection and intensity of infections. These differences in the colonization pattern of the crops studied might explain the generally held view that crops with course root gained more VAM compared to those with fine roots or these differences might be due to presence of diverse type of VAM in the rhizosphere soil of individual crop plant species. Dehne (1987) and Sieverding (1991) reported that these type of variation in percentage of infection

and intensity of infection of VAM under natural condition is depended on the indigenous VAM fungi, presence of host plant and different edaphic factors (e.g. soil texture, pH, conductivity, organic matter, phosphorus etc.). In the present study, most of the species showed lower infection. The plant with low mycorrhizal infection has low intensity of infection suggesting that arbuscules are either absent or low in number. Arbuscules are the nutrient exchanging organ of VAM for effecting association (Smith and Gianinazzi-Pearson, 1990); absence of this structure may influence the further growth of the VAM for more infection.

Three different treatments were taken to evaluate the role of different concentrations of arsenic solution on seed germination of radish and tomato by blotter method. The seedling emergence was varied significantly at different concentration. The seedling emergence was recorded at 3, 5 and 7 days after sowing. The highest results of seedling emergence of the two selected crops were recorded in case of control Petri plates followed by 10 ppm and 500 ppm arsenic solution. It was revealed from the study that the seedling emergence of radish and tomato decreased with the increase of arsenic concentration.

In plastic tray experiment the seedling emergence of tomato, radish and garlic differed significantly due to the application of different concentrations of arsenic solution and inoculation of mycorrhiza at 3, 5 and 7 days after sowing. Result revealed that treatment T_3 (10 ppm arsenic solution + mycorrhiza) gave the highest seedling emergence in radish and tomato but in garlic the highest seedling

mycorrhizal treated poly bags. Arsenic addition above 10 ppm significantly reduced per cent germination. At the highest level (500 ppm) of arsenic addition with mycorrhiza, only 63.33% and 56.66% germination was found in radish and tomato respectively. In this study, it was observed that the per cent germination significantly reduced with the increase of arsenic concentration.

Regarding germination percentage in response to arsenic amended soil, there is not enough work has yet been done so far. Present findings are similar with Vishwakarma and Singh, 1996 and Matsubara *et al.*(1994) who investigated the effects of inoculation with Vesicular-arbuscular mycorrhizal fungi (*Glomus etunicatum* or *Glomus intraradices*) on seedling growth of 17 vegetable crop species and reported that the growth was noticeably enhanced by VAMF inoculation to some of the selected crops studied in the present investigation . AM fungi promote phosphate uptake in low phosphate soils during the early stages of plant growth. Under nursery conditions, mycorrhizal inoculation improved growth of seedlings (Giri *et al.*, 2005).

Number of leaves was determined in poly bag experiment. Number of leaves of tomato and radish decreased gradually with the increase of arsenic concentrations (10 ppm to 500 ppm). The number of leaves of radish and tomato increased in mycorrhizal inoculated treatments than non-inoculated ones. Data was recorded after 20, 30 and 45 days of sowing. In comparison to all the treatments mycorrhizal treatment T_4 (10 ppm arsenic solution + mycorrhiza) gave the highest result and the lowest number of leaves of radish and tomato was recorded in case

of treatment T_8 (500 ppm arsenic solution) in all the three recorded time. It was revealed from the study that the number of leaves of radish and tomato was the lowest in only arsenic treated poly bags but when we added mycorrhiza with those treatments, the number of leaves of radish and tomato increased.

The results are in agreement with Ahmed *et al.* (2006) who reported that the number of leaves of lentil decreased significantly with the increase of arsenic concentration. He also reported that mycorrhizal inoculation reduced As concentration in roots and shoots. This study shows that growing lentil with compatible AM inoculums can minimize As toxicity.

Shoot height and root length of garlic, tomato and radish was observed in plastic tray experiment after 20 and 30 days of sowing. In all the two recorded periods it was observed that, shoot height and root length of radish and tomato increased in mycorrhiza inoculated poly bags than non-inoculated and decreased with the increase of arsenic concentrations. On the other hand, shoot height and root length of garlic increased with the increase of arsenic concentrations.

Shoot height and root length were also observed in poly bag experiment. Shoot height and root length of radish and tomato was found higher in all the mycorrhiza inoculated treatments. Shoot height and root length of radish and tomato was recorded at 30, 45 and 60 days after sowing. Shoot height and root length of radish and tomato differs significantly due to the relevance of different concentrations of

arsenic solution and inoculation of mycorrhizal fungi. Among the 10 treatments, treatment T_4 (10 ppm arsenic + mycorrhiza) gave the best result whereas, treatment T_8 (500 ppm arsenic solution) gave the lowest result in all the three recorded periods. Mycorrhizal inoculation significantly enhanced shoot height and root length of radish and tomato in comparison to non-inoculation. This was probably due to uptake of nutrient, which increased vegetative growth. Shoot height and root length of radish and tomato was decreased with the increase of arsenic concentrations. The increased root growth as reported in this study is an agreement with Gaur and Adholeya (2000). They reported the higher growth inoculated with AM fungi some other crops such as onion, potato and garlic.

Introduced *Glomus caledonium* was effective in improving plant growth and dual inoculation with indigenous VAM fungi was most effective. The tripartite system, indigenous VAM, G. *caledonium* and *Rhizobium phaseoli* improved plant growth and resulted in increased nodulation and nitrogenase activity (Mathew and Johri, 1989). Ultra *et al.* (2006) reported the AM inoculation as well as P application reduced As toxicity symptoms, most clearly so in the +AM–P treatment. They also reported that Plant growth was highest in the +AM + P treatment.

Under glasshouse condition in an As-contaminated soil arbuscular mycorrhizal (AM) fungus (*Glomus mosseae*) increased both Root length and dry weight markedly under the zero-P treatments. (Xia *et al.*, 2007).

Ahmed *et al.* (2006) reported that Plant height, plant biomass and shoot and root P concentration/off take increased significantly due to mycorrhizal infection. Plant height, plant biomass, root length and mycorrhizal infection decreased significantly with increasing As concentration.

Fresh weight of shoot and root were determined in plastic tray experiment. In this study mycorrhiza inoculation significantly increased fresh weight of shoot and root. In case of radish and tomato, fresh weight of shoot and root decreased gradually with the increase of arsenic concentrations but in case of garlic fresh weight of shoot and root increased significantly with the increase arsenic concentrations and mycorrhiza inoculated treatments gave better performance even though there was a high level of arsenic concentration.

Both fresh weight and dry weight of shoot and root were also examined in poly bag experiment. The fresh and dry weight of shoot and root of radish and tomato were recorded after 30, 45 and 60 days of sowing. The highest fresh and dry weight of shoot and root was recorded in treatment T_4 (10 ppm arsenic solution + mycorrhiza) and the lowest was recorded in treatment T_8 (500 ppm arsenic solution) in all the three recorded time. In comparison to all the treatments better result was obtained where mycorrhiza was inoculated than non-inoculated. It was revealed from the study that the fresh and dry weight of shoot and root was the lowest in only arsenic treated poly bags but when we added mycorrhiza with those treatments both the fresh and dry weight of shoot and root was increased. This was

probably due to uptake of nutrient, which Increased vegetative growth and hence greater translocation of photosynthesis from leaf to shoot and thereby enhanced shoot growth and weight. Shoot biomass significantly improved in all cases of inoculated plants (Tarafdar and Parveen, 1996). The results are more or less similar with Carling and Brown (1980) who reported that colonization by most Glomus isolates significantly increased plant shoot dry weight in low fertility soil. Root, shoot and total plant dry weight were significantly greater in mycorrhizal plants than in non-mycorrhizal controls in Abelmoscus esculentus (Krishna and Bagyaraj, 1982). Fresh weights of root and shoot increased when the plants were inoculated with VAMF (Matsubara *et al.*, 1994). Root and shoot dry weights were higher in mycorrhizal than non-mycorrhizal plants (Giri *et al.*, 2005).

The results are similar with Xia *et al.* (2007) they reported that dry weight and root biomass both increased markedly when maize plants inoculated with arbuscular mycorrhizal (AM) fungus (*Glomus mosseae*) under glasshouse condition in an arsenic amended soil.

Plant biomass, shoot and root P concentration/off take increased significantly due to mycorrhizal infection. Plant height, leaf/ pod number, plant biomass, root length and mycorrhizal infection decreased significantly with increasing As concentration (Ahmed *et al.,* 2006). Mycorrhizal colonization increased plant biomass at As application rates of 25, 50 and 75 mg kg (-1) (Liu *et al.* 2005). Agely *et al.* (2005)

found that the AM fungi not only tolerated As amendment, but their presence increased frond dry mass at the highest As application rate.

In this study, significant reduction in mycorrhizal root colonization was observed due to arsenic toxicity. (Ahmed *et al.*, 2006) reported that mycorrhizal infection decreased significantly with increasing As concentration. Liu *et al.* (2005) conducted a glasshouse pot experiment on tomato plants to study the effect of arbuscular mycorrhizal (AM) colonization by *Glomus mosseae* BEG167 on the yield and arsenate uptake of in soil experimentally contaminated with five As levels. Mycorrhizal colonization was little affected by As application and declined only in soil amended with 150 mg As kg^{-1}.

It is revealed from the study that the arbuscular mycorrhizal fungi have a positive role in response to nutrient uptake (N, P, K and S) and mycorrhizal fungi inoculated treatments significantly enhanced nutrient uptake by radish and tomato shoots in comparison to other treatment. The highest result was found in case of treatment T_4, on the other hand T_8 gave the lowest result among the 10 different treatments. Results of this experiment also showed that with the increase of arsenic concentrations the amount of nutrient uptake decreased.

Arbuscular mycorrhizal (AM) fungus *(Glomus mosseae)* had their most significant effect on P uptake. Mycorrhizal inoculation reduced As concentration in roots and shoots. Shoot P concentration/offtake, root P offtake and mycorrhizal infection

A positive response of AMF was found in terms of arsenic uptake by shoots of tomato and radish in poly bag experiment. AMF inoculation significantly reduced arsenic uptake. In case of AMF inoculation, lower amount of arsenic was found from AMF inoculated pots than non-inoculated pots. In both cases treatment T_3 (10 ppm arsenic solution + mycorrhiza) gave better performance than other treatments. The present result are more or less similar with Ahmed *et al.* (2006) they found that shoot arsenic concentration and offtake in mycorrhizal plants were significantly lower than in non-mycorrhizal plants. They also observed that arsenic significantly reduced shoot P concentration and offtake because of the reduction in root growth. Chen *et al.* (2007) reported that mycorrhizal fungi might play an important role in protecting plants against arsenic contamination. They also reported that the decreased shoot As concentrations were largely due to "dilution effects" that resulted from stimulated growth of AM plants and reduced As partitioning to shoots. Xia *et al.* (2007) examined the effects of arbuscular mycorrhizal fungus and phosphorus addition on arsenic uptake by maize plants from an As-contaminated soil. Their results indicated that AM fungal inoculation decreased shoot As concentrations when no P was added. Ultra *et al.* (2007) set up an experiment to find out the effects of arbuscular mycorrhiza (AM) and phosphorus application on arsenic toxicity in As-contaminated soil. They reported that shoot As concentrations were reduced by AM inoculation. Liu *et al.* (2005) conducted a glasshouse pot experiment to study the effect of arbuscular

mycorrhizal (AM) colonization by *Glomus mosseae* on the yield and arsenate uptake of tomato plants in soil experimentally contaminated with five As levels. They informed that shoot As concentration increased with increasing As addition up to 50 mg kg^{-1} but decreased with mycorrhizal colonization. Mycorrhizal colonization may have increased plant resistance to potential As toxicity at the highest level of As contamination.

CHAPTER 6

SUMMARY AND CONCLUSION

In Bangladesh, arsenic contamination of groundwater is one of the major causes of arsenic-related disorder in 80% of its total population (Alam *et al.*, 2002; Das *et al.*, 2004). Arsenic contaminated groundwater is not only used as drinking water but also used as irrigation purposes of crops, particularly in dry season. Thus, it enters into plant and introduce to our food chain. It is found that crops and vegetables were a sustainable source of arsenic to the Bangladeshi people and leads to problems in human health. With a view of those problems, a number of experiments were performed to know the behavior of arsenic on some crops particularly on vegetables. The investigation of percent root infection and intensity of infection of AMF of different crops and weeds root collected from different arsenic affected area of Manikganj district showed varied infection. Out of eight villages, the highest percent root infection of crops was found in Diapar village and that was 15.86% and the lowest percent root infection was found in East Dashora village and that was 2.14%. Out of three villages, the highest percent root infection of weeds was found in Jatrapur village and that was 10.33% and the lowest percent root infection was found in West Dashora village and that was 9.88%. The comparison of *Zea mays* and some weeds (*Leucas aspera* and *Croton sparisiflorus*) collected from different location showed varied infection. It is revealed from the comparison figure that the average percent root infection was

higher in weeds than crops in all the three villages. Varied intensity of infection was also found from location to location. Most of the cases the intensity of infection has a tendency to be in scale-0, 1 and 2 than 3.

In artificial condition, a number of experiments were done to know the role of AMF on seed germination of some crops under different concentrations of arsenic solution. Seed germination was varied at different concentrations of arsenic solution. Is case of Garlic seed germination was not affected by the arsenic toxicity but in other two crops higher seed germination was recorded when low concentrations of arsenic solution was used.

A number of arsenic concentrations (10ppm, 100ppm and 500ppm) were used to see the role of AMF on physical and chemical growth of different crops. Physical and chemical growth of some crops was hampered due to high toxicity of arsenic solution and some crop like garlic can tolerate it.

The data of different physical growth parameters were recorded from both plastic tray and poly bag experiments. In case of tomato and radish 10 ppm arsenic solution with mycorrhiza treated pots gave the best result but in garlic 500 ppm arsenic solution with mycorrhiza gave the best result.

From poly bag experiment, we also determine different chemical parameters. The nutrient uptake (N, P, K and S) was highly influenced by AMF inoculation in arsenic amended soil. The highest amount of nutrient was uptake when 10ppm arsenic solution with mycorrhiza was used. All growth parameters reduced

significantly due to high toxicity of arsenic and increase significantly due to mycorrhizal inoculation.

In terms of arsenic uptake by shoots of tomato and radish, AMF inoculation helps to reduce arsenic uptake. When crops are grown in arsenic amended soil, then arsenic can be translocated within the shoots of those crops but mycorrhiza inoculation can helps to significantly reduce the translocation of arsenic.

Mycorrhizal fungi help to improve both the physical and chemical growth even though there was a high level of arsenic concentration. It means AMF somehow or rather increased physical and chemical growth or plant can tolerate in a high concentrations of arsenic solution.

Our country is one of the poorest and densely populated countries in the world. It is essential to improve our total crop production and can meet up our increasing demand through a least-expensive technology. Mycorrhizal technology is simple, low inputs and nature farming technology by which our crop production will be benefitted. Therefore, it is necessary to use this technique as one of our major cultural management practice in respect of reduction of arsenic toxicity and improve our crop production.

REFERENCES

REFERENCES

Abdul, B.A. and Anderson, J.D. (1972). Physiological and biochemical deterioration of seeds. *In*: Kozlowsky, T.T. (ed) *Seed Biology*. Academic Press, New York. pp. 283 - 315.

Agely, A. A., Sylvia, D.M. and Ma, L.Q. (2005). Mycorrhizae increase arsenic uptake by the hyperaccumulator Chinese brake fern (*Pteris vittata* L.). *J. Environ. Qual.* **34**(6): 2181-2186.

Ahmed, F.R.S., Killham, K. and Alexander, I. (2006). Influences of arbuscular mycorrhizal fungus *Glomus mosseae* on growth and nutrition of lentil irrigated with arsenic contaminated water. *Plant Soil.* **283**(1-2): 33-41.

Alam, M.G., Allinson, G., Stagnitti, F., Tanaka, A., Westbrooke, M. (2002). Arsenic contamination in Bangladesh groundwater: a major environmental and social disaster. *Int. J. Environ. Health Res.* **12**: 235-253.

Arriola, L. (1997). Arbuscular Mycorrhizal Fungi and *Trichoderma harzianum* in relation to border cell production and *Fusarium* root rot of Asparagus (*Glomus intraradices, Fusarium oxysporum*). *Michgan State University.* **36**(1):109.

Augusti, K. T. (1977). Hypocholesterolaemic effect of garlic. *Indian J. Exp. Biol.* **15**(6): 489-490.

Baath, E. and Hayman, D. S. (1984). Effect of soil volume and plant density on mycorrhizal infection and growth response. *Plant Soil.* 77*:* 373 - 376.

Barea, J. M. (1991). Vesicular-arbuscular mycorrhizae as modifiers of soil fertility. *In:* Stewart, B. A. (ed.), *Advan. Soil Science.* Springer-verlag, New York, Inc. pp. 1-40.

BBS (Bangladesh Bureau of Statistics). (2007). Monthly Statistical Bulletin, June. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, pp. 66-67.

Bethlenfalvay, G. J. and Linderman, R.G. (1992). Mycorrhizae in Sustainable Agriculture. Special Publication No, 54. *Am. Soc. Agrono.* Madison. Wiscon pp. 1-28.

Bethlenfalvay, G. J. and Lindermann, R.G. (1992). Mycorrhizae and Crop Productivity. *In:* Berthlenfalvay, G.J. and Linderman, R.G. (Eds.). Mycorrhizae in Sustainable Agriculture. *Am. Soc. Agron.*, ASA Special Publication, 54: 1-27.

BGS (British Geological Survey). (2000). Executive summary of the main report of Phase I, Groundwater studies of arsenic contamination in Bangladesh, by British Geological Survey and Mott MacDonald (UK) for the Government of Bangladesh, Ministry of Local Government, Rural Development and Cooperatives, Department of Public health Engineering, and Department for International Development. (URL: http://www.dainichi-consul.co.jp/english/article/DFID-sum.html).

Bonifacio, E., Nicolotti, G., Zanini, E. and Cellerino, G.P. (1999). Heavy metal uptake by Mycorrhizae of beech in contaminated and uncontaminated soils. *Fresenius Environ. Bull.* 7: 408-413.

Bradley, R., Burt, A. J. and Read, D. J. (1981). Mycorrhizal infection and resistance to heavy metal toxicity in *Calluna vulgaris. Nature,* **292**: 335–337.

Bradley, R., Burt, A. J. and Read, D. J. (1982). The biology of mycorrhiza in the Ericaceae.VIII. The role of mycorrhizal infection in heavy metal resistance. *New Phytol.* **91**: 197–209.

Bremner, J.M. and C.S. Mulvaney. (1982). Total Nitrogen. *In:* Miller, R.H. and D.R. Xeeny. Methods of Soil Analysis. *Am. Soc. Agron.* Inc. Madison, Wisconsis, USA. pp. 595-622.

Brown, M, S., Ferrera,-Cerrato, R. and Bethlenfalvay, G. J. (1992). Mycorrhiza-mediated nutrient distribution between associated soybean and corn plants evaluated by the diagnosis and recommendation integrated system (DRIS). *Symbiosis*, **12** (1): 83-94.

Brown, M. T. and Wilkins, D. A. (1985). Zinc tolerance of mycorrhizal Betula. *New Phytol.* **99**: 101–106.

Carling, D. E. and Brown, M. F. 1980. Relative effect of vesicular arbuscular mycorrhizal fungi on the growth and yield of soybeans. Soil Sci. Soci. America J. 44 (3): 528-592.

Chen, B. D., Xiao, X. Y. and Zhu, Y. G. (2007). The arbuscular mycorrhizal fungus *Glomus mosseae* gives contradictory effects on phosphorus and arsenic acquisition by *Medicago sativa* Linn. *J. Sci. Total Environ.* **379**(2/3): 226–234.

Chowdhury, T.R., Basu, G.K., Mandal, B.K., Samanta, G., Chowdhury, U. K., Chanda, C. R., Lodh, D., Lal, R. S., Saha, K. C., Roy, S., Quamruzzaman, Q. and Charaborti, D.(1999). Arsenic poisoning in the Ganges delta. *Nature*, **401**: 545–546.

Danneberg, G., Latus, C., Zimmer, W., Hundes-Hagen, B., Schneider-Poetsch, H. and Bothe, H. (1992). Influence of Vesicular Arbuscular Mycorrhiza on Phytohormone balances in Maize. *J. Plant Physiol.* **141**: 33-39.

Das, H.K., Mitra, A.K., Sengupta, P.K., Hossain, A., Islam, F. and Rabbani, G.H. (2004). Arsenic concentrations in rice, vegetables, and fish in Bangladesh: a preliminary study. *Environ. Int.* **30**: 383-387.

Dehne, H. W. (1987). Improvement of the VA-mycorrhizal status in agriculture and horticulture. *In: Trans. XIIIthe Int. Cong. Soil. Sci.*. Hamburg. pp. 817 – 825.

Dhar, R.K., Biswas, B.K., Samanta, G., Mandal, B.K., Chakraborti, D., Roy, S., Jafar, A., Islam, A., Ara, G., Kabir, S., Khan, A.W., Ahmed, S.A. and Hadi, S.A. (1997). Groundwater arsenic calamity in Bangladesh. *Current Science,* **73**: 48–59.

Dong, Y., Zhu, Y.G., Smith, F.A., Wang, Y., Chen, B. (2007). Arbuscular mycorrhiza enhanced arsenic resistance of both white clover (*Trifolium repens* Linn.) and ryegrass (*Lolium perenne* L.) plants in an arsenic-contaminated soil. Department of Soil Environmental Science, Research Center for Eco-Environmental Sciences, the Chinese Academy of Sciences, 18 Shuangqing Road, Beijing 100085, China.

Edathii, T.T., Manian, S. and Udaiyan, K. (1994). Early establishment of native vesicular arbuscular mycorrhizas in three vegetable crops of South India – a comparative study. *Pertanika J. of Trop. Agril. Sci.* **17**(3): 157-161.

Eltrop, L. and Marschner, H. (1996). Growth and mineral nutrition of non-mycorrhizal and mycorrhizal Norway spruce (*Picea abies*) seedlings grown in semi-hydroponic sand culture. Growth and mineral nutrient uptake in plants supplied with different forms of nitrogen. *New Phytol.* **133**(3): 469-478.

Furland, V. and Bernier-Cardon, M. (1989). Effect of N, P and K on formation of vesicular- arbuscular mycorrhizae growth and mineral content of onion. *Plant Soil.* **113:** 167-174.

Gaur, A. and Adholeya, A. (2000). Response of three Vegetable crops to AM fungal inoculum in nutrient deficient soils amended with organic matter. *Symbiosis,* **29**: 19-31.

George, E. (2000). Nutrient uptake. *In:* Kapulnick, Y. and Douds, D.D. (eds.), Arbuscular mycorrhizas: physiology and function. Jr. Kluwer Academic Press. pp. 307-344.

Giri, B., Kapoor, R. and Mukerji, K.G. (2005). Effect of the Arbuscular Mycorrhizae *Glomus fasciculatum* and *G. macrocarpum* on the growth and nutrient content of *Cassia siamea* in a semi-arid Indian wasteland soil. *New Forests.* **29**(1): 63-73.

Gonzalez, C.C., Harris, P. J. and Dodd, J. (2002). Arbuscular mycorrhizal fungi confer enhanced arsenate resistance on *Holcus lanatus. New Phytol.* **155**: 163–171.

Gopalan, C., Rama, B.V. and Balasubramanian, S.C. (1989). Nutritive Value of Indian Foods. National Institute of Nutrition, Hyderabad.

Howeler, R.H., Sieverding, E. and Saif, S. (1987). Practical aspects of mycorrhizal technology in some tropical crops and pastures. *Plant Soil.* **100**: 249-283.

http://www.soesju.org/arsenic/bangladesh.htm

http://www.umanitoba.ca/afs/agronomists_conf/proceedings/2006/akhter_arbuscular_mycorrhizal.pdf

Hunt, J. (1980). Determination of total sulphur in small amount of plant material Analyst. **105**: 83-85.

Jalali, B.L. and Chand, H. (1988). Role of VAM in biological control of plant diseases. *In:* Mohadevan, A., Raman, N. and Natarajan, K. (eds.), Mycorrhizae for Green Asia. Proceedings of the First Asian Conference on Mycorrhizae, Madras, India. pp. 209-215.

Jalali, B.L. and Thareja, M.L. (1981). Suppression of *Fusarium* wilt of chickpea in vesicular-arbuscular mycorrhizal-inoculated soils. *Inter. Chickpea news letter.* **4**: 21-22.

Jones, M. D. and Hutchinson, T. C. (1988a). Nickel toxicity in mycorrhizal birch seedlings infected with *Lactarius rufus* or *Scleroderma flavidium*. 2. Uptake of nickel, calcium, magnesium, phosphorus and iron. *New Phytol.* **108**: 461–470.

Jones, M. D. and Hutchinson, T. C. (1988b). The effects of nickel and copper on the axenic growth of ectomycorrhizal fungi. *Can. J. Bot.* **66**: 119–124.

Karagiannidis, N., Bletsos, F. and Stavropoulosm, N. (2002). Effect of Verticillium wilt (*Verticillium dahliae Kleb.*) and Mycorrhiza *(Glomus mosseae*) on root colonization, growth and nutrient uptake in tomato and eggplant seedlings. *Scientia horticulturae*. **94**(1-2): 145-156.

Khan, M.K., Sakamoto, K. and Yoshida, T. (1995). Dual inoculation of groundnut with *Glomus* sp. and *Bradyrhizobium* sp. enhanced the symbiotic nitrogen fixation as assessed by 15 N-technique. *Soil Sci. Pl. Nutri.* 41(4): 769-779.

Kim, D.Y., Lee, Y.J., Goo, N.I., Jung, J. and Kim, J.G. (2006). Effects of Arbuscular Mycorrhizal Fungi Inoculation on Arsenic and Phosphorus Uptake by *Trifolium repensin* and *Oenothera odorata* Jacq. in Arsenic Contaminated Soil. International Union of Soil Science. 158-13.

Koske, R. E. and Gemma, J. N. (1989). A modified procedure for staining roots to detect VA-mycorrhizas. *Mycol. Res.* **92**: 486-488.

Krishna, K.R. and Bagyaraj, D.J. (1982). Effect of vesicular arbuscular mycorrhiza and soluble phosphate on *Abelmoscus esculentus* (L.) Moench, *Plant Soil.* **64**: 209-213.

Leung, H.M., Ye Z.H. and Wong M.H. (2006). Interactions of mycorrhizal fungi with *Pteris vittata* (As hyperaccumulator) in As-contaminated soils. *Environ. Pollut.* **139**: 1-8.

Leyval, C., Turnau, K. and Haselwandter, K. (1997). Effect of heavy metal pollution on mycorrhizal colonization and function: physiological, ecological and applied aspects. *Mycorrhzia.* 7: 139–153.

Liu, Y., Zhu, Y. G. and Chen, B. D. (2005). Yield and arsenate uptake of arbuscular mycorrhizal tomato colonized by *Glomus mosseae* BEG167 in As spiked soil under glasshouse conditions. *Environ Int.* **31**: 867–873.

Liu. Y, Zhu, Y. G, Chen, B.D., Christie, P. and Li, XL. (2005). Influence of the arbuscular mycorrhizal fungus *Glomus mosseae* on uptake of arsenate by the As hyperaccumulator fern *Pteris vittata* L. *Mycorrhiza.* **15**(3):187-192.

Loth, F.G. (1996). Abundance of Vesicular Arbuscular Mycorrhizal fungi spores at different sites as affected by sewage sludge applications. *Bodenkultur* **47**(2):89-96.

Mahmud, R., Mridha, M.A.U., Sultana, A., Sultana, N., Xie, H.L. and Umemura, H. (1999). Biodiversity of VAM fungi in soils of crop field. *Nat. Farm. Sustain. Environ.* **2**:43-50.

Masri, B. M. (1997). Mycorrhizal inoculation for growth enhancement and improvement of the water relations in mungosteen (*Garcinia mangostana* L.) seedlings. *Ph. D. Thesis. University putra Malaysia. Serdung. Malaysia.*

Mathew, J. and Johri, B. N. (1989). Effect of indigenous and introduced VAM fungi on growth of mungbean. *Mycol. Res.* **92** (4): 491-493.

Matsubara, V. I., Haraba, T. and Yakuwa, T. (1994). Effect of vesicular-arbuscular mycorrhizal fungi inoculation on seedling growth in several species of vegetable crops. *J. Jap. Soci. Hort. Sci.* **63** (3): 619-628.

Meharg, A.A. and Macnair, MR. (1990). Uptake, accumulation and translocation of arsenate in arsenate-tolerant and non-tolerant *Holcus lanatus* L. *New Phytol.* **122**: 1171-1177.

Miller, R.M. and Jastrow, J.D. (1994). Vesicular Arbuscular Mycorrhizae and biogeochemical cycling. *In:* F.L. Pfleger and R.G. Linderman (eds.). Mycorrhizae and Plant Health. *Am. Phytopathol. Soc. St. Paul, MN.* 189-212.

Morton, J.B. and Benny, G.L. (1990). Revised classification of Vesicular Arbuscular Mycorrhizal fungi (Zygomycetes): A new order, Glomales, two new sub-orders, Glomineae and Gigasporaceae and two new families, Acaulosporaceae and Gigasporaceae with an amendation of Glomaceae. *Mycotaxon,* **37**: 471-492.

Mosse, B. (1973). Advances in the study of vesicular-arbuscular mycorrhiza. *Annu. Rev. Phytopathol.* **11**: 171–196.

Mridha, M. A. U. and Xu, H. L. (2001). Nature Farming with arbuscular mycorrhizae in Bangladesh. *J. Crop Prod.* **3**: 303-312.

Mridha, M. A. U., Sultana, A., Sultana, N., Xu, H. L. and Umemura, H. (1999). Biodiversity of VA mycorrhizal fungi of some vegetable crops in Bangladesh. Proc. International Symposium on World Food Security and Crop Production Technologies for Tomorrow, October 8-9, 1998. Kyoto, Japan 330-331.

Mridha, M.A.U and Dhar, P.P. (2007). Biodiversity of arbuscular mycorrhizal colonization and spore population in different agro forestry trees and crop species growing in Dinajpur, Bangladesh. *J. For. Res.* **18**: 91-96.

Murphy, J. and J.P. Riley. (1962). A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta.* 27: 31-36.

Nedumpara and Mercy, J. (1996). Interactions of Vesicular-Arbuscular Mycorrhizal fungi, herbicides and crops. *Iowa State University.* **57**-06(b), p. 3557, 97.

Nickson, R. T., McArthur, J. M., Burgess, W., Ahmed, K. Z., Ravenscroft, P. and Rahman, M. (1998). Arsenic poisoning of Bangladesh groundwater. *Nature.* **395**: 338–338.

Phiri, S., Rao, I.M., Barrios, E. and Singh, B.R. (2003). Plant growth, Mycorrhizal association, Nutrient uptake and Phosphorus dynamics in a Volcanic-ash soil in Colombia as affected by the establishment of *Tithonia diversifolia. J. Sustain. Agril.* **21**(3): 43-61.

Pond, E.C., Menge, J.A. and Jerrel, W.M. (1984). Improve growth of tomato in salinized soil by Vesicular Arbuscular Mycorrhizal fungi collected from saline soils. *Mycologia.***79**: 74-84.

Read, D. J., Koucheki, H. K. and Hodgson, J. (1976). Abruscular mycorrhizal in natural vegetation systems. I. The occurrence of infection. *New Phytol.* **77**: 641.

Richardson, D.M., Allsopp, N., Antonio, C.M.D., Milton, S.J. and Rejmanek, M. (2000). Plant inventions the role of mutualisms. *Biol. Rev.Camb. Phytol.Soc.***75**: 65-93.

Saif, S.R. (1977). The influence of stage of host development on vesicular-arbuscular mycorrhizae and endogonaceous spore population in field-grown vegetable crops. 1. Summer-grown crops. *New Phytol.* **79**: 341 - 348.

Sasai, K. (1991). Effect of phosphate application on infection of vesicular arbuscular mycorrhizal fungi in some horticultural crops. *Scientific Rep. Miyagi Agric. Coll.* **39**:1-9.

Sharples, J. M., Meharg, A. A., Chambers, S. M. and Cairney, J. W. G. (2000). Mechanism of arsenate resistance in the Ericoid mycorrhizal fungus *Hymenoscyphus ericae*. *Plant Physiol.* **124**: 1327–1334.

Sieverding, E. (1991). Vesicular-arbuscular mycorrhizal management in tropical agrosystem. Germany: GTZ publishers.

Smith, S. E. and Gianinazzi-Pearson, V. (1990). Phosphate uptake and arbuscular activity in mycorrhizal *Allium cepa L.:* effect of photon irradiance and phosphate nutrition. *Aus. J. Plant Physiol.* **17**: 177- 188.

Smith, S.E. and Read, D.J. (1997). Mycorrhizal Symbiosis, 2nd edn. Academic Press, London, U.K.

Sramek, F., Dubsky, M. and Vosatka, M. (2000). Effect of Arbuscular Mycorrhizal fungi and *Trichoderma harzianum* on three species of balcony plants. *Rastlinna Vyroba.* **146**: 127-131.

Sreeramulu, K.R., Shetty, Y.V. and shetty, T.K.P. (1996). Effect of VA mycorrhiza on the growth of two important leafy vegetables. *Madras Agril. J.* **83**(6): 362-364.

Srivastava, R., Roseti, D. and Sharma, A.K. (2007). The evaluation of microbial diversity in a vegetable based cropping system under organic farming practices. *Applied Soil Ecology*, **36**(2-3): 116-123.

Sylvia, D.M. (1990). Distribution, structure and function of external hyphae of Vesicular Arbuscular Mycorrhizal fungi, *In:* J. E. Box and L.H. Hammond (eds). Rhizosphere Dynamics. Westview Press. Boulder. Co. pp. 144-167.

Syvertsen, J.P. and Graham, J.J. (1999). Phosphorus supply and Arbuscular Mycorrhizas fungi increase growth and net gas exchange response in two Citrus spp. Grown at elevated CO_2. *Plant Soil* **208**: 209-219.

Tamaki, S. and Frankenberger, W.T. (1992). Environmental biochemistry of arsenic. *Rev. Environ. Contamin. Toxicol.* **124**: 79–110.

Tarafdar, J.C. and Praveen, K. (1996). The role of Vesicular Arbuscular Mycorrhizal fungi on crop, tree and grasses grown in an arid environment. *J. of Arid Envirt.* **34**: 197-203.

Tondel, M., Rahman, M., Magnuson, A., Chowdhury, I. A., Faruquee, M. H. and Ahmed, S. A. (1999). The relationship of arsenic levels in drinking water and prevalence rate of skin lesions in Bangladesh. *Environ. Health Perspect.* **107**: 727–729.

Trimble, M.R. and Knowles, N.R. (1995). Influence of Vesicular-Arbuscular Mycorrhizal fungi and Phosphorus on growth, Carbohydrate partitioning and mineral-nutrition of greenhouse Cucumber (*Cucumis-sativus l*) plants during establishment. *Can. J. of Plant Sci.***75**: 239-250.

Trotta, A., Falaschi, P., Cornara, L., Minganti, V., Fusconi, A., Drava, G. and Berta, G. (2006). Arbuscular mycorrhizae increase the arsenic translocation factor in the As yperaccumulating fern *Pteris vittata* L. *Chemosphere,* **65**(1):74-81.

Ultra, V.U., Tanaka, S., Sakurai, K. and Iwasaki, K. (2007). Effects of arbuscular mycorrhiza and phosphorus application on arsenic toxicity in sunflower (*Helianthus annuus* L.) and on the transformation of arsenic in the rhizosphere. *Plant Soil.* **290**(1-2): 29-41.

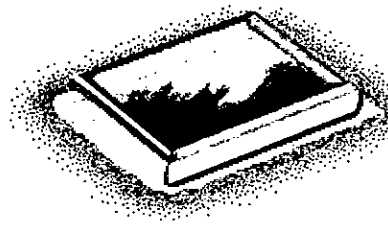
Vishwakarma, V. and Sing M. P. (1996). Response of six forest species of inoculation with vesicular-arbuscular mycorrhizae. *New Botanist*, **23:** 37-43.

Wani, P.V. and Konde, B.K. (1996). Arbuscular Mycorrhizal association in Garlic. *J. Maharashtra Agril. Univ.* **21**: 420-423.

Wassermann, J. L., Mineo, L., Majumdar, S. K. and Vantyne, C. (1987). Detection of heavy metals in oak mycorrhizae of northeastern Pennsylvania forests, using X-ray microanalysis. *Can. J. Bot.* **65**: 2622–2627.

Woolson, E.A., Axely, J.H. and Kearney, P.C. (1973). The chemistry and phytotoxicity of arsenic in soils: II. Effects of time and phosphorus. *Proceedings of the American Society of Soil Scientists*, **37**: 254-259.

Xia, Y.S., Chen, B.D., Christie, P., Smith, A., Wang, Y.S. and Li, X.L. (2007). Arsenic uptake by arbuscular mycorrhizal maize (*Zea mays* L.) grown in an arsenic -contaminated soil with added phosphorus. *J. Environ. Sci.* **19**(10): 1245-1251.



APPENDIX

Appendix I. The poster was presented in the 20th New Phytologist Symposium, University of Aberdeen, Scotland, U.K. 26–27 June 2008.

ROLE OF ARBUSCULAR MYCORRHIZA IN CROP GROWTH IN ARSENIC AMENDED SOIL

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USDA

INTRODUCTION

The agricultural crops are getting contaminated with arsenic because of irrigation with arsenic contaminated ground water and causing significant risk to animal and human health through soil-crop transfer. Since 1993 arsenic contamination in ground water drew attention in Bangladesh. Out of 64 districts, 61 districts are affected with arsenic contamination in ground water (Plate 1) . More than 70-80 million people are threatened with the problem. Arsenic poisoning causes skin pigmentation, development of warts, ulcers, cancer etc. (Plate 2). Mycorrhizal fungi can reduce the uptake of arsenic from the irrigation water to crop growth (Ahmed *et al.*, 2006; Yun-sheng, *et al.*, 2007).

MATERIALS AND METHODS

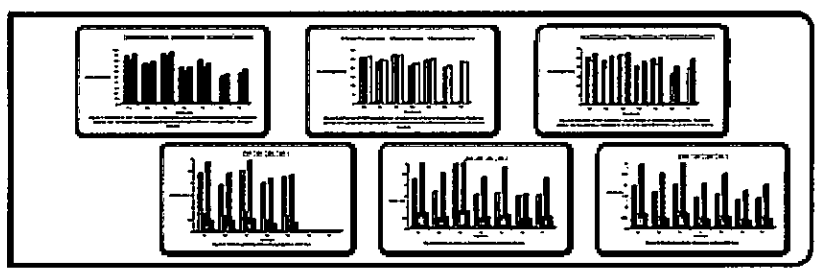
The role of arbuscular mycorrhizal fungi in crop growth in arsenic amended soil was studied with three agricultural crops namely: *Amaranthus gangeticus*, *Raphanus sativus* and *Lycopersicon esculentum*. The plants were grown in arsenic amended soils (10ppm, 100ppm and 500ppm arsenic solution) with or without mycorrhizal inoculation. The treatments were T_1 = Control; T_2 = 10 ppm Arsenic solution; T3 = 10 ppm Arsenic solution + Mycorrhiza; T_4 = 100 ppm Arsenic solution; T_5 = 100 ppm Arsenic solution+ Mycorrhiza; T_6 = 500 ppm Arsenic solution; T_7 = 500 ppm Arsenic solution + Mycorrhiza.

Table 1. Influence of AMF inoculation on fresh and dry weight of shoot and root of *Amaranthus gangeticus*, *Raphanus sativus* and *Lycoporsicon esculentum* in soil amended with different concentrations of arsenic solution

Treatments	Fresh weight (g) at 60 DAS						Dry weight (g) at 60 DAS					
	Amaranthus gangeticus		*Lycopersicon esculentum*		*Raphanus sativus*		*Amaranthus gangeticus*		*Lycopersicon esculentum*		*Raphanus sativus*	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Control	35.00 e (5.93)	7.45 e (2.81)	34.60 f	7.10 f (2.76)	36.00 f	5.80 f (2.51)	2.95 e (1.86)	1.32 e (1.35)	2.77 f (1.81)	1.31 e (1.35)	2.95 f (1.86)	1.25 f (1.32)
10 ppm Arsenic solution	33.20 d (5.81)	5.00 c (2.34)	28.80 c	6.40 d (2.43)	32.80 d	4.20 d (2.17)	1.02 c (1.23)	0.07 c (1.21)	1.21 d (1.31)	0.99 d (1.22)	1.21 c (1.31)	0.85 d (1.16)
10 ppm Arsenic solution + Mycorrhiza	36.00 f (6.04)	8.51 f (3.00)	35.10 f	7.80 g (2.90)	36.90 g	6.90 g (2.72)	3.00 e (1.87)	1.57 f (1.44)	3.10 g (1.90)	1.72 f (1.49)	3.03 g (1.88)	1.36 g (1.30)
100 ppm Arsenic solution	29.36 b (5.46)	4.25 b (2.17)	26.30 b	3.10 b (1.90)	29.40 b	3.10 b (1.00)	0.99 b (1.22)	0.67 b (1.08)	0.90 b (1.18)	0.89 c (1.04)	0.99 b (1.22)	0.62 c (1.06)
100 ppm Arsenic solution + Mycorrhiza	32.90 c (5.76)	6.12 d (2.57)	33.80 e	6.80 e (2.61)	34.10 e	4.90 e (2.32)	1.41 d (1.36)	0.89 d (1.22)	1.41 e (1.36)	1.01 d (1.22)	1.50 e (1.41)	0.88 e (1.22)
500 ppm Arsenic solution	0 a (0.71)	0 a (0.71)	17.47 a	2.80 a (1.84)	27.20 a	2.40 a (1.70)	0 a (0.71)	0 a (0.71)	0.59 a (1.04)	0.29 a (0.88)	0.75 a (1.12)	0.34 a (0.92)
500 ppm Arsenic solution + Mycorrhiza	0 a (0.71)	0 a (0.71)	31.80 d	4.90 c (2.32)	31.60 c	3.90 c (2.10)	0 a (0.71)	0 a (0.71)	1.03 c (1.24)	0.34 b (0.91)	1.26 d (1.32)	0.68 b (1.04)

RESULTS AND DISCUSSION

The overall growth was higher in arsenic contaminated soil inoculated with mycorrhizal fungi (Plate 3). The results indicated that at higher concentrations of arsenic, the seed germination was affected more than the lower concentrations (Fig. 1). A positive germination response to AM was observed in all the selected plants. Root length and shoot height, leaf number, both fresh and dry weight of root and shoot were higher in case of AM inoculated plants in comparison to their respective treatments (Table 1; Fig. 2 & 3). Higher nutrient uptake and less arsenic content were recorded in mycorrhiza inoculated plants (Fig. 4, 5 & 6). Mycorrhizal fungi may play an important role in protecting plants against arsenic contamination (Ahmed *et al.*, 2006; Yun-sheng, *et al.*, 2007).



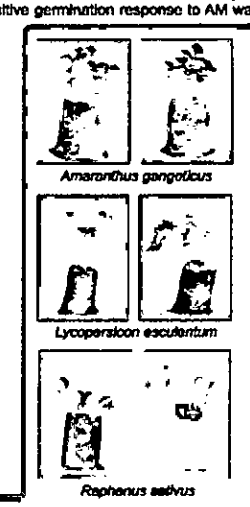


Plate 3. Plant growth in arsenic contaminated (100 ppm) soil with and without mycorrhiza

References

Ahmed, F.R.S.; Killham, K.; Alexander, I. 2006. Influence of arbuscular mycorrhizal fungus *Glomus mosseae* on growth and nutrition of lentil irrigated with arsenic contaminated water. *Plant and Soil*, 283(1-2):33-41.

Yun-sheng, X.; Bao-dong, C.; Peter, C.; Andrew, S.; You-shen, W.; and Xiao-lin, L. 2007. Arsenic uptake by arbuscular mycorrhizal maize (*Zea mays* L.) grown in an arsenic contaminated soil with added phosphorus. *Journal of Environmental Sciences*, 19(10): 1245-1251.