CHAPTER - 1
Screening of efficient AM fungi to understand their efficacy on *Triticum aestivum* L.varieties.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is a global food crop and it is one of the important crops grown in India. The current day emphasis is on sustainable agriculture which is aimed at less use of inorganic fertilizers and pesticides to protect adverse effect on soil health and fertility. The use of microbial inoculants plays an important role in sustainable agriculture. It was well established from the previous research that agricultural crop plants can get benefit from mycorrhizal colonization (Koide and Schreiner,1992). Arbuscular Mycorrhizal Fungi (AMF) are significant biofertilizers known to play key role in low cost and high economic output (Azcon- Acquilar & Barea 1997). The beneficial effects of inoculation with AMF have been reported by several workers (George *et al.*, 1995). The application of AMF in agriculture is greatly restricted because they can not be cultured independently without host plant. AMF are known to establish a symbiotic association with the roots of crop plants and are known to the influence plant growth response in natural ecosystems. AMF symbiosis could result in the increased yield of wheat particularly in low phosphorous soil. It was well established from the previous research that AMF increase the availability of nutrients to the host plants particularly phosphorous (Xavier *et al.*, 1997).

In order to derive maximum benefits from AMF inoculation, it is necessary to use right type of AMF isolate. Scientific efforts are made at
global level towards yield improvement and sustainability of wheat with right type of AMF isolate. All AMF isolates are not equally effective to enhance the growth and yield of *Triticum aestivum* L. varieties. These symbiotic fungi help to increase nutrients acquisition at low cost of carbon expenditure (Graham and Eissenstat, 1995).

The relationship between AM fungi and their host plants is usually considered as non specific. The lack of specificity results in considerable variation in symbiotic responses (Ianson and Lindermann, 1991). Although AM Fungi are not host specific, they show host preference. AM fungal species differed in their ability to colonize the roots of host plants and also differ in the uptake of nutrients from the soil (Gracy Sailo and Bagyaraj, 2005). It has been reported that colonizing ability and growth promoting effect is different in different AM fungal species (Lindermann and Davis, 2004; Sensoy *et al.*, 2007) AM fungi vary considerably in their population biology ecological specificity and symbiotic activity (Giovannetti and Gianinazzi Pearson, 1994). AMF are generally considered to have a broad host ranges. Some species are more effective with particular host plants in increasing nutrient uptake and plant growth (Werner, 1992). The extent of plant nutrition promotion by AMF can depend upon specific host plant and AM fungal species (Vander Heijden *et al.*, 1998). The Plant response to different AM fungal inoculation differs considerably through their Physiological and nutritional responses. Most crop plants are not colonized by the efficient AM fungus. The knowledge of efficient AM Fungus for each crop could be very promising solution towards

The objective of present research work is to evaluate and compare the ability of AM fungi to increase nutrient uptake, dry weight, plant height, and yield produced per plant to screen the most efficient AM Fungus for *Triticum aestivum* L. varieties.
 REVIEW OF LITERATURE

Gray and Gerdemann (1967) found that *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. significantly increased phosphorus uptake by tulip poplar (*Liriodendron tulipifera* L.). Bethlenfalvay *et al.*, (1989), explained that host response not only differ with fungal species, but also with geographic isolates of the same species. The response range may be due to changing efficiencies in universal uptake and also because of physiological interactions between the symbionts.

Read (1992), suggested that hyphal transport might supply adequate water to maintain physiological functions when hydraulic conductivity of the soil begins to limit uptake at root surface. Rosendahl and Sen (1992), explained that enzymatic polymorphism in different AM fungi may be related to their efficiency in root colonization and influence on Plant growth. Bethlenfalvay (1992), explained mycorrhizal symbiosis is crucial component of both plant and soil health.

Koide (1993), reported that roots colonized by AM Fungi can have higher specific water uptake. Daft and Hogarth (1993), reported that mixed inoculation did not enhance or even weakened the growth promotion effects. Abbott and Gazey (1994), reported that AM Fungi differ in the extent of root colonization, they also differ in their capacity to form propagules. Growth and nutrient contents of the host plant were positively related to the percentage of root colonization. Mathur and Vyas (1995), reported variations in colonization of AM fungi and reported the production of highly nutritive pods of
Cyamopsis tetragonoloba by arbuscular mycorrhizae. Of all the 6 AM species, Glomus fasciculatum (Thaxt.) Gerd. and Trappe. caused maximum increase in sugar and protein content. Chandrasekhar et al., (1995), reported that inoculation of mulberry with appropriate VAM fungus yields a considerable improvement in plant characters.

Marschner (1995), reported that mycorrhizal fungi have the ability to acquire P and give high yield under limited phosphorous supply. Bever et al., (1996), reported that laboratory and field studies showed the different sporulation rates with different AMF species. Edathil et al., (1996), reported that maximum benefits could be derived by the host plants when they are inoculated with single most efficient AM fungus. Becard (1997), explained that isoflavanoids present in the root exudates of a variety of leguminous plants activate genes responsible for nodulation and AM colonization, flavanoid profiles differ considerably among host plants. Zhao et al., (1997), reported that, AM symbiotic efficiency has been attributed to the spread of root colonization, the production of external mycelium and to the amount of arbuscular tissue present in the colonized roots. Smith and Read (1997), revealed about increasing evidence of host specific difference in plant responses to AM Fungi. Species and strains of AM fungi have been shown to differ in the extent to which they increase plant growth.

Sieverding and Galvez (1998a). investigated the inoculation response of cassava clones to AM fungal species in low phosphorous Soil.
Rajan et al., (2000), had showed *Glomus leptotichum* was the best AM symbiont for teak (*Tectona grandis*), out of nine AMF species in soil low in available P at pH 5.6. Hyphal architecture of AM fungi could also influence the growth of host plants at pre symbiosis and post symbiosis stages and might explain the difference in their competitive colonization ability. Ramananda and Sreenivasa (2000), had studied the influence of AM fungi on growth of onion (*Allium cepa* L.), maximum growth was observed in plants inoculated with *Aculospora laevis* Gerd. and Trappe. and *Gigaspora margarita* Becker and Hall. Garcia- Garrido et al., (2000), explained that enzymatic activity of the external hyphae associated with degree of colonization.

Bagayoko et al., (2000), have sown response of the host plant varies with species of AM Fungi and high percentage of root colonization generally enhanced shoot dry weight and nutrient uptake of the host plant. Kehri and Chandra (2001), studied the performance of black gram (*Phaseolus mungo*) with six AMF species. Maximum growth and yield was observed in plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. and *Glomus macrocarpum* Tul. and Tul. Gill et al., (2002), compared the root colonization and spore population of *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe., *G. Mosseae* Gerd. and Trappe., *Gigaspora gigantea* Gerd. and Trappe. and *Gigaspora margarita* Becker and Hall. on Chick pea. Maximum plant growth was observed in plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe., and lowest with *Gigaspora margarita* Becker and Hall.
Hirsch (2003), explained that root exudates play an active role in the regulation of symbiotic and protective interactions with microorganisms. Langley and Hungate (2003), noted that mycorrhiza can have a multitude of direct effects on the decomposition process below ground. Lindermann and Davis (2004), reported that colonizing ability and growth promoting effect of different AMF species for a given plant are variable. Tawaraya and co-workers (2006), demonstrated that AMF in associations with the plants increase P availability by solubilizing the insoluble fraction of inorganic P, which significantly increased P uptake by onion (Allium cepa L.) and consequent P concentration in the plant tissue. Voets et al., (2006), reported that anastomoses were observed in mycelial networks of Glomus species, the same was absent in Gigaspora species. Glomus species could dominate over Gigaspora species and produce better nutritional effects.

Powell et al., (2007), explained that differences in colonization levels due to varietal differences were also observed in transgenic herbicide tolerant soybeans. Perner et al., (2007), suggested that mycorrhizal colonization increased shoot P and K concentrations and number of flowers of Pelargonium peltatum. Smith and Read (2008), explained that large body of evidence has shown that plant growth responses to mycorrhizal colonization depends both on plant and fungal species and on experimental and environmental conditions.
MATERIALS AND METHODS

I. Isolation of AM fungal spores, their observation and identification.

AM fungal spores were collected by decanting and wet sieving method (Gerdemann and Nicolson, 1963). The gravity of spores is lesser than that of soil particles. Successive decantation of soil suspension followed by sieving with fine mesh could isolate the spores from soil.

Ten rhizospheric soil samples were collected from each wheat growing field. For the isolation of spores different mesh sizes, viz., 500μm 250μm 100μm and 50μm were used.

Procedure followed for the isolation of AM fungal spores mentioned as follows.

1. 50 g rhizospheric soil was taken and assayed.
2. Soil was dispersed in 1 liter of distilled water and the suspension was left undisturbed for 1-2 minutes to allow heavier soil particles to settle down.
3. The suspension was passed through a series of sieves of various mesh size stacked in descending order (500μm – 50μm).
4. Washing and decanting was repeated twice in order to increase spore recovery.
5. After ensuring that all the colloidal particles have passed through the sieve, the remains of each of the sieves were washed and the washings were collected separately in beakers.
6. Spores were placed by using needle and are transferred to the slide containing Lactophenol.

7. Clean cover glass slips were placed on drops of Lactophenol.

8. Slides were observed under stereo microscope. Spores were identified by the help of Schenck and Pervez manual (1990).

II. Establishment of monospecific culture by using funnel technique.

1) AM spores extracted by using wet sieving and decantation method (Gerdemann and Nicolson, 1967) were collected by using needle and were stored in watch glass at 4°C.

2) Spores were examined daily till the day of inoculation and spores with changed morphology were discarded.

3) Before inoculation, water was added to the watch glass containing spores.

4) The selected spores were surface sterilized using 200 ppm streptomycin Sulphate solution for 3-5 minutes and later washed with distil water and again surface sterilized with 2% chloramines T solution for 3-5 minutes.

5) After surface sterilization, the spores were serially washed with distil water for 4 to 5 times.

6) Funnels used in this experiment were plugged on the lower side with absorbent cotton and filled with 1:1 sand and soil mixture was added to the funnel. Sand and soil mixtures were added to the top of the funnel at the ratio of 1:1. Top of the funnel was then wrapped with aluminum
foil and sterilized in the autoclave for 45 minutes at 121°C and 15 lbs pressure. This process of sterilization was repeated for three consecutive days.

7) The surface sanitized spores were added to the funnel by making a small slit at the centre of aluminum foils. The spores were then placed 2-3 cm below the soil and covered with soil. Over this, 3-4 *Sorghum* seeds were sown.

8) The set of funnels were then placed in conical flasks containing sterile distilled water. So that soil in the funnel becomes wet due to capillary action of water. The entire set up was placed in glass house for 45-50 days.

9) After 45-50 days, the plants along with soil were transferred to 15 cm diameter pot containing sterile sand soil mix (3:1 W/W). About 40-50 sterilized sorghum seeds were planted and watered regularly. Hoagland solution was given as and when required.

10) After another 60 days, *Sorghum* roots were checked for the colonization. If the colonization was observed, then watering is stopped. The shoot portion is chopped off at the soil level. The roots were then chopped to fine pieces and mixed well with the soil. The mixture acts as pure inoculum. It was then stored at 4°C for future use.

**III Estimation of AM Fungal Spores**

Various methodologies have been used for counting AM fungal spores and to assess AM Fungal spores distribution. The procedure described by Gaur
and Adholeya (1994), was used to determine spore count in rhizospheric soil of pot grown plants. A filter paper (Whatman No.1, size 11 cm diameter), was taken and folded two times (vertical to each other), then filter paper was reopened. Two lines were drawn to divide filter paper into four equal quadrants. Vertical lines were drawn on one half of the filter paper so as to divide it into approximately fifteen columns with each column about 0.5 cm apart. Each column was numbered and the direction of counting was marked. Filter paper was then folded in such a way that the marked portion became receiving surface for the sample during filtration. This filter paper with sample spores was spread on the bigger petriplate and was observed in stereomicroscope and by moving the Petri plate the spores were counted in every space between the lines numbered.

IV Assessment of AMF colonization (Philips & Hayman, 1970)

Per cent root colonization was determined by Philips and Hayman (1970) method. The method involve following steps.

1. Wash the root samples in water, cut the root samples in to 1 cm segments and boil at 90°C for 2 hrs in 10% KOH.
2. Pour off KOH and rinse the root segments in tap water until no brown colour appears in the rinse water.
3. Root segments were placed in 0.5N HCl for 3 to 4 minutes and then pour of HCl.
4. Root segments were stained with 0.5% tryphan blue for over night.
5. Mount the root segments on slide by taking lactophenol. Observe under compound microscope for mycorrhizal colonization.

Percent root colonization was determined with following equation.

\[
\text{Percent root colonization} = \frac{\text{No. of root fragments colonized}}{\text{Total No. of root fragments}} \times 100
\]

V. Experimental Design:

Soil analysis.

Red sandy soil (Altisol) was taken for the study. Physicochemical analysis of soil was performed. The soil parameters were mentioned in Table 1.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>196.0 Kg/ha</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>8.9 Kg/ha</td>
</tr>
<tr>
<td>Potassium</td>
<td>290 Kg/ha</td>
</tr>
<tr>
<td>Sulphur</td>
<td>21.3 Kg/ha</td>
</tr>
<tr>
<td>Calcium</td>
<td>19.0 mg/100gm</td>
</tr>
<tr>
<td>Magnesium</td>
<td>11.5 mg/100gm</td>
</tr>
<tr>
<td>Copper</td>
<td>4.3 ppm</td>
</tr>
<tr>
<td>Zinc</td>
<td>2.5 ppm</td>
</tr>
<tr>
<td>Manganese</td>
<td>24.6 ppm</td>
</tr>
</tbody>
</table>
**Determination of soil pH (Jackson, 1973):**

10g of soil was powdered and mixed with double distilled water in 1:5 ratio. This was thoroughly shaken and kept aside for an hour and pH of the supernatant was recorded with the help of Elico pH meter.

**Estimation of available Nitrogen in soil (Jackson, 1973):**

20 g of soil was taken in 800 ml dry Kjeldahl flask followed by 20ml of distilled water. 100ml each of 0.32% KMNO₄ and 2.5% NaOH solution were added to the flask. The froth boiling was prevented by adding liquid paraffin (1ml) and bumping was avoided by adding a few boiling chips. The contents were distilled in a Kjeldahl assembly at a steady rate. Liberated ammonia was collected in air Earlhen Meyer flask containing 20ml of 2% basic acid solution (with methyl red + bromocresol green indicator) with the absorption of ammonia, the pinkish colour turns green. After 30 minutes, it was treated with 0.5 N H₂SO₄ till the colour changes to original. Blank (without soil) was run simultaneously. Available Nitrogen was calculated with the help of following formula.

\[
N(\%) = \frac{TV \times N \times 1.4}{\text{Weight of soil sample}}
\]

Titration values (TV) = Sample titration – Blank titration value.

N- Nitrogen

**Determination of available ‘P’ in soil by Olsen's method (1954):**

5g of soil was taken in 250ml Earlhen Meyer flask, 100ml of sodium bicarbonate (0.5N) and one tea spoon full of activated charcoal were added to
flask and shaken well for 30 minutes on shakers. Later the content was filtered through Whatmann filter paper No.4. 5ml filtrate was pipette out into 25 ml of volumetric flasks and was neutralized with 1:4 H₂SO₄ using paranitrophenol as indicator. The volume was made up to 25 ml by adding distilled water and 1 ml of molybdic acid reagent avoiding excess effervescence. Blue colour developed when few crystals of stannous oxalate were added. The solution was shaken well and control was read in Elico calorimeter at 660nm within 10 minutes. A calibration curve was plotted using KH₂PO₄ a standard from which amount of phosphorous was estimated.

\[
P(\%) = \frac{C \text{ (mg)} \times \text{volume of Sample solution}}{10 \times \text{aliquot (ml)} \times \text{weight of sample}}
\]

Where C = (mg) ‘P’ obtained from graph.

**Estimation of Phosphorous in plant extract (Jackson 1973):**

5ml of aliquot was taken in 50 ml volumetric flask. 10 ml each of ammonium molybdate and ammonium vandate were added. The volume made up to 50 ml by adding deionized water and shaken well. The intensity of yellow colour was read on spectrophotometer at 470nm. Using 0, 5, 10, 15, and 20 ppm from the standard P solution calibration curve was drawn. The P concentration was calculated as follows.

\[
P(\%) = \frac{C \text{ (mg)} \times \text{volume of Sample solution (ml)}}{10 \times \text{aliquot (ml)} \times \text{weight of sample}}
\]

Where C = (mg) P obtained from graph.
Estimation of micronutrients

Micronutrients were estimated by AAS (Atomic Absorption Spectrometer). 1 g sample was taken in a volumetric flask, to this 1ml of acid mixture was added and the content of the flask was mixed by stirring. The flask was placed on low heat hot plate in a digestion chamber. Then the flask is heated until the production of red NO₂ fumes ceases. The contents were allowed to evaporate until the volume is reduced to about 3-5 ml but not to dryness. The complete digestion was confirmed when liquid became colourless. 20ml of deionized water was added after cooling the flask and solution was used for the determination of micronutrients.

Determination of Cu, Zn and Mn

The stock solutions were prepared by dissolving each micronutrient. Standard solutions were prepared from respective solutions using 5, 10, 15 20, 25, 30 and 35 ppm calibration curve was drawn.

**Copper (Cu):** Dissolve 1 gm of Copper metal in minimum volume of (1+1) HNO₃ and diluted in 1 litre of 1% (V/V) HCl.

\[
Cu \left( \mu g^{-1} \right) = \frac{C \times \text{solution Vol (ml)}}{\text{Sample Wt (g)}}
\]

Where \( C = \text{ppm cu obtained from graph} \)

**Manganese (Mn):** 1 g of Mn metal was dissolved in minimum volume of (1+1) HNO₃ and diluted with 1 litre of 1% (V/V) HCl.

\[
Mn \left( \mu g^{-1} \right) = \frac{C \times \text{solution Vol (ml)}}{\text{Sample Wt (g)}}
\]

Where \( C = \text{ppm Mn obtained from graph} \)
**Zinc (Zn):** Dissolve 0.5g of Zinc in minimum vol of (1+1) HNO₃ and diluted to liter with 1% (V/V) HCl.

\[
Zn (\mu g^{-1}) = \frac{C \text{ (ppm)} \times \text{Solution vol (ml)}}{\text{Sample wt (g)}}
\]

C = ppm Zn obtained from graph.

**Plant cultivation and harvest**

Soil was sterilized using autoclave by maintaining temperature of 120° C at 20 PSI for 15 minutes. Sterilized soil was taken in poly bags measuring 5 inch diameter. Poly bags were placed in open field conditions in randomized complete block designe with three replicates per treatment.

Following treatments were given.

1. Sterilized soil without AM inoculum (Control)
2. Sterilized soil with inoculum of *Glomus fasciculatum* (Thaxt.) Gerd.
   and Trappe.
3. Sterilized soil with inoculum of *Sclerocystis dussii* (Pat.) V.Honn.
4. Sterilized soil with inoculum of *Aculuspora laevis* Gerd. and Trappe
5. Sterilized soil with inoculum of *Gigaspora margarita* Becker and Hall

Four varieties of *Triticum aestivum* L were grown with above treatments. Plants were watered regularly on alternate days till harvest. 10 ml of Hogland’s solution minus ‘P’ was given to each pot for all treatments once in 15 days.

Plants were harvested after 60 DAS (Day After sowing) and 90 DAS. Uprooted plants were used for measuring parameters like plant height, root and
shoot dry weight, percentage of ‘P’ in shoot, percent of mycorrhizal colonization, relative mycorrhizal dependency and Absolute Growth Rate (AGR). After complete maturity 100 grains weight and yield produced per plant were measured.

Dry weight of the root and shoots were measured by placing the root and shoot samples of plants in oven at 700C for 48 hours.

Absolute Growth rate (AGR) was calculated by using following formula.

\[
AGR = \frac{W_2 - W_1}{T_2 - T_1}
\]

Where

\(W_1 = \) Dry weight of Plant in grams at time \(T_1\)
\(W_2 = \) Dry weight of plant in grams at time \(T_2\)

Relative Mycorrhizal Dependency (RMD)

Relative mycorrhizal dependency was determined by using following formula (Menge et al., 1978).

\[
RMD = \frac{\text{Dry wt of mycorrhizal plant} - \text{Dry wt of non mycorrhizal plant}}{\text{Dry wt of mycorrhizal plant}} \times 100
\]

Statistical Analysis

Statistical tests were performed with SPSS for window version 9.0. The data were analyzed by analysis of variance (ANOVA) to test the effect of AM inoculation. Duncan’s multiple range test (DMRT) at \(P = 0.05\) was used to compare means.
RESULTS

Experimental observations revealed that the plants have shown varied growth response to different AM fungi. All AM fungi resulted in the increase of growth parameters, but it was *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. resulted in significant increase of growth parameters compared to other AM fungi.

**Plant height**

Plant height was measured in plants grown under control and inoculated treatments at 60 DAS and 90 DAS (Days After Sowing) stages. Inoculated plants have shown more plant height than those grown under control. Plants show varied response to different AM fungi. Plant height was more in the plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. and *Aculospora laeves* Gerd. and Trappe. compared to plants inoculated with other AM fungi at 60 as well as 90 DAS plants (Figures 1.1 and 1.2). The plants belonging to DWR -162, DWR-195 and DWR -225 varieties had shown good response to AMF inoculation. There was significant increase in plant height as observed in inoculated plants compared to control plants. The plants belonging to variety NI-5439 had shown lesser response to AMF inoculation. *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. resulted in maximum increase of the plant height in all varieties of *Triticum aestivum* L. It was *Aculospora laevis* Gerd. and Trappe. resulted in moderate increase in the plant height. Plants inoculated with *Gigaspora margarita* Becker and Hall. and *Sclerotystis dussii* (Pat.) V.Honn. had shown poor response. They resulted in
lesser increase in plant height in inoculated plants as compared to plants grown in control.

**P content in shoot (mg dry wt)**

Phosphorous content in shoot is very important indicator of mycorrhizal activity. Experimental results had shown significant increase of P content in inoculated plants compared to control plants. Uptake of P in *Triticum aestivum* L. varieties vary with different AM fungi. Shoot P concentration was relatively more in plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. Plants inoculated with *Aculospora laevis* Gerd. and Trappe. had resulted in moderate P uptake. Where as the other two AM fungal species *Gigaspora margarita* Becker and Hall. as well as *Sclerocystis dussii* (Pat.) V.Honn. had resulted in poor P up take. It was *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske. resulted in more P acquisition than other three AM fungi. About 100 to 220% increase in P concentration in shoot was observed in plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske.

It was DWR-162 and DWR-225 responded well to mycorrhizal inoculation in terms of P acquisition. Plant belonging to NI-5439 variety had shown comparatively lesser P shoot concentration than other three varieties. P concentration in shoot had shown that plants inoculated *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske. were able to acquire more P and accumulate in shoot when compared to the plants inoculated with other AM fungi taken for study.
Dry weight of shoot

Dry weight of shoot was measured in experimental plants at 60 and 90 DAS Stage. AMF inoculated plants had shown significant increase in shoot dry weight compared to control plants. The degree of increase varies with different AM fungi. Plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske. had shown highest dry weight of shoot. *Aculospora laevis* Gerd. and Trappe. had resulted in moderate increase in dry weight of shoot, whereas *Gigaspora margarita* Becker and Hall. and *Sclerocystis dussii* (Pat.) V.Honn. had resulted in least increase over control plants. Inoculated plants belonging to DWR-162, DWR-195 and DWR-225 had shown significant increase in dry weight of shoot. About 30 to 35% increase in shoot dry weight was observed in inoculated plants over control plants.

Absolute Growth Rate (AGR)

AGR was comparatively more in AM inoculated plants. Varied AGR was observed with different AMF species. Plants belonging to DWR-162, DWR-225 and NI-5439 varieties have shown the highest AGR with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske. Plants belonging to DWR-195 have shown high AGR with *Aculospora laevis* Gerd. and Trappe. All *Triticum aestivum* L.varieties have shown poor AGR with *Sclerocystis dussii* (Pat.) V.Honn.
PLATE-I

A. Mass multiplication of AMF by using *Sorghum Vulgare* L. as host plant.

B. Macerated root segment, showing arbuscules, vesicles and hyphae.
PLATE- II
Spores of AM fungi recovered from rhizospheric soils of
*Triticum aestivum* L.varieties


B. *Aculospora laevis* Gerd. and Trappe.

C. *Sclerocystis dussii* (Pat.) V.Honn.

D. *Gigaspora margarita* Becker and Hall.
PLATE-III A

A. Effect of AM fungi on growth parameters of *Triticum aestivum* L. 
DWR-162 variety at 60 DAS stage.

1. Plants grown in control.
2. Plants inoculated with *Gigaspora margarita* Becker and Hall.
4. Plants inoculated with *Aculospora laevis* Gerd. and Trappe.
5. Plants inoculated with *Sclerocystis dussii* (Pat.) V.Honn.

B. Effect of AM fungi on growth parameters of *Triticum aestivum* L. 
DWR-195 variety at 60 DAS stage

1. Plants grown in control.
2. Plants inoculated with *Sclerocystis dussii* (Pat.) V.Honn.
4. Plants inoculated with *Gigaspora margarita* Becker and Hall.
5. Plants inoculated with *Aculospora laevis* Gerd. and Trappe.
PLATE - III A
PLATE-III B

A. Effect of AM fungi on growth parameters of Triticum aestivum L. DWR-225 variety at 60 DAS stage.

1. Plants grown in control.
3. Plants inoculated with *Aculospora laevis* Gerd. and Trappe.
4. Plants inoculated with *Gigaspora margarita* Becker and Hall.
5. Plants inoculated with *Sclerocystis dussii* (Pat.) V.Honn.

B. Effect of AM fungi on growth parameters of Triticum aestivum L. NI-5439 variety at 60 DAS stage.

1. Plants grown in control.
3. Plants inoculated with *Aculospora laevis* Gerd. and Trappe.
4. Plants inoculated with *Gigaspora margarita* Becker and Hall.
5. Plants inoculated with *Sclerocystis dussii* (Pat.) V.Honn.
PLATE-IV A

A. Effect of AM fungi on growth parameters of Triticum aestivum L. DWR-162 variety at 90 DAS stage.

1. Plants grown in control.
3. Plants inoculated with *Aculospora laevis* Gerd. and Trappe.
4. Plants inoculated with *Sclerocystis dussii* (Pat.) V.Honn.
5. Plants inoculated with *Gigaspora margarita* Becker and Hall.

B. Effect of AM fungi on growth parameters of Triticum aestivum L. DWR-195 variety at 90 DAS stage.

1. Plants grown in control.
3. Plants inoculated with *Aculospora laevis* Gerd. and Trappe.
4. Plants inoculated with *Sclerocystis dussii* (Pat.) V.Honn.
5. Plants inoculated with *Gigaspora margarita* Becker and Hall.
PLATE-IV B

A. Effect of AM fungi on growth parameters of Triticum aestivum L.
DWR-225 variety at 90 DAS stage.

1. Plants grown in control.
3. Plants inoculated with *Aculospora laevis* Gerd. and Trappe.
4. Plants inoculated with *Gigaspora margarita* Becker and Hall.
5. Plants inoculated with *Sclerocystis dussii* (Pat.) V.Honn.

B. Effect of AM fungi on growth parameters of Triticum aestivum L.
NI-5439 variety at 90 DAS stage.

1. Plants grown in control.
3. Plants inoculated with *Aculospora laevis* Gerd. and Trappe.
4. Plants inoculated with *Gigaspora margarita* Becker and Hall.
5. Plants inoculated with *Sclerocystis dussii* (Pat.) V.Honn.
Relative Mycorrhizal Dependency (RMD)

Relative Mycorrhizal Dependency (RMD) was measured at 60 and 90 DAS stage. Plants belonging to four *Triticum aestivum* L.varieties have shown higher RMD at 60 DAS than 90 DAS stage. There was a significant difference in RMD between 60 & 90 DAS stages. Plants belonging to DWR-162 and DWR-225 varieties have shown maximum RMD, whereas NI-5439 had shown poor RMD with all AM fungi. RMD was very high in plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske. and *Aculospora laevis* Gerd. and Trappe. compared to other two AM fungal species. Least RMD was observed in plants inoculated with *slerocystis dussii* (Pat.) V. Honn.

Grain Yield per Plant

There was increased grain yield in inoculated plants compared to control plants. Mycorrhizal colonization had resulted in significant increase in grain yield. Plants belonging to four *Triticum aestivum* L.varieties had shown varied response to different AM fungi. Plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske. have shown comparatively more yield than the plants inoculated with other AM fungi. Plants inoculated with *Aculospora leavis* Gerd and Trappe. have shown moderate increase in grain yield, whereas *Gigaspora margarita* Becker and Hall. and *Slerocystis dussii* (Pat.) V.Honn. had resulted in least increase in yield over control plants. DWR-225 & DWR-162 respond better to
mycorrhizal colonization, plants of these two varieties had shown comparatively more yield than other two varieties.

100 grains weight

100 grain weight was measured in control and inoculated plants. Plants inoculated with AM fungi exhibited more grain weight over control plants. It was DWR-162 & DWR-225 varieties which showed the highest 100 grains weight. However more increase in 100 grain weight was observed in plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. and *Aculospora laevis* Gerd. and Trappe. Plants inoculated with *Sclerocystis dussii* (Pat.) V. Honn. and *Gigaspora margarita* Becker and Hall. have shown lesser increase in 100 grain weight over control plants.

Mycorrhizal colonization

Per cent mycorrhizal colonization was observed at 60 DAS than 90 DAS in four *Triticum aestivum* L. varieties. The per cent of mycorrhizal colonization differ at 60 and 90 DAS duration. The per cent of mycorrhizal colonization was more at 60DAS stage than 90DAS stage. Plants belonging to *Triticum aestivum* L. varieties have shown varied degree of colonization with different AM fungal species. Per cent mycorrhizal colonization with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. and *Aculospora laevis* Gerd. and Trappe. was more than *Sclerocystis dussii* and *Gigaspora margarita*. The experimental results revealed that *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. and *Aculospora laevis* Gerd. and Trappe. showed preference in
colonizing the roots of *Triticum aestivum* L. varieties than *Sclerocystis dussii* (Pat.) V. Honn. and *Gigaspora margarita* Becker and Hall. Among four *Triticum aestivum* L. varieties, DWR-162 and DWR-225 had shown more percent root colonization than other two varieties. The variety NI-5439 had shown least percent mycorrhizal colonization.

Table 1.1: Effect of different AM Fungi on growth parameters of *Triticum aestivum* L. DWR-162 variety at 60 DAS.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height</th>
<th>RDW</th>
<th>SDW</th>
<th>PMC</th>
<th>RMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>15.1</td>
<td>0.096</td>
<td>0.30</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>LFSC</td>
<td>23.00</td>
<td>0.198</td>
<td>0.710</td>
<td>73.0</td>
<td>83.01</td>
</tr>
<tr>
<td>ALVS</td>
<td>21.25</td>
<td>0.210</td>
<td>0.636</td>
<td>71.33</td>
<td>73.50</td>
</tr>
<tr>
<td>SDSS</td>
<td>17.23</td>
<td>0.146</td>
<td>0.470</td>
<td>67.33</td>
<td>48.9</td>
</tr>
<tr>
<td>GMRG</td>
<td>20.3</td>
<td>0.153</td>
<td>0.537</td>
<td>63.00</td>
<td>51.84</td>
</tr>
</tbody>
</table>

Table 1.2: Effect of different AM Fungi on growth parameters of *Triticum aestivum* L. DWR-195 variety at 60 DAS.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height</th>
<th>RDW</th>
<th>SDW</th>
<th>PMC</th>
<th>RMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>16.40</td>
<td>0.10</td>
<td>0.436</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>LFSC</td>
<td>24.7</td>
<td>0.19</td>
<td>0.746</td>
<td>65.66</td>
<td>85.80</td>
</tr>
<tr>
<td>ALVS</td>
<td>23.00</td>
<td>0.166</td>
<td>0.723</td>
<td>64.66</td>
<td>76.52</td>
</tr>
<tr>
<td>SDSS</td>
<td>19.40</td>
<td>0.130</td>
<td>0.646</td>
<td>60.0</td>
<td>52.08</td>
</tr>
<tr>
<td>GMRG</td>
<td>19.26</td>
<td>0.143</td>
<td>0.676</td>
<td>61.66</td>
<td>75.80</td>
</tr>
</tbody>
</table>

CN-Control, LFSC-*Glomus fasciculatum*, ALVS-*Aculospora laevis*, SDSS-*Sclerocystis dussii*, GMRG-*Gigaspora margarita*, RDW-Root Dry Weight, SDW-Shoot Dry Weight, PMC-Percent Mycorrhizal Colonization, RMD-Relative Mycorrhizal Dependency. ANOVA Duncan’s multiple range test (DMRT) at P = 0.05 was used to compare means.
Table 1.3: Effect of different AM Fungi on growth parameters of *Triticum aestivum* L. DWR-225 variety at 60 DAS.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height</th>
<th>RDW</th>
<th>SDW</th>
<th>PMC</th>
<th>RMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>15.00</td>
<td>0.073</td>
<td>0.256</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>LFSC</td>
<td>23.66</td>
<td>0.19</td>
<td>0.506</td>
<td>65.33</td>
<td>45.74</td>
</tr>
<tr>
<td>ALVS</td>
<td>17.80</td>
<td>0.123</td>
<td>0.456</td>
<td>65.6</td>
<td>63.00</td>
</tr>
<tr>
<td>SDSS</td>
<td>16.46</td>
<td>0.110</td>
<td>0.436</td>
<td>62.66</td>
<td>35.14</td>
</tr>
<tr>
<td>GMRG</td>
<td>16.90</td>
<td>0.113</td>
<td>0.484</td>
<td>51.33</td>
<td>66.59</td>
</tr>
</tbody>
</table>

CN-Control, LFSC-Glomus fasciculatum, ALVS-Aculospora laevis, SDSS-Sclerocystis dussii, GMRG-Gigaspora margarita, RDW-Root Dry Weight, SDW-Shoot Dry Weight, PMC-Percent Mycorrhizal Colonization, RMD-Relative Mycorrhizal Dependency. ANOVA Duncan’s multiple range test (DMRT) at P = 0.05 was used to compare means.

Table 1.4: Effect of different AM Fungi on growth parameters of *Triticum aestivum* L. NI-5439 variety at 60 DAS.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height</th>
<th>RDW</th>
<th>SDW</th>
<th>PMC</th>
<th>RMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>22.10</td>
<td>0.073</td>
<td>0.340</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>LFSC</td>
<td>33.33</td>
<td>0.116</td>
<td>0.586</td>
<td>58.0</td>
<td>53.1</td>
</tr>
<tr>
<td>ALVS</td>
<td>33.60</td>
<td>0.113</td>
<td>0.410</td>
<td>49.2</td>
<td>55.6</td>
</tr>
<tr>
<td>SDSS</td>
<td>27.7</td>
<td>0.100</td>
<td>0.500</td>
<td>45.33</td>
<td>44.32</td>
</tr>
<tr>
<td>GMRG</td>
<td>30.76</td>
<td>0.95</td>
<td>0.450</td>
<td>48.2</td>
<td>40.9</td>
</tr>
</tbody>
</table>

CN-Control, LFSC-Glomus fasciculatum, ALVS-Aculospora laevis, SDSS-Sclerocystis dussii, GMRG-Gigaspora margarita, RDW-Root Dry Weight, SDW-Shoot Dry Weight, PMC-Percent Mycorrhizal Colonization, RMD-Relative Mycorrhizal Dependency. ANOVA Duncan’s multiple range test (DMRT) at P = 0.05 was used to compare means.
Table 1.5: Effect of different AM Fungi on growth parameters of *Triticum aestivum* L. DWR-162 variety at 90 DAS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height</th>
<th>RDW</th>
<th>SDW</th>
<th>PMC</th>
<th>RMD</th>
<th>AGR</th>
<th>% of P content in shoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>31.50 ±0.28d</td>
<td>0.17</td>
<td>0.77</td>
<td>.....</td>
<td>.....</td>
<td>0.13 ±0.00d</td>
<td>0.24 ±0.01d</td>
</tr>
<tr>
<td>LFSC</td>
<td>50.50 ±2.0a</td>
<td>0.341</td>
<td>1.0</td>
<td>68.00</td>
<td>60.40</td>
<td>0.25 ±0.05a</td>
<td>0.65 ±0.12a</td>
</tr>
<tr>
<td>ALVS</td>
<td>46.76 ±0.64b</td>
<td>0.25</td>
<td>0.93</td>
<td>58.00</td>
<td>58.00</td>
<td>0.20 ±0.04a</td>
<td>0.47 ±0.02b</td>
</tr>
<tr>
<td>SDSS</td>
<td>42.33 ±0.35c</td>
<td>0.22</td>
<td>0.87</td>
<td>47.33</td>
<td>48.90</td>
<td>0.16 ±0.05a</td>
<td>0.35 ±0.02c</td>
</tr>
<tr>
<td>GMRG</td>
<td>42.40 ±1.21c</td>
<td>0.21</td>
<td>0.91</td>
<td>52.00</td>
<td>34.55</td>
<td>0.19 ±0.05a</td>
<td>0.36 ±0.02c</td>
</tr>
</tbody>
</table>

CN-Control, LFSC-Glomus fasciculatum, ALVS-Aculospora laevis, SDSS-Sclerocystis dussii, GMRG-Gigaspora margarita, RDW-Root Dry Weight, SDW-Shoot Dry Weight, PMC-Percent Mycorrhizal Colonization, RMD-Relative Mycorrhizal Dependency. ANOVA Duncan’s multiple range test (DMRT) at *P* = 0.05 was used to compare means.

Table 1.6: Effect of different AM Fungi on growth parameters of *Triticum aestivum* L. DWR-195 variety at 90 DAS.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height</th>
<th>RDW</th>
<th>SDW</th>
<th>PMC</th>
<th>RMD</th>
<th>AGR</th>
<th>% of P content in shoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>27.16 ±0.44d</td>
<td>0.12</td>
<td>0.61</td>
<td>---</td>
<td>---</td>
<td>0.11 ±0.01d</td>
<td>0.22 ±0.01d</td>
</tr>
<tr>
<td>LFSC</td>
<td>48.11 ±0.28a</td>
<td>0.27</td>
<td>0.90</td>
<td>58.66</td>
<td>33.47</td>
<td>0.18 ±0.05a</td>
<td>0.48 ±0.02a</td>
</tr>
<tr>
<td>ALVS</td>
<td>46.3 ±2.33b</td>
<td>0.24</td>
<td>0.84</td>
<td>50.33</td>
<td>26.60</td>
<td>0.22 ±0.01a</td>
<td>0.44 ±0.03b</td>
</tr>
<tr>
<td>SDSS</td>
<td>43.06 ±3.35bc</td>
<td>0.16</td>
<td>0.71</td>
<td>45.36</td>
<td>22.17</td>
<td>0.15 ±0.05a</td>
<td>0.39 ±0.04c</td>
</tr>
<tr>
<td>GMRG</td>
<td>44.6 ±2.9b</td>
<td>0.193</td>
<td>0.73</td>
<td>52.66</td>
<td>27.33</td>
<td>0.16c ±0.02c</td>
<td>0.42 ±0.02bc</td>
</tr>
</tbody>
</table>

CN-Control, LFSC-Glomus fasciculatum, ALVS-Aculospora laevis, SDSS-Sclerocystis dussii, GMRG-Gigaspora margarita, RDW-Root Dry Weight, SDW-Shoot Dry Weight, PMC-Percent Mycorrhizal Colonization, RMD-Relative Mycorrhizal Dependency. ANOVA Duncan’s multiple range test (DMRT) at *P* = 0.05 was used to compare means.
Table 1.7: Effect of different AM Fungi on growth parameters of *Triticum aestivum* L. DWR-225 variety at 90 DAS.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height</th>
<th>RDW</th>
<th>SDW</th>
<th>PMC</th>
<th>RMD</th>
<th>AGR</th>
<th>% of P in shoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>38.8</td>
<td>0.12</td>
<td>0.65</td>
<td>----</td>
<td>----</td>
<td>0.07</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>±0.3c</td>
<td>±0.01d</td>
<td>±0.01d</td>
<td></td>
<td></td>
<td>±0.000d</td>
<td>±0.08d</td>
</tr>
<tr>
<td>LFSC</td>
<td>43.40</td>
<td>0.340</td>
<td>1.16</td>
<td>66.12</td>
<td>53.10</td>
<td>0.216</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>±2.3a</td>
<td>±0.14a</td>
<td>±0.05a</td>
<td>±3.1a</td>
<td>±0.08a</td>
<td>±0.01a</td>
<td>±0.03a</td>
</tr>
<tr>
<td>ALVS</td>
<td>42.76</td>
<td>0.30</td>
<td>0.95</td>
<td>49.33</td>
<td>48.74</td>
<td>0.14</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>±1.00a</td>
<td>±0.09b</td>
<td>±0.01b</td>
<td>±4.6b</td>
<td>±0.24b</td>
<td>±0.01c</td>
<td>±0.02b</td>
</tr>
<tr>
<td>SDSS</td>
<td>40.01</td>
<td>0.18</td>
<td>0.81</td>
<td>41.00</td>
<td>34.00</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>±0.6b</td>
<td>±0.06cd</td>
<td>±0.02c</td>
<td>±1.5d</td>
<td>±2.4d</td>
<td>±0.02c</td>
<td>±0.02c</td>
</tr>
<tr>
<td>GMRG</td>
<td>39.50</td>
<td>0.25c</td>
<td>0.80</td>
<td>46.12</td>
<td>40.08c</td>
<td>0.17</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>±0.2c</td>
<td>±0.09</td>
<td>±0.02c</td>
<td>±3.1c</td>
<td>±3.66</td>
<td>±0.02b</td>
<td>±0.01c</td>
</tr>
</tbody>
</table>

CN-Control, LFSC-Glomus fasciculatum, ALVS-Aculospora laevis, SDSS-Sclerocystis dussii, GMRG-Gigaspora margarita, RDW-Root Dry Weight, SDW-Shoot Dry Weight, PMC-Percent Mycorrhizal Colonization, RMD-Relative Mycorrhizal Dependency. ANOVA Duncan's multiple range test (DMRT) at P = 0.05 was used to compare means.

Table 1.8: Effect of different AM Fungi on growth parameters of *Triticum aestivum* L. NI-5439 variety at 90 DAS.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height</th>
<th>RDW</th>
<th>SDW</th>
<th>PMC</th>
<th>RMD</th>
<th>AGR</th>
<th>% of P in shoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>33.5</td>
<td>0.16</td>
<td>0.63</td>
<td>----</td>
<td>----</td>
<td>0.08</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>±0.04d</td>
<td>±0.02d</td>
<td>±0.02d</td>
<td></td>
<td></td>
<td>±0.000d</td>
<td>±0.05d</td>
</tr>
<tr>
<td>LFSC</td>
<td>42.8</td>
<td>0.31</td>
<td>0.91</td>
<td>50.5</td>
<td>36.56</td>
<td>0.18</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>±2.45a</td>
<td>±0.05a</td>
<td>±0.01a</td>
<td>±1.73a</td>
<td>±1.56a</td>
<td>±0.01a</td>
<td>±0.07a</td>
</tr>
<tr>
<td>ALVS</td>
<td>39.5</td>
<td>0.28</td>
<td>0.90</td>
<td>45.0</td>
<td>34.6</td>
<td>0.15</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>±2.0b</td>
<td>±0.06b</td>
<td>±0.02a</td>
<td>±2.4b</td>
<td>±1.17b</td>
<td>±0.03b</td>
<td>±0.02b</td>
</tr>
<tr>
<td>SDSS</td>
<td>37.8</td>
<td>0.23</td>
<td>0.70</td>
<td>43.33</td>
<td>32.9</td>
<td>0.13</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>±1.5c</td>
<td>±0.05c</td>
<td>±0.08c</td>
<td>±2.3c</td>
<td>±2.79d</td>
<td>±0.04c</td>
<td>±0.08c</td>
</tr>
<tr>
<td>GMRG</td>
<td>38.6</td>
<td>0.27b</td>
<td>0.85</td>
<td>42.5</td>
<td>33.5</td>
<td>0.14</td>
<td>0.32c</td>
</tr>
<tr>
<td></td>
<td>±1.5bc</td>
<td>±0.01</td>
<td>±0.03b</td>
<td>±1.73d</td>
<td>±2.6c</td>
<td>±0.01b</td>
<td>±0.01</td>
</tr>
</tbody>
</table>

CN-Control, LFSC-Glomus fasciculatum, ALVS-Aculospora laevis, SDSS-Sclerocystis dussii, GMRG-Gigaspora margarita, RDW-Root Dry Weight, SDW-Shoot Dry Weight, PMC-Percent Mycorrhizal Colonization, RMD-Relative Mycorrhizal Dependency. ANOVA Duncan's multiple range test (DMRT) at P = 0.05 was used to compare means.
Table 1.9: Effect of AM Fungi on Number of grains produced per plant in *Triticum aestivum* L. varieties.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>DWR -162</th>
<th>DWR -195</th>
<th>DWR -225</th>
<th>NI-5439</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>25.33</td>
<td>22.00</td>
<td>28.00</td>
<td>21.00</td>
</tr>
<tr>
<td>±0.67e</td>
<td>±0.58d</td>
<td>±1.50d</td>
<td>±0.057d</td>
<td></td>
</tr>
<tr>
<td>LFSC</td>
<td>40.5</td>
<td>36.33</td>
<td>46.00</td>
<td>29.60</td>
</tr>
<tr>
<td>±2.5b</td>
<td>±2.96a</td>
<td>±1.20a</td>
<td>±3.30a</td>
<td></td>
</tr>
<tr>
<td>ALVS</td>
<td>42.66</td>
<td>23.34</td>
<td>42.00</td>
<td>28.33</td>
</tr>
<tr>
<td>±2.90a</td>
<td>±0.58c</td>
<td>±1.20b</td>
<td>±0.90b</td>
<td></td>
</tr>
<tr>
<td>SDSS</td>
<td>33.33</td>
<td>28.00</td>
<td>35.66</td>
<td>25.00</td>
</tr>
<tr>
<td>±0.88d</td>
<td>±0.50bc</td>
<td>±3.21c</td>
<td>±1.50cd</td>
<td></td>
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<tr>
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<td>32.00</td>
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<td>±0.58b</td>
<td>±0.90b</td>
<td>±1.9c</td>
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</tbody>
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CN-Control, LFSC - *Glomus fasciculatum*, ALVS - *Aculospora laevis*, SDSS - *Sclerocystis dussii*, GMRG-Gigaspora margarita. ANOVA Duncan's multiple range test (DMRT) at P = 0.05 was used to compare means.

Table 1.10: Effect of AM Fungi on 100 grains weight in *Triticum aestivum* L. varieties.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>DWR -162</th>
<th>DWR -195</th>
<th>DWR -225</th>
<th>NI-5439</th>
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CN-Control, LFSC- *Glomus fasciculatum*, ALVS - *Aculospora laevis*, SDSS- *Sclerocystis dussii*, GMRG-Gigaspora margarita. ANOVA Duncan's multiple range test (DMRT) at P = 0.05 was used to compare means.
Fig. 1.1 - Plant Height at 60 DAS in control and AM inoculated *Triticum aestivum* L. varieties.

![Plant height at 60 DAS](image)

**CN-Control, LFSC- *Glomus fasciculatum*, ALVS- *Aculospora laevis*, SDSS- *Sclerocystis dussii*, GMRG- *Gigaspora margarita*.**

Fig. 1.2 - Plant Height at 90 DAS in control and AM inoculated *Triticum aestivum* L. varieties.

![Plant height at 90 DAS](image)

**CN-Control, LFSC- *Glomus fasciculatum*, ALVS- *Aculospora laevis*, SDSS- *Sclerocystis dussii*, GMRG- *Gigaspora margarita*.**
Fig. 1.3 - Percent mycorrhizal colonization in *Triticum aestivum* L. varieties at 60 DAS

![PMC at 60 DAS](image)

- DWR-162
- DWR-195
- DWR-225
- NI-5439

CN-Control, LFSC- *Glomus fasciculatum*, ALVS-*Aculuspora laevis*, SDSS-*Sclerozystis dussii*, GMRG-*Gigaspora margarita*, PMC- Per cent Mycorrhizal Colonization.

Fig. 1.4: Percent mycorrhizal colonization in *Triticum aestivum* L. varieties at 90 DAS.

![ PMC at 90 DAS](image)

CN-Control, LFSC- *Glomus fasciculatum*, ALVS-*Aculuspora laevis*, SDSS-*Sclerozystis dussii*, GMRG-*Gigaspora margarita*, PMC- Per cent Mycorrhizal Colonization.
Fig. 1.5: Relative Mycorrhizal Dependency (RMD) of *Triticum aestivum* L.varieties to various AM fungi at 60 DAS.

![Graph showing RMD at 60 DAS](image)

Fig. 1.6: Relative Mycorrhizal Dependency (RMD) of *Triticum aestivum* L.varieties to various AM fungi at 90 DAS.

![Graph showing RMD at 90 DAS](image)

Fig. 1.7- Root Dry Weight (RDW) in control and AM inoculated *Triticum aestivum* L. varieties at 60 DAS.

![RDW at 60 DAS](chart)

Fig. 1.8: Effect of different AM fungi on root dry weight in *Triticum aestivum* L. varieties at 90 DAS.

![RDW at 90 DAS](chart)

CN-Control, LFSC- *Glomus fasciculatum*, ALVS- *Aculospora laevis*, SDSS- *Sclerocystis dussii*,
GMRG- *Gigaspora margarita*
Fig. 1.9 - Percentage of P in shoot in control and AM inoculated *Triticum aestivum* L. varieties at 90 DAS.

![Graph showing percentage of P in shoot comparison between control and AM inoculated varieties.]

Fig. 1.10: Effect of different AM fungi on AGR in *Triticum aestivum* L. varieties at 90 DAS.

![Graph showing AGR comparison between control and AM inoculated varieties.]

CN-Control, LFSC- *Glomus fasciculatum*, ALVS- *Aculospora laevis*, SDSS- *Sclerocystis dussii*, GMRG-*Gigaspora margarita*
Fig. 1.11: Effect of different AM fungi on shoot dry weight in *Triticum aestivum* L. varieties at 90 DAS.

Grain yield per plant

<table>
<thead>
<tr>
<th>Treatment</th>
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<th>SDSS</th>
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CN-Control, LFSC- *Glomus fasciculatum*, ALVS- *Aculospora laevis*, SDSS- *Sclerocystis dussii*, GM-RG-*Gigaspora margarita*, PMC- Percent Mycorrhizal Colonization

Fig. 1.12: Effect of AM Fungi on number of grains yield per plant in *Triticum aestivum* L. varieties.

Grain yield per plant

<table>
<thead>
<tr>
<th>Treatment</th>
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CN-Control, LFSC- *Glomus fasciculatum*, ALVS- *Aculospora laevis*, SDSS- *Sclerocystis dussii*, GM-RG-*Gigaspora margarita*
Fig. 1.13: Effect of AM Fungi on 100 grains weight in *Triticum aestivum* L. varities.

CN-Control, LFSC- *Glomus fasciculatum*, ALVS-*Aculospora laevis*, SDSS-*Sclerocystis dussii*, GMRG-*Gigaspora margarita*.
DISCUSSION

Arbuscular mycorrhizal fungi help in nutrient uptake. Use of AM fungi as fertilizer helps in the establishment of plants. Panwar and Vyas (2002), reported the inoculation effect of AM fungi on assimilating enzyme concentration in *Moringa conconensis*. Concentration of assimilating enzymes increase in plants inoculated with AM fungi. This may enhance the rate of photosynthesis resulted in increased biomass production and seed yield. All AM fungi tested induced a higher growth in host plants by acquiring more nutrients. Bago *et al.*, (1996), demonstrated that extra radical AM fungal hyphae are able to take up essential universal nutrients and transport from soil to plants. Increased biomass production, yield and grain weight might be due to increased uptake of nutrients, regulation of water potential and increased accumulation of polyphosphates. Present findings correlate with these earlier investigations

Prabakaran *et al.*, (1995a), studied the performance of *Sorghum* cultivars to AM fungi like *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske., *Glomus mossae* Gerd. and Trappe. , *Gigaspora margarita* Becker and Hall. and *Aculuspora leavis* Gerd. and Trappe. AM inoculation induced increased growth and yield than uninoculated control plants. Among these mycorrhizae *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. resulted more increases of plant growth and yield. Our results correlates with these findings, the *Triticum aestivum* L. varieties and showed the highest biomass production and yield with *Glomus*
Glomus fasciculatum (Thaxt.) Gerd. and Trappe emend. Walker and Koske. than other AM fungi. Results of present research work confirmed that Triticum aestivum L. varieties show preference to Glomus fasciculatum (Thaxt.) Gerd. and Trappe emend. Walker and Koske. over other three AMF species taken for the study.

The Glomus fasciculatum (Thaxt.) Gerd. and Trappe emend. Walker and Koske. is a predominant AM fungus in slightly acidic to slightly alkaline soils. The soil pH plays major role in the host fungus symbiotic relationship. Soil pH favours colonization by Glomus fasciculatum (Thaxt.) Gerd. and Trappe emend. Walker and Koske. This AM fungus show high level of infectivity and is an aggressive colonizer, the per cent root colonization was found to be more with Glomus fasciculatum (Thaxt.) Gerd. and Trappe emend. Walker and Koske. It maintains growth of host plants to optimum than other AM fungal isolates. Colonization of roots by AM fungi greatly increased the uptake of phosphorus by extra radial mycorrhizal hyphae. The shoot P concentration was found to be more in AM inoculated plants. Similar results were obtained by Chen et al., (2005). Terafdar et al., (1992), documented the effect AM fungi on growth of mung bean and cluster bean, the experimental results exactly correlates with our findings. Hung et al., (1990), suggested that early colonization of roots by AM fungi is important to get benefit from symbiosis. Vierheilig and Ocampo (1991), found that Glomus mosseae (Nicol. and Gerd.) Gerd. and Trappe was more effective than Glomus fasciculatum (Thaxt.) Gerd. and Trappe emend. Walker and Koske. in stimulating the growth of several
wheat cultivars although there was no much significant difference in AMF colonization. Present experimental results revealed that *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. stimulates more growth in wheat cultivars than other AM fungal species. The per cent of root colonization do not affects the growth directly. But the wheat cultivars had shown maximum per cent root colonization with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske.

Bever (2002), had reported the AM fungal host specificity. AM fungal species showed host specific differences. AM colonization and growth rates of AM fungal species depend on the host plant which they associate. There was no relationship between biomass produced and percentage of mycorrhizal colonization. Only wheat grain yield was significantly co-related with the percentage of mycorrhizal colonization. All *Triticum aestivum* L. varieties show maximum per cent root colonization with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske, followed by *Aculospora laevis* Gerd. and Trappe. Plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske. had produced highest yield, followed by those inoculated with *Aculospora laevis* Gerd. and Trappe. Similar findings were observed by Taludar and Germida (1994), in wheat. Mosse (1972), reported the difference in the ability of AM fungal species to Stimulate Plant growth for *Paspalum notatum*. Carling and Brown (1980) and Dhillon (1992), reported the importance of evaluating potential inoculant strains with plants Species. Our results revealed that *Glomus fasciculatum* (Thaxt.) Gerd. and
Trappe emend. Walker and Koske. was the potential AM fungus that can promote the growth in *Triticum aestivum* L. varieties. Response to mycorrhizal symbiosis is consistent within the varieties of a species. Our experimental results strongly advocate variation in growth and yield due to genotype. Mycorrhizal symbiosis resulted in some degree of increased growth response with slight variation. Similar observations were made by Hetrick *et al.*, (1996).

Present experimental results suggested that there was variation in per cent root colonization in *Triticum aestivum* L. varieties. The most effective AM Fungi produces higher amount of mycelium than other AM fungi & more per cent root colonization. This helps to increase soil aggregation to maintain better soil moisture. In contrast the AM fungus that is less effective had shown lesser colonization. *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend. Walker and Koske. had produced higher per cent root colonization than other AM fungi has resulted in more yield than other AM fungi. Marulanda *et al.*, (2003), reported the similar results. Kothari *et al.*, (1991), explained that the most important factor that influences the efficiency of AM fungal strains seems to be their external mycelium. Jocobson *et al.*, (1992), reported that there is no clear relationship that seems to exist between the amount of external hyphae in soil and growth response observed in colonized plants. Other factors such as difference in the rate of appersorium formation and translocation, uptake capacities of nutrients seem to have influence on the efficiency of AM fungi.
Tilak and Singh (1988), reported that inoculation with *Aculospora* species, *Gigaspora margarita* Becker and Hall. and *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. resulted in greater dry matter production by *Pennisetum americanum* and greater P uptake than control. Shoot P concentration was found to be high in inoculated plants. Further it was also observed that shoot P concentration was found to be higher in the plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. Champawat and Pathak (1993), studied the effect of AM fungi on growth and nutrient uptake of pearl millet. They noticed greater shoot and root dry weight, P and N uptake in plants inoculated with *Gigaspora calospora* than non inoculated plants. Sesila and Bagyaraj (1990), studied the response of upland rice to AM fungi, maximum yield was recorded in plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. These findings strongly support present experimental results. Inoculated plants have shown higher shoot P concentration, dry weight and yield over control plants. The effectiveness of the symbiosis with respect to plant growth and yield was influenced by the magnitude of the fluxes of phosphate and other nutrients to the plant.
Inoculation with arbuscular mycorrhizal fungi was able to enhance biomass production as well as grain yield in four *Triticum aestivum* L. varieties. AMF inoculation certainly helped to enhance the growth and yield in four *Triticum aestivum* L. varieties. Varied growth response was observed with different AMF species. Among the AMF isolates taken for the study the *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe. emend.Walker and Koske. was the best AM fungus among the four species tested. It is the best AM fungus compared to other three AM fungi. DWR-162 and DWR-225 were showing preference to mycorrhizal colonization, RMD was relatively more in these varieties.