CHAPTER- 4

Impact of *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend. Walker and Koske. on photosynthetic rate, stomatal conductance and RuBp carboxylase efficiency in *Triticum aestivum* L. varieties

INTRODUCTION

Wheat is an important cereal crop that ranks first globally. It is cultivated all over the world under different agro climatic conditions. In most parts of India bread wheat (*Triticum aestivum* L.) is cultivated under irrigation as well as rain fed conditions. The growing season is characterized by low rainfall and relatively high evaporative.

Arbuscular mycorrhizal (AM) fungi are widespread mycorrhizal associations between soil microorganisms and roots of higher plants. Organic carbon derived from photosynthesis is transferred to these symbionts and organic carbon maintains the development of spores and fruit bodies in most mycorrhiza types by the translocation of substance to the growing margins of the extra radical mycelium (Smith and Read, 1997). AM fungi are known to enhance plant growth and yield by increasing the uptake of water and nutrients from soil (Podila and Douds, 2001). Availability of nutrients can affect the physiological processes, in particular photosynthesis when not supplied in adequate quantities (George *et al.*, 1992). Carbohydrate dependency of mycorrhizal fungi has been tested. Allocation of photosynthates to mycorrhizal fungi represent a major carbon cost to plants (Kochar and Johnson, 1984) and...
increased photosynthetic rates to support arbuscular mycorrhizal symbiosis (Love lock et al., 1997; Jifton et al., 2002)

AM association can affect the host plants in terms of stomatal movement and photosynthetic rate in leaves. It has been shown that arbuscular mycorrhizal association can increase chlorophyll content, transpiration and photosynthetic rates in wheat (Panwar, 1991). Inoculation of host plants with arbuscular mycorrhizal fungi resulted in changing the stomatal behavior and photosynthetic rate. Stomata are the main path for higher plants to exchange matter and energy with their environment. By varying the width of stomatal pores plant are able to control the flux of CO₂ and water between the leaf and surrounding air in response to changes in environmental factors. AM Fungi may function as metabolic sink causing more mobilization of photosynthates to roots, this helps to provide a stimulus for greater photosynthetic activity (Allen et al, 1981).

Studies on the influence of mycorrhizal colonization on photosynthetic rate, stomatal conductance, chlorophyll content, and RuBp carboxylase efficiency in locally grown Triticum aestivum L. varieties has not been made.

Present study was undertaken to investigate the influence of AM fungus Glomus fasciculatum (Thaxt.) Gerd. and Trappe emend.Walker and Koske on photosynthetic rate, stomatal conductance water use efficiency and RuBp carboxylase in Triticum aestivum L. varieties DWR-162, DWR-195, DWR-225 and NI-5439 under normal watered conditions.
Many earlier investigators reported the effect of arbuscular mycorrhizae on physiological processes in different host species. Losel and Cooper (1979), observed greater translocation of photosynthates to root of mycorrhizal onion and suggested that this could reflect increased photosynthesis in leaves. Experiments carried out by Allen et al., (1981), confirmed the mycorrhizal effects on Plant growth, they had shown that the rate of photosynthesis was higher in mycorrhizal than in non-mycorrhizal plants. Allen and Allen (1981), reported higher transpiration and photosynthetic rates, chlorophyll concentration ratios in grass Bouteloua gracilis under mycorrhizal inoculation. Allen et al., (1982), reported that levels of cytokinins and gibberellins produced in mycorrhiza inoculated plants increases. Under the influence of these hormones the chlorophyll content and photosynthetic rates were found to be high. Harley and Smith (1983), reported the demand for host photosynthates depends upon the amount of fungi associated with the root and its metabolic rate. Mycorrhizal roots have higher respiratory activity than non mycorrhizal roots. They had observed increased amounts of soluble carbohydrates in infected roots. Colonization enhanced assimilate allocation by host. A higher sink strength should be caused by mycorrhizae. Siwak and Walker (1986), explained the effect of available inorganic phosphate on the rate of photosynthesis, P deficiency can limit the rate of photosynthesis. Wang et al., (1989), reported that photosynthetic storage and transport rates have been increased by arbuscular mycorrhizal fungi.
Nemec and Vu (1990), reported the improved photosynthetic rates in *Citrus aurantium* L. inoculated with *Glomus intraradices* as compared to uninoculated plants. Sanchez – Diaz *et al.*, (1990), confirmed the higher photosynthetic rate and CO₂ exchange rates in *Medicago Sativa* L. inoculated with arbuscular mycorrhizal fungi. Approximately 30 % more CO₂ exchange rate and 55% higher photosynthetic rate was observed in mycorrhizal plants than non mycorrhizal ones. Jakobsen and Rosendahl, (1990) estimated that arbuscular mycorrhizal fungi could use up 20% of total fixed CO₂ in young Plant. Nemec and Vu (1990), reported that inoculation of sour orange with *Glomus intraradices* accounted for improved photosynthetic CO₂ fixation. Johnson *et al.*, (1992), explained arbuscular mycorrhizal colonization stimulates important metabolic processes, such as photosynthesis. Higher photosynthetic rate and stomatal conducatance was observed in mycorrhial *citrus Sinensis* L. Koide (1993) revealed that leaf photosynthesis can increase among AM colonized plants as a function of phosphorus (P) nutrition and stomatal conductance, compared with non-mycorrhizal hosts.Davies *et al.*, (1993), reported higher amount of chlorophyll in mycorrhizal than non-mycorrhizal plants, higher concentration of chlorophyll is associated with higher photosynthetic rate. Phavaphutanon *et al.*, (1996), reported higher WUE in mycorrhizal plants. Levy *et al.*, (1983), had reported higher water conductivity by arbuscular mycorrhiza inoculated plants. Smith and Read (1997), revealed that inoculated roots receive 4 to 20% more photosynthates than non-mycorrhizal roots. Wright *et al.*, (1998), explained that arbuscular
mycorrhizal fungi can constitute physiologically important sink. Yano-Melo et al., (1999), reported that *Glomus clarum* and *Glomus etunicatum* enhanced growth, photosynthesis and transpiration rates of *Musa* species and these effects were due to improved P-nutrition.

Auge (2001), explained that AM colonization of host maize plants had a beneficial effect upon both plant water relations and CO$_2$ assimilation. Wu and Xia (2006), reported that *Citrus tangerine* seedlings inoculated with *Glomus versiforme* had higher photosynthetic rates than corresponding control seedlings.
MATERIALS AND METHODS

Experiments were conducted in polybags measuring 15 cm diameter. The sterilized soil and sand was mixed in 1:1 ratio and filled in the polybags. Grains of four locally grown *Triticum aestivum* L. varieties DWR-162, DWR-195, DWR-225 and NI-5439 were used for the experiments. The grains of these varieties were collected from wheat research station, University of Agricultural Sciences Dharwad, India. Grains were surface sterilized with 2% sodium hypochloride solution. To remove the traces of sodium hypochlorite, grains were then washed with distilled water 4 times. About 4 grains were placed in each polybags. Control polybags were not added with arbuscular mycorrhizal fungal inoculum. Inoculated plants were treated with arbuscular mycorrhizal fungus *Glomus fasciculatum*. Before sowing grains inoculum of *Glomus fasciculatum* was placed 2cm below the soil. Two treatments were maintained in triplicates arranged in randomized complete block design.

**Control treatment.** Plants were grown in polybags containing sterile soil and sand mix without any AM inoculum. Plants were regularly watered on alternate days.

**Inoculated treatment.** Plants were grown in polybags containing sterile soil and sand mix with arbuscular mycorrhizal inoculum (*Glomus fasciculatum*). Plants were regularly watered on alternate days.

**Source of AM Inoculum**

The arbuscular mycorrhizal fungus *Glomus fasciculatum* was isolated according to decanting and wet sieving method (Gerdemann and Nicolson,
1963). AM fungus was mass multiplied by using host plant *Sorghum vulgare* L. grown on sterile soil. Finally three month old multiplied arbuscular mycorrhizal inoculum was used for the experiment.

**Determination of photosynthetic rate, stomatal conductance WUE, Ci and \( \frac{C_i}{C_a} \) by IRGA (Infra Red Gas Analyzer)**

IRGA LICOR 6400 is portable instrument used to measure the fluxes of CO\(_2\) and water. The parameters were measured on a portion of leaf enclosed in a chamber where the CO\(_2\) concentration, humidity, leaf temperature and light are controlled. The instrument calculates the photosynthetic rate, stomatal conductance, transpiration rate and the concentration of CO\(_2\) in the intercellular air spaces within the leaf.

PAR is adjusted to 1500 \( \mu \) mol photons m\(^{-2}\) s\(^{-1}\). Flag leaf is inserted in to the leaf cuvette of IRGA. Measurements were taken between 9 AM to 11 AM inside the laboratory at 27\(^\circ\)C - 29\(^\circ\)C room temperature. Infra red gas analyzer was installed with reference (incoming) and sample (Outgoing) CO\(_2\) and water (H\(_2\)O) concentrations. Before measuring a fast check up was performed according to check list to confirm good condition of the instrument. An attached LED (Light Emitting Diode) light Source was used to ensure stable light source during measurements. The external concentration of CO\(_2\) was controlled by a CO\(_2\) mixer at approximately 360 ppm cuvette was closed, parameters such as photosynthetic rate, stomatal conductance; \( \frac{C_i}{C_a} \), \( C_i \) and WUE were recorded. Three sets reading were taken for each treatment belongs
to the four *Triticum aestivum* L. varieties. The data was downloaded from the instrument.

Water use efficiency was calculated by following relationship (Osmond *et al.*, 1980).

\[
WUE = \frac{\text{Net Photosynthetic rate}}{\text{Stomatal conductance}}.
\]

Ci/Ca ratio represents carboxylase efficiency, where
- Ci - Internal CO\(_2\) concentration.
- Ca - Ambient CO\(_2\) concentration

Higher the ratio value lesser will be the efficiency and lesser the ratio value higher will be the carboxylase efficiency.

**Determination of total chlorophyll content**

Total leaf chlorophyll content was determined with SPAD-502 Portable Chlorophyll meter (Minolta Camera Co.Ltd. Japan). First leaf (from the top) was used for the measurement of total chlorophyll content. The leaf was inserted into sample slot of the measuring head. Press and hold it until a beep sounds and the measurement value appeared in the displays.

This value will automatically stored in the memory. The values measured by the SPAD-502 correspond to the amount of Chlorophyll present in the leaf. The values are calculated based on the amount of light transmitted by the leaf in two wave length regions in which absorbance of chlorophyll is different.
RESULTS

Net photosynthetic rate, stomatal conductance, WUE, carboxylase efficiency, total chlorophyll content was recorded in mycorrhizal and non mycorrhizal plants.

**Total Chlorophyll content:**

Inoculated plants belong to four *Triticum aestivum* L. varieties have shown higher chlorophyll content than those grown in control treatments. Difference in the total chlorophyll content was observed between the varieties (Table 4.1). DWR-195 and DWR-225 had shown higher chlorophyll content under inoculated treatments. In DWR-225 total chlorophyll content was increased to about 30 per cent, DWR-162 & DWR-195 had shown the increase of about 10 per cent under inoculation treatments over the control. Plants belong to NI-5439 variety had shown comparatively lesser chlorophyll content (Figure 4.1). Results revealed that DWR-225 responds better to mycorrhizal colonization than other three varieties.

**Photosynthetic rate**

Plants belong to four *Triticum aestivum* L. varieties had shown higher photosynthetic rate under inoculation treatment than control. Mycorrhizal colonization was able to enhance the photosynthetic rate in four varieties of *Triticum aestivum* L. at 60 and 90 DAS (Days after sowing) stage. Higher photosynthetic rate was observed in plants of four varieties at 90 DAS than 60 DAS stage grown under both control and inoculation treatments. At 60 DAS stage plants belong to DWR-162 had shown comparatively higher
photosynthetic rate than other three varieties, plants belongs to N1-5439 variety had shown lesser photosynthetic rate. Mycorrhizal colonization was able to enhance photosynthetic rate in all the varieties (Figure 4.2). DWR-225 and DWR-162 varieties respond well to mycorrhizal colonization and had shown comparatively more increase in photosynthetic rate than other two varieties (Table 4.2).

At 90 DAS stage, inoculated plants had shown higher photosynthetic rate than those grown in control treatment. Plants belongs to four *Triticum aestivum* L. varieties except NI-5439 had shown comparatively higher photosynthetic rate (Figure 4.3). In DWR-162, DWR-195, DWR-225 varieties 10 to 30% increase in photosynthetic rate was observed due to mycorrhizal colonization (Table 4.3).

<table>
<thead>
<tr>
<th>Name of the variety</th>
<th>CN</th>
<th>IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWR 162</td>
<td>46.63</td>
<td>50.50</td>
</tr>
<tr>
<td></td>
<td>±5.48</td>
<td>±2.75</td>
</tr>
<tr>
<td>DWR195</td>
<td>49.50</td>
<td>52.53</td>
</tr>
<tr>
<td></td>
<td>±2.57</td>
<td>±3.24</td>
</tr>
<tr>
<td>DWR225</td>
<td>41.33</td>
<td>57.50</td>
</tr>
<tr>
<td></td>
<td>±0.89</td>
<td>±0.90</td>
</tr>
<tr>
<td>NI5439</td>
<td>38.30</td>
<td>42.96</td>
</tr>
<tr>
<td></td>
<td>±5.34</td>
<td>±1.36</td>
</tr>
</tbody>
</table>

**Table 4.1: Effect of *Glomus fasciculatum* on total Chlorophyll content (mg/g fresh weight) in *Triticum aestivum* L. varieties at 90 DAS (Days After Sowing).**

CN-Control, IN- Inoculated

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Table 4.2: Effect of *Glomus fasciculatum* on photosynthetic rate, stomatal conductance, water use efficiency (WUE) in *Triticum aestivum* L. varieties at 60 Days After Sowing (DAS).

<table>
<thead>
<tr>
<th>Name of the Variety</th>
<th>Photosynthetic rate (A)</th>
<th>Stomatal Conductance (gs)</th>
<th>Water use efficiency (WUE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CN</td>
<td>IN</td>
<td>CN</td>
</tr>
<tr>
<td>DWR 162</td>
<td>1.78 ±0.09</td>
<td>2.18 ±0.64</td>
<td>0.023 ±0.00</td>
</tr>
<tr>
<td>DWR195</td>
<td>1.23 ±0.21</td>
<td>1.70 ±0.64</td>
<td>0.018 ±0.00</td>
</tr>
<tr>
<td>DWR225</td>
<td>1.28 ±0.30</td>
<td>1.8 ±0.10</td>
<td>0.021 ±0.00</td>
</tr>
<tr>
<td>NI5439</td>
<td>1.22 ±0.22</td>
<td>1.49 ±0.25</td>
<td>0.015 ±0.00</td>
</tr>
</tbody>
</table>

CN-Control, IN-Inoculated

Table 4.3: Effect of *Glomus fasciculatum* on photosynthetic rate, stomatal conductance, water use efficiency (WUE) in *Triticum aestivum* L. varieties at 90 DAS.

<table>
<thead>
<tr>
<th>Name of Variety</th>
<th>Photosynthetic rate (A)</th>
<th>Stomatal Conductance (gs)</th>
<th>Water use efficiency (WUE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CN</td>
<td>IN</td>
<td>CN</td>
</tr>
<tr>
<td>DWR 162</td>
<td>1.48 ±0.052</td>
<td>2.19 ±0.178</td>
<td>0.02 ±0.09</td>
</tr>
<tr>
<td>DWR195</td>
<td>1.91 ±0.070</td>
<td>2.47 ±0.178</td>
<td>0.03 ±0.00</td>
</tr>
<tr>
<td>DWR225</td>
<td>2.21 ±0.15</td>
<td>2.50 ±0.180</td>
<td>0.031 ±0.00</td>
</tr>
<tr>
<td>NI5439</td>
<td>2.04 ±0.09b</td>
<td>2.10 ±0.138</td>
<td>0.024 ±0.00</td>
</tr>
</tbody>
</table>

CN-Control, IN-Inoculated
PLATE V A

A. Effect of soil properties on growth parameters of *Triticum aestivum* L.DWR-162 variety at 90 DAS stage under control and inoculated treatments.

1. Plants grown in Altisol under control treatment.

B. Effect of soil properties on growth parameters of *Triticum aestivum* L.DWR-195 variety at 90 DAS stage under control and inoculated treatments.

1. Plants grown in Altisol under control treatment.
A. Effect of soil properties on growth parameters of *Triticum aestivum* L.DWR-225 variety at 90 DAS stage under control and inoculated treatments.

1. Plants grown in Altisol under control treatment.

B. Effect of soil properties on growth parameters of *Triticum aestivum* L.NI-5439 variety at 90 DAS stage under control and inoculated treatments.

1. Plants grown in Altisol under control treatment.
Table 4.4: Effect of *Glomus fasciculatum* on Ci, Ci/Ca in *Triticum aestivum* L. varieties at 90 DAS.

<table>
<thead>
<tr>
<th>Name of Variety</th>
<th>Ci CN</th>
<th>Ci IN</th>
<th>Ci/ca CN</th>
<th>Ci/ca IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWR 162</td>
<td>268.6</td>
<td>225.0</td>
<td>0.62</td>
<td>0.56</td>
</tr>
<tr>
<td>±13.24</td>
<td>±14.19b</td>
<td>±0.10</td>
<td>±0.03</td>
<td></td>
</tr>
<tr>
<td>DWR195</td>
<td>292.0</td>
<td>211.3</td>
<td>0.633</td>
<td>0.584</td>
</tr>
<tr>
<td>±16.07</td>
<td>±27.86</td>
<td>±0.12</td>
<td>±0.08</td>
<td></td>
</tr>
<tr>
<td>DWR225</td>
<td>264.0</td>
<td>192.0</td>
<td>0.72</td>
<td>0.523</td>
</tr>
<tr>
<td>±21.22</td>
<td>±6.11</td>
<td>±0.06</td>
<td>±0.02</td>
<td></td>
</tr>
<tr>
<td>NI5439</td>
<td>247.3</td>
<td>228.3</td>
<td>0.690</td>
<td>0.593</td>
</tr>
<tr>
<td>±21.85</td>
<td>±14.85</td>
<td>±0.05</td>
<td>±0.07</td>
<td></td>
</tr>
</tbody>
</table>

CN-Control, IN-Inoculated

*C*<sub>I</sub>- Internal CO<sub>2</sub> Concentration. *C*<sub>a</sub>- Ambient CO<sub>2</sub> Concentration

Fig 4.1: Total chlorophyll content in control and inoculated plants belong to *Triticum aestivum* L. varieties at 60 DAS.
Fig. 4.2: Photosynthetic rate (A) in control and inoculated plants belong to *Triticum aestivum* L. varieties at 60 DAS.

![Graph showing photosynthetic rate at 60 DAS for different varieties.](image)

Fig. 4.3: Photosynthetic rate (A) in control and inoculated plants belong to *Triticum aestivum* L. varieties at 90 DAS.

![Graph showing photosynthetic rate at 90 DAS for different varieties.](image)
Fig. 4.4: Stomatal Conductance in control and inoculated plants belong to *Triticum aestivum* L. varieties at 60 DAS.

![Stomatal Conductance (gs) at 60 DAS](image)

Fig. 4.5: Stomatal Conductance in control and inoculated plants belong to *Triticum aestivum* L. varieties at 90 DAS.

![Stomatal Conductance (gs) at 90 DAS](image)
Fig. 4.6: WUE in control and inoculated plants belong to *Triticum aestivum* L. varieties at 60 DAS.

![WUE at 60 DAS](image1)

Fig. 4.7: WUE in control and inoculated plants belong to *Triticum aestivum* L. varieties at 90 DAS.

![WUE at 90 DAS](image2)

WUE – Water Use Efficiency. DAS – Days After Sowing.
Fig. 4.8: Internal CO\textsubscript{2} concentration (Ci) in control and inoculated plants belong to *Triticum aestivum* L. varieties at 60 DAS.

![Graph showing internal CO\textsubscript{2} concentration at 60 DAS for control and inoculated plants of *Triticum aestivum* L. varieties.]

Fig. 4.9: C\textsubscript{i}/C\textsubscript{a} in control and inoculated plants belong to *Triticum aestivum* L. varieties at 60 DAS.

![Graph showing C\textsubscript{i}/C\textsubscript{a} at 60 DAS for control and inoculated plants of *Triticum aestivum* L. varieties.]

C\textsubscript{i} - Internal CO\textsubscript{2} concentration. C\textsubscript{a} - Ambient CO\textsubscript{2} concentration.
**Stomatal Conductance (gs)**

Stomatal conductance was high at 90 DAS stage than 60 DAS stage (Tables 4.2 and 4.4). Mycorrhizal colonization resulted in higher stomatal conductance. Inoculated plants have shown significantly higher stomatal conductance than non mycorrhizal plants, at 60 DAS stage. DWR-162 and DWR-225 had shown higher stomatal conductance under control as well as inoculation treatments. Plants belong to NI-5439 do not show any increase in stomatal conductance due to inoculation (Figure 4.4). Plants belongs to DWR-195 variety did not show significant increase in stomatal conductance due to mycorrhizal inoculation.

At 90 DAS stage inoculated plants have shown comparatively higher stomatal conductance than the plants grown in control treatment. This is because plants at 90 DAS stage had shown higher photosynthetic rate than at 60 DAS (Figure 4.5). The rate of photosynthesis could be correlated with stomatal conductance. However, increase in photosynthetic rate was not exactly correlated with increase of stomatal conductance. Stomatal conductance in DWR-162, DWR-195 and DWR-225 remain high compared to NI-5439.

**Water Use Efficiency (WUE)**

Water use efficiency (WUE) was high in inoculated plants than the plants grown under control treatment. Significant difference in WUE was found in plants grown under control as well as inoculated treatments. Mycorrhizal colonization enabled the plants to increase WUE at 60 and 90
DAS stage. WUE was high at 60 DAS stage than 90 DAS stage. Higher WUE was observed in plants belonging to DWR-162 and DWR-225 varieties under control and inoculated treatments at 60 DAS stage, DWR-195 variety had shown moderate WUE. Plants belonging to NI-5439 variety have shown comparatively lesser WUE.

WUE observed at 90 DAS stage was comparatively lesser than in 60 DAS stage. The mycorrhizal colonization resulted in lesser increases of WUE at 90 DAS. Plants belonging to DWR-195, DWR-162 and DWR-225 varieties had shown increase in WUE under inoculated treatments than those grown under control treatments. Poor response to mycorrhizal inoculation was observed in plants belonging to NI-5439 variety, there is no difference in WUE between plants grown under control and inoculated treatments. Over all results on WUE observation revealed that WUE was more at 60 DAS stage than 90 DAS. DWR-162, DWR-195 and DWR-225 had shown increased WUE under inoculated treatments than control at both 60 DAS and 90 DAS stages.

**Internal CO₂ Concentration (Ci)**

The CO₂ present in leaf tissue was taken in to consideration to correlate photosynthetic rate and carboxylase efficiency had shown lesser Ci concentration was observed in inoculated plants than control. Higher photosynthetic rate in inoculated plants resulted in lesser Ci concentration. Plants belonging to DWR-225 variety had shown least internal carbon dioxide concentration compared to other varieties under inoculated treatments.
indicating higher photosynthetic rate. Moderate CO₂ concentration was observed in DWR-195, higher CO₂ concentration was observed in NI-5439 variety indicating lesser photosynthetic rate. Plants belonging to DWR-225 respond well to mycorrhizal colonization and have shown lesser internal CO₂ concentration, inoculated plants belong to DWR-225 have shown least CO₂ concentration.

**Ci/Ca ratio**

Ca refers to ambient CO₂ concentration. The ratio between Ci and Ca shows the efficiency of carboxylating enzyme taking part in CO₂ assimilation. Lesser the ratio value more the efficiency of enzyme. Results obtained from the experiments revealed higher efficiency of carboxylating enzyme in inoculated plants than in control. Ci/Ca ratio was lesser in inoculated plants compared to control. Plants belonging to DWR-225 and DWR-195 had shown lesser Ci/Ca ratio under inoculated conditions than the other two varieties. Plants belonging to DWR-225 variety have shown better response to mycorrhizal inoculation compared to other varieties. Carboxylase efficiency was greatly enhanced in this variety due to mycorrhizal inoculation.
DISCUSSION

AM inoculated plants display higher photosynthetic rate than non mycorrhizal counter parts. AM Symbiosis increased photosynthetic rate by increasing chlorophyll content in the leaves. Present research findings are supported by Davies et al., (1993); Mathur and Vyas, (1995); Gemma et al., (1997); Auge (2001). The present research findings were supported by Giri and Mukarji, ((2004); Sannazzaro et al.,(2006); Colla et al., (2008). Mathur and Vyas (2000), observed that arbuscular mycorrhizal root colonization increased chlorophyll synthesis which would be associated with higher photosynthetic rate in mycorrhizal plants. Ruiz-Lozano et al., (1996), observed that AM plants had shown higher photosynthetic rate than in control plants. AM colonization increase the foliar concentrations of soluble carbohydrates and chlorophyll content. The present research work supports these findings.

Inoculated plants belonging to different Triticum aestivum L. varieties had shown higher photosynthetic rate and stomatal conductance in comparison with non mycorrhizal plants. Photosynthetic rate and stomatal conductance are correlated. AM inoculated plants have shown more photosynthetic rate and stomatal conductance due to increased uptake of water and minerals. Bevege et al., (1975), investigated the role of arbuscular mycorrhizal fungi in enhancing the photosynthetic rate. AM Fungi may function as metabolic sink causing basipetal mobilization of photosynthates to roots, thus providing greater stimulus for greater photosynthetic activity. Levi and Krikun, (1980), observed improved photosynthesis of mycorrhizal citrus plants following water uptake suggesting that improvement was associated with stomatal regulation.
Higher intercellular CO₂ concentration (Ci) is beneficial for photosynthesis. AM fungal colonization can elevate the photosynthetic ability through improving the gas exchange rates. AM Symbiosis can improve photosynthetic rate and stomatal conductance mainly through increasing efficiency of PS-II and regulating the energy bifurcation between photochemical and non-photochemical events. These observations were supported by the Min Sheng et al., (2008). Photosynthetic rates may change through direct action on RuBp carboxylase. The present investigations revealed the inoculation effect of mycorrhiza on internal CO₂ concentration as well as carboxylase efficiency. Increased photosynthetic rate utilizes more CO₂ present in the leaf tissues resulting in lesser Ci concentration in mycorrhizal plants than non-mycorrhizal ones. Shimsi and Ephrat (1975) showed positive correlations between photosynthetic rate, stomatal conductance and Ci concentration. The research of Arans et al., (1993); Morghan et al., (1993) and Sayre et al., (1995), are strongly support the present research findings.

AM inoculated plants had shown higher WUE than non mycorrhizal plants occupy large soil volume and absorb greater amount of water and nutrients when compared to non-mycorrhizal plants. Greater water conductivity could be observed in mycorrhizal plants than non-mycorrhizal ones. Higher water uptake and water conductivity enhances both stomatal conductance as well as WUE in mycorrhizal plants when compared to non-mycorrhizal ones. These research findings were strongly correlates with earlier workers Bethlen falvay et al., (1988), Hardie and seyton, (1981).
CONCLUSION

*Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. certainly enhances the uptake of nutrients and water. Plants inoculated with *Glomus fasciculatum* (Thaxt.) Gerd. and Trappe emend.Walker and Koske. have shown more chlorophyll content, photosynthetic rate, stomatal conductance and carboxylase efficiency compared to plants in control. Among the four *Triticum aestivum* L.varieties taken for the study, it was DWR-225 had shown very good response to mycorrhizal inoculation. Significant increase in chlorophyll content, photosynthetic rate, stomatal conductance as well as carboxylase efficiency was observed in this variety. NI-5439 had shown poor response to mycorrhizal colonization, where as DWR-195 and DWR-162 have shown moderate response.