ORGANIC MATTER EFFECT ON *Glomus intrarradices* IN BEANS (*Phaseolus vulgaris* L.) GROWTH CULTIVATED IN SOILS WITH TWO SOURCES OF WATER UNDER GREENHOUSE CONDITIONS

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**SUMMARY**

The objective of this research was to evaluate the effect of organic matter on the association with *Glomus intrarradices* and soil contamination on beans (*Phaseolus vulgaris* L.). The study was done under greenhouse conditions at the Montecillo Campus of the Postgraduate College, Mexico. Two soils were used, one irrigated with sewage water and the other one with clean water from a well. Half of the plants were inoculated with *Glomus intrarradices*. Vermicompost was used as a source of organic matter. There were highly significant increases (p≤0.05) in all the variables recorded due to the application of organic matter, and to the inoculation with *Glomus intrarradices*. The irrigation source of the soils used for this experiment only had a significant effect (p≤0.05) on pod number and nitrogen fixation. The best growth and grain yield occurred with inoculated plants and supplementary organic matter.

**Key words:** Soil contamination, vermicompost, sewage water, arbuscular endomycorrhiza, edible legumes.

Farmers usually apply chemical fertilizer. Its cost has been increasing dramatically in the last years [18]. Organic matter sometimes is applied as fertilizer as a sole source or in combination with chemical products. However, its consequences on beneficial microorganisms as endomycorrhiza need to be understood in order to improve their usage.

*Glomus intrarradices* has been used to improve plant growth under different conditions, included contaminated soils. Several researchers consider that this kind of fungi as the most important organisms on earth interacting in agro environments. More than 80% of all terrestrial plants, among them most of the horticultural and crop plants have a symbiotic relationship with these fungi. The stimulation of plant growth can be attributed mainly to the improvement of phosphorus nutrition [1, 9, 12, 17, 23].

*Glomus intrarradices* has increased bean yield 36% [19]. Novella et al. [21] had reported augmented corn and bean yield when they were cultivated together and were inoculated with a combination of *Rhizobium* and mycorrhiza.

*Glomus mosseae* amplified shoot growth four times [27]. Mycorhizal development was better under no tillage conditions than using conventional one in an oat-wheat rotation [6]. Mineral nitrogen improves biomass and root growth when mycorrhiza is present [26].

**INTRODUCTION**

Common bean is the most important legume in Mexico. More than 1.5 million hectares were planted in 2011 in this country. This surface was reduced in 2012 due to severe drought conditions [24]. It is cultivated mainly in areas where water is scarce under rainfall conditions. Sewage water it is used for its irrigation in some regions. Studies on its effect on plant growth and yield are needed.
MATERIALS AND METHODS

The study was done under greenhouse conditions at the Postgraduate College, Montecillo Campus, State of Mexico, in the spring and summer of 2012. Two soils, from Tocuila, Texcoco, Mexico, were used. One was irrigated with sewage water, and the other one with clean water from a well. Their characteristics are shown in Table 1.

Table 1 Soil analysis for the two types, one irrigated with sewage water and the other with clean one.

<table>
<thead>
<tr>
<th>Soil sample</th>
<th>pH</th>
<th>EC (dm sec⁻¹)</th>
<th>OM (%)</th>
<th>TN (mg kg⁻¹)</th>
<th>NO₃ (mg kg⁻¹)</th>
<th>P (mg kg⁻¹)</th>
<th>CEC (C mol (+) kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil depth 0-5</td>
<td>7.44</td>
<td>349</td>
<td>2.5</td>
<td>0.098</td>
<td>18</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>Residual water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil depth 5-10</td>
<td>7.37</td>
<td>454</td>
<td>2.48</td>
<td>0.096</td>
<td>17</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Residual water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil depth 10-40</td>
<td>7.44</td>
<td>475</td>
<td>2.45</td>
<td>0.094</td>
<td>15</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Residual water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil depth 0-5</td>
<td>7.52</td>
<td>314</td>
<td>2.49</td>
<td>0.097</td>
<td>17</td>
<td>14</td>
<td>18</td>
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<tr>
<td>Clean water</td>
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<td></td>
<td></td>
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<tr>
<td>Soil depth 5-10</td>
<td>7.75</td>
<td>332</td>
<td>2.47</td>
<td>0.095</td>
<td>16</td>
<td>13</td>
<td>17</td>
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<tr>
<td>Clean water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil depth 10-40</td>
<td>7.85</td>
<td>384</td>
<td>2.43</td>
<td>0.092</td>
<td>13</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Clean water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: pH= Hydrogen potential, EC=Electrical conductivity, OM= Organic matter, TN= Total nitrogen, NO₃= Nitric nitrogen, CEC= Cation Exchange Capacity.

The inoculation was done during the planting, mixing 5 g of sand with sorghum roots with 78% colonization of *Glomus intraradices* and 1050 spores per 100 g of inert material. Two levels of *Glomus* were applied, with and without *Glomus*.

Organic matter was applied as a vermicompost. It was prepared using 60 kg of bovine manure, 25 kg of melon waste, and 15 kg of wheat straw. The mixture was subjected four months to the action of earthworms. Four doses were applied. In every bag of three kg, 0, 28.86 g, 57.7 g, and 86.46 g of vermicompost were mixed. They are equivalent to 0, 25, 50, and 75 t ha⁻¹ of organic matter.

The variables evaluated were: plant height (PH, cm), leaf area (LA, cm²), pod number (PN), grain dry weight (GDW, g), root length (RL, cm), root volume (RV cm³), root dry weight (RDW, g), pod dry weight (PDW, g), grain number (GN) biomass dry weight (BDW, g), white nodule number (WNN), red nodule number (RNN), and total nodule number (TNN).

A factorial arrangement with 16 treatments (4x2x2) was used with a completely randomized block design with three replications. An analysis of variance for all variables registered was done and a Tukey mean comparison test for the significant variables.

RESULTS AND DISCUSSION

The soil texture was sandy loam. The pH was alkaline. It was higher in the soils irrigated with clean water. The difference was greater in the 10-40 cm depth. The soil with clean water had a pH of 7.85, and that with sewage water, only 7.44 (Table 1). The electrical conductivity (EC), organic matter (OM), total nitrogen (TN), nitric nitrogen (NO₃), phosphorous (P), Cation Exchange Capacity (CEC), calcium (Ca), potassium (K), sodium (Na), iron (Fe), zinc (Zn), and copper (Cu) quantities are higher in the soils that were irrigated with sewage water.

In both soils, total nitrogen (TN), and the nitric nitrogen (NO₃) quantities were low. The distribution were higher in the 5-10 cm layer. No ammoniacal nitrogen (NH₄) was found in the two soils. It explains why total nitrogen is only slightly higher on the soils that were irrigated with sewage water that had a higher organic matter [20].

The levels of Cu were below the threshold for considering them as contaminants [5]. No Cr and Ni traces were found.

There were highly significant differences (p≤0.01) in all the variables recorded due to the application of organic matter, and to the inoculation with *Glomus intraradices*.

The pod number, and the white, red, and total nodule number were significantly affected (p≤0.05) for the contamination from the soil with sewage water. Their higher content of nitric and total nitrogen could reduce the nodule number. It is well known the antagonistic effect between nitrogen content is soils and nitrogen fixation [7]. The lack of effect on growth and yield could be explained by the low N fixation [8, 22].

A positive effect of inoculation with *Glomus intraradices* was found. The highly significant differences (p≤0.01) among treatments for all the variables recorded generated a beneficial effect on plant growth due to an improvement in the absorption of mineral nutrients required by the plants [2, 3]. This behavior was similar to that found by Gardezi *et al*. [8, 9, 12, 13 and 14].

Yield, root and shoot growth from plants with mycorrhiza were superior to those without inoculation (Table 2). The treatments with
mycorrhiza were 54% taller, had 25% more leaf area (Figure 2), 48% heavier shoot dry weight, 47% longer roots, 56% greater root volume, and 48% more root dry weight (Figure 3). This is an indication of a positive effect of mycorrhiza on plant growth originated by better mineral nutrient absorption required by the plant [1, 2]. Gardezi et al. [10, 11, 12] also found this beneficial effect in Leucaena leucocephala associated with endomycorrhiza and with *Rhizobium*. Positive responses to the inoculation with mycorrhiza were also found in a number of species [24], including beans [2].

The inoculation with Glomus intraradices improved root and shoot growth. It also had a beneficial effect on the biological nitrogen fixation, and a superior absorption of nutrients [12]. Thus, it contributed to higher yield in beans, coinciding with other studies [2]. Inoculated plants had 38% heavier pods and yielded 116% more grain (Table 2, and Figure 1).

**Table 2. Honest significant difference of the effect of Glomus intraradices on common bean (*Phaseolus vulgaris* L.).**

<table>
<thead>
<tr>
<th>Glomus intraradices</th>
<th>Plant height (cm)</th>
<th>Dry weight aerial part (g)</th>
<th>Leaf area (cm²)</th>
<th>Grain number (ln)</th>
<th>Grain dry weight (g)</th>
<th>Pod dry weight (g)</th>
<th>Pod number (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inoculated</td>
<td>124.54a2</td>
<td>24.29a2</td>
<td>448.79a</td>
<td>10.959a</td>
<td>2.8906a</td>
<td>3.0000a</td>
<td>2.1849a</td>
</tr>
<tr>
<td>No inoculated</td>
<td>100.667b</td>
<td>16.375b</td>
<td>357.92b</td>
<td>5.083b</td>
<td>2.1667b</td>
<td>5.083b</td>
<td>1.8475b</td>
</tr>
</tbody>
</table>

In-transfromated to natural log. Means with the same letter in each column are not significantly different (Tukey α = 0.05)

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![Figure 1](image1.png)

**Figure 1.** Effect of inoculation with *Glomus intraradices* and different doses of organic matter (vermicompost) on soils with two types of irrigation on leaf area of three cultivars common bean (*Phaseolus vulgaris* L.).

Key: Glumus=0: Noninoculated, Glumus=1: Inoculated with *Glomus intraradices*. The vertical lines indicate standard error.

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Plant growth was affected by the organic matter application (Table 3). It provided significantly higher (*p<0.01*) plant height in all the treatments compared with the control. Aryal et al. [3] found similar results. Only the higher quantities gave heavier dry weight of the aerial part (Figure 4). A similar situation was found in the leaf area (Figure 2).

**Table 3. Honest significant difference of the effect of organic matter (vermicompost) on common bean (*Phaseolus vulgaris* L.).**

<table>
<thead>
<tr>
<th>Organic matter t*ha-1</th>
<th>Plant height (cm)</th>
<th>Dry weight aerial part (g)</th>
<th>Leaf area (cm²)</th>
<th>Grain number (ln)</th>
<th>Grain dry weight (g)</th>
<th>Pod dry weight (g)</th>
<th>Pod number (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>90.167b</td>
<td>15.333b</td>
<td>361.67b</td>
<td>2.289b</td>
<td>4.833b</td>
<td>2.083b</td>
<td>1.824b</td>
</tr>
<tr>
<td>25</td>
<td>115.000b</td>
<td>22.917a</td>
<td>402.50ab</td>
<td>2.511ab</td>
<td>7.9717b</td>
<td>2.667a</td>
<td>1.949ab</td>
</tr>
<tr>
<td>50</td>
<td>121.417a</td>
<td>23.250a</td>
<td>434.25a</td>
<td>2.968a</td>
<td>13.250a</td>
<td>2.833a</td>
<td>2.131a</td>
</tr>
<tr>
<td>75</td>
<td>121.833a</td>
<td>23.250a</td>
<td>434.25a</td>
<td>2.968a</td>
<td>13.250a</td>
<td>2.833a</td>
<td>2.131a</td>
</tr>
</tbody>
</table>

In-transfromated to natural log. Means with the same letter in each column are not significantly different (Tukey α = 0.05)

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![Figure 2](image2.png)

**Figure 2.** Effect of inoculation with *Glomus intraradices* on soils with two types of irrigation on leaf area of three cultivars common bean (*Phaseolus vulgaris* L.).

Key: Glumus=0: Noninoculated, Glumus=1: Inoculated with *Glomus intraradices*. The vertical lines indicate standard error.

Root length and root volume (Figure 5) were also significantly greater (*p≤0.05*) only with the two higher applications of vermicompost. However, all the doses of organic matter gave heavier roots.

Organic matter also promoted nitrogen fixation. All the vermicompost applications had a significantly higher total nodule number. However, only the elevated dose was related with a greater white and red nodule number.

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1 Increase percentages are referred to the values found in bean plants inoculated with mycorrhiza compared to those without inoculation.
In an analogous way with mycorrhizal inoculation, the organic matter improved plant growth, shoot height and shoot weight. Therefore, as a result, photosynthetic production increased. Pod number was higher with organic matter (Figure 3). Grain yield was 174% enhanced with the highest dose of organic matter compared with the control (Figure 1, Table 3). Thus, the poorest growth and grain yield occurred with uninoculated plants that lacked supplementary organic matter.

The nitrogen fixation, measured as the nodule number (white, red, and total) was higher in the soils irrigated with clean water (Table 4). A plausible explanation for this finding is the antagonistic effect between nitrogen content is soils and nitrogen fixation [7]. The soils watered with sewage water had higher total and nitric nitrogen (Table 1). Gardezi et al. [15, 16] found similar results in previous experiments.

**CONCLUSIONS**

Mycorrhizal inoculation and nitrogen fixation provided higher bean root and shoot growth and therefore, better yields. Previous evidence with legumes showed that they have benefited with this symbiosis because the treatments with this fungus produce the highest values for all evaluated variables. The application of organic matter, as vermicompost, improved plant growth, and grain yield. The
contamination from the soil by sewage water did not affect plant growth or yield. It only affected nitrogen fixation.

ACKNOWLEDGMENTS

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LITERATURE CITED


