The aim of this study is to investigate the difference between the growth of plants with and without mycorrhiza in vegetation studies that will be conducted in arid regions. In order to determine the effects of mycorrhiza, Forsythia x intermedia plant was chosen because of its wide usage in Landscape Architecture application studies due to its esthetic and functional properties and because of its common existence in dense-massive vegetative designs. Forsythia x intermedia plants were planted in Soil (S), Soil + River Sand (SS), Soil + River Sand + Organic Matter (SSO) medium at three application areas with different annual rainfall values. By taking measurements once in every three months; the heights, diameters and number of leaves were determined. In the 6th and the last measurement period, plants were taken from the roots of the plants and mycorrhiza colonization percentages were calculated. At the end of the research it was found that the plants with mycorrhiza had the largest height and diameter values at Gumushane application area in SSs media, at Macka application area in SSOs media and at Trabzon application area in SS media. Mycorrhizal plants with the most number of leaves were at Gumushane application area in SSOs media, in Macka and Trabzon application areas at SSO media. The highest mycorrhiza colonization percentage values were obtained at Gumushane application area in SSO (52.78%) and SSOs (41.16%) medium as compared to values obtained from other areas.

Key words: Glomus mosseae, Forsythia x intermedia, vesicular-arbuscular mycorrhiza, drought stress.

INTRODUCTION

In landscape architecture, at large field and dense plant usages, deficiencies in maintenance and other necessary operations depending on the ecological conditions cause severe economical losses. In addition to this, another important problem is drought during summer period in the planning region. Therefore, the growth of plants slows down and their nourishment relations can be effected in a negative way, the plants remain weak, they do not give the demanded visual effect and in some situations this can lead to death. As a result, they also loose their impact in the design. Plants can resist drought only with regular and sufficient care, watering and organic material additions. This causes work power and money loss. Besides, excessive usage of fertilizer damages the natural balance of the soil. In fields with these kinds of situations, mycorrhiza helps the plant to grow in a healthy way without going into stress.

In problematic fields with less humidity in the soil, mycorrhiza increases plants’ resistance to drought. With the help of its rootlets that can spread into earth, it can maintain water which is far away from plant (Cooper, 1984). Mycorrhiza is the most commonly known coexistence between the plant roots and microorganisms. This coupling creates a line between the soil and the plant and plays an important role in water transfer (Marschner, 1995; Mukerji et al., 2000). While mycorrhiza helps the plant for absorbing soil minerals and soil water in an efficient way, the plant gives carbohydrates to the mycorrhiza, which are necessary for its development.
Biological material and growing conditions

In the study, 2 years old plants of the *Forsythia x intermedia* were used, which were grown in polyethylene dish of 2lt capacity. 3 different planting environments were prepared. For sterilization purposes against root infections, these mediums were left in autoclave under 121°C and 2 atmosphere pressure for 1 h (Matsubara et al., 2000). Prepared medium are:

1. Soil (S)
2. Soil + River Sand (1:1) (SS)
4. Soil + River Sand + Organic Matter (3:6:1) + sterilization (SSOs)
5. Soil + River Sand + Organic Matter (3:6:1) + sterilization (SSs)
6. Soil + River Sand + Organic Matter (3:6:1) + sterilization (SOSs)

Burned animal fertilizers of two years were used as the organic matter.

In greenhouses, the plants were planted in polyethylene tubes separately and 4 g of *Gliomus mosseae* was inoculated for each plant. The plants were also placed in these media without inoculation (control groups). After mycorrhiza inoculation procedure, 500 mg N (Nitrogen) and 200 mg K (Potassium) were applied for each 2lt tube. Ammonium sulfate, triple super phosphate and potassium sulfate were used as fertilizer sources.

The plants were watered twice in every week in a way such that same amount of water (~200 ml) was supplied to each tube. Also, savage grasses were removed from media mechanically during the study. In the greenhouse stage, mycorrhiza was inoculated to 6 different groups and the non-inoculated controls. *Forsythia x intermedia* plants were planted in the application areas after 6 months. The plants were removed from the tubes and planted with their root surrounding media in the application areas (Trabzon, Macka, Gumushane) with equal numbers and the study was done with 13 plants in each medium. The application areas were chosen among 3 regions with different annual average rainfall values. The 1st application area was in Trabzon with annual total rainfall of 806.0 mm, the 2nd application area was in Macka town of Trabzon with annual total rainfall of 603.9 mm, the 3rd application area was in Gumushane with annual total rainfall of 480.8 mm.

The 1st area in the city center of Trabzon is at 40° 59' north latitude and 039° 46' east longitude with an average altitude of 179 m. The 2nd area in Macka town of Trabzon is at 40° 48' north latitude and 039° 36' east longitude with an average altitude of 343 m. The 3rd area in Gumushane is at 40° 26' north latitude and 039° 30' east longitude with an average altitude of 1193 m (Figure 1).

Mycorrhizal plants in the greenhouse were again inoculated with mycorrhiza in the application area. 2 g of mycorrhiza was placed in the planting hole before the plants were removed from their polyethylene tubes and planted. After the plants were planted in the application areas in May, 2007, watering was done in 3 different regions in May and June once in every week, and June-August twice in every week. No watering was done in 2007 fall and 2008 winter months, instead the plants were left in natural conditions. Special attention was given for the plants to take equal amounts of water (~700 ml) in each application area.

Measurements

During the field studies, in order to observe the effects of the applications on plant growth, the heights and the root collar diameter of the plants in all 3 different application areas were measured once in every 3 months, and the numbers of leaves *Forsythia x intermedia* plants patch of their leaves, the leaf counting was not done in the 3rd measurement period, December, 2008, but only plant height and diameter values were measured. In September, 2008, which was the last measurement period, samples were taken from the capillary roots of the plants. The collected capillary roots were separately placed in previously prepared laboratory tubes containing FAA solution consisting of Formaldehit, Ethanol and Acetic Acid; and tubes were labeled.

The staining process was done according to Koske and Gemma (1989). The stained capillary tubes were placed on lamels
according to the method developed by Giovannetti and Mosse (1980), and observed under microscope to determine whether mycorrhiza was infected or not. The results were recorded as percentages. The colonization percentage of mycorrhiza was calculated with the following formula (Ishii and Kadoya, 1994):

\[
\% \text{ colonization} = \left( \frac{\text{Total number of mycorrhizal roots}}{\text{Total number of roots counted}} \right) \times 100
\]

**Statistical analysis**

Within the context of this study, in order to present the differences in the values obtained from the measurements made on the plants, multidirectional variance analyses was performed. For properties in which statistically significant differences were observed, in order to determine the homogenous subgroups Duncan analysis was done. While performing these analysis SPSS statistics package program (SPSS 12.0 Inc., 2003) was used.

**RESULTS**

The variance analysis results showing the effect of mycorrhiza and control applications on *Forsythia x intermedia* plants’ height and diameter values in three different test regions along with arithmetic average and standard deviation values are presented in Table 1. In Gumushane, Macka and Trabzon application areas at different growth media, although the effect of mycorrhiza inoculation on the heights of *Forsythia x intermedia* was not at statistically significant level (P<0.05), the effect on diameter and leaf number values were statistically significant (P<0.05). It was found that the effects of field and medium factors on the plant height, diameter and leaf number values of *Forsythia x intermedia* plants were statistically significant (P<0.05).

**Plant height**

In Gumushane application area where the annual rainfall value is the lowest, it was determined that the mycorrhiza inoculation had positive effects only at S, SSs and SSOs media while the control plants in Ss, SS and SSO media had higher plant length values as compared to mycorrhizal plants. Among the plants with mycorrhiza the highest average height value (88.55 cm) was recorded in mycorrhizal plants that grew in SSs media. In Macka application area, it was determined that the mycorrhiza inoculation was effective on plant height only at S and
Table 1. The effects of mycorrhiza, fields and growing media on the height, diameter and leaf number values of the *Forsythia x intermedia* plant.

<table>
<thead>
<tr>
<th>Area</th>
<th>Medium</th>
<th>Height(cm)</th>
<th>Diameter(mm)</th>
<th>Number of leaves (item)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mycorrhiza +</td>
<td>Mycorrhiza -</td>
<td>Mycorrhiza +</td>
</tr>
<tr>
<td>Gumushane</td>
<td>S</td>
<td>70.05 ± 14.5 ab</td>
<td>60.79 ± 8.8 a</td>
<td>7.61 ± 0.7 b</td>
</tr>
<tr>
<td></td>
<td>Ss</td>
<td>68.04 ± 11.6 a</td>
<td>76.26 ± 13.3 b</td>
<td>7.16 ± 0.7 a</td>
</tr>
<tr>
<td></td>
<td>SS</td>
<td>72.94 ± 12.1 b</td>
<td>81.00 ± 14.0 c</td>
<td>6.94 ± 1.0 a</td>
</tr>
<tr>
<td></td>
<td>SSs</td>
<td>88.55 ± 17.2 d</td>
<td>79.18 ± 11.8 bc</td>
<td>8.19 ± 1.7 d</td>
</tr>
<tr>
<td></td>
<td>SSO</td>
<td>80.94 ± 14.5 c</td>
<td>87.28 ± 23.2 d</td>
<td>8.19 ± 1.7 d</td>
</tr>
<tr>
<td></td>
<td>SSOs</td>
<td>83.88 ± 13.7 c</td>
<td>78.94 ± 12.4 bc</td>
<td>8.12 ± 1.2 cd</td>
</tr>
<tr>
<td></td>
<td>Macka</td>
<td>70.79 ± 13.5 ab</td>
<td>55.98 ± 10.7 a</td>
<td>7.58 ± 0.9 b</td>
</tr>
<tr>
<td></td>
<td>Ss</td>
<td>73.00 ± 19.1 b</td>
<td>82.22 ± 19.1 b</td>
<td>7.10 ± 0.9 a</td>
</tr>
<tr>
<td></td>
<td>SS</td>
<td>68.40 ± 9.0 a</td>
<td>84.52 ± 14.4 b</td>
<td>7.00 ± 1.2 a</td>
</tr>
<tr>
<td></td>
<td>SSs</td>
<td>73.58 ± 9.5 b</td>
<td>81.83 ± 12.5 b</td>
<td>7.26 ± 0.8 ab</td>
</tr>
<tr>
<td></td>
<td>SSO</td>
<td>72.95 ± 9.5 ab</td>
<td>93.31 ± 12.2 c</td>
<td>7.44 ± 0.9 b</td>
</tr>
<tr>
<td></td>
<td>SSOs</td>
<td>88.96 ± 17.7 c</td>
<td>78.20 ± 19.8 b</td>
<td>8.22 ± 1.3 c</td>
</tr>
<tr>
<td>Trabzon</td>
<td>S</td>
<td>75.00 ± 15.9 a</td>
<td>63.29 ± 12.0 a</td>
<td>8.78 ± 1.7 b</td>
</tr>
<tr>
<td></td>
<td>Ss</td>
<td>75.09 ± 10.5 a</td>
<td>76.95 ± 12.3 b</td>
<td>8.08 ± 1.3 a</td>
</tr>
<tr>
<td></td>
<td>SS</td>
<td>79.55 ± 18.4 a</td>
<td>77.57 ± 8.3 c</td>
<td>8.69 ± 1.5 b</td>
</tr>
<tr>
<td></td>
<td>SSs</td>
<td>80.31 ± 10.6 a</td>
<td>81.79 ± 13.5 c</td>
<td>8.99 ± 1.4 b</td>
</tr>
<tr>
<td></td>
<td>SSO</td>
<td>93.95 ± 17.6 b</td>
<td>93.68 ± 13.0 d</td>
<td>9.08 ± 1.3 b</td>
</tr>
<tr>
<td></td>
<td>SSOs</td>
<td>89.87 ± 17.9 b</td>
<td>82.27 ± 17.4 c</td>
<td>9.06 ± 1.2 b</td>
</tr>
</tbody>
</table>


*The measurement time averages were compared on column bases according to Duncan test.

In Ss, SS, SSs and SSO media it was observed that the control plants were taller in average than mycorrhizal plants. The biggest average height value for the plants with mycorrhiza was recorded in SSOs medium with 88.96 cm. In Trabzon application area, it was determined that the mycorrhiza inoculation was effective in S, SS, SSO and SSOs media, and the control group plants were taller in Ss and SSs media. The highest value was measured at mycorrhiza-inoculated plants in SSOs medium with 89.87 cm.

**Plant diameter growth**

In Gumushane application area it was found that mycorrhiza applied *Forsythia x intermedia* plants at S, SSs and SSOs media had higher average plant diameter values as compared to plants in control group; whereas the mycorrhiza inoculation was not effective in Ss, SS and SSO media. The highest value of 8.19 mm was obtained from a plant with mycorrhiza in SSs medium. In Macka application area, the mycorrhiza inoculation was effective only in S and SSOs media. It was found that the control group plants in Ss, SS, SSs and SSO media had higher diameter values. The highest diameter value among the plants with mycorrhiza, 8.22 mm, was obtained from the plants in SSOs media. When the plant diameter values of the plants in Trabzon application area were investigated, it was found that mycorrhiza inoculation had positive effects on plant diameter values in all medium. The highest value, 9.08, was recorded in SSOs media where mycorrhiza inoculation was done.

**Number of leaves**

In Gumushane application area, it was found that mycorrhiza applied plants had more leaves in average than the control group plants. In all medium of the Gumushane test field, it was determined that mycorrhiza inoculation was effective on the number of leaves regardless of the type of medium. The highest average number of leaves, 211.31, was found in plants with mycorrhiza in SSOs media. It was observed that the plants in the Ss control group plants had more leaves than the mycorrhizal plants. When the plant leaf numbers in the Trabzon test region were investigated, it was seen that the mycorrhiza inoculation were effected on all media, and number of leaves were higher as compared to plants in the control groups. Highest number of leaves (403.92) was obtained at plants with mycorrhiza in the SSO medium.
Mycorrhizal colonization (%)

When the effects of Gumushane, Macka, Trabzon and different growing medium on the mycorrhiza colonization percentage in the *Forsythia x intermedia* plant roots were investigated, it was determined that mycorrhiza showed the best development in SSO and SSOs medium at the Gumushane application area. Among the fields, the highest percentage was 52.78% in Gumushane application area and it was measured in the sterile SSOs media. The lowest value (18.44%) was found in the S media of Trabzon application area. It was found that average mycorrhiza colonization percentage values were much higher in Gumushane application area (Figure 2). The low rainfall and high average temperature values of this region had encouraged mycorrhiza growth.

DISCUSSIONS

When the application areas are compared in general, it was seen that SSO mixture is the best growing media among all growing medium. Also, it was determined that mycorrhiza makes the best development in this growing media. In Gumushane application area, which is the field with least total annual rainfall value, the plants lacked water and could not grow as good as the plants in other regions. Despite this, in this region it was found that plants with mycorrhiza were more enduring than control group plants and they developed better as far as height, diameter and leaf number values are concerned. Under the same conditions, in the study made with *Cotoneaster franchetti* plant that is evergreen, it was found that Mycorrhiza has effects on the plant height, diameter growth and number of leaves in Gumushane application area where the annual average temperature values are more than other application areas. Mycorrhiza has effected positively growth of the plants having drought stress, provided their healthy growing (Pulatkan, 2010). Mycorrhiza had encouraged the plants to have more leaves than they would have in normal conditions.

It was seen that the development of plants in all types of medium were better than the control group plants just like the results of the study that Carpio (2002) made on *Acacia greggii*, *Diospyros virginiana* and *Platanus occidentalis* plants. In previous studies made by Giri et al., (2007) on *Acacia nilotica* under salt stress and by Sanchez-Blanco et al., (2002) on *Cistus albidus* and *Cistus monspeliensis* earth covering plants preferred due to their beautiful flowers, it was also found that plants inoculated with mycorrhiza had higher leaf weight values as compared to control plants. In a similar study made with *Rosmarinus officinalis* plant subjected to water stress test, it was found that with mycorrhiza inoculation the heights of plants increase and they developed better (Sanchez-Blanco et al., 2004). In another study made with *Gmelina arborea* plant, it was discovered that the plant height values were bigger in mycorrhizal plants as compared to the control group (Sanon et al., 2005). It was mentioned that with mycorrhiza inoculation the total plant weight increases in *Abutilon theophrasti* which is a preferred species in vegetation designs like *Forsythia x intermedia* because of its esthetical properties (Koide et al., 2000). In another study made with *Prunus cerasifera*,
it was declared that the developments of plants with mycorrhiza were higher as compared to control plants (Berta et al., 1995). In the studies carried out to find out the effect of mycorrhiza on the rotting disease in the roots, it is stated that mycorrhiza inoculation has a positive effect on the rotting problem in Asparagus officinalis L. plants and reduce the plant deaths to minimum. Also it was seen plants inoculated with mycorrhiza are higher than non-inoculated (Matsubara et al. 2000b).

In the study made by Calvet et al., (2001) on Prunus persica plant, it was mentioned that mycorrhiza colonization percentage in the plant roots reach high values in sterile growing medium. At the same time, both in sterile and non-sterile media, the diameter development and wet weight values were higher in mycorrhiza plants as compared to control group plants just like plant height values. At high temperature values, arid fields and low fertile soils the success rate of mycorrhiza existing at plant root and soil increases as well as spore formation rate (Hetrick, 1984, Menge, 1984). Tibbett and Cairney (2007) have announced the necessary temperature value for Vesicular-Arbuscular Mycorrhiza development to be between 10/12 and 20/25°C; and that at low temperatures VAM motion decreases significantly. Mycorrhiza colonization percentage values at Forsythia x intermedia plant roots were taken in September, 2008 when final height, diameter and leaf number measurements were made. In the study made by Estaun et al., (1997) on Rosmalinus officinalis plant, it was found that mycorrhiza colonization rates in plant root were higher in samples taken September as compared to samples taken in other months. Also it was reported that total plant weight values were higher in mycorrhiza-inoculated plants as compared to other plants, and plants with mycorrhiza grow better as a result of this.

Conclusions

As a result of this study, it was found that mycorrhiza application was extremely useful for plants especially in the regions with low rainfall values and having drought problems. Also it was seen that mycorrhiza has its best growth in the soil, river sand, and organic matter mixture medium in greenhouse and areas studies. To have successful results in planting studies, it is suggested that using both mycorrhiza and this medium or organic matter reinforcement. In the fields of regions without drought problem, no big difference was seen between plants with mycorrhiza inoculation and other plants.

In all three application areas, it was determined that mycorrhiza encourages development and leaf formation in Forsythia x intermedia plants, and helps the plant to form lots of leaves with good quality. The visual and esthetic value of plant increases with rich and vivid leaf structure. This is desired property for plants which are to be used in vegetation designs. Especially in the vegetation studies that will be made in droughty regions with limited water supplies and where caring possibilities are low, mycorrhiza inoculation plant will create a good form and give the desired impression.

ACKNOWLEDGEMENT

This study was accepted as project and supported by Karadeniz Technical University Scientific Research Projects Department with grant no 2005.113.03.3.

REFERENCES

Carpio L (2002). Effects of Arbuscular Mycorrhizal Fungi on Growth, Physiology, and Irrigation Run-off of Selected Ornamental Crops. PhD dissertation, Texas A&M University, Texas, USA.


Pulatkan M (2010). Effects of Inoculation with Mycorrhiza on Forsythia x intermedia and Cotoneaster franchetti Plants under Different Climate Conditions and in Various Growing Medium. PhD dissertation, Karadeniz Technical University, Trabzon, Turkey.


