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THE EFFECT OF SOLARIZATION AND MYCORRHIZA APPLICATION ON PLANT GROWTH, YIELD AND QUALITY OF MELON GROWN IN GREENHOUSE

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Abstract

In this study, melon seedlings were planted on solarized plots and non-solarized plots in autumn season. In addition, by applying mycorrhiza (Endo Roots Soluble (ERS)) to some seedlings, the effects of both solarization and mycorrhiza on planth growth, yield and quality were investigated in melon. In this study, yield per plant, plant biomass values and some quality analysis of fruits were investigated. According to the results of the study, it has been observed that the combined application with solarization and mycorrhiza affects the yield and quality more positively than other applications. This application was followed only by the values obtained in the plots where solarization was applied. While the galling index was determined as 7.25 and 4.63 in the control and only mycorrhiza applications, the same values were 0.38 combined with solarization and mycorrhizal were applied and 0.63 plots where only solarization was applied. It has been determined that applying solarization and mycorrhizal together provides an increase of 53.3% in yield. This increase was 41.8% in plots with only solarization but not mycorrhiza. However, it has been determined that the application of only mycorrhiza on plots without solarization provides an advantage of 5.3% in yield compared to control (non-solarized). The plants grown in the plots without solarization were heavily affected by root-knot nematodes (*M. incognita*) and weeds, thus the yield and quality decreased.

Key words: Soil solarization, Vesicular arbuscular mycorrhizae (VAM), Melon, Greenhouse, Silifke, Yield.

Introduction

Melon (*Cucumis melo* L.) is an annual vegetable. Turkey's total production is about 1.78 million tons of melons and Mersin provides approximately 22 thousand tons of this production. In greenhouse, Turkey's production is about 205.000 tons, while about 1.000 tons in Mersin (Anon., 2019). Solarization is known as an application to suppress weeds, insects and soil-borne plant pathogens by increasing the soil temperature using solar energy under a transparent plastic cover (Stapleton *et al*., 1986; Baysal-Gürel *et al*., 2019). Some researchers were reported that the solarization technique is more suitable in Mediterranean climates with high summer temperatures and is very effective in controlling soil-borne fungi, nematodes and weeds (Shlevin *et al*., 2003; Roe *et al*., 2004; Oka *et al*., 2007; Arslan *et al*., 2012). Solarization of soil, growth promoting Bacillus spp. and because it reduces only mesophilic organisms without killing beneficial microorganisms such as mycorrhizal fungi, so it is accepted as one of the new approaches in soil disinfection (Stapleton & DeVay, 1982; Stapleton & DeVay, 1984). Solarization, grafting, different chemicals, bio-fumigation, hot water vapor, composting and soilless culture cultivation are prominent applications as alternative applications to chemical used in disinfecting the soil. Researchers mostly focused on solarization, grafting and applications in which they are used together to increase yield and quality by controlling soil-borne pathogens (Yılmaz *et al*., 2007).

Lira-Saldivar *et al*., (2003), they applied solarization for 30 days in a study they did. They reported that the temperature in the top layer of 1.5 and 10 cm of the soil increased 55°C and 44°C, significantly decreasing the weed outflow and development, resulting in an increase in yield. In a study conducted in Italy, they investigated the permanent effect of solarization in tomato and melon cultivation. In this study, it was reported that this increase was 116% in the first year, 284% and 263% in the second and third years, respectively, in tomato as a result of solarization in the second and third years, and that this increase was 162% and 368% in melon, respectively (Candido *et al*., 2008). In another study, it was reported that solarization of grafted melon cultivation in greenhouses accelerated plant growth and increased yield (Çelik *et al*., 2012).

Yılmaz *et al*., (2011), in a study on cucumber, it was found that the combination of grafting and solarization reduces soil borne pathogens and nematodes and increases yield; The cost of these applications by manufacturers in Turkey report that is considered to be appropriate and environmentally friendly practices. Yücel *et al*., (2015) studied soil disinfection practices in greenhouse vegetable cultivation and strawberry cultivation in a study they conducted. These researchers stated that nematodes cause significant yield losses in strawberry cultivation and greenhouse vegetable cultivation; reported that even solarization application alone significantly reduced the nematode rate (0.2-0.3 in solarization application) compared to the control (5.7-6.6).

There is a symbiotic relationship between the plant and mycorrhiza. In this relationship, plants provide carbon to mycorrhiza mushrooms, while mycorrhizal fungi provide water and nutrients to the plant (Ortaş, 1998; Ted, 2002). Ted (2002) reported that mycorrhiza inoculation accelerates the growth of the plant, improves the soil structure, protects the plant from its pathogens, prevents drought exposure and strengthens its survival ability. Torun & Türkmen (2018) reported that the use of Arbuscular Mycorrhizal Fungus (AMF) in Melons *Fusarium oxysporum* f.sp. They reported that melonis increased resistance to the no.1 race and that *G. intraradices* mycorrhiza species had the best effect in increasing the endurance level.

In this study, the effects of solarization and mycorrhiza on the yield and quality were investigated in a nematode-infested glass greenhouse in melon cultivation.

Material and Method

Plant material and experiment plan: Çıtırex F1 melon variety was used as a melon variety. The seedlings were planted in the glass greenhouse on February 17, 2020. Planting was done in double rows at 100 x (50 50) cm row spacing. The experiment was set up with 4 replicates and 20 plants per repetition and according to a randomized complete blok desing.

In the experiment, the field was plowed during the summer period and solarization was applied for 8 weeks. While the plots were created in the experiment (1) plots with solarization (S); (2) application of mycorrhiza and solarization combined (M + S); (3) non- solarized as a control [C(-S)]; and (4) it was planned as a mycorrhiza application to the plots which are non-solarized [M(-S)]. Seedlings to be applied to Mycorrhiza (Endo Roots Soluble (ERS) were prepared 10 g L^{-1} and the seedlings were dipped in mycorrhizal water before planted for 60 second.

Observations and analysis: When the fruits reach the harvest time, 5 plants from each repetition were removed from the soil together with their roots and the roots were separated from the plants and then those roots were thoroughly washed with tap water. The number of leaves (pieces) of the plants, plant height (cm), stem diameter (mm), fresh and dry plant weights, fresh and dry root weights, root lengths were taken. Until the plants reached constant weight in the open, the roots were dried at 65°C for 48 hours until they reached constant weight, and their dry weight was taken. Stem diameters were measured with a digital caliper, roots with a ruler and plant height with a tape measure. Five fruits representing the average were taken from each repetition and weighed and the average fruit weight (g) was found. These fruits were cut in the middle and fruit height (cm), fruit diameter (cm), seed house diameter and height (cm), and solubility ratio was measured as stated by Yarsi, (2003) and the analyis of Total Soluble Solids Content (TSSC) were made for Brix refratometry. The weight of the total fruits harvested from each repetition was divided by the number of plants and the yield per plant was calculated as gramme (g).

Galling index value: It was made by applying 0-10 growth rate index to the galls (Zeck, 1971) formed on the roots of 10 plants that were removed incidentally from each repetition.

Data analysis: SPSS 13.0 (SPSS Inc., Chicago, IL, USA) package program was used and the difference between applications was made according to Duncan test ($p \leq 0.05$).

Results and Discussion

When Tabo 1 is examined, it is seen that the application of mycorrhiza + solarized plots caused a significant increase in the number of leaves. While the number of leaves of the plants in the plots with S + M application was 51.8, this value was 46.5 in the plants in S plots. While there were 35.0 leaves in the plots where M(-S) application was applied, this value was determined as 30.3 in the C(-S). It was observed that the effect of solarization and mycorrhiza application on the number of leaves was statistically significant. The effects of the applications on the plant height were also found to be statistically significant. While the C(-S) plants had the lowest value with 200.8 cm, this value was measured as the highest value with 238.0 cm in the plots where solarization and mycorrhizal were applied together (S + M) (Table 1).

Considering the stem diameters, they were included in the same group statistically, taking the highest values with 14.07 mm and 13.25 mm in S+M and S applications, respectively. In C(-S) plants, it was measured as the lowest with 10.58 mm. The effect of the applications was found to be statistically significant on the fresh and dry weights of the plants and the root fresh and dry weights. Looking at the plant's fresh weight, while the plants in the C(-S) plots got the lowest with 1.55 kg, it was reached the highest value with 2.63 kg in S+M application. Plant dry weights were also found statistically significant and results parallel to plant fresh weights were obtained. In root fresh weight, these values were determined as 9.96 g in C(-S), 15.67 g in M(-S) application, 19.85 g only in S application and 22.14 g in S+M plants. Root dry weights gave similar results to root fresh weights. In root length measurements, it was statistically in the same group with C(-S) application (18.0 cm) and M(-S) application (18.1 cm) values, while S+M and S application took the highest values with 27.6 cm and 27.5 cm, respectively as took place in a different group.

The effects of solarization and mycorrhiza applications on yield and quality in melon cultivation in a glass greenhouse were given in figures. When figures are examined, it is seen that S and S+M applications gave more advantageous results than C(-S) and M(-S) applications. S+M application had the highest value with 2.31 kg fruit weight, while S application received the second highest value with 2.05 kg. These values were determined as 1.44 kg in C(-S) and 1.56 kg M(-S), respectively (Fig. 1a). Similar results were obtained in fruit diameter, fruit height, seed house diameter and seed house height (Fig. 1b - 1e). In these measurements, values were found higher in S+M and S applications compared to other applications. When we look at the Total Soluble Solids Content (TSSC) analysis of fruits, it was measured as 8.5 and 8.4 in the plots where S+M and in S application, and they were statistically included in the same group. These measurement values were found to be 7.8 in C(-S) and 8.0 in M(-S) application (Fig. 1f).

It was observed that there were statistically significant differences in yield per plant (Fig. 1g). The yield per plant was determined as 3.45 kg S+M in plants and was determined as the highest value. In S application was the second highest yield with 3.19 kg. The C(-S) had the lowest value with 2.25 kg. These results are in agreement with Gosling *et al*., (2006), Zayed *et al*., (2013) in pepper and Cimen *et al*., (2010) in latuce and Sabatino *et al*., (2020) in aggplant.

While the gal index was determined as 7.25 and 4.63 in C(-S) and M(-S) applications, respectively. The galling rates of S+M and S applications were 0.38 and 0.63, respectively (Fig. 1h). Root knot nematodes form large and small galls on the roots of plants, preventing the plants from taking water and nutrients from the soil. In plants with nematodes, fruit weight, fruit size, biomass and yield were lower than solarization + mycorrhiza applications and only solarization. It has been determined that the productivity and quality increase when the soil pathogens are struggled in melon cultivation in greenhouses. This results are the smilar by Yucel *et al*., (2015).

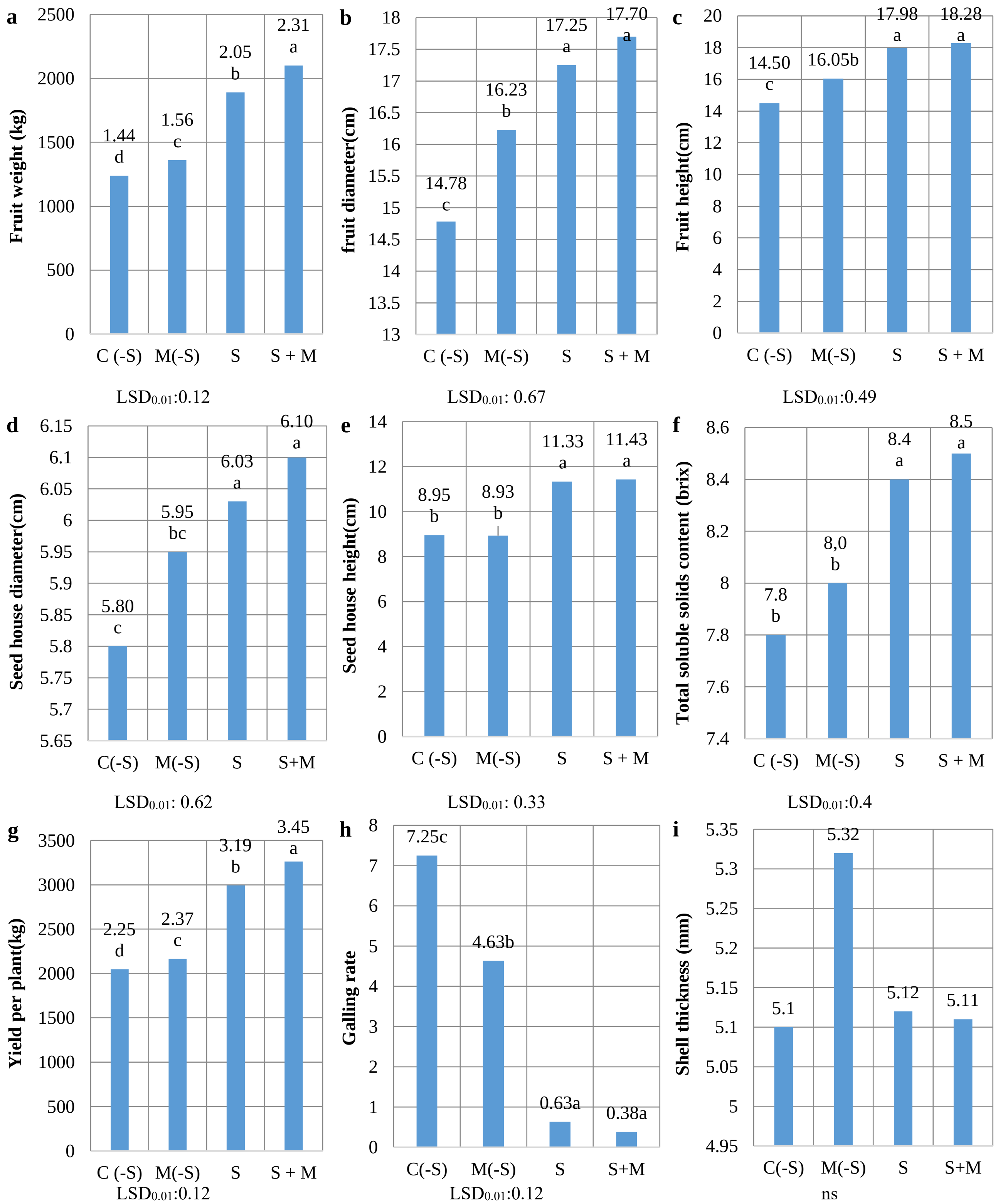

Fig. 1. a; Fruit weight, b; Fruit diameter, c; Fruit height, d; Seed house diameter, e; Seed house height, f; Total soluble solids content, g; Yield per plant, h; Galling rate, ı; Shell thickness
Not: All the figures mean followed by the same letters do not significantly difference in $p \leq 0.01$ and ns: no difference
-S: Non- solarized application; C: control, M: mycorrizha, S: solarization, S+M: Solarization + Mycorrizha

Table 1. The effects of solarization and mycorrhiza application on biomass and root-knot nematodes galling rates in melon plants.

Applications	Number of leaves (piece)	Plant height (cm)	Stem diameter (mm)	Plant fresh weight (kg)	Plant dry weight (kg)	Root fresh weight (g)	Root dry weight (g)	Root length (cm)
C(-S)	30.3b	200.8d	10.58c	1.55d	0.28c	9.96d	0.89d	18.0b
M (-S)	35.0b	209.8c	11.68b	1.87c	0.29c	15.67c	1.26c	18.1b
S	46.5a	230.3b	13.25a	2.46b	0.31b	19.85b	1.67b	27.5a
S + M	51.8a	238.0a	14.07a	2.63a	0.38a	22.14a	2.43a	27.6a
$LSD_{0.01}$	5.4	6.1	0.94	0.28	0.07	2.13	0.28	1.2

Mean followed by the same letters do not significantly difference in $p \leq 0.05$

-S: Non-solarized application; C: Control, M: Mycorrizha, S: Solarization, S+M: Solarization + Mycorrizha

Table 2. Correlation values among some datas.

	Number of leaves	Fruit weight	Plant dry weight	Root dry weight	Root length	Galling rate	Yield per plant
Number of leaves	1	0.954**	0.828**	0.871**	0.879**	0.923**	0.940**
Fruit weight		1	0.850**	0.903**	0.948**	0.946**	0.984**
Plant dry weight			1	0.947**	0.743**	0.774**	0.849**
Root dry weight				1	0.811**	0.864**	0.891**
Root length					1	0.938**	0.968**
Galling rate						1	0.952**
Yield per plant							1

** 0.01

Table 2 shows the correlations between some datas. When Table 2 is examined, it is seen that there is a strong relationship among number of leaves, fruit weight, Plant dry weight, root dry weight, root length, galling rate and yield per plant. It was determined that there was a strong relationship between yield with these parameters. It is seen that the highest relationship with yield per plant is between fruit weight (0.984**), root length (0.968**) and number of galls (0.952**). Looking at these correlations, it can be said that root length and nematode density in the soil are more effective than other factors in yield per plant.

Conclusion

Considering the results of this study, it is seen that the application of solarization and mycorrhiza in melon cultivation in greenhouses positively affects the plant growth, yield and quality. Solarization should be applied especially in places with nematode problems. Solarization application of 6 - 8 weeks in the summer period prevents the emergence of weeds and nematodes (*Meloidogyne* spp.), allowing the plants to form a more comfortable and healthy root and naturally better plant nutrient. Thus, efficiency and quality are increased. When Figure 1f is examined, it is seen that the roots of the plants taken from the solarized plots do not have or have very few nematodes, while the roots of the plants taken from the non-solarized plots have a high density of nematodes. Gal index was determined as 7.25 and 4.63 in control and only mycorrhiza applications, while the same values were 0.38 and 0.63 in plots where solarization and mycorrhizal were applied together and only in plots where solarization was applied. Root knot nematodes form large and small galls on the roots of plants, preventing the plants from taking water and nutrients. Parameter values such as fruit weight, fruit size and yield in plants with nematodes were found to be lower than solarization and solarization + mycorrhiza applications. It has been determined that the productivity and quality increase when the soil pathogens are struggled in melon cultivation in greenhouses. The biggest reason for the difference in yield between applications is considered to be the damage caused by root knot nematode (*M. incognita*) and weeds. At the same time, by applying mycorrhiza, the roots of plants are encouraged to develop better and make better use of nutrients in the soil. These results are smilar to some studies (Boenel *et al*., 2023; Liu *et al*., 2023; Pérez-Rodriguez *et al*., 2020).

In this study, it has been determined that the combined application of solarization and mycorrhiza in melon cultivation in nematode soils provides an increase of 53.3% in yield per plant and 41.8% in only solarization application. Çelik *et al*., (2012) reported in their study that grafting and solarization caused an increase in the yield of melon. For this reason, it was concluded that it would be beneficial to apply solarization in greenhouses with nematode and weed problems. It has been determined that with the solarization application, mycorrhizal application contributes to the productivity increase. In a study conducted on peppers, it was reported that the efficiency of mycorrhiza application in peppers increased (Altuntaş *et al*., 2016). Gruenzweig *et al*., (1993) reported that the reason for the increase in yield and plant growth may be due to physiological changes, such as increased photosynthetic activity and consequently increase in protein level, delayed senescence (and therefore increase in economic efficiency) and these may be connected solarization.

Solarization in melon cultivation in greenhouses reduced the nematode density and allowed plant roots to develop more easily. With the application of mycorrhiza, plants benefit from nutrients better, allowing increased productivity, quality and plant development. Our results are in accord with those of other authors (Avio *et al*., 2018; Sabatino *et al*., 2020; Jamiolkowska *et al*., 2020; Yahaya *et al*., 2021). In addition, through the use of solarization and mycorrhiza, input costs have been reduced and environmentally friendly agriculture has been supported by saving on pesticides which are used against soil pathogens and chemical fertillizers. This issue was also touched upon in the studies and it was emphasized that this is important for the future (Rubin *et al*., 2007; Chafai *et al*., 2023). Based on the results of this study, both solarization and mycorrhiza applications in nematode-infested soils increase yield and quality in melon cultivation. Suggestions should be provided to farmers in this direction.

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