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Full Length Research Paper

Effect of solarization and vesicular arbuscular mychorrizal on weed density and yield of lettuce (*Lactuca sativa* L.) in autumn season

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This study was conducted on trial field of Faculty of Agriculture, Dicle University, Diyarbakir, Turkey in 2007 growing season. The experiment established on a loamy- clay soil with the seedlings of Yedikule lettuce (*Lactuca sativa* L.) infected by Vesicular Arbuscular Mychorrizal (VAM) fungus, *Glomus intraradices.* The goal was to increase the yield and quality in lettuce production. The VAM infected and disenfected lettuce seedlings propagated in greenhouse conditions were planted by the split-plot designs-random model. The study was conducted as the main plot applied solarization and non-solarization and subplot with VAM and without VAM which resulted in four repetitions. The solarized field had an increased soil temperature: the increase in the temperature was 11°C in 5 cm depth, 8°C in 20 cm and 5°C in 30 cm. This situation continued to the end of the growth season and also inhibited the germination of weed plants. In the solarized area, the plant height, plant crown-width and yield showed significant increase during the vegetative season of 45 days long. The data was significant for three growth factors. In solarized area, the average weight of lettuce was obtained to be 138.85 g but in control parcel the average weight was 30.85 g. The increases in VAM parcel for three growth factors were significant. But the interaction between solarization and VAM was found non significant. To determine VAM before testing in laboratory, VAM dutied like a bridge from donor lettuce to receiver wild mustard (*Sinapsis arvensis* L.) as observed in the experiment because mustrad has no symbiosis life with this fungus. Also the laboratory findings supported this; the number of spores, number of VAM infected and infection rate were higher both in main parcel of solarized and in the subplot parcel planted with VAM seedlings than the nonsolarized parcel and non VAM seedlings. The results for both criteria were significant in solarization and VAM application. But the interaction with VAM and solarization was insignificant. As a result, one can note that the VAM inoculation after solarization application is beneficial for growing lettuce especially in the fall of season.

Key words: Soil solarization, vesicular arbuscular mycorrhizal, *Glomus intraradices,* lettuce, weed, yield, donor and receiver plant.

INTRODUCTION

Diseases in the soil sources and weed plants are the most common problems which decraese the yield intensive vegetable growing. This problem can be prevented by soil fumigation and crop rotation. As it is known, the chemicals used in fumigation have negative effect on ecology. The most common chemical used in fumigation, Methyl-bromide, is banned since 2005 because of its damaging effect on the stratospheric ozone layer (Katan, 1999). It is possible and beneficial to use solar energy, a practice referred to as “soil solarization”, instead of fumigation. “Soil solarization” is a term that refers to disinfestation of soil by the heat generated from trapped

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Abbreviation: VAM, Vesicular arbuscular mychorrizal.

solar energy (Katan, 1987). This method eradicates or reduces soil-borne pathogens and weed seed germination by thermal inactivation (Tekin and Cimen, 2001; Lalitha et al., 2003; Hassing et al., 2004). All these changes effect plant development positively and can increase the yield. In lettuce growing, it is possible to increase the yield and earliness, eradicating some diseases caused by soil-borne pathogens by solarization (Patricio at al., 2006).

Beside the intended changes, solarization also decreases some beneficial microorganisms in the soil (Ortas et al., 1998; Schreiner et al., 2001). Mycorrhiza is the first name among these microorganisms, which is a symbiotic association between a fungus and the roots of a plant (Smith and Read, 2008).

In recent years, the study about bringing soil artificially inoculated mycorrhiza is very common. By this application, increases in yield and plant growth were reported in some cultural plant studies (Afek et al., 1991; Wininger et al., 2003; Ngakou et al., 2006).

In this study, our goal is to obtain higher yield from lettuce (*Lactuca sativa* L.) growing with mycorrhizal inoculation after soil solarization application.

MATERIALS AND METHODS

The study was conducted in the field of loamy-clay structure soil in the Faculty of Agriculture at Dicle University. The polythene of 0.02 mm thickness used as a cover sheet material for solarization application and 4 digital soil thermometers were used to measure the soil temperature at 5, 10, 20 and 30 cm depth of Yedikule lettuce variety used as a plant material. The seeds were sown in viol included torf substrate to get seedlings. The vesicular arbuscular mycorrhiza (VAM) fungus, *Glomus intraradices,* used in the study were taken from Soil Department at Faculty of Agrıculture, Çukurova University. The experiment conducted as the main plot applied solarization and non-solarization, and VAM and nonVAM parcels were subplots with four repetitions according to the split-plot desings-random model.

Soil solarization

According to the experimental design, soil treatment machines were used to remove weed, root pieces and soil clod in the experiment area. Then the area was irrigated by surface irrigation till to field capacity. Harrow, plough and other soil treatment machines were used to smooth the experiment area.

The experiment area was covered with transparent polythene material in 7 x 15 m size. All sides of polythene were put under the soil with a depth of 25 cm and 50 cm. But in control parcel nothing has been done except soil treatment.

After the polythene covering, both in control and solarizated parcels, thermometers measured the soil temperature at a depth of 5, 10, 20 and 30 cm. The thermometeres measured the soil temperature at 14:00 h in two days interval from 25 July, 2007 to 10 September, 2007. Solarization treatment was ended on 2nd October, 2007.

Inoculation of VAM fungus and seed sowing

Lettuce seedlings were grown in controlled conditions. Torf was used as substrate and autoclaved for sterilization at 121°C during 90 min. Each viols included 45 eyes filled with sterilized torf and a mixture of soil with VAM (20 g per each eye). Then this composition was covered with enough amount of torf. The lettuce seeds were sown in the viols included above, mix with VAM and nonVAM, on 26th of August, 2007.

Transplanting of seedlings

As soon as solarization was completed, weeds were counted and soil treatment was done on the surface level. According to the experimental design, there were 16 parcels of 2.5 x 3.5 m size. The seedlings of VAM and non VAM were transplanted to the experiment area in the early morning (07:00 - 09:00) with 45 x 35 cm space in each parcel that includes 50 seedlings. During the vegetative period no culturel treatment was applied to plants except irrigation.

Observation the plant growth and harvesting

After transplanting the seedlings, cultural treatments were applied to the experiment. Surface ırrrigation was done during two weeks but later, it was stopped because of seasonal rains. The measurements and observations began 35 days later till harvesting. The following data were taken in all parcels to obtain the effect of VAM and solarization on plant growth:

Plant height (cm): Each plant was measured from the soil surface to top of the plant.

Plant crown-width (cm): This is the average of width and length of the top of the plant.

Plant weight (g): All plants harvested, cleaned and cut from the roots were weigthed. The avarege value was found by taking the arithmetic mean.

Marketable yield: All harvested plants were cleaned from injuried leaves and weighted to obtain the mean value.

Determination of VAM infection and counting spor

VAM fungi in the soil on the lettuce roots were isolated according to "wet eliminated method" and number of spores were counted (Gerdemann and Nicolson, 1963). For this treatment, 10 g of soil sample was weighed and eliminated wetly with the screen 50 μm above and 250 μm below. The sample in the centrifuge tubes with 100 ml capacity centrifuged for 10 min at 3500 rotation per minute (rpm) level to collapse the spores at the bottom in soil solution. Clear water in tubes sprouted out and centrifuged again with 50% sugar solution to cleave the mycorrhizal fungus with the soil and then pure water was added after sproud the sugar solution. Spores in the pure water samples were counted by a stereo microscope with 25 times enlargement.

After harvesting, soil around the roots were thrown away and cleaned with city water and then pure water. The cleaned roots were dried on paper and then kept in an alcohol solution. "Root infection method" was applied to determine the effect of VAM. The cleaning and painting treatments on roots were done according to Koske and Gemma (1989). The roots were cut at a 1 cm length and were put in test tubes included 10% KOH solution to soften and kept in a 65°C stove for one hour. The roots filtered from KOH solution and then were bleached by adding HCI into the tubes. These samples were kept in 65°C stove for 15 min. Then 1% Trypanblue solution was added homogenously into the tubes and then kept in a 65°C stove for 15 min. Trypanblue was removed from the tubes and lactic acid was added on roots in tubes for preservation

Table 1. The soil temperature in different depths of solarized and nonsolarized area.

Treatments	Soil Temperature (°C)				
		5 cm	10 cm	20 cm	30 cm
Solarized	Mean	39.2	36.3	34.8	32.4
	High	49.0	41.0	35.0	34.0
	Low	35.0	31.0	33.0	32.0
Nonsolarized	Mean	28.0	27.0	25.5	24.4
	High	38.0	33.0	28.0	26.0
	Low	25.0	24.0	25.0	23.0

Table 2. Mean number of weed species in solarized and nonsolarized with VAM and non VAM plots (m^2).

Treatments	Johnson grass	Wild mustard
Solarized	-	-
Nonsolarized	385.62 **	49.00 **
VAM	66.50	33.12
NonVAM	88.75 ^{NS}	15.87 *
S x VAM	NS	*

* and **, Significant at P< 0.05 and 0.01, respectively; NS: not significant.

and kept in a 65°C stove for 15 min. The samples removed from the stove were put in the petri plates and infected roots were determined. The infection rate of roots was obtained with a mycroscope in 40 - 60 enlargements (Gionnetti and Mosse, 1980).

RESULTS AND DISCUSSION

Effect of solarization on soil temperature

The average values of soil temperature were given in Table 1. As shown in the table, average soil temperature at 5 cm depth was 49°C in solarized plots and this was 11 degrees higher than nonsolarized plots. This increase was measured at 8, 7 and 5°C, respectively, in 10, 20 and 30 cm of depth in solarizated parcels. These results were lower because of clay soil character. However, our findings are supported with early studies by Chase et al. (1999), Tekin and Cimen (2001) and Hassing et al. (2004).

Effect of solarization and VAM applications on weeds

After solarization, the area was observed before transplanteing the seedlings, but no weeds were seen. But in nonsolarized parcels, 17 plants of Johnson grass (*Sorghum halepense)* and 3 plants of cocklebur (*Xanthium strumarium*) per square area were observed. And also, the effects of solarization on weeds were continued after 45 days of transplanting all seedlings in the experiment area. There were no weeds observed in solarized main parcel (Table 1, Figures 3a and b). The parcells of nonsolarized, the number of Johnson grass were increased at 385.62/ m^2 (Table 2, Figures 1c and d). Not only was Johnson grass, also 49.00/m^2 of wild mustards (Sinapsis arvensis) counted. In the nonsolarized parcell, the effect of VAM on Johnson grass was insignificant but on Wild mustard plants the VAM had significant effect at a 5% level and the number of Wild mustard doubled in the non VAM application (Table 2).

The dormant weed seeds became active by the irrigation for solarization and their sensitivities increased to high temperature; hence, their population might have been decreased or dead (Tekin and Cimen, 2001; Lalitha et al., 2003; Hassing et al., 2004).

A framework to identify VAM around the roots

VAM not only caused an increase in the number of Wild mustards but also had a positive effect on growth of this plant. It is observed that the seeds of Wild mustard germinated around the lettuce plants show better development than in space rows (Figures 2 and 3). Note that no treatment have been done such as fertilization except surface irrigation in the experiment. Wild mustard around the lettuce could have been grown better than those in space rows of lettuce because of richer nutrients. Lettuce is a mycorrhizal plant (Jackson at al., 2002), whereas Wild mustard is a non mycorrhizal one (Wang and Qiu, 2006) which may have resulted in some nutrient flows from lettuce to wild mustard. Transport of nutrients from lettuce to Wild mustard must have been by VAM. There are no researches or reports regarding the bridge

Figure 1. Effect of solarization and VAM on lettuce growth: (a) solarized + VAM, (b) solarized + non VAM, (c) nonsolarized + VAM and (d) nonsolarized + nonVAM.

Figure 2. Difference the growth of wild mustards nearby lettuce plant and away from it in a nonsolarized + VAM plot.

Figure 3. Growth of lettuce and wild mustard plants side by side in nonsolarized + VAM plot.

Table 3. Determination of vesicular arbuscular mycorrhiza (VAM) on lettuce root in experiment parcels.

Treatments	Number of infection^{y}	Root infection (%)	Number of spore
Solarized	8.25	41.25	61.18
Nonsolarized	7.62 *	38.12 *	32.06 ^{NS}
VAM	11.50	57.50	61.18
NonVAM	4.37 **	21.87 **	32.06 ^{NS}
S x VAM	NS	NS	NS

* and **, Significant at P< 0.05 and 0.01, respectively; NS: not significant; ^{y}: infection number per 20 lettuce root.

between only these plants through the VAM hyphae. However, it was reported that mychorizal supply the nutrient flowing between the donor and receiver plants (Simard et al., 1997; Robinson and Fitter, 1999**;** Jordan et al., 2000).

As it is accepted previously, mychorizal duty like a bridge for nutrient flowing so that being of VAM on lettuce root, and this situation was also supported by laboratory studies. After harvesting, the roots were tested in the laboratory. According to the investigation on lettuce roots, the infection number and rate were higher in the main solarized parcels than nonsolarized one. This difference was significant at a 5% level (Table 3). Both data were higher in the mychorizal application and the differences were statistically significant at 1% level. The interection between solarization and VAM was not significant. Although soil-borne pathogens and beneficial microorganisms were dead by soil solarization, the roots were partly infected

Table 4. Effect of solarization and VAM on the growth and yield for lettuce.

Treatments	Plant height (cm)	Plant crown width (cm)	Weigth lettuce (g)	Marketable (g)
Solarized	13.16	21.66	138.85	125.96
Nonsolarized	7.85 **	14.76 **	30.33 **	26.56 **
VAM	11.15	19.10	92.53	83.12
NonVAM	9.86 *	17.32 *	76.65 *	69.40 *
S x VAM	NS	NS	NS	NS

* and **, significant at 0.05 and 0.01, respectively; NS: not significant.

with residues of the VAM spores (Ortas and Harris, 1996). To effect the development of plant by VAM the root infection rate is expected above 50% (Smith and Read, 2008). As it is shown in Table 3, this rate was obtained at 57%. The number of VAM infection was also doubled parallel of this addition.

Effect of solarization and VAM on the growth and yield for lettuce

The observations were taken on the 45th day of planting the seedlings to the experiment area; plant height and crown-width increased in big amount and this increament also was seen in yield. For all the three growth factors, the findings were significant at 1% level (Table 4, Figures 1a and b). The avarege weigth of lettuce in solarized parcels was 138.85 and 30.33 g in non-solarized parcels. The effect of solarization on weed seeds germination was inhibited with high temperature (Table 1), inoculum amount of soil-borne pathogens decreased. Plant development conserved the soil moisture by polythene cover. Our findings were also supported with early studies (Hassing et al., 2004; Patricio et al., 2006).

Plant heigth, crown width and the weight of marketable lettuce were increased by VAM and solarization treatment, these were significant at 5% level (Table 4, Figures 1c and d). The interaction was insignificant between solariztion and VAM. Mychorizal effect on lettuce development was not as much as solarization application. This may be as a result of late transplanting of the seedlings and cold weather became earlier during the harvest. The vegetative season was 45 days and this had shortened the period of symbiosis between lettuce and VAM. Also, our findings were similar with other findings. Lettuce had symbiosis with VAM (Jackson et al., 2002), plants show better development in dry condition (Azcon et al., 1996) because of increasing in photosynthesis products (Azcon et al., 1992)

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