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Full Length Article

Effect of Soil Solarization and Arbuscular Mycorrhizal Fungus (*Glomus intraradices*) on Yield and Blossom-end Rot of Tomato

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ABSTRACT

The study was aimed to investigate the effect of tomato seedlings of Falcon variety (*Lycopersicum esculantum* L.*)* inoculated with arbuscular mycorrhizal (AM) fungus *Glomus intraradices* in solarized and non solarized parcels on yield and blossom end rot (BER) that cause yield loses in tomato growing. The experiment established according to split-plot design with four replicates as main plot of solarization and sub-plot of mycorrhizal in total 16 parcels. The solarized field increased the soil temperature (11, 8, 7 & 5^{o}C) than non-applied in different soil depth (5, 10, 20 & 30 cm). The contents of N, P, K, Ca, Mg, Mn, Zn and Cu were increased in leaves by solarization. The levels of P, K, Mg, Fe, Mn, Zn and Cu in leaves were higher in plots inoculated with AM than without non AM. The effect of solarization on yield was significant and was three times higher than non solarized control. However, AM had no effect on yield. In this study, the expected yield was not obtained, because of blossom end rot (BER). The effect of neither solarization nor AM was seen on this physiological disorder in tomato. However, high temperature affected these abiotic diseases. During the vegetative season, incidence of BER occurred 100% of the high temperature in July-August, whereas this rate was rapidly decreased and was not observed during the cool periods at the end of growing season. The results of this study show that solarization can be applied and recommended for growing tomato in the region, but the research about factors resulting in BER must be accelerated. © 2010 Friends Science Publishers

Key Words: Arbuscular mycorrhizal; Blossom-end rot; Soil solarisation; Tomato; Yield

INTRODUCTION

The main problem in tomato growing is the yield reduction caused by soil borne pathogens and weeds. This problem could be eliminated by soil fumigation with chemical and crop rotation. However, it was known that these chemicals had harmful effect on ecology. The most common chemical used in fumigation, methyl bromide has been recommended to be banned since 2005, because it is an ozone-depleting molecule (Albritton *et. al*., 1998).

It is possible and beneficial to use solar energy instead of fumigating soil. "Soil solarization" is a term that refers to disinfestations of soil by the heat generated from trapped solar energy (Katan, 1987). This method eradicates or reduces soil-borne pathogens, root-knot nematodes (Yucel *et al*., 2007) and weed seed germination by thermal inactivation (Lalitha *et al*., 2001). However, the destruction or death of beneficial organisms in the soil may have been by solarization (Schreiner *et al*., 2001). Among these, the most widespread mutualistic symbiosis is the arbuscular mycorrhizal (AM) fungi. AM symbiosis leads to increase root surface (Javaid *et al*., 2007; Javaid & Riaz, 2008). In the soil with salinity character and poor by nutrients such as phosphor, tomato has high symbiotic life with these organisms (Al-Karaki & Hammad, 2001). It was reported that the yield could be increased in tomato after these fungi had been added back into the fumigated soil, because the population of mycorrhizal may have decreased or dead by fumigation or solarization (Ortas *et al*., 2003). The ecosystem that occurred between plant and AM fungi led to cell defense responses associated with localized and systemic resistance to soil-borne pathogens induced in tomato (Cordier *et al*., 1998).

Blossom end rot (BER) is a very common physiological disorder in *solanaceae* mostly for tomato, pepper and eggplant. So far, most studies have been done on BER and it has been reported to have come as a result of low calcium levels in fruit distal due to competition for Ca uptake with other mineral nutrients in the soil. Mg is the first element of those to compete. The amount of Ca and Mg is quite less in fruit although Mg/Ca rate is high due to high mobility of Mg. Transmission of Ca to the fruit is inhibited by high concentration of Mg (Gunes *et al*., 2002).

Uptaking of Ca occurs in the first few weeks of fruit growth when cell wall develops. At mature stage of fruit development, Ca is transformed into water-soluble form and

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leave from the cell wall (Gunes *et al*., 2002). The others which inhibited uptaking of Ca are NH4 and K (Bar-Tal *et al*., 2001a).

The main cause for Ca deficiency in plant organs is its low mobility in the plant from matured tissues to young ones. Ca uptake and transport in the plant is strongly dependent on transpiration (Bar-Tal, 2005) and air flowing over fruit clusters reduced BER incidence (Wui & Takano, 1995). A critical concentration of Ca in tomato fruit has not yet been found (Saure, 2001). It was reported that transpiration of fruit surface had a role in translocation of Ca via xylem to pepper fruit. Hence, large fruit surface, that is, pepper cultivar with more pore or stomata is an admissible resistant variety to BER (Bar-Tal, 2005). On the other hand, irrigation frequency and increasing Ca concentration in the irrigation water was reported to have been an effective mean to reduce the incidence of BER (Bar-Tal *et al*., 2001b). The BER incidence due to higher temperatures was correlated with a rapid fruit growth rate during the early stages of fruit development at high temperatures (Wui & Takano, 1995; Gunes *et al*., 2002). The studies were focused on the subject of these factors.

The main objective of this study was to determine the effects of vesicular arbuscular mycorrhizal (VAM) *Glomus intraradices* fungus on yield and blossom-end rot disease in tomato growing.

MATERIALS AND METHODS

The study was conducted in the field of loamy-clay structure soil in Agriculture Faculty of Dicle University, Turkey. The polythene as a cover sheet material was used 0.02 mm thickness, also 4 digital soil thermometers for measuring the soil depth from 5, 10, 20 and 30 cm for solarization. Falcon tomato variety was used as a plant material and its seeds were sown in viol included torf substrate to get seedlings. The arbuscular mycorrhizal (AM) fungus *Glomus intraradices* used in the study was provided by Soil Department Agriculture Faculty of Çukurova University. A split plot design was employed with two main treatments (solarized & non-solarized) and AM with non-AM as subplots. The experiments were arranged as randomized complete blocks with four replicates.

Soil solarization: The experimental plot surface was mechanically cleared of weeds and before solarization; plots were irrigated by surface irrigation to field saturation. The experiment area was covered with transparent polythene material in 7 × 15 m size. All sides of polythene were put under the soil with a depth of 25 cm and 50 cm. However, in control parcel, nothing has been done except soil treatment. After the polythene covering, both in control and solarized parcel, thermometers measured the soil temperature at a depth of 5, 10, 20 and 30 cm. The thermometers measured the soil temperature at 2 P.M in two days interval from 25 July to 10 September, 2007. Soil solarization was carried out during the warmest months of the summer season in Diyarbakir. However, transparent polyethylene sheets had been covered by the time seedlings of tomato was transplanted into field.

Inoculation of AM fungus and seed sowing: Tomato seedlings were grown in controlledconditions. Torf was used as substrate and autoclaved for sterilization at 121ºC for 90 min. Each viol included 45 eyes filled with sterilized torf and mixture soil included AM (20 g/eye). Then this composes covered with enough amount of torf. Later tomato seeds sown in the viols included above mix with AM and non-AM, on 03 March 2008.

Transplanting of seedlings: According to the experiment design, 16 parcels were formed with solarization and non-solarization as main parcels with AM and non-AM as sub-plots. The seedlings of AM and non AM were transplanted to the experiment area in early morning (07:00-09:00) with 120 x 50 cm space in each parcel that included 40 seedlings on 15 April, 2008.

Harvesting schedule: Tomato fruit was harvested nine times from 22 July to 26 November during the growing season in 2008. Unmarketable fruits were classified as exhibiting sunburn damage, blossom end rot, misshapen fruits, disease symptoms and other defects. The total yield in each plot was calculated as yield/plant.

Incidence of blossom-end rot (BER): During the harvest, the fruits with BER were collected in other cups and weighted from the healthy ones. The healthy fruits had no symptoms but, those with BER had characteristic symptoms as black tissue at the distal end of ripening fruits.

Soil sampling and methods of analysis: Before establishing the experiment, soil samples were taken from 30cm depth. At first, they were prepared with air-dry samples and then became available for analysis after they were passed through 2 mm diameter screen. Afterwards, soil samples were analyzed according to following methods:

Texture was determined by hydrometer method (Bouyoucos, 1951). Soil pH and electrical conductivity (EC) as mmhos/cm was measured in water with a 1:2.5 ratio of soil solution according to Jackson (1962), lime (%) by Scheibler calcimeter method (Caglar, 1949), organic material (%) by using modified Walkley-Black Method (Jackson, 1962), available P levels were determined by using the Olsen test (Olsen & Sommers, 1982). Exchangeable potassium, calcium and magnesium were determined using AAS (atomic absorption spectrophotometer) after soil samples were shaken up with 1 N ammonium acetate (pH: 7) and extracted (Richards, 1954). Available levels of Iron, Zinc, Manganese, Cupper were determined using AAS after soil samples were shaken with DTPA solution (pH: 7.3), filtered and extracted (Lindsay, 1972).

Leaf sampling and methods of analysis: During the fourth harvest (Jones Jr. *et al*., 1991), the following analyses were conducted after the sample young fully mature leaves had been taken in order to determine the tomato nutrient levels with different treatments:

The amount of total N per unit dry weight in leaf samples was determined by modified Kjeldahl methods in the Kjeltec System (Kacar, 1972); Total phosphorus was determined by the Vanado Molybdate method (Kacar, 1982); The contents of K, Ca and Mg (%) with those of Fe, Zn and Mn (ppm) were determined by AAS in the extracts after wet burning procedure (Kacar, 1972); Boron content was determined by using Azometin H. Spectrophotometric method (Wolf, 1939).

Statistical analysis: Analysis of variance (ANOVA) was performed by MSTATC the microcomputer program.

RESULTS AND DISCUSSION

Effect of solarization on soil temperature: The effects of solarization on soil temperatures at four depths are shown in Table I. The solarized field increased the soil temperature (11, 8, 7 & 5°C) than non-applied in different soil depth (5, 10, 20 & 30 cm). These results were lower because of clay soil character. However, our findings are supported with early studies (Chase *et al*., 1999).

Soil and leaf analysis: The soil of the experimental area analyzed at a depth of 0–30 cm was a clay texture with alkaline reactions (pH 7.9), no salinity problem (EC 0.39 µmoh/L) and also, adequate organic matter (1%). There was inadequate available P (13 mg/kg) and Zn (0.5 mg/kg), although there were adequate exchangeable Ca (7204 mg/kg), Mg (830 mg/kg) and K (261 mg/kg) contents with available Fe (6.3 mg/kg), Mn (3.8 mg/kg) and Cu (1 mg/kg). These results showed that it is most suitable for tomato growing and confirm previous studies indicated that it has been grown best in soil, which is supplied with deep, silty soil, well-drained, no salinity problem with a pH: 5.5 to 7.5, high in organic matter and nutrients (Sevgican, 1989).

The leaf samples per sub-plot were taken in order to determine the effect between solarized and non-solarized with AM and non-AM (Table II). The mean nutrient levels for plant were compared to determine optimal values for tomato (Jones Jr. *et al*., 1991). Ca, Mg, Mn, Zn, Cu and B contents were sufficient, but N, P and K contents were insufficient in leaf for all treatments (Table II). Fe content in the leaves was adequate in with inoculated VAM, but was inadequate inoculated non AM. The eight elements content were higher in solarized plots than non-solarized ones, except Fe and B contents.

Germinated weed seeds, which compete with the crop for nutrients were killed by the effect of high temperature due to solarization (Lalitha *et al*., 2001) also, the amount of inoculums for soilborne plant pathogens were decreased or eradicated (Yucel *et al*., 2007; Candido *et al*., 2008) and, therefore, more nutrients must have been taken by tomato plants. The contents of P, K, Mg, Fe, Mn, Zn and Cu in leaves were higher in plots with inoculated AM than non-AM parcels. In contrast, the level of B was higher in non-AM plots than those with AM. Differences between AM and non AM for N and Ca were approximately equal.

Table I: The soil temperature in different depth of solarized and non-solarized area

Treatments	Soil Temperature (°C)			
	5 cm	10 cm	20 cm	30 cm
	39.15[x]	36.30	34.80	32.40
Solarized	49.00[y]	41.00	35.00	34.00
	35.00[z]	31.00	33.00	32.00
	28.00	27.00	25.50	24.40
Non solarized	38.00	33.00	28.00	26.00
	25.00	24.00	25.00	23.00

([x]) Mean,([y]) the highest and ([z]) the lowest value for temperatu

Fig. 1: Incidence of BER in tomato fruits at the different harvest times (2008)

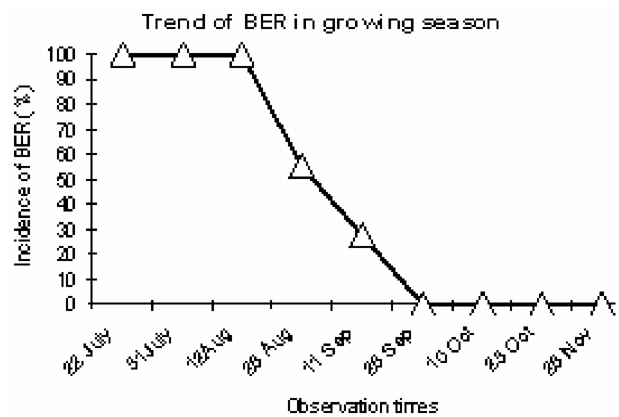
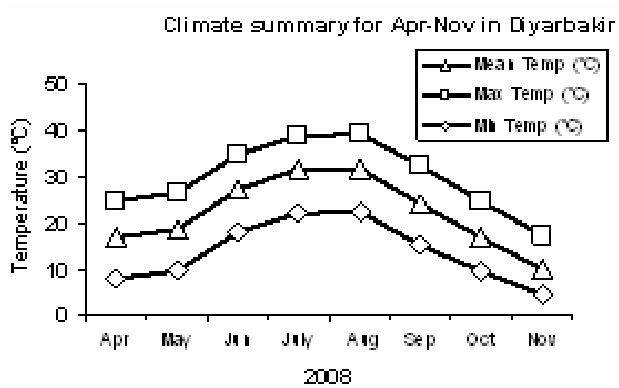


Fig. 2: The climate value during the tomato growing season in Diyarbakir



Increasing contents of nutrient elements in leaf show that tomato plant must have taken up more nutrients from soil into leaf tissue as its root surface was increased thanks to AM. These findings and interpretation of results conform to those in previous works. It was reported that the external hyphae of AM could deliver up to 80% of plant P, 25% of plant N, 10% of plant K, 25% of plant Zn and 60% of plant Cu in a study (Marschner & Dell, 1994). Mycorrhizal inoculation also increased zinc and copper uptake of tomato, eggplant and pepper under field conditions after soil fumigation (Ortas *et al*., 2003).

Table II: Influence of Solarization and vesicular arbuscular mycorrhizal (VAM) fungus on nutrients uptake by tomato

Treatments	Nutrient Elements									
	(mg g^{-1})					(mg kg^{-1})				
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Solarized	3.05	0.21	2.70	7.75	1.10	55.5	107.5	25.5	41.0	99.5
Non solarized	2.95	0.16	2.15	6.15	0.90	65.0	80.0	23.5	35.5	110.5
AM	2.95	0.22	2.85	6.80	1.20	84.5	121.5	27.5	43.0	72.0
NonAM	3.05	0.15	2.00	7.10	0.80	36.0	80.0	21.5	33.5	138.0
Sol- AM	3.00*	0.25	3.10	8.10	1.30	81.0	139.0	29.0	47.0	71.0
Sol-NonAM	3.10	0.17	2.30	7.40	0.90	30.0	76.0	22.0	35.0	128.0
Non Sol-AM	2.90	0.19	2.60	5.50	1.10	88.0	104.0	26.0	39.0	73.0
NonSol-Non AM	3.00	0.14	1.70	6.80	0.70	42.0	84.0	21.0	32.0	148.0
Optimal levels	3.2-4.5	0.5-1.2	5.0-10.0	1.5-2.4	0..32-0.8	60-300	50-250	20-250	5-50	25-75

* mean of three replicates

Table III: Effect of solarization and vesicular arbuscular mycorrhizal (VAM) on yield and blossom end rot (BER) in tomato (2008)

Treatments	Yield (kg)					BER^{y} (%)
	Total of 3 harvest (Parcel)	Total of 6 harvest (Parcel)	Total of 9 harvest (Parcel)	Total of nine harvest		
	12.08.2008	26.09.2008	26.11.2008	Per plant	Per acre	
Solarized	33.20	42.99	46.28	1.15	1915	65.63
Non solarized	10.19	15.11	17.95	0.44	733	62.70
Solarization	**	**	**	**	**	NS
VAM	20.21	27.41	30.29	0.75	1249	63.86
Non VAM	23.17	30.69	33.94	0.84	1399	64.47
VAM	NS	NS	NS	NS	NS	NS
Sol- VAM	31.80	41.48	44.59	1.11	1849	65.12
Sol- Non VAM	34.60	44.50	47.97	1.19	1982	66.14
Non Sol- VAM	8.63	13.34	16.00	0.40	666	62.61
Non Sol- Non VAM	11.75	16.88	19.91	0.49	816	62.79
SXVAM	NS	NS	NS	NS	NS	NS

Observation on total of 6 harvests; *, **, significant at 0.05 and 0.01 levels respectively, NS = not significant

Effect of solarization and AM on yield of tomato: The effect of solarization and VAM on yield for tomato is cumulatively given in Table III. Relating to the increase for content of nutrients in leaves, increase in yield has been obtained by solarization and findings were significant ($P<0.01$). In addition, 70% of total nine harvests were obtained in the first 3 ones in solarized parcels but this value was 60% in non solarized plots. In this period, the yields obtained in solarized parcels were 3 times higher than that in non-solarized ones, but this was decreased 2.5 times at the end of the growing season. Our findings conform to those of Candido *et al.* (2008).

In contrast to solarization, the effect of AM on yield was not observed (Table III). The contents of seven nutrient elements, except B, Ca and N, in leaves were increase (Table II). Thus there appears to have been an increase in content of seven nutrients in leaves with AM inoculation, except B, Ca and N (Table II). There may have been inadequate mutualistic symbiosis between the root system of tomato and fungal hyphae due to the fact that tomato has a strong root system, which can develop deeply (Esau, 1977). However, an earlier study showed that there has been yield increase of 52% with artificial AM inoculation in fumigated soil for tomato (Ortas *et al*., 2003). The expected yield was not obtained in experiment plots on account of the fact that there was a high incidence of blossom-end rot (BER) fruits, which have been a serious problem in tomato growing.

Incidence of BER in plots experiments: In the first six harvests, there was not any effect on BER from both solarization and AM (Table III). We did not find in previous studies, whether or not there was influence of solarization and AM on BER.

The incidence of BER for tomato fruits harvested is given in Fig. 1. Due to BER 65% of the total yield was not marketable. The incidence of physiological disorder as symptom was seen in all fruits during the first 3 harvests. This period was begin from half of July to the first week of August and was the highest temperature of the year (Fig. 2). BER incidence on fruits was decreased by decrease in high temperature in September and symptom was not observed during the cool weather (October-November).

Blossom-end rot (BER) is a very common abiotic disease in tomatoes and fruit vegetables such as peppers, eggplant and sometimes melons and summer squash. So far, most studies done on BER and it reported that it occurred as a result of low calcium levels in fruit distal due to competition for Ca uptake with other mineral nutrients in the soil (Bar-Tal *et al*., 2001a). In addition it may also be caused by other abiotic factors such as irrigation, drought stress and excessive soil moisture fluctuations (Bar-Tal *et al.*, 2001b).

Our results show that all fruits of tomato harvested were lost during the high temperature (July-August), because of BER. In fact, previous works showed that BER was induced by temperature increment during the cell division and rapid vegetative growth (Wui & Takano, 1995b).

CONCLUSION

The contents of nutrient elements were increased by soil solarization and arbuscular mycorrhizal (AM) in the lives of tomato. Consequently, effect of solarization on yield was three times higher than non-solarized. However, AM had no effect on increment in yield. The expected marketable yield was not obtained, because of blossom end rot (BER). The results of this study show that solarization can be applied and recommended for tomato growing in the region, but the research about factors resulting in BER must be accelerated.

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