The effect of duration of solarization on controlling branched broomrape (*Phelipanche ramosa* L.) and some weed species

Der Effekt der Solarisationsdauer auf ästigen Sommerwurz (Phelipanche ramosa L.) und einige andere Unkrautarten

Özhan Boz*, Mehmet Nedim Doğan & Derya Öğüt
Adnan Menderes Üniversity, Faculty of Agriculture, Dept. of Plant Protection, 09100-Aydın/Turkey
*Corresponding Author, ozhanboz@yahoo.com

DOI: 10.5073/jka.2012.434.089

Summary

In this study, the effects of two-, four- and six-week periods of solarization on *Phelipanche ramosa* and other weeds were determined in tomato greenhouses between 2007-2009 in Aydin Province/Turkey. In the first year, the maximum temperatures recorded in the soil in the solarized area were 54 °C at a depth of 5 cm, 47 °C at 10 cm and 41 °C at 20 cm. In the second year, the maximum temperatures in the solarized area were 44.5 °C at 5 cm, 39.7 °C at 10 cm and 34.7 °C at 20 cm. In the first season, regardless of solarization time, solarization reduced the density of *Amaranthus viridis*, *Setaria verticillata*, *Urtica urens*, *Solanum nigrum*, *Portulaca oleracea*, *Chenopodium album* and *Stellaria media* by 99-100 %. Solarization's effect on *P. ramosa* was 100 % regardless of the duration of solarization. In the second year, 2-, 4- and 6-week solarization periods, respectively, reduced *A. viridis* by 67, 73 and 93 %; *S. verticillata* by 78, 80 and 94 %; *U. urens* by 99, 100 and 100 %; and *S. media* by 100 % for all treatments. When *P. ramosa* was examined, a 2-week solarization period was found to result in a 20 % decrease and a 4-week solarization period resulted in a 47 % decrease. Six weeks of solarization reduced *P. ramosa* by 74 %. Additionally, there was an increase in tomato yield in response to longer periods of solarization.

Keywords: Broomrape, solarization, weed control

Zusammenfassung

Bei den Versuchen zwischen 2007 und 2009 in Aydin, Türkei wurde die Wirkung von zwei, vier- und sechswöchiger Bodensolarisation auf eine parasitierende Unkrautart *Phelipanche ramosa* und andere Unkrautarten untersucht. Im ersten Versuchsjahr waren die maximalen Bodentemperaturen bei 5, 10 und 20 cm Bodentiefe 54, 47 bzw. 41 °C. Im zweiten Versuchsjahr wurden niedrigere Temperaturen erreicht, so dass bei 5,10 und 20 cm Bodentiefe die maximalen Temperaturen 44,5, 39,7 bzw. 34,7 °C betrugen. Ergebnisse zeigten, dass beim ersten Versuch *P. ramosa* bei allen Bodensolarisationsdauer zu 100 % kontrolliert wurde. Ebenfalls wurden andere Arten wie *Amaranthus viridis*, *Setaria verticillata*, *Urtica urens*, *Solanum nigrum*, *Portulaca oleracea*, *Chenopodium album* und *Stellaria media* bei 99-100 % kontrolliert. Beim zweiten Versuch war die Wirkung der Solarisation abhängig von der Dauer. Beim *A. viridis* erzielte 2-, 4- und 6-wöchige Solarisation eine Wirkung von 67, 73 bzw. 93 %. *S. verticillata* Bekämpfung war 70, 80 und 94 % bei 2-,4- und 6-wöchige Solarisation. *U. urens* und *S. media* Bekämpfung lag bei 99-100 % unabhängig von der Solarisationsdauer. Bei *P. ramosa* 2-, 4 und 6-wöchige Solarisation erzielten 20, 47 und 74 % Wirkung. Der Tomatenertrag war höher mit verlängerter Solarisationsdauer.

Stichwörter: Solarisation, Sommerwurz, Unkrautbekämpfung

1. Introduction

Tomatoes are produced in a considerable number of fields in Turkey. Weeds, diseases and insects cause significant damage to tomato production in fields and greenhouses. In tomato greenhouses in Western Anatolia/Turkey, 51 weed species were found in Mugla, 34 species in Denizli and 30 species in Aydin. *Amaranthus* spp. was the most abundant species in the three provinces. *Portulaca oleracea, Chenopodium album*, *Trifolium* spp., *Cyperus rotundus*, *Setaria verticillata* and *Stellaria media* were dominantly found in all three provinces (BOZ et al., 2008). *Phelipanche ramosa* (Syn: *Orobanche ramosa*) is also an important problem in some cultivation areas. KROSCHEL (2001) stated that the most important *Orobanche* spp. include *O. crenata*, *O. cumana*, *O. cernua*, *O. ramosa*, *O. aegyptiaca*, *O. minor* and *O. foetida*. These species parasitize plants belonging to the Asteraceae, Fabaceae and Solanaceae families (KROSCHEL, 2001). *O. ramosa* and *O. aegyptiaca* complex was found in Mugla, Denizli and Aydin provinces/Turkey (Boz et al., 2008). Nemli and Demirkan (1988) stated that *O. ramosa* has been a problem in tomato fields in the past and will continue to be a problem in the future. Orel-Aksoy and Uygur (2003) conducted weed surveys in tomato greenhouses in the East Mediterranean Region of Turkey and found *Orobanche* species as *O. ramosa* and *O. aegyptiaca*. Abdallah et al. (1999) stated that *O. ramosa* was found in industrial tomato and potato in Algeria. In Egypt, about 50 % of the yield of tomato was lost due to the attachment of *O. ramosa* and *O. aegyptiaca* (Hassanein and Salim, 1999). Müller-Stöver et al. (1999) noted that *Orobanche* species were present in 50 % of the surveyed tomato fields in Egypt. Abdalla and Dabrowski (1997) stated that the yield of winter tomato crops heavily infested with broomrape was decreased by 40-80 %.

Soil solarization refers to the process of covering soil with a transparent sheet during the appropriate period. A transparent sheet is the modern tool used to capture solar energy to heat the soil in an open field or a greenhouse (Katan and DeVay, 1991). With solarization, soil is mulched during the hottest months (in Turkey, generally June to August) in an attempt to increase the maximum temperature to lethal. This is an environmentally friendly soil disinfection method that keeps weed seeds, soil-borne diseases and nematodes under control and improves soil productivity as it has no risk to live residues. This method can also be regarded as economical, depending on the plant being cultivated (Katan and DeVay, 1991). During solarization, the maximum and minimum temperatures of the air and their duration, the speed of wind and its duration, the texture, color, and moisture content of the soil and the characteristics of polyethylene are the more important components affecting the level of control (Stapleton, 1996). Parker (1994) stated that in Crete, *Orobanche* has been controlled by solarization and methyl bromide. In Israel, *Orobanche* was controlled by solarization and some fumigation. Farmers in Jordan have also used solarization to control *Orobanche*.

In order to explore the problems experienced by tomato producers, this study aimed to determine the effect of two-, four- and six-week solarization periods on *Phelipanche ramosa* (Syn: *Orobanche ramosa*) and other weeds in tomato greenhouse.

2. Material and Methods

Experiments were carried out between 2007 and 2009 in two tomato-growing seasons using greenhouses in Germencik in the Aydin province located in western Turkey (37° 51' N, 27° 50' E; an altitude of about 57 masl).

In order to determine the effect of different duration of solarization (two, four and six weeks) on the control of *P. ramosa* and some weeds, plots were established according to a randomized complete block design, with four replications. Each plot was 5.5 m * 5.5 m = 30.25 m^2. The study was repeated twice. The soil was flood-irrigated and treatments were applied as follows: Soil was prepared using a moldboard plough followed by a disk harrow, and beds were prepared on moistened soil. Plots were covered manually with clear polyethylene sheets (0.1 mm), including the soil between the raised beds. In order to prevent the loss of heat that results from the application of clear polyethylene to the plot, the borders of the plots were carefully covered. The periods of solarization in the first experiment began on 24 June 2007 for 6 weeks, 8 July 2007 for 4 weeks and 22 July 2007 for 2 weeks; all solarization periods ended 5 August 2007. The second experiment began on 7 July 2008 for 6 weeks, 21 July 2008 for 4 weeks and 4 August 2008 for 2 weeks of solarization; all periods ended 17 August 2008. After the solarization periods for the first experiment were completed, tomato seedlings (cv. Selin) were planted on 06 September 2007. In the second experiment, seedlings (cv. Pegasus) were planted on 26 August 2008. Drip irrigation was used to irrigate the plants in all of the experiments.

2.1 Soil temperature

Soil temperature was recorded in solarized and untreated control plots at depths of 5, 10 and 20 cm for two years using a data logger (HOBO® data logger U12-006, Bourne, MA, USA). The data for 16:00 are given in Table 1.

2.2 Evaluation of the effect of the treatments on weed species

In order to determine the effect of the different durations of solarization on other weeds, the weeds were counted four times in every plot within a 50 cm * 50 cm = 0.25 m^2 wooden-frame and converted to 1 m^2. In order to avoid a border effect, the counted area began 0.5 m from the edge of the plot. All *P. ramosa* in the 4.5 m * 4.5 m (20.25 m^2) area were carefully uprooted. The effectiveness of the treatments on *P. ramosa* was evaluated by counting the broomrape shoots after the plant was obtained from the soil.

2.3 Evaluation of the effect of the treatments on tomatoes

In order to determine the effect of the treatments on tomato yields, 20 plants from two inner rows starting 0.5 m from the edge of the plot were marked. The mature fruit of the marked plants was collected and the weight of the fruits was recorded. The means of the 20 plants are reported.

2.4 Statistical analyses

Analyses of variance were conducted using SPSS statistical software (version 14.00). Comparisons of means were performed using with Tukey's test at an $\alpha = 0.05$ level.

3. Results

3.1 Soil Temperature

The maximum temperature of the soil during solarization was recorded as 54 °C at a depth of 5 cm in 2007. The maximum temperature was 48 °C in areas in which no solarization was applied. At a depth of 10 cm, the maximum temperature was 47 °C in a solarized area and 41 °C in an area in which no solarization was applied. At a depth of 20 cm, the maximum temperatures were 41 °C and 35 °C in solarized and non-solarized soils, respectively (Tab. 1).

Tab. 1 The maximum temperature (°C) of solarized and non-solarized areas at three soil depths.

Tab. 1 *Die Maximaltemperatur* (°C) *der solarisierten und nicht-solarisierten Areale in den drei Bodentiefen.*

		5 cm	10 cm	20 cm
2007	Solarized	54.0	47.0	41.0
	Non-solarized	48.0	41.0	35.0
2008	Solarized	44.5	39.7	34.7
	Non-solarized	42.1	36.2	31.4

In 2008, the soil temperature at a depth of 5 cm was recorded at 44.5 °C in a solarized area and as 42.1 °C in an area where no solarization was applied. The soil temperature at a depth of 10 cm depth was 39.7 °C in a solarized area and 36.2 °C in an area in which no solarization was applied. The soil temperatures at a depth of 20 cm were 34.7 °C and 31.4 °C for solarized and non-solarized soil, respectively.

3.2 Effect of solarization on weeds and branched broomrape

3.2.1 Effects on weeds in the first year (2007-2008 season)

In the first year of study, solarization, regardless of duration, prevented the germination of some weed species; specifically, germination of *Amaranthus viridis*, *Setaria verticillata, Urtica urens, Solanum nigrum, Portulaca oleracea, Chenopodium album* and *Stellaria media* were reduced by 99-100 %. It also had some effect on *Cyperus rotundus* (60-75 % reduction) which was statistically not significant (Tab. 2).

Tab. 2 Effect of different durations of solarization on some weeds (First year, 2007-2008 season).

Tab. 2 *Der Effekt unterschiedlicher Solarisationszeitspannen auf einige Unkräuter (Erstes Versuchsjahr, 2007-2008).*

	Treatments				
Weeds	**Untreated Control**	**Solarization (2 weeks)**	**Solarization (4 weeks)**	**Solarization (6 weeks)**	
Amaranthus viridis	180.0[1]a[2]	1.0b	0.1b	0.0b	
Reduction of A. viridis (%)	-	99.4[3]	99.9	100	
Seteria verticillata	113.7a	0.5b	0.5b	0.0b	
S. verticillata (%)	-	99.6	99.6	100	
Urtica urens	44.0a	0.0b	0.0b	0.0b	
Urtica urens (%)	-	100	100	100	
Solanum nigrum	43.3a	0.0b	0.0b	0.0b	
S. nigrum (%)	-	100	100	100	
Portulaca oleracea	24.1a	0.3b	0.0b	0.0b	
P. oleracea (%)	-	98.8	100	100	
Chenopodium album	21.1a	0.0b	0.0b	0.0b	
C. album (%)	-	100	100	100	
Stelleria media	17.5a	0.0b	0.0b	0.0b	
S. media (%)	-	100	100	100	
Cyperus rotundus	20.6	8.3	5.1	7.3	N.S.
C. rotundus (%)	-	59.7	75.2	64.6	

[1] The number of weeds for each species is given as number per m2;
[2] Within rows, means followed by the same lower-case letter do not differ significantly (α = 0.05);
[3] The reduction of species are reported as the % reduction in numbers compared to the control

3.2.2 Effects on weeds in the second year (2008-2009 season)

The reduction in the germination of *A. viridis* was about 67-93 %, *S. verticillata* was reduced by about 78-94 % and germination of *U. urens* and *S. media* was prevented entirely (100 %; Tab. 3).

Tab. 3 Effect of different durations of solarization on some weeds (Second year, 2008-2009 season).

Tab. 3 *Der Effekt unterschiedlicher Solarisationszeitspannen auf einige Unkräuter (Zweites Versuchsjahr, 2008-2009).*

	Treatments			
Weeds	**Untreated Control**	**Solarization (2 weeks)**	**Solarization (4 weeks)**	**Solarization (6 weeks)**
Amaranthus viridis	90.9[1]a	30.4ab[2]	24.5ab	6.8b
Reduction of A. viridis (%)	-	66.6[3]	73.0	92.5
Seteria verticillata	124.9a	27.5b	24.6b	7.0b
S. verticillata (%)	-	78.0	80.3	94.4
Urtica urens	41.3a	0.3b	0.0b	0.0b
Urtica urens (%)	-	99.3	100	100
Stelleria media	35.3a	0.0b	0.0b	0.0b
S. media (%)	-	100	100	100
Cyperus rotundus	6.5b	10.1ab	7.4ab	18.4a
C. rotundus (%)	-	+55.4	+13.8	+183.0

[1] The number of weeds for each species is given as number per m^2
[2] Within rows, means followed by the same lower-case letter do not differ significantly (α = 0.05)
[3] The reduction of species are reported as the % reduction in numbers compared to the control

3.3 Effect of solarization on *Phelipanche ramosa*

In first year, no *P. ramosa* was observed in the plots where solarization was applied. Solarization's effect on reducing *P. ramosa* was 100 % regardless of the duration of solarization (Tab. 4).

Tab. 4 Effect of different durations of solarization *Phelipanche ramose*.

Tab. 4 *Der Effekt unterschiedlicher Solarisationszeitspannen auf* Phelipanche ramose.

	First year (2007-08 season)		Second year (2008-09 season)	
Treatments	***P. ramosa* (Number of shoots/plot)**	**Reduction in *P. ramosa* shoots (%)**	***P. ramosa* (Number of shoots/plot)**	**Reduction in *P. ramosa* shoots (%)**
Untreated Control	229.8a	-	316.5a	-
Solarization (2 weeks)	0 b	100	252.6ab	20.2
Solarization (4 weeks)	0 b	100	168.3bc	46.8
Solarization (6 weeks)	0 b	100	82.2c	74.0

Within column, means followed by the same lower-case letter do not differ significantly ($\alpha = 0.05$)

In the second year of the study, 2-, 4- and 6-week solarization periods resulted in reductions of 20, 47 and 74 %, respectively. The results for the 4- and 6-week durations were statistically significant compared to the untreated control (Tab. 4).

3.4 Effects of solarization on the yield of tomatoes

In the first year of study, the increase in tomato yield paralleled the solarization period extension. The highest yield was obtained from the plots solarized for 6 weeks. The increase in yield was 27 % in plots solarized for 4 weeks and 36 % in plots solarized for 6 weeks (Tab. 5). In the second year of study, the increase in yield was 19 % in plots solarized for 4 weeks and 24 % in plots for solarized 6 weeks.

Tab. 5 Effect of different durations of solarization on the yield of tomato plants.

Tab. 5 *Der Effekt unterschiedlicher Solarisationszeitspannen auf Tomatenerträge.*

	First year (2007-08 season)		Second year (2008-09 season)	
Treatments	**Yield of tomatoes (g/20 plants)**	**% increase in the yield of tomatoes**	**Yield of tomatoes (g/20 plants)**	**% increase in the yield of tomatoes**
Untreated Control	24516.5b	-	16985.0b	-
Solarization (2 weeks)	28132.0ab	14.8	16692.5b	0.0
Solarization (4 weeks)	31116.0ab	26.9	20260.0ab	19.3
Solarization (6 weeks)	32271.0a	35.7	21111.0a	24.4

Within column, means followed by the same lower-case letter do not differ significantly (Tukey= 0.05)

4. Discussion

When the results were examined, soil temperature was observed to depend on soil depth. Additionally, although solarization time increased soil temperature by 6 °C in the first experiment, it led to only a 2.5-3.5 °C increase in soil temperature in the second year of study. The low solarization effect in the second year was thought to be a result of the low temperature of the area. Previous studies have observed an increase in temperature that was similar to or higher than that seen in our study. In the Mediterranean Region of Turkey, YÜCEL et al. (2007) found that at depths of 10 and 20 cm, the temperature was about 10 °C greater in solarized areas than in non-solarized area. The maximum soil temperature increased to 40.9 and 47.1 °C separately, in two years at a 15 cm-depth in the Aegean Region (KAŞKAVALCI, 2007). BÜLBÜL and UYGUR (2009) stated that solarization (8 weeks) increased the temperature more than 10 °C, controlled *P. ramosa* effectively and increased the tomato yields in Adana/Turkey. VIZANTINOPOULOS and KATRANIS (1993) stated that the maximum temperature in solarized areas was 7-9 °C warmer than that in non-solarized areas at a depth of 7.5 cm. IOANNOU (2000) stated that solarization increased the maximum soil temperature by about

9 °C in Cyprus. Finally, SAHILE et al. (2005) stated that solarization with clear polyethylene increased temperatures from 32 to 48 °C, 33 to 46 °C and 37 to 49 °C in three different locations in Ethiopia.

Tomato yield in our studies increased in response to soil solarization. The results of these studies examining the use of solarization to control weeds and its effect on yield are in accordance with other studies. VIZANTINOPOULOS and KATRANIS (1993) stated that three or four weeks of solarization was effective against *Triticum aestivum*, *P. oleracea*, *Digitaria sanguinalis*, *S. nigrum* and *Amaranthus* spp. in Greece. IOANNOU (2000) stated that solarization for eight weeks in Cyprus increased tomato yield and had an effect on weed control for *Malva* spp., *Amaranthus* spp., *Chrysanthemum* spp., *C. album*, *Calendula arvensis*, *Lolium rigidum* and *U. urens*. However, little effect was found for *Convolvulus arvensis* and *C. rotundus*. In Western Anatolia in Turkey, the maximum soil temperatures at depths of 5 and 10 cm were 55 and 50 °C, respectively, for 44 days of solarization. This solarization controlled *Poa annua*, *P. oleracea* and *Amaranthus retroflexus* effectively, but did not control *C. rotundus* and *Conyza canadensis* (BENLIOĞLU et al., 2002). In addition, average maximum temperatures of 47.6 and 52.1 °C at a depth of 5 cm for 49-52 days of solarization controlled *Poa annua*, *P. oleracea*, *Amaranthus retroflexus* and *Echinochloa cruss-galli* but not *C. canadensis* (BENLIOĞLU et al., 2005). Also, BENLIOĞLU et al. (2002, 2005) stated that solarization increased the yield of strawberry plants. In 2004, after solarization for 45-50 days (average of 47.5 °C), weeds such as *P. oleracea*, *A. retroflexus*, *Raphanus raphanistrum*, *P. annua* and *Matricaria chamomille* were suppressed, but *C. canadensis* was not (BOZ, 2004).

In our experiments, higher temperatures controlled *P. ramosa* (Syn: *Orobanche ramosa*) regardless of the duration of solarization. In other studies examining the control of *Orobanche* species in Jordan, ABU-IRMAILEH (1991) stated that 100 % reduction of *O. aegyptiaca* was obtained after solarization for 6 weeks, but not all weeds were sensitive. In addition, tomato yield was increased. SAHILE et al. (2005) stated that solarization for two, four, and six or eight weeks decreased the abundance of *O. ramosa* and *O. cernua* by different amounts and that tomato yield was generally increased in three different locations in Ethiophia. ABDALLA and DABROWSKI (1997) stated that solarization for 6-7 weeks controlled *Orobanche* and many other weeds and increased the yield of tomatoes by 63 %. LINKE (1999) suggested four weeks of solarization for the control of *Orobanche*; shorter periods of solarization were not sufficient to inhibit the seeds of *Orobanche*. MAUROMICALE et al. (2005) found that solarization controlled *O. ramosa* and increased the yield of tomatoes in Italy.

In our study, solarization led to an increase in tomato yield. An increase in available nutrients due to solarization could be partly responsible for this increase in yield. For example, after the application of solarization, weeds, nematodes and fungi were decreased and the mineralization of available organic matter was increased (LINKE, 1999). Addition, ARORA and YADURAJO (1998) stated that solarization increased the NO_3-N and NH_4-N concentrations compared to non-solarized areas in India.

It is apparent that solarization that achieves high temperatures is the best method of weed control in tomato cultivation in greenhouse conditions where weed and *P. ramosa* cause trouble.

Acknowledgements

The authors gratefully acknowledge the Scientific and Technological Research Council of Turkey for the support given to this project ((TUBITAK-106 G 072). And also thank Dr. Zeynel DALKILIÇ, Dr. Filiz BÜLBÜL, and to American Journal Experts for English Grammar.

References

ABDALLA, N.E.K. AND Z.T. DABROWSKI, 1997: EFFECT OF SOIL SOLARIZATION ON *OROBANCHE* IN THE CENTRAL SUDAN. SECOND INTERNATIONAL CONFERENCE ON SOIL SOLARIZATION AND INTEGRATED MANAGEMENT OF SOILBORNE PESTS. 16-21 MARCH. ALEPPO, SYRIA, PP. 240-245.

ABDALLAH, F.A., A. HAMADACHE, M. KHEDDAM AND M.E. MAATOUGUI, 1999: LE PROBLEME DE L'OROBANCHE EN ALGERIE. IN: KROSCHEL J, M. ABDERABIHI AND H. BETZ (EDS.): ADVANCES IN PARASITIC WEED CONTROL AT ON-FARM LEVEL. VOL. II, JOINT ACTION TO CONTROL *OROBANCHE* IN THE WANA REGION, PP. 17-25.

Abu-Irmaileh, B.E., 1991: Weed control in squash and tomato fields by soil solarization in the Jordan Valley. Weed Research **31**, 125-133.

Arora, A. and N.T. Yaduraju, 1998: High-temperature effects on germination and viability of weed seeds in soil. Journal of Agronomy and Crop Science **181**, 35-43. Abstract.

Benlioğlu, S., Ö. Boz, A. Yildiz, G. Kaşkavalci and K. Benlioğlu, 2002: Soil solarization options in Aydin strawberry without methyl bromide. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 6-8 November, 8, 1-5.

Benlioğlu, S., Ö. Boz, A. Yildiz, G. Kaşkavalci and K. Benlioğlu, 2005: Alternative soil solarization treatments for the control of soil-borne diseases and weeds of strawberry in the Western Anatolia of Turkey. Journal of Phytopathology **153**, 423–430.

Boz, Ö., 2004: Efficacy and profitability of solarization for weed control in strawberry. Asian Journal of Plant Science **3**, 731-735.

Boz, Ö., M.N. Doğan, D. Öğüt and K. Kir, 2008: Occurrence of weeds in greenhouse tomato in the Aegean Region of Turkey with special emphasis on *Orobanche* spp. Journal of Plant Diseases and Protection **Special Issue XXI**, 521-526.

Bülbül, F. and F.N. Uygur, 2009: The effect of soil solarization on broomrape in greenhouse tomato. In: Rubilales, D., J. Wetswood and A. Uludag (eds.), 10th World Congress on Parasitic Plants. p. 97. 8-12 June, Kusadasi/Turkey.

Hassanein, E. and A. Salim, 1999: Country paper about *Orobanche* and its control in Egypt, 1999. In: Kroschel J., M. Abderabihi and H. Betz (eds.): Advances in Parasitic Weed Control at on-Farm Level. Vol. II, Joint Action to Control *Orobanche* in the Wana Region, pp. 27-35.

Ioannou, N., 2000: Soil solarization as a substitute for methyl bromide fumigation in greenhouse tomato production in Cyprus. Phytoparasitica **28**, 1-9.

Kaşkavalci, G., 2007: Effects of soil solarization and organic amendment treatments for controlling *Meloidogyne incognita* in tomato cultivars in Western Anatolia. Turkish Journal of Agriculture and Forestry **31**, 159-167.

Katan, J. and J.E. De Vay, 1991: Soil solarization. CRS Press, London, UK. 267 p.

Kroschel, J., 2001: A Technical Manual for Parasitic Weed Research and Extension. Kluwer Academic Publishers. p. 256.

Linke, K.H., 1999: Status quo of *Orobanche* management: Preventive, cultural, and physical control. In: Kroschel J, M. Abderabihi and H. Betz (eds.): Advances in Parasitic Weed Control at on-Farm Level. Vol. II, Joint Action to Control *Orobanche* in the Wana Region, pp. 107-133.

Mauromicale, G., A.L. Monaco, A.M.G. Longo and A. Restuccia, 2005: Soil solarization, a nonchemical method to control branched broomrape (*Orobanche ramosa*) and improve the yield of greenhouse tomato. Weed Science **53,** 877-883.

Müller-Stöver, D., M.A. Adam, O.A. Al-Menoufi and J. Kroschel, 1999: Importance of *Orobanche* spp. in two Regions of Egypt-Farmers: perceptions and difficulties, and prospects of control. In: Kroschel J, M. Abderabihi and H. Betz (eds.): Advances in Parasitic Weed Control at on-Farm Level. Vol. II, Joint Action to Control *Orobanche* in the Wana Region, pp. 37-52.

Nemli, Y. and H. Demirkan, 1988: Problem of broomrape in tomato plantation in Marmara Region of Turkey. The Journal of Turkish Phytopathology **17**, 126.

Orel-Aksoy, E. and F.N. Uygur, 2003: Distribution of *Orobanche* spp. in the East Mediterranean Region of Turkey. 7th EWRS (European Weed Research Society) Mediterranean Symposium. Adana-Turkey. pp. 131-132.

Parker, C., 1994: The present state of the *Orobanche* problem. Germination ecology of *Striga* and *Orobanche* an overview. Biology and management of *Orobanche*. In: Pieterse, A.H., J.A.C. Verkleij and S.J. ter Borg (eds.): Proceedings of the third International workshop on *Orobanche* and related *Striga* research, Royal Tropical Institute, Netherlands, 1994, pp. 36-48.

Sahile, G., G. Abebe and M.A.T. Abdel-Rahman, 2005: Effect of soil solarization on *Orobanche* soil seed bank and tomato yield in central rift valley of Ethiopia. World Journal of Agricultural Science **1**, 143-147.

Stapleton, J.J., 1996: Fumigation and solarization practice in plasticulture systems. HortTechnology **6**, 189-192.

Vizantinopoulos, S. and N. Katranis, 1993: Soil solarization in Greece. Weed Research **33**, 225-230.

Yücel, S., İ.H. Elekçioğlu, C. Can, M.A. Söğüt and A. Özarslandan, 2007: Alternative treatments to methyl bromide in the Eastern Mediterranean Region of Turkey. Turkish Journal of Agriculture and Forestry **31**, 47-53.