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Methyl Bromide Alternatives for Controlling *Meloidogyne incognita* in Pepper Cultivars in the Eastern Mediterranean Region of Turkey

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Abstract: The efficacy of soil solarization in combination with *Trichoderma* spp. (S+Tr), dazomet (S+D 300, 400 and 500 kg ha^{-1} of dosages) and fresh chicken manure (S+CM 12.5 t ha^{-1}) as methyl bromide (MB) alternatives against root-knot nematodes on pepper cultivars was investigated in plastic greenhouses in the eastern Mediterranean Region of Turkey. Soil solarization for 6 weeks increased soil temperature by 8.4 and 7.8 °C at 10 cm soil depth in 2000 and 2001, respectively. Second stage juvenile (J2) populations of *M. incognita* were efficiently reduced by S + Tr, S + D300, S + D400, S + D500, S + CM, and MB treatments until May 16 in both the first and second years. However, J2 population began to increase after February in untreated control plots. Root gall indices were low (0.7 to 1.9) in all treatments except untreated control where gall index was approximately 6 (0 to 10 galling index scale). All the alternative treatments to MB effectively suppressed the damage of root-knot nematodes during the entire vegetation period. Yield values were not significantly different between alternative treatments and MB in the experiments.

Key Words: Chicken manure, dazomet, methyl bromide, pepper, root-knot nematode, soil solarization

Doğu Akdeniz Bölgesi'nde Biber Çeşitlerinde *Meloidogyne incognita* ile Mücadelede Metil Bromüre Alternatif Yöntemler

Özet: Doğu Akdeniz Bölgesi'nde farklı biber seralarında metil bromür (MB) alternatif olarak toprak solarizasyonunun Trichoderma (S+Tr), dazomet (S+D 300, 400 ve 500 kg ha^{-1} dozlarında) ve yaş tavuk gübresi (S+CM, 12.5 t ha^{-1}) ile kombine uygulamalarının Kök-ur nematodlarına karşı etkinlikleri araştırılmıştır. Solarizasyon (6 hafta) yapılan alanda 10 cm toprak derinliğinde sıcaklıklar 2000 ve 2001 yıllarında sırasıyla 8.4 ve 7.8 °C artmıştır. Her iki yılda da, Kök-ur nematodunun ikinci dönem larva (L2) populasyonları S+Tr, S+D300, S+D400, S+D500, S+CM ve MB uygulamaları ile 16 Mayıs'a kadar önemli oranda düşürülmüştür. Uygulama yapılmayan kontrol parsellerinde ise, L2 populasyonu Şubat ayında artmaya başlamıştır. Uygulama yapılan parsellerin tümünde bitki köklerinde urlanma oranları çok düşük seviyelerde bulunurken (0.7 ile 1.9), uygulama yapılmayan kontrol parsellerinde urlanma oranı yaklaşık 6 olarak tespit edilmiştir (0 – 10 urlanma oranı ıskalası). MB'e alternatif olarak denemeye alınan tüm uygulamalarda yetiştirme sezonu süresince Kök-ur nematodları başarılı bir şekilde önlenmiştir ve alternatif uygulamalar ile MB arasında verim değerleri açısından önemli bir farklılık belirlenmemiştir.

Anahtar Sözcükler: Tavuk gübresi, dazomet, metil bromür, biber, kök-ur nematodları, toprak solarizasyonu

Introduction

The root-knot nematodes are an important agronomic pest of numerous crops grown in tropical and subtropical regions of the world. They are sedentary endoparasitic nematodes and cause root cell deformation. Plant roots injured by nematodes are susceptible to soil borne pathogens, and increased crop losses occur due to resulting disease complexes (Taylor, 1979; Sikora and Carter, 1987). *Meloidogyne incognita*, *M. javanica, M. arenaria* and *M. hapla* are the most widespread root-knot nematodes in the world (Nestcher and Sikora, 1990), and were detected in bananas and vegetables in Turkey

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(Yüksel, 1974; Elekçioğlu and Uygun, 1994). In addition, *M. incognita* was reported to be the most commonly observed root-knot nematode on pepper cultivars in the Mediterranean Region of Turkey (Söğüt and Elekçioğlu, 2000).

Fumigant biocides such as methyl bromide (MB) and nematicides are commonly used as soil fumigants to control root-knot nematodes and soil borne diseases of vegetables in Turkey. Such chemicals have been banned in European countries and many states in the USA due to their hazardous effects on human health, environment, depleting the ozone layer and their residues in soil and water (Broun and Supkoff, 1994; U.S.EPA, 1999). Therefore, the use of MB will be banned by 2015 all over the world, whereas Turkey plans to remove it by 2007 (Yücel et al., 2001). As many farmers are highly dependent on this chemical, there is an urgent need to develop alternative control strategies that are more environmentally friendly.

Recently, soil solarization has been a popular method for soil disinfestation against soil borne pathogens and nematodes. However, soil solarization alone may not be consistently effective to control these pests. Therefore, to increase its effect, it is usually combined with cultural, biological and/or chemical (preferably at reduced dosages) methods (Chellemi and Olson, 1994; Katan, 1996; Fuentes et al., 1997; Coelho et al., 1999).

The aim of the present study is to test the efficacy of several MB alternatives for controlling *M. incognita* in pepper grown under plastic greenhouses in the eastern Mediterranean region of Turkey.

Materials and Methods

Five parallel experiments in the summer of 2000 and one experiment in the summer of 2001 were conducted on pepper cultivars (*Capsicum annum* L.) in plastic greenhouses in Kazanlı and Adanalıoğlu, Mersin, Turkey. Amazon F1, Donna F1, Banko 07 F1, C. Madison F1 and Kazanlı Sivrisi F1 cultivars were grown in each plastic greenhouse (PG) in the experiments, and the plastic greenhouses were designated as PG1, PG2, PG3, PG4, PG5 and PG6 (Table 1). All greenhouses were naturally infested with *M. incognita* and had previously hosted pepper crops severely damaged by *M. incognita*. Soil samples collected from each replication prior to the treatments revealed an average infestation of 105-1513 *M. incognita* second stage juveniles (J2) per 50 ml of soil.

Soil texture components were 6.6% clay, 4.6% loam and 88.9% sand in PG1, and 27.8% clay, 13.7% loam and 58.5% sand in PG2. Other plastic greenhouses had 11.5% to 18% clay, 8.5% to 16.2% loam and 71.2% to 74.5% sand texture components. Soils were calcareous, low in salt and had an alkaline pH (pH: 7.4 to 7.8) in all plastic greenhouses.

Table 1. Pepper cultivars and treatments applied to plastic greenhouses.

Year 1 (2000-2001)					Year 2 (2001-2002)
Plastic greenhouse1 (PG1) Amazon F1 [a]	Plastic greenhouse2 (PG2) Donna F1	Plastic greenhouse3 (PG3) Banko 07 F1	Plastic greenhouse4 (PG4) C.Madison F1	Plastic greenhouse5 (PG5) K.Sivrisi	Plastic greenhouse6 (PG6) Amazon F1
S + Tr [b]	S + Tr	S + Tr	S + Tr	S + Tr	S + Tr
S + CM [c]	S + CM	S + CM	S + CM	S + CM	S + D300
S + D400 [d]	S + D400	S + D400	S + D400	S + D400	S + D400
MB [e]	Untreated control	Untreated control	MB	Untreated control	S + D500
Untreated control			Untreated control		MB
					Untreated control

[a] Pepper cultivars

[b] S+Tr: Solarization + *Trichoderma* spp. (Promot Plus, T-22)

[c] S+CM: Solarization + fresh chicken manure (12.5 t ha^{-1})

[d] S+D: Solarization + Dazomet 97% GR (Doses: 300, 400, 500 kg ha^{-1})

[e] MB: Methyl Bromide (98%) (Doses: 600 kg ha^{-1})

Experiments in each PG were established in July after harvesting previous pepper crops. Before treatments, plastic sheets above the PG were removed and the soil was ploughed, and then watered to saturation. A week later, the soil was rotary cultivated, and then divided into plots each measuring 2 x 4 m^2 in each PG. For soil solarization, drip irrigation pipes were placed into the plots with 25-cm intervals for irrigation, and then covered with clear polyethylene mulch (0.07 mm). Polyethylene mulch was covered for a 6 week period between July and September 2000 and 2001.

Trichoderma spp., dazomet (97%) and fresh chicken manure were combined with soil solarization for each plastic greenhouse. *Trichoderma* spp. was applied after the soil solarization. Dazomet and fresh chicken manure were applied to plots before soil solarization.

Trichoderma spp. was applied twice with 1-month interval. In 2000, Promot Plus (JH Biotech, INC., ingredients: *Trichoderma koingii* 3 x 10^7 cfu/g dry weight and *T. harzianum* 2 x 10^7 cfu/g dry weight) was applied to the seedlings' compost at a concentration of 50 g 20 l^{-1}. Later, the plants were transferred to solarized plots, and the second Promot Plus treatment was applied through irrigation system a rate of 2 kg ha^{-1} to each PG. In 2001, T-22 Planter Box (BioWorks, Inc., ingredient: *T. harzianum* Rifai strain KRL-AG2 1 x 10^7 cfu g^{-1} dry weight) was applied to the seedlings' compost at a concentration of 50 g 20 l^{-1} twice with 1- month interval. Then, the plants were transferred to solarized plots.

Fresh chicken manure was used in experiments conducted in year 1, and was uniformly distributed on the soil surface at 12.5 t ha^{-1} for each plot. Similarly, dazomet (97%), the granular pesticide, was broadcasted on to the soil surface. Then, dazomet and chicken manure were incorporated into a depth of 10- to 15 cm with a rototiller. In the first year, dazomet was applied at 400 kg ha^{-1} dosage. In the second year, it was applied at dosages of 300, 400 and 500 kg ha^{-1} in plots. After the applications of dazomet and fresh chicken manure, drip irrigation pipes were placed into plots with 25-cm intervals, and then clear polyethylene mulch (0.07 mm) covered the soil surface for 6 weeks.

Methyl bromide 98% plus 2% chloropicrin was applied to PG1 and PG4 in the first year and PG6 in the the second year at 600 kg ha^{-1} under the polyethylene mulch. The polyethylene mulch was removed a week later.

In year 1 and 2, plastic sheets were removed from the PG in September for the new growth season. Pepper seedlings were transplanted in October and harvested in July. All experiments were established with 5 replications per treatment in each PG.

Assessment of root-knot nematodes

Fluctuation of second stage juveniles: Soil samples for analysis of second stage juveniles of *M. incognita* were collected from all plots in each plastic greenhouse prior to the treatment (for initial population), after the soil solarization and throughout the growing season with 3-week intervals until the harvest. Each soil sample consisted of 3 soil cores (2.5 cm diam. x 30 cm depth) collected in a systematic pattern from each plot (8 m^2 area). The 3 cores were mixed, and a 50 ml (100 g) subsample was removed from each soil sample. Second stage juveniles of *M. incognita* were extracted by using a modified Baermann funnel method using 50 ml of soil (Hooper, 1986). Then, nematodes were counted under a light microscope.

J2 population densities of *M. incognita* were followed in all treatments from October to July. Finally, the fluctuation of J2 population in each treatment and each pepper cultivar was determined and showed graphically.

Root galling index: The root galling index was determined by examining 10 plant root systems in each plot using a galling index scale of 0 to 10 (Barker, 1985), where 0 represented roots with no galls, and 10 represented maximal degree of galling at the end of the growing season.

Yield evaluation

The yield data were taken from each treatment as the total harvest at the end of the season, regardless of replication in each plastic greenhouse in year 1. Therefore, yield evaluation was carried out for the first year according to the pepper cultivar and treatments by using univariate analysis. Total fruit yield was taken from each treatment in 5 plastic greenhouses for each replication; then, main effects of treatments and pepper cultivar on total fruit yield were determined.

Statistical analysis: Root galling index and total fruit yield were analyzed following standard procedures for analysis of variance (ANOVA), and differences between means were separated by Student Newman Keuls (S-N-K) test, and differences referred to in the text were significant at the <0.05 level of probability. All analysis was performed using SPSS 10.0 (SPSS Inc., Chicago, Illinois, US).

Results

Soil temperature: The individual temperatures recorded were higher in solarized plots than those in non-solarized plots (Table 2). In 2000, the mean maximum temperature recorded in the solarized plot was 42.3 ± 0.8 °C, while in the non-solarized plot it was 31.2 ± 0.8 °C. In 2001, the corresponding temperatures were 45.4 ± 0.4 °C and 34.0 ± 0.7 °C, respectively. The mean difference between solarized and non-solarized treatments was 8.4 ± 0.7 °C and 7.8 ± 0.4 °C in year 1 and 2, respectively. The maximum absolute temperatures were 45.0 °C and 46.4 °C in solarized and 34.0 °C and 36.7 °C in the non-solarized plots in year 1 and 2, respectively.

J2 Population fluctuation: Meloidogyne incognita showed good growth and reproduction on all the pepper cultivars grown in plastic greenhouses (Figures 1 and 2). In year 1, J2 population remained low until February in all pepper cultivars in the untreated control plots except C. Madison grown in PG4. J2 density began to increase with increasing temperature at the beginning of the spring. However, the number of juveniles began to increase after November in C. Madison cv. in PG4.

In PG1, root-knot nematode juveniles were not detected in the soil for the entire season in S+Tr and S+CM plots. Also, they were low until May in S+D400 plot. In MB plot, J2 density was low until the beginning of April and showed a rapid increase until the end of the growing season (Figure 1). In PG2, second stage juveniles were not detected in S+Tr and S+CM plots until May. However, J2 was present in low density until the end of April in S+D400 plot, and then its density showed a large increase in May (Figure 1). In PG3, all soil treatments dramatically reduced J2 populations during the growing season (Figure 1). In PG4, J2 was not found in MB and S+D400 plots until May. Though the number of J2 was low till April in S+Tr plot, afterward it gradually increased in early June. Moreover, in S+CM plot, J2 density was extremely high between April and May (Figure 1). In PG5, J2 was reduced to undetectable levels during the growing season in S+D400 plot. However, J2 population gradually increased from April 3 to May 16 in S+Tr and S+CM plots (Figure 1).

In year 2, root-knot nematode juveniles were nearly undetectable until April 30 in all treatments except for untreated control plots in PG6. J2 population exhibited a progressive increase between April 30 and May 27 in all treatments, but this increment was very low compared to the untreated control plot (Figure 2).

Root galling index: In year 1, root galling severity was dramatically reduced in S+Tr, S+D400, S+CM and MB plots compared to the untreated controls in all experiments ($P < 0.05$) (Table 3). Galling indices in MB plots were higher than S+Tr, S+D400 and S+CM plots in 2 plastic greenhouses (PG1 and PG4). While no significant differences observed between MB and other alternative methods in PG4, the difference between MB

Table 2. Soil temperatures (°C) at 10 cm depth during soil solarization and difference between solarized and non-solarized treatments based on an average of recording per reading.

	Soil temperature in solarized plot				Soil temperature in non-solarized plot				
Date	Max. [b]	Mean [c]	Change [d]	Absolute max. [e]	Max. [b]	Mean [c]	Change [d]	Absolute max. [e]	Difference [a]
3 July - 24 Aug. 2000	42.3 ± 0.8	37.3 ± 1.3	10.0 ± 0.6	45.0	31.2 ± 0.8	28.9 ± 0.7	4.5 ± 0.3	34.0	8.4 ± 0.7
17 July - 03 Sept. 2001	45.4 ± 0.4	39.2 ± 1.5	12.5 ± 0.3	46.4	34.0 ± 0.7	31.4 ± 0.8	5.2 ± 0.7	36.7	7.8 ± 0.4

[a] Mean of difference of average soil temperature between solarized and non-solarized treatments

[b] Mean maximum soil temperature (averaged over treatments)

[c] Mean temperature (averaged over all recordings)

[d] Mean change of temperature (average of the daily difference between the highest and the lowest recordings)

[e] Maximum recorded temperature

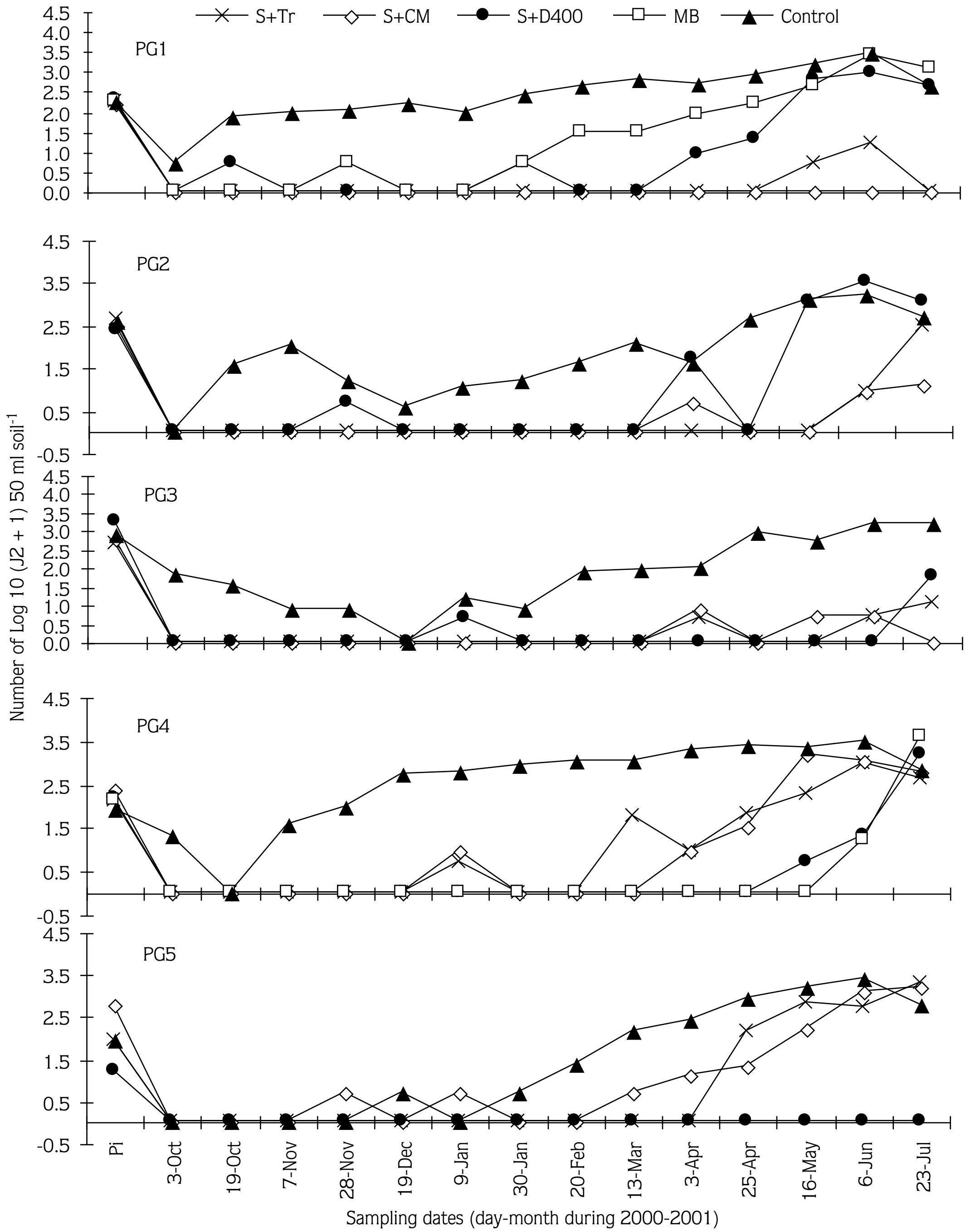

Figure 1. Population dynamics of J2 of *Meloidogyne incognita* in 5 plastic greenhouses during 2000-2001 growing periods. Amazon F1, Donna F1, Banko 07 F1, C. Madison and Kazanlı Sivrisi were grown in PG1, PG2, PG3, PG4 and PG5, respectively. (Pi: Initial population of second stage juveniles).

and other alternative methods was significant in PG1 ($P < 0.05$) (Table 3). The galling indices among S+Tr, S+D 400 and S+CM were similar and no significant differences were observed in PG1, PG3 and PG4. On the other hand, gall indices of S+D 400 in PG2 and S+CM in PG5 were significantly higher than the other alternatives for each plastic greenhouse.

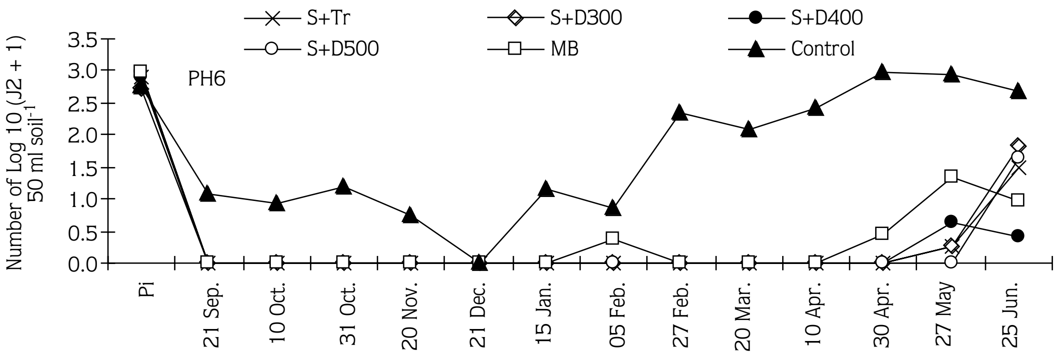

Figure 2. Population dynamics of J2 of *Meloidogyne incognita* in PG6 during 2001-2002 growing periods. Amazon F1 was grown in PG6 (Pi: Initial population of second stage juveniles).

In year 2, root galling indices were low in all treatments when compared to the untreated control plot ($P < 0.05$) (Table 3). Although the least galling indices were observed on S+D300, the differences among S+D300, S+D400 and S+D500 were not significant ($P < 0.05$) (Table 3).

Yield Evaluation: Although there were no statistically significant yield differences pepper cultivars in year 1, yield differences among treatments were significant ($P < 0.05$). There were no significant differences for fruit yield between MB and alternative treatments ($P < 0.05$) (Figure 3). Yield was markedly reduced in control plots, and, the difference between the treatments and untreated control was significant ($P < 0.05$) (Figure 3). Fruit yield was reduced in the range of 74% to 78% in control plots compared to the treatments in year 1 (Figure 3). In year 2, fruit yield was not reliably obtained from experimental site, and, therefore, it was not evaluated.

Discussion

Meloidogyne incognita well developed and reproduced on all pepper cultivars that were grown in plastic greenhouses. In the untreated control plots, galling indices were found to be between 4.5 and 7.3 according to the galling index scale of 0 to 10. Most researchers are in agreement that plant varieties are important in regulating the development of root-knot nematodes (Wallace, 1963; Ferris and Van Gundy, 1979; Khan and Khan, 1991; Vito et al., 1991). There are few resistant pepper cultivars among the available cultivars and hybrids to *M. incognita* (Netscher and Sikora, 1990). In our experiments, pepper cultivars were found to be moderately susceptible to *M. incognita*.

Soil solarization conditions were suitable to control *M. incognita* in the eastern Mediterranean region of Turkey. The respective differences in mean soil temperatures due to solarization at 10 cm soil depth were 8.4 ± 0.7 °C and 7.8 ± 0.4 °C in 2000 and 2001, respectively. Similarly, Cartia et al. (1997) reported a temperature increase of 9-11 °C at 15 cm soil depth in solarized soil in Italy. Chellemi and Olson (1994) reported an average temperature difference of 8 °C between solarized and control plots at 15 cm soil depth in Florida. Yücel (1995) reported a temperature difference of 7 °C and 6 °C at 10 cm soil depth in 1990 and 1991, respectively, in the eastern Mediterranean region of Turkey, which were close to our results.

The effectiveness of soil solarization on various nematode species was reported by different studies (McSorley and Parrado, 1986; Heald and Robinson, 1987; Stapleton et al., 1987; Sharma and Nene, 1990; Chellemi et al., 1993; Bisheya et al., 1997; Lamberti et al., 2000). On the other hand, Stapleton and Heald (1991) expressed some disadvantages of soil solarization including production models, various environmental conditions and errors in applications. Since plant parasitic nematodes are mobile organisms in different soil depths, and cover a larger area in a field, they may be more resistant than the other soil borne organisms to soil solarization. Further, it was reported that solarization had little effect on nematodes in several studies (Fuentes et al., 1997; Yücel et al., 1998). Lamberti and Noling (1997) reported that soil solarization was the most important method being able to combine other control

Table 3. Effect of methyl bromide and soil solarization in combination with *Trichoderma* spp., fresh chicken manure and dazomet on root galling index measured at the end of the growing season in year 1 and 2.

Plastic G.houses	Treatments	Galling Index ± SE
PG 1* (Amazon F1)	Solarization+Trichoderma	0.0 ± 0.0 a
	Solarization+Dazomet 400	0.4 ± 0.2 a
	Solarization+Chicken manure	0.0 ± 0.0 a
	Methyl bromide	1.8 ± 0.1 b
	Untreated Control	5.8 ± 0.1 c
PG 2* (Donna F1)	Solarization+Trichoderma	1.7 ± 1.0 ab
	Solarization+Dazomet 400	3.0 ± 0.5 b
	Solarization+Chicken manure	0.5 ± 0.3 a
	Untreated Control	5.9 ± 0.1 c
PG 3* (Banko 07 F1)	Solarization+Trichoderma	0.0 ± 0.0 a
	Solarization+Dazomet 400	0.1 ± 0.1 a
	Solarization+Chicken manure	0.2 ± 0.2 a
	Untreated Control	6.3 ± 0.2 b
PG 4* (C. Madison F1)	Solarization+Trichoderma	1.2 ± 0.3 a
	Solarization+Dazomet 400	1.5 ± 1.0 a
	Solarization+Chicken manure	1.2 ± 0.4 a
	Methyl bromide	2.1 ± 0.6 a
	Untreated Control	7.3 ± 0.3 b
PG 5* (K. Sivrisi F1)	Solarization+Trichoderma	0.5 ± 0.2 b
	Solarization+Dazomet 400	0.04 ± 0.04 a
	Solarization+Chicken manure	2.6 ± 0.2 c
	Untreated Control	4.5 ± 0.4 d
PG 6** (Amazon F1)	Solarization+Trichoderma	0.8 ± 0.2 a
	Solarization+Dazomet 300	0.9 ± 0.2 a
	Solarization+Dazomet 400	1.0 ± 0.2 a
	Solarization+Dazomet 500	1.0 ± 0.2 a
	Methyl bromide	1.0 ± 1.0 a
	Untreated Control	4.9 ± 1.0 b

* : 2000-2001 growing period
**: 2001-2002 growing period
Column means followed by the same letter are not significantly different ($P < 0.05$) according to Student Newman Keuls test (SE: Standard Error).

methods for integrated nematode management. Suppression of *M. incognita* was improved when solarization was used in conjunction with chemical fumigation (Chellemi et al., 1997) or composted chicken litter (Gamliel and Stapleton, 1993).

Meloidogyne incognita was satisfactorily managed by soil solarization combined with *Trichoderma* spp., dazomet and fresh chicken manure as an alternative to MB in our experiments. On the other hand, roots of pepper plants in all treatments in each PG were galled by

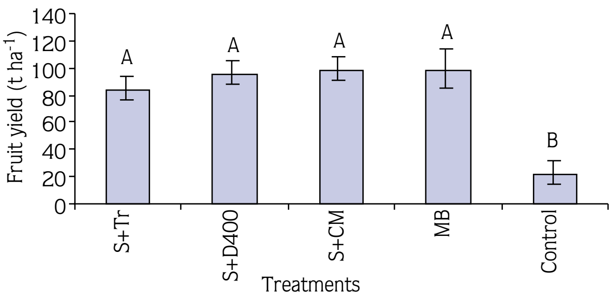

Figure 3. Fruit yield differences between soil disinfestation treatments in year 1 (The same letter indicates no significant difference ($P < 0.05$) in accordance with S-N-K test).

this pest with a range of 10% and 20%. Root-knot nematodes are very successful organisms in nature and they have very high fecundity. Therefore, second stage juveniles in soil may form a large population in a short time when soil temperatures were favorable through the end of the growing season.

Juveniles of root-knot nematodes in soil were reduced effectively during the growing season and root galling indices were low in all soil solarization treatments combined with *Trichoderma* spp. plots in both years. *Trichoderma* isolates, as a biological control agent against soil borne diseases, have long been reported to be effective and some commercial preparations are currently available (Amadioha, 1999; Gromovykh et al., 1999). An isolate of *T. harzianum* (T-22) was reported to control *M. javanica* (Sharon et al., 1998). However, T-22 isolate, which was used in our experiments, was not effective for controlling *M. incognita* population on bell pepper cv. Amazon in controlled conditions (unpublished data). Pepper roots treated with T-22 exhibited gall development, but they developed as much as uninfected roots.

Fresh chicken manure (CM), as the source of organic matter, was combined with soil solarization only in year 1. J2 population and root gall indices were decreased to a very low level by S+CM treatment compared to the untreated control plots. Kaplan et al. (1992), Kaplan and Noe (1993) and Mian and Rodriguez-Kabana (1982) reported that the application of fresh chicken manure reduced populations of root-knot nematodes. Gamliel and Stapleton (1993) reported a temperature increase of 2 ^{o}C when soil solarization was applied in combination with chicken manure. In the same study, solarization alone was less effective compared to its combination with fresh chicken manure. It should be noted that some negative effects could occur such as salinity and aridity when CM is used excessively in the soil (Conn and Lazarovits, 1999; Riegel and Noe, 2000). It has been reported that organic matter addition to soil increases microbial activity and improves soil texture. When combined with solarization, pathogen propagules might be weakened by heat stress and might be more effectively controlled by combination with organic matter (Gilreath et al., 1998; Gamliel et al., 1999; Eshel et al., 2000).

In year 1, root-knot nematode juveniles in soil were suppressed effectively with S+D400 application in all the plastic greenhouses until off-season except for the PG2. In addition, root galling indices were also reduced by S+D400 in year 1. Similarly, in the second year, all of the dazomet dosages effectively controlled root-knot nematodes and reduced root galling indices to very low levels. Dazomet is known as an effective fungicide with a broad spectrum, even though some studies reported unsatisfactory results in controlling nematodes and soil borne pathogens (Gilreath et al., 1994; Gilreath et al., 1998). Dazomet also possesses several important negative characteristics including low methyl isothiocyanat concentration, requirement of high temperature for its evaporation from soil, and reduced control of nematodes and soil borne pathogen propagules at higher soil depths. Because of these disadvantages, Gamliel et al. (2001) recommended the combination of dazomet and solarization for disease control. Although S+D300 treatment effectively suppressed root-knot nematodes in this study, it should be noted that it might not be effective against some nematodes and some soil borne pathogens, and therefore, we recommended S+D400 treatment to suppress both nematodes and other pathogens.

MB was listed as a class I ozone depleting substance by the US Environmental Protection Agency in 1993 and its production was ceased in 1994. Its use was also prohibited in 2005 in developed countries and it will be phased out by the year 2015 in developing countries. Turkey intends to remove it by 2007 (Yücel et al., 2001). With the impending elimination of MB, growers will need viable alternatives to manage a wide range of pests. All treatments investigated in the study are viable and cost effective alternatives to MB in plastic greenhouses. Soil solarization plus chicken manure, *Trichoderma* spp. or dazomet (300, 400 and 500) treatments in many cases are more economical than MB treatment and their efficiency to control *M. incognita* was comparable to that of MB. In addition, there was no significant difference for fruit yields between MB and alternative soil disinfestation treatments against nematodes in this study, indicating that these treatments are viable alternatives to MB and growers can implement them and avoid significant yield losses caused by *M. incognita* when MB usage is banned.

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