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Alternative Treatments to Methyl Bromide in the Eastern Mediterranean Region of Turkey

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Abstract: This study aimed to establish the economic and technical applicability of the alternative control methods to methyl bromide (MB) in pepper and eggplant. These crops were grown in plastic houses and tunnels including open field strawberry cultivation in the East Mediterranean region of Turkey and were assessed over the 2000-2002 growing season. In addition the study using a pre and post questionnaire aimed to monitor the change in farmer practices who have adopted alternative techniques other than MB, and their understanding of the environmental concerns associated with MB such as ozone depletion. Experiments were conducted under farmer's field conditions, and solarization was combined with fresh cow manure, low dosage pesticides and/or antagonistic microorganisms. Effect of these treatments on soil-borne pathogens and nematodes were determined, and also yield.The results indicated solarization combined with dazomet at 400 kg ha^{-1} was just as effective as MB application to soil-borne diseases and nematode control in plastic-houses. In this treatment, yield was obtained as much as in MB treatments in eggplant, while pepper and strawberry yield was less. Yield was determined as 109 and 36 t ha^{-1} in fresh cow manure combined with solarization treatment, however it was 115 and 51 t ha^{-1} in MB in eggplant and strawberry, respectively. This application was preferred to the MB alternative due to its low cost applicability. Results obtained from the questionnaire indicated that 91% of the farmers were using MB in 2000, and this decreased to 66% by 2002. Farmers' awareness to the alternative applications to MB increasing from 3% to 13%, and that MB is an ozone depleting fumigant over the same period rose from 7% to 13%.

Key Words: Methyl bromide, solarization, dazomet, soil-borne pathogen, root-knot nematode, questionnaire

Türkiye'nin Doğu Akdeniz Bölgesi'nde Metil Bromüre Alternatif Uygulamalar

Özet: Bu çalışmanın amacı, Doğu Akdeniz Bölgesi plastik sera ve tünellerinde biber ve patlıcanda, açıkta ise çilek yetiştiriciliğinde 2000 – 2002 üretim sezonunda metil bromüre (MB) alternatif mücadele yöntemlerinin teknik ve ekonomik açıdan uygulanabilirliğini araştırmaktır. Ayrıca çalışmanın başlangıcı ile bitiminde yapılan anket çalışmalarıyla MB kullanan üreticilerin oranındaki değişim, MB'in ozon delici maddeler arasında olduğunun bilinmesi ve MB'e alternatif uygulamaları benimseyen üreticilerin oranları belirlenmiştir. Üretici koşullarında yürütülen denemelerde; solarizasyon+yaş sığır gübresi, solarizasyon+düşük doz kimyasal ve antagonist mikrorganizma aşılanmış fidelerin solarizasyon uygulanan toprağa dikilmesi uygulamaları yapılmıştır. Uygulamaların toprak kökenli patojenler ve bitki paraziti nematodlara karşı etkinlikleri belirlenmiş ve verim değerleri kaydedilmiştir. Solarizasyon uygulaması ile kombine edilen dazomet (400 kg ha^{-1}) uygulaması patojenler ve bitki paraziti nematodlara karşı MB'e yakın oranda etkili olmuş ve elde edilen verim patlıcanda, MB uygulamasına benzer olurken biber ve çilekte daha düşük bulunmuştur. Solarizasyon uygulamasının yaş sığır gübresi ile kombinasyonu ise ekonomik olması nedeniyle dikkate alınması gereken bir alternatif olmuştur. Bu uygulamayla patlıcan ve çilekte 109 ve 36 t ha^{-1} olan verim, MB uygulamasında sırasıyla 115 ve 51 t ha^{-1} olarak belirlenmiştir. Anket çalışması sonucunda, 2000 yılında görüşme yapılan üreticilerin yaklaşık % 91'i MB kullanırken bu oranın 2002'de % 66'ya düştüğü, MB'i ozon delici madde olarak bilenlerin oranı % 7 iken % 13'e yükseldiği ve üreticilerin yalnızca % 3'ünün alternatif uygulamalar hakkında bilgi sahibi iken bu oranın yapılan yayım faaliyetleri sonucu % 13'e yükseldiği belirlenmiştir.

Anahtar Sözcükler: Metil bromür, solarizasyon, dazomet, toprak kökenli patojen, kök-ur nematodları, anket

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Introduction

In Turkey, 90% of the 52,800 ha vegetable production is in the Mediterranean region (Titiz, 2004), however major disease problems caused by soil-borne pathogens and nematodes influence the quality and quantity of the production. As this is an important economic issue, many researchers have conducted different studies to investigate various methods of control for these diseases. The most important soil-borne pathogens repored from plastic-house grown vegetables include *Fusarium* spp., *Rhizoctonia* spp., *Verticillium* spp., (Yücel and Çınar, 1989; Yücel, 1995; Yücel et al., 1998; Can et al., 2004), and the nematodes, *Meloidogyne incognita* and *M. javanica* (Söğüt and Elekçioğlu, 2000).

Although MB has been used for soil fumigation to control these soil-borne pathogens and nematodes, it will be banned in Turkey as of 2007 except for some exceptions where critical use is needed. Studies in other Mediterranean countries indicate that soil solarization and its combination with some pesticides or organic compounds are known to be an effective alternative control method to MB in plastic-houses (Katan, 1987, Yücel et al., 2002; Fritsch, 2002). In Turkey, however, there is not any study on the effect of soil solarization combined with organic compounds. Thus, in this study, the effect of MB alternative applications on soil-borne pathogens and nematodes on pepper, eggplant and strawberry grown in the east Mediterranean region was investigated to determine efficient control measures over the 2000-2002 growing season.

Materials and Methods

Solarization application

The experiments were conducted in strawberry, pepper and eggplant grown areas in Adana and Mersin during 2001-2002 growth season.

Treatments

The biological control agent *Trichoderma harzianum* (T-22 Planter Box), the fumigant dazomet (98% a.i.) (Basamid) and fresh organic cow manure were combined with soil solarization in each plastic house. *T. harzianum* was included in combination with solarization only for control of soil-borne diseases since it not known to affect nematodes.

Before planting in the greenhouse the pepper and eggplant seeds were planted for 1 month into seedling media containing *T. harzianum* (50g/20 liters of water) in the nursery to allow the fungus to colonize the roots. After this the inoculated seedlings were then transplanted into the solarized soil in the demonstration. Since, strawberries are produced directly from seedlings, *Trichoderma* could not be applied. Therefore, it was tested only for pepper and eggplant.

Dazomet and fresh cow manure were applied to experiment sites before soil solarization. Registered dosage of dazomet used against soil-borne pathogens and nematodes is at the rate of 600 kg ha^{-1}. Considering dazomet was combined with solarization in this study, a lower range of doses were selected for use including 300 kg ha^{-1}, 400 kg ha^{-1}, and 500 kg ha^{-1}. The chemical was applied with a dazomet applicator and then the top 15 cm soil mixed thoroughly using a garden rotavator. Following this, fresh cow manure was applied to soil at 40 t ha^{-1}. The manure was first distributed and homogenized on soil, and as with dazomet was thoroughly mixed upto 15 cm soil depth using a garden rotavator.

After dazomet and cow manure applications, soil was covered with polyethylene sheets 0.050 mm thick in the areas planted to eggplant and pepper, and 0.025 mm thick in strawberry areas. The different thickness of plastic used relates to the period of solarization where thickness of plastic was increased to prevent damage given by environmental conditions such as rain and wind.

For strawberry, ridges were made right after chemical and manure applications in soil, and these ridges were then covered with plastic. Solarization in pepper and eggplant carried on within the period of 8-10 weeks, from July to September, whereas it remained a shorter period of time (4-6 weeks) in strawberry fields. Soil temperatures at 10, 20 and 30 cm depths were recorded during solarization in experimental areas with HOBO make temperature data collectors. Pepper seedlings were transplanted in September-October, strawberry seedlings were transplanted in August, and eggplant seedlings were transplanted in December.

Determination of treatment effects on soil-borne pathogens

The plants were periodically examined during the vegetative period for soil-borne pathogens. Disease

incidence was calculated by using the formula $\%MG_I=[(D_C-D_T)/D_C].100$, where $\%MG_I$ = the percent effect, D_C = number of diseased plants in control, D_T = number of diseased plants in treatments (Karman, 1971).

Determination of treatment effects on root-knot nematodes

The population density changes of *M. incognita* second stage juveniles (J2) in soil were determined for each 5 replicates, both before treatment and at the end of the growing season in order to determine initial population density (Pi) and final population density (Pf). Soil samples were taken from replicated plots (12 m^2 areas) by removing 3 cores from the 0 to 30 cm soil depth. Soil nematodes were extracted through a modified Baermann funnel (Hooper, 1986) method and the number of root-knot nematode J2s were evaluated in 50 cm^3 soil and counted using a light microscope.

The root gall index was determined on 10 plant root systems / plot using a gall index scale of 0 to 10 (Barker, 1985) where 0 represented roots with no galls and 10 those with maximal degree of galling at the end of growing season.

Data Analysis

J2 population density changes of root-knot nematodes were determined before and at the end of the treatments. The effects of the treatments were determined by using Henderson-Tilton Formula (Karman, 1971). Depending upon the experimental design, root galling index and disease incidence were analyzed according to the standard procedures for analysis of variance, and differences between means were separated by Duncan's multiple comparison tests. All analysis were performed using SPSS 10.0 (SPSS Inc., Chicago, Illinois, US). Fruit yield was not statistically analysed, since the yield had been totally taken from each treatment at the end of vegetation period.

Questionnaire and training studies

Questionnaire to the growers was given at the beginning and at the end of the study. The aim of the questionnaire was to determine; i) producer profile, ii) sources of seeds, seedlings, and chemicals used by the farmers, iii) sources of agricultural advise, iv) use of MB, v) awareness on MB phase-out program, vi) information on use of the MB alternatives. The questionnaire was administered by the members of the project team in the years 2000 and 2002 with the participation of 100 farmers from Adana and Mersin provinces. In addition, farmers, technical staff, pesticide companies and dealers were trained about the applications of MB alternatives by conducting meetings, audiovisual education through radios, newspapers and brochures.

Results

Temperature changes

The soil temperature values are presented in Table 1, which indicates the temperature changes between soil solarization with and without manure and untreated control in experimental areas.

Soil temperatures at 10 and 20 cm depths in solarized and nonsolarized soils were recorded as 47 and 45 °C and 37 and 36 °C, respectively in strawberry plots. The maximum soil temperature at 10 and 20 cm soil depths in solarization combined with fresh cow manure plots reached to 52 and 47 °C, respectively.

Temperature values at 20 cm soil depth of solarized and nonsolarized plots in eggplant plastic-houses in Mersin province exhibited 10 °C difference. Temperature values obtained from soil solarized with the combination of fresh cow manure soil was 10-15 °C higher than both

Table 1. The soil temperatures recorded in the solarized and nonsolarized plots at 10 and 20cm soil depth measured after treatments.

Soil depth (cm)	Solarized soil temperature (°C)	Solarized soil temperature + fresh cow manure (°C)	Unsolarized soil temperature (°C)
10	47	52	37
20	45	47	36

those of the solarized and nonsolarized ones at 10 cm soil depth in strawberry.

The effect of the treatments on soil borne diseases and root-knot nematodes

Effectiveness of MB alternative methods on soil-borne pathogens and root-knot nematodes are given in Tables 2, 3 and 4.

Disease incidence on peppers in the soil solarized with a combination of dazomet at 400 and 500 kg ha^{-1} dosage was the same as the one treated with MB (Table 2). In eggplant, effect on disease incidence in plots having solarization combined with dazomet at 400 and 500 kg ha^{-1} dosages or with fresh cow manure was the same as the one MB applied (Table 2). In strawberry, solarization combined with dazomet at 400 kg ha^{-1} had the same effect on disease incidence with MB.

Table 2. Effect of MB alternative methods on soil-borne pathogens at the end of the growing season.

Treatments	Disease incidence (%)			
	Pepper	Eggplant	Strawberry 1	Strawberry 2
Solarization + dazomet 300 kg ha^{-1}	12.5 b*	21.3 b	11.2 b	10.0 a
Solarization + dazomet 400 kg ha^{-1}	5.0 a	16.3 a	5.0 a	7.5 a
Solarization + dazomet 500 kg ha^{-1}	5.0 a	16.0 a	nt**	nt
Solarization + *Trichoderma*	20.0 c	21.5 b	nt	12.5 b***
Solarization + fresh cow manure	nt	16.6 a	11.2 b	nt
MB application	5.0 a	15.0 a	5.0 a	nt
Untreated Control	38.7 d	25.0 c	18.7 c	25.0 c

* The lower capitals next to numbers indicate different groups determined by Duncan's multiple comparison tests ($P < 0.05$)

** not tested

*** evaluated as solarization alone

Table 3. Effect of MB alternatives on the number of *Meloidogyne incognita* juveniles in pepper and eggplant at the end of the growing season.

Treatments	Pepper				Eggplant			
	J2 of *M. incognita* / 100 g soil			Galling Index	J2 of *M. incognita* / 100 g soil			Galling Index**
	Pi*	Pf*	%		Pi	Pf	%	
Solarization+dazomet 300 kg ha^{-1}	752	4	99.5	0.68 ± 0.19 a	200	32	99	0.10 ± 0.06 a
Solarization+dazomet.400 kg ha^{-1}	968	20	98.2	1.04 ± 0.15 a	400	0	100	1.00 ± 0.00 a
Solarization+dazomet 500 kg ha^{-1}	984	0	100	0.96 ± 0.20 a	200	0	100	0.05 ± 0.05 a
Solarization+*Trichoderma*	828	4	99.6	0.80 ± 0.18 a	200	4	99.5	0.15 ± 0.15 a
Solarization+fresh cow manure***	nt	nt	nt	nt	160	4	99.8	0.00 ± 0.00 a
MB	1040	65	94.6	0.50 ± 0.31 a	120	88	96	0.05 ± 0.05 a
Untreated Control	890	1040	-	4.91 ± 0.50 b	40	740	-	2.30 ± 0.47 b

* Pi: Initial population of J2, Pf: Final population of J2

** According to the 0-10 galling index scale (Barker, 1985)

***not tested

The lower capitals next to numbers indicate different groups determined by Duncan's multiple comparison tests ($P < 0.05$)

Table 4. Effect of MB alternative methods on total vegetable and fruit yield at the end of the growing season.

Treatments	Total Yield (t ha^{-1})			
	Pepper	Eggplant	Strawberry 1	Strawberry 2
Solarization+dazomet 300 kg ha^{-1}	59	112	36	42
Solarization+dazomet 400 kg ha^{-1}	63	112	37	49
Solarization+dazomet 500 kg ha^{-1}	78	113	nt	nt
Solarization+*Trichoderma*	39	112	30*	38
Solarization+fresh cow manure	nt	109	36	nt
Control (MB application)	80	115	51	nt
Untreated Control	23	94	20	nt

nt: not tested

Since there was not a problem related with nematodes in strawberry experimental fields, no evaluation was made. In pepper and eggplant growing experimental plots, on the other hand, all the alternative methods reduced J2 population of the root-knot nematodes more than 90 %. Furthermore, galling indices in plant roots which grown soil solarization combined with different dazomet dosages and fresh manure plots were the same as those of the MB. There was no statistically significant difference regarding the effects of all of the alternative methods on galling indices on pepper and eggplant compared to those of the MB (Table 3).

In addition, total yield values were low in the untreated control plots, but values in the alternative applications were close to the yield parameters of the MB plots (Table 4).

The key findings of the questionnaire administered at the beginning and at the end of the project are given in Table 4. It reveals that awareness of farmers about MB damage to ozone in the Mediterranean region increased from 7% to 13%. Moreover, the number of the farmers knowing the MB phase out in Turkey increased from 35% up to 82%, and awareness of the farmers knowledge about the alternatives to MB alternative applications raised the percentage from 3% to 13% (Table 5).

In addition to above mentioned applications, 11 educational meetings involving technical staff, farmers, pesticide firms and dealers were conducted providing the farmers with appropriate handouts, and arranging the field days for dissemination of MB alternative methods.

Table 5. Results of questionnarie studies in the Eastern Mediterranean Region of Turkey in 2000 and 2002.

Subject	2000*	2002
MB usage among farmers	91	66
Farmers who were not aware of alternative methods' cost	51	32
Farmers to beware of ozone depleting effect of MB	7	13
Farmers knowing of MB phase out in the world	44	82
Farmers to be aware of MB phase out in Turkey	35	82
Farmers knowing of MB alternative methods	3	13
Farmers received information on alternative applications from pesticide dealers	69	74
Farmers received information on alternative applications from Ministry of Agriculture and Universities	11	40
Farmers with information on solarization	27	53
Farmers who thought of MB alternative applications as a solution when informed	32	59

* Ratios taken as percentages (%) at the beginning (year 2000) and at the end (year 2002) of the project activities.

Discussion

Maximum soil temperature differences between solarized and nonsolarized soils detected from all experimental fields were 8-10 °C. Fresh cow manure applications indicated and additional 2-7 °C increase in temperature when compared against straight solarization. Thus, in strawberry grown plots, temperature values in solarization combined with fresh cow manure soil was 10-15 °C higher than those obtained from solarized and nonsolarized values at 10 cm soil depth.

Cartia et al. (1997) reported the 9-11 °C temperature increase at 15 cm soil depth in solarized soil, in Ragosa (Italy). In addition, Chellemi and Olson (1994) reported an average of 8 °C temperature difference between solarized and control plots at 15 cm soil depth in Florida. In the east Mediterranean region of Turkey, 7 °C and 6 °C temperature difference were reported at 10 cm soil depth in 1990 and 1991 respectively (Yücel, 1995).

In this study, the results revealed that all methods alternative to MB effectively controlled *M. incognita* and the soilborne pathogens. It is thought that soil solarization for vegetable production has great potential in the south of Turkey due to the Mediterranean climate. Similar results were obtained in other Mediterranean countries (Katan and Devay, 1991; Besri, 2002; Tjamos et al., 2002). Related researchers from different subtropical and tropical regions of the world reported that various plant parasitic nematodes and soil borne pathogens could be reduced by soil solarization (Heald and Robinson, 1987; Chellemi et al., 1993).

The results also revealed that solarization combined with dazomet at 400 kg ha^{-1} showed a similar effect on the soil borne pathogens, root-knot nematode control, and yield when compared to those obtained by the MB applications in pepper, eggplant and strawberry grown under protected conditions or in open field. However, Gireath et al. (1998) reported that dazomet has a minimal effect against nematodes. Dazomet has some disadvantages at the low methyl isothiocyanate (MITC) concentrations, less controlling effect on nematodes and pathogen propagules.

Solarization combined with fresh cow manure reduced root-knot nematodes and soil borne pathogens. Fresh cow manure in additon to solarizing soil increased temperatures by 2-7 °C, which is higher than those of solarized alone in strawberry plots. Gamliel and Stapleton (1993) reported a 2 °C rise when solarization is combined with chicken manure. Solarization applied with fresh cow manure was found to be an economical approach to MB, which is consistent with the results of a study carried out in Spain (Lopez et al., 2002).

Education and data dissemination studies conducted during the project helped increase farmer awarness and interest interest on the subject with their knowledge increasing from 3% to 13%. Effect of meetings, audiovisual education through radios and newspapers and brochures also increased farmers interest.

The percentage of the farmers thinking MB alternative applications as a solution increased from 32% to 59% and this increase may have resulted from the on-site education at the demonstration parcels.

According to results obtained in this study, application of solarization combined with low dosage of dazomet as a MB alternative could be recommended in greenhouses that have high soil-borne pathogens and nematodes disease problems. In the case of relatively less problematic greenhouses and in strawberry production areas, application of solarization combined with fresh cow manure could be suggested because of low cost and satisfactory effect on pathogen management. Further studies on the effectivness of soil solarization and testing new pesticides with fumigation activity continue in the Eastern Mediterranean region of Turkey in order to promote the most economical and environmentally sustainable farming practices.

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