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Full Length Research Paper

Effects of olive processing waste, chicken manure and Dazomet on weeds with or without soil solarisation

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Three non-chemical weed control alternatives (chicken manure (10 t ha^{-1}), olive processing waste (OPW) (30 t ha^{-1}), and solarisation (6-7 weeks at > 40.9 - 47.1°C at a 15 cm soil) were applied to greenhouse grown tomatoes alone and in combination and were compared with a soil fumigant (dazomet) for the ability to control weeds. Both dazomet (485 kg a.i. ha^{-1}) and solarisation provided excellent control of common purslane, slender amaranth and bristly foxtail. Excellent weed control was also achieved with a half dose of dazomet (242.5 kg a.i. ha^{-1}) plus 21 days of solarisation. OPW provided moderate control of these weeds, but chicken manure did not. OPW and chicken manure applied with solarisation provided 100% control of common purslane, slender amaranth and bristly foxtail, but did not significantly improve control compared to solarisation alone. OPW plus a short-duration of solarisation may provide weed control that is comparable to dazomet in greenhouse grown tomatoes.

Key words: Chicken manure, olive processing waste, solarisation, dazomet, weed control, tomatoes.

INTRODUCTION

Turkey is a major producer of tomatoes both for fresh consumption and for the processing industry, ranking third in the world behind China and the USA (Sırtıoğlu, 2004). Tomatoes produced for processing comprise about 25% of Turkey's total production, with the remainder grown for domestic consumption (Sırtıoğlu, 2004). Tomatoes are grown throughout Turkey, but the bulk of their production is concentrated in the Marmara and Aegean regions, where the climatic conditions are ideal. Tomatoes are also produced in greenhouses in southern Turkey for fresh consumption in urban areas during the winter and spring seasons.

Weeds are a big problem in greenhouses in the tomato-growing areas. Species such as *Amaranthus* spp. are prevalent in the Aegean region provinces of Muğla, Denizli and Aydın and have been observed in over 90% of the surveyed areas. *Portulaca oleracea*, *Chenopodium album*, *Trifolium* spp., *Cyperus rotundus*, *Setaria verticallata* and *Stellaria media* have been found in all three of these provinces (Boz et al., 2008). The *Orobanche ramosa/aegyptiaca* complex was also found in tomato-growing greenhouses in the East Mediterranean (Orel-Aksoy and Uygur, 2003) and Aegean regions of Turkey (Boz et al., 2008).

Tomato yields are reduced if weeds are not controlled within the first 30-45 days after planting (Labrada, 1994). In addition to a decrease in tomato yield resulting from competition with the weeds, weeds are hosts to certain diseases and insects that cause secondary negative effects on tomatoes. Farmers have used methyl bromide to control weeds, but this fumigant is ozone depleting and will be phased out of use. Currently, some farmers in specific areas in Turkey are using dazomet, metham sodium and dichloroprophene. There is increasing interest in using these fumigants in addition to solarisation.

Soil solarisation is the practice of covering the soil with a transparent sheet during suitable conditions. Transparent sheets are a modern tool used to capture the solar energy to heat the soil in a field or greenhouse (Katan and De Vay, 1991). In the practice of soil solarisation, the soil is covered during the hottest months (In Turkey, generally June to August) in order to increase the maximal temperature to levels that are lethal to weeds. Soil solarisation can control the seeds of weeds, soil borne diseases and nematodes while increasing crop yield without any risk to the environment (Katan and De Vay, 1991).

Important factors for the effectiveness of solarisation include the temperature profile (including the maximum and minimum temperatures), the wind speed throughout the procedure, the texture of the soil, the soil colour, the soil moisture content and the characteristics of the polyethylene (Stapleton, 1996).

Olive processing waste (OPW) is a by-product of olive oil production. When olives are pressed to produce oil, two sub-products are obtained: the prina containing broken seed parts and is utilized for heating and the OPW, which is collected in a pool outside of the factory. From July-August, the OPW loses water by evaporation and becomes a solid known as “solid OPW” (Boz et al., 2003). OPW is a significant problem for the environment because of its toxic content and antibacterial phenolic compounds that can contaminate the soil (Hamdi and Garcia, 1993; Ramos-Cormenzana et al., 1995; Martirani et al., 1996; Yeşilada et al., 1998; Paredes et al., 1999; Garcia et al., 2000; Galiatsatou et al., 2002; Hışıl et al., 2003; Casa et al., 2003; D’Annibale et al., 2004; Roig et al., 2006). However, in spite of its effects as a pollutant, OPW contains a high density of organic material that is rich in potassium and phosphorous and that can be broken down by microbial activity (Püskülcü et al., 1995; Karaman, 2002). The application of OPW as a fertiliser has been shown to improve the yield of olive trees (Püskülcü et al., 1995) and strawberry plants (Albay, 2003). Interestingly, OPW has also been shown to suppress the growth of weeds (Ghosheh et al., 1999; Boz et al., 2003; Albay, 2003), which is tested in this experiment.

Dried chicken manure (CM) is another organic material. The average plant nutrients per ton of cage layer of dry, dusty (moisture content of 15%) poultry manure is nitrogen 70, phosphorus 70 and potash 46 (North, 1984).

Dazomet is a soil sterilant that is used to control some soil-borne fungus, nematodes, soil insects and weeds. This fumigant is made active in soil, as it is converted to methyl isothiocyanate, formaldehyde, hydrogen sulphide and monomethylamine. The biological activation of dazomet depends on the soil moisture, while its decomposition rate depends on the soil type, humidity and temperature. This fumigant kills seedlings before they are able to emerge from the soil. Dormant seeds, however, which have impermeable seed coats, may not be killed by this fumigant (Vencill et al., 2002). Dazomet is a fumigant that can be used alone or in combination with other compounds to control weeds (Nemli and Emiroğlu, 1993; Yücel et al., 2002; Benlioğlu et al., 2002; Unruh et al., 2002; Gilreath and Santos, 2004; Öğüt, 2007).

Because of the phase out of methyl bromide, the object of this study is to investigate the effects of chicken manure (CM), olive processing waste (OPW), dazomet and solarisation in various combinations on the control of weeds in greenhouse-grown tomatoes. This was an integrated study conjunction with controlling *Meloidogyne incognita* in tomato by Kaşkavalcı (2007) who evaluated the results of tomato yield. The effect of treatments on weed control and tomato yield is discussed here.

MATERIALS AND METHODS

Experiments were carried out between 2002-2004 during the tomato-growing season using greenhouses in Incirliova and Germencik, which are located in the Aydin province in the west of Turkey (37°, 51' N, 27° 50' E, altitude about 57 m). A system of randomised complete block design with 4 replicates was used, with the following treatments (Table 1):

a) Chicken manure (CM) (10 t ha^{-1})
b) Olive processing waste (OPW) (30 t ha^{-1})
c) Solarisation (6 and 7 weeks)
d) Dazomet (Basamid 485 kg a.i. ha^{-1})
e) CM plus solarisation
f) OPW plus solarisation
g) Half doses of dazomet plus solarisation
h) Half doses of dazomet plus 21 days of solarisation

Prior to all of the applications, the soil was prepared using a mouldboard plough followed by a disk harrow. The field was flood-irrigated to a depth of 50 to 60 cm and treatments were applied as described below.

For solarisation, raised beds of moistened soil were prepared that were 25 cm in height and 40 cm in width, with 50 cm between the rows. Size of each plot was occurred as about 6 by 2.7 m. The plots were covered manually with transparent polyethylene sheets (110 µm), including the soil between the raised beds.

Dazomet on its own (Basamid 485 kg a.i. ha^{-1}) was applied once with a special granular sprayer and was incorporated into the soil by rotary tillers to a depth of 0 - 15 cm. Raised beds were formed and covered with transparent polyethylene sheets and watered for 1 h by drip irrigation. After 1 week, transparent polyethylene sheets were removed for aeration.

OPW and chicken manure on their own were applied once before transplanting (Table 1). OPW in solid form was applied at a depth of 0-15 cm and at a concentration of 30 tons ha^{-1} to moistened soil using a rotary tiller. The raised beds were formed at a later point. Chicken manure was applied at a concentration of 10 tons ha^{-1} following the same method used for OPW.

Combination treatments using OPW and chicken manure plus solarisation were applied as described for each treatment alone. For both treatments, raised beds were prepared and covered manually with transparent polyethylene sheets.

After the applications, a total of 32,000 tomato seedlings (cv. 7314-Beril, Rijk Zwaan) were planted per hectare (on 22 and 28 August for fields 1 and 2 in 2002; on 17 and 14 August for fields 3 and 4 in 2003). Drip irrigation was used to water the plants in all of the experiments.

The soil temperature was recorded using a data logger at a depth of 15 cm in solarised and untreated control plots in one greenhouse and these data were also used for the other greenhouse (Kaşkavalcı, 2007).

Evaluation of the treatments on following weed species

The effectiveness of the treatments on preventing the emergence of weed seeds was evaluated (on 25, September 2002 for fields 1 and 2; on 17 and 21 September, 2003 for fields 3 and 4) before hand-

Table 1. Introduction of the experimental sites and the treatments used in 2002 and 2003.

Field no.	Treatments	Dates	Dose a.i. kg/ha and days
2002 1	1. Control	Non-treated	-
	2. Chicken manure	Aug. 17	10 tons
	3. Olive Processing Waste (OPW)	Aug. 17	30 tons
	4. Solarisation	June 22- Aug. 08	7 weeks
	5. Chicken manure + Solarisation	June 22- Aug. 08	10 tons
	6. OPW+Solarisation	June 22- Aug. 08	30 tons
	7. Dazomet	Aug .09- Aug. 15	485 kg
	8. 1/2 Dose Dazomet + Solarisation	June 22 -Aug. 08	242.5 kg
2	1. Control	Non-treated	-
	2. Chicken manure	Aug. 20	10 tons
	3. Olive Processing Waste (OPW)	Aug. 20	30 tons
	4. Solarisation	July 08 - Aug. 26	7 weeks
	5. Chicken manure+Solarisation	July 08 - Aug. 26	10 tons
	6. OPW+Solarisation	July 08 - Aug. 26	30 tons
	7. Dazomet	Aug. 12 - Aug. 20	485 kg
	8.1/2Dose Dazomet+Solarisation	July 08 - Aug. 26	242.5 kg
2003 3	1. Control	Non-treated	-
	2. Chicken manure	July 31	10 tons
	3. Olive Processing Waste (OPW)	July 31	30 tons
	4. Solarisation	July 3 - Aug. 11	6 weeks
	5. Chicken manure + Solarisation	July 3 - Aug. 11	10 tones
	6. OPW + Solarisation	July 3 - Aug. 11	30 tons
	7. Dazomet	July 24 - July 30	485 kg
	8. 1/2 Dose Dazomet + 21 Days Solarisation	July 10-July 31	242.5 kg
4	1.Control	Non-treated	-
	2.Chicken manure	July 31	10 tons
	3.Olive Processing Waste (OPW)	July 31	30 tons
	4.Solarisation	June 29- Aug. 07	6 weeks
	5.Chicken manure + Solarisation	June 29- Aug. 07	10 tons
	6.OPW + Solarisation	June 29 -Aug. 07	30 tons
	7.Dazomet	July 24 - July 31	485 kg
	8.1/2 Dose Dazomet + 21 Days Solarisation	July 10 - July 31	242.5 kg

hoeing by counting the weed seedlings in a 0.2 m^2 (0.5 by 0.4 m) area and converting these values to 1 m^2. *Portulaca oleracea, Amaranthus viridis* and *Seteria verticillata* were counted on four randomly chosen sites in each plot and the results are shown in Tables 2 and 3. After counting, the weeds were removed by hand.

As the fruits matured, the tomato yield was estimated from 4 plants in each plot and the yield results were presented in Kaşkavalcı (2007).

Analyses of variance (ANOVA) were calculated using the SPSS statistical software (version 14.00; SPSS). Comparisons of means were made in accordance with the Tukey test at the p = 0.05 level.

RESULTS

Temperature

The maximum soil temperatures measured in the non-solarised and solarised areas were 39.3 and 47.1ºC, respectively, in 2002 and 34.8 and 40.9ºC, respectively, in 2003 (Kaşkavalcı, 2007). Therefore, the clear polyethylene sheets increased the soil temperature by about 6 - 8ºC.

The effect of treatments on common purslane (*Portulaca oleracea* L.)

The results for inhibition of common purslane growth are shown in Tables 2 and 3. Common purslane was suppressed using chicken manure by 20 - 33%, but this was an unsatisfactory level of control. OPW suppressed this weed by 83-86%. Solarisation by itself almost completely

Table 2. Effect of the different treatments on the weeds (2002 - 2003 season).

Treatments	***P. oleracea* (Common purslane)**		***A. viridis* (Slender amaranth)**		***S. verticillata* (Bristly foxtail)**	
	No/m^2	**Reduction (%)**	**No/m^2**	**Reduction (%)**	**No/m^2**	**Reduction (%)**
Non-treated control	105.2 a	0.0	39.2 a	0.0	22.5 a	0.0
Chicken manure	70.5 b	33.0	22.0 b	43.9	9.5 b	57.8
Olive Processing Waste (OPW)	17.5 c	83.4	5.3 c	86.5	5.6 b	75.1
Solarisation	1.3 c	98.8	0.0 c	100	0.0 c	100
Chicken manure+Solarisation	0.0 c	100	0.0 c	100	0.0 c	100
OPW+Solarisation	0.0 c	100	0.0 c	100	0.0 c	100
Dazomet	1.4 c	98.7	0.0 c	100	0.0 c	100
1/2 Dose Dazomet+Solarisation	0.3 c	99.7	0.0 c	100	0.0 c	100

Values in the same column with different letters show a significant difference at $P < 0.05$ according to Tukey multiple range test.

Table 3. Effect of the different treatments on the weeds (2003 - 2004 season).

Treatments	***P. oleracea* (Common purslane)**		***A. viridis* (Slender amaranth)**		***S. verticillata* (Bristly foxtail)**	
	No/m^2	**Reduction (%)**	**No/m^2**	**Reduction (%)**	**No/m^2**	**Reduction (%)**
Non-treated control	69.5 a	0.0	52.8 a	0.0	51.6 a	0.0
Chicken manure	55.3 b	20.4	28.8 b	45.5	25.5 b	50.6
Olive Processing Waste (OPW)	10.0 c	85.6	7.7 c	85.4	8.9 c	82.8
Solarisation	0.0 c	100	0.0 d	100	0.0 d	100
Chicken manure+Solarisation	0.0 c	100	0.0 d	100	0.0 d	100
OPW+Solarisation	0.0 c	100	0.0 d	100	0.0 d	100
Dazomet	0.0 c	100	0.0 d	100	0.0 d	100
1/2 Dose Dazomet 21 days +Solarisation	0.0 c	100	0.0 d	100	0.0 d	100

Values in the same column with different letters are significantly different at $P < 0.05$ according to Tukey multiple range test.

eliminated common purslane, and dazomet at 485 kg a.i. ha^{-1} provided almost 100% control of common purslane. Treatments used in combination with solarisation, including chicken manure with solarisation, OPW with solarisation and half doses of dazomet with 21 days solarisation, also successfully inhibited this weed.

The effect of treatments on slender amaranth (*Amaranthus viridis* L.)

The results for inhibition of slender amaranth growth are shown in Tables 2 and 3. Slender amaranth growth was suppressed by about 45% using chicken manure, but this was not an acceptable result. Treatment with OPW suppressed the growth of slender amaranth by 86%. Only the use of solarisation or dazomet gave 100% control of this particular weed. Treatments with chicken manure, OPW and dazomet combined with solarisation were also successful.

The effect of treatments on bristly foxtail (*Setaria verticillata* [L.] P.B.)

The results for the inhibition of bristly foxtail growth are shown in Tables 2 and 3. Chicken manure suppressed bristly foxtail by 51-58%, but this level of control was unsatisfactory. OPW suppressed this weed by about 75 - 83%. Only dazomet or solarisation provided total suppression. The use of chicken manure gave poor results in controlling this species. However, combinations of chicken manure, OPW and dazomet (at half dose) with solarisation (both 21 days and more than 40 days) worked very well (Tables 2 and 3).

While in the first year, dazomet (2617.4 g/plant), ½ Dose dazomet+solarisation (2529.6 g/plant), chicken manure (2440.5 g/plant), chicken manure+solarisation (2341.6 g/plant) and solarisation (2329.3 g/plant) gave more yield than non-treated plots (1710.7 g/plant). In the second year, OPW+solarisation (3748.8 g/plant), ½ dose dazomet+short term solarisation (3748.3 g/plant), dazomet (3349.2 g/plant) and solarisation (3196.1 g/plant) gave higher yield than non-treated plots (2622.0 g/plant) Kaşkavalcı (2007). The tomato yield was detailed discussed in Kaşkavalcı (2007).

DISCUSSION

In this experiment, OPW has herbicidal effects on some of the summer weeds in Turkey. Boz et al. (2003), Albay (2003), Albay and Boz (2003) and Öğüt (2007) have previously demonstrated the herbicidal effects of OPW. The herbicidal action of OPW against broomrape has also been demonstrated (Ghosheh et al., 1999). OPW at 3 and 4.5 kg/m^{-2} controlled the *Portulaca oleracea* 63 and 98% in maize and sunflower (Boz et al., 2003). OPW was also shown to effectively control the common purslane (Öğüt, 2007). In another study, solid OPW provided a 79% decrease in common purslane in strawberries (Albay and Boz, 2003). The reason for OPW's effectiveness could be that it contains toxic and antibacterial phenolic substances (Hamdi and Garcia, 1993; Ramos-Cormenzana et al., 1995; Martirani et al., 1996; Yeşilada et al., 1998; Paredes et al., 1999; Garcia et al., 2000; Galiatsatou et al., 2002; Hışıl et al., 2003; Casa et al., 2003; D'Annibale et al., 2004; Roig et al., 2006).

Our results demonstrated that while chicken manure is capable of suppressing weeds, the decrease is not significant. Although Major et al. (2005) stated that chicken manure increased the weed coverage, Haidar et al. (1999) stated that it reduced the duration of solarisation required for the suppressing of seeds of dodder from 6 to 2 weeks.

In our study, solarisation and its combinations controlled the weeds effectively. Our results with solarisation support other findings. Average maximal temperatures at a depth of 5 cm were 47.6 and 52.1°C for 49 and 52 days of solarisation con-trolled the common purslane and increased the yield of strawberries (Benlioğlu et al., 2005). Kumar et al. (1993) stated that solarisation for 32 days increased the yield of soybeans while decreasing the growth of *Dactyloctenium aegyptium*, *Achrachne racemosa*, *Trianthema monogyna* and *Cyperus rotundus* from seeds in India, but *Cyperus rotundus* from tubers became more prevalent. Vizantinopoulos and Katranis (1993) stated that 3 or 4 weeks of solarisation were effective at decreasing volun-teer wheat (*Triticum aestivum*), *Portulaca oleracea*, *Digi-taria sanguinalis*, *Solanum nigrum* and *Amaranthus* spp. in Greece. Hartz et al. (1993) found that the solarisation significantly controlled the annual weeds and increased the yield of strawberry plants. Economou et al. (1997) stated that solarisation for 1 month killed the seeds of the *Avena sterilis*, *Bromus diandrus* and *Sinapis arvensis*. In another study, solarisation for 10, 20, 30 and 40 days significantly decreased the weed number and increased the yield of cabbage (Haidar and Iskandarani, 1997). Arora and Yadurajo (1998) stated that solarisation average about 53°C at 5 cm for 30 days significantly decreased the *Avena fatua*, *Phalaris minor*. Ioannou (2000) stated that solarisation maximum soil temperatures obtained in two local about 43-45°C in depth of 15-20 cm for 8 weeks gave effective control of weeds such as *Malva* sp., *Amaranthus* sp., *Chrysanthemum* sp., *Chenopodium* sp., *Calendula arvensis*, *Lolium rigidum* and *Urtica urens*. However, the same report demonstrated that solarisation had little effect on *Convolvulus arvensis* and *Cyperus rotundus*. Solarisation also increased the yield of tomato in Cyprus. In Western Anatolia of Turkey, the maximum soil temperatures at soil depths of 5 and 10 cm were 55 and 50ºC after 44 days of solarisation, which was able to control the annual bluegrass (*Poa annua*), common purslane (*Portulaca oleracea*) and redroot pigweed (*Amaranthus retroflexus*), but not the purple nutsedge (*Cyperus rotundus*) or horseweed (*Conyza canadensis*) (Benlioğlu et al., 2002). The average maximal temperatures at a depth of 5 cm were 47.6 and 52.1ºC for 49-52 days of solarisation and this was suffi-cient to control the annual bluegrass, common purslane, redroot pigweed and barnyardgrass (*Echinochloa crussgalli*), but it could not controlled the horseweed (Benlioğlu et al., 2005). In 2004, solarisation for 45-50 days gave an average temperature of 47.5ºC and was able to suppress weeds such as common purslane, redroot pigweed, wild radish (*Raphanus raphanistrum*), annual bluegrass and wild chamomille (*Matricaria chamomille*), but was unable to suppress horseweed (Boz, 2004). Solarisation reduced the weed numbers by 86-94% and weed biomass by 94-99% as compared to the non-solarised areas (Stapleton et al., 2005).

Dazomet was able to effectively control the weeds in our study, in agreement with other reports. For example, Csinos et al. (1997) stated that dazomet controlled the *Gnaphalium purpureum* L. var. *purpureum* at 81 - 95%, *Oenothera laciniata* at 92-95% and *Linaria canadensis* at 93%. Unruh et al. (2002) stated that dazomet controlled the purple nut-sedge by 56-80%. Benlioğlu et al. (2002) stated that dazomet decreased the annual bluegrass, common purslane and redroot pigweed, but not purple nutsedge or horseweed. Gilreath and Santos (2004) stated that purple nutsedge was influenced by fumigants such as dazomet. Öğüt (2007) stated that the common purslane was effectively controlled by dazomet.

The treatments also led to an increase in tomato yield compared to non-treated plots as discussed in Kaşkavalcı (2007).

The results of our study suggest that the major weed species (common purslane, slender amaranth and bristly foxtail) which are found in the tomato-growing areas in the Aydın region can be controlled successfully either by using dazomet (485 kg a.i. ha^{-1}) or solarisation (6-7 weeks at 40.9-47ºC). Effective control of these weeds was also achieved using chicken manure, OPW and half-doses of dazomet in combination with solarisation, even if the duration of the solarisation was reduced to 21 days. Soil temperatures must be raised to a sufficiently high level to kill all weed seeds regardless of the duration of solarisation. Chicken manure and OPW used alone did not provide adequate weed control, but OPW was the more effective treatment of the two. It can be concluded that solarisation, both used solely and in combination with dazomet or OPW, could be successfully used to control weeds in the process of tomato production in Turkish greenhouses.

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