Indian Phytopath. 67 (3) : 238-242 (2014)

RESEARCH ARTICLE

Integration of soil solarization with soil amendments, botanicals and microbial pesticides for the management of soil-borne diseases of strawberry

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ABSTRACT: Treatment combination of soil solarization with different amendments, were either applied before solarization (neem cake or neem granules or cauliflower leaves or leaves/ seed of five local plants) or after solarization (*Trichoderma viride, Pseudomonas florescence*) for management of soil borne diseases of strawberry. Among these, combination of soil solarization with transparent polyethylene mulch (25 µm thick) for 40 days with soil amendment of neem cake was found most effective and statistically at par in efficacy with treatment combination of soil solarization and root dip of strawberry runners and drenching with Saaf (0.2 %) in reducing the combined incidence mainly comprising of crown rot (*Rhizoctonia solani*), southern blight (*Sclerotium rolfsii*) and wilt (*Fusarium oxysporum* f. sp. *fragariae*) by 96.2 % in comparison to unsolarized control. This treatment also resulted up to 70.6 % increase in plant height, 72.4 % in root length, 176.4 % in number of runners per plant, 148.8 % in average fruit weight and 108.7 % in yield per hectare in comparison to control. Other treatment combinations of soil solarization with soil amendments applied before soil solarization were also found statistically at par. Treatment combinations of soil solarisation with the two microbial bio-pesticides were found slightly less effective.

Key words: Integrated management, solarisation, soil borne pathogens, strawberry

Strawberry (*Fragaria* x *ananassa*) is infected by number of soilborne diseases and among these crown rot (*Rhizoctonia solani*), southern blight (*Sclerotium rolfsii*), leather rot (*Phytophthora cactorum*), red stele (*Phytophthora fragariae* f sp. *fragariae*) and wilt (*Fusarium oxysporum* f.sp. *fragariae*) have been reported to be important in different countries (Bhardwaj and Raj, 2004; Fang *et al.*, 2012). These diseases are difficult to control due to repeated cultivation of the crop in the same piece of the land and heavy build up of inoculums in the form of sclerotia and other overwintering spores. There is need for some new approaches for the management of these diseases due to banning of methyl bromide and adverse effect of other chemical pesticides on the beneficial microbes present in the soil. Soil solarization (SS) is one of the important physical methods which is cost effective for the management of soil-borne pathogens in different crops (Katan, 1981). Soil solarization involves the use of thin transparent polyethylene mulch for capturing solar energy for heating the soil to a limit which is either lethal or sub-lethal to the different propagules of the pathogens (Katan, 1981; Negi and Raj, 2013). Soil solarization has been found more effective against soil-borne pathogens when integrated with other non-chemical methods of disease management (Gamliel and Stapleton, 1993; Raj and Sharma, 2009; Raj and Upmanyu, 2013; Stevens *et al.*, 2003). Hence, present investigation was carried out to find out the efficacy of integration of soil solarization with soil amendments, bio-fumigants, botanical and microbial pesticides on the incidence of soil-borne diseases of strawberry in the field.

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MATERIALS AND METHODS

These studies were carried out in the laboratory and experimental farm of Department of Plant Pathology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh in India during 2008 to 2010.

Evaluation of local botanicals against important soil-borne pathogens of strawberry for use as soil amendment

Fourteen native plants were evaluated against three important soil-borne pathogens (*Rhizoctonia solani*, *Sclerotium rolfsii*, *Fusarium oxysporum* f.sp. *fragariae*) of strawberry to know their efficacy by poison food technique in potato dextrose agar medium. Fresh leaves (45 to 60 days old) of *Aloe barbadensis*, *Bougainvillea glabra*, *Eucalyptus globulus*, *Lantana camara*, *Mentha longifolia*, *Ocimum sanctum*, *Roylea elegans*, *Cryptolepsis buchanani*, *Mentha piperita*, *Thuja chinensis*, *Urtica divocia*, *Vitex negundo*, *Pogostemone benghalensis* and seeds of *Melia azedarach* were taken and 100 % formulations were made on weight and volume (w/ v) basis in the water (Raj and Tomar, 2013). Out of these five (*M. azedarach, R. elegans, B. glabra, O. sanctum, C. buchanani*) most effective were taken to make a soil amendment by adding equal parts of leaves of all except for *M. azedarach* where mature seeds (light yellowish colour) were taken.

Soil solarization

Field experiments were conducted during 2008-09 and 2009-10 in a field where strawberry was grown for the last 3 years and the field had high incidence of diseases like crown rot (*R. solani*), southern blight (*S. rolfsii*) and wilt (*F. oxysporum* f.sp. *fragariae*). Plant mortality due to different soil-borne diseases varied between 38.1 to 84.3 % during 2004-2007 and more than 90 % mortality was recorded due to above mentioned three pathogens. There were two similar sets of treatments (solarized and unsolarized plots) during both the years having 3 replications with plot size of 1m x 4 m. However, in 2009-10, one treatment of neem granules as soil amendment was also added. During both the years, plots of one set of the treatments were irrigated to saturation level and then covered with thin (25 µm thick) white transparent polyethylene mulch during 21st May to 30th June for 40 days. Effect of soil solarization was recorded on soil temperature daily at 2 PM at 5 and 20 cm soil depth during the period of solarization with the help of dial type digital thermometer. Air temperature was also recorded daily at 2 PM with the help of thermometer during the period of solarization. In the solarized plots, different treatments were applied either before solarization or after solarization. In the unsolarized plots, the effect of similar treatments was observed without covering the plots with the polyethylene mulch.

Integration of different effective treatments for the management of the soil-borne diseases in the field

To develop an integrated technology for the management of different soil-borne diseases of strawberry, an experiment was laid out in a randomized block design in the experimental farm of the Department of Plant Pathology, Nauni, Solan during June 2008-09 and 2009-10. Different methods of disease management like application of soil amendments, formulation of *Trichoderma viride*, neem-based formulations and fungicides were integrated and applied under field conditions both under solarized and unsolarized conditions. Soil amendments namely cauliflower leaves, neem (*Azadirachta indica*) cake, local botanical formulation of five plants were applied at the rate of 10 tonnes/ha and neem granules with Azadirachtin 0.15 % (E.I.D. Parry (India) Ltd.) (50 g/m^2) were applied before putting the mulch in treatment of solarization. Talc-based formulation of *T. viride* (50 g/m^2 taken out of one Kg formulation mixed in 25 Kg of farmyard manure) was applied after solarization. Liquid formulation of *Pseudomonas florescence* in broth was applied as root dip of the runners for 30 minutes before planting of the runners. Saaf (12 % carbendazim + 63 % mancozeb) (0.2%) was applied as root dip of the runners for 30 minutes followed by three drenching at an interval of 20 days starting after one month after transplanting of the runners. Six plants (30 cm × 60 cm) of Chandler variety per m^2 were planted in the 2nd week of October. Recommended dosages of farmyard manure (25 to 30 tonnes/ ha) and chemical fertilizers (75 Kg. N, 40 Kg. P_2O_5, 40 Kg. K_2O/ha) were added to all the plots before solarization.

The experiment to observe the effect of integration of soil solarization and amendment of cauliflower leaf residues on viability of propagules of the wilt pathogen was laid out in the field in completely randomized block design (Gomez and Gomez, 1984). Each treatment was replicated thrice. Effect of different treatments was observed on incidences of collar and root rot of strawberry and also on different growth parameters of the crop i.e. shoot length and root length of the plant, number of runners, flowers and fruits per plant, average fruit weight and yield. The data on different growth parameters were recorded by randomly selecting 6 plants per replication. Date of first flowering was also recorded in different treatments. Number of runners produced per plant in each treatment was also counted in the last.

RESULTS AND DISCUSSION

Soil solarization with transparent polyethylene mulch increased the maximum average soil temperature to 38.3°C and 40.2°C in comparison to 29.8°C and 30.1°C under unsolarized soil in 2008 and 2009, respectively. Increase of 9.2°C to 9.4°C in average maximum temperature was recorded in 2008 and 2009, respectively in comparison to uncovered soil. Further, average maximum air temperature during 2008 and 2009 was 30.1°C and 33.8°C, respectively. Mulching with transparent polyethylene sheet has been reported to increase soil temperature in all studies of solarization but the level of increase in temperature depends on the average maximum air temperature prevailing at a particular location (Katan, 1981).

Among different native botanicals evaluated to select five best to use as mixture as soil amendment, 29.5 to 65.0% inhibition in mycelium was recorded in *S. rolfsii* at 10% per cent concentration of water based formulation. In *R. solani*, these five best resulted in 16.3 to 54.3% reduction in mycelia growth, while in *F. oxysporum* f. sp. *fragariae*, it resulted in 25.7 to 47.9% reduction in the mycelia growth at 10 % concentration of the water based formulations.

Field trials conducted in 2008-09 and 2009-10 indicate that soil solarization in combination with soil amendments was found statistically at par in efficacy with root dip and drenching with Saaf, in reducing the incidence of different soil-borne diseases in the field in strawberry (Table 1). Moreover, this integration was found even better considering the growth and yield parameters of strawberry crop grown in different treatments. In 2008-09, there was no mortality of plants in treatment combination of soil solarization and soil amendment of cauliflower leaves before soil solarization which was comparable with root dip and drenching in Saaf. Treatment combinations of SS with neem cake and SS with dry botanical formulation with disease incidence of 1.6 % in each were found statistically at par with combination of SS with root dip and drenching with Saaf (Table 1). Treatment combinations of SS with *T. viride* and *P. florescence* formulations were found slightly less effective than treatment combination of SS with Saaf. In 2009-10 also, almost similar findings were recorded in all the treatments. Here, though treatment combination

Table 1. Effect of different treatment combinations of soil solarization with soil amendments and root treatments on plant mortality due to soil-borne diseases and other growth parameters of strawberry

Treatment		Plant mortality(%)		Plant height (cm)		Root length (cm)		Number of runners / plant		Average fruit weight (g/fruit)		Yield (q/ha)	
		2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Neem granules (50 g/ m^2) as soil amendment before solarisation	S	—	3.66 (9.04)	—	43.3	—	20.0	—	17.1	—	16.8	—	138.0
	US	—	12.93 (20.99)	—	33.9	—	15.9	—	12.8	—	14.0	—	127.5
Neem cake (10 MT/ha) (soil amendment before solarization	S	1.67 (6.06)	1.83 (4.52)	43.70	44.6	19.33	20.7	18.84	17.0	17.23	17.4	140.7	139.4
	US	11.67 (19.95)	11.1 (19.46)	36.60	34.6	17.47	16.4	12.53	13.2	15.47	14.7	130.4	129.6
Dry Field Formulation (10 MT/ ha) (Soil amendment before solarization)	S	1.67 (6.06)	3.66 (9.04)	43.17	44.7	19.03	19.8	17.47	17.5	16.77	17.2	139.4	138.3
	US	10.83 (19.19)	12.93 (20.99)	35.97	34.9	16.50	15.9	10.93	12.7	15.20	14.4	127.5	128.9
Pseudomonas florescence (Root dip in liquid culture broth)	S	5.83 (13.91)	7.36 (15.53	42.80	43.9	18.23	19.0	18.53	14.6	16.10	16.3	134.9	137.3
	US	15.83 (23.43)	14.77 (22.52)	35.43	33.1	15.23	15.3	12.40	11.9	13.37	13.7	126.4	129.1
Trichoderma viride (soil application after solarization)	S	3.33 (10.37)	5.5 (13.56)	43.33	43.7	19.67	19.0	18.67	14.4	17.07	16.2	140.5	137.2
	US	12.50 (20.54)	12.93 (20.99)	35.93	32.7	17.27	15.1	12.40	11.4	15.40	13..5	128.6	128.7
Saaf (0.2%) (Root dip + drenching)	S	0 (0)	0 (0)	40.73	42.3	17.90	17.2	14.20	14.0	14.90	15.6	132.3	135.8
	US	1.67 (6.06)	5.5 (13.56)	34.57	31.5	14.63	14.0	11.53	10.7	12.40	12.4	122.7	127.4
Cauliflower leaves (10 MT/ha) (soil amendment before solarization)	S	0 (0)	3.66 (9.04)	43.27	43.2	19.40	20.4	16.0	16.7	16.53	16.8	135.4	134.8
	US	9.17 (17.59)	12.93 (20.99)	37.33	32.6	17.30	15.6	11.47	13.1	15.27	14.0	124.4	121.4
Control	S	10.0 (18.35)	12.93 (20.99)	39.40	37.5	17.90	16.1	13.33	13.4	15.97	12.6	122.8	129.7
	US	42.50 (40.68)	48.10 (43.91)	29.37	26.0	14.07	11.6	6.87	7.4	11.53	9.6	80.1	66.1
$CD_{0.05}$	Treatment (T)	2.79	5.22	0.86	1.43	0.75	1.23	0.76	1.03	0.86	0.66	3.02	3.93
	Solarization (S)	1.49	2.61	0.46	0.71	0.40	0.61	0.40	0.51	0.46	0.33	1.01	1.96
	Interaction (TxS)	3.95	7.38	1.22	2.02	1.06	1.74	1.07	1.46	1.23	0.94	4.27	5.55

*Figures in the parentheses are angular transformed values; S, Solarized and US, unsolarized of SS with Saaf resulted in no mortality of the plants yet the treatment was found statistically at par with treatment combinations of SS with different soil amendments where the plant mortality ranged between 1.8 to 3.6% (Table 1). However, these combinations of SS with soil amendments were found more effective than treatment of Saaf without SS. SS has been found effective against different pathogens like *Pythium*, *Rhizoctonia*, *Cylindrocarpon* and *Phytophthora fragariae* f. sp. *fragariae* in strawbeery and raspberry (Pinkerton *et al*., 2002). Specifically, SS has been reported to be effective for the management of *Fusarium* wilt and southern blight (*S. rolfsii*) of strawberry (Bhardwaj and Raj, 2004; Cho and Moon, 1984; Komada and Fukui, 1982). Similarly, SS has been reported to be effective against diseases caused by *R. solani, S. rolfsii, Phytophthora fragariae* f. sp. *fragariae* and many other soil-borne pathogens (Mihail and Alcorn, 1984; Yaqub and Shahzad, 2009; Yildiz *et al*., 2010; Widodo and Budiarti, 2009). Soil solarization in combination with soil amendments, crucifer residues and microbial pesticides like *Trichoderma* spp., *Gliocladium* sp., *Pseudomonas* sp. has also been reported to be effective in strawberry, gladiolus, vegetables and other crops against different soil-borne diseases (Barrau *et al*., 2009; Camprubi *et al*., 2007; Fang *et al*., 2012; Porras *et al*., 2007; 2009; Njoroge *et al*., 2008; Raj and Upmanyu, 2013; Ristaino *et al*., 1991). Lodha and Israel (2005) also reported the effectiveness of combination of soil solarization with amendment of mustard residues or mustard oil-cake or *Verbesina encelioides* in reducing the incidence of wilt in cumin caused by *F. oxysporum* f. sp. *cumini*.

Combination of SS with soil amendments and microbial pesticides resulted in better growth and yield of the fruits than combination of SS with Saaf (Table 1). In both the years, combination of SS with soil amendment of neem cake resulted in best growth characteristics and yield. In 2008-09, this treatment resulted in 7.0% increase in plant height, 7.8 % in root length, 32.3% in number of runners per plant, 15.4% in average fruit weight and 6.3% in yield per hectare in comparison to treatment combination of SS and Saaf which indicate the significance of such treatments. This treatment was far superior to control (without SS and any other treatment) with 70.6 % increase in plant height, 34.0% in root length, 176.4% in number of runners per plant, 148.8% in average fruit weight and 75.0 % in yield per hectare. Similarly, in 2009-10 also this treatment resulted in 2.3% increase in plant height, 16.2% in root length, 22.1% in number of runners per plant, 7.6% in average fruit weight and 2.0% in yield per hectare in comparison to treatment combination of SS and Saaf. This treatment was far superior to control with 66.5% increase in plant height, 72.4% in root length, 131.0% in number of runners per plant, 75.0% in average fruit weight and 108.7% in yield per hectare. In addition, flowering in solarized treatments occurred 12 to 17 days earlier than unsolarized treatments. Most of the treatment combinations of SS with soil amendments and microbial pesticides were found statistically at par with each other in most of the growth characteristics and yield parameters thus proving the superiority of these treatments over combination of SS and chemical treatment of Saaf and SS alone. These studies corroborates the earlier findings where SS in combination with soil amendments, microbial bio-pesticides, beneficial microorganisms and crucifer residues have been found effective against *Fusarium* wilt of gladiolus, white root rot of apple (*Dematophora necatrix*), sapling wilt of citrus (*R. solani, F. oxysporum*) and damping-off of vegetable crops in reducing the incidence of the diseases and increasing different growth and yield characteristics (Raj, 2004; Raj and Upmanyu, 2006; Raj and Sharma, 2009; 2010). The mechanism for explaining increased growth responses and yield in plants has been attributed to chemical factors (like release of nutrients and other growth factors, nullification of toxins) and biological factors (elimination of minor or unknown pathogens and stimulation of beneficial micro-organisms) (Chen and Katan, 1980; Stevens *et al*., 2003).

Thus, treatment combination of soil solarization with transparent polyethylene mulch (25 µm thick) for 40 days with different soil amendments before solarization and also application of bio-control agents like *T. viride* and *P. florescence* after solarization were found effective for the management of different soil-borne diseases of strawberry. These treatments were at par in efficacy with treatment combination of soil solarization with root dip and drenching with Saaf in reducing the incidence of plant mortality but these treatments were superior in different growth characteristics and yield parameters of the crop.

ACKNOWLEDGEMENT

The author is thankful to Department of Science and Technology, Government of India for funding this project.

REFERENCES

Barrau, C., Porras, M., Romero, E., Zurera, C., Ramos, N., Soares, C., Neto, E., Marreiros, A., Entrudo, J. and Romero, F. (2009). *Brassica carinata* for control of *Phytophthora* spp. in strawberry field crops. *Revista de Ciências Agrárias* **32**(2): 135-138.

Bhardwaj, U. and Raj, H. (2004). Mulching with transparent polyethylene and root dip in fungicides for the management of collar and root rot of strawberry. *Indian Phytopath.* **57**: 48-52.

Camprubí, A., Estaún, V., El Bakali, M.A., Garcia-Figueres, F. and Calvet, C. (2007). Alternative strawberry production using solarization, metham sodium and beneficial soil microbes as plant protection methods. *Agr. Sust. Develop.* **27**: 179-184.

Chen, Y. and Katan, J. (1980). Effect of solar heating of soils by transparent polyethylene mulching on their chemical properties. *Soil Sci.* **130**: 271-277.

Cho, C.T. and Moon, B.J. (1984). Studies on the wilt of strawberry caused by *Fusarium oxysporum* f. sp. *fragariae* in Korea. *Korean J. Plant Prot.* **23**: 74-81.

Fang, X., You, M.P. and Barbetti, M.J. (2012). Reduced severity and impact of *Fusarium* wilt on strawberry by manipulation of soil pH, soil organic amendments and crop rotation. *Eur. J. Plant Pathol.* **134**: 619-629.

Gamliel, A. and Stapleton, J.J. (1993). Characterization of antifungal compounds evolved from solarized soil amended with cabbage residue. *Phytopathology* **83**: 899-905.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. Wiley and Sons, New York.

Katan, J. (1981). Solar heating (solarization) of soil for control of soil-borne pests. *Ann. Rev. Phytopathol.* **19**: 211-236.

Komada, T. and Fukui, T. (1982). Solar heating in closed plastic house for control of soilborne diseases V. Application for control of Fusarium wilt of strawberry. *Ann. Phytopathol. Soc. Japan* **48**: 570-577.

Lodha, S. and Israel, S. (2005). Combining solar heat, on-farm wastes and summer irrigation for improved control of *Fusarium oxysporum* f. sp.*cumini*. *Acta Horiculturae* **698**: 181-186.

Mihail, J.D. and Alcorn, S.M. (1984). Effects of soil solarization on *Macrophomina phaseolina* and *Sclerotium rolfsii*. *Plant Dis.* ***68:*** 156-159.

Negi, H.S. and Raj, H. (2013). Effect of soil solarization on pathogenic potential and viability of *Fusarium oxysporum* f.sp. *dianthi* causing wilt in carnation. *Indian Phytopath.* **66**: 273-277.

Njoroge, S.M.C., Riley, M.B. and Keinath, A.P. (2008). Effect of Incorporation of *Brassica* spp. Residues on Population Densities of Soilborne Microorganisms and on Damping-off and Fusarium Wilt of Watermelon. *Plant Dis.* **92**: 287-294.

Pinkerton, J.N., Ivors, K.L. and Reeser, P.W. (2002). The Use of Soil Solarization for the Management of Soilborne Plant Pathogens in Strawberry and Red Raspberry Production. *Plant Dis.* **86**: 645-651.

Porras, M., Barrau, C., Arroyo, F. T., Santos, B., Blanco, C. and Romero, F. (2007). Effects of soil solarization and *Trichoderma* on strawberry production. *Plant Dis.* **91**: 142-146.

Porras, M., Barrau, C. and Romero, F. (2009). Effects of *Trichoderma* and soil solarisation on *Phytophthora cactorum* in strawberry fields. *Acta Horticulturae* **842**: 649-652

Raj, H. (2004). Effect of solarization of farm yard manure amended soil for management of damping-off caused by *Pythium ultimum*, *Rhizoctonia solani*, *Sclerotium rolfsii* in vegetable crops in nurseries. *Indian J. Agric. Sci.* **74**: 425-459.

Raj, H. and Sharma, S.D. (2009). Integration of soil solarisation and chemical sterilization with beneficial microorganisms for the control of white root rot and growth of nursery apple. *Scientia Horticulturae* **119**: 126-131.

Raj, H. and Sharma, S.D. (2010). Combination of soil solarization, vesicular-arbuscular mycorrhiza and *Azotobacter chrococcum* for the management of seedling wilt of citrus. *Indian Phytopath.* **63**: 282-285.

Raj, H. and Tomar, M. (2013). Use of Aqueous and Cow Urine based Plant Extracts against Post-harvest Diseases of Apple. *J. Mycol. Plant Pathol.* **43**(2): 246-249.

Raj, H. and Upmanyu S. (2006). Solarization of soil amended with residues of cabbage leaves and corm treatment with fungicides for management of wilt (*Fusarium oxysporum*) of gladiolus (*Gladiolus grandiflorus*). *Indian J. Agric. Sci.* **76**: 307-311.

Raj, H. and Upmanyu, S. (2013). Integration of soil solarization, corm treatment and soil amendment for the management of *Fusarium* wilt of gladiolus. *Indian Phytopath.* **66**: 28-33.

Ristaino, J.B., Perry, K.B. and Lumsden, R.D. (1991). Effect of soil solarization and *Gliocladium virens* on sclerotia of *Sclerotium rolfsii,* soil microbiota and the incidence of southern blight in tomato. *Phytopathology* **81**: 1117-1124.

Stevens, C., Khan, V.A., Rodrigvez-Kabana, R., Ploper, C.D., Backman, P.A., Collins, D.J., Brown, J.E., Wilson, M.A. and Igwegde, E.C.K. (2003). Integration of soil solarization with chemical, biological and cultural control for the management of soil-borne diseases of vegetables. *Plant and Soil* **253**: 493-496.

Yaqub, F. and Shahzad, S. (2009). Effect of solar heating by polyethylene mulching on sclerotial viability and pathogenicity of *Sclerotium rolfsii* on mungbean and sunflower. *Pak. J. Bot.* **41**: 3199-3205.

Yildiz, A., Benlioglu, S., Boz, O. and Benlioglu, K. (2010). Use of different plastic for soil solarisation in strawberry growth and time-temperature relationships for the control of *Macophomina phaseolina* and weeds. *Phytoparasitica* **38**: 463-473.

Widodo and Budiarti, T. (2009). Suppression of Fusarium root rot and southern blight on peanut by soil solarisation. *Journal of ISSAAS* **15**: 118-25.

Received for publication: February 21, 2014
Accepted for publication: June 30, 2014