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Integrated Management of Soil Borne Diseases by Improving Soil Health with Physical and Chemical Treatments

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A B S T R A C T

Soil-borne diseases result from a reduction of biodiversity of soil organisms. Restoring beneficial organisms that attack, repel, or otherwise antagonize disease-causing pathogens render a soil disease-suppressive. Plants growing in such suppressive soil resist diseases much better than in soils low in biological diversity. Beneficial organisms increased to the soil environment through the use of compost and other organic amendments. Soil solarization significantly increased in soil temperature (10-12°C) was observed as compared to non-solarized plots at 5, 10 and 15 cm depths, however, maximum rise in temperature (58°C and 56.1°C) was recorded at 5 cm depth during 2013 and 2014, respectively. Further soil solarisation was also found effective in reducing the pathogen population.

Introduction

Soil borne diseases are the major constraints in the successful cultivation of crop and a number of pathogens have been found to be associated with such diseases, of which *Fusarium oxysporum*, *Rhizoctonia solani* and *Pythium aphanidermatum* (fungi), *Ralstonia solanacearum* (bacterium) and *Meloidogyne incognita* (root knot nematode) are the most common (Doolittle, 1953; Das and Chattopadhyay, 1955; Darekar and Mhase, 1988). Managing the soil borne diseases though quite difficult, however, various measures have been adopted to manage them with the aim to either eliminate or reduce the primary inoculum in soil in or on the seed or propagating material, besides making the hosts evade or defend the attack of the pathogens involved. Soil solarization is a simple nonchemical technique that captures radiant heat energy from the sun which leads to control or suppression of soil borne plant pathogens such as fungi, bacteria, nematodes, and pests along with weed seed and seedlings. Under suitable climatic conditions, solarization can control a wide spectrum of soil borne pests including fungi, bacteria, weeds and insects (Gamliel and Stapleton, 1993).

Soil solarization, a hydrothermal process, was studied for assessment of its effect on physical (temperature, pH and moisture) properties of soil. Several workers have reported increase in temperature and conservation of soil moisture while soil solarization due to the trapping of the solar energy by polyethylene sheets and preventing the heat loss caused by evaporation and convection, thus creating a greenhouse effect (Elad *et al.*, 1980; Katan, 1981). Soil solarization integrated with different amendments and bioagents increases the efficacy of soil solarization and prolonged effectiveness of soil solarization.

Materials and Methods

Soil solarization

The nursery beds were irrigated to the level of field capacity to ensure the presence of adequate moisture during the period of solarization. These beds were covered with low density transparent polyethylene sheets of 25 µm thickness, placing the ends of the sheets in furrows and buried with compact soil to ensure that all the edges were thoroughly sealed.

In order to record the soil temperature, soil thermometers were placed at 5, 10 and 15 cm soil depths, beneath the polyethylene sheets, during the entire period of solarization. Temperature of the uncovered (non-solarized) plots was also recorded. Soil temperatures were recorded daily at 06.00 and 14.00 hours and interpreted in results on weekly basis.

Soil amendments

Decomposed Farm Yard Manure (FYM) was inoculated with most effective fungal and bacterial biocontrol agents viz., *Trichoderma viride* isolate Tv_4 (1 x 10^7 cfu/ml) and *Pseudomonas fluorescens* isolate Pf_2 (1 x 10^8 cfu/ml) and then applied to the nursery fields @ 2000 g/m^2. Spent compost of button mushroom i.e., compost left after harvesting of mushroom was added to the nursery beds @ 2000 g/m^2. The details of the treatments are as: T_1 =Soil solarisation, T_2= Soil fumigation, $T_{3=}$ Non-solarized soil + *Trichoderma viride* + FYM @ 1000 g/m^2, $T_{4=}$ Non-solarized soil + *Pseudomonas fluorescens* + FYM @ 1000 g/m^2, T_5 =Spent compost of button mushroom @ 1000 g/m^2 and T_6 =Control (untreated plots). All the experiments were conducted in Randomized Block Design with three replications at Research Farm at Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu.

Observations regarding microbial population

Microbial population in different treatments were recorded by analyzing soil samples using soil dilution plate method (Dhingra and Sinclair, 1995). Fungal population was recorded by counting the number of colonies developed on PDA after plating 1ml of 10^{-4} dilution in a petriplate. For evaluating bacterial load 1ml of 10^{-6} dilution was used for plating on Nutrient Agar (Allen, 1957). Actinomycete population was counted on Actinomycetes Specific Medium (ASM) by plating 1ml of 10^{-7} dilution (Kuznetsov and Rao, 1972).

Population of nematodes was recorded from different treatments. To isolate nematode the soil samples from different locations were processed by sieving and decanting method (Cobb, 1918).

Results and Discussion

Soil temperature

The average soil temperature profiles recorded at 5, 10 and 15cm depths in both solarized and non-solarized plots are presented in Table 1. In the year 2013, maximum soil temperature in the non-solarized plots at 5 cm depth ranged from 37 to 47^{0}C and in solarized plots from 47.8 to 58.8^{0}C, whereas, the minimum soil temperature in non-solarized plots ranged from 14.1 to 25^{0}C, and in solarized plots from 23.9 to 34.3^{0}C.

At 10 cm depth the maximum soil temperature in non-solarized plots was 32.7 to 43.5^{0}C and in solarized plots 40.6 to 51.5^{0}C, whereas, minimum temperature in non-solarized plots ranged from 17.6 to 25.6^{0}C and in solarized plots 23.6 to 30.4^{0}C. Similarly, at 15 cm depth, the average maximum soil temperature in non-solarized plots ranged from 28 to 38.9^{0}C, and in solarized plots from 34.2 to 46.1^{0}C, whereas, the minimum temperature in non-solarized plots varied from 19.3 to 28.5^{0}C and in solarized plots from 27.4 to 35^{0}C.

In the year 2014, maximum soil temperature in the non-solarized and solarized plots at 5cm depth ranged from 32.6 to 44.6^{0}C and 44.2 to 56.1^{0}C, whereas, the minimum soil temperature ranged from 17.4 to 24.2^{0}C and 26.8 to 34.6^{0}C, respectively.

At 10 cm depth the maximum soil temperature recorded in the non-solarized and solarized plots ranged from 32.5 to 38.3^{0}C and 41 to 50^{0}C, whereas, the minimum soil temperature from 20.6 to 28.2^{0}C and 26.5 to 35.2^{0}C, respectively. Similarly, at 15 cm depth maximum temperature in the non-solarized and solarized plots ranged from 27.6 to 38.8^{0}C and 35.9 to 43.1^{0}C, whereas, the minimum temperature ranged from 22 to 29.9^{0}C and 30.2^{0}C to 37.1^{0}C, respectively.

Microbial population

Soil samples collected from nursery plots, given different treatments, were examined for the presence of microbial population.

Fungal population

A perusal of data presented in the Table 2 reveal that in the year 2013, fungal population in the solarized nursery plots was minimum (13.67×10^4), it was followed by fumigated nursery plots (15.33×10^4). Fungal population was maximum in spent compost treated plots (47.67×10^4), followed by plots amended with FYM + Tv_4 (33.67×10^4) and plots with FYM treated with Pf_2 (29.67×10^4). In non-solarized control plots the fungal population recorded was 26.33×10^4. Similar trend was observed in the year 2014.

Bacterial population

In the year 2013, bacterial count recorded (Table 2) from solarized nursery plots and fumigated nursery plots was minimum (40.33×10^6, in each), which was followed by fumigated nursery plots (43.33×10^6). Bacterial population was maximum in plots amended with spent compost (86.33×10^6), followed by plots having FYM treated Tv_4 (81.67×10^6) and FYM treated with Pf_2 (78.33×10^6). In the non-solarized plots the bacterial count was 75.33×10^6. Similar trend was observed in the year 2014.

Actinomycetes population

The data presented in Table 2 further revealed that in the year 2013, the actinomycetes count recorded from fumigated nursery plots was minimum (11.33×10^5), followed by plots amended with spent compost (11.67×10^5). Actinomycetes population was maximum (22.67×10^5) in solarized nursery plot. In the control plots the population was 15.33×10^5.

Table.1 Soil temperature recorded at different depths from solarized and non–solarized plots during 2013 and 2014

Meteorological Standard Week	Soil temperature (^{0}C) at different depths											
	Non-solarized plots						Solarized plots					
	5cm		10cm		15cm		5cm		10cm		15cm	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Year 2013												
16	37.0	14.1	32.7	17.6	28.0	19.3	47.8	23.9	40.6	23.6	34.2	**27.4**
17	38.5	16.5	34.1	21.2	28.4	22.8	49.7	26.5	43.4	28.0	37.8	**30.9**
18	43.1	19.0	36.6	23.3	32.1	25.7	55.0	29.0	45.7	28.2	40.6	**33.6**
19	44.7	17.1	39.7	22.0	34.8	24.4	56.9	26.8	48.0	26.3	42.5	**30.7**
20	47.0	19.5	43.5	24.0	38.9	26.9	58.8	29.2	51.5	29.0	46.1	**33.8**
21	44.5	25.0	39.6	25.6	34.0	28.5	56.6	34.3	48.1	30.4	42.6	**35.0**
22	46.8	18.8	41.8	24.7	37.7	27.0	57.0	28.4	50.9	30.0	44.3	**34.0**
Year 2014												
16	34.9	17.4	32.5	20.6	27.6	22.0	46.2	26.8	41.0	26.5	35.9	**30.2**
17	32.6	19.0	34.9	23.2	28.1	23.5	44.2	29.0	43.7	29.0	37.4	**32.0**
18	37.7	19.9	34.4	23.4	31.2	25.5	50.0	29.9	43.4	29.8	40.0	**33.5**
19	38.8	19.4	35.3	22.2	32.0	25.0	51.3	28.1	46.2	28.2	40.5	**31.0**
20	42.0	21.7	37.2	24.8	32.3	26.1	54.4	31.3	46.9	31.7	41.1	**34.9**
21	42.4	22.9	36.7	26.9	33.1	28.3	55.2	31.2	47.3	33.5	42.0	**36.2**
22	**44.6**	**24.2**	**38.3**	**28.2**	**33.8**	**29.9**	**56.1**	**34.6**	**50.0**	**35.2**	**43.1**	**37.1**

Table.2 Effect of soil solarization and addition of soil amendments on the soil microbial population

Treatment	Average number of colonies (cfu/g of soil)			Nematode population per 250 g soil
	Fungi ($1x10^4$)	Bacteria ($1x10^6$)	Actinomycetes ($1x10^5$)	
Year 2013				
Soil solarization	13.67*(3.83)	40.33 (6.43)	22.67 (4.86)	137.67 (11.78)
Soil fumigation	15.33 (4.04)	43.33 (6.66)	11.33 (3.51)	148.67 (12.22)
Non-solarized soil + FYM + *T. viride* (Tv_4)	33.67 (5.89)	81.67 (9.09)	12.33 (3.65)	155.33 (12.50)
Non-solarized soil + FYM + *P. fluorescens* (Pf_2)	29.67 (5.54)	78.33 (8.90)	12.67 (3.69)	166.67 (12.95)
Non-solarized soil + SCM	47.67 (6.98)	86.33 (9.35)	11.67 (3.56)	158.67 (12.62)
Non-solarized soil (check)	26.33 (5.23)	75.33 (8.74)	15.33 (4.04)	437.00 (20.93)
$S.E_m$ (±)	0.03	0.02	0.04	0.10
CD(P=0.05)	0.094	0.074	0.130	0.303
Year 2014				
Soil solarization	13.00 (3.74)	39.33 (6.35)	21.33 (4.73)	136.67 (11.73)
Soil fumigation	16.67 (4.20)	44.67 (6.76)	12.67 (3.69)	150.67 (12.31)
Non-solarized soil + FYM + *T. viride* (Tv_4)	33.00 (5.83)	82.33 (9.13)	13.67 (3.88)	156.67 (12.54)
Non-solarized soil + FYM + *P. fluorescens* (Pf_2)	29.00 (5.48)	78.67 (8.93)	13.33 (3.79)	169.00 (13.03)
Non-solarized soil + SCM	48.33 (7.02)	85.00 (9.27)	11.00 (3.45)	160.00 (12.69)
Non-solarized soil (check)	25.67 (5.16)	74.00 (8.66)	14.67 (3.96)	441.33 (21.02)
$S.E_m$(±)	0.04	0.02	0.05	0.10
CD(P=0.05)	0.131	0.063	0.163	0.326

*Figures given in parenthesis are transformed (arc sin) values; Soil fumigation [5 L formalin solution per bed (1 m^2)]; FYM=Farm yard manure [2kg per bed (1 m^2)]; SCM=Spent compost of mushroom [2kg per bed (1 m^2)]
T. viride @ 10^7 spores per ml; *P. fluorescens* @ 10^8 colony forming units (cfu) per ml.

In the year 2014 actinomycetes colonies recorded from plots amended with spent compost were minimum (11×10^5), followed by fumigated nursery plots (12.67×10^5).

Maximum actinomycetes colonies were recorded from solarized nursery plots (21.33×10^5). In the control plots (non-solarized plots) the population recorded was 14.67×10^5.

Nematode Population: In the year 2013, minimum nematode population was recorded from solarized plots (137.67), which was followed by fumigated nursery plots (148.67), and plots amended with FYM treated with Tv_4 (155.33). Maximum nematode population per 250g soil was recorded from the nursery plots amended with FYM treated with Pf_2 (166.67), followed by plots amended with spent compost (158.67). In non-solarized plots the population recorded was 437. Similar trend was observed in the year 2014.

Soil solarization, a hydrothermal process, was studied for assessment of its effect on physical (temperature, pH and moisture) properties of soil. Soil solarization significantly increased in soil temperature (10-12°C) was observed as compared to non-solarized plots at 5, 10 and 15cm depths, however, maximum rise in temperature (58 and 56.1°C) was recorded at 5 cm depth during 2013 and 2014, respectively. Several workers have reported increase in temperature while soil solarization due to the trapping of the solar energy by polyethylene sheets and preventing the heat loss caused by evaporation and convection, thus creating a greenhouse effect (Elad *et al.,* 1980; Katan, 1981). Chellemi *et al.,* (1994) recorded the temperature profiles at different depths and found maximum increase of temperature at 5 cm depth. Khulbe and Chaube (2000) reported that mulching of pre-irrigated plots with polythene sheetings increased daily average temperature by 12-15°C. In the solarized plots the pH recorded was significantly higher than other treatments which included soil fumigation, non-solarized soil + FYM + *T. viride* (isolate Tv_4), non-solarized soil + FYM + *Pseudomonas fluorescens* (Pf_2), non-solarized soil + spent compost and non-solarized soil (check). Sharma and Sharma (2004) also reported that pH was higher in the solarized plots as compared to non-solarized plots at 10 and 30 cm soil depths. The studies also revealed that at the end of solarization period the moisture conserved was significantly higher in solarized plots as compared to soil fumigation and non-solarized plots. In non-solarized plots, solar radiations falling on earth cause loss of moisture through evapotranspiration since white thin transparent polyethylene sheets provide insulation against escape of heat and moisture from soil (Chen and Katan, 1980; Katan, 1987; Ahmad *et al.,* 1996). The rise in soil temperature resulted in decrease of fungal, bacterial and nematode population, whereas, there was increase in the actinomycetes population due to their thermophillic nature. Our findings are in conformity with different workers (Stapleton and De-Vay, 1982; Sharma *et al.,* 2000; Sharma and Sharma, 2004; Verma and Sharma, 2005).

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