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Soil Solarization: an Eco-friendly Management Technique of Damping-off of Tomato

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ABSTRACT

The present study was conducted at experimental farm and laboratory of Dept. of Plant Pathology of Dr. YSPUHF, Nauni, Solan Himachal Pradesh in May 2017–November 2018. The objective of the study was to evaluate the effect of thermal water bathas well as soil solarization on soil temperature and viability of soil borne pathogens of tomato. The disease occurs in two phases i.e. pre-emergence and post emergence that leads to severe infection and crop loss. These pathogens are more likely to influence the development of damping-off disease and their eradication remains a difficult task. Among various eco-friendly methods of disease management, soil solarization is a recourse technique and has been attempted in the present study in mulched and un-mulched beds at three depths i.e., 5, 10 and 20 cm to check the effect of soil solarization on soil temperature. Nursery beds covered with polythene mulch noticed rise in soil temperature and data was recorded for two consecutive crop seasons i.e., 2018 and 2019, where average/ mean weekly temperature was recorded in range of 35.99° to 43.87°C and 29.25° to 41.68°C, respectively. The highest temperature was recorded for the nursery beds with 5 cm depth and vice-versa. Overall, conclusive evidence of the survival and killing of pathogens *F. oxysporum* and *R. solani* was observed for the corresponding 10 to 20 days and 30 to 40 days schedule of the soil solarization that represents the existence of pathogens.

KEYWORDS: Damping-off, eco-friendly management, soil solarization, tomato

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated crops in different countries (Tamburino et al., 2020). This cropis affected by more than 200 diseases caused specially by soil borne fungi. Major fungal pathogens that cause diseases in tomato are *Sclerotium rolfsii*, *Rhizoctonia solani*, *Verticillium dahliae, Fusarium* sp., *Pythium* sp. etc. (Singhet al., 2017).

Damping-off is a frequent nursery disease in the horticultural crops which appears in both pre and post emergence stages (Weiland et al., 2014). Numerous soil-borne fungi and fungal like organisms associated with damping-off are *Rhizoctonia, Fusarium*, *Sclerotium* and oomycetes such as *Pythium*, *Phytophthora* (Elshahawy and El Mohamedy, 2019, Arora et al., 2021).These pathogens survive in plant debris and soil organic matter by developing dormant structures such as sclerotia, chlamydospores, oospores thereby inducing heavy economic losses when established in the nursery soil. Such structures remain viable for longer period of time which creates difficulty in managing this disease (Larkin, 2015, De Corato, 2020, Gullino et al., 2022).

Several control strategies are deployed for management of soil borne diseases but each one has some negative impact in one way or other as these are unsafe to environment, not budget friendly and difficult to procure (Molin et al., 2021, Arora et al., 2022). Most of the farmers depend upon the chemical methods of disease management but it leads to development of fungicide resistance,depletes the useful properties of soil and toxic to microbial communities (Van Bruggen et al., 2016, Ons et al., 2020, Jayalakshmi et al., 2021).

One chemical free method ingaining importance due to its cost effectiveness and easy accessibility that works by trapping solar energy and improving the soil healthis soil solarization (Thakur et al., 2022). It is a sustainable technique that involvesthe use of sunny and warm lands for the entrapment of solar radiationwith polyethylene sheet to increasethe temperature (commonly in the range of 45–55°C) at soil depth of 5cm and inhibits the population and propagules of soil borne plant pathogens (Kanaan et al., 2015, Devendra et al., 2015, Van Bruggen et al., 2016, Hasan, 2018).

Increased temperature through solarization in the middle of summerwhen the temperature is on peak,helps in reducing the numbers, viability, germination of spores, sclerotia and apothecial formation. During this time period, soil receives the maximum sunlight which checks the perpetuation of pathogens (Saremi and Saremi, 2013, Deb et al., 2020). Energy radiated from the sun is deadly to many soil-borne pathogens. It improves soil texture and the nutrients availability in the soil which are essential for the growth and developmentof plants (Rylander et al., 2020). Besides the reduction in soil-borne pathogens, soil solarization also leads to increased growth response of plants (Achmon et al., 2017). This method integrates well with other techniques such as mulching and soil amendments to enhance its overall effectiveness against diseases and increases crop yield (Monteiro and Santos, 2022).

Primary requirement for soil solarization is optimum soil temperature (4–6 weeks) and it fits in most of Indian rural areas(Mawaret al., 2022). It reduces the disease incidence caused by soil borne pathogens with increase in temperature rise to that particular level which is deadly to many soil borne pathogens.Therefore, in the next coming years, it could be considered a sort of paradigm of sustainable crop protection (Katan, 2015, Gill et al., 2017).

Considering the seriousness of disease, present study was conducted to determine the thermal sensitivity of isolated pathogens under *in vitro* conditions by giving exposure to different temperatures. Further, the effect of soil solarization was evaluated on viability of soil borne pathogens causing damping-off of tomato under field conditions.

2. MATERIALS AND METHODS

The following experiments were conducted under *in vitro* and field conditions in the month of May 2017 to November 2018 at Dr. YSPUHF Nauni, Solan, Himachal Pradesh, India.

2.1. Thermal sensitivity of isolated pathogens under in vitro conditions

To study the thermal sensitivity of inocula of isolated pathogens i.e. *P. ultimum*, *F. oxysporum, R. solani* and *S. rolfsii* under *in vitro* conditions, the mass culture of these pathogens grown on corn sand media (5 g) was placed in a piece of muslin cloth which were then placed at three different temperatures 35°C, 40°C and 45°C in the hot water bath for three different durations i.e. 5, 10 and 20 m. After exposure, small bits of test pathogens were placed on sterilized PDA Petriplates under aseptic conditions and were incubated at 25±1°C for one week. Pathogens were also grown in Petri dishes without exposure for comparison. Observations on the growth of the fungi were recorded till the plates in control were fully grown and data was recorded as the per cent growth inhibition of the test pathogens over control was calculated according to Vincent (1947) as under:

$I = (C-T/C)\times100$

Where,

I =Inhibition (%)

C =Linear growth in control (mm)

T=Linear growth in treatment (mm)

2.2. Effect of soil solarization on soil temperature under field conditions

The experiment was carried out during May–June for two consecutive years i.e. 2018 and 2019 at experimental farm of Department of Plant Pathology, UHF, Nauni with Latitude 30–51'44.7444"and Longitude 77–10'9.1488", Himachal Pradesh, India. Raised beds (1×1 m^2) were prepared and covered with polyethylene sheet (25 μm) after irrigation up to the field capacity one day prior to mulching. Unsolarized beds were kept as control. The edges of the sheets were buried in the soil to make them airtight. The polythene sheet was removed after 45 days and the temperature at three depths (5, 10 and 20 cm) was measured in solarized and unsolarized beds by dial soil thermometer at 2:00 PM daily. After solarization, tomato seeds were sown in lines in the same solarized beds.

2.3. Effect of soil solarization on viability of the pathogens under field conditions

To study the effect of soil solarization on the viability of the pathogens in soil, the mass culture of the pathogens i.e. *P. ultimum*, *F. oxysporum*, *R. solani* and *S. rolfsii* grown on corn sand media and placed in nylon sieve bags (20 g bag^{-1}) which were then placed at 5 cm depth in the plots prior to mulching with polyethylene sheets and also in unsolarized plots. One nylon bag contained onefungal culture of each pathogen separately which was retrieved after 10, 20 and 30 days. The viability of these test fungi was monitored by placing fungal cultures onto sterilized PDA Petriplates under aseptic conditions and was incubated at 25±1°C.

2.4. Statistical analysis

The data recorded from *in vitro* and field experiments were subjected to statistical analysis. The differences exhibited by treatments in various experiments were tested for their significance at 5 per cent level using standard procedure as described by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Thermal sensitivity of inocula of isolated pathogens in vitro

Data (Table 1) showed that with the increase in the temperature from 35°C to 40°C and 45°C, there was a general increase in percent mycelial growth inhibition of all the four fungal pathogens, The highest inhibition was observed at 45°C temperature giving 6.59, 6.84, 5.70 and 4.03 % inhibition with *P. ultimum, F. oxysporum, R. solani*and *S. rolfsii,* respectively.

Table 1: In vitro thermal sensitivity of inocula of four pathogens of damping-off of tomato on mycelial growth inhibition at different temperatures and exposure durations

Tempera-ture (oC)	Exposure time (m)															
	Mycelial growth inhibition of fungal pathogens (%)															
	P. ultimum				*F. oxysporum*				*R. solani*				*S. rolfsii*			
	5	10	20	Mean	5	10	20	Mean	5	10	20	Mean	5	10	20	Mean
35	0.88	3.33	5.99	3.4	1.55	4.33	4.66	3.51	0.66	2.88	2.77	2.10	0.22	0.99	2.99	1.40
40	5.78	6.43	8.43	6.88	2.88	4.55	6.21	4.54	1.22	3.88	5.10	3.40	0.22	0.99	2.88	1.36
45	4.46	6.66	8.66	6.59	5.66	7.10	7.77	6.84	5.33	5.33	6.44	5.70	3.11	4.33	4.66	4.03
Mean	3.70	5.47	7.69	-	3.36	5.32	6.21	-	2.40	4.03	4.77	-	1.88	2.10	3.51	-
CD (p=0.05)																
Tempera-ture (A)	1.58				1.55				0.81				0.65			
Exposure time (B)	1.37				1.34				0.82				0.56			
A×B	2.74				2.07				1.41				1.12			

Data further revealed that similar trend of growth inhibition was observed for exposure durations exhibiting an increase in growth inhibition with the increase in exposure time from 5 to 10 and 20 m. All the exposure durations were statistically different from each other for all the four pathogens.

It was reported by Cartia and Asero (1994), Sharma and Sharma (2002) that thermal sensitivity of artificially pathogen inoculated wheat seeds and naturally infected root segments when exposed to different temperatures and durations of 1–4 h, the survival of the pathogen was inversely proportional to both temperature and duration of exposure. Thus, *Dematophora necatrix,* a soil borne pathogen was much more sensitive to heat above 40°C, whereas, temperature below 40°C can be lethal for pathogen when maintained for longer periods.

3.2. Effect of soil solarization on soil temperature under field conditions

Effect of soil solarization on soil temperature in mulched and unmulched beds at three depths (5, 10 and 20 cm) was recorded for two consecutive crop seasons i.e., year I (2018) and Year II (2019) and data obtained are presented in Table 2 and 3.

The data (Table 2) indicated that there was a significant increase in soil temperature in nursery beds covered with polythene mulch (25 μm) as compared to the unmulched beds (non solarised beds) at all depths (Table 3). Maximum increase in the mean weekly temperature was recorded at 5 cm depth followed by 10 and 20 cm. During the year I, in case of mulched nursery beds highest average/ mean weekly temperature of (43.87°C) was recorded at 5 cm depth while the lowest (35.99°C) was at 20 cm depth. During year II, maximum increase in the mean weekly temperature of (41.68°C) was recorded at 5 cm depth followed by 10

Table 2: Effect of soil solarization on soil temperature during in solarized nursery beds

Duration (week)	Temperature (°C) in solarized nursery beds									
	5 cm			10 cm			20 cm			Overall mean
	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean	
1	46.14	29.78	37.96	41.71	26.71	34.21	37.64	23.85	30.74	34.10
2	43.92	31.42	37.67	40.07	27.92	33.99	34.50	25.07	31.10	34.25
3	40.71	33.78	37.24	38.50	31.21	34.85	33.64	28.57	31.02	34.38
4	41.14	34.00	37.57	37.57	31.9	34.73	34.55	27.50	33.30	35.20
5	42.00	37.21	39.60	38.21	34.00	36.10	35.35	31.25	35.57	37.09
6	46.07	39.14	42.60	42.35	36.07	39.21	37.50	33.65	36.82	39.54
7	47.11	39.75	43.43	43.20	37.25	40.22	38.78	34.87	29.78	37.81
Mean	43.87	41.68	-	40.23	32.15	-	35.99	29.25	-	-
Overall mean		39.43			36.18			36.05		-

Table 3: Effect of soil solarization on soil temperature in non-solarised nursery beds

Duration (week)	Temperature (°C) in non-solarized nursery beds									
	5 cm			10 cm			20 cm			Overall mean
	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean	
1	41.35	27.14	34.24	37.78	24.21	30.99	34.42	21.07	27.74	30.99
2	34.50	28.78	31.64	32.50	24.78	28.64	31.00	21.57	26.28	28.85
3	38.07	30.92	34.49	35.68	28.21	31.94	32.35	25.28	28.81	31.74
4	38.64	34.14	36.39	35.71	26.42	31.06	33.78	23.71	28.74	32.06
5	39.87	35.00	37.43	34.85	30.21	32.53	31.71	26.28	28.99	32.98
6	40.07	36.28	38.17	37.28	32.92	35.10	34.45	29.42	31.93	35.06
7	41.71	36.75	39.23	38.71	32.25	35.48	35.50	30.00	32.75	35.82
Mean	39.17	32.71	-	36.07	28.42	-	33.31	25.32	-	-
Overall mean		35.94			32.45			23.32		-

Temperature range (°C)		
Year	Solarized nursery beds	Non-solarized nursery beds
2018	34–47	31–41
2019	23–39	21–36

and 20 cm with the temperature of 32.15°C and 29.25°C, respectively (Table 3). Nursery beds mulched with polythene sheet showed an increase in average/ mean weekly temperature. In general, with increasing soil depths, there is rise in temperature progressively. Maximum temperature of (37.81°C) was recorded in the seventh week while the lowest (34.10°C) was in the first week.

In the present investigation, maximum rise of 3.4°C in mean soil temperature was attained in mulched beds at 5 cm depth over unmulched beds. The rise in soil temperature due to soil solarization was in consonance with various workers (Al-Karaghouli and Al-Kayssi, 2001, Akhtar et al., 2012, Negi and Raj, 2013).

3.3. Effect of soil solarization on viability of the pathogens causing damping-off of tomato under field conditions

It is clear from the data (Table 4) that viability of the pathogens had an inverse relationship with duration of the soil solarization. With the increase in the duration of soil solarization, viability of the pathogen decreased. Soil solarization for 10 to 20 days resulted in the survival of all the pathogens. Soil solarization for 30 days resulted in killing of the pathogens *F. oxysporum* and *R. solani* while all the pathogen were found dead after 40 days of soil solarization and could not be recovered. In case of non-solarized control, pathogens were viable at all the depths even after 40 days. Therefore, it was observed that soil solarization for 30 days was sufficient to reduce the viability of pathogens to some extent but 40 days were required for complete loss of viability.

Table 4: Effect of soil solarization on viability of the pathogens causing damping-off of tomato under field conditions

Duration (days)	Viability of the pathogens							
	Solarized nursery beds				Non solarized nursery beds			
	P. ultimum	*F. oxysporum*	*R. solani*	*S. rolfsii*	*P. ultimum*	*F. oxysporum*	*R. solani*	*S. rolfsii*
10	+	+	+	+	+	+	+	+
20	+	+	+	+	+	+	+	+
30	+	-	-	+	+	+	+	+
40	-	-	-	-	+	+	+	+

+ denotes viable pathogen, - denotes non-viable pathogen

Soil solarization for 30 days was sufficient to reduce the viability of *F. oxysporum* and *R. solani* but 40 days were required for complete loss of viability of all the pathogens. These results were in agreement with findings of various workers (Raj et al., 1997; Reddy et al., 2006) who had already reported the effectiveness of soil solarization against pathogens causing damping-off.

4. CONCLUSION

An alternative and safe management system of disease management is soil solarization. This method is cost effective, integrates well with plastic mulch and provides significant management of the soil borne pathogens. This permit less use of chemical fumigants as it rely on locally available resources. Increase in use of plastic technology supports soil solarization method of disease management. Reduction in soil borne pathogens reported in the above-mentioned methods offer a satisfactory tool for integrated programme of disease management.

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