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Effect of soil solarization on the growth of onion (*Aliium cepa* L.) and onion blight disease

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Abstract
Soil solarization, with the addition of soil amendments, was carried out for a period of six weeks. The maximum temperature of solarized plots was 9.2–11.3ºC higher than that of non-solarized plots and the minimum temperatures in solarized plots were 7.5–12.1ºC higher than non-solarized plots. Moisture was conserved most effectively (10.05 percent) in the solarized plots treated with FYM, followed by poultry manure (9.27 percent), whereas, the least amount of moisture was conserved in plots supporting none of the amendments (1.72 percent). At the end of solarization, maximum fungal colonies (26×10^4) were detected in solarized plots amended with poultry manure, maximum actinomycete colonies (268×10^3) and maximum bacterial count (416.00×10^3), were obtained in solarized plots with none of the amendments. The maximum root and shoot length, and yield were recorded in the seedlings from the nursery treated with solarization and in which FYM had been added. The average number of leaves recorded was also highest for solarized plots treated with FYM and least in non-solarized untreated plots. There was a gradual increase in the foliar blight disease intensity in the crop obtained from solarized plots treated with different amendments, from 1st to 11th standard week. However, from 11th to 13th SW, there was a steep rise in intensity in case of all the amendments.

Keywords: soil solarization, onion blight, soil amendments

Introduction
Onion is an important vegetable crop grown worldwide for its wide range of uses ranging from culinary to medicinal values. Onion blight is a major bottleneck in its successful cultivation. A number of pathogens have been found responsible for the disease, of which *Alternaria porri, A. alternata* and *Stemphylium vesicarium* are the most common [1, 2, 3]. However, in the Jammu Division of Jammu & Kashmir state, the pathogens found associated with the foliar blight were *Alternaria alternata, A. porri, A. tenuissima, Stemphylium vesicarium, Cladosporium allii-cepae* and *Colletotrichum circinans.* The disease can be effectively managed by the application of fungicides but due to adverse effects of fungicides, the need of the hour is to look for eco-friendly measures for the management of the disease. One such measure is soil solarization whereby the soil is covered by polythene so that the temperature of the soil raises to high levels and the pathogens are killed. The present studies were carried out with this objective in mind.

Materials and Methods
Raised (15 cm) nursery beds of 1x1m size were prepared and irrigated to the level of field capacity to ensure the presence of adequate moisture during the period of solarization. Each bed was incorporated with the soil amendments given below, separately and evaluated for effect, if any, on diseases management.

Farmyard manure	1000 g/m^2
Sawdust	250 g/m^2
Compost	1000 g/m^2
Mustard cake	100 g/m^2
Poultry manure	1000 g/m^2

One plot was kept devoid of any soil amendment which served as a check. The beds were covered with transparent polyethylene sheet of 25 µm thickness, placing the ends of the sheets in furrows buried with compact soil to assure that all the edges were thoroughly sealed (Plate Ia). In order to record the soil temperature, soil thermometers were placed at a depth of 5 cm beneath the polyethylene sheet during the entire period of solarization. Temperature of the uncovered (non-solarized) plots were also recorded. Soil temperature was recorded daily at 06.00 and 14.00 hours.

Soil moisture conservation in each treatment was calculated by the following formula:

$$\text{Soil moisture conservation (\%)} = 100 (M_o - M_t) / M_o$$

Where, M_o = Moisture content of the soil before solarization
M_t = Moisture content of the soil after solarization

For determining the soil pH, 20 g of soil from each treatment was dissolved separately in 50 ml of distilled water and pH was recorded by pH meter.

After solarization, the microbial population in different treatments was recorded. Serial dilutions of 1g soil were prepared for each of the treatments separately, in sterilized distilled water. The fungal load was recorded by counting the number of colonies developed on potato dextrose agar after plating 1 ml of 10^{-4} dilution. A dilution of the order 10^{-3} was used for estimating the bacterial and actinomycetes colonies. For bacteria, plating was done on nutrient agar, whereas, for actinomycetes plating was done on actinomycetes specific medium.

Subsequently sowing of the onion seed of cultivar N-53 was done on 1st November. All the recommended agronomic practices were followed as per the package of practices, throughout the growing season. At the time of transplantation root and shoot length and number of leaves of the plants were recorded. The following scale was used for rating disease intensity [4]:

0: No disease symptoms
1: Few spots towards the tip, covering less than 10 per cent leaf area
2: Several dark purplish patches, covering less than 20 per cent leaf area
3: Several patches with paler outer zone, covering up to 40 percent leaf area
4: Long streaks, covering 75 per cent leaf area or breaking of leaves from centre
5: Complete drying of leaves or breaking of leaves from the base.

The per cent disease intensity (PDI) was calculated as given below [5]:

$$\text{PDI} = \frac{\text{Total sum of numerical ratings}}{\text{Number of leaves observed} \times \text{Maximum disease rating}} \times 100$$

Fresh bulb yield per plot was recorded for each treatment after harvest and transformed into q/ha. All the data recorded were analyzed statistically by suitable transformations.

Results and Discussion

a) Soil temperature.

The average temperature profiles recorded during the two years in the solarized and non-solarized plots are presented in Fig 1. Soil solarization during the forty-five day period resulted in considerable increase in soil temperatures. The average maximum soil temperature recorded in the solarized plots was 51.4°C, whereas, it was 40.8°C during the corresponding period in non-solarized plots. The lowest temperature of 36.2°C was recorded in the 1st week in the solarized plot, whereas, in non-solarized plots the lowest temperature of 23.7°C was recorded in the 4th week. On an average the maximum temperature of solarized plots was 9.2–11.3°C higher than that of non-solarized plots and the minimum temperatures in solarized plots were 7.5–12.1°C higher than non-solarized plots.

Soil solarization resulted in an increase in soil temperature to the extent of 12.1°C. Several workers have reported an increase in temperature in solarized soil 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 [6, 7]. Chellemi *et al*. recorded the temperature profiles at different depths and found maximum increase in temperature at 5 cm depth after 32 to 39 days of solarization [8]. It has been found that several biological processes including antagonist pathogen interactions, which contributed to pathogen control, were stimulated and chemical and physical processes took place during soil solarization [9].

b) Soil pH.

At the end of solarization, the pH of the soil in each nursery plot treated with various soil amendments and check was recorded (Fig. 2). It was observed that the pH of the soil was highest (7.40) in solarized plots without any soil amendment, followed by solarized plots amended with poultry manure (7.38), FYM (7.32), spent compost (7.30) and unamended non-solarized plots (7.18). The lowest pH was recorded in solarized plots amended with mustard cake (6.90) followed by sawdust treated plots (7.00).

c) Soil moisture.

Moisture was most effectively conserved in the solarized plots treated with FYM (10.05 percent), followed by poultry manure (9.27 percent) and mustard cake (5.89 percent). The moisture conservation was 5.81 and 5.29 percent in the solarized plots amended with spent compost and sawdust, respectively. The least amount of moisture was conserved in plots supporting none of the amendments (1.72 percent).

d) Microbial population.

Soil samples collected from different nursery plots incorporated with various amendments were examined for the presence of various micro-organisms under *in vitro* conditions (Plate I). The maximum fungal colonies were detected from solarized nursery plots amended with poultry manure (26×10^4), followed by FYM amended nursery plots (20×10^4) and nursery plots with no amendments (16.67×10^4). In the solarized plots with no amendments, 268×10^3 colonies of actinomycetes were obtained, whereas, 256×10^3 colonies were observed in solarized nursery plots amended with spent compost and 192×10^3 in FYM amended solarized plots. The bacterial count was highest (416.00×10^3) in solarized nursery plots without any amendments and least in solarized nursery plots amended with poultry manure (42.00×10^3) (Table 1).

e) Growth of onion seedlings.

The maximum root and shoot length (7.93 and 15.51 cm in the first year; 9.90 and 25.85 cm in the second year, respectively) were recorded in the seedlings from the nursery treated with solarization to which FYM was added, followed by the plots amended with poultry manure (Table 2). The average root length and shoot length was minimum in solarized plots amended with sawdust. The average number of leaves recorded during the first year, was highest in the solarized plots treated with FYM (3.40), followed by poultry manure and mustard cake (2.93, each), spent compost (2.73), untreated solarized (2.40) and least in untreated non-solarized plots and plots treated with sawdust (2.33, each) (Table 3).

Our results are in conformity with Lal *et al.* [10] who reported that plant height, number of leaves per plant, bulb size and bulb yield increased with increasing the rates of FYM from

zero to 100 t ha^{-1}. The beneficial effects of soil solarization have been reported by Adentuji [11], Srivastava and Tiwari [12] and Champawat and Sharma [13]. However, it was found that sawdust was ineffective in increasing plant growth and conserving moisture which is in confirmity with Adentuji [11] and Rahman and Khan [14].

f) Effect on onion foliar blight.

The seedlings obtained from solarized nursery plots treated with various soil amendments were transplanted in the field and monitored at fortnightly intervals for recording the disease progression. The data presented in Table 3 and 4 depicts the per cent disease intensity recorded in the crop for which the seedlings were obtained from solarized nursery plots treated with various soil amendments. The data indicates that, in the first standard week the lowest disease intensity of 9.67 percent was recorded in the plants obtained from solarized nursery plots amended with FYM. However, it was at par with the plants obtained from solarized nursery plots treated with spent compost having disease intensity of 13.81 percent, mustard cake (13.29 percent) and poultry manure (11.91 percent) but it differed significantly in the plants obtained from the solarized nursery plots treated with sawdust (17.54 percent) as well as solarized untreated plots (15.96 percent) and non-solarized untreated plots (16.37 percent). The percent disease intensity at the time of maturity (13^{th} SW) was lowest in the plants obtained from the solarized plots treated with FYM. The average yield recorded was maximum (260.46 q/ha) in the plots for which the plants were obtained from solarized plots treated with FYM and least (225.70 q/ha) in the plants obtained from the sawdust treated plots. In the second year the data obtained was comparable to that of the first year, as is evident from Table 4.

Disease development has been found to occur at a rapid rate late in the growing season coinciding with the physiological ageing of the onion plants and build up of infected tissue where sporulation could occur. Individual onion leaves have also been found increasingly susceptible as they age and the emerging leaves were more prone to pathogen attack the closer they emerged to bulb maturity. Differences in damage among onion leaves of various ages and increasing damage on leaves that emerge close to maturity have also been reported in case of purple blotch of onion by Miller [15]. Older leaves were also more susceptible to *Cladosporium allii-cepae* [16].

Table 1: Effect of soil solarization and addition of soil amendments on the soil microbial population

Treatment	Fungi ($\times 10^4$)	Actinomycetes ($\times 10^3$)	Bacteria ($\times 10^3$)
Soil Solarization (S)	16.67	268.00	416.00
S + FYM	20.00	192.00	224.00
S + spent compost	10.67	256.00	110.00
S + Sawdust	4.67	121.33	83.00
S + mustard cake	3.33	161.33	107.00
S + poultry manure	26.00	65.33	42.00
Non-solarized untreated (check)	12.67	120.00	100.00

Table 2: Effect of soil solarization and addition of soil amendments on the growth of onion seedlings

Treatment	Root length (cm)			Shoot length (cm)			No. of leaves		
	Year I	Year II	Average	Year I	Year II	Average	Year I	Year II	Average
Soil Solarization (S)	6.66	7.60	7.13	12.89	16.83	14.86	2.40	2.90	2.65
S + FYM	7.93	9.90	8.92	15.51	25.85	20.68	3.40	3.30	3.35
S + spent compost	7.18	7.90	7.54	13.69	17.80	14.75	2.73	3.00	2.87
S + Sawdust	6.19	7.20	6.69	9.39	15.35	12.37	2.33	2.40	2.37
S + mustard cake	7.29	8.10	7.69	14.79	19.80	17.29	2.93	3.10	3.02
S + poultry manure	7.61	9.15	8.38	15.37	22.65	19.01	2.93	3.20	3.07
Non-solarized untreated (Check)	6.59	7.30	6.95	12.75	15.55	14.15	2.33	2.80	2.56

Average of 100 plants

Table 3: Effect of soil solarization and addition of soil amendments on the onion foliar blight during the first year

Treatment	Percent disease intensity at different standard weeks							Yield (q/ha)
	1	3	5	7	9	11	13	
Soil solarization (S)	15.96(23.55)	16.60(24.04)	16.87(24.25)	19.71(26.36)	24.36(29.57)	26.38(30.90)	50.35(45.20)	237.79
S + FYM	09.67(18.12)	13.49(21.55)	14.87(22.68)	15.83(23.45)	18.64(25.58)	24.38(29.59)	42.41(40.63)	260.46
S + Spent compost	13.81(21.82)	16.02(23.59)	16.12(23.67)	18.54(25.50)	23.55(29.03)	25.37(30.24)	49.54(44.74)	248.37
S + Sawdust	17.54(24.76)	19.15(25.95)	20.02(26.58)	20.82(27.15)	31.30(34.02)	33.29(35.24)	56.41(48.68)	225.70
S + Mustard cake	13.29(21.38)	14.61(22.47)	15.79(23.41)	17.23(24.53)	20.64(27.02)	25.22(30.15)	47.59(43.62)	254.42
S + Poultry manure	11.91(20.19)	14.19(22.13)	14.97(22.76)	16.04(23.61)	19.52(26.22)	25.09(30.06)	46.24(42.84)	255.93
Non-solarized untreated (Check)	16.37(23.87)	17.10(24.43)	18.98(25.83)	20.00(26.57)	26.37(30.90)	29.10(32.65)	53.46(46.98)	233.26
C. D. (p=0.05)	5.66	5.36	4.78	4.04	1.38	0.25	1.11	

Figures given in parentheses are transformed (angular) values

Table 4: Effect of soil solarization and addition of soil amendments on the onion foliar blight during the second year

Treatment	Percent disease intensity at different standard weeks							Yield (q/ha)
	1	3	5	7	9	11	13	
Soil solarization (S)	11.33(19.67)	12.94(21.08)	15.61(23.27)	15.49(23.18)	15.99(23.57)	18.64(25.58)	34.37(35.89)	290.70
S + FYM	08.75(17.21)	09.36(17.81)	09.80(18.24)	12.63(20.82)	13.50(21.56)	15.30(23.03)	28.49(32.26)	317.91
S + Spent compost	09.96(18.40)	12.20(20.44)	14.60(22.46)	15.28(23.01)	15.42(23.12)	18.50(25.47)	33.48(35.35)	295.24
S + Sawdust	11.52(19.84)	15.79(23.41)	16.35(23.85)	19.42(26.15)	20.49(26.91)	23.45(28.96)	35.36(36.49)	281.63
S + Mustard cake	09.34(17.80)	11.37(19.71)	13.51(21.57)	14.42(22.32)	14.52(22.40)	18.48(25.46)	31.42(34.09)	299.77
S + Poultry manure	09.28(17.74)	10.51(18.92)	12.15(20.40)	13.67(21.70)	14.48(22.37)	17.09(24.42)	30.57(33.57)	304.31
Non-solarized untreated (Check)	11.47(19.80)	13.09(21.21)	15.53(23.21)	16.32(23.83)	17.45(24.69)	23.13(28.74)	34.40(35.91)	288.89
C. D. (p=0.05)	0.63	1.49	2.19	0.44	0.31	0.25	0.32	

Figures given in parentheses are transformed (angular) values

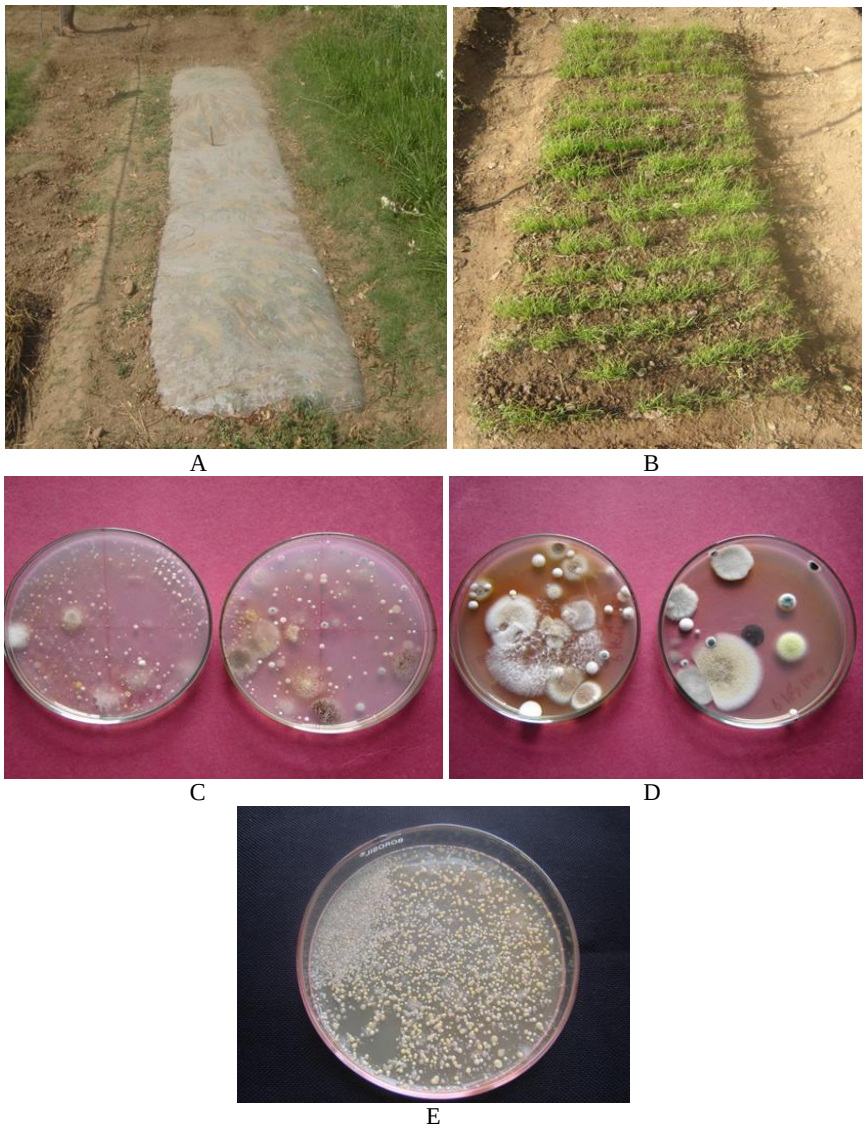

Plate I: (a) Solarization in nursery plots; (b) Nursery raising in solarized plots; (c) bacteria; (d) fungi; and (e) actinomycetes associated with solarized plots

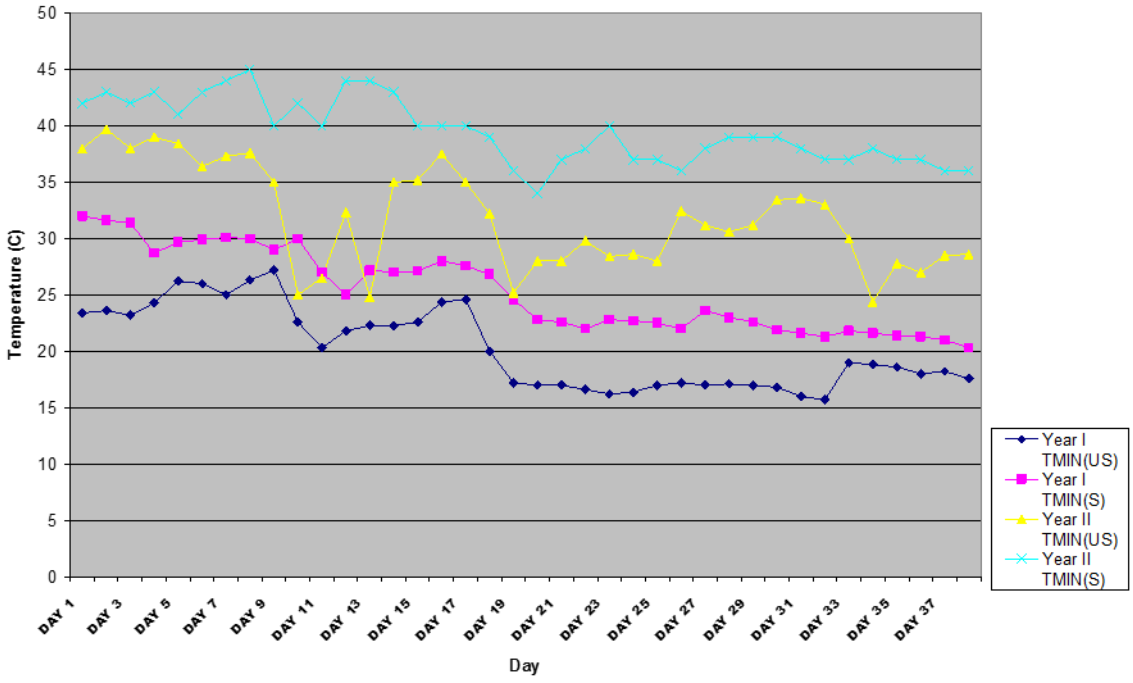

Fig 1. Temperature variation in solarised and unsolarised plots

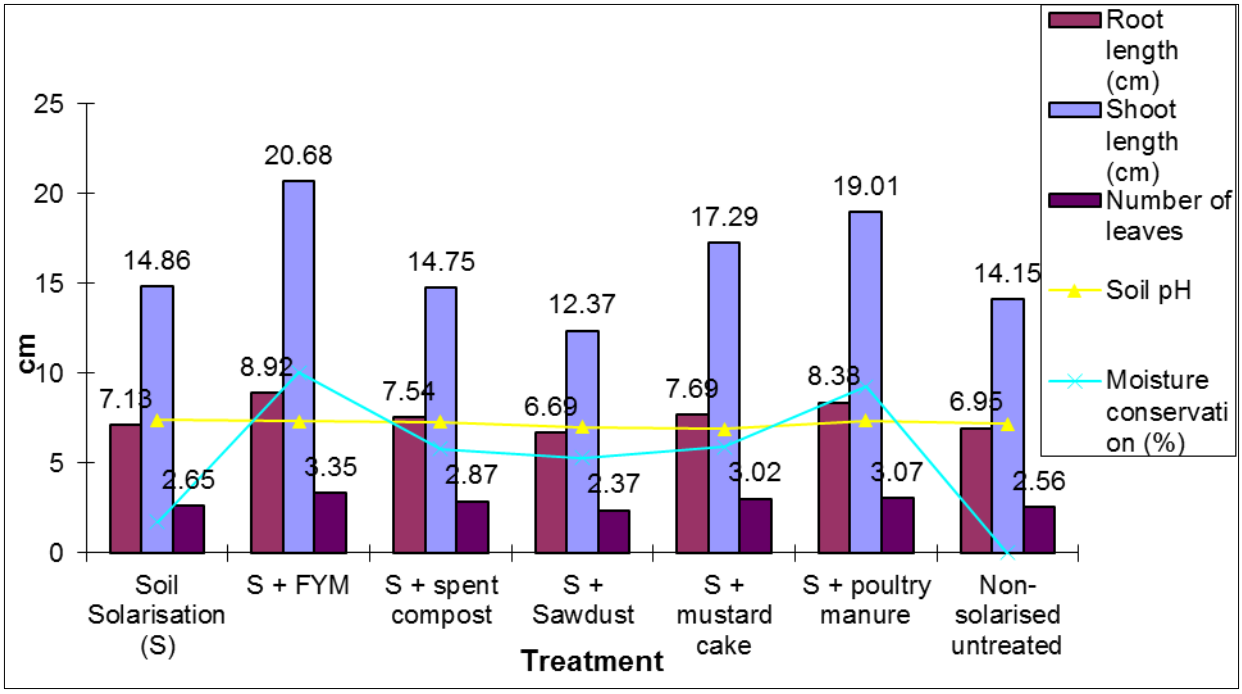

Fig 2: Effect of soil solarization and addition of soil amendments on growth of onion seedlings and physical properties of soil

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