The Pharma Innovation Journal 2023; 12(12): 813-816

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(12): 813-816

www.thepharmajournal.com
Received: 20-09-2023
Accepted: 29-11-2023

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Integrated management of green gram wilt caused by *Fusarium oxysporum* using soil solarization along with soil amendment, fungicides and bio-agents

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Abstract
Wilt of green gram caused by *Fusarium oxysporum* is one of the most devastating diseases which causes huge losses in the crop. In present investigation, field study was conducted during *Rabi* season 2022-23 to integrate the treatment of soil solarization alone and soil solarization along with soil amendment *viz.*, neem cake, three bio-agents *viz*., *Trichoderma harzianum*, *T. longibrachiatum*, *T. koningii* and two fungicides carbendazim 50% WP and captain 50% WP against pathogen causing wilt disease of green gram. Among various treatments, soil solarization along with seeds treatment of carbendazim 50% WP @ 2g/kg was most effective showing least wilt incidence (8.33%) followed by soil solarization along with seeds treatment of captain 50% WP @ 2g/kg (10.87%), soil solarization along with seeds treatment of *T. harzianum* (13.33%), soil solarization along with seeds treatment of *T. longibrachiatum* (16.28%), soil solarization along with soil application of neem cake (19.05%), soil solarization along with seeds treatment of *T. koningii* (21.95%),%), soil solarization along with soil application of neem cake (19.05%) and soil solarization alone was least effective (26.32%) over untreated control.

Keywords: Green gram, *Fusarium oxysporum*, soil amendment, bioagents, fungicides

Introduction
Green gram scientifically known as *Vigna radiata* (L.) Wilczek belongs to family Leguminaceae and commonly called as mung bean. India is its primary origin and is mainly cultivated in South East Asia. It is the third important pulse crop of India grown in nearly 16 percent of the total pulse area of the country. The crop is known to be infected with various fungal, bacterial and viral diseases. Among these various diseases, wilt of green gram caused by *Fusarium oxysporum* is one of the most devastating diseases which causes huge losses in the crop. The disease was responsible for causing significant barrier to the effective cultivation of green gram in the *Konkan* region of Maharashtra as well as other parts of the country. It is necessary to find out the most bona fide ways of controlling the disease through integrated approach of disease management by using easily available soil amendment, fungicides and beneficial bio-agents. This study will provide the farmer with the most trustworthy, genuine and effective techniques required for overcoming and managing the incidence and huge losses caused by wilt of green gram.

Materials and Methods
The present study was conducted at Department of Agronomy, College of Agriculture, Dapoli, Dist. Ratnagiri. The experiment was laid out in plots (2m x 1m^2) in Randomized Block Design with three replications during *Rabi* 2022-23. In this study, it was intended to combine soil solarization treatment along with soil amendment *viz.*, neem cake and seed treatment with fungicides carbendazim 50% WP, captan 50%WP and three bioagents *viz*., *Trichoderma harzianum*, *T. longibrachiatum*, *T. koningii*. Soil solarization treatment was given for 45 days (March - April) to entire plot using transparent polyethene sheet (0.05mm) except control which was left opened (without sheet). Neem cake was applied as a soil amendment, fungicides and bioagents were applied as seed treatment to the healthy green gram seeds which were used for sowing after soil solarization was done.
Germination (%), wilt incidence (%) and % Reduction over control were calculated applying following formulae.

$$\text{Germination (\%)} = \frac{\text{No. of seeds germinated}}{\text{Total no. of seeds sown}} \text{ X } 100$$

$$\text{Wilt incidence (\%)} = \frac{\text{Total number of wilted plants}}{\text{Total number of plants observed}} \text{ X } 100$$

$$\text{Reduction (\%)} = \frac{C - T}{C} \text{ X}100$$

Where,
T = Wilt Incidence (%) in treatments plot.
C = Wilt Incidence (%) in untreated control plot

Results and Discussion

An integrated approach for the management of the wilt of green gram caused by *Fusarium oxysporum* using various fungicides, bioagents, soil amendments along with soil solarization and soil solarization alone was carried out under field conditions during *Rabi* 2022- 23. Fungicides such as carbendazim 50% WP and captan 50% WP, Bio-agents such as *T. harzianum, T. koningii, T. longibrachiatum* and one organic amendment *viz.,* Neem cake (soil application) were selected and integrated along with soil solarization to manage green gram wilt (*Fusarium oxysporum*).

Results from table 1 and plate I revealed that Soil solarization treatment was done using transparent polyethylene mulch of 0.05 mm. Soil temperature was recorded using soil thermometer at 5cm soil depth. The average maximum temperature (morning) recorded in solarized plot was 26.9º C i.e., there was 2.9 ºC increase in temperature over non-solarized plot which was 24.0 ºC. The average maximum temperature (afternoon) recorded in solarized plot was 40.4ºC i.e., there was 9.1 ºC increase in temperature over non-solarized plot which was 31.3 ºC. The average maximum temperature (evening) recorded in solarized plot was 38.3ºC i.e., there was 8.2 ºC increase in temperature over non-solarized plot which was 30.1 ºC.

Table 1: Daily observations of soil temperature during soil solarization

Date	Morning (º c)		Afternoon (º c)		Evening (º c)	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
22-02-2023	24.50	21.50	36.50	28.00	35.00	26.50
23-02-2023	24.00	21.00	37.00	27.50	34.00	25.00
24-02-2023	25.00	21.50	36.50	27.50	34.00	25.50
25-02-2023	24.00	21.00	36.50	27.00	34.50	25.00
26-02-2023	24.50	22.00	36.00	27.50	34.00	26.00
27-02-2023	25.00	21.50	37.00	28.00	35.50	27.00
28-02-2023	25.00	21.00	36.00	27.00	35.00	25.00
01-03-2023	24.50	21.50	36.50	27.50	35.00	26.00
02-03-2023	25.00	21.00	36.00	27.00	34.00	25.00
03-03-2023	25.00	21.50	36.50	27.00	35.50	26.50
04-03-2023	24.50	22.00	37.00	28.00	34.50	27.00
05-03-2023	24.00	21.00	38.00	27.50	35.00	25.00
06-03-2023	24.50	21.50	37.00	27.50	35.50	25.50
07-03-2023	24.50	22.00	38.50	28.00	36.00	26.50
08-03-2023	24.00	22.50	38.00	31.00	36.00	29.00
09-03-2023	24.50	22.00	39.00	34.00	37.00	30.00
10-03-2023	25.00	22.00	40.00	36.00	38.50	34.50
11-03-2023	27.00	25.00	40.50	36.00	39.00	35.00
12-03-2023	28.50	25.50	39.50	35.50	38.00	34.50
13-03-2023	28.00	26.00	41.00	36.50	39.00	34.00
14-03-2023	27.50	25.00	42.00	32.50	40.50	31.50
15-03-2023	29.00	26.00	40.00	32.50	39.00	32.00
16-03-2023	28.50	26.00	39.50	31.50	38.00	31.00
17-03-2023	28.00	26.00	42.00	33.00	40.50	32.50
18-03-2023	29.00	26.50	43.00	32.00	41.00	31.00
19-03-2023	28.50	25.50	42.50	32.50	40.50	31.50
20-03-2023	29.00	26.00	44.00	34.00	43.00	32.00
21-03-2023	29.00	25.00	38.00	29.50	37.00	29.00
22-03-2023	27.00	24.00	39.50	30.00	38.50	29.00
23-03-2023	28.00	25.00	43.00	33.00	42.50	32.00
24-03-2023	29.00	26.00	42.00	32.00	45.00	32.00
25-03-2023	28.00	25.00	42.50	33.00	42.00	32.50
26-03-2023	28.50	25.00	42.00	32.50	41.50	32.00
27-03-2023	28.00	24.00	43.00	32.50	41.50	31.00
28-03-2023	29.00	25.50	44.40	32.50	43.00	32.00
29-03-2023	28.00	25.00	44.00	33.50	42.50	32.00
30-03-2023	29.50	26.50	44.00	33.50	42.00	32.50
31-03-2023	29.50	26.00	45.50	34.00	45.00	33.50
01-04-2023	29.00	26.50	45.00	33.00	44.00	32.50
02-04-2023	28.50	26.50	45.50	34.00	44.50	33.00
03-04-2023	29.50	26.50	45.50	34.50	44.00	34.00
04-04-2023	29.00	26.50	45.00	34.50	44.50	34.00
05-04-2023	29.00	26.00	45.50	34.50	44.50	34.50

Plate 1: Soil Solarization

The seeds of susceptible green gram cv. TMB 37 were treated before sowing with the fungicides *viz.*, carbendazim 50% WP, captan 50% WP and bioagents *viz., T. harzianum, T. koningii, T. longibrachiatum* whereas the soil was applied with organic amendment *viz.*, Neem cake as per the treatment detail.
Fungicide and bio-agent treated seeds of green gram cv. TMB-37 were sown (30 cm x 10 cm) in randomized plots (block size 2 m x 1m per treatment). The crop was grown by applying all recommended package of practices and irrigated as and when required.

Percent germination
Results from fig. 1 and table 2 revealed that there was increased percent germination by integrating treatments with various fungicides, bioagents and soil amendment along with soil solarization. The percent seed germination significantly improved and it was observed in the range of 94.11 to 68.62. Highest seed germination was recorded in seed treatment with carbendazim 50% WP (94.11%) followed by captan 50% WP (90.19%), *T. harzianum* (88.23%), *T. longibrachiatum* (84.31%), soil application of neem cake (82.35%), seed treatment with *T. koningii* (80.39%) and + least germination percent was observed in soil solarization alone (74.50%) of green gram cv. TMB-37.

Percent wilt incidence
All treatments influenced significantly the disease incidence which was recorded against untreated control. The wilt incidence recorded ranged from 8.33 percent in carbendazim 50% WP to 26.32 percent in solarization alone and 62.86 percent in untreated control. The lowest wilt incidence recorded with carbendazim 50% WP (8.33%) followed by captan 50% WP (10.87%), *T. harzianum* (13.33%), *T. longibrachiatum* (16.28%), soil application of neem cake (19.05%), seed treatment with *T. koningii* (21.95%) and highest wilt incidence observed in soil solarization alone (26.32%) which was found least effective.

Percent disease control
All treatments significantly improved the disease control percent as compared untreated control. The disease control percent recorded ranged from 58.13 to 86.74 percent over untreated control. The highest disease control percent recorded with Carbendazim 50% WP (86.74%) followed by captan 50% WP (82.71%), *T. harzianum* (78.79%), *T. longibrachiatum* (74.10%), soil application of neem cake (69.70%), seed treatment with *T. koningii* (65.08%) and the lowest disease control percentage was observed in soil solarization alone (58.13%).

Table 2: Integrated management of *Fusarium* wilt disease

Tr. No.	Treatments	Germination (%)	Wilt Incidence (%)	Percent Reduction over control
T1	Soil Solarization	74.50 (59.67)	26.32 (30.86)	58.13
T2	Soil Solarization + Soil application of neem cake @ 1.5 tonnes/ha	82.35 (65.15)	19.05 (25.87)	69.70
T3	Soil Solarization + Seed treatment with *T. harzianum* @ 6g/kg	88.23 (69.93)	13.33 (21.41)	78.79
T4	Soil Solarization + Seed treatment with *T. koningii* @ 6g/kg	80.39 (63.71)	21.95 (27.93)	65.08
T5	Soil Solarization + Seed treatment with *T. longibrachiatum* @ 6g/kg	84.31 (66.66)	16.28 (23.79)	74.10
T6	Soil Solarization + Seed treatment with captan 50% WP @ 2g/kg	90.19 (71.74)	10.87 (19.25)	82.71
T7	Soil Solarization + Seed treatment with carbendazim 50% WP @ 2g/kg	94.11 (75.95)	8.33 (16.77)	86.74
T8	Control	68.82 (55.93)	62.86 (52.45)	-
SE(m) ±		0.63	0.50	
C.D at 5%		1.82	1.53	

The results of present investigation are in close consonance with Harender raj *et al.* (2016) [3] who studied integrated management of carnation wilt caused by *Fusarium oxysporum f. sp. dianthi* using soil solarization and soil amendments.
Same results were recorded by Maheshwari *et al.* (2008) [2] who tested the seven fungitoxicants against *Fusarium oxysporum f sp. lentis* in which carbendazim was proved effective in checking the fungal growth followed by captan.
Same inferences were also drawn by Chauhan *et al.* (1988) [1] who carried out field tests of soil solarization on pigeonpea (*Cajanus cajan* (L.) Millsp.) and chickpea (*Cicer arietinum* L.) against *Fusarium* wilt.

Plate 2: Experimental plot general view

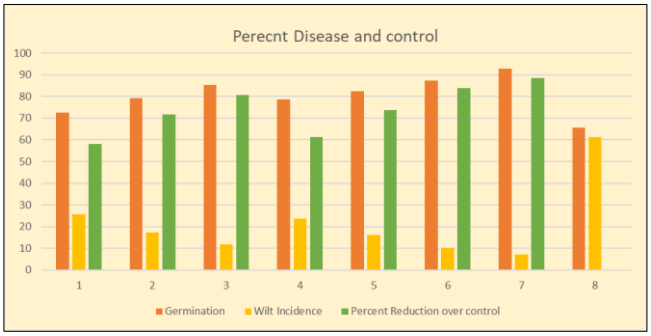

Fig 1: Percent Disease and control

Conclusions

From the results of present experiment, it is concluded that wilt of green gram incited by *Fusarium oxysporum* can be effectively controlled by integrating treatment of soil solarization along with Seed Treatment with Carbendazim 50% WP @ 2g/kg.

Acknowledgement

Authors are thankful to the Department of Plant Pathology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, (M.S.), India for providing necessary facilities.

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