

Original Research Article

Management of *Fusarium* wilt of eggplant caused by *Fusarium oxysporum* f.sp. *melongenae* using organic soil amendments

ABSTRACT: Brinjal is one of the important vegetable crops in India. Its production is affected by many pests and diseases, and *Fusarium* wilt disease is one of them, which causes great losses in yield. The disease is usually controlled by chemical application, which not only develops resistance in disease-causing pathogens but also has deleterious effects on human health and the environment. So, in the present study, alternative methods of control that are ecofriendly, safe, easy, and affordable by using organic soil amendments were tested both in vitro and in pot culture studies. In the present study, among the aqueous extracts tested at 10 and 15 percent concentrations in vitro, neem cake showed maximum mycelial inhibition (80.88% and 85.56%), followed by mustard cake (78.72% and 73.41%) against the test pathogen. However, the lowest inhibition was recorded with cotton cake extract (34.06% and 54.67%). Similarly, pot culture studies yielded similar results. Out of nine organic amendments tested against *Fusarium* wilt in pot conditions, neem seed cake recorded the lowest wilt incidence (22.19% and 16.95%), followed by mustard cake (23.49% and 17.54%) at 100 and 150 g concentrations, respectively, whereas treatments with vermicompost, goat manure, and poultry manure showed lower inhibition against wilt incidence when compared to the remaining oil cake organic amendments at both concentrations tested.

Key words: Egg Plant, *Fusarium* Wilt, Organic Amendments, Disease Management

Introduction

Brinjal is commonly known as Eggplant (*Solanum melongena* Linn.) It belongs to the family Solanaceae. Brinjal is a widely grown vegetable crop in Asian countries, probably a native of South Asia. Brinjal is growing throughout India covering an area of 668.72 thousand ha with production of 123.99 thousand tonnes and productivity of 18.53 M. tonnes / ha. In Maharashtra, the area, production and productivity of Brinjal were 221.40 thousand ha, 433.28 thousand tonnes and 19.68 M. tones / ha, respectively during 2016-17 (Horticultural statistics at a glance, 2017). *Fusarium* species are the most important plant pathogens in the world and highly variable because of their genetic makeup and changes in environment in which they grow causing morphological changes (Nelson, 1983). *Fusarium* wilt of eggplant

caused by *Fusarium oxysporum* f. sp. *melongenae* is an economically important soil borne disease limiting eggplant production worldwide. This pathogen was initially reported in Japan (Matuo and Ishigami, 1958), and next in China (Zhuang *et al.* 2005). It is extremely difficult to control soil-borne fungi through conventional strategies such as the use of synthetic fungicides, etc. Since their spores are able to survive for many years in the soil, biological control strategies for this pathogen should, therefore, be carefully selected and handled in an eco-friendly way instead of using chemical fungicides.

The incorporation of crop residues into the soil, organic wastes, composts and peats have been proposed to control diseases caused by soil borne pathogens. Many of these amendments reduced pathogen populations (George *et al.*, 2001). The highest per cent growth inhibition of *Fusarium* pathogen was observed in soybean cake (32.96%), followed by groundnut cake (29.63%). The lowest per cent growth inhibition was observed in saw dust (06.47%) (Rani and Mane, 2014). Similarly, the highest per cent growth of inhibition was observed in neem cake and the lowest per cent growth inhibition was observed in groundnut cake (Pandey *et al.*, 2014). *Fusarium* wilt of tomato controlled by soil amendments with composts (Harender and Kapoor., 1997). Organic soil amendments neem cake, FYM, Soybean cake, Cotton cake were stimulated the activities of microorganisms that are antagonistic to plant-parasitic nematodes (Muhammad *et al.*, 2010). Considering all the positive characteristics of organic soil amendment towards disease suppression it was an important and eco-friendly approach for controlling soil borne pathogens (Palti and Katan, 1997; Singh and Sitaramaiah, 1971). The association of bio-control agent like *Trichoderma harzianum* and organic amendments in rhizosphere is reported to have great effect against soil borne pathogens (Moon *et al.* 1988). Considering the above facts the present study was undertaken to find out the eco-friendly components against *Fusarium* wilt disease of eggplant.

Material and Methods

***In-vitro* evaluation of aqueous extracts of organic soil amendments against wilt causing pathogen in egg plant**

As per the procedure given by Dhingani *et al.*, (2013), aqueous extracts of Neem seed cake, Castor cake, Cotton seed cake, vermicompost, Farm Yard Manure (FYM) etc., were prepared as mentioned in below treatments. Forty grams of each organic amendment was suspended in a conical flask in 150 ml of sterilized distilled water and kept for 15 days. Every day, the flasks were shaken to thoroughly mix and dissolve the content. The extract was

strained through muslin cloth after 15 days and then filtered in 150 ml using Whatman filter paper No-41. Conical flasks were sterilized for 20 minutes in autoclave at 121⁰C. The autoclaved extracts were tested against test pathogen using poisoned food technique at concentrations of 10 and 15 per cent (Vincent, 1927). For each treatment, three replications were maintained. According to the formula given by Dennis and Webster (1971) per cent inhibition of mycelial growth was estimated.

$$I = \frac{C - T}{C} \times 100$$

Where,

I = Per cent inhibition of mycelial growth

C = Colony diameter in control (mm)

T = Colony diameter treatment (mm)

Experimental details:

Design : Completely Randomized Design (CRD)

Replications : Three

Treatments : Ten

List 1 : Treatment details

Tr. No.	Treatments	Tr. No.	Treatments
T ₁	Neem seed cake	T ₆	Cotton seed cake
T ₂	Mustard cake	T ₇	Vermicompost
T ₃	Safflower cake	T ₈	Goat Manure
T ₄	Ground nut cake	T ₉	Poultry Manure
T ₅	Soya cake	T ₁₀	Control (Untreated)

Evaluation of organic soil amendments against incidence of wilt disease under Pot culture studies

Earthen pots containing 4 kg of soil were amended with 100 and 150 g of amendments in separate treatments with a maximum of 10 organic amendments (as specified under treatments). These treatments were assessed against test pathogen in pot culture using soil application and sick soil system. All the test amendments were physically grinded to rough powder and applied in the pots. Unamended soil was used as control. Three replications were maintained in a fully randomized model for each treatment. Earthen pots (45 cm dia.) filled with potting soil mixture: sand (3:1) and multiplied to this mass (Sand: Maize medium)

isolate culture FOM 22 was applied (@ 50 g / kg potting mixture), adequately watered and incubated for 10-12 days to proliferate the pathogen and make the potting mixture / soil sick with test pathogen.

The experimental amendments were added to the earthen pots containing sick soil / potting mixture (@ 50 g per kg mixture), thoroughly mixed, properly watered and kept in open space. There replications were maintained. After a week of application for amendments, the surface sterilized (1 per cent NaOCl) healthy Arka sirish seeds (10 seeds / pot) were sown, watered as and when required to maintain a water holding capacity of 50 per cent. The untreated control was maintained for the earthen pots containing sick soil (without any amendments) and sown with seeds.

Experimental details:

Design : Completely Randomized Design (CRD)
 Replications : Three
 Treatments : Ten

List 2 : Treatment details

Tr. No.	Treatments	Tr. No.	Treatments
T ₁	Neem cake	T ₆	Cotton Cake
T ₂	Mustard cake	T ₇	Vermicompost
T ₃	Safflower cake	T ₈	Goat Manure
T ₄	Ground nut cake	T ₉	Poultry Manure
T ₅	Soya cake	T ₁₀	Control (Untreated)

Observations were recorded on Pre-emergence mortality (PREM) after a week of sowing and post-emergence mortality (POEM) / wilting at 90 days after sowing. Per cent of pre-emergence mortality (PREM) and post-emergence mortality (POEM) / wilting were calculated using the following formulae:

$$\text{PREM (\%)} = \frac{\text{No. of seeds ungerminated}}{\text{Total no. of seeds sown}} \times 100$$

$$\text{POEM (\%)} = \frac{\text{No. of seedlings died}}{\text{Total no. of seedlings}} \times 100$$

Results and discussion

***In vitro* efficacy of aqueous extracts of organic amendments against the growth of pathogen**

The results (Table I, Fig.I, and Plate I and II) indicated that all the aqueous extracts of organic amendments had significant inhibitory effect on *Fusarium oxysporum* f.sp. *melongenae* at both the concentrations tested. It was observed the increase in concentration of extract there by decrease in mycelial growth of the pathogen.

At 10 per cent concentration of aqueous extracts of Neem cake and Mustard cake were highly significant by inhibiting the mycelial growth of pathogen at 5 days after inoculation (11.29 mm and 14.39 mm) and 7 days after inoculation (18.85 mm and 23.92 mm) with a mean growths o 15.07 mm and 19.16 mm respectively. Moreover, the growth inhibitions were also reflected inversely and highest level of growth inhibition at 5th and 7th DAI with Neem cake (83.31% and 79.05 %) and Mustard cake (78.72% and 73.41 %) with a mean growth inhibition (80.88% and 75.70%) as compared to control.

The third and fourth superior treatments were safflower cake (19.14 mm and 30.87 mm) and groundnut cake (22.60 mm and 31.97 mm) with a mean mycelia growths of 25.01mm and 27.29 mm respectively at 5 and 7 DAI. Similar trend in growth inhibition was observed with Safflower cake (71.70 % and 65.72%) and Groundnut cake (66.59 % and 64.52 %) with a mean inhibition of 68.28 per cent and 65.39 per cent respectively at 5 and 7 DAI.

The remaining treatments that showed substantial inhibition effect against the pathogen were Soya cake (24.37 mm and 31.12 mm), Vermicompost (29.87 mm and 42.08 mm),Goat manure (30.67 mm and 42.19 mm),Poultry manure (31.57 mm and 41.81 mm) and Cotton cake (44.81 mm and 59.14 mm) which were on par with each other showing mean growth inhibitions of 27.75 mm,35.98 mm,36.43 mm,36.69 mm, 51.98 mm respectively over control (90 mm) at 5th and 7th DAI. Similarly, these treatments were shown the significant growth inhibition as in Soya cake (63.98 % and 65.34 %), Vermicompost (55.88% and

53.24%), Goat manure (54.66% and 53.11%), poultry manure (53.34% and 53.54%) and cotton cake (33.76% and 34.28%) respectively at 5 and 7 DAI with a mean growth inhibition of 64.80 per cent, 54.36 per cent, 53.78 per cent, 53.45 per cent and 34.08 per cent.

In other dosage at 15 per cent concentration of aqueous extracts of Neem cake and Mustard cake were highly significant by inhibiting the mycelial growth of pathogen at 5 days after inoculation (9.29 mm and 12.39 mm) and 7 days after inoculation (13.47 mm and 15.23 mm) with a mean of 11.38mm and 13.81mm respectively. Moreover, Neem cake and Mustard cake shown greatest level of growth inhibition at 5 DAI (86.26 % and 81.68%) and 7 DAI (85.02% and 83.07%) with a mean inhibition of 85.56 per cent and 82.48 per cent compared to control. The third and fourth superior treatments at 15 per cent concentration of aqueous extracts were safflower cake (15.23 mm and 16.59 mm) and Groundnut cake (15.34mm and 21.63 mm) with a mean of 15.91 mm and 18.49 mm respectively at 5 and 7 DAI. Similarly, growth inhibition showed by Safflower cake (77.48 % and 81.55%) and Groundnut cake (77.33 % and 75.96 %) were significant with a mean inhibition of 79.82 per cent and 76.55 per cent respectively at 5 and 7 DAI (Table I, Fig.I, and Plate I and II).

Though, the remaining treatments were shown substantial inhibition effect against the pathogen, they were on par with each other as in the order of Soya cake (17.85 mm and 21.17 mm), Vermicompost (20.81 mm and 31.33 mm), Goat manure (21.27 mm and 32.33 mm), Poultry manure (22.03 mm and 33.33 mm) and Cotton cake (29.14mm and 42.33 mm) with a mean inhibition of 19.51 mm, 26.07 mm, 26.80 mm, 27.70 mm and 35.74 mm respectively over control (90 mm) at 5 and 7 DAI. Similarly, these treatments were shown the significant growth inhibition as in soya cake (73.62 % and 76.48 %), vermicompost (69.24 % and 65.18 %), goat manure (68.56 % and 64.07 %), poultry manure (67.43 % and 62.92 %) and cotton cake (56.92% and 52.96%) respectively at 5 and 7 DAI with a mean growth inhibition of 75.25 per cent, 66.93 per cent, 66.00 per cent, 64.86 per cent and 54.67 per cent, respectively.

Present results were in agreement with the earlier workers (El-Mohamedy *et al.* 2015 and Ramesh and Singh, (2017)). A high reduction of enzymatic activities of pathogen by aqueous extract of neem cake might be due to the presence of biological active constituents such as gedunin (tetranortriterpenoid) or Azadirachtin (Amadioha, 2000; Sadre *et al.*, 1983). Compost extracts reported significant inhibition of test pathogen mycelial growth, probably due to the toxic substances and nutrient content ratio in the culture media. Thus the suppressive effect of compost would be a combination of biotic and abiotic factors (Suarez-Estrella *et al.* 2012; Kamal *et al.*, 2013).

Effect of organic soil amendments against the incidence of wilt disease of eggplant under pot culture studies

The results showed that all the organic amendments significantly inhibited the disease. The results were presented in the Table II, PLATE III and Fig.II.

At 100 gram concentration, the disease incidence was recorded with all the test amendments ranged from 22.19 to 36.52 per cent, as against 72.57 per cent in untreated control. However, significantly lowest *Fusarium* wilt disease incidence was recorded with neem seed cake (22.19 %) with reduction of 69.42 per cent over control. While, Mustard cake and Safflower cake recorded 23.49 and 28.34 per cent disease incidence, respectively with reduction of 67.62 and 60.95 per cent over control. These were followed by the amendments viz., groundnut cake (31.97 %), soybean seed cake (32.85 %), Vermicompost (35.03 %), goat manure (34.39 %), poultry manure (35.04 %) and cotton seed cake (36.32 %), with reduction of 55.94, 54, 51.72, 52.60, 51.70 and 49.67 per cent over control respectively. All these were at par with each other.

At 150 gram concentration, the disease incidence was recorded with all the test amendments ranged from 16.95 to 33.15 per cent, as against 72.75 per cent in untreated control. However, significantly lowest *Fusarium* wilt disease incidence was recorded with neem seed cake (16.95 %) with reduction of 76.64 per cent over control. While, Mustard cake and Safflower cake recorded 17.54 and 20.29 per cent disease incidence, respectively with reduction of 75.82 and 72.04 per cent over control. These were followed by the amendments viz., groundnut cake (23.48 %), soybean seed cake (24.51 %), vermicompost (23.33 %), goat manure (25.92 %) , poultry manure (27.16 %) and cotton seed cake (33.15 %), with reduction of 67.67,66.21,67.84,64.28,62.56 and 54.31 per cent over control respectively, but these were at par with each other (Table II, PLATE III and Fig.II).

The research findings were in agreement with several earlier experimental findings. Organic amendments were found to be effective in reducing the incidence of wilt and also improving seed germination. The highest percentage of plant survival was recorded when neem cake followed by mustard cake (Goudar and Srikant Kulkarni, 1998).

Organic amendments have the capability to modify soil characteristics such as concentration of nutrients (e.g., P, K, and Fe), pH, NO₃ content, organic material, and structure. Since these traits were decisively shaping the structure of the soil-resident microbiota, there was no doubt that organic amendments addition into soil will eventually affect microbial contents and their activity. The decline in the pathogen population in the

organic amendments can be predicted to some extent based on the heat generation activity of soil and its ammonium ion content. Some residual levels of suppressiveness were believed to be attributed to abiotic factors such as pH and carbon sources. (Salem *et al.* 2012; Ling *et al.* 2012).

The composts treatments *viz.*, vermicompost, goat manure and poultry manure were performed next to the some of the organic amendment treatments because usually they do not provide complete control of disease and therefore control of pathogens requires successful application of biocontrol agents at the right time and place. The competitive exclusion of deleterious pathogens were directly related to the ability of the bacteria in the rhizosphere to grow successfully (Nautiyal *et al.*2002).

Several researchers noticed that compost induced suppressiveness operated by several mechanisms including induced resistance (ISR) associated with certain native strains of PGPR *viz.*, *Pseudomonas* and *Bacillus* (Singhai *et al.*, 2011). The suppression of disease accompanied by reduced root and stem colonization by pathogen and induced resistance in the plant or from the both (Suarez-Estrella *et al.*2012). As the organic amendments host the antagonistic microbial biomass would result various biotic mechanisms such as competition, antibiosis and hyper parasitism. This could perform a direct action on a pathogen by compost. (Shen *et al.*, 2015).The solid manure and manure extract directly prevent *Fusarium* wilt when a circular association of microorganisms around the particle of manure (Zhao *et al.*, 2015).

Conclusion: Among nine organic amendments evaluated against *F. oxysporum* f.sp. *melongenae*, neem seed cake was found highly effective in reducing the disease incidence followed by mustard cake both under laboratory and pot culture studies. The other organic amendments like safflower cake, ground nut cake, vermicompost also yielded positive results. From this study, we conclude that application of soil organic amendments which are safe, environmental friendly and cheap act as better alternative to chemical control of disease management .

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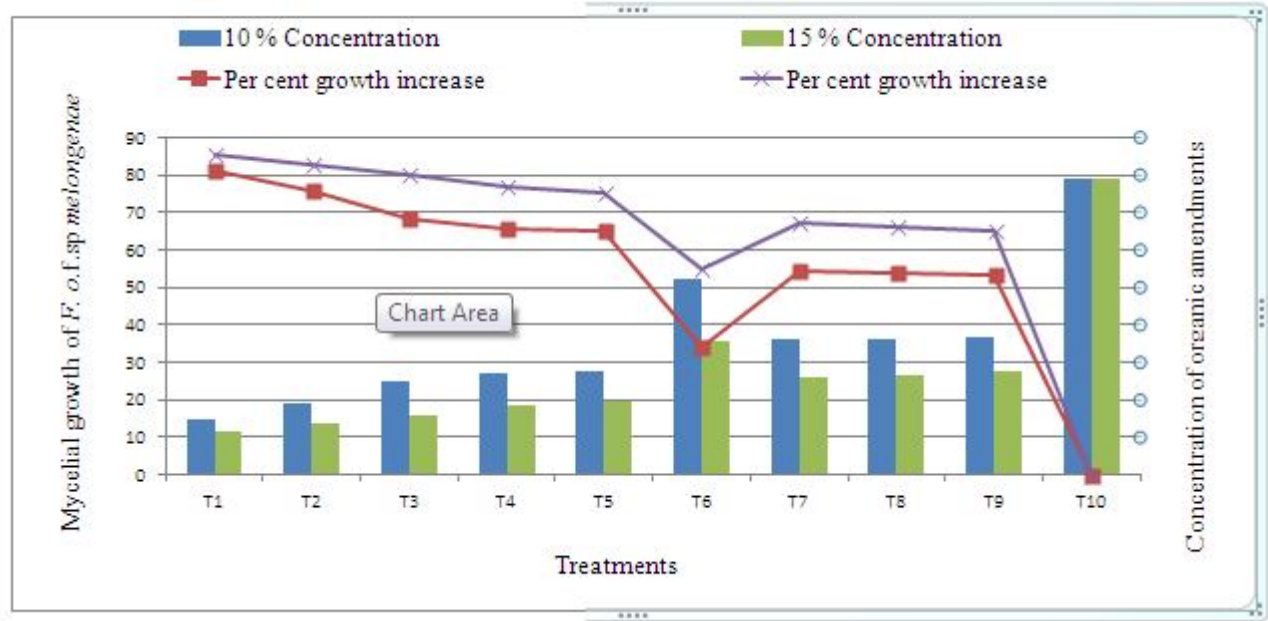
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Table I. *In vitro* efficacy of aqueous extracts of organic amendments against mycelial growth of *Fusarium oxysporum f.sp.melonigenae*

Mycelial Growth of <i>Fusarium oxysporum</i> (mm)													
Tr. No	Treatments	10 % Concentration						15 % Concentration					
		5 DAI	Growth inhibition(%)	7 DAI	Growth inhibition(%)	Mean	Mean Growth inhibition(%)	5 DAI	Growth inhibition (%)	7 DAI	Growth inhibition(%)	Mean	Mean Growth inhibition(%)
T1	Neem Cake	11.29	83.31 (65.86)	18.85	79.05 (62.74)	15.07	80.88	9.29	86.26 (68.22)	13.47	85.02 (67.22)	11.38	85.56
T2	Mustard cake	14.39	78.72 (62.50)	23.92	73.41 (58.94)	19.16	75.70	12.39	81.68 (64.63)	15.23	83.07 (65.68)	13.81	82.48
T3	Safflower cake	19.14	71.70 (57.85)	30.87	65.72 (54.15)	25.01	68.28	15.23	77.48 (61.65)	16.59	81.55 (64.56)	15.91	79.82
T4	Groundnut cake	22.60	66.59 (54.67)	31.97	64.52 (53.42)	27.29	65.39	15.34	77.33 (61.54)	21.63	75.96 (60.62)	18.49	76.55
T5	Soya cake	24.37	63.98 (53.10)	31.12	65.34 (53.91)	27.75	64.80	17.85	73.62 (59.13)	21.17	76.48 (60.96)	19.51	75.25
T6	Cotton Cake	44.81	33.76 (35.38)	59.14	34.28 (35.82)	51.98	34.06	29.14	56.92 (48.99)	42.33	52.96 (46.68)	35.74	54.67
T7	Vermicompost	29.87	55.88 (48.35)	42.08	53.24 (46.84)	35.98	54.36	20.81	69.24 (56.3)	31.33	65.18 (53.82)	26.07	66.93
T8	Goat Manure	30.67	54.66 (47.65)	42.19	53.11 (46.78)	36.43	53.78	21.27	68.56 (55.87)	32.33	64.07 (53.15)	26.80	66.00
T9	Poultry Manure	31.57	53.34 (46.89)	41.81	53.54 (47.02)	36.69	53.45	22.03	67.43 (55.21)	33.37	62.92 (65.56)	27.70	64.86
T10	Control	67.65	0.00	90.00	0.00 (0.00)	78.83	0.00	67.65	0.00	90.00	0.00 (0.00)	78.83	0.00
	SE(m)±	1.04	1.05	1.51	0.97			1.37	1.23	0.79	0.57		
	C.D.(P=0.01)	3.09	3.14	4.50	2.90			4.09	3.67	2.35	1.70		

21
22
23



Concentration of organic amendments

24
25
26

Treatments

Fig. I. *In vitro* efficacy of aqueous extracts of organic amendments against mycelial growth of *Fusarium oxysporum* f.sp. *melongenae* in eggplant

Aqueous extracts of organic amendments used against *Fusarium oxysporum* f.sp. *melongenae* under *in vitro* conditions



PLATE I

Effect of aqueous extracts of organic amendments against *Fusarium oxysporum* f.sp. *melongenae* under *in vitro* conditions at 5th and 7th day after inoculation

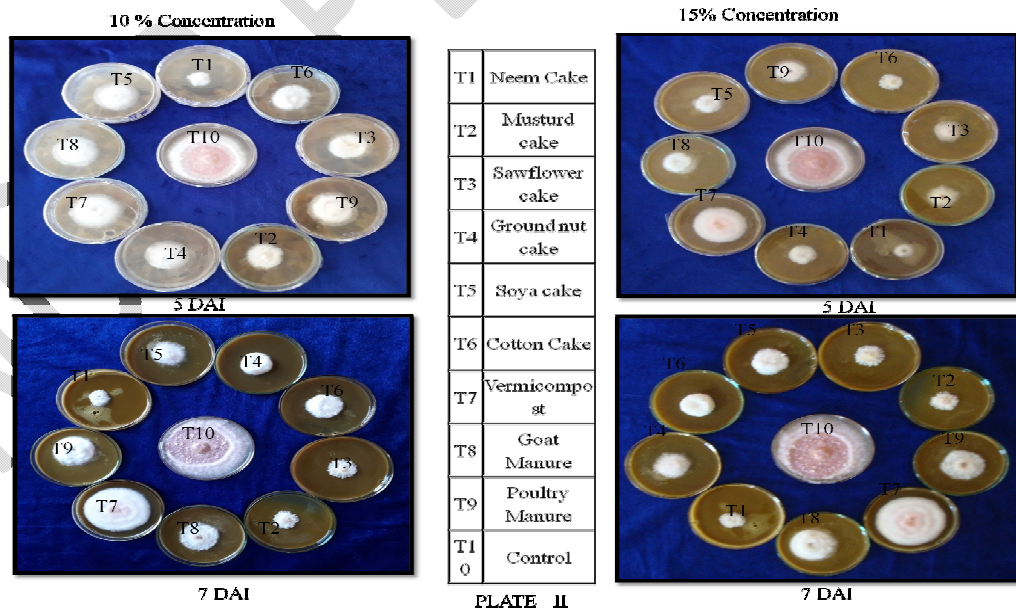


PLATE II

Table II. Effect of organic amendments on *Fusarium* wilt (Pot culture)

Tr. No.	Treatments	Per cent disease incidence at 100 DAS			
		100 gm Concentration	Reduction over control	150 gm concentration	Reduction over control
T ₁	Neem Cake	22.19 (28.08)	69.42	16.95 (24.29)	76.64
T ₂	Mustard Cake	23.49 (28.97)	67.62	17.54 (24.74)	75.82
T ₃	Safflower Cake	28.34 (32.14)	60.95	20.29 (26.74)	72.04
T ₄	Ground nut Cake	31.97 (34.41)	55.94	23.48 (28.97)	67.64
T ₅	Soya Cake	32.85 (34.95)	54.72	24.51 (29.65)	66.21
T ₆	Cotton Cake	36.52 (36.34)	49.67	33.15 (35.13)	54.31
T ₇	Vermicompost	35.03 (36.27)	51.72	23.33 (28.87)	67.84
T ₈	Goat Manure	34.39 (35.89)	52.60	25.92 (31.39)	64.28
T ₉	Poultry Manure	35.04 (36.28)	51.70	27.16 (30.58)	62.56
T ₁₀	Control	72.57 (58.42)	0.00	72.57 (58.42)	0.00
	SE(m)_±	0.63		0.739	
	C.D.(P=0.01)	1.88		2.196	

*Figures in the parenthesis are angular transformed values DAS: Days after sowing

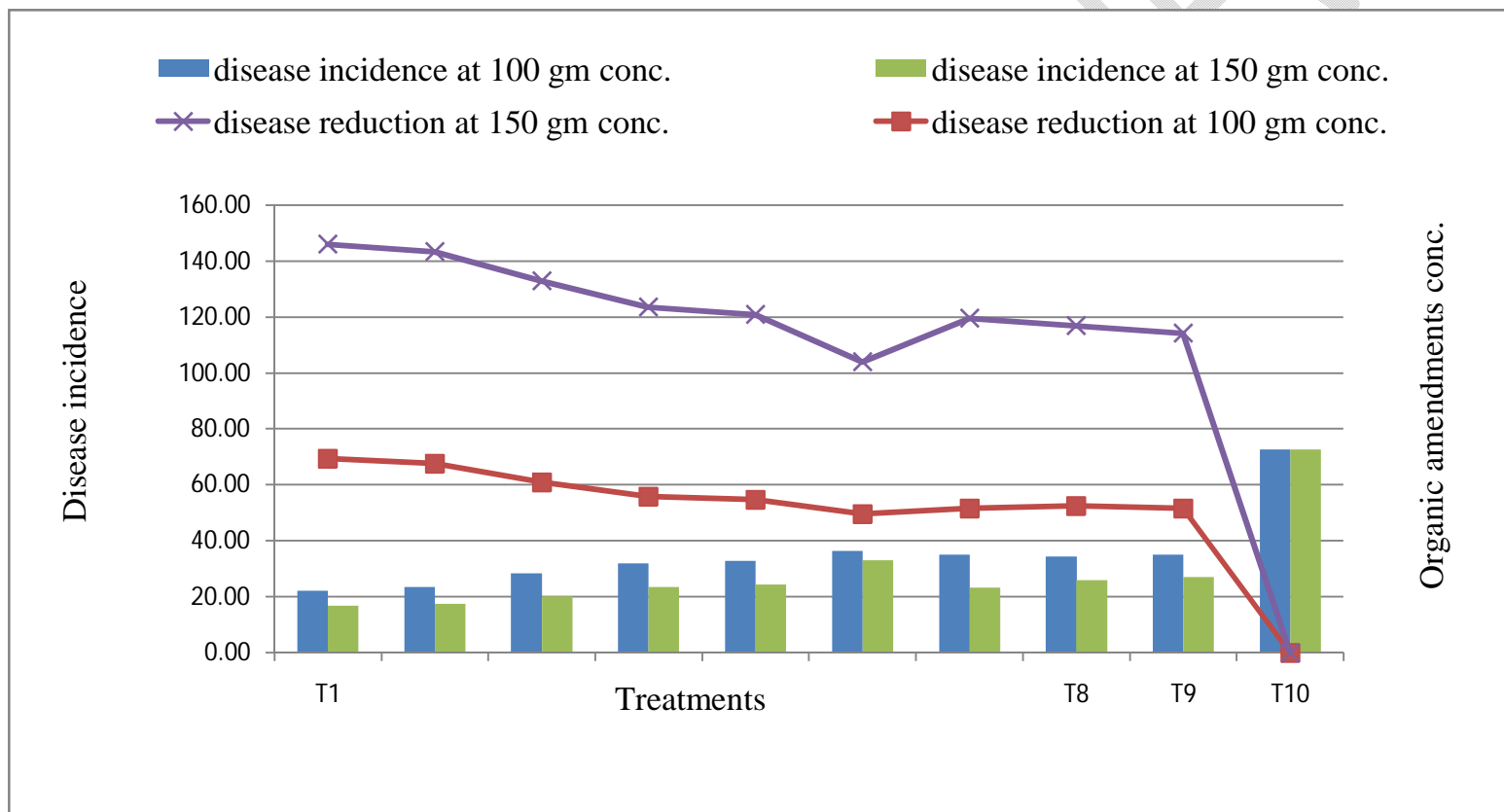


Fig.II.Effect of organic amendments in the management of *Fusarium* wilt in brinjal under glasshouse conditions (Pot culture)

Effect of organic amendments on *Fsarium* wilt in brinjal under glasshouse conditions (pot culture)



Organic amendments @100 gm/4 kg soil



Organic amendments @150 gm/4 kg soil

PLATE III