RESEARCH ARTICLE

Enhancing tomato wilt resistance through organic soil amendments: A comprehensive study on the impact of various treatments

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Sarita, Bhandari S, Singh S. Enhancing tomato wilt resistance through organic soil amendments: A comprehensive study on the impact of various treatments. AGBIR.2024;40(1):846-849.

Tomato (*Solanum lycopersicum*) holds considerable significance in Indian cuisine but its production faces challenges from various biotic stressors, with *Fusarium* wilt being a major concern. This study assesses the efficacy of diverse soil amendments (Karaj oil cake, Linseed cake, Bone meal, Horne meal, Vermicompost, Poultry manure, Blood meal and Mustard cake) in combating *Fusarium* wilt in tomato plants. Ten distinct treatments were administered to analyze their impact on multiple growth parameters, including shoot length, root length, seedling length, fresh shoot weight, fresh root weight, fresh seedling weight, and wilt intensity. The findings revealed notable enhancements in growth parameters among treated plants compared to the control. Treatments T_5 (*Fusarium oxysporum*+Vermicompost) and T_6 (*Fusarium oxysporum*+Poultry manure) demonstrated the highest percent control, with values of 56.5% and 56.2%, respectively. Promisingly, treatments involving and demonstrated higher control percentages, offering potential sustainable and ecofriendly solutions for managing *Fusarium* wilt of tomato crops.

Key Words: *Soil amendments; Length; Growth; Sustainable; Wilt; Ecofriendly*

INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the most versatile vegetable with wide usage in Indian culinary tradition [1]. It belongs to the genus Lycopersicon under Solanaceae family. Tomatoes are a prominent vegetable crop that has grown in popularity over the previous century. The number of biotic and abiotic stressors in tomato production is a restriction. Anthracnose, phytopthora, leaf blight, *Fusarium* wilt, bacterial wilt, damping-off, and root rot are some of the most common diseases that damage tomato production. *Fusarium* wilt, caused by the *Fusarium oxysporum* fungus, has recently arisen as a severe concern [2-5]. The major disease contributing to the loss in the production of this important crop is *Fusarium* wilt, which is caused by pathogenic formaespecialis i.e., *lycopersici* of the soil-inhabiting fungus *Fusarium oxysporum* (Sacc.) W.C. Synder and H.N. Hans. [6]. *Fusarium* wilt caused by *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) W.C. Synder and H.N. Hans is the major limiting factor in the production of tomato. These pathogens prove challenging, primarily because of their enduring presence in the soil and their ability to infect the vital vascular tissues and subterranean parts of plants. Complicating matters is the absence of registered fungicides, highlighting the urgent need for effective and environmentally friendly alternatives. Various strategies have been experimented, both in laboratory settings and tomato greenhouses. These include exploring indigenous fungi and bacteria [7,8], fungal and bacterial endophytes [3,5], aqueous and organic extracts [9], resistant rootstocks [4,10], composts [11], and various resistance inducers [12]. Farmers are nonetheless facing increasing pressure from soil borne diseases in spite of these efforts. Because of persistent tomato cultivation in the same fields, favorable weather conditions for diseases, common cultural methods, and the introduction of novel pathogenic strains, these pathogens frequently reach significant concentrations in the soil [2-4]. Because of its effects on beneficial species and potential harm to human and animal health, the use of chemical pesticides to manage *Fusarium* wilt and other soil-borne infections has a number of disadvantages. As a result, the emphasis now is on creating lasting, other strategies for controlling these infections. Since soil additives have the ability to alter the rhizospheric microbial community's composition, which in turn affects the soil's resistance to pathogens, they have emerged as a viable tactic to accomplish this goal. For example, studies on the effects of organic manures on soil microbial community manipulation and effective control of soil-borne diseases have been shown.

Several studies have investigated the intricate mechanisms through which the addition of organic materials can bring about these changes in the soil microbial community. Understanding these mechanisms is crucial for optimizing the use of organic amendments in agriculture. This research has shed light on how organic materials influence the microbial ecology of the soil, impacting the abundance and diversity of various microbial populations. This information can help design focused and efficient strategies to improve soil health and inhibit the spread of dangerous diseases. Overall, maintaining the long-term health and productivity of agricultural systems while minimizing harm to the environment and human health calls for a shift towards sustainable and environmentally conscious methods for addressing soil-borne diseases like *Fusarium* wilt.

MATERIALS AND METHODS

The study titled "Enhancing tomato wilt resistance through organic soil amendments: A comprehensive study on the impact of various treatments" was conducted in the Plant Pathology laboratory in collaboration with the Plant Breeding department at RNB Global University, Bikaner, in 2023. Effect of soil amendments on tomato wilt was evaluated and treatments were: T_1 (*Fusarium oxysporum*+Karaj oil cake), T_2 (*Fusarium oxysporum*+Linseed cake), T_3 (*Fusarium oxysporum*+Bone meal), T_4 (*Fusarium oxysporum*+Horne meal), T_5 (*Fusarium oxysporum*+Vermicompost), T_6 (*Fusarium oxysporum*+poultry manure), T_7 (*Fusarium oxysporum*+Blood meal), T_8(*Fusarium oxysporum*+Mustard cake), T_9 (*Fusarium oxysporum*) and T_{10} Control. Tomato selection-7 was sown in the pots (Four numbers of sets were maintained) and the statistical design is CRD. The experimental soil was combined with various treatment components in 1:3 ratios. Pots were left for a month following the soil amendment experiment. Data were collected on the percentage of seedlings at 18 Days After Sowing (DAS), the wilt intensity was observed at various DAS, and the growth characteristics of the seedlings, including shoot length, root length, height, fresh shoot root, and seedling weight at 30 DAS.

Isolation of pathogen

The collected diseased sample was washed properly with distilled water. Infected tissues along with adjacent small unaffected tissues from this sample were cut into small pieces (2-5 mm) in aseptic condition and then with the help of flame-sterilized forceps transferred to a sterile Petri plate containing 0.1 percent $HgCl2$ (mercuric chloride) and immersed it for 30-60 seconds. Then in the distilled water pieces were washed 2-3 times serially to remove traces of mercuric chloride. 2-3 pieces were transferred aseptically to Petri plates (containing PDA) and then plates were incubated at 28 ± 1°C and

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Received: 05-Dec-2023, Manuscript No. AGBIR-23-122462; **Editor assigned:** 07-Dec-2023, Pre QC No. AGBIR-23-122462 (PQ); **Reviewed:** 25-Dec-2023, QC No. AGBIR-23-122462; **Revised:** 03-Jan-2024, Manuscript No. AGBIR-23-122462 (R); **Published:** 11-Jan-2024, DOI:10.35248/0970-1907.24.40.846-849

observed after 48 h. The pathogen was identified based on morpho-cultural characteristics.

Purification of pathogen

For the purification of pathogen culture, hyphal tip method (by using inoculation needle fungal mycelia were picked up and then transferred aseptically to the freshly prepared PDA slants) was used.

Maintenance of pathogen

The pathogen was maintained by sub culturing on the freshly prepared slants of PDA and stored at 5 ± 1°C.

Wilt intensity

$$Disease\ intensity = \frac{Sum\ of\ all\ numerical\ ratings \times 100}{Total\ number\ of\ plants\ assessed \times Maximum\ scale}$$

Maximum scale *Fusarium* wilt disease rating scale was given by Saha et al., [13]

0-3 disease rating scale

0=No infection/healthy=Resistant (R)

1=Leaf yellowing=Moderately Resistant (MR)

2=Leaf yellowing+plant wilting=Moderately Susceptible (MS)

3=Leaf yellowing+plant wilting+plant death=Susceptible (S)

Standard germination (%)

In each petri plate, 25 seeds were arranged and placed in the germinator at 25°C ± 1°C for 14 days [2]. The seedlings were assessed at regular intervals, and after fourteen days, the per cent of normal seedlings were counted as germination.

$$Germination\ \% = \frac{Normal\ seedlings}{Total\ no\ of\ seeds} \times 100$$

Radical length (cm)

During the final count in each replication, the radical length of 10 randomly selected seedlings was determined using the measurement scale.

Plumule length (cm)

On the last count in each replication, the plumule length of 10 randomly chosen seedlings was measured using a measuring scale.

Seedling length (cm)

Ten randomly chosen seedlings were counted at the end of each replication, and the length of each seedling was measured using a measuring scale.

Fresh weight of seedlings (g)

The fresh weight of the seedlings was evaluated following the final count in the standard germination test, conducted over a period of 14 days. Ten healthy seedlings were selected at random from each replication of the germination test.

Dry weight of seedlings (g)

Following the initial weighing, the seedlings were subjected to a 48-hour drying period in an oven set at a temperature range of 65-70°C. The dried seedlings were subsequently weighed to determine the average seedling dry weight.

Seedling vigor index

The seedling vigor index was calculated using two distinct methods, as described by AbdulBaki et al., [14].

Seedling vigor index I

The seedling vigor index I was derived using the formula:

$$Seedling\ vigor\ index\ I = Standard\ germination\ (\%) \times Seedling\ length\ (cm)$$

Seedling vigor index II

The seedling vigor index II was calculated using the formula:

$$Seedling\ vigor\ index\ II = Standard\ germination\ (\%) \times Seedling\ dry\ weight\ (g)$$

Statistical analysis: Statistical analysis of experiment was carried out using opstat software at http://hau.ac.in.

RESULTS AND DISCUSSION

The results presented in Table 1 show the impact of different treatments (T_1 to T_{10}) on various growth parameters of the seedlings. The effect of different treatments on growth characters of tomato seedlings is presented. All the treatments were differed significantly in terms of growth characters such as shoot length, seedling height, fresh shoot weight, fresh root weight and fresh seedling weight of tomato seedlings. Significant variation was recorded in terms of all the growth parameters of tomato seedlings.

Among all the treatments Treatment T_6 demonstrated the highest mean shoot length of 33.1 cm, followed by T_7 at 28.5 cm. T_1 and T_2 also showed substantial shoot lengths of 20.0 cm and 19.8 cm, respectively. T_9 and T_{10} exhibited the lowest shoot lengths among the treatments, with means of 14.0 cm and 14.8 cm, respectively. Applications of bio-enriched vermicompost and host resistance had a major impact on tomato growth and yield components. The application of bio-enriched vermicomposts enriched with rice bran and cow dung, along with poultry manure and cow dung resulted in increased plant height, branching, and leaf number on tomato plant. This could be attributed to a reduction in the incidence and severity of *Fusarium* wilt, as well as improved nutrient availability and the presence of soil enzymes like urease, phosphomonoesterase, phosphodiesterase, and arylsulphatase, as reported by Albiach et al., [15]. Through the synthesis of organic matter, the recycling and uptake of nutrients, and the activity of the rhizosphere microbial population for plant growth and health, these soil enzymes play significant roles in the biochemical functioning of soils and soil fertility [16,17].

Treatment T_1 had the longest mean root length at 9.0 cm, followed by T_7 at 8.0 cm. T_9 and T_{10} documented the shortest root length among the treatments, with means of cm 3.9 and 4.2 cm, respectively. The maximum seedling length was observed in Treatment T_1 resulted in the longest seedling length with a mean of 35.6 cm, followed by T_6 at 34.7 cm and T_7 at 33.0 cm. The findings of the present study corroborate with the findings of the Islam et al., [18]. They found that the poultry waste increased germination of chilli seedlings over control. T_9 and T_{10} displayed the shortest seedling lengths among the treatments, with means of 16.9 cm and 21.5 cm, respectively. According to Azarmi et al., [19] adding vermicomposting to the soil for tomato growing considerably enhanced the organic C, N, P, K and Zn contents compared to control treatment. Zn levels in soil improved significantly as a result of the use of vermicompost [20].

Treatment T_7 showed the highest mean fresh shoot weight of 2.6 g, followed by T_1 (1.2 g) and T_2 (1.1 g). T_9 exhibited the lowest fresh shoot weight among the treatments, with a mean of 0.1 g. The maximum fresh root weight was observed in T_2 (1.5 g), followed by T_6 (1.2 g) and T_7 (1.2 g). T_9 documented the lowest fresh root weight among the treatments, with a mean of 0.1 g.

The maximum fresh seeding weight was observed in T_2 (2.5 g), followed by T_8(2.2 g) and T_7 (1.6 g). T_9 showed the lowest fresh seedling weight among the treatments, with a mean of 0.8 g. Similarly, Antoniou et al., [21] found that tomatoes planted in soil supplemented with biocontrols exhibited higher growth and yield. The positive effects of vermicomposts on the growth, productivity, and quality of a range of crop plants were observed [21-28].

The impact of different soil amendments on wilt intensity (%) of tomato was evaluated and data documented in Table 2. Statistical analysis of the data revealed significant variations among the treatments, with a significance level of $P \leq 0.01$. The results indicate significant variations in wilt intensity among the different treatments. Treatments T_5 and T_6 demonstrated the highest percent control, with values of 56.53% and 56.25%, respectively. Conversely, T_9 exhibited the highest wilt intensity (74.34%), highlighting its limited efficacy in controlling the wilt in Tomato crop. The Critical Difference (C.D.) of 1.135 suggests that treatments with percent control values differing by more than this threshold can be considered significantly different. Therefore, T_5 and T_6 can be regarded as the most effective treatments, showing statistically higher control compared to others. Numerous studies have shown that adding compost to soil can effectively suppress a number of significant soil-borne diseases, including as *Fusarium* wilts [29]. By reducing the severity of the disease, these composts control plant diseases through biotic and abiotic mechanisms [30]. It was demonstrated that populations of fluorescent *Pseudomonas* species and non-pathogenic strains of *Fusarium* *oxysporum* contributed to the supressivness process toward *Follicus fusarium* [29]. These microbial populations that sustain the supressiveness effect interact with abiotic properties, such as pH and the type of clays present [30,31].

The biopesticide efficacy of four green composts against *fusarium* wilt in melon plants was evaluated by Ros et al., [29] along with the impact of soil quality in soils amended with composts. Green composts demonstrated several positive traits, including enhanced plant development and reduced *fusarium* wilt in melon plants. The results of this investigation support those of Szczech [32], Rahman [33], and Islam et al., [18] discovered that the addition of vermicompost to container media considerably reduced the ability of *Fusarium oxysporum* f. sp. *lycopersici* to infect tomato plants. Because vermicompost has a suppressive quality and its application rate directly correlated with the protective effect's increase and inhibition. According to Rahman [33] using 3 tons of mustard oil cake and 5 tons of partially decomposed poultry manure two weeks before to seeding improved the prevalence of chickpea collar rot. According to Islam et al., [34], poultry waste improved germination above control by 32.27% and decreased damping off by 82.16% in chili. Similarly, bio-control agents help in management of wilt diseases (57%) in chilli [35].

TABLE 1
Effect of soil amendment on tomato growth parameters

Treatments	Shoot length (cm)	Root length (cm)	Seedling length (cm)	Fresh shoot weight (g)	Fresh root weight (g)	Fresh seedling weight (g)
T_1	20.0 ± 6.372	9.0 ± 3.147	35.6 ± 8.324	1.2 ± 0.937	0.2 ± 0.048	0.3 ± 0.128
T_2	19.8 ± 2.290	7.7 ± 0.669	23.2 ± 3.337	1.1 ± 0.013	1.5 ± 1.168	2.5 ± 1.191
T_3	17.8 ± 0.621	6.9 ± 0.154	26.7 ± 0.560	0.3 ± 0.052	0.2 ± 0.215	1.2 ± 0.380
T_4	17.3 ± 0.759	6.8 ± 0.348	22.5 ± 0.359	0.4 ± 0.091	0.1 ± 0.058	0.7 ± 0.074
T_5	17.3 ± 0.414	6.3 ± 0.060	24.7 ± 0.254	0.4 ± 0.055	0.2 ± 0.111	0.6 ± 0.035
T_6	33.1 ± 5.044	7.4 ± 0.428	34.7 ± 5.458	0.7 ± 0.065	1.2 ± 0.103	0.6 ± 0.030
T_7	28.5 ± 2.597	8.0 ± 0.275	33.0 ± 2.521	2.6 ± 0.176	1.2 ± 0.009	1.6 ± 0.571
T_8	19.1 ± 2.293	6.5 ± 0.367	21.3 ± 2.841	1.6 ± 0.135	0.3 ± 0.015	2.2 ± 0.373
T_9	14.0 ± 0.848	3.9 ± 0.210	16.9 ± 1.315	0.1 ± 0.048	0.1 ± 0.070	0.8 ± 0.230
T_{10}	14.8 ± 0.680	4.2 ± 0.548	21.5 ± 0.445	0.4 ± 0.119	0.3 ± 0.004	0.9 ± 0.150
C.D.	5.491	3.077	10.345	4.539	N/A	1.339
SE(m)	2.926	1.06	3.565	1.564	0.38	0.461
SE(d)	4.138	1.499	5.041	2.212	0.538	0.652
C.V.	29.011	31.664	27.484	160.127	234.289	81.617

TABLE 2
Effect of soil amendments on tomato wilt diseases management

	Wilt intensity (%)	
Treatments	Wilt intensity	Per cent control
T_1	48.44 (44.08)	34.8
T_2	28.29 (32.11)	43.2
T_3	42.21 (40.50)	43.2
T_4	37.58 (37.79)	49.4
T_5	32.52 (34.75)	56.2
T_6	32.31 (34.62)	56.5
T_7	46.53 (42.99)	37.4
T_8	46.82 (43.16)	37
T_9	74.34 (59.54)	-
T_{10}	-	-
C.D.	1.135	
SE(m)	0.379	
SE(d)	0.536	

CONCLUSION

The results suggest significant variations in the growth parameters among the different treatments, highlighting the potential influence of the applied treatments on the development of seedlings. This study underscores the critical issue of *Fusarium* wilt in tomato production and the urgent need for sustainable management strategies. The diverse organic amendments investigated exhibited varying degrees of impact on seedling growth and wilt control. Notably, treatments incorporating fish meal and blood meal showed promising results in reducing wilt intensity. These findings contribute valuable insights to the development of effective and environmentally friendly approaches for controlling soil-borne pathogens, ensuring the long-term health and productivity of tomato crops. Further research and validation are warranted to optimize these strategies for practical application in agricultural systems.

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