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Research Article

Integrated Management of Wilt of Chilli (*Capsicum Annum* L.) Caused by Fusarium Oxysporum F. Capsici. in Western Uttar Pradesh

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Abstract

Chilli (*Capsicum annum* L.) is the most widely grown solanaceous crops in the world Chilli is an important spice cum vegetable crop of the Solanaceae family grown around the world for its pungent flavor. However, their production has reduced over several years due to the attack of various fungal and bacterial pathogens and various abiotic factors. Fusarium wilt of chilli is one of the most important diseases as it drastically reduces the yield. In the present research work a total of 4 different botanical extracts and 4 isolates of Trichoderma were evaluated against the growth of wilt pathogen Fusarium oxysporum f. capsici. Among them Neem extract and Tr1 isolate of Trichoderma viride recorded better results hence they were selected for further study under pot culture conditions on the incidence of Fusarium wilt of chilli. In local variety of chilli Out of 5 different treatments tested, highest germination (94.25%) was recorded from T1. And, highest percent disease inhibition of Fusarium wilt (70.56%) was recorded from T1. On a similar condition, plant growth parameters such as improved plant height, dry weight, no. of flowers/ fruits per plant and fruit length were recorded from plants treated with T1. The integrated disease management (IDM) strategies perform better result in reducing disease as compared to that of chemical control besides improving yield and growth of treated plants of chilli.

Keywords: *Chilli; Fusarim capsici Trichoderma asperellum; Neem extract.*

Introduction

Chilli (*Capsicum annuum* L) *are* the most widely grown and commercially important vegetable crops in India.This country is the primary producer, exporter, and consumer of chilli in the world. Chilli, scientifically identified as *Capsicum annuum* L. (chromosome number 2n=24), is a member of the Solanaceae family. This plant holds significance as a crucial vegetable and spice crop cultivated worldwide. Chilli was first introduced into India by Portuguese traders in the year 1584 This crop are considered the vital source of nutrients, thus helping in combating various human health diseases and disorders. These crops are prone to multiple diseases, and the most devastating is the wilt in terms of incidence and yield loss. In India, the wilt of chilli has emerged as a severe threat, with disease incidence of 2–80%. The two critical fungal species i.e., *Fusarium oxysporum* and *Fusarium solani* are involved with chili wilt in India, whereas, *Fusarium moniliforme and Fusarium pallidoroseum* are the other two species found in some parts of India. Recently, *F. equiseti* has been reported from Kashmir valley as the causal agent of chili wilt. Global yield losses due to the disease are estimated to range between 10 and 85%. Apart from chilli wilt affects a wide variety of crops such as tomato, tobacco, cucurbits, legumes etc. The characteristic symptoms of wilt disease are slight yellowing of the leaves that wither and defoliate prematurely. Browning of the vascular tissues, stunting, and necrosis are the other

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symptoms. According to some reports the *Fusarium palfidoroseum Sacc*. Is the primary causal agent of wilt in Kashmir valley. The losses due to this disease is reported to be 30–40% annually in the country.

India holds the distinction of being the leading global producer and consumer of chilli, with an impressive total production of approximately 4.221 billion tonnes. In India, the states of Andhra Pradesh, Karnataka, Tamil Nadu, and Maharashtra collectively contribute to around 75% of the total cultivated area dedicated to chilli. Additionally, chilli cultivation extends to Haryana, covering an estimated 13.290 thousand hectares and yielding a total production of 141.650 thousand tonnes (NHB). Chilli production is being affected by so many constraints which include diseases among which wilt disease caused by Fusarium spp. play a very crucial role. Wilt symptoms initiate with a mild yellowing of older leaves, progressing to younger leaves, leading to chlorosis and dryness. Subsequently, the entire plant gradually withers and eventually dies . Plant morphological alterations caused by Fusarium spp. include wilting, stunting, crumbling of seedlings, necrosis, leaf fall, and chlorosis. The symptoms of wilting are indicative of severe water stress, which is mainly brought on by vascular occlusion. In the cultivation of chili peppers worldwide, these changes result in yield losses that range from 10% to 80%. The fungus enters the plant from the roots and moves up to the cortex from there. In this area, it forms microconidia that climb and enter the sap stream. Furthermore, vascular veins become clogged by the mycelia from germinated spores, which eventually causes wilting and plant death. Chemical agents have been used extensively and without prejudice to reduce the incidence and stop the spread of this plant disease for decades, which has resulted in a number of ecological issues. Currently, the agriculture industry is moving toward ecological disease management strategies, where the use of chemicals is either restricted or outright forbidden. Plant extracts provide a practical way to handle. Fusarium wilt disease, which can be used as a substitute for fungicides because of their potent antifungal qualities. Numerous botanicals, including Garlic, Neem, Datura leaf extract, and several plant oils, are effectively used in disease treatment techniques. This is explained by the fact that they are safe for the environment and do not harm species that are not their intended targets. When evaluated in field condition, Neem oil dramatically decreased the incidence of Fusarium wilt, according to earlier research by Singh *et al*. and Sitara *et al*. (2011). clearly stated that Neem oil significantly reduced the incidence of *Fusarium* wilt when tested under field conditions. Liquid organic formulations are dynamic organic inputs derived from the fermentation of animal products over a specific period. Macro and micronutrients, as well as hormones that promote plant growth, are abundant in these formulations. Plant growth and development are significantly improved when organic liquid formulations, such panchagavya, are applied. Furthermore, a number of plant diseases are suppressed by these formulations. Since biocontrol agents (BCAs) are compatible with a variety of organic practices and exhibit little to no resistance, they are frequently seen as a safer and more environmentally friendly option to chemical fungicides for the biological control of plant diseases. It is true that Trichoderma spp. is well-known and extensively researched biocontrol agents that have proven successful in controlling plant diseases and fostering plant development. Some species of the fungus Trichoderma, which is frequently found in soil, have advantageous qualities for plants. Competition, the release of enzymes that break down cell walls, and the release of antimicrobial metabolites are the primary methods by which antagonistic bacteria inhibit pathogens. An alternative sustainable management strategy for Fusarium wilt must be developed in light of the efficacy of the afore mentioned liquid organic, botanical extracts, and biocontrol agents. This strategy should have a synergistic effect on the growth and yield parameters of chillies grown in pot culture.

MATERIALS AND METHODS

The survey was conducted in chilli fields of Meerut and Muzaffar nagar of Uttar Pradesh. The disease was
identified based on the symptoms and the pathogen responsible for *Fusarium* wilt. The pathogen was isolated from the tissues of the infected plants parts which were collected separately. A total of 4 different botanical extracts *viz*., Neem leaf Extract, Parthenium leaf extract, Lantana camara extract and Eucalyptus leaf extract were prepared as per standard protocols and assayed against *Fusarium* spp. In-vitro by employing poisoned food technique at two different concentrations i.e., 1.0% and 2.0%. Similarly, 4 isolates of *Trichoderma* i.e., Tr1, Tr2, T3, Tr4 were tested against *Fusarium* spp. *in vitro* by using dual culture technique.

Per cent growth inhibition (I) = $\frac{(C-T)}{C} \times 100$

C – Radial growth of pathogen in control plates

T – Radial growth of pathogen in treated plates

Integrated Management of *Fusarium* wilt of Chilli under Pot Culture

In the integrated management of chilli wilt the outcomes from in vitro studies, Tr1 derived from *Trichoderma* spp. and Neem oil extract from botanical sources were specifically chosen. These selections undergo testing in experimental pot culture conditions in combinations with Parthenium hysterophorus, to investigate both their individual and collective impact on the occurrence of wilt disease in chili caused by *Fusarium* spp. The experiment was put in randomized block design with a total of 5 treatments and 3 replications.

The treatments were applied as seed treatments before sowing. The treatments were as follows.

T1 - Neem extract *and Trichoderma spp*

T2 - Parthenium hysterophorus and *Trichoderma spp.*

T3 – Lantana camara *and Trichoderma* spp.

T4 – Eucalyptus leaf extract and *Trichoderma* spp.

T5 – Carbendazim, T6- control.

Dose of treatments:

Neem Extract @ 2.0%, Parthenium hysterophorus @ 3%, Trichoderma spp. @ 4g/kg and Carbendazim @ 2g/kg Chilli seeds of local variety were sown in trays following treatments and transplanted to pots with sterilized soil after 4 weeks. The intensity of the disease (Percent disease incidence) was calculated and compared with that of controls 30 days after transplantation of seedlings.

Percent disease incidence = No. of infected plants / Total number of plants observed * 100

Observations on Growth and Yield Parameters

The growth and yield characters such as plant height (cm), biomass (g), no. of flowers per plant, no. of fruits per plant, fruit length was recorded from each treatment at different intervals.

RESULTS AND DISCUSSION

All botanicals are found significantly superior over the control among the four botanical extracts tested, highest inhibition of the mycelial growth of the pathogen was recorded by Neem extract (55.35%) at 2.0% concentration (Table 1). Followed by Parthenium hysterophorus extract (48.80%) at 2.0% concentration. However, Lantana camara extracts and eucalyptus leaf extracts recorded significantly lower and similar percent inhibition of mycelial growth of pathogens at both the tested concentrations i.e., 1.0% and 2.0%. Khokhar *et al*. [14] in which they tested the effect of five different botanicals extracts on the mycelial growth of *Fusarium verticillioides* and reported that Neem oil at 0.2% concentration recorded 52.2% inhibition of mycelial growth. Singh *et al*. tested the effect of 12 botanicals at 4 different concentrations and reported that Neem oil and garlic oil at 10% concentration completely inhibited the growth of chilli wilt pathogen *Fusarium oxysporum*. The presence of antimicrobial compounds might be responsible for the inhibitory effect of plant extracts against plant pathogens. Ramprasad, Manea *et al*.

The Anti-fungal activity of Neem products

might be due to the presence of compounds such as nimbin, nimbidin, salannin, azadirachtin etc.

The four different *Trichoderma* isolates are isolated from the rhizosphere region of healthy chilli plants. All the tested isolates of *Trichoderma* significantly reduced the growth of chilli wilt pathogen *in vitro*. Between the isolates highest radial growth inhibition of the pathogen was recorded by Tr1 at 65.90% followed by Tr2 (58.20%) and Tr3 (56.50%) which were significantly on par with each other. However, the minimum radial growth inhibition of the pathogen was record by Tr2 at 54.12% (Table 2). Based on the morphological studies, the isolate Tr1 was identified as *Trichoderma asperellum*. The inhibitory effect of different *Trichoderma* spp. (*Trichoderma longibrachiatum*, *T. harzianum* and *T. atroviride*) against *Fusarium solani* was proved earlier by Boureghda et al. Islam *et al*. Reported that *Trichoderma harzianum* recorded a remarkable 81.67% mycelial growth inhibition of *Fusarium oxysporum* in dual culture technique after 7 days. Mishra *et al*. revealed that among different Trichoderma isolates tested, CA-09 recorded maximum growth inhibition of *Fusarium oxysporum* f.sp. *capsici*. They further reported that the main mechanisms behind the inhibition of radial growth of pathogens might be due to competition, mechanical obstruction and hyper parasitism. *Trichoderma* spp. produces a range of enzymes, including chitinase, cellulase, β-1-3-glucanase, and protease, along with secondary metabolites. Saravanakumar *et al*., Li *et al*., These substances help in the breakdown of the cell walls in soil-borne pathogens, leading to the inhibition of their mycelial growth.

Effect of Different Treatments on Germination Per Cent and Incidence of Fusarium wilt

The total of 6 different treatments were tested under pot culture conditions on the incidence of Fusarium wilt of chilli. Among all the treatments tried, highest germination (94.25%) was recorded from the plants treated with T1 which is a combination of Neem extract and Trichoderma. This was followed by treatments T2 and T3 which recorded germination of 85.24% and 84.35% respectively. The minimum germination of 75.85% was recorded by treatment T4 in which the seeds were treated with eucalyptus leaf extract alone (Table 3). However, the seeds treated with carbendazim recorded 80.25% germination which is statistically on par with T4. The control resulted in to germination of 71.52% in comparison of treated seed.

In pot culture conditions all the treatments significantly reduced the incidence of Fusarium wilt. Among the treatments, highest disease inhibition was recorded from T1 which was 75.57% in which the plants are treated with a combination of Neem extract and Trichoderma. Similarly, treatments T2, T3 and T4recorded percent disease inhibition of 61.93%, 48.80% and 36.85% respectively. The lowest percent disease inhibition was recorded from the treatments T23and T4 which are statistically on par with each other. However, plants treated with carbendazim recorded highest percent disease inhibition of 78.90 in chilli.

Table 1. Effect of different botanical extracts on the mycelial growth of Fusarium sp. by using poisoned food technique

S. No	Concentration		Colony Diameter (mm)*				Percent Inhibition		
		Neem leaf extract	Parthenium hysterophorus extract	Lantana camara extract	Eucalyptus leaf extract	Neem leaf extract	Parthenium hysterophorus extract	Lantana camara extract	Eucalyptus leaf extract
1	1.0	36.88	40.25	56.66	54.67	36.80	30.80	21.28	20.78
2	.2.0	48.38	56.35	58.88	59.04	51.36	46.70	25.90	24.50
3	Control	72.33	72.33	72.33	72.33	0.0	0.0	0.0	0.0
CD at 5%		3.22	1.55	3.78	5.56	-			

SE (m)±		0.91	0.50	1.14	1.54				

Table 2. Effect of different *Trichoderma* spp. on the radial growth of *Fusarium* spp. by using dual culture technique

S. No.	*Trichoderma* spp.	Radial Growth* (mm)	Percent inhibition
1	Tr1	34.94	65.90
2	Tr2	32.10	54.10
3	Tr3	28.86	51.05
4	Tr4	24.70	49.28
5	Control	64.30	-
CD at 5%		3.45	-
SE (m)±		1.14	

Effect of Different Treatments on different Growth Parameters of Chilli.

Out of total of 5 different treatments were tested in pot culture conditions along with a chemical check and a control. All the treatments significantly increased the growth treated plants. Among them, highest plant growth parameters such as plant height (64.80 cm), dry weight (40.13), no. of flowers per plant (24), no. of fruits per plant (45) and fruit length (9.0 cm) was recorded from the plants treated with T1 which is a combination of Neem extract, and *Trichoderma asperellum* (Table 4). This was followed by T2 in which the seeds were treated with Parthenium hysterophorus extract and *T. asperellum.* However, the minimum growth parameters were recorded from the plants in which the seeds were treated with Eucalyptus extract *Trichoderma* (T4). However plants treated with carbendazim recorded higher growth characteristics, they were statistically on par with T1. This shows that the combination of Neem extract + *T. asperellum* + performed superior to that of a chemical fungicide (carbendazim) in terms of decreased disease incidence and improved plant growth promotion in chilli.

Similar tests were conducted by Islam *et al*., who examined the impact of Trichoderma harzianum in greenhouse settings. They found that the treated plants had a minimum incidence of Fusarium wilt in chillies (38.46%). Additionally, they reported that the treated plants' growth characteristics, including shoot length, root length, and vigor index, among others, had increased. Trichoderma produces a variety of secondary metabolites into the soil around the roots, including siderophores, gibberellins, and indole-3-acetic acid. dissolve phosphorus and other minerals such as magnesium (Mg), manganese (Mn), and iron (Fe). These compounds may help plants develop more effectively while reducing their vulnerability to disease. Zhou *et al*., in a recent study, Bhat *et al*., Examined the impact of T. viride on the incidence of fusarium wilt in chillies in two distinct locations. They found that the treated plants had lower disease incidence rates (10.8% and 38.5%) in both seasons. Similarly, applying Trichoderma spp. as soil drenching reduced the disease incidence to 24.7% from 83% in the control group. In addition to reducing disease, the treated plants showed improvements in fresh weight, dry weight, shoot length, and root length. These results are consistent with previous studies showing that Trichoderma spp. have been successful in increasing the development of pepper, tomato, and lettuce plants. Trichoderma species are known to produce a variety of compounds that promote plant development and to improve nutrient uptake, which in turn helps treated plants achieve gains in a range of growth and yield metrics.

The presence of vital nutrients and chemicals that promote plant growth, like IAA, GA3, and cytokinins, is responsible for the enhanced plant growth and yield characteristics seen in treated plants. It has been discovered that panchagavya lowers the frequency of Fusarium wilt brought on by Fusarium oxysporum and Fusarium solani. Apart from its capacity to stimulate plant growth, the antifungal properties of Panchagavya are attributed to the presence of antagonist microbes and ammonia toxicity. These elements

are essential for preventing plant diseases.

Table 3. Effect of different treatments on germination and incidence of *Fusarium* wilt disease at 60 Day after Treatment.

Treatment No	Treatments	Germination (%) *	Percent disease incidence (%) *	Percent efficacy of disease control (%) *
1	Neem extract and *Trichoderma asperellum* (Tr1)	94.25	25.53	75.57
2	*Parthenium hyserophrousTricho-derma spp.* (Tr2)	85.24	18.57	61.93
3	Lantana camara and *Trichoderma* spp. (Tr3)	84.35	15.51	48.80
4	Eucalyptus leaf extract *Trichoderma* spp. (Tr4)	75.85	8.46	36.85
5	Carbendazim	88.20	7.24	78.90
6	control	71.52	28.55	-
CD at 5%		4.466	-	
SE (m)±		1.7621		

Table 4. Effect of different treatments on various growth parameters of chilli

Treatment No	Treatments	Plant Height (cm)	Dry weight (g)	Flowers per plant	Fruits per plant	Fruit Length (cm)
1	Neem extract and *Trichoderma asperellum* (Tr1)	64.80	40.13	24	44	8.5
2	*Parthenium hyserophrousTricho-derma spp.* (Tr2)	58.28	32.52	17	38	8.0
3	Lantana camara and *Trichoderma* spp. (Tr3)	52.94	28.00	14	34	7.3
4	Eucalyptus leaf extract *Trichoderma* spp. (Tr4)	48.72	34.10	12	30	6.5
5	Carbendazim	60.60	36.10	22	42	8.2
6	control	51.31	31.91	16	34	7.2
CD at 5%		2.8	1.04	0.88	1.94	0.34
SE (m)±		0.92	0.35	0.24	0.64	0.12

CONCLUSION

In the present study results shows that Tr1 isolate of *Trichoderma* significantly reduced the growth of the pathogen under in vitro conditions along with Neem leaf extract at 2.0%. When they are tested under pot culture conditions in combination they significantly reduced the incidence

Fusarium wilt incidence and even enhanced the growth and yield parameters of treated plants of chilli. When compared to that of plants treated with Carbendazim,. So it can be recommended to the famers to use the combination Neem leaf extract and *Trichoderma* to managing *Fusarium* wilt of chilli caused by *Fusarium oxysporum* f.sp. capsici.

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