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Management of *Fusarium* wilt of Tomato (*Lycopersicum esculentum* Mill.) by liquid formulation of *Trichoderma harzianum*

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The present investigation was carried out to understand the efficacy of liquid formulation of *Trichoderm harzianum* 1.5% AS(AMMFA TH-1) against the Fusarium wilt of tomato under field trials by using soil drenching at different intervals. It was found that all the treatments significantly reduced the disease incidence as compared to control (untreated) plots. Among them, AMMFA TH-1@10 ml/lt showed minimum disease incidence (7.74%) as compared to control (23.21%). The percent reduction over control of disease was observed in the same treatment (AMMFA TH-1@10 ml/lt) of 66.65 per cent followed by chemical treatment after 4 times of soil drenching.All treatments showed better results on growth parameters of tomato. The average yield were highest (548.53q/ha) inAMMFA TH-1 @10 ml/lt and lowest in the control plot (370.67q/Ha). The same treatments showed highest gross income, net income and benefit cost ratio (3.52) while the minimum benefit cost ratio (1.95) was observed in control. Hence, the use of liquid formulation of *Trichoderma* as biocontrol agent is useful and beneficial form reducing the wilt disease of tomato and also recommend as one of the management practice under organic farming.

Keywords : Disease incidence, management, tomato wilt, *Trichoderma*

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular warm season crops which belong to the family Solanaceae. It is a native crop of Peru and Mexico. It is also known as the poor man's apple in Nepal with an average national consumption of 11.97kg/person/year. It is known as a productive as well as protective food because of its wide spread production and its special nutritive values; 100 gm of tomato contains 48 mg calcium, 20 mg phosphorus, 0.4 mg iron, 2.7 mg vitamin C and vit. B complex, vit. A, sulphur, potassium in small amounts and an energy content of 20 calories per 100 gm of its fruit that are important for human health.

The pulp and juice of tomato is very digestible, culinary, dietary therapeutic, promoter of gastric secretion and blood purifier. Tomato is the most consumed crop all over the world and ranks second next to the potato in acreage and first among the processing crops. During 2018-19, the crop was cultivated in an area of 4.73 million hectares all over the world with production of 169.96 million tones and an average yield of 34.66 t/ha (Anonymous, 2019).

Annual production of tomato in India throughout 2018-19 was 20515.24MT with an area of about 814 thousand ha, and productivity of 27.8 MT/ha, in Maharashtra state, it is grown in an area of about 43.64 thousand hactares with production of 976.58.MT, and productivity of 22.07MT/ha (Anonymous, 2018). Many diseases occurred on tomato plants viz., wilt, damping-off, early blight, late blight, leaf curl, tobacco mosaic, root-knot, etc. Among the diseases Fusarium wilt remains to be a challenging top player in terms of difficulty in management. Fusarium wilt of tomato is caused by *Fusarium oxysporum* f.sp. *lycopersici* and it is a devastating disease in major tomato growing regions worldwide. Being a highly destructive pathogen, it causes severe damage to crops

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especially tomato plant amounting to around 10% - 50% yield loss in many tomato producing areas of the world (Ghazalibiglar *et al*., 2016).

Fusarium often causes yellowing on one side of the plant or leaf which begins with the older, bottom leaves and later followed by wilting, browning, and defoliation. Growth is typically stunted , infected plants often die before maturation and little or no fruit develops . Being soil borne in nature, the pathogen infects through the plants roots causing vascular wilt and advances to the stele through the cortex causing browning or blackening of xylem vessels. Thus, brown vascular tissue can be found when the infected stem is cut at its base. This disease is one of the most prevalent and damaging disease in areas where tomatoes are grown extensively because the pathogen is soil-borne in nature and therefore, application of fungicides to control this disease is almost an impractical task. Besides, excessive misuse of a variety of fungicides by ignorant farmers has caused many serious health hazards to the applicator as well as the consumers of the treated crops and also has led to environment pollution and increase in resistance to it among the pathogens. Owing to these reasons , many alternative methods to control the disease have been studied and tried with the major emphasis on the method of biological control using fungi and bacteria such as *Trichoderma harzianum, Pythium oligandrum, Achromobacter xylosoxydans, Penicillium oxalicum* and *F. oxysporum* (Mohamed and Haggag, 2006; Le Floch *et al*., 2003: Chanu *et al*. 2018, 2024; Chaprapani *et al.* 2019). Out of these, the probability of biological control using most promising bio-control agent; the genus *Trichoderma*, has been described (Papavizas, 1985). Biological control of soil-borne plant pathogens through antagonistic offer environmentally safe and cost effective alternative to chemicals (Abdallah *et al.* 2016).

Trichoderma species is one of such fungus that shows antagonistic activity against several deadly plant pathogens by production of secondary metabolites and enzymes (Sharma and Sharma, 2020). *Trichoderma harzianum* stimulates the growth of plants by producing metabolites that promote developmental processes, thereby allowing greater root development and absorbent hairs, which favors the mobilization of nutrients from the soil and also accelerates the decomposition of organic matter and minerals. Soil application with *T. harzianum* provides a basis for the comparison of various agronomic parameters such as number of flowers, fruits number, leaves number, aerial part length, root length, fresh weight of the aerial part and fresh weight of root part of tomato plants.

Utilization of modern pesticides and chemical compounds has been done by farmers to control such plant pathogen. However, these chemicals do not degrade completely in soil, thus it pollutes the soil by leaving the toxic residues. So, chemical treatments against soil-borne root pathogens are very dangerous thus limits the chemical control and the high concern for the preservation of the environment is necessary. *Trichoderma* strains are appealing alternatives to hazardous fumigants and fungicides. Therefore, the objectives of the present study were to assess the ability of *Trichoderma* spp. in decreasing the disease severity of *Fusarium* spp. in tomato under *in-vivo* conditions. The studies on the management of Fusarium wilt of tomato by *Trichoderma harzianum* were carried out to understand on the disease incidence and growth promotion on tomato.

MATERIALS AND METHODS

The present investigations on Fusarium wilt of Tomato was carried out during 2019-2020 and 2020-2021 at Department of Plant Pathology, College of Agriculture, Central Agricultural University, Imphal, Manipur. The materials and procedures performing the experiments are explained in details here. All the laboratory experiment studies, Borosil glassware were used. The glassware were cleaned by keeping in solution of 60g Potassium dichromate solution, 60ml of concentrated Sulphuric acid dissolved in a litre of distilled water for a day i.e., 24 hours , followed by washed with detergent solution and washing them under running tap water several times and finally with distilled water. Sterilization of the experiment materials, solid and liquid media were subjected to steam sterilization by autoclaving at 1.1kg per cm² (121.6^{0}C) of pressure for 20 minutes. The plant tissues were surface sterilized in 1% Sodium hypochlorite solution followed by three changes in sterile distilled water. Potato Dextrose Agar (PDA) was used for *in vitro* study. It was used for isolation, purification and maintenance of isolates. To prepare PDA medium, 200 g of skin peeled potatoes were taken and they were sliced to small pieces. The sliced potatoes were boiled in 500ml of distilled water in a clean vessel for 25 minutes. Simultaneously, 2 0g of agar was mixed in another 500ml of warm water. The potato extract was collected by filtering through muslin cloth and 20 g of dextrose was added to the filtrate solution and was mixed thoroughly. The potato dextrose solution was mixed with agar solution and mixed thoroughly using a glass rod. Finally the volume of the mixture was made up to 1l by using distilled water.

Collection of the diseased samples

Isolation and Identification of the pathogen Samples of wilt infected tomato plants were collected from the field and isolation of the pathogen was carried out in the laboratory, Department of Plant Pathology, College of Agriculture, CAU, Imphal. The roots and the collar regions of the wilted plants sample were washed thoroughly in tap water in order to remove the sticking soil particles. Samples were cut into small pieces with the help of sterilized needle blade and these pieces were surface sterilized with 1% sodium hypochlorite solution for 1 minute and three serial washing were done in sterilized distilled water to remove the traces of sodium hypochlorite. Under laminar flow, these pieces were transferred to sterilized petri plates containing Potato dextrose agar (PDA). The petri plates were incubated at 27±1°C in BOD incubator and observed periodically for the fungal growth. The fungal colonies developed in each petri plate was isolated separately by taking 1mm size hyphal tip with the help of cork borer and transfer to another petri plate containing PDA. The inoculated plates were kept inside BOD incubator for the growth and sporulation of the fungus. Identification of the causal pathogen of wilt of tomato collected from experimental field was done in the laboratory by observing under the microscope from the pure culture of the fungus obtained from infected plant. Pathogenicity test for the isolated fungus was conducted in the laboratory following Koch’s postulates. Soil inoculation with pathogen was done by means of rice seed inoculum technique of Weideman and Wehner (1993).

Field experiment

The experiment was conducted in the Fusarium sicked plot at College of Agriculture, CAU, Imphal. Tomato variety Abhimanyu was used as test plant in the experiment. Efficacy of liquid formulation of *Trichoderma harzianum*1.5% AS (AMMFA TH-1) was evaluated for their effectiveness against the Fusarium wilt of Tomato in the field. Five different doses of each *Trichoderma* viz., 2.5ml /l of water, 3.5ml / l of water, 5ml / l of water, 6.25 ml / l of water, 10ml / l of water were tested and one *Trichoderma harzianum-local* (10ml /l t of water) was used as check(Biocontrol). A chemical fungicide carbendazim (1g/lt of water) was used as check (Chemical) and the untreated plots were kept as control. The field trials were taken up in Randomized block design (RBD) with eight treatment and three replications. Plot size were 2.5mX1.5m with spacing of 30cm row to row and 30cm plant to plant. Root drenching was done four times. First root drenching was done at 20 days after transplanting and remaining three were done 15 days after each treatment.

Observations was recorded as follows :

- Mortality rate – Pre-count, 3, 7 and 14 days after each application.
- Percent Reduction Over Control (%ROC) at 14 days after each application.
- Yield to tomato per plot per kg. and in quintal per Ha.

The percentage increase in yield over control was calculated by using following formula,

$$\text{Yield Increased (\%)} = 100 \times \frac{T - C}{C}$$

Where,

T= Yield of treatment(q/ha)

C= Yield of untreated control (q/ha)

The return per rupee invested (Cost benefit ratio), i.e. called input-output ratio is calculated by using the following formula:

Return per rupee invested =Gross return/ Total cost of cultivation.

(This index provides an estimate of the benefit, derived from the expenditure incurred in adopting a particular system.)

Where,

Gross return=The total monetary values of the economic produce obtain from the crop raised which is calculated based on the local market prices of the produce and expressed on unit area basis.

Cost of cultivation = It is as per hectare basis for each treatment by taking into account the inputs, labor and operational costs.

RESULTS AND DISCUSSION

Disease Incidence

Fusarium wilt is one of the important soil borne disease1111 of tomato. Generally, soil borne diseases are difficult to manage as compared to foliar disease. The present experiment was conducted to under stand the effect of liquid formulation of *Trichoderma harzianum* 1.5% AS (AMMFA TH-1) against Fusarium wilt of tomato (*Solanum lycopersicum*).The experiment was conducted during the rabi season during 2019-20 and 2020-2021. Details of the experimental results are discussed in this chapter.

The disease incidence was scored in each treatment (soil drenching at root region- 4times) at interval of 3, 7, 10 and 14 days. First treatment was done at 20days after planting (DAP). After first treatment, there was no Fusarium wilt symptom observed at 3, 7, 10 and 14days. There was observation of Fusarium wilt incidence on tomato plants after 2nd soil drenching and results are presented in (Table 1). It is evident that disease incidences were ranges from 0.60 to 4.76% at 14 days after 2nd drenching. The results showed non-significant on the disease incidence among the treatments.

The Fusarium wilt incidence at 3, 7, 10 and 14 days after 3rd time soil drenching arepresented in (Table 2). The results showed that Fusarium wilt incidence were ranges from 1.19 to4.76%, 2.38 to 7.14%, 4.76 to 9.52% and 7.14 to 13.09% respectively at 3, 7, 10 and 14 days after 3rd drenching during 2019 -2020. During 2020 -2021, Fusarium wilt incidence were ranges from 2.38 to 9.52%, 3.57 to 11.90%, 5.95 to 15.47% and 7.14 to 17.85% respectively at 3, 7, 10and 14 days after 3rd drenching. In both the seasons, the highest disease incidence was observed to the control plot (15.47),whereas lowers was observed to AMMFA TH-1@10ml/lt(5.36%).

The Fusarium wilt incidence at 3, 7, 10 and 14 days after 4th time soil drenching arepresented in (Table 3). The results showed that Fusarium wilt incidence were ranges from 8.33 to16.66%, 8.33 to 20.23%, 8.33 to 22.61% and 8.33 to 22.61% respectively at 3, 7, 10 and 14 days after 4th drenching during 2019 -2020. During 2020 - 2021, Fusarium wilt incidence were ranges from 8.33 to 20.33%, 7.14 to 21.42%, 7.14 to 23.81% and 7.14 to 23.81% respectively at 3, 7, 10 and 14 days after 4th drenching. In both the seasons, the highest disease incidence was observed to the control plot (23.21%),whereas lowers was observed to AMMFA TH-1@10ml / l (7.74%).

Percent Reduction over Control

The data on Percent Reduction over Control (%ROC) presented in Table 4. It is observed from the table that % ROC were ranges from 12.39 to 87.39%, 19.20 to 65.35% and 20.51 o66.65%r espectively after 2nd, 3rdand 4thdrenching.

Yield

Tomato was harvested time to time depending on the ripening of the fruit and total yield wascalculated by adding all the piece harvest (Table 5). In the year 2019-2020, yields were ranges from 13.90to 20.57 kg per plot. During the year 2020-2021, yield of tomato were ranges from 13.13 to19.30kg per plot. The same yield was converted in quintal (q) per hectare (ha). The pooled data showed that yield of tomato were ranges from360.53 to 531.47 q/ha. Highest yield of tomato was obtained in the AMMFA TH-

Table 1: Incidence of Fusarium wilt of tomato during 2019-2020 and 2020-2021(after2nd treatment*)*

Treatments	TREATMENTS	Disease Incidence (%)								
		7day			10day			14day		
		2020 2019	2020-2021	POOLED	2019-2020	2020-2021	POOLED	2019-2020	2020-2021	POOLED
T1	AMMFA TH-1@2.5ml/l	1.19** (1.14)	1.19 (1.14)	1.19 (1.14)	1.19 (1.14)	2.38 (1.58)	1.79 (1.36)	2.38 (1.58)	5.95 (2.52)	4.17 (2.05)
T2	AMMFA TH-1@3.75ml/l	0.00 (0.71)	1.19 (1.14)	0.60 (0.93)	1.19 (1.14)	1.19 (1.14)	1.19 (1.14)	1.19 (1.14)	2.38 (1.58)	1.79 (1.36)
T3	*AMMFA TH-1*@5ml/l	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	1.19 (1.14)	0.60 (0.93)	1.19 (1.14)	2.38 (1.58)	1.79 (1.36)
T4	AMMFA TH-1@6.25ml/t	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	1.19 (1.14)	0.60 (0.93)	0.00 (0.71)	1.19 (1.14)	0.60 (0.930
T5	AMMFA TH-1@10ml/l	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	1.19 (1.14)	0.60 (0.93)
T6	*Trichoderma harzianum-native* @10ml/l	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	1.19 (1.14)	1.19 (1.14)	1.19 (1.14)	1.19 (1.14)	1.19 (1.14)	1.19 (1.14)
T7	Chemicaltreatment (Bavistin)@1g/l	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	1.19 (1.14)	0.60 (0.93)
T8	Control	1.19 (1.14)	2.38 (1.58)	1.79 (1.36)	2.38 (1.58)	4.76 (2.27)	3.57 (1.92)	3.57 (1.83)	5.95 (2.52)	4.76 (2.17)
S.E(d)±		0.32	0.40	0.25	0.46	0.52	0.35	0.56	0.58	0.41
C.D.(5%)		NS	NS	NS	NS	NS	NS	NS	NS	NS

**Figure in the parenthesis is angular transformed value

1@10ml/l treated plot (531.47 q/ha) and lowest in control plot (360.53q/ha).

It is evident from the results that treatment with *Trichoderma harzianum* gave complete control of *Fusarium oxysporum* on 30 and 120 days old tomato plants. Debbarma (2015) also conducted field experiment by using two *Trichoderma* spp. viz., *Trichoderma harzianum* and *Trichoderma viride* against *F. oxysporum* f.sp. *pisi* and showed significant reduction in disease incidence. Similar findings were recorded by Kapoor *et al*. (2012) who reported that *T. viride* and *P. fluorescens* resulted in maximum reduction of seed rot, root rot and wilt (*Fusarium oxysporum*) of pea. *Trichoderma* strains exert biocontrol against *F. oxysporum* directly by mechanisms such as hyperparasitism, mycoparasitism or indirectly by competing for nutrients and space, modifying the environmental conditions, or promoting plant growth. *Trichoderma* spp. are known to produce a number of antibiotics such as Trichodermin, Trichodermol, Hsrzianum A, Harzianolide. Ramezani (2010) also reported the mycoparasitism and inhibitory effects of five *Trichoderma* species on the growth of the causal agent of tomato Fusarium wilt.Vinale *et al.* (2008) reported that the antagonistic nature of Trichoderma spp. was due to release of various enzymes which can degrade cell wall and secondary metabolites of host fungus. Pant and Mukhopadhayay (2001) also reported that biocontrol agents like *T. harzianum* and *T. virens* antagonize pathogens by antibiosis, mycoparasitism or other form of direct exploitation. Carbendazim and Benomyl against two isolates each of *Fusarium oxysporum* and *Alternaria solani* obtained from tomato using poison food technique , significantly inhihibited the growth of the fungus.

Table. 2: Incidence of Fusarium wilt of tomato during 2019-2020 and 2020-2021(after3^nd^treatment)

Treatments	Details	Disease Incidence (%) 3 DAY			7 DAY			10 DAY			14 DAY		
		2019-2020	2020-2021	POOLED	2019-2020	2020-2021	POOLED	2019-2020	2020-2021	POOLED	2019-2020	2020-2021	POOLED
T1	AMMFA TH-1@2.5ml/l	3.57**(2.02)	9.52 (3.15)	6.55 (2.59)	5.95 (2.52)	9.52 (3.15)	7.74 (2.83)	9.52 (3.15)	13.09 (3.68)	11.31 (3.42)	11.90 (3.51)	13.09 (3.68)	12.50 (3.60)
T2	AMMFA TH-1@3.75ml/l	1.19 (1.14)	4.76 (2.27)	2.98 (1.71)	4.76 (2.27)	7.14 (2.71)	5.95 (2.49)	8.33 (2.96)	10.71 (3.32)	9.52 (3.14)	10.71 (3.35)	10.71 (3.32)	10.71 (3.33)
T3	*AMMFA TH-1*@5ml/l	2.38 (1.58)	3.57 (2.02)	2.98 (1.80)	2.38 (1.58)	4.76 (2.27)	3.57 (1.92)	4.76 (2.27)	5.95 (2.52)	5.36 (2.39)	7.14 (2.71)	5.95 (2.52)	6.55 (2.61)
T4	AMMFA TH-1@6.25ml/t	1.19 (1.14)	2.38 (1.58)	1.79 (1.36)	2.38 (1.58)	3.57 (2.02)	2.98 (1.800	4.76 (2.27)	4.76 (2.27)	4.76 (2.27)	7.14 (2.76)	4.76 (2.27)	5.95 (2.52)
T5	AMMFA TH-1@10ml/l	1.19 (1.14)	2.38 (1.58)	1.79 (1.36)	3.57 (2.02)	3.57 (2.02)	3.57 (2.02)	4.76 (2.27)	4.76 (2.27)	4.76 (2.27)	5.95 (2.52)	4.76 (2.27)	5.36 (2.39)
T6	*Trichoderma harzianum-native*@10ml/l	2.38 (1.39)	4.76 (2.27)	3.57 (1.83)	3.57 (1.83)	4.76 (2.27)	4.17 (2.05)	4.76 (2.27)	5.95 (2.52)	5.36 (2.39)	7.14 (2.71)	7.14 (2.76)	7.14 (2.74)
T7	Chemicaltreatment (Bavistin)@1g/l	2.38 (1.58)	4.76 (2.27)	3.57 (1.92)	2.38 (1.58)	5.95 (2.52)	4.17 (2.05)	4.76 (2.27)	8.33 (2.96)	6.55 (2.61)	5.95 (2.52)	8.33 (2.96)	7.14 (2.74)
T8	Control	4.76 (2.27)	9.52 (3.15)	7.14 (2.71)	7.14 (2.71)	11.90 (3.51)	9.52 (3.11)	9.52 (3.15)	15.47 (3.99)	12.50 (3.57)	13.09 (3.68)	17.85 (4.27)	15.47 (3.97)
S.E(d)±		0.64	0.42	0.38	0.57	0.34	0.33	0.33	0.27	0.21	0.36	0.27	0.22
C.D.(5%)		1.37	0.91	0.82	1.22	0.72	0.71	0.71	0.58	0.46	0.77	0.57	0.48

** Figure in the parenthesis is angular transformed value

The data calculated on cost of cultivation, gross returns, net returns and cost benefit ratio as influenced by AMMFA TH-1(Table 6). The highest cost of cultivation (Rs 150773.22/ha) was observed under T5 and T6, lowest (Rs150734/ha) was found under T8 (control). Out of various treatments, the highest gross return (Rs 531466.67/ha) was obtained under under T5, followed by T7; Chemical treatment (Bavistin)@1g/lt (Rs 491200/ha) and lowest in T8 (Control) (Rs 294660/ha). Among the different treatments, the highest net return (Rs 380693.45/ha) was obtained under under T5 followed by T7; Chemical treatment (Bavistin)@1g/lt (Rs 340452.24/ha) and lowest in T8 (Control) (Rs 143926/ha). The maximum benefit cost ratio (3.52) was obtained under under T5 followed by T7 ; Chemical treatment (Bavistin) @ 1g/lt (3.26) and lowest benefit cost ratio (1.95) was obtained in T8 (Control).

Biocontrol is a promising tool to maintain current level of agriculture production by reducing the release of polluting chemical pesticides to the environment causing health hazards. The native potent *Trichoderma* spp. will provide great antagonist potential for the management of soil borne diseases. The present investigation will give information regarding the potentiality of native *Trichoderma* spp. for the management of Fusarium wilt of tomato.

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DECLARATION

Conflict of interest**.**Authors declare no conflict of interest.

Table. 3: Incidence of Fusarium wilt of tomato during 2019-2020 and 2020-2021(after4th treatment*)*

Treatments	Details	Disease Incidence (%) 3 DAY			7 DAY			10 DAY			14 DAY		
		2020 2019	2020-2021	POOLED	2019-2020	2020-2021	POOLED	2019-2020	2020-2021	POOLED	2019-2020	2020-2021	POOLED
T1	AMMFA TH-1@2.5ml/l	3.57**(2.02)	9.52 (3.15)	6.55 (2.59)	5.95 (2.52)	9.52 (3.15)	7.74 (2.83)	9.52 (3.15)	13.09 (3.68)	11.31 (3.42)	11.90 (3.51)	13.09 (3.68)	12.50 (3.60)
T2	AMMFA TH-1@3.75ml/l	1.19 (1.14)	4.76 (2.27)	2.98 (1.71)	4.76 (2.27)	7.14 (2.71)	5.95 (2.49)	8.33 (2.96)	10.71 (3.32)	9.52 (3.14)	10.71 (3.35)	10.71 (3.32)	10.71 (3.33)
T3	*AMMFA TH-1*@5ml/l	2.38 (1.58)	3.57 (2.02)	2.98 (1.80)	2.38 (1.58)	4.76 (2.27)	3.57 (1.92)	4.76 (2.27)	5.95 (2.52)	5.36 (2.39)	7.14 (2.71)	5.95 (2.52)	6.55 (2.61)
T4	AMMFA TH-1@6.25ml/t	1.19 (1.14)	2.38 (1.58)	1.79 (1.36)	2.38 (1.58)	3.57 (2.02)	2.98 (1.800	4.76 (2.27)	4.76 (2.27)	4.76 (2.27)	7.14 (2.76)	4.76 (2.27)	5.95 (2.52)
T5	AMMFA TH-1@10ml/l	1.19 (1.14)	2.38 (1.58)	1.79 (1.36)	3.57 (2.02)	3.57 (2.02)	3.57 (2.02)	4.76 (2.27)	4.76 (2.27)	4.76 (2.27)	5.95 (2.52)	4.76 (2.27)	5.36 (2.39)
T6	*Trichoderma harzianum-native*@10ml/l	2.38 (1.39)	4.76 (2.27)	3.57 (1.83)	3.57 (1.83)	4.76 (2.27)	4.17 (2.05)	4.76 (2.27)	5.95 (2.52)	5.36 (2.39)	7.14 (2.71)	7.14 (2.76)	7.14 (2.74)
T7	Chemicaltreatment (Bavistin)@1g/l	2.38 (1.58)	4.76 (2.27)	3.57 (1.92)	2.38 (1.58)	5.95 (2.52)	4.17 (2.05)	4.76 (2.27)	8.33 (2.96)	6.55 (2.61)	5.95 (2.52)	8.33 (2.96)	7.14 (2.74)
T8	Control	4.76 (2.27)	9.52 (3.15)	7.14 (2.71)	7.14 (2.71)	11.90 (3.51)	9.52 (3.11)	9.52 (3.15)	15.47 (3.99)	12.50 (3.57)	13.09 (3.68)	17.85 (4.27)	15.47 (3.97)
S.E(d)±		0.64	0.42	0.38	0.57	0.34	0.33	0.33	0.27	0.21	0.36	0.27	0.22
C.D.(5%)		1.37	0.91	0.82	1.22	0.72	0.71	0.71	0.58	0.46	0.77	0.57	0.48

**Figure in the parenthesis is angular transformed value

Table. 4 : Percent Reduction over control (%ROC) of Fusarium wilt of Tomato

Treatments	Details	DiseaseIncidence(%) After 2nd Drenching (PooledData)	After 3rd Drenching (PooledData)	After 4th Drenching (PooledData)	PercentReduction overcontrol(%ROC) After 2nd Drenching (PooledData)	After 3rd Drenching (PooledData)	After 4th Drenching (PooledData)
T1	AMMFA TH-1@2.5ml/l	4.17**(2.05)	12.50 (3.60)	18.45 (4.34)	12.39	19.20	20.51
T2	AMMFA TH-1@3.75ml/l	1.79 (1.36)	10.71 (3.33)	15.47 (3.98)	62.39	30.77	33.35
T3	*AMMFA TH-1*@5ml/l	1.79 (1.36)	6.55 (2.61)	10.12 (3.24)	62.39	57.66	56.40
T4	AMMFA TH-1@6.25ml/t	0.60 (0.930	5.95 (2.52)	11.31 (3.43)	87.39	61.54	51.27
T5	AMMFA TH-1@10ml/l	0.60 (0.93)	5.36 (2.39)	7.74 (2.86)	87.39	65.35	66.65
T6	*Trichoderma harzianum-Local*@10ml/l	1.19 (1.14)	7.14 (2.74)	10.12 (3.25)	75.00	53.85	56.40
T7	Chemicaltreatment (Bavistin)@1g/l	0.60 (0.93)	7.14 (2.74)	8.93 (3.06)	87.39	53.85	61.53
T8	Control	4.76 (2.17)	15.47 (3.97)	23.21 (4.87)	-	-	-

**Figure in the parenthesis is angular transformed value

Table.5: Yield of Tomato on different treatments against Fusarium wilt of tomato during 2019-2020 and 2020-2021

Treatments	Details	Yield(Kg/Plot)			Yield(q/ha)		
		2019-2020	2020-2021	POOLED	2019-2020	2020-2021	POOLED
T1	AMMFA TH -1@2.5ml/l	15.33	14.12	14.73	408.80	376.53	392.80
T2	AMMFA TH -1@3.75ml/l	15.83	15.62	15.73	422.13	416.53	419.47
T3	*AMMFA TH-1*@5ml/l	16.83	15.07	15.95	448.80	401.87	425.33
T4	AMMFA TH-1@6.25ml/t	17.83	14.84	16.34	475.47	395.73	435.73
T5	AMMFA TH -1@10ml/l	20.57	19.30	19.93	548.53	514.67	531.47
T6	*Trichoderma harzianum-native* @10ml/l	16.93	16.49	16.71	451.47	439.73	445.60
T7	Chemicaltreatment (Bavistin)@1g/l	18.77	18.07	18.42	500.53	481.87	491.20
T8	Control	13.90	13.13	13.52	370.67	350.13	360.53
S.E(d)±		1.37	1.04	0.86	-	-	-
C.D.(5%)		2.94	2.22	1.84	-	-	-

Table. 6 : Economics analysis as influence by AMMFA TH-1on tomato (values are mean of two years

Treatment	Yield (t/ha)	Gross return	Total cost of production	Net Return	B:C Ratio
T1	39.28	392800.00	150743.81	242056.20	2.61
T2	41.95	419466.67	150747.73	268718.94	2.78
T3	42.53	425333.33	150753.61	274579.72	2.82
T4	43.57	435733.33	150758.51	284974.82	2.89
T5	53.15	531466.67	150773.22	380693.45	3.52
T6	44.56	445600.00	150773.22	294826.78	2.96
T7	49.12	491200.00	150747.76	340452.24	3.26
T8	29.47	294660.00	150734.00	143926.00	1.95

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