

Original Research Article

<https://doi.org/10.20546/ijcmas.2018.711.235>

## Development of Suitable IDM Approaches for Management of Fusarium Wilt of Tomato [*Fusarium oxysporum* f.sp. *lycopersici* (Sacc.) Snyder and Hansen] under Climate Change

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### ABSTRACT

Integration of different methods for suitable management of Fusarium wilt revealed that the minimum disease severity was found in case of soil application with Mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium* + first foliar application with Benfil (Carbendazim) + second foliar application with Matco (Metalaxyl + Mancozeb), representing the value 6.50% as against 54.65 per cent in case of control. Growth promoting effect of plants has also been noticed due to application of IDM practices. The maximum shoot length and root length was observed in the treatment of soil application with Mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium* + first foliar application with Benfil (Carbendazim) + second foliar application with Matco (Metalaxyl + Mancozeb) representing the values 45.50cm and 37.00cm, respectively at 45 DAT against 29.50cm and 10.15cm in case of control and 23.40cm and 8.50cm in case of control 2. Fresh and dry weights of the shoots were also found maximum in the same treatment, representing the values 66.50gm and 21.50gm, respectively. Similar observations have also been recorded in case of fresh and dry weights of roots with the values 36.50gm and 12.30gm, respectively. Maximum number of branches and flowers/plant were also found in the T<sub>7</sub> treatment where soil application with Mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium* + first foliar application with Benfil (Carbendazim) + Second foliar application with Matco (Metalaxyl + Mancozeb) showing 13.60 branches/plant and 90.60 flowers/plant where in case of control-1 the values are 5.80 and 50.90 and control-2 values are 3.60 and 16.40. The maximum yield with 1.703kg/plant was also obtained from the same treatment.

#### Keywords

Fusarium wilt,  
IDM, Bio agents,  
Bio-fertiliser and  
Fungicides

#### Article Info

##### Accepted:

15 October 2018

##### Available Online:

10 November 2018

### Introduction

Tomato (*Lycopersicon esculentum* Mill.) is considered as one of the most important and remunerative vegetable crops cultivated throughout the world owing to its high nutritive values as well as its antioxidant and

curative properties. It is a major contributor to the fruits and vegetables diet of humans throughout the world (Kapasiya *et al.*, 2015). Tomato is susceptible to several diseases like damping off, early blight, late blight, Fusarium wilt, verticillium wilt, bacterial wilt, tomato mosaic virus etc. Among them,

Fusarium wilt caused by *Fusarium oxysporium* f.sp. *lycopersici* (Sacc.) Snyder and Hansen is an economically important disease of tomato crop worldwide (Beckman, 1987; Hanaa *et al.*, 2011). The disease is responsible to cause severe losses ranges from 3.58-20.63% (Sharma *et al.*, 1985). The pathogen is polyphagous in nature and has wide adaptability under climate changes (Singh, 2014; Gill *et al.*, 2016, Bhupendra *et al.*, 2017). Therefore management of the disease is very difficult and single method is not sufficient for management of the disease. Mukhopadhyay (1987) found an integrated approach of using cultural measures, biological control, chemical control for management of the Disease. Narender and Sharma (2015) found that bio fumigation of affected soil for 30 days with taramira crop residues, application of formulation of *T. viride* after mixing with FYM and inoculation of transplants with culture consortia of indigenous AM fungi resulted in to controlling the Fusarium wilt. An Integrated approach using Carbendazim, *T. viride* along with Neem seed kernel extract resulted in reduction of wilt incidence caused by *Fusarium oxysporum* against cumin (Bhatnagar *et al.*, 2013). Minuto *et al.*, (2000) reported that the combination of soil solarization with reduced dosage of Dazomet and methylbromide controls *Fusarium* and *Verticillium* wilts in tomato. Under field conditions, the combination of *T. harzianum* with soil solarization or with a reduced dose of methyl bromide resulted in significant disease control of Fusarium wilt (Sivan and Chet, 1993). Combination of the biocontrol agent *P. fluorescens* with the mineral element zinc significantly reduced disease severity of Fusarium wilt of tomato (Duffy and Defago, 1997). Considering the above point's in view current research was done to develop integrated disease management strategies against *Fusarium oxysporium* f.sp. *lycopersici* in Tomato.

## Materials and Methods

### Isolations of pathogen

The diseased plant showing typical wilt symptom was used for isolation of the pathogen. The diseased plant's roots were taken and washed thoroughly with tap water and finely with distilled water to remove all dust particles. The diseased part of the root is cut into small pieces by sterilized blade in such a way that each piece had small bits of diseased and healthy parts. The chopped pieces were dipped in mercuric chloride solution (0.1%) for 30 seconds rinsed in sterilized distilled water thrice and dried off with sterilized filter paper. The small pieces were then placed on PDA based media which was previously pour in sterilized Petri plates. The plates were finally sealed with paraffin tape and were incubated at  $25 \pm 1^{\circ}$  C. The Petri plates were observed daily to find out the presence of mycelium around the bits. As soon as mycelia growth is notices around the bits, the pathogen was purified by hyphal tip culture method.

### Collection of Bio – fertilizers

Bio-fertilizers *viz.*, *Rhizobium* and *Azotobacter* were collected from Department of Soil Science and Agriculture Chemistry, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur to conduct the present study. The bio-fertilizers are used to conduct the experiment at Glass house complex of Department of Plant Pathology, C.S. Azad University of Agriculture and Technology, Kanpur during *Kharif* season 2016-18.

### Collection of Bio – agents

Bio - agents *viz.*, *Trichoderma harzianum* and *Trichoderma viride* of  $10^8$  CFU were collected from Department of Plant Pathology, Chandra Shekhar Azad University of Agriculture &

Technology, Kanpur to conduct the present investigation.

### Collection of seedlings

Tomato seedling of variety Azad T-6 was obtained from Vegetable Research Farm, C.S.A. University of Agriculture & Technology, Kanpur to conduct the experiment.

### Seedling treatment

Seedling were placed in each jar containing require concentration of each solution of *T.harzianum*, *Rhizobium* and *Azotobacter* for two hours and are kept in shade before transplanting into the pots.

### Effect of IDM approach on growth parameters and disease severity of fusarium wilt in tomato

The experiments were conducted during 2016-2018 at Glasshouse complex, Department of Plant Pathology, C.S.A. University of Agriculture and Technology, Kanpur. The tomato seedling of variety 'Azad T-6' was used to conduct the experiment.

The details of the treatments were given as follows:-

T<sub>1</sub> = Soil application with mushroom spent @ 3:1 ratio in proportionate to soil + seedling treatment with *T. harzianum* @ 10<sup>7</sup> CFU+ first foliar application with Benfil (Carbendazim 50% WP) @0.1% at 30 DAT+ second foliar application with Matco (Metalaxyl(8%) + Mancozeb(74%).72% WP) @ 0.2% at 45 days after transplanting (DAT).

T<sub>2</sub> = Soil application with mushroom spent @ 3:1 ratio in proportionate to soil + seedling treatment with *Rhizobium* @ 4gm/lit water+ first foliar application with Benfil

(Carbendazim 50% WP) @0.1% at 30 DAT+ second foliar application with Matco (Metalaxyl (8%)+ Mancozeb (74%). 72%WP) @ 0.2% at 45DAT.

T<sub>3</sub> = Soil application with mushroom spent @ 3:1 ratio in proportionate to soil + seedling treatment with *Azotobacter* @ 4gm/lit of water+ first foliar application with Benfil (Carbendazim 50% WP) @0.1% at 30 DAT+ second foliar application with Matco (Metalaxyl (8%) + Mancozeb (74%). 72%WP) @ 0.2% at 45DAT.

T<sub>4</sub> = Soil application with mushroom spent @ 3:1 ratio in proportionate to soil + combined seedling treatment with *T. harzianum* @ 10<sup>3</sup> CFU and *Rhizobium*@ 2gm/lit of water + first foliar application with Benfil (Carbendazim 50% WP) @0.1% at 30 DAT+ second foliar application with Matco (Metalaxyl(8%)+ Mancozeb(74%).72% WP) @ 0.2% at 45DAT.

T<sub>5</sub> =Soil application with mushroom spent @ 3:1 ratio in proportionate to soil + combined seedling treatment with *Rhizobium* @ 2gm/lit water and *Azotobacter*@2gm/lit of water+ first foliar application with Benfil (Carbendazim 50% WP) @0.1% at 30 DAT+ second foliar application with Matco (Metalaxyl(8%)+ Mancozeb(74%).72% WP) @ 0.2% at 45DAT.

T<sub>6</sub> = Soil application with mushroom spent @ 3:1 ratio in proportionate to soil + combined seedling treatment with *T. harzianum* @ 10<sup>3</sup> CFU and *Azotobacter* @ 2gm/lit of water + first foliar application with Benfil (Carbendazim 50% WP) @ 0.1% at 30 DAT+ second foliar application with Matco (Metalaxyl(8%)+ Mancozeb (74%).72% WP) @ 0.2% at 45DAT.

T<sub>7</sub> = Soil application with mushroom spent @ 3:1 ratio in proportionate to soil + combined seedling treatment with *T. harzianum* @ 10<sup>3</sup> CFU and *Azotobacter* @ 2gm/lit of water and

Rhizobium@ 2gm/lit of water + first foliar application with Benfil (Carbendazim 50% WP) @0.1% at 30 DAT+ second foliar application with Matco (Metalaxyl (8%) + Mancozeb (74%). 72%WP) @ 0.2% at 45DAT.

T<sub>8</sub> = Soil application with of mushroom spent @ 250gm/pot.

T<sub>9</sub> = Soil application with mushroom spent @ 250gm/pot + inoculation with pathogen.

At 28 DAT plants were inoculated with spore suspension of *F. o. f sp. lycopersicae* @ 10<sup>6</sup> conidia/ml. Four replications per treatment were kept to conduct the experiment.

Observations pertaining to the effect of different treatments were recorded as per following parameters and days.

Plant height (cm) at 30, 45 and 60 days after transplanting.

Fresh weight of shoot (g) at 45 days after transplanting.

Dry weight of shoot (g) at 45 days after transplanting.

Root length (cm) and morphology at 45 days after transplanting

Fresh weight of root (g) at 45 days after transplanting

Dry root weight (g) at 45 days after transplanting.

Average number of branches per plant at 45 days

Disease severity (%) at 45 days after transplanting

Fruiting parameters and yield of crop (g)

## **Growth parameters**

### **Shoot length**

Tomato seedlings were transplanted in earthen pots in the glasshouse and shoot length was measured 30, 45 and 60 days age of tomato plants with the help of scale.

### **Root length**

The root length tomato was measure at 45 days age of plant. Prior to measure the root lengths of tomato plants, pots were irrigated and the seedlings were up rooted carefully, roots of seedlings were separated from the shoots and washed with water to remove soil particles and then root length (cm) were measured with the help of scale.

### **Fresh weight**

Forty five days after transplanting, the shoots and roots of tomato plant were weighted on an electronic balance and the data was recorded as gm.

### **Dry weight**

The fresh plant sample of 45 days age of plants is being collected and then shoots and roots were dried in an oven at 70<sup>0</sup>C until constant weight.

It was then weighted on an electronic balance and the data was recorded as gm.

### **Measurement of disease severity**

The disease severity was monitored visually after inoculation with pathogen. The disease severity was recorded using 0-4 scale (Weitang *et al.*, 2004) where zero representing no infection and four denoting plants completely infected. The 0-4 scale of the disease Incidence was classified as follows:-

No infection

Slight infection which is about 25% of full scale, one or two leaves become yellow.

Moderate infection, two or three leaves become yellow, 50% of leaves become wilted

Extensive infection, all plant leaves become yellow, 75% of leaves become wilted, and the plants die.

Complete infection, the whole plant leaves become yellow, 100% of leaves become wilted and the plants die.

The percentage of disease incidence was determined using the formula:-

$$\text{Disease incidence (\%)} = \frac{(\sum \text{Scale} \times \text{number of plants infected})}{(\text{highest scale} \times \text{Total number of Plants})} \times 100$$

### Yield/plant

The edible fruits were harvested twice a week from each selected plant and weighted with the help of physical balance and graded as per weight.

The total weight of all picking was recorded after adding weight of fruits at each picking and represented as gm.

### Results and Discussion

Seven various effective management components using seedling treatments (*T. harzianum*, *Azotobacter* and *Rhizobium*), soil treatments (Mushroom spent) and Foliar applications (Carbendazim 50% WP, (Metalaxyl(8%)+ Mancozeb(74%). 72% WP) were used to suppress the population of wilt causing pathogen (*Fusarium oxysporium* f.sp. *lycopersici*) in tomato and their effects on shoot length (cm), root length (cm), fresh and

dry weight of shoot (gm), fresh and dry weight of root (gm), disease severity (%), flowering, branching and yield of tomato.

### Effect of different IDM practices on growth parameters and disease severity of Fusarium wilt of tomato

#### Shoot length

The data presented in the Table 1, showed that all the treatments were able to significantly increase the shoot length over both the controls at 30, 45, 60 days after transplanting. Among the various IDM practices, the maximum shoot length was recorded in the treatment T<sub>7</sub> (Soil application with mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium* + two foliar sprays with Benfil (Carbendazim) and Matco (Metalaxy+ Mancozeb) representing 28.90, 45.50 and 57.90cm at 30, 45 and 60 days after transplanting, followed by T<sub>6</sub> treatment (Soil application with mushroom spent + combined seedling treatment with *T. harzianum* and *Azotobacter* + two foliar spray with Carbendazim and Metalaxy+ Mancozeb) showing 26.50, 42.10 and 54.70cm against control-1 (healthy) representing as 17.50, 29.50, 36.40cm and control-2 (diseased) as 14.30, 23.40 and 30.20cm at 30, 45 and 60 days after transplanting.

Ravindra *et al.*, (2015) also found that seed treatment with *T. harzianum* + soil application of neem cake powder + foliar spray of carbendazim significantly increased shoot and root lengths of tomato. Yogesh *et al.*, (2015) also reported that among the different integrated approaches, soil application of FYM + seedling treatment with bio-formulation of *Trichoderma harzianum*+ foliar spray of mancozeb reduced the disease severity of early blight of tomato and increased the growth parameters and branching pattern of plant.



### Fresh and dry weight of Shoot

Fresh and dry shoots were weighted on an electronic balance and the data presented in the Table 1, showed that all the treatments were able to increase the fresh and dry weights of shoots over control-1 and control-2. The maximum fresh and dry weight of shoots was recorded in T<sub>7</sub> treatment where treatment was given as soil application with mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium* + two foliar sprays with Benfil (Carbendazim) and Matco (Metalaxy+ Mancozeb) representing 66.50gm and 21.50 gm respectively, at 45 days after transplanting, which is increased by 92.75 & 146.30 and 91.96 & 123.70 per cent over control-1 (Healthy) and control-2 (Diseased plant), respectively. The T<sub>6</sub> treatment (Soil application with mushroom spent + combined seedling treatment with *T. harzianum* and *Azotobacter* + foliar spray with Benfil (Carbendazim) and with Matco (Metalaxy+ Mancozeb) showing the values 63.15gm and 19.00gm at 45 days after transplanting representing second highest among the treatments.

Among the all combinations, the minimum fresh and dry weight was recorded in T<sub>2</sub> (Soil application with mushroom spent +seedling treatment with *Rhizobium* + two foliar spray with Benfil (Carbendazim) and with Matco (Metalaxy+ Mancozeb) treatment, representing 48.60 and 12.70gm which are also superior as 40.865 and 13.40 and 80.00 and 32.3 per cent increased over control-1 and control-2. Tippannaves *et al.*, (2005) had observed that the *Azotobacter* significantly increase the tillering, drymatter accumulation and growth parameter. Ravindra *et al.*, (2015) found that the fresh and dry weight of shoot in tomato crop significantly increased by the combine application of seed treatment with *T. harzianum* + soil application of neem cake powder + foliar spray of Carbendazim.

### Root length

Forty five days after transplanting, the tomato plant was uprooted and the root length was measured by using scale. It is evident from the data showed that the maximum root length was recorded in the treatment T<sub>7</sub> where the treatment was given as soil application with mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium*+ two foliar sprays with Benfil (Carbendazim) and Matco (Metalaxy+ Mancozeb) representing 37.00 cm against 10.15 and 8.5cm in case of control-1 and control-2, respectively at 45 days after transplanting (Table 2) which was followed by the T<sub>6</sub> treatment (Soil application with mushroom spent + combined seedling treatment with *T. harzianum* and *Azotobacter* + two foliar sprays with Benfil (Carbendazim) and Matco (Metalaxy+ Mancozeb), representing 29.00cm at 45 days after transplanting. The morphology of the roots was also found variable among different treatments. Among the various combinations, robust spreading root system was found maximum in T<sub>7</sub> treatment. From the table, it is cleared that all the treatments are able to increase the root length over control which are also statistically significant to each other. Kishan *et al.*, (2015) found that integrated approaches changes the morphology of root.

The well-developed robust root system is found in combine treatment withsoil application of FYM @100gm/pot+ Neem cake@ 100gm/pot + seedling treatment with bio-formulation of *Azotobacter* @5% +foliar spray of Carbendazim @0.1%) whereas, in case of control, poorly developed, less branching and less fibrous root system are found. Gopinathan and Prakesh (2014) found that vermicompost enriched with bio-fertilizer increased plant height, root length, number of branches, number of leaves and the productivity of tomato.

**Table.1** Effect of different IDM practices on Shoot length at different days after transplanting and disease severity of *Fusarium* wilt of tomato

S. No.	Treatment	Shoot length			Fresh weight of shoot (gm)	% increase of fresh weight over control -1	% increase of fresh weight over control-2	Dry weight of shoot (gm)	% increase of dry weight of shoot over control 1	% increase of dry weight of shoot over control -2	Disease severity (%) 45 DAT
		30 DAT	45 DAT	60 DAT							
1.	T <sub>1</sub> - SA with MS + ST with <i>T. harzianum</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	22.00	37.60	47.60	57.30	66.08	112.20	15.30	36.60	59.40	14.55
2.	T <sub>2</sub> - SA with MS + ST with <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb.	19.60	34.30	43.50	48.60	40.86	80.00	12.70	13.40	32.30	19.20
3.	T <sub>3</sub> - SA with MS + ST with <i>Azotobacter</i> + 1 <sup>st</sup> FA with Carbendazim+ 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	20.40	32.40	44.80	52.40	51.88	94.10	13.60	21.42	41.70	17.30
4.	T <sub>4</sub> - SA with MS + ST with <i>T. harzianum</i> + <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	25.20	40.80	53.10	61.80	79.13	128.80	17.50	56.25	82.30	9.40
5.	T <sub>5</sub> -SA with MS + ST with <i>Rhizobium</i> and <i>Azotobacter</i> +1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	23.70	39.20	50.30	60.10	74.20	122.60	16.30	45.53	69.80	11.70
6.	T <sub>6</sub> - SA with MS+ ST with <i>T. harzianum</i> and <i>Azotobacter</i> + 1 <sup>st</sup> FA with Carbendazimand2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	26.50	42.10	54.70	63.15	83.04	133.90	19.00	69.64	97.90	7.25
7.	T <sub>7</sub> -SA with MS+ ST with <i>T. harzianum</i> , <i>Azotobacter</i> and <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	28.90	45.50	57.90	66.50	92.75	146.30	21.50	91.96	123.90	6.50
8.	T <sub>8</sub> Control(Healthy)- Soil application with of MS	17.50	29.50	36.40	34.50		27.70	11.20		16.70	0
9.	T <sub>9</sub> Control(diseased)- Soil application with of MS+inoculation with pathogen	14.30	23.40	30.20	27.00	-21.73		9.60	-14.28		54.65
10.	C.D.	1.294	1.164	1.164	1.450			1.422			1.199
11.	SE(m)	0.432	0.389	0.389	0.484			0.475			0.401
12.	SE(d)	0.611	0.550	0.550	0.685			0.672			0.567
13.	C.V.	3.400	1.866	1.448	1.601			5.416			4.443

SA = Soil Application, MS = Mushroom Spent, ST = Seedling Treatment, FA = Foliar Application.

**Table.2** Effect of different IDM practices on growth characteristics of roots of tomato at 45 days after transplanting

S. No.	Treatment	Root length (cm)	% increase of root length over control-1	% increase of root length over control-2	Fresh weight of root (gm)	% increase of fresh weight of root over control-1	%increase of fresh weight of root over control- 2	Dry weight of root (gm)	% increase of dry weight of root over control-1	% increase of dry weight of root over control-2
1.	T <sub>1</sub> -SA with MS + ST with <i>T. harzianum</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	23.20	128.50	172.90	26.50	55.90	89.30	7.85	86.90	101.20
2.	T <sub>2</sub> -SA with MS + ST with <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb.	20.50	101.90	141.20	23.00	35.30	64.30	5.70	35.70	46.10
3.	T <sub>3</sub> -SA with MS + ST with <i>Azotobacter</i> + 1 <sup>st</sup> FA with Carbendazim+ 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	22.00	116.70	158.80	24.50	44.20	75.00	6.55	55.90	67.90
4.	T <sub>4</sub> -SA with MS + ST with <i>T. harzianum</i> + <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	27.00	166.00	217.60	29.00	70.60	107.10	9.95	136.90	155.10
5.	T <sub>5</sub> -SA with MS + ST with <i>Rhizobium</i> and <i>Azotobacter</i> +1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	25.5	151.20	200.00	27.50	61.80	96.40	8.35	98.80	114.10
6.	T <sub>6</sub> -SA with MS+ ST with <i>T. harzianum</i> and <i>Azotobacter</i> + 1 <sup>st</sup> FA with Carbendazimand2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	29.00	185.70	241.20	33.00	94.10	135.70	10.25	144.00	162.80
7.	T <sub>7</sub> -SA with MS+ ST with <i>T. harzianum</i> , <i>Azotobacter</i> and <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	37.00	264.50	335.20	36.50	114.70	160.70	12.30	192.80	215.30
8.	T <sub>8</sub> - Control-1(Healthy)-Soil application with of MS	10.15		19.41	17.00		21.40	4.20		7.70
9.	T <sub>9</sub> -Control-2(diseased)-Soil application with of MS+inoculation with pathogen	8.50	-16.25		14.00	-17.64		3.90	-7.10	
10.	C.D.	1.934			2.445			1.006		
11.	SE(m)	0.646			0.816			0.336		
12.	SE(d)	0.914			1.155			0.475		
13.	C.V.	4.956			5.510			7.581		

SA = Soil Application, MS = Mushroom Spent, ST = Seedling Treatment, FA = Foliar Application.



**Table.3** Effect of various IDM practices on yield attributing characters and yield of tomato

S. No.	Treatment	No of branches	No of flowers /plant	No of fruits/plant			Wt of fruits			Total yield( gm)
				<25gm	25-50gm	>50gm	<25gm	25-50gm	>50gm	
1.	T <sub>1</sub> - SA with MS + ST with <i>T. harzianum</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	8.00	71.30	5	12	12	95	468	612	1175
2.	T <sub>2</sub> - SA with MS + ST with <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb.	6.20	64.50	7	10	8	147	360	424	931
3.	T <sub>3</sub> - SA with MS + ST with <i>Azotobacter</i> + 1 <sup>st</sup> FA with Carbendazim+ 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	7.40	68.20	6	13	9	102	442	486	1030
4.	T <sub>4</sub> - SA with MS + ST with <i>T. harzianum</i> + <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	10.30	77.50	6	14	14	114	518	742	1374
5.	T <sub>5</sub> -SA with MS + ST with <i>Rhizobium</i> and <i>Azotobacter</i> +1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	9.60	73.80	7	15	12	133	554	624	1311
6.	T <sub>6</sub> - SA with MS+ ST with <i>T. harzianum</i> and <i>Azotobacter</i> + 1 <sup>st</sup> FA with Carbendazimand2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	12.40	82.00	6	17	15	108	629	810	1547
7.	T <sub>7</sub> -SA with MS+ ST with <i>T. harzianum</i> , <i>Azotobacter</i> and <i>Rhizobium</i> + 1 <sup>st</sup> FA with Carbendazim + 2 <sup>nd</sup> FA with Metalaxy+ Mancozeb	13.60	90.60	8	16	18	144	592	972	1703
8.	T <sub>8</sub> Control(Healthy)- Soil application with of MS	5.80	50.90	9	7	5	198	252	280	730
9.	T <sub>9</sub> Control(diseased)- Soil application with of MS+inoculation with pathogen	3.60	16.40	4	2	1	86	37	51	174
10.	C.D.	1.309	2.309							0.069
11.	SE(m)	0.437	0.771							0.023
12.	SE(d)	0.618	1.090							0.033
13.	C.V.	8.862	2.019							3.611

SA = Soil Application, MS = Mushroom Spent, ST = Seedling Treatment, FA = Foliar Application.

### **Fresh and dry weight of root**

Fresh and dry roots were weighted on an electronic balance and the data presented in the Table 2, showed that all the treatments were able to increase the fresh and dry weights of roots over control-1 and control-2. The maximum fresh and dryweight of root was recorded in T<sub>7</sub> treatment (Soil application with mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium*+ two foliar sprays with Benfil (Carbendazim) and Matco (Metalaxy+ Mancozeb) representing 36.50 and 12.30gm at 45 days after transplanting which is increased 114.7 and 192.80 per cent over control-1 and 160.70 and 215.00 per cent over control-2. Similar observations have also been reported by several workers (Yogesh *et al.*, 2015, Singh *et. al.* 2016, Ravindra, *et al.*, 2015)

### **Disease Severity**

Disease is major constraints of increase production and productivity of any crops. In contrast, adoption of suitable management practices is more important to reduce disease severity and to get maximum profit. In the present study also, among the various IDM packages maximum reduction of disease severity was found in treatment T<sub>7</sub> where treatments were given as soil application with mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium*+ two foliar sprays with Benfil (Carbendazim) and Matco (Metalaxy + Mancozeb) representing only 6.50% disease severity against 54.65% in case of control. Effectiveness of mushroom composts use as soil amendments in controlling the disease could possibly be due to enhanced activity of other non-parasitic microbes (fungi/bacteria) providing antagonism to the tomato wilt pathogen and/or decomposition products of composts being non- favourable for the

multiplication of the inoculum. Christopher *et al.*, (2010) has been found that seed plus soil application of *T. harzianum* along with organic amendments reduced wilt incidence and increased the fruit yield of tomato. Biological control integrated with fungicidal treatment has also been found more reliable approach to manage soil borne plant pathogen was reported by Mukhopadhyay (1987). Ganie *et al.*, (2013) observed that the application of bio-agents *viz.*, *T.viridae* and *Azotobacter* is effective in reducing disease severity of Fusarium wilt in tomato caused by *F. o. f.sp. lycopersici*.

### **Effect of IDM practices on yield attributing characters and yield of tomato**

Yield attributing characters like number of branches, flowers and fruit yield have been gradually increased in the treated plants (Table 3) where the maximum number of branches and flowers were produced in treatment T<sub>7</sub> with 13.60 branches/plant and 90.60 flowers/plant, respectively followed by treatment T<sub>6</sub> with 12.04 branches/plant and 82 flowers /plant. The matured fruits were harvested and were graded according to the weight *viz.*, (<25gm, 25-50gm and >50gm) using physical balance. It was found that the maximum number of large size fruits with 18 was obtained from T<sub>7</sub> Treatment(Soil application with mushroom spent + combined seedling treatment with *T. harzianum*, *Azotobacter* and *Rhizobium* + two foliar sprays with Benfil (Carbendazim) which is also representing highest yield as 1.703 kg per plant which was followed by T<sub>6</sub> treatment (Soil application with mushroom spent + combined seedling treatment with *T. harzianum* and *Azotobacter* + two foliar spray with Benfil (Carbendazim) and Matco (Metalaxy + Mancozeb) as 15 large size fruits and total yield 1.547kg per plant. In case of control-1 and control-2, the number of large size fruits are 5 and 1, respectively and their

yield as 730 and 174 gm per plant. The maximum number of small size and medium size fruits was obtained from T<sub>8</sub> and T<sub>6</sub> treatments, respectively. From the Table 3 it is also cleared that the increase number of fruiting ability are found in T<sub>7</sub> treatment which is 42 against 7 in case of control-2. The reduction in wilt incidence mediated through bio agents in combination with organic amendments, was found to have direct effect on improving yield attributing characters (number of branches, flowers, plant height etc.) leading to increase in yield reported by Pandey *et al.*, (2005). Jayaraj and Ramabadrana (1999) also reported that increase in the yield and total biomass was due to occasional synergism of *Rhizobium* + *Trichoderma* in black gram. Ravindra (2015) found that the yield of tomato crop significantly increased by the combine application of seed treatment with *T. harzianum* + soil application of neem cake powder + foliar spray of carbendazim.

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#### How to cite this article:

Vallabhaneni Tilak Chowdary, S.K. Biswas, Deepak Baboo and Sumit Kumar. 2018. Development of Suitable IDM Approaches for Management of Fusarium Wilt of Tomato [*Fusarium oxysporum* f.sp. *lycopersici* (Sacc.) Snyder and Hansen] under Climate Change. *Int.J.Curr.Microbiol.App.Sci.* 7(11): 2090-2101. doi: <https://doi.org/10.20546/ijcmas.2018.711.235>