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Effect of IDM practices on germination, growth parameters, yield and severity of late blight of potato caused by *Phytophthora infestans* (Mont.) de Bary

Anuj Bansal, SK Biswas and Saurabh Kumar

Abstract

The IDM practices have ability to increase tuber germination and growth parameters, yield of potato and reduced severity of late blight of potato. The highest germination percentage was recorded from soil application of FYM + Poultry manure and Tuber treatment with *T. harzianum* during both the years. IDM approaches have ability to increases growth parameters and increase yield per plant in potato. The maximum plant height with 15.65, and 54.25 cm in 2016-17 and 15.75, and 55.00 cm in 2017-18 at 30, and 60 days' age of seedling was found in T₉ treatment (Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum* + two foliar spray with Equation Pro). Similarly, total yield as 449.40 and 417.30 gm per plant was also obtained from T₉ (Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum*+ three foliar spray with Equation Pro) treated plant as against 218.78 gm and 211.68 gm in case of control in year 2016-17 and 2017-18 respectively. As per concerned of disease severity of late blight, the minimum with 9.05% and 14.92% during 2016-17 and 9.65 and 15.10% during 2017-18 were recorded in T₉ (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro) treated plant as against 61.35 and 82.55 and 62.00 & 82.95% at 75 and 90 days after sowing respectively in case of control.

Keywords: Potato, late blight, IDM practices, fungicides and disease severity

Introduction

Potato (*Solanum tuberosum* L.) belongs to the family Solanaceae, considered as "King of vegetables". It is an important tuberous crop cultivated for vegetable, food and several other processed products. The worldwide production of potatoes was about 324 million tons during 2010. (F.A.O 2011). The five major potato producing country in the world are China (96.01 MT), India (45.9 MT), Russia (30.9 MT), Ukraine (23.0 MT) and USA (19.9 MT) during 2013-14 (FAOSTAT 2016). India produced about 453.44 lakh tons of potato from 1922.2 ha. of land which is 21.6 percent of total area under vegetables. Uttar Pradesh ranked first in potato production in India but at per concerned on productivity, the state is far behind those other countries like Europe and America. The main reasons of low productivity are diseases like, early blight, late blight, leaf spot, dry rot, charcoal rot, black scurf, common scab, soft rot, leaf roll etc. Among them, late blight caused by *Phytophthora infestans* (Mont.) de Bary is most destructive disease that had led to most un-famous catastrophe in Ireland (England) during 1840-1845. The management of the disease can be done through host resistance, cultural, biological and use of fungicides. There is no doubt that use of fungicides is the best strategy for management of the disease. But indiscriminate use of synthetic pesticides, plant pathogens are gaining resistance against them and also creating environmental and toxicological problems to our ecosystem. In this context, IDM practices have been taken in great concerned for management of plant diseases to minimize the use of synthetic chemicals. Binyam *et al.*, (2014) [2] cost effective management of late blight was obtained by integrating potato varieties with the lowest rate of Ridomil application. Morajdhawaj *et al.*, (2016) also found that IDM practices as soil application of mustard cake + tuber treatment and foliar spray with *T. viride* was found best in stimulating germination, increase plant height and also to decline late blight severity at different days after sowing under climate change. Sumit *et al.*, (2018) also found that severity of late blight of potato can reduced by IDM practices as Soil application of FYM @ 125gm/pot + waste of mushroom cultivation with *Trichoderma harzianum* @ 5gm/kg + tuber treatment with *Azotobacter* @ 5% + foliar spray with Ridomil @ 0.25%).

Keeping the above point in view, the study was undertaken as “Effect of IDM practices on germination, growth parameters, yield and severity of late blight of potato caused by *Phytophthora infestans* (Mont.) de Bary” in the present investigations.

Materials and Methods

Collection of seed tuber

Truly labelled potato seed tubers of variety "Kufri Bahar" were obtained from Central Potato Research Institute, Campus Meerut to conduct the experiment.

$$\text{Amount of fungicide formulation} = \frac{\text{Concentration required (\%)} \times \text{volume required in litre}}{\text{Concentration of toxicant in fungicidal formulation}}$$

Tuber seed treatment

The seed tubers were treated with bio- formulation of *T. harzianum* @ 5 gm/kg of tuber. The seed tubers were treated by dipping the tuber in prepared solution separately. The treatments were given 4 hours before the sowing of tuber.

Foliar spray with fungicides

At 70 days, plants inoculated with spore suspension of *P. infestans* and after 48 hrs. plants were sprayed with fungicide like Equation Pro and Curzate. Three spray schedules were given at 15 days interval.

Effect of integrated approaches on seed tuber germination, plant height, disease severity and tuber yield

The experiment was conducted at the wire house complex, Department of Plant Pathology, C.S.A. University of Agriculture and Technology, Kanpur. The seed tubers of potato variety 'KufriBahar' were treated with bio formulations of *T. harzianum* and sown in 45cm earthen pots, which were previously filled with a sterilized sandy loam soil. In each pot, one seed tubers were sown and watered regularly. Three replications per treatment and three pots were sown with untreated seed tubers served as control. The treatment details were given as follows:

- T₁ = Soil application with FYM + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Equation Pro.
 T₂ = Soil application with FYM + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Curzate.
 T₃= Soil application with Mushroom compost + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Equation Pro.
 T₄ = Soil application with Mushroom compost + Tuber

Collection of bio-agents

All these bio-agents were collected from Department of Plant Pathology, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur to conduct the present study. The experiment was conducted in the wire house complex of Department of Plant Pathology, C.S. Azad University of Agriculture and Technology, Kanpur during Rabi season 2016-17 and 2017-18.

Solution preparation of fungicide

The fungicide spray were prepared by the following formula

treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Curzate.

T₅= Soil application with Poultry manure + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Equation Pro.

T₆ = Soil application with Poultry manure + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Curzate.

T₇= Soil application of FYM + Mushroom compost + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Equation Pro.

T₈= Soil application of FYM + Mushroom compost + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Curzate.

T₉= Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Equation Pro.

T₁₀= Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Curzate.

T₁₁= Soil application of FYM + Mushroom compost + Poultry manure + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Equation Pro.

T₁₂= Soil application of FYM + Mushroom compost + Poultry manure + Tuber treatment with *T. harzianum*@ 5g/kg of tuber + three foliar spray with Curzate.

T₁₃= Soil application of FYM (Control).

Germination percentage

Seed tuber treated with different bio formulations was responsible for early breaking of seed tuber. The observation on germination of tuber was taken at every 24 hours up to 15 days. Germination percentage was calculated by use of following formula:

$$\text{Germination \%} = \frac{\text{Number of germinated seed tubers}}{\text{Number of total seeds}} \times 100$$

Plant height

For this purpose, three plants were selected randomly from tagged plots. The shoot height was measured (in cm) from the soil surface at basal portion of flag leaf with the help of meter scale. The average of three plants height was divided by 3 for obtaining their mean to consider plant height. The height of the plant was measure of 30 and 60 days' age of plant.

Disease severity

Inoculation with *Phytophthora infestans*

At 70 days' age, plants were inoculated with spore suspension

of pathogen. The concentration of sporangia was maintained at 10⁶ sporangia/ml. The spore suspension was prepared from seven days old culture of the pathogen. The homogenized, spore suspension were inoculated on the foliage of each plant. The plants were then covered with polythene bags for 48hrs to provide suitable moisture and humidity for growth and development of the pathogen.

Measurement of disease severity

Observations for measuring the disease severity were taken after 5 days of pathogen inoculation. The disease severity was

recorded on a 0 - 9 scale. Fifty leaves randomly selected from the pot were taken for measurement of disease severity. The leaves with 1 – 9% infection received 1, 10% infection received 2, 11 – 25% infection received 3, 26 – 40% infection received 4, 41 – 60% infection received 5, 61 – 70% infection

received 6, 71 – 80% infection received 7, 81- 90% infection received 8, 91 – 100% infection received 9 (Malcolimson, 1976) [12].

The disease severity of individual plants was calculated by following formula.

$$\text{Disease severity PDI} = \frac{\text{Sum of numerical rating}}{\text{Total number of leaves examined} \times \text{maximum rating}} \times 100$$

Result and Discussion

Preliminary research works based on effectivity of fungicides viz. Equation Pro, Curzate and bio agents. *T. harzianum* have been incorporated in the IDM practices. The observations were taken on germination, growth parameters and disease severity in potato were undertaken.

Germination (%)

As the seedling began to emerge from the soil, germination percentage was calculated by recording the number of emerged seedlings from number of potato tuber sown. The result presented in table-1 showed that the T9 (Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro., T10 (Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate and T12 (Soil application of FYM + Mushroom compost + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate are good in germination of potato tuber, representing 100% germination against 60% in case of control during 2016-17 whereas, during 2017-18, Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum*

+ three foliar spray with Equation Pro. and Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate are good in germination of potato tuber, representing 100% germination against 65% in case of control. Kumar *et al.*, (2001) investigated on strains of *A. chroococum* and their mutants performed better in all the varieties to increase germination and yield of potato over control. Azarmi *et al.*, (2011) reported that the seed germination rate was affected by *Trichoderma* application and shoot height and shoot diameter, fresh and dry weight of shoot in tomato seedlings were increased significantly. They also found that soil amended by *Trichoderma* sp. had marked increase in leaf number and area of leaf. Chandani *et al.*, (2009) [4] found that the combined inoculation of Arbuscular mycorrhizal fungi with *Trichoderma* synergistically increased dry shoot mass when compared with inoculation of *Trichoderma* and Arbuscular mycorrhizal fungi alone. Sumit *et al.*, (2018) reported that the treatment (Soil application of FYM @ 125gm/pot + waste of mushroom cultivation with *Trichoderma harzianum* @ 5gm/kg + tuber treatment with *Azotobacter*@ 5% + foliar spray with Ridomil @ 0.25%) also exhibited increased tuber germination per cent.

Table 1: Effect of IDM approaches on germination and plant height of potato at different days of interval (Wire house condition) during 2016-17

Treatments	Germination (%)	Effect of IDM on plant height of potato at different days (cm)				30 DAS	60 DAS	Per cent Increase of plant height over control at 60 days
		30 DAS	60 DAS	Per cent Increase of plant height over control at 60 days	Germination (%)			
T ₁ = SA with FYM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	80	13.15	45.20	35.33	85	13.30	45.70	34.02
T ₂ = SA with FYM + TTwith <i>T. harzianum</i> + 3 FS with Curzate	75	12.95	44.15	35.18	80	13.00	44.85	31.52
T ₃ = SA with MC + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	70	12.05	38.85	16.32	75	11.95	38.30	12.32
T ₄ = SA with MC + TT with <i>T. harzianum</i> + 3 FS with Curzate.	80	11.75	37.45	12.13	70	12.00	37.95	11.29
T ₅ = SA with PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	90	13.80	48.35	44.76	85	13.10	47.70	39.88
T ₆ = SA with PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	90	13.45	46.75	39.97	90	13.60	47.00	37.83
T ₇ = SA of FYM + MC + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	85	12.50	42.90	28.44	80	13.05	43.40	27.27
T ₈ = SA of FYM + MC + TT with <i>T. harzianum</i> + 3 FS with Curzate	70	12.25	40.30	20.66	75	12.45	40.95	20.09
T ₉ = SA of FYM + PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	100	15.65	54.25	62.43	100	15.75	55.00	61.29
T ₁₀ = SA of FYM + PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	100	14.90	53.15	59.13	100	15.00	53.75	57.62
T ₁₁ = SA of FYM + MC + PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	90	14.35	51.85	55.24	90	14.50	52.20	53.08
T ₁₂ = SA of FYM + MC + PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	100	14.05	50.50	51.20	95	14.15	51.00	49.56
T ₁₃ = Soil application of FYM (Control)	60	10.12	33.40	-	65	10.90	34.10	
S.Em±	1.291	0.173	0.597	-	1.278	0.192	0.531	
CD at 5%	3.775	0.505	1.744	-	3.737	0.560	1.553	

Notes: SA= Soil application, TT= Tuber Treatments, FS= Foliar spray, MC= Mushroom compost, PM= Poultry manure

Growth parameter

Enhancement of plant growth is an important parameter of higher crop yield. The data presented table-1 showed that the plant height of potato was increase in all the treatments over control. The maximum plant height was found in T₉ treatment (Soil application of FYM + Poultry manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro), representing the value, 15.65, and 54.25 cm at 30, and 60 days' age of seedling, respectively against 10.12, and 33.40

cm in case of control during 2016-17 and 15.75, and 55.00 cm at 30, and 60 days' age of seedling, respectively against 10.90 and 34.10 cm in case of control during 2017-18 from the same treatment. (Table-2). Singh *et al.*, (2015) [15] reported that the seed treatment with *T. harzianum* + soil application of neem cake powder + foliar spray of carbendazim, increased shoot length fresh and dry weight of shoot and root in tomato. As per yield is concerned, it has found that the maximum yield was obtained per plant from the treatment given as seed

treatment with *T. harzianum* + soil treatment with neem cake powder + foliar spray with carbendazim, showing the value of 500 g per plant which was followed by the treatment given as seed treatment with *T. harzianum* + soil treatment with neem cake powder + foliar spray with neem leaf extract showing 470 g per plant. Similar finding was reported by Morajdhawaj *et al.*, (2017). Lal *et al.*, (2017)^[11] was recorded in treatment when *Bacillus subtilis* (BS-0.25%) + *Trichoderma viride* (TV-0.7%) was applied before disease appearance found higher yield.

Tuber size and yield

The effect of different treatments on tuber size and yield was studied after harvesting. Tubers were graded as large (more than 50 gm), medium (25 gm – 49.5 gm) and small (less than 25 gm) in size. The data represented in table-2 showed that maximum number of large size tubers were harvested from T9 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro), T10 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate) and T11 (Soil application of FYM + Mushroom Compost + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro) treated plant, representing 3 tubers each with total weight of 205.63 gm, 182.68 gm and 175.60gm per plant. Similarly, the maximum number of medium size tuber was obtained in T9 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro) treated plant, representing 3 tubers with total weight of 92.43 gm per plant followed by T5 (Soil application with Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro), T10 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate), T11 (Soil application of FYM + Mushroom Compost + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro), T12 (Soil application of FYM + Mushroom Compost + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate), T7 (Soil application of FYM + Mushroom Compost + Tuber treatment with *T. harzianum* + three foliar spray with Equation pro), T6 (Soil application with Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate) and T8 (Soil application of FYM + Mushroom Compost + Tuber treatment with *T. harzianum* + three foliar spray with Curzate.) treated plant, representing 2 tubers for each treatment with the total weight of 90.54, 84.60, 82.15, 72.36, 70.43, 62.08 and 60.30 gm respectively, during 2016-17. On the other hand, during 2017-18, the data represented in table-3 showed that the maximum number of

large size tubers with 3 tubers each per plant were harvested from T9 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro), T10 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate), T11 (Soil application of FYM + Mushroom Compost + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro) and T5 (Soil application with Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro) treatments, representing total weight of 183.55 gm, 172.65gm, 169.45 gm and 169.45 gm per plant, respectively. It has also found from the table that the maximum number of medium size tuber was obtained only from T9 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro), treated plant, representing 2 tubers with the total weight of 78.30gm per plant. The maximum number of small size tuber, was found in T4 (Soil application with Mushroom Compost + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro) treatment followed by T3 (Soil application with Mushroom compost + Tuber treatment with *T. harzianum* + three foliar spray with Curzate.) representing the 19 and 18 tubers, respectively.

As per yield is concerned, the highest total yield as 449.44 gm and 417.30gm per plant was obtained from T9 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation pro) treated plant during 2016-17 and 2017-18, respectively. The T10 (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate.) treated plant was showing 427.58gm and 387.45gm per plant representing, second highest among the treatment during both the years. From the table, it is also cleared that all the IDM approaches were statistically significant in respect of potato yield. Mansoor *et al.*, (2001)^[13] reported that the *Azotobacter* significantly increases the yield characters like tiller and tuber of potato. Biswas *et al.*, (2015)^[3] also reported that seed treatment and soil application with bio fertilizers of *Azotobacter* significantly increased grain and straw yield of wheat. Tippannaves *et al.*, (2005)^[16] had observed that the *Azotobacter* significantly increased the tillering, dry matter accumulation and growth parameter. Datnoff *et al.*, (1995)^[5] found that *Trichoderma* sp. enhanced the growth of tomato yield. Singh *et al.*, (2015)^[15] found that the yield of tomato crop was significantly increased by the combined application of seed treatment with *T. harzianum* + soil application of neem cake powder + foliar spray of carbendazim. Mansoor *et al.*, (2001)^[13] also observed that the *Azotobacter* improved plant height and shoot dry weight of okra significantly.

Table 2: Effect of IDM approaches on tuber size and yield of potato (Wire house condition) during 2016-17

Treatments	Large (>50gm)		Medium (25-49.5gm)		Small < 25 gm		Total Yield (gm/ plant/pot)	Per cent increase yield over control
	Total No. of Tuber	Weight	Total No. of Tuber	Weight	Total No. of Tuber	Weight		
T ₁ = SA with FYM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	1	60.50	1	45.60	9	180.50	286.60	35.39
T ₂ = SA with FYM + TT with <i>T. harzianum</i> + 3 FS with Curzate	2	120.40	1	49.80	10	109.61	279.41	31.99
T ₃ = SA with MC + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	1	055.60	1	48.00	17	172.77	276.37	30.56
T ₄ = SA with MC + TT with <i>T. harzianum</i> + 3 FS with Curzate.	0	0	1	38.65	15	180.35	219.00	3.46
T ₅ = SA with PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	2	140.80	2	90.54	7	105.40	336.74	59.08

T ₆ = SA with PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	2	110.35	2	62.08	9	134.60	307.03	45.04
T ₇ = SA of FYM + MC + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	1	60.80	2	70.43	13	152.30	288.53	36.30
T ₈ = SA of FYM + MC + TT with <i>T. harzianum</i> + 3 FS with Curzate	1	51.60	2	60.30	14	123.08	234.98	11.01
T ₉ = SA of FYM + PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	3	205.63	3	92.43	9	151.38	449.44	112.32
T ₁₀ = SA of FYM + PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	3	182.68	2	84.60	10	160.30	427.58	101.99
T ₁₁ = SA of FYM + MC + PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	3	175.60	2	82.15	9	145.68	403.43	90.58
T ₁₂ = SA of FYM + MC + PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	2	155.42	2	72.36	9	139.63	366.99	73.37
T ₁₃ = Soil application of FYM (Control)	0	0	1	37.00	21	174.68	211.68	
S.Em±	0.030	1.559	0.022	1.196	0.197	2.365	5.648	
CD at 5%	0.089	4.557	0.065	3.496	0.576	6.913	16.509	

Notes: SA= Soil application, TT= Tuber Treatments, FS= Foliar spray, MC= Mushroom compost, PM= Poultry manure.

Table 3: Effect of IDM approaches on tuber size and yield of potato (Wire house condition) during 2017-18

Treatments	Large (>50gm)		Medium (25-49.5gm)		Small < 25 gm		Total Yield (gm/ plant/ pot)	Per cent increase yield over control
	Total No of Tuber	Weight	Total No. of Tuber	Weight	Total No. of Tuber	Weight		
T ₁ = SA with FYM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	1	56.77	1	49.66	11	183.38	289.81	32.47
T ₂ = SA with FYM + TT with <i>T. harzianum</i> + 3 FS with Curzate	2	114.17	2	63.38	9	105.61	283.16	29.43
T ₃ = SA with MC + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	0	0	1	45.60	18	186.77	232.37	6.21
T ₄ = SA with MC + TT with <i>T. harzianum</i> + 3 FS with Curzate.	0	0	1	37.66	19	186.32	223.98	2.38
T ₅ = SA with PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	3	169.45	2	71.52	05	85.30	326.27	49.13
T ₆ = SA with PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	2	108.51	2	60.16	08	135.15	303.82	38.87
T ₇ = SA of FYM + MC + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	1	60.75	2	63.05	14	147.40	271.20	23.96
T ₈ = SA of FYM + MC + TT with <i>T. harzianum</i> + 3 FS with Curzate	1	53.70	2	67.31	16	127.07	248.08	13.39
T ₉ = SA of FYM + PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	3	183.55	2	78.30	10	155.45	417.30	90.74
T ₁₀ = SA of FYM + PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	3	172.65	2	74.50	9	140.30	387.45	77.10
T ₁₁ = SA of FYM + MC + PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	3	169.45	2	73.10	8	137.85	380.04	73.71
T ₁₂ = SA of FYM + MC + PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	2	158.50	2	68.45	9	132.25	359.00	64.09
T ₁₃ = Soil application of FYM (Control)	0	0	1	35.57	23	183.21	218.78	-
S.Em±	0.033	1.832	0.022	1.062	0.180	2.145	4.409	-
CD at 5%	0.096	5.355	0.065	3.104	0.525	6.270	12.889	-

Notes: SA= Soil application, TT= Tuber Treatments, FS= Foliar spray, MC= Mushroom compost, PM= Poultry manure

Disease severity

The effect of IDM practices significantly reduced disease severity of late blight of potato as compared to control in wire house condition (Table-4). Among the treatment, minimum disease severity with 9.05% and 14.92% during 2016-17 and 9.65 and 15.10% during 2017-18 were recorded in T₉ (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Equation Pro) treated plant as against 61.35 and 82.55 and 62.00 & 82.95% at 75 and 90 days after sowing, respectively in case of control. The treatment, T₁₀ (Soil application of FYM + Poultry Manure + Tuber treatment with *T. harzianum* + three foliar spray with Curzate) treatment representing 12.18% and 15.37% and 12.82 and 16.00% disease severity at 75 and 90 days after sowing during 2016-17 and 2017-18, respectively indicating

second lowest among the treatments. Morajdhwaj *et al.*, (2016) also found that incorporation of bio-fertilizers in soil + tuber treatment with bio agents + foliar spray with bio formulation effectivity managed the late blight of potato. Effective control of late blight requires implementing an integrated disease management approach was reported by several workers (Kirk, 2009; Kirk *et al.*, 2013)^[10, 9]. Biswas *et al.*, (2015)^[3] found that seed treatment and soil application with bio fertilizers of *Azotobacter* declined the disease severity of spot blotch from 73.7% to 42.6% in wheat. Mishra *et al.*, (2015)^[14] reported that the minimum disease severity of early blight of tomato which was 8.56% was found in case of soil application of FYM + seed treatment with bio formulation of *T. harzianum* + foliar spray of Mancozeb. Sumit *et al.*, (2018) recorded lowest disease severity in

treatment (Soil application of FYM @ 125gm/pot + waste of mushroom cultivation with *Trichoderma harzianum* @

5gm/kg + tuber treatment with *Azotobacter* @ 5% + foliar spray with Ridomil @ 0.25%).

Table 4: Effect of IDM approaches on disease severity of late blight of potato during 2016-17

Treatments	Disease severity at different days intervals (%)			
	2016-17		2017-18	
	75 Days	90 Days	75 Days	90 Days
T ₁ = SA with FYM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	19.46	23.34	19.16	23.00
T ₂ = SA with FYM + TT with <i>T. harzianum</i> + 3 FS with Curzate	21.94	25.82	21.08	26.05
T ₃ = SA with MC + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	26.45	28.55	26.90	28.95
T ₄ = SA with MC + TT with <i>T. harzianum</i> + 3 FS with Curzate.	28.36	32.15	28.85	32.65
T ₅ = SA with PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro.	16.63	19.28	17.05	20.40
T ₆ = SA with PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	17.37	21.40	17.95	21.80
T ₇ = SA of FYM + MC + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	23.08	26.08	22.90	25.98
T ₈ = SA of FYM + MC + TT with <i>T. harzianum</i> + 3 FS with Curzate	25.30	27.95	25.05	27.15
T ₉ = SA of FYM + PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	9.05	14.92	9.65	15.10
T ₁₀ = SA of FYM + PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	12.18	15.37	12.82	16.00
T ₁₁ = SA of FYM + MC + PM + TT with <i>T. harzianum</i> + 3 FS with Equation Pro	13.46	16.21	14.00	16.85
T ₁₂ = SA of FYM + MC + PM + TT with <i>T. harzianum</i> + 3 FS with Curzate	15.21	18.86	15.04	18.50
T ₁₃ = Soil application of FYM (Control)	61.35	82.55	62.00	82.95
SEm±	0.292	0.319	0.422	0.488
CD at 5%	0.855	0.934	1.233	1.426

Notes: SA= Soil application, TT= Tuber Treatments, FS= Foliar spray, MC= Mushroom compost, PM= Poultry manure

Conclusion

Thus, the present finding of study revealed that IDM approaches have ability to increases growth parameters like tuber germination, plant height, yield per plant and decrease disease severity. Thus, the present IDM modules can be recommended in farmer's field against *P. infestans*, causes late blight of potato.

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