Int.J.Curr.Microbiol.App.Sci (2020) *9*(6): 1739-1747

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 6 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.906.216

Efficacy of Bio-Pesticides on Tomato (*Solanum lycopersicum* L.) Var. Solan Lalima, Fruit Yield and Seed Quality under Mid Hill Conditions of Himachal Pradesh

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Keywords

Trichoderma viride, Neem oil, HaNPV, *Bacillus thuringiensis* and bio-pesticides.

Article Info

Accepted:
18 May 2020
Available Online:
10 June 2020

A B S T R A C T

Fruit yield, seed yield and seed quality parameters were worked out in Solan lalima variety of tomato during *kharif* season of the year 2018 in Solan district of Himachal Pradesh. *Trichoderma viride*, Neem Cake and oil, cow urine, *Bacillus thuringiensis* and HaNPV were used as bio-pesticides in different concentration and combinations. The applications of *Trichoderma viride* @ 50 g/plot + FYM @ 10 kg/plot + Neem oil @ 5ml/l in tomato crop is significantly better for number of healthy fruits harvested (22.80), average fruit weight per plant (79.43 g), number of seeds per fruit (95), seed yield per plant (6.22 g), seed yield per ha (184.22 kg), germination percentage (91.75%), seedling length (20.30 cm), speed of germination (19.45), dry weight of seedling (1.78 mg), seed vigour index I (1861.83) and II (163.36) and 1000 seed weight (2.92 g) over the other treatments. The results of the present study suggested that *Trichoderma viride* and neem oil in combination have a great potential to increase the yield and seed quality of tomato crop.

Introduction

Tomato (*Solanum lycopersicum* L.*)* is one of the most important solanaceous vegetable crop grown throughout the world. It is occupying an area of 5.02 million hectare with an annual global production of 170.75 million tonnes (16). In Himachal Pradesh, the largest part of tomato is produced in the mid hills and especially in the Solan district which is contributing more than 42% of total cultivated area and more than 44% of total production (2).

The major insect pests and diseases which play most important role in the economic losses of tomato crop includes buck eye rot, late blight, viral diseases, fruit borers and leaf

miners. The foremost control approach is the application of inorganic chemicals in field conditions for the immediate advantage of convenience, simplicity, rapid action, flexibility and economics. However it results in several problems like development of resistance against different chemicals for targeted pests, outbreak of secondary pests, environmental pollution, health hazards and reduction of biodiversity of natural enemies and thus increasing the cost of production (13). According to the World Health Organization (WHO) million of peoples are affected every year by overuse of insecticide and pesticides (3)**.**

Biopesticides are naturally occurring substances that control pests and diseases by the mechanisms which are ecologically safe and sound. The most commonly used biological agents are biofungicides (*Trichoderma*), bioherbicides (*Phytopthora*) bioinsecticides (*Bacillus thuringiensis*) and botanicals (Neem based biopesticides). Biopesticides have an important role in crop protection and growth regulation besides they are cheaper, safe and affordable for small and marginal farmers. Another advantage of biopesticides is that they are not very persistent (20).

Materials and Methods

The experiment was laid out in the farm and laboratory of Department of Seed Science and Technology, Dr. YSP University of Horticulture and Forestry, Nauni, Solan (HP) during 2018-19 in Randomized Complete Block Design (Factorial) in the field and in Completely Randomized Design. Well established healthy seedlings were transplanted at a spacing of 90 x 30 cm in plots having a size of 2.7 m x 1.2 m. The experiments were initiated during the last week of May. A total of three sprays of each treatment were administered at 30^{th} , 45^{th} and 60^{th} day after seedling transplanting and observation were recorded after 3^{rd} , 7^{th} and 14^{th} day of each spray. The different modules studied are given below.

M_1	***Trichoderma viride* @50 g/plot + FYM @ 10 kg/plot + Neem oil @ 3 ml/l**
M_2	*Trichoderma viride* @ 50 g/plot + FYM @ 10 kg/plot + *Bacillus thuringiensis*@ 2g/l
M_3	*Trichoderma viride* @ 50 g/plot + FYM @ 10 kg/plot + HaNPV (250LE) @ 1ml/l
M_4	*Trichoderma viride* @ 50 g/plot + FYM @ 10 kg/plot + Neem oil @ 5ml/l
M_5	*Trichoderma viride* @ 50 g/plot + FYM @ 10 kg/plot + Cow urine @ 50ml/l
M_6	Neem Cake @100 g/plot + FYM @ 10 kg/plot + Neem oil @ 3 ml/l
M_7	Neem Cake @ 100 g/plot + FYM @ 10 kg/plot + *Bacillus thuringiensis* @ 2g/l
M_8	Neem Cake @ 100 g/plot + FYM @ 10 kg/plot + HaNPV (250 LE) @ 1ml/l
M_9	Neem Cake @ 100 g/plot + FYM @ 10 kg/plot + Neem oil @ 5ml/l
M_{10}	Neem Cake @ 100 g/plot + FYM @ 10 kg/plot + Cow urine @ 50ml/l
M_{11}	Control

The data were recorded on a plot basis and the number of fruit per plant, fruit weight and fruit yield per plant were determined on freshly harvested fruits from the healthy plant. To determine seed yield red ripe fruits were harvested manually; seed were extracted from the fruit by using fermentation method as recommended by the ISTA, then dried to approximately 8% moisture content, cleaned, weighed (g) and g plot^{-1} values converted to kg ha^{-1} based on plot dimensions for each location. The seed weight was measured on a randomly selected samples of 1000 counted seeds dried to < 8% moisture content and expressed as grams per 1000 seeds. Seed yield per plot germination percentage, speed of germination, seedling length, seedling dry weight, seed vigour index-I and II were analysed on freshly harvested seed as per the ISTA guidelines (4). Four hundred seed from each treatment were taken at random and the test was carried out in four replication having 100 seeds in each replication. Seedling length was measured of selected ten healthy seedlings on last day of germination test. Later these seedlings are dried in an oven at a temperature about 60^{0}c of 48 hrs for seedling dry weight recorded in milligrams (mg).
Germination was calculated by using the formula:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds used}} \times 100$$

Speed of germination was calculated on the formula of Maguire (1977) (12).

$$\text{Speed of Germination} = \frac{X_1}{Y_1} + \frac{X_2 - X_1}{Y_2} + \cdots\cdots\cdots\cdots \frac{X_n - X_{n-1}}{Y_n}$$

where, X_1, X_2 and X_n are number of seeds germinated on first, second and nth day respectively and Y_1, Y_2 and Y_n are number of days from sowing to first, second and nth count respectively. Speed of germination is measured by top of paper method.

Seedling vigour index-I was calculated as per the formula given by Abdul and Anderson (1973)(1).

Seedling vigour index-I = Germination (%) × Seedling length (cm)

Seedling vigour index-II was calculated as per the formula given by Abdul and Anderson (1973) (1).

Seedling vigour index-II = Germination (%) x Seedling dry weight (mg)

The statistical analysis for Completely Randomized Design (CRD) and Randomized Complete Block Design (RCBD) was done as per design of the experiment as suggested by Gomez and Gomez (1984) (8) using computer software OP Stat.

Results and Discussion

Fruit and seed yield

The data pertaining to the effect of biopesticides on tomato crop have been presented in Table.1. Statistical analysis of the data indicated that biopesticides application had a significant influence on fruit yield and seed quality attributes. It was observed that the application of different biopesticides had shown positive response significantly as compared to module M_{11} (control). Among the modules, M_4 (*Trichoderma viride* @ 50 g/plot + FYM @ 10 kg/plot + Neem oil @ 5ml/l) module had the maximum value for all the selected parameters for the analysis of seed quality and yield components of "Solan lalima" variety of tomato crop. Number of fruits per plant were found significantly highest in M_4 (22.80) among all other modules and it was statistically at par with module M_1 (22.26). Application of neem oil increase the production of disease-free fruit in tomato and

pepper in field conditions, respectively (17). Number of fruits production was positively influenced by the *Trichoderma* application (6). The maximum average fruit weight per plant was found significantly high in M_4 (79.43g) with at par with module M_1 (77.83g) and M_9 (76.33g) with lowest in M_{11} control (69.33g). The maximum fruit yield/ ha was found significantly high in M_4 (536.57q) with at par with module M_1 (513.21q) with lowest in M_{11} control (256.21q).

Maximum fruit weight (132g) was observed by application of *Trichoderma* @100 g/m^2 on tomato crop (22). The highest fruit yield per plant (1.81 kg) was found in module M_4, which was statistically at par with module M_1 (1.73 kg). Same results were found in *Trichoderma* treated plot and minimum in control plot for fruit yield per tomato plant (10, 14, 22).

Seed yield is an ultimate objective in any research work where experiment conducted exclusively for seed production. Application of different biopesticides increased the number of seeds per fruit significantly as compared to control (75.47).The maximum number of seeds per fruit (95.00) were recorded in M_4 module and it was statistically at par with treatment M_1 (93.53) module This might be due to *Trichoderma* effect which produce cytokinins- like molecules e.g zeatin and gibberellins GA_3 or GA_3- related. (21) reported same result for fruit yield per plant in the same crop.

A cursory glance of the data indicated that the application of different biopesticides had exhibited significant effects on seed yield per plant (g). Among the biopesticides modules, M_4 module registered maximum seed yield per ha (184.22 kg) which was statistically at par with M_1 (178.28 kg).

While the minimum seed yield per hectare (78.06 kg) was found in module M_{11} (control). The same results were conformity with different researchers (9, 15, 18, 22).

Seed quality parameters

The data recorded on the effect of biopesticides on seed quality parameters of tomato crop have been presented in Table.2. Highest germination percentage of seed (91.75 %) was recorded in M_4 (*Trichoderma viride* @ 50 g/plot + FYM @ 10 kg/plot + Neem oil @ 5ml/l) module which was statistically at par with module M_1 (90.25%). Significantly the minimum germination percentage (79.75%) was recorded in module M_{11} (control). A perusal of data indicated that maximum speed of germination (19.45) was observed in M_4 module which was statistically at par with module M_1 (18.53) and significantly different to the lowest speed of germination (12.92) in control (M_{11}). This might be due to *Trichoderma* species producing growth factors which increase the rate of seed germination (7, 23). Seedling length measurement suggest the initial growth advancement of seed and is an essential component to determine the seed vigour index-I.

The maximum seedling length was observed for the seeds harvested from the plot which were treated with *Trichoderma viride* and neem oil. This might be attributed to the fact that application of *Trichoderma* and neem oil might have produced the bold seeds due to the presence of the higher amount of stored food material which reflects in higher test weight. The maximum seedling length (20.30 cm) was recorded for the seed lot which was harvested from the plants treated with M_4 module and found to be statistically at par with module M_1 (19.70 cm).

However, minimum seedling length (13.90 cm) was observed for the seeds harvested from the module M_{11} (control).

Table.1 Effects of different bio-pesticides on fruit yield and seed yield of tomato crop

S.No.	Modules	No. of Healthy fruits/ plant	Fruit weight(g)	Fruit yield /ha (q)	No. of seeds per fruit	seed yield (kg/ha)
M_1	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + NSKE @ 3 ml/l	22.26	77.83	513.21	93.53	178.28
M_2	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + Bt@ 2g/l	18.33	73.87	401.26	86.20	131.60
M_3	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + HaNPV(250) @ 1ml/l	19.80	72.00	422.27	83.00	137.30
M_4	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + Neem Oil @ 5ml/l	22.80	79.43	536.57	95.00	184.22
M_5	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + Cow Urine@ 50ml/l	17.27	74.77	382.56	84.67	121.31
M_6	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + NSKE @2-3 ml/l	18.93	75.22	421.98	89.83	143.63
M_7	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + Bt@ 2g/l	18.40	72.03	392.59	83.60	127.61
M_8	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + HaNPV(250) @ 1ml/l	19.60	71.19	413.35	80.40	130.26
M_9	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + Neem Oil @ 5ml/l	19.94	76.33	450.78	91.17	154.53
M_{10}	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + Cow Urine@ 50ml/l	16.40	74.00	359.60	81.47	109.63
M_{11}	**Control**	12.47	69.33	256.21	75.47	78.06
	C.D	**0.92**	**3.32**	**26.90**	**1.53**	**7.30**

Table.2 Effects of different bio-pesticides on seed quality parameters of tomato crop

S.No.	Modules	Germination percentage	Speed of germination	Seedling length	seedling Dry weight	SVI-I	SVI-II	1000 seed weight
M_1	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + NSKE @ 3 ml/l	90.25 (9.55)	18.53	19.70	1.73	1779.23	156.16	2.89
M_2	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + Bt@ 2g/l	86.25 (9.34)	16.78	18.43	1.69	1589.53	145.47	2.81
M_3	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + HaNPV(250) @ 1ml/l	86.50 (9.35)	17.18	18.57	1.70	1605.65	147.10	2.82
M_4	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + Neem Oil @ 5ml/l	91.75 (9.63)	19.45	20.30	1.78	1861.83	163.36	2.92
M_5	*Trichoderma viride* @50g/plot + FYM@ 10 kg/plot + Cow Urine@ 50ml/l	85.00 (9.27)	16.58	18.27	1.68	1552.11	142.53	2.80
M_6	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + NSKE @2-3 ml/l	86.00 (9.33)	17.40	18.11	1.67	1557.00	143.33	2.85
M_7	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + Bt@ 2g/l	85.50 (9.30)	16.37	17.66	1.64	1509.10	139.88	2.80
M_8	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + HaNPV(250) @ 1ml/l	85.75 (9.31)	16.60	17.71	1.66	1518.75	142.31	2.79
M_9	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + Neem Oil @ 5ml/l	88.50 (9.46)	18.02	18.73	1.71	1657.63	151.32	2.87
M_{10}	Neem Cake @ 100g/plot + FYM@ 10 kg/plot + Cow Urine@ 50ml/l	84.25 (9.23	16.09	17.28	1.61	1455.93	135.65	2.77
M_{11}	**Control**	79.75 (8.99)	12.92	13.90	1.26	1108.38	100.48	2.70
	C.D	**2.51**	**1.05**	**0.94**	**0.05**	**88.04**	**6.33**	**0.06**

These results are confirmed by the seed treatment with neem oil which produces the highest seedling length (19.09 cm) and high seed vigour index (1569) in tomato crop (19). Seedling dry weight is an important component and helps to determine the seed vigour index-II and ultimately gives an idea of the vigour of seeds. The maximum seedling dry weight (1.78 mg) was recorded for the seed lot which was harvested from the plants treated with M_4 module and it was statistically at par with module M_1 (1.73 mg). However, minimum seedling dry weight (1.26 mg) was recorded for the seeds harvested from the M_{11} (control) module. This might be attributed to the fact that application of neem oil and *Trichoderma* might have produced healthy and quality seeds that have sufficient food reserves for vigorous seedling production. These results were conformed with *Trichoderma* application, which interestingly increases seedling dry weight in tomato when compared to the control (5).

The germination test is not sufficient enough to provide all the information about the quality and performance of seeds under the field conditions. So, the vigour status of the seed becomes an important parameter, as it determines the actual seed germination and performance of seeds under field conditions. In the present studies, M_4 had resulted in the higher seed vigour index-I and II (1861.83) and (163.36). Both vigour indexes found statistically at par with module M_1 (1779.23) and (156.16). However, minimum seed vigour index (1108.38) and (100.48) were reported in M_{11} (control) module respectively. The treatment of tomato seeds with *Trichoderma* increases seedling vigour significantly (11). The highest 1000 seed weight (2.92 g) was observed in the application of M_4 module, which is statistically at par with treatment M_1 (2.89 g) and M_9 (2.87 g). Significantly the lowest 1000 seed weight (2.70 g) was recorded in module M_{11} (control).

Same result was observed with *Trichoderma* treatment for higher 1000 seed weight production (3g) in tomato (21).

Acknowledgment

The authors are thankful to the professor and Head, Department of Seed Science & Technology, YSP University of Horticulture and Forestry, Nauni (Solan), India for providing necessary guidance and facilities during the course of investigations.

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How to cite this article:

Vikrant, Rajinder Singh Rana, R. Vinay Kumar, S. Balaji Naik and Ramesh. V. M. 2020. Efficacy of Bio-Pesticides on Tomato (*Solanum lycopersicum* L.) Var. Solan Lalima, Fruit Yield and Seed Quality under Mid Hill Conditions of Himachal Pradesh. *Int.J.Curr.Microbiol.App.Sci.* 9(06): 1739-1747. doi: https://doi.org/10.20546/ijcmas.2020.906.216