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Bio-efficacy of bio-pesticides, botanicals and new molecules of insecticides against thrips on tomato

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Abstract
A field trial was conducted during 2016 at Haveli farm, Bagalkot to evaluate the efficacy of different biopesticides, botanicals and new molecules of insecticides against thrips and GBNV disease incidence on tomato. Among the different insecticides evaluated, thiamethoxam 25WG @ 0.20 g/l and diafenthiuron 50 WP @ 1.25 g/l were found to be superior in reducing both thrips population and GBNV disease incidence as compared to other insecticides tested. Among the botanicals and bio-pesticides evaluated, azadiractin 10,000 ppm @ 1.00 ml/l and *Lecanicillium lecanii* (2×10^8 cfu/g) @ 2.00 g/l were found to be effective.

Keywords: thrips infestation, disease incidence, biopesticides and botanicals

Introduction
Tomato, *Solanum lycopersicum* L. belongs to the genus *Solanum* under Solanaceae family. It is a native to Peruvian and Mexican region. Tomato is one of the most important "protective foods" as it is a rich source of minerals, vitamins and organic acids. Tomato crop is grown in India in an area of 789 thousand hectares with a production of 19377.09 tonnes. The major tomato producing states in the country are Madhya Pradesh, Karnataka, Andhra Pradesh, Telangana, Gujarat, Odisha, West Bengal, Bihar, Maharashtra, Chhattisgarh, Tamil Nadu, Uttar Pradesh, Haryana and Himachal Pradesh. These States account for 91 per cent of the total production of the country. In Karnataka, it occupies an area of 63.73 thousand hectares with a production of 2,138.13 thousand million tonnes and productivity of 33.55 tonnes per hectare [1]. The major tomato growing districts of Karnataka are Kolar, Haveri, Belgaum, Chikballapur, Mandya, Tumkur, Davangere, Mysore and Chamarajanagar [1].

Among the several biotic and abiotic factors that significantly hamper tomato production and maintain its yield at a very low level [2, 3], diseases and insects are in a prominent position. The average losses estimated by the action of pests represent about 15 per cent of the agricultural production [4]. However, in some localities and under certain local cultivation conditions, yield losses of up to 95 per cent have been reported [5]. The extent of yield losses depends on the intensity of attacks by diseases and pests [6].

Tomato is reported to be susceptible plant to over 40 viruses belonging to different genera and families. Among them, Tospoviruses are very important. Incidence of Tospoviruses in vegetable crops is increasing year by year and more so in tomato [7]. In India, Tospovirus on tomato was observed for the first time from Niligiris in 1975 and reported as Tomato Spotted Wilt Virus (TSWV). Later it was reported from Andhra Pradesh [8], Karnataka [9], Maharashtra [10] and Tamil Nadu [11].

Among the tospovirus reported in India, Groundnut bud necrosis virus (GBNV), Peanut yellow spot virus (PYSV) and Watermelon Bud Necrosis Virus (WBNV) have been reported to infect broad range of vegetables (tomato, potato, chilli, peppers and watermelon). Of these, the GBNV is causing a considerable yield loss in tomato [12]. The yield loss depends mainly on the level of infection, stage of the crop, thrips population and severity of the disease. Though the incidence of Tospovirus on tomato reported up to 30 per cent in Northern India, it lead to 100 per cent yield loss, when infection occurred within 30 days of planting [13].

GBNV is transmitted by at least 11 species of thrips, including *Frankliniella fusca* (Hinds), *Frankliniella occidentalis* (Pergande), *Frankliniella schultzei* Trybon, *Thrips palmi* Karny, *Scirtothrips dorsalis* Hood, *Thrips setosus* Moulton, *Thrips tabaci* Lindemon *etc.* However, in

the past two decades increased globalization and open agricultural trade has resulted in the expansion of the geographical distribution and host range of the thrips pest [14].
Use of chemicals is one of the most common and popular method of its control. Now- a- days, a large number of newer insecticides and botanicals are available in market. Bio-efficacy of these chemicals need to be studied for formulating effective and economical management strategies of any insect pest [15].
At present, repeated applications and indiscriminate use of different pesticides by the farmers for the control of thrips has led to the development of resistance. In order to impede the development of insecticide resistance it is always advisable to use insecticides from different classes in rotation. The present investigations were, therefore, planned to evaluate efficacy of some insecticides, botanicals and bio pesticides against thrips and GBNV disease incidence on tomato.

Materials and Methods
A field trial was conducted during 2016 at Haveli farm, Bagalkot to evaluate the efficacy of different biopesticides, botanicals and new molecules of insecticides against thrips and GBNV disease incidence on tomato. The experiment was laid out in a randomized block design with ten treatments replicated three times. Variety 501 (Namdhari) was transplanted by adopting spacing of 90cm×60cm between rows and among plants, respectively with the plot size of 5×4 m. Before transplantation, the seedlings were dipped in a solution of imidacloprid 200 SL at 0.5 ml mixed in 1 litre of water for 10 min. Then the treated seedlings were planted in assigned plots. The regular agronomic operations were followed equally for all treatments as per the package of practices of University of Horticultural Sciences, Bagalkot. A total of four sprays were given at fifteen days interval starting from 25 days after transplantation by using knapsack sprayer. The treatment details are mentioned in the Table 1.
Pre-treatment observations on number of thrips (nymphs and adults) were made a day before treatment imposition and post treatment counts were made at three, seven, ten and fifteen days after each spray. Thrips counts were recorded on ten randomly selected plants in each replication by tapping tender shoots on stiff black paper board. The fallen thrips including adults and nymphs were counted visually. The mean population of thrips per plant was worked out for each field separately.
The observation was also made on GBNV disease incidence at ten days after each spray. For this purpose, thirty plants were selected randomly in each replication. Of the 30 plants observed, the number of healthy and plants infected with GBNV disease was recorded to work out per cent disease incidence by using following formula.

$$\text{Per cent disease incidence} = \frac{\text{Number of plants infected}}{\text{Total number of plants observed}} \times 100$$

Statistical Analysis
Data obtained in respect of thrips population and per cent GBNV disease incidence recorded during management study was subjected to square root and arc sine transformation, respectively before analyzing the data with one way ANOVA. The treatment means were separated by using DMRT.

Results and Discussion
A field experiment was conducted during *Summer* season of 2016, to evaluate the efficacy of different components of integrated pest management program against thrips in tomato.

Thrips infestation
The results indicated that, all the insecticidal treatments were found significantly superior in reducing thrips population over untreated control. The diafenthiuron @ 1.25 g/l and thiamethoxam @ 0.20 g/l among chemical insecticides, azadirachtin @ 1.00 ml/l from botanical insecticides and *Lecanicillium lecanii* @ 2.00 g/l from bio-pesticides recorded least number of thrips per plant as compared to other treatments evaluated in their respective group. Pre-treatment number of thrips in all the plots ranged from 4.33 to 16.00 per plant and treatment differences were non-significant (Table 2).
At the first spray, significantly less number of thrips of 1.25 per plant was seen in plots treated with thiamethoxam 25 WG @ 0.20 g/l of water and it was statistically superior over other treatments. The next best treatment in the rank was diafenthiuron 50 WP @ 1.25 g/l of water by recording 2.33 thrips per plant, followed by imidacloprid 30.50 SC @ 0.30 ml/l of water and acetamaprid 20 SP @ 0.25 g/l of water by recording 2.92 and 3.17 thrips per plant and these treatments were on par with each other. The minimum thrips infestation of 5.58 per plant was recorded from the plots treated with azadirachtin 10,000 ppm @ 1.00 ml/l of water as that of plots treated with NSKE 5% @ 50 g/l of water. Whereas, in case of bio-pesticides treated plots, the *Lecanicillium lecanii* (2×10^8 cfu/g) @ 2.00 g/l of water recorded lowest thrips infestation of 8.08 per plant and it was significantly superior over *Beauveria bassiana* (2×10^8 cfu/g) @ 2.00 g/l (Table 6).
At second spray, significantly less number of thrips per plant of 0.67 was recorded from where plants received foliar spray of thiamethoxam 25 WG @ 0.20 g/l of water and it was significantly superior over other treatments, followed by diafenthiuron 50 WP @ 1.25 g/l of water and imidacloprid 30.50 SC @ 0.30 ml/l of water treated plots (1.17 & 2.08 thrips/ plant, respectively) and these treatments were on par with each other. Among the botanicals treated, the mean number of thrips appeared to be the lowest on azadirachtin 10,000 ppm @ 1.00 ml/l of water treated plants and it was significantly lower than NSKE 5% @ 50 g/l of water treated plants (5.58 & 9.25 thrips/ plant, respectively). However, the level of thrips suppression by *Lecanicillium lecanii* (2×10^8 cfu/g) @ 2.00 g/l of water did not differ significantly from that of *Beauveria bassiana* (2×10^8 cfu/g) by recording 7.58 and 8.67 thrips per plant, respectively
(Table 6).
In the third spray, the mean number of thrips were significantly fewer (0.33 thrips/plant) in diafenthiuron 50 WP @ 1.25 g/l of water treated plants than other chemical insecticides treated plants. Suppression of thrips by the thiamethoxam 25 WG @ 0.20 g/l of water and imidacloprid 30.50 SC @ 0.30 ml/l of water did not differ statistically by recording 0.75 and 1.17 thrips per plant, respectively. Among the insecticides treated, the maximum thrips infestation of 6.67 per plant was recorded from the plots where seedlings were dipped in imidacloprid 200 SL @ 0.50 ml/l of water for ten minutes as compared to other treatments. Azadirachtin 10,000 ppm @ 1.00 ml/l of water appeared to be the most effective and it was significantly reduced the thrips population as compared to NSKE 5% @ 50 g/l by recording 5.50 and 9.42 thrips per plant, respectively. *Lecanicillium lecanii* (2×10^8 cfu/g) @ 2.00 g/l of water was similarly effective and

its effect was not statistically different from that of *Beauveria bassiana* (2×10^8 cfu/g) @ 2.00 g/l (6.50 & 0.17 thrips/plant, respectively) (Table 6).

Overall, after four sprays of different treatments, Thiamethoxam 25 WG @ 0.20 g/l of water and diafenthiuron 50 WP @ 1.25 g/l of water were found to be superior in reducing thrips population up to 94.77 & 92.78 per cent, respectively as compared to other insecticides tested. The next best treatments in the rank were imidacloprid 30.50 SC @ 0.30 ml/l of water and acetamaprid 20 SP @ 0.25 g/l of water (86.97% & 82.84%) which was effective in reducing thrips population. Among the botanicals evaluated, the azadirachtin 10,000 ppm @ 1.00 ml/l of water was reduced thrips up to 61.93 per cent as compared to NSKE 5% @ 50 g/l of water. Next effective treatment among biopesticides was *Lecanicillium lecanii* (2×10^8 cfu/g) @ 2.00 g/l of water by reducing thrips up to 50.88 per cent (Table 6).

Disease incidence

As the crop stage advanced, the disease incidence also increased in all nine treatments. Before imposition of treatments, the per cent GBNV disease incidence was ranged from 0.00 to 3.33 and treatment differences were non-significant (Table 7).

At fifteen days after first spray, significantly less GBNV disease incidence of 4.44 per cent was observed in both thiamethoxam 25 WG @ 0.20 g/l of water and diafenthiuron 50 WP @ 1.25 g/l of water and these treatments were on par with each other. Next best treatment in the rank was imidacloprid 30.50 SC @ 0.30 ml/l of water (6.67%). Among the botanicals treated, the azadirachtin 10,000 ppm @ 1.00 ml/l of water recorded the lowest per cent disease incidence of 12.22 and it was significantly different from NSKE 5% @ 50 g/l of water (16.67%). The plots treated with *Lecancillium lecanii* (2×10^8 cfu/g) @ 2.00 g/l of water was recorded minimum GBNV disease incidence of 14.44 per cent as compared to other bio-pesticide treated plots (Table 7).

On the fifteen days after second spray, the lowest GBNV disease incidence of 8.89 per cent was recorded from where the plots were treated with diafenthiuron 50 WP @ 1.25 g/l of water and it was on par with thiamethoxam 25 WG @ 0.20 g/l of water (10.00%) and imidacloprid 30.50 SC @ 0.30 ml/l of water (10.00%). The next best treatment in the rank was acetamaprid 20 SP @ 0.25 g/l of water as a foliar spray by recording disease incidence of 13.33 per cent. Among the botanicals and bio-pesticides treated, the Azadirachtin 10,000 ppm @ 1.00 ml/l of water and *Beauveria bassiana* (2×10^8 cfu/g) @ 2.00 g/l of water was recorded minimum disease incidence of 20.00 and 21.11 per cent, respectively (Table 7).

At fifteen days after third spray, the plots treated with diafenthiuron 50 WP @ 1.25 g/l of water recorded minimum disease incidence of 11.11 per cent and it was significantly superior over other treatments, followed by thiamethoxam 25 WG @ 0.20 g/l of water and imidacloprid 30.50 SC @ 0.30 ml/l of water (13.33 & 15.56%) and these treatments were on par with each other. The highest per cent disease incidence of 31.11 was recorded from the both plots where seedlings were dipped in imidacloprid 200 SL @ 5.00 ml/l of water and *Beauveria bassiana* (2×10^8 cfu/g) @ 2.00 g/l of water given as a foliar spray. Among the plots treated with botanicals, the azadirachtin 10,000 ppm @ 1.00 ml/l of water was recorded minimum GBNV disease incidence of 25.56 per cent (Table 7).

On the fifteenth day after fourth spray, the plots treated with thiamethoxam 25 WG @ 0.20 g/l of water and diafenthiuron 50 WP @ 1.25 g/l of water recorded minimum disease incidence of 14.44 and 17.78 per cent, respectively and these treatments were statistically superior over all other treatments. The imidacloprid 30.50 SC @ 0.30 ml/l of water and acetamaprid 20 SP @ 0.25 g/l of water were next best treatments in the order by recording GBNV disease incidence of 21.11 and 27.78 per cent. Among the botanicals and bio-pesticides tested, the azadirachtin 10,000 ppm @ 1.00 ml/l of water and *Lecanicillium lecanii* (2 x 10^8 cfu/g) @ 2.00 g/l of water were found to be superior by recording 34.44 and 36.67 per cent GBNV disease incidence, respectively (Table 7).

Overall, it was observed that all the chemical insecticide treatments were found significantly superior in reducing the GBNV disease incidence as compared to botanicals and bio-pesticides evaluated. Among the chemical insecticides evaluated, both thiamethoxam 25 WG @ 0.20 g/ of water and diafenthiuron 50 WP @ 1.25 g/l of water recorded highest percentage reduction of disease incidence over control (70.10 & 70.07, respectively) and proved significantly superior to the rest of the treatments. It was followed by imidacloprid 30.50 SC @ 0.30 ml/l of water, which recorded 62.19 per cent disease reduction over control. Among the botanicals and bio-pesticides treated, the azadirachtin 10,000 ppm @ 1.00 ml/l of water and *Lecanicillium lecanii* (2×10^8 cfu/g) @ 2.00 g/l of water recorded maximum per cent disease reduction over control (34.64 and 24.40%, respectively) (Table 7).

Pre-treatment count of thrips and GBNV disease incidence in all the plots ranged from 4.33 to 16.00 thrips per plant and 0.00 to 3.33 per cent and there was no significant differences among the treatments. The reduction in the thrips infestation and disease incidence after four sprays of different treatments on tomato has indicated that, the chemical insecticides such as thiamethoxam @ 0.20 g/l and diafenthiuron @ 1.25 g/l found superior by reducing thrips infestation to the extent of 94.77 and 92.78 per cent, respectively and subsequent disease incidence (70.07 and 70.07%, respectively) as compared to other chemical insecticides evaluated. Of the botanicals tested, Azadirachtin @ 1.00 ml/l and from bio-pesticides *Lecanicillium lecanii* @ 2.00 g/l recorded thrips infestation of 61.93 and 50.88 per cent, respectively and disease incidence of 34.64 and 24.40 per cent, respectively. Thus, proving their effectiveness in their respective groups. However, both of them were statistically inferior in terms of reducing thrips and GBNV disease incidence as compared to chemical insecticides. Considering the efficacy of these components, they were selected while developing different pest management modules for further evaluation against thrips and GBNV disease incidence on tomato under field conditions (Fig. 1).

Present findings are in confirmation with that of who compared different IPM components for their efficacy on tomato against *T. palmi*. Results revealed that, the *s*eed treatment with imidachoprid (0.005%) alone was found effective, which was on par with the border crop with maize and package of practice (seed treatment with Thiram 1.25 g). The application of insecticide, imidachloprid at 0.005 per cent at 15 days interval in the main field was found effective which kept the vector population at low level (0.91 /leaf of plant) and reduced the disease incidence (40.63%) at 80 DAT. This was further more effective when used in sequence with other chemicals like Thiomethaxam (0.05%), Acetamiprid (0.02%) and Intrepid (0.5%) which recorded lower level of vector population (0.55/leaf) and disease incidence (6.54%)

[16].

Similarly, the efficacy of Difenthiuron 50% WP against thrips on chilli was also recorded in the field trial carried out at Horticulture research farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during Rabi-summer, 2014-15 and 2015-16. The mean data revealed that among the treatments, during first season DIFACE 600 ml/ha (Difenthiuron50% WP + Acetamiprid 20% SP) recorded the mean lowest population 3.29 and 3.35 thrips/3 leaves per plant as against 9.33 and 9.43 thrips in untreated check, respectively after first and second spray. During second season (Rabi-summer 2015-16) after 1st and 2nd spray almost similar trends were observed and minimum mean population of thrips (1.57 and 1.97) were recorded in DIFACE 600 ml/ha treatment [17].

Similarly, four different insecticides such as acephate, imidacloprid, cypermethrin, dimethoate and three botanicals, *Allium sativum* extract, *Allium cepa* extract and NSKE were evaluated for their bio-efficacy against chilli thrips. Among insecticides, imidacloprid 17.8 SL reduced maximum thrips population (82.46%) followed by acephate 75 SP (80.86%). Among botanicals, NSKE 5% reduced a maximum 64.50 Per cent population, while garlic and onion extract showed comparatively less performance with population reduction of 55.98 Per cent and 51.53 Per cent, respectively. Among all treatments, the highest percent increase in yield over control was obtained from plots treated with imidacloprid 17.8 SL (45.42%) followed by cypermethrin 12.5 EC (38.15%). Amongst botanicals, greater percent increase in the yield was recorded by application of *A. sativum* extract (34.46%), followed by *A. cepa* extract (22.33%). The C: B ratio for all treatments was analyzed and found to be highest in case of imidacloprid 17.8 SL (1:16.66) whereas the lowest of 1:7.39 in case of dimethoate 0.03 EC [18].

Three field trials were carried out during summer 1999, *kharif* 1999 and *rabi*-summer 2000 to evaluate the efficacy of different insecticides and botanical extracts against the chilli thrips. Among all treatment combinations, imidacloprid 75 WS at 5 g/kg of seed treatment and imidacloprid 200 SL at 0.05 per cent as a foliar spray showed minimum disease incidence (3.7%) indicating imidacloprid as best in minimizing the disease incidence as well as spread of the disease. Whereas, plant products evaluated such as neem leaf extract and sorghum leaf extract recorded highest disease incidence [19].

Table 1: Details of treatments imposed for managing thrips and Groundnut bud necrosis viral disease incidence on tomato

Treatments	Details	Dose (g or ml/l)	Dose (g a.i./ha)
T_1	Azadirachtin 10,000 ppm	1.00	50.00
T_2	NSKE 5%	50.00	-
T_3	*Lecanicillium lecanii* (2×10^8 cfu/g)	2.00	2×10^{11} cfu
T_4	*Beauveria bassiana* (2×10^8 cfu/g)	2.00	2×10^{11} cfu
T_5	Seedling dip with Imidacloprid 200 SL	0.50 ml/l for 10 min	-
T_6	Thiamethoxam 25 WG	0.20	25.00
T_7	Diafenthiuron 50 WP	1.25	312.50
T_8	Acetamaprid 20 SP	0.25	31.25
T_9	Imidacloprid 30.50 SC	0.30	37.50
T_{10}	Untreated control	-	-

Table 2: Bio-efficacy of botanicals, bio-pesticides and chemical insecticides against thrips on tomato at first spray during 2016

Treatments	Dose (g a.i./ha)	No. of thrips/ Plant				
		Before spray	3 DAS	7 DAS	10 DAS	15 DAS
T_1-Azadirachtin 10,000 ppm	50.00	9.33 (2.97)	6.00 $(2.53)^{bcd}$	5.33 $(2.35)^{cdef}$	4.67 $(2.23)^{bcd}$	6.33 $(2.49)^{bcd}$
T_2- NSKE 5%	-	16.00 (4.03)	12.67 $(3.55)^{d}$	6.33 $(2.58)^{def}$	10.00 $(2.97)^{cd}$	8.33 $(2.70)^{bcde}$
T_3- *Lecanicillium lecanii* (2×10^8 cfu/g)	2×10^{11} cfu	7.00 (2.72)	6.67 $(2.66)^{bcd}$	8.67 $(2.97)^{ef}$	5.67 $(2.39)^{bcd}$	11.33 $(3.33)^{de}$
T_4- *Beauveria bassiana* (2×10^8 cfu/g)	2×10^{11} cfu	13.33 (3.68)	10.33 $(3.25)^{cd}$	9.00 $(2.96)^{ef}$	8.00 $(2.83)^{cd}$	9.67 $(3.06)^{cde}$
T_5- Seedling dip with Imidacloprid 200 SL	-	4.33 (2.20)	4.00 $(2.07)^{ab}$	5.00 $(2.12)^{bcde}$	4.67 $(2.21)^{bcd}$	5.33 $(2.24)^{abcd}$
T_6- Thiamethoxam 25 WG	25.00	6.33 (2.60)	1.33 $(1.27)^{a}$	0.33 $(0.88)^{a}$	0.67 $(1.05)^{ab}$	2.67 $(1.60)^{ab}$
T_7- Diafenthiuron 50 WP	312.50	13.00 (3.65)	5.33 $(2.28)^{abc}$	1.00 $(1.18)^{ab}$	0.00 $(0.70)^{a}$	3.00 $(1.65)^{ab}$
T_8- Acetamaprid 20 SP	31.25	8.67 (2.86)	5.33 $(2.33)^{abc}$	2.33 $(1.65)^{abcd}$	3.33 $(1.80)^{abc}$	1.67 $(1.24)^{a}$
T_9- Imidacloprid 30.50 SC	37.50	6.67 (2.38)	3.00 $(1.82)^{ab}$	1.67 $(1.44)^{abc}$	2.67 $(1.74)^{abc}$	4.33 $(2.07)^{abc}$
T_{10}- Untreated control	-	13.67 (3.74)	12.67 $(3.62)^{d}$	11.33 $(3.44)^{f}$	12.67 $(3.53)^{d}$	13.33 $(3.63)^{e}$
S.Em±		-	0.370	0.380	0.453	0.379
CD (p=0.05)		NS	1.094	1.131	1.342	1.135

Figures in parenthesis indicate square root $\sqrt{x+0.5}$ transformed values

Figures in each column followed by same alphabet (s) are not significantly different (P=0.05) NS- Non significant DAS- Days after Spray

Table 3: Bio-efficacy of botanicals, bio-pesticides and chemical insecticides against thrips on tomato at second spray during 2016

Treatments	Dose (g a.i./ha)	No. of thrips/ Plant			
		3 DAS	7 DAS	10 DAS	15 DAS
T_1-Azadirachtin 10,000 ppm	50.00	5.00 (2.07)^{abc}	4.67 (1.99)^{bcd}	4.67 (2.17)^{bc}	8.00 (2.88)^{cde}
T_2- NSKE 5%	-	9.33 (3.05)^{bcd}	7.33 (2.67)^{de}	7.00 (2.56)^{c}	13.33 (3.69)^{ef}
T_3- *Lecanicillium lecanii* (2×10^8 cfu/g)	2×10^{11} cfu	10.33 (3.28)^{cd}	5.67 (2.44)^{cd}	4.67 (2.25)^{bc}	9.67 (3.16)^{cde}
T_4- *Beauveria bassiana* (2×10^8 cfu/g)	2×10^{11} cfu	8.67 (2.94)^{bcd}	7.67 (2.72)^{de}	7.33 (2.73)^{cd}	11.00 (3.36)^{def}
T_5- Seedling dip with Imidacloprid 200 SL	-	5.33 (2.27)^{abcd}	6.33 (2.46)^{cd}	7.00 (2.50)^{c}	8.00 (2.83)^{cde}
T_6- Thiamethoxam 25 WG	25.00	0.67 (0.99)^{a}	0.33 (0.88)^{ab}	0.00 (0.70)^{a}	1.67 (1.38)^{a}
T_7- Diafenthiuron 50 WP	312.50	1.67 (1.38)^{a}	0.00 (0.70)^{a}	0.33 (0.88)^{ab}	2.67 (1.76)^{ab}
T_8- Acetamaprid 20 SP	31.25	1.00 (1.18)^{a}	1.33 (1.27)^{abc}	2.67 (1.56)^{abc}	6.00 (2.51)^{bcd}
T_9- Imidacloprid 30.50 SC	37.50	2.67 (1.66)^{ab}	0.67 (1.05)^{ab}	0.33 (0.88)^{ab}	4.67 (2.25)^{abc}
T_{10}- Untreated control	-	12.33 (3.52)^{d}	14.00 (3.78)^{e}	16.67 (4.10)^{d}	18.67 (4.33)^{f}
S.Em±		0.483	0.412	0.486	0.341
CD (p=0.05)		1.429	1.229	1.443	1.000

Figures in parenthesis indicate square root $\sqrt{x+0.5}$ transformed values
Figures in each column followed by same alphabet (s) are not significantly different (P=0.05) DAS- Days after Spray

Table 4: Bio-efficacy of botanicals, bio-pesticides and chemical insecticides against thrips on tomato at third spray during 2016

Treatments	Dose (g a.i./ha)	No. of thrips/ Plant			
		3 DAS	7 DAS	10 DAS	15 DAS
T_1-Azadirachtin 10,000 ppm	50.00	5.67 (2.44)^{bcd}	3.67 (1.90)^{bc}	5.00 (2.10)^{bcd}	7.67 (2.63)^{bcde}
T_2- NSKE 5%	-	9.67 (3.12)^{de}	8.67 (2.95)^{cd}	8.67 (3.02)^{de}	10.67 (3.20)^{e}
T_3- *Lecanicillium lecanii* (2×10^8 cfu/g)	2×10^{11} cfu	6.67 (2.62)^{cd}	4.33 (2.01)^{bcd}	6.00 (2.53)^{cd}	9.00 (2.86)^{de}
T_4- *Beauveria bassiana* (2×10^8 cfu/g)	2×10^{11} cfu	8.33 (2.91)^{d}	6.33 (2.50)^{cd}	10.00 (3.19)^{de}	8.00 (2.72)^{cde}
T_5- Seedling dip with Imidacloprid 200 SL	-	9.00 (2.98)^{d}	9.67 (3.18)^{de}	9.67 (2.80)^{d}	11.33 (3.41)^{e}
T_6- Thiamethoxam 25 WG	25.00	1.33 (1.35)^{ab}	0.00 (0.70)^{a}	0.67 (0.99)^{ab}	1.00 (1.18)^{ab}
T_7- Diafenthiuron 50 WP	312.50	0.33 (0.88)^{a}	0.00 (0.70)^{a}	0.33 (0.88)^{ab}	0.67 (1.05)^{a}
T_8- Acetamaprid 20 SP	31.25	3.67 (1.97)^{abcd}	1.00 (1.18)^{ab}	1.67 (1.35)^{abc}	2.33 (1.64)^{abcd}
T_9- Imidacloprid 30.50 SC	37.50	2.33 (1.64)^{abc}	0.67 (1.05)^{ab}	0.00 (0.70)^{a}	1.67 (1.35)^{abc}
T_{10}- Untreated control	-	18.00 (4.25)^{e}	18.33 (4.29)^{e}	17.00 (4.17)^{e}	16.00 (4.03)^{e}
S.Em±		0.390	0.402	0.456	0.509
CD (p=0.05)		1.165	1.199	1.353	1.500

Figures in parenthesis indicate square root $\sqrt{x+0.5}$ transformed values
Figures in each column followed by same alphabet (s) are not significantly different (P=0.05) DAS- Days after Spray

Table 5: Bio-efficacy of botanicals, bio-pesticides and chemical insecticides against thrips on tomato at fourth spray during 2016

Treatments	Dose (g a.i./ha)	No. of thrips/ Plant			
		3 DAS	7 DAS	10 DAS	15 DAS
T_1-Azadirachtin 10,000 ppm	50.00	6.33 (2.60)^{b}	5.00 (2.31)^{c}	3.33 (1.79)^{bcd}	1.33 (1.27)^{abc}
T_2- NSKE 5%	-	9.00 (3.02)^{bc}	7.67 (2.74)^{cd}	4.00 (2.01)^{cde}	3.67 (2.03)^{cd}
T_3- *Lecanicillium lecanii* (2×10^8 cfu/g)	2×10^{11} cfu	7.00 (2.63)^{b}	5.00 (2.29)^{bc}	3.67 (1.96)^{cde}	2.33 (1.64)^{bcd}
T_4- *Beauveria bassiana* (2×10^8 cfu/g)	2×10^{11} cfu	8.00 (2.87)^{bc}	5.33 (2.37)^{cd}	6.67 (2.63)^{de}	3.33 (1.94)^{cd}
T_5- Seedling dip with Imidacloprid 200 SL	-	8.00	8.00	6.00	4.00

		(2.85)^{bc}	(2.89)^{cd}	(2.51)^{de}	(2.01)^{cd}
T_{6}- Thiamethoxam 25 WG	25.00	0.33 (0.88)^{a}	0.00 (0.70)^{a}	0.00 (0.70)^{a}	0.33 (0.88)^{ab}
T_{7}- Diafenthiuron 50 WP	312.50	0.00 (0.70)^{a}	0.33 (0.88)^{a}	0.00 (0.70)^{a}	0.00 (0.70)^{a}
T_{8}- Acetamaprid 20 SP	31.25	2.00 (1.53)^{a}	1.67 (1.46)^{ab}	0.67 (1.05)^{abc}	0.67 (0.99)^{ab}
T_{9}- Imidacloprid 30.50 SC	37.50	1.33 (1.27)^{a}	1.67 (1.46)^{ab}	0.33 (0.88)^{ab}	0.33 (0.88)^{ab}
T_{10}- Untreated control	-	13.67 (3.71)^{c}	9.67 (3.18)^{d}	8.33 (2.93)^{e}	4.67 (2.17)^{d}
S.Em±		0.358	0.293	0.342	0.286
CD (p=0.05)		1.065	0.852	1.025	0.854

Figures in parenthesis indicate square root $\sqrt{x+0.5}$ transformed values
Figures in each column followed by same alphabet (s) are not significantly different (P=0.05) DAS- Days after Spray

Table 6: Bio-efficacy of botanicals, bio-pesticides and chemical insecticides against thrips on tomato at different sprays during 2016 (pooled mean of four observations in each spray)

Treatments	Dose (g a.i./ha)	Mean no. of thrips/ plant at different sprays				Pooled mean	% reduction over control
		I spray	II spray	III spray	IV spray		
T_{1}-Azadirachtin 10,000 ppm	50.00	5.58 (2.36)^{cde}	5.58 (2.37)^{cd}	5.50 (2.19)^{c}	4.00 (2.11)^{c}	5.17	61.93
T_{2}- NSKE 5%	-	9.33 (3.00)^{ef}	9.25 (3.12)^{e}	9.42 (3.04)^{d}	6.08 (2.54)^{cd}	8.52	37.26
T_{3}- *Lecanicillium lecanii* (2×10^{8} cfu/g)	2×10^{11} cfu	8.08 (2.84)^{def}	7.58 (2.84)^{de}	6.50 (2.54)^{cd}	4.50 (2.23)^{cd}	6.67	50.88
T_{4}- *Beauveria bassiana* (2×10^{8} cfu/g)	2×10^{11} cfu	9.25 (2.97)^{ef}	8.67 (3.02)^{de}	8.17 (2.82)^{cd}	5.83 (2.50)^{cd}	7.98	41.24
T_{5}- Seedling dip with Imidacloprid 200 SL	-	4.75 (2.11)^{bcd}	6.67 (2.67)^{de}	9.92 (3.14)^{d}	6.50 (2.64)^{de}	6.96	48.75
T_{6}- Thiamethoxam 25 WG	25.00	1.25 (1.09)^{a}	0.67 (1.05)^{a}	0.75 (0.83)^{ab}	0.17 (0.81)^{a}	0.71	94.77
T_{7}- Diafenthiuron 50 WP	312.50	2.33 (1.46)^{ab}	1.17 (1.29)^{ab}	0.33 (0.56)^{a}	0.08 (0.76)^{a}	0.98	92.78
T_{8}- Acetamaprid 20 SP	31.25	3.17 (1.70)^{abc}	2.75 (1.80)^{bc}	2.17 (1.44)^{b}	1.25 (1.33)^{b}	2.33	82.84
T_{9}- Imidacloprid 30.50 SC	37.50	2.92 (1.70)^{abc}	2.08 (1.59)^{ab}	1.17 (1.07)^{ab}	0.92 (1.16)^{ab}	1.77	86.97
T_{10}- Untreated control	-	12.50 (3.51)^{f}	15.42 (3.95)^{f}	17.33 (4.15)^{e}	9.08 (3.06)^{e}	13.58	-
S.Em±		0.534	0.241	0.249	0.171	-	-
CD (p=0.05)		0.855	0.726	0.740	0.497	-	-

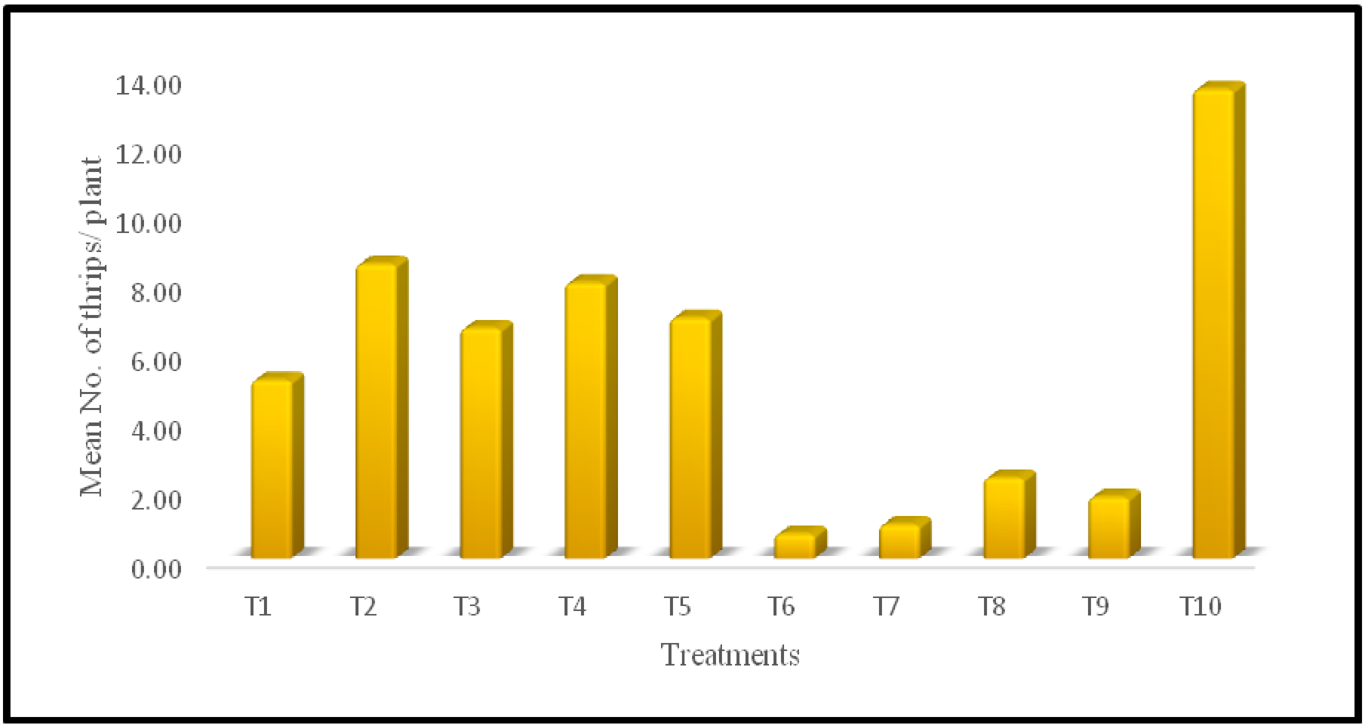
Figures in parenthesis indicate square root $\sqrt{x+0.5}$ transformed values
Figures in each column followed by same alphabet (s) are not significantly different (P=0.05)

Table 7: Bio-efficacy of botanicals, bio-pesticides and chemical insecticides against Groundnut bud necrosis viral disease incidence on tomato at different sprays during 2016

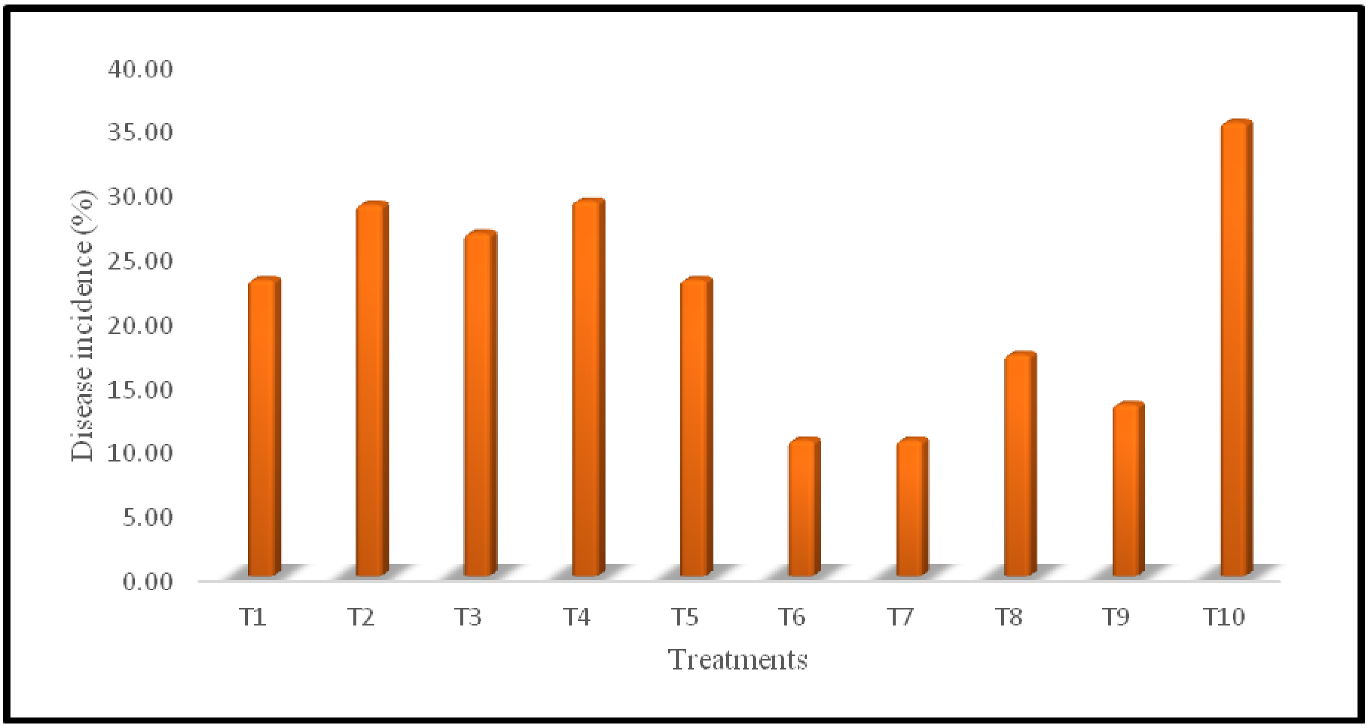
Treatments	Dose (g a.i./ha)	GBNV disease incidence (%) at different sprays					Pooled mean	% reduction over control
		Before spray	I spray	II spray	III spray	IV spray		
T_{1}- Azadirachtin 10,000 ppm	50.00	1.11 (3.86)	12.22 (20.32)^{d}	20.00 (26.35)^{bcd}	25.56 (30.35)^{cd}	34.44 (35.93)^{cd}	23.06	34.64
T_{2}- NSKE 5%	-	2.22 (5.34)	16.67 (24.02)^{e}	25.56 (30.35)^{de}	33.33 (35.24)^{def}	40.00 (39.24)^{de}	28.89	18.11
T_{3}- *Lecanicillium lecanii* (2×10^{8} cfu/g)	2×10^{11} cfu	0.00 (0.52)	14.44 (22.30)^{de}	24.44 (29.61)^{de}	31.11 (33.88)^{de}	36.67 (37.16)^{d}	26.67	24.40
T_{4}- *Beauveria bassiana* (2×10^{8} cfu/g)	2×10^{11} cfu	2.22 (5.34)	20.00 (26.52)^{f}	21.11 (27.26)^{cd}	34.44 (35.91)^{ef}	41.11 (39.84)^{de}	29.17	17.32
T_{5}- Seedling dip with Imidacloprid 200 SL	-	0.00 (0.52)	7.78 (16.12)^{bc}	16.67 (24.02)^{bc}	31.11 (33.90)^{de}	36.67 (37.25)^{d}	23.06	34.64
T_{6}- Thiamethoxam 25 WG	25.00	1.11 (3.86)	4.44 (12.00)^{a}	10.00 (18.01)^{a}	13.33 (21.31)^{ab}	14.44 (22.30)^{a}	10.56	70.07
T_{7}- Diafenthiuron 50 WP	312.50	0.00 (0.52)	4.44 (12.00)^{a}	8.89 (17.28)^{a}	11.11 (19.43)^{a}	17.78 (24.92)^{a}	10.56	70.07
T_{8}- Acetamaprid 20 SP	31.25	1.11 (3.86)	8.89 (17.12)^{c}	13.33 (21.31)^{ab}	18.89 (25.54)^{bc}	27.78 (31.75)^{bc}	17.22	51.19
T_{9}- Imidacloprid 30.50 SC	37.50	1.11 (3.86)	6.67 (14.64)^{b}	10.00 (18.28)^{a}	15.56 (22.91)^{ab}	21.11 (27.26)^{ab}	13.33	62.21

T_{10}- Untreated control	-	3.33 (8.66)	21.11 (27.33)^{f}	32.22 (34.58)^{e}	41.11 (39.88)^{f}	46.67 (43.09)^{e}	35.28	-
S.Em±		-	0.699	1.781	1.759	1.679	-	-
CD (p=0.05)		NS	2.075	5.297	5.226	4.995	-	-

Mean per cent disease incidence values in parenthesis indicate Arc sine transformed values
Figures in each column followed by same alphabet (s) are not significantly different (P=0.05)
NS- Non significant



A. Thrips infestation



B. GBNV Disease incidence

T_1- Azadirachtin 10,000 ppm
T_2- NSKE 5%
T_3- *Lecanicillium lecanii* (2×10^8 cfu/g)
T_4- *Beauveria bassiana* (2×10^8 cfu/g)
T_5- Seedling dip with Imidacloprid 200 SL
T_6- Thiamethoxam 25 WG
T_7- Diafenthiuron 50 WP
T_8- Acetamaprid 20 SP,
T_9- Imidacloprid 30.50 SC and
T_{10}- Untreated control

Fig 1: Efficacy of botanicals, bio-pesticides and chemical insecticides against thrips infestation and Groundnut bud necrosis viral disease on tomato after four rounds of spraying

Conclusion

Among the different insecticides evaluated, thiamethoxam 25WG @ 0.20 g/l and diafenthiuron 50 WP @ 1.25 g/l were found to be superior in reducing both thrips population and GBNV disease incidence as compared to other insecticides tested. Among the botanicals and bio-pesticides evaluated, azadiractin 10,000 ppm @ 1.00 ml/l and *Lecanicillium lecanii* (2×10^8 cfu/g) @ 2.00 g/l were found to be effective.

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