International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2024; SP-9(1): 248-252

https://www.mathsjournal.com
Received: 13-12-2023
Accepted: 16-10-2024

Efficacy of different modules against major sucking pests of tomato

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Abstract
A field trial was conducted during 2023 on the farmer's field, A/P Tardal, Tal- Hatkanangale, Dist - Kolhapur, Maharashtra, India to evaluate the efficacy of different modules against major sucking pests i.e. aphids, thrips and whitefly on tomato. Among the different modules evaluated, module M1 (Root treatment with Imidacloprid 17.8 SL @ 0.25 ml/l water for 30 minutes + Spraying of *Lecanicillium lecanii* @ 5 g/l at ETL of pests + Spraying of Spinosad 45% SC @ 0.5 ml/l at 15 days after first spray + Spraying of HaNPV @ 1 ml/l at 15 days after second spray) found to be superior in reducing sucking pest population.

Keywords: Efficacy, imidacloprid, *Lecanicillium lecanii*, Spinosad

Introduction

Tomato (*Lycopersicon esculentum* Miller) holds significant importance as a vegetable crop with widespread cultivation globally, forming a staple in the daily diet of a majority of people (Hussain and Bilal, 2007) [6]. In India, it ranks as the second most crucial vegetable crop, cultivated throughout the country in all seasons, namely *Kharif*, *Rabi*, and summer. The extensive cultivation of tomatoes spans approximately 8.31 lakh hectares, resulting in a production of 206.2 lakh tonnes annually. Major contributors to tomato cultivation in India include Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka, West Bengal, and Odisha (Anonymous, 2023) [1].

Tomatoes are particularly susceptible to insect pests and diseases, a characteristic attributed to their delicate and soft composition in comparison to other crops. The tomato ecosystem faces significant challenges from both major and minor pests. Among the notable pests affecting tomatoes are the fruit borer (*Helicoverpa armigera* Hubner), two-spotted mite (*Tetranychus urticae*), beet armyworm (*Spodoptera exigua* Hubner), common armyworm (*Spodoptera litura* Fabricius), whitefly (*Bemisia tabaci* Gennadius), aphid (*Aphis gossypii* Glover), and leaf miner (*Liriomyza trifolii* Burgess). On a global scale, the tomato pinworm (*Tuta absoluta* Meyrick) is recognized as a highly destructive invasive pest that significantly impacts tomato crops. (Rawat, 2020) [10].

Sap-sucking insects, including thrips, aphids, whiteflies, and jassids, pose a threat to tomato plants on a global scale. These insects extract leaf sap by feeding on the plant's phloem tissue and secrete saliva containing enzymes such as pectinases, cellulases, phenol oxidases, and peroxidases at feeding sites. The enzymatic action contributes to the breakdown of host cells, facilitating insect infestation. Moreover, these sap-sucking insects act as primary vectors for viral diseases, and their feeding activities manifest in symptoms like leaf curling, withering, leaf droppings, and premature fruit drop (Shahrin *et al*., 2021) [15]. Given the substantial damage caused by these pests to tomato crops and the existing management practices, the present study aims to evaluate the efficacy of different methods against sap-sucking pests affecting tomatoes.

Material and Methods

An experiment was conducted during summer, 2023 on the farmer's field, A/P Tardal, Tal-Hatkanangale, Dist-Kolhapur, and Maharashtra, India.

The experiment was laid out in Randomized Block Design (RBD). There were nine modules with three replications. Tomato cultivar Ansal seedlings, were transplanted in the main field with a plot size of 4.0 X 3.0 m and spacing of about 65 × 45 cm on 31st January 2023. Irrigation was provided through drip immediately after transplanting. Seedling root dip was imposed while transplanting and the other treatments were imposed according to the schedule. Module details given in table 1.

Table 1: Module details

Modules	Module Details
M1	Root treatment with Imidacloprid 17.8SL @ 0.25 ml /l water for 30 minutes + Spraying of *Lecanicillium lecanii* @ 5 g/l at ETL of pests + Spraying of Spinosad 45% SC @ 0.5 ml/l at 15 days after first spray + Spraying of HaNPV @ 1 ml/l at 15 days after second spray
M2	Dipping of seedlings in Thiamethoxam 25 WG @ 1 gm/l 3 hrs before transplanting + Erection of yellow sticky traps (2 traps @ 100 m^2) after appearance of pests + Spraying of Chlorantraniliprole 18.5 SC @ 0.5 ml/l + Spraying of *Bacillus thuringiensis kurstaki* @ 1.25 ml/l at 15 days after first spray
M3	Planting of marigold as a trap crop + Foliar spray of NSE 5% at ETL of pests + Spraying of *Metarhizium anisopliae* @ 5 g/l at 15 days after first spray + Spraying of Spinosad 45% SC @ 0.5 ml/l at 15 days after second spray
M4	Installation of pheromone trap @ 1 trap/350 m^2 + Spraying of *Metarhizium anisopliae* @ 5 g/l at ETL of pests + Spraying of entomopathogenic nematodes @ 10 g/l at 15 days after first spray + Spraying of Dimethoate 30 EC @ 2 ml/l at 15 days after second spray
M5	Planting of beans as a trap crop + Release of *Trichogramma chilonis* adults @ 16000/ha + Spraying of Lambda cyhalothrin 5% EC @ 1.33 ml/l + Spraying of Flubendamide 39.35SC @ 0.2 ml/l at 15 days after first spray
M6	Spraying of *Beauveria bassiana* @ 5 g/l at ETL of pests + Spraying of Dimethoate 30 EC @ 2 ml/l at 15 days after first spray + Spraying of Lambda cyhalothrin 5% EC @ 1.5 ml/l at 15 days after second spray + Spraying of Tetraniliprole SC 200 @ 0.5 ml/l at 15 days after third spray
M7	Foliar spray of *Lecanicillium lecanii* @ 5 g/l at ETL of pests + Foliar spray of NSE 5% @ 1 ml/ at 15 days after first spray + Spraying of Chlorantraniliprole 18.5 SC @ 0.4 ml/l at 15 days after second spray + Spraying of Tetraniliprole SC 200 @ 0.5 ml/l at 15 days after third spray
M8	Spraying of *Metarhizium anisopliae* @ 5 g/l at ETL of pests + Spraying of Dimethoate 30 EC @ 2 ml/l at 15 days after first spray + Spraying of HaNPV @ 1ml/l at 15 days after second spray + Spraying of Flubendamide 39.35 SC @ 0.2 ml/l 15 days after third spray
M9	Untreated Control

Insecticides Application

The sprays of insecticides were applied with the help of battery-operated knapsack sprayer. The quantity of spray fluid required for treating the crop per plot was calculated by spraying untreated control plot with water. The quantity of each insecticidal formulation was worked out and mixed in required quantity of water. Care was taken to cover all plants parts thoroughly while spraying and to avoid the drift to the neighbouring plots. Spraying was done in the morning and care was taken to wash the pump with water while switching on from one insecticide to another. Total four sprayings were given. First spraying was given 20 DAT, second 30 DAT, third 45 DAT, and last spraying was given at 60 DAT.

4.2 Method of recording observations

Observations on the population of sucking pests were recorded from five randomly selected plants per plot which was tagged after selecting for this purpose. The number of sucking pests namely aphids, thrips and whiteflies were recorded from three leaves (top, middle and bottom) per plant. Observations were recorded one day before spray and 30, 40, 55 and 70 days after transplanting. (Chakraborthy *et al.*, 2011) [3] The percent reduction in pest population over control was calculated by using following formula.

$$\text{Per cent reduction in population} = \frac{X1\text{-}X2}{X1} \times 100$$

Where, X1 = population in control plots
X2 = population in treated plots

Statistical analysis

Statistical analysis of data was carried out as per the analysis of variance technique given by Panse and Sukhatme (1967).

Results and Discussions

The results obtained during the course of investigations are presented under the following heads.

Effect of different modules on aphids (*Aphis gossypii* Glover) of tomato

The data regarding the mean survival population of aphids on tomatoes, one day before and 30, 40, 55 and 70 days after transplanting are outlined in Table 2 and graphically depicted in fig.1. All modules demonstrated significant efficacy in reducing aphid populations when observations were recorded at 30 days after transplanting (DAT). Among the modules, module M1 demonstrated the highest effectiveness with 4.13 aphids per leaf, which was at par with module M2 (5.24 aphids per leaf) and module M6 (6.20 aphids per leaf). The maximum survival population of aphids was observed in module M7 (8.75 aphids per leaf) compared to the untreated control (18.75 aphids per leaf).

At 40 DAT, module M1 exhibited significantly superior performance compared to the other modules, recording a survival population of 5.09 aphids per leaf. Module M6 (6.15 aphids per leaf) and M2 (6.40 aphids per leaf) were found to be at par with module M1 and ranked next in terms of efficacy.

At 55 DAT, module M1 emerged as the most effective, registering a survival population of 4.97 aphids per leaf. Module M2 (6.31 aphids per leaf) and module M5 (6.57 aphids per leaf) followed in order of efficacy. The maximum survival population of aphids was noted in module M7 (10.04 aphids per leaf) among the modules, compared to the untreated control M9 (16.28 aphids per leaf).

At 70 DAT, module M1 emerged as the most effective, recording a survival population of 6.31 aphids per leaf. Module M2 (6.95 aphids per leaf) and module M5 (9.26 aphids per leaf) followed in order of efficacy. The maximum survival population of aphids was observed in module M3 (11.78 aphids per leaf) among the modules, compared to the untreated control M9 (16.97 whiteflies per leaf).

Considering the overall performance of all the modules, it was observed that they showed notable superiority over the control in decreasing the aphid population. Module M1 demonstrated the highest efficacy with 5.12 aphids per leaf. The next promising modules were M2 (6.22 aphids per leaf), M5 (7.75 aphids per leaf), and M6 (7.89 aphids per leaf), which were effective in the subsequent order of efficacy. Module M7 (9.94 aphids per leaf) was found to be the least effective.

The module M1 and M2 demonstrated the highest percentage reduction of aphids over the control, i.e., 70.37 percent and 64.00 percent, respectively. Module M5 showed a 55.14 percent reduction of aphids over the control in the next order of efficacy. Module M7 (42.48 percent) was relatively less effective in controlling the aphids.

All the evaluated modules demonstrated a significant effectiveness in reducing the aphid population compared to the control. Consistent with the current findings, Mahendiran *et al*., (2015) [9] also documented the efficacy of module M1, consisting of imidacloprid 17.8 SL against aphids.

Wade *et al*., (2020) [18] found that the treatment with *L. lecanii* at a concentration of 5 ml/l was the most effective treatment for aphids, resulting in 1.47 aphids per 3 leaves and it also recorded a significant increase in tomato yield compared to other treatments. Kaur and Singh (2013) [8] reported that imidacloprid 17.8 SL at a concentration of 0.3 ml/l was an effective treatment at 10 days after spray, resulting in 123.08 aphids per 15 leaves, which aligns with our findings.

Table 2: Effect of different modules on aphids (*Aphis gossypii* Glover)

Module	Mean survival population of aphids/leaf						Percent Reduction over control
	Precount	30 DAT	40 DAT	55 DAT	70 DAT	Mean	
M1	9.66 (3.19)	4.13 (2.11)	5.09 (2.32)	4.97 (2.33)	6.31 (2.61)	5.12 (2.37)	70.37
M2	10.15 (3.26)	5.24 (2.39)	6.40 (2.62)	6.31 (2.60)	6.95 (2.71)	6.22 (2.59)	64.00
M3	12.37 (3.58)	7.89 (2.89)	9.08 (3.09)	9.66 (3.18)	11.78 (3.50)	9.60 (3.17)	44.47
M4	10.98 (3.38)	7.84 (2.87)	8.98 (3.06)	9.71 (3.18)	11.69 (3.49)	9.55 (3.17)	44.76
M5	10.78 (3.35)	7.11 (2.76)	8.09 (2.92)	6.57 (2.66)	9.26 (3.08)	7.75 (2.87)	55.14
M6	14.44 (3.86)	6.20 (2.59)	6.15 (2.57)	8.62 (3.01)	10.62 (3.33)	7.89 (2.89)	54.34
M7	13.26 (3.71)	8.75 (3.04)	9.49 (3.15)	10.04 (3.24)	11.51 (3.46)	9.94 (3.23)	42.48
M8	11.80 (3.51)	8.48 (2.96)	9.39 (3.11)	9.93 (3.20)	11.42 (3.39)	9.80 (3.21)	43.29
Untreated control	14.27 (3.84)	18.75 (4.36)	17.35 (4.21)	16.28 (4.07)	16.97 (4.17)	17.29 (4.21)	-
S.E. ±	0.064	0.195	0.197	0.199	0.221		
C.D. (5%)	NS	0.59	0.59	0.60	0.66		
C.V.		11.75	11.38	11.33	11.59		

DAT- Days after Transplanting, NS-Non significant, *Figures in the parentheses are square root transformed values

Effect of different modules on thrips (*Thrips tabaci* Lindeman) of tomato

The data regarding the survival population of thrips on tomatoes one day before and 30, 40, 55 and 70 days after transplanting are outlined in Table 3 and graphically depicted in fig.1. All the modules were significantly effective in reducing the population of thrips when observations were recorded at 30 days after transplanting (DAT). Module M1 was identified as the most effective, with 1.44 thrips per leaf, significantly superior to all other modules. Module M2 (1.75 thrips per leaf) and M6 (2.22 thrips per leaf) were equally effective as Module M1 and followed in order of efficacy. The maximum mean survival population of thrips was observed in module M5 (5.26 thrips per leaf) among the module treatments, compared to the untreated control (5.51 thrips per leaf).

At 40 DAT, module M1 was significantly superior to the other modules, recording 2.13 thrips per leaf. Module M2 (2.19 thrips per leaf) and M6 (2.53 thrips per leaf) were on par with module M1 and next in order of efficacy.

Observations at 55 DAT showed that all the modules were significantly superior to the control in reducing the thrips population. Module M1 was identified as the best module (2.11 thrips per leaf) followed by M2 (2.33 thrips per leaf) and M6 (3.66 thrips per leaf) in the next order of efficacy. However, modules M3 and M7 were the least effective, recording 4.77 and 4.66 thrips per leaf, respectively.

At 70 DAT, module M1 (2.51 thrips per leaf) was identified as the best module compared to other modules. Module M2 (2.69 thrips per leaf) and M6 (5.15 thrips per leaf) were next in order of efficacy. The maximum survival population of thrips was observed in module M3 (5.53 thrips per leaf) among the modules, compared to the untreated control (9.98 thrips per leaf).

Considering the overall performance of all the modules, they were significantly superior to the control in reducing the thrips population. Module M1 (2.04 thrips per leaf) was identified as the best treatment. The next promising module was M2 (2.23 thrips per leaf). Module M6 (3.39 thrips per leaf) and M5 (4.08 thrips per leaf) were equally effective in the next order of efficacy. Module M3 (4.74 thrips per leaf) was identified as the least effective.

Module M1 and M2 recorded the highest percentage reduction of thrips over the control, i.e., 72.86 percent and 70.33 percent, respectively, followed by M6 (55.01 percent), M5 (45.90 percent), and M4 (42.22 percent). All the tested modules were significantly effective over the control in reducing the thrips population. Similar to the present findings, the effectiveness of Module M1, consisting of imidacloprid 17.8 SL against thrips, was also reported by Sujatha *et al*., (2017) [17], Wagh *et al*., (2017) [19] and Sangle *et al*., (2017) [12].

The treatment with *L. lecanii* (2 X 10^8 cfu/g) at 2.00 g/l was found to be effective for thrips control among the botanicals and biopesticides and significantly increased tomato yield. Similar results regarding the effectiveness of this biopesticide against thrips were obtained earlier by Shruthi *et al*., (2021) [16]. Bambhaniya *et al*., (2018) [2] reported that imidacloprid at 0.005 percent gave very good results against sucking pests in tomatoes, confirming the present findings.

Table 3: Effect of different modules on thrips (*Thrips tabaci* Lindeman)

Module	Mean survival population of thrips/leaf						Percent Reduction over control
	Recount	30 DAT	40 DAT	55 DAT	70 DAT	Mean	
M1	4.55 (2.22)	1.44 (1.39)	2.13 (1.61)	2.11 (1.57)	2.51 (1.73)	2.04 (1.59)	72.86
M2	4.51 (2.21)	1.75 (1.49)	2.19 (1.63)	2.33 (1.65)	2.69 (1.78)	2.23 (1.65)	70.33
M3	4.57 (2.22)	4.64 (2.25)	4.04 (2.11)	4.77 (2.25)	5.53 (2.46)	4.74 (1.58)	37.07
M4	4.55 (2.22)	4.42 (2.19)	3.91 (2.08)	3.60 (2.00)	5.51 (2.45)	4.35 (1.38)	42.22
M5	4.37 (2.18)	5.26 (2.39)	5.55 (2.46)	2.40 (1.69)	3.11 (1.88)	4.08 (1.77)	45.90
M6	4.54 (2.21)	2.22 (1.65)	2.53 (1.74)	3.66 (2.03)	5.15 (2.37)	3.39 (1.47)	55.01
M7	4.53 (2.21)	4.57 (2.24)	4.35 (2.14)	4.66 (2.21)	5.20 (2.37)	4.69 (1.81)	37.73
M8	4.62 (2.21)	4.44 (2.19)	4.02 (2.08)	3.91 (2.06)	5.18 (2.38)	4.38 (1.89)	41.54
Untreated control	4.49 (2.20)	5.51 (2.44)	6.51 (2.61)	8.18 (2.83)	9.98 (3.18)	7.54 (2.64)	-
S.E. ±	0.023	0.147	0.146	0.139	0.165		
C.D. (5%)	NS	0.44	0.44	0.42	0.50		
C.V.		12.58	12.38	11.85	12.52		

DAT- Days after Transplanting, NS- Non-significant,*Figures in the parentheses are square root transformed values

Effect of different modules on whitefly (*Bemisia tabaci* Gennadius) of tomato: The data regarding the mean survival population of whiteflies on tomatoes one day before and 30, 40, 55, and 70 days after transplanting are presented in Table 4 and graphically depicted in fig.1. At 30 days after transplanting (DAT), all the modules were significantly superior in reducing the population of whiteflies. Module M1 was the most effective, recording 2.26 whiteflies per leaf, at par with Module M2 (2.33 whiteflies per leaf) and M6 (2.51 whiteflies per leaf). Module M4 had the highest survival population of whiteflies (4.51 whiteflies per leaf) among the modules, compared to the untreated control (8.31 whiteflies per leaf).

At 40 DAT, Module M1 remained significantly superior, with a survival population of 3.36 whiteflies per leaf. Module M2 (3.48 whiteflies per leaf) and M6 (5.33 whiteflies per leaf) were at par with Module M1 and followed in order of efficacy.

At 55 DAT, Module M1 continued to be the best, recording a survival population of 1.04 whiteflies per leaf. Module M2 (1.06 whiteflies per leaf) and Module M5 (1.82 whiteflies per leaf) were next in order of efficacy. Module M8 had the maximum survival population of whiteflies (2.31 whiteflies per leaf) among the modules, compared to untreated control Module M9 (9.91 whiteflies per leaf).

At 70 DAT, Module M1 was identified as the best module, recording a survival population of 4.35 whiteflies per leaf. Module M2 (4.66 whiteflies per leaf) and M6 (4.82 whiteflies per leaf) followed in order of efficacy. Module M5 had the maximum survival population of whiteflies (8.42 whiteflies per leaf) among the modules, compared to untreated control Module M9 (9.42 whiteflies per leaf).

Considering the overall performance of all the modules, they were significantly superior to the untreated control in reducing the whitefly population. Module M1 (2.75 whiteflies per leaf) was identified as the best module. The next promising modules were M2 (2.88 whiteflies per leaf), M6 (3.37 whiteflies per leaf), and M8 (4.99 whiteflies per leaf), effective in the next order of efficacy. Module M5 (5.21 whiteflies per leaf) was identified as the least effective.

Module M1 and M2 recorded the highest percentage reduction of whiteflies over the control, i.e., 71.26 percent and 69.90 percent, respectively. Module M6 showed a 61.08 percent reduction of whiteflies over the control in the next order of efficacy. Module M5 (45.55 percent) was relatively less effective in controlling the whitefly.

All the tested modules were significantly effective over the control in reducing the whitefly population. Similar to the present findings, the effectiveness of Module M1, consisting of imidacloprid 17.8 SL and *L. lecanii* against whiteflies, was also reported by Gosalwad *et al*., (2015) [5] and Kar (2017) [7].

The treatment with imidacloprid 17.8 SL was found to be the most effective treatments for whiteflies and recorded a significantly increased yield of tomatoes. Similar results regarding the effectiveness of these insecticides against this pest were obtained earlier by Sarangdevot *et al*., (2006) [13], Zawrah *et al*., (2020) [20] and Das and Islam (2014) [4].

Kar (2017) [7] reported that imidacloprid at 175 ml/ha was the most effective treatment with 100 percent control of pest population at 5 days after spray and also with a minimum population at 10 and 15 days after spray, confirming our findings. The treatment with chlorantraniliprole 185 SC at 30 g a.i. /ha was found to be the next effective treatment in controlling *B. tabaci* and preventing transmission of the begomovirus Tomato yellow leaf curl virus (TYVMV). These results are confirmatory and have been recommended by Schuster *et al*., (2013) [14].

Table 4: Effect of different modules on whitefly (*Bemisia tabaci* Gennadius)

Module	Mean survival population of whitefly/leaf						Percent Reduction over control
	Precount	30 DAT	40 DAT	55 DAT	70 DAT	Mean	
M1	5.04 (2.35)	2.26 (1.66)	3.36 (1.95)	1.04 (1.24)	4.35 (2.20)	2.75 (1.54)	71.26
M2	5.64 (2.47)	2.33 (1.68)	3.48 (1.99)	1.06 (1.25)	4.66 (2.27)	2.88 (1.83)	69.90
M3	5.13 (2.36)	3.95 (2.10)	5.93 (2.52)	2.18 (1.63)	7.98 (2.90)	5.00 (2.43)	47.75
M4	5.40 (2.41)	4.51 (2.23)	5.75 (2.50)	2.15 (1.63)	7.93 (2.89)	5.08 (2.30)	46.96
M5	5.47 (2.43)	4.26 (2.18)	6.37 (2.62)	1.82 (1.51)	8.42 (2.97)	5.21 (2.17)	45.55
M6	5.71 (2.48)	2.51 (1.73)	5.33 (2.40)	2.26 (1.66)	4.82 (2.30)	3.37 (2.00)	61.08
M7	5.42 (2.42)	4.31 (2.19)	5.77 (2.50)	2.24 (1.65)	8.00 (2.91)	5.10 (2.30)	46.99
M8	5.57 (2.46)	4.29 (2.19)	5.60 (2.46)	2.31 (1.67)	7.78 (2.86)	4.99 (2.34)	47.91
Untreated control	5.66 (2.48)	8.31 (2.92)	10.71 (3.33)	9.91 (3.20)	9.42 (3.10)	9.58 (2.73)	-
S.E.±	0.079	0.144	0.162	0.117	0.179		
C.D. (%)	NS	0.43	0.49	0.35	0.54		
C.V.		11.94	11.37	11.90	11.46		

DAT- Days after Transplanting, NS-Non-significant, *Figures in the parentheses are square root transformed values

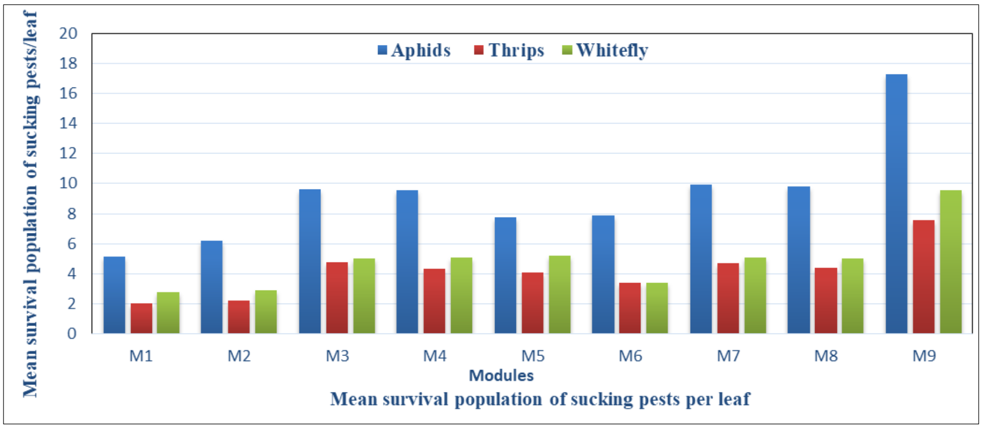

Fig 1: Graphical representation of effect of different modules on sucking pest population

Conclusion

The studies carried out on efficacy of different modules on pests of tomato revealed that the module M1 (5.12 aphids/leaf) was found most superior in reducing population of aphids. The next best modules were M2 (6.22 aphids/leaf) and M5 (7.75 aphids/leaf). The module M1 (2.04 thrips/leaf) was found most superior in reducing population of thrips. The next best modules were M2 (2.23 thrips/leaf) and M6 (3.39 thrips/leaf). The module M1 (2.75 white flies/leaf) was found most superior in reducing population of whitefly. The next best modules were M2 (2.88 white flies/leaf) and M6 (3.37 white flies/leaf).

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