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Population dynamics and management of aphid (*Aphis gossypii* Glover) in bitter gourd (*Momordica charantia* L.)

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ABSTRACT: Bitter gourd (*Momordica charantia* L.) is an important cucurbitaceous vegetable cultivated widely in India, valued for its high nutritive and medicinal properties. However, its productivity is severely constrained by insect pests, particularly aphids (*Aphis gossypii*), fruit fly (*Dacus cucurbitae*), red pumpkin beetle (*Aulacophora foveicollis*), epilachna beetle (*Henosepilachna vigintioctopunctata*), and others. Among these, aphids not only cause direct damage through sap feeding also act as vectors of viral diseases, resulting in significant yield reduction. A field survey was conducted at Kadachanenthal and Vadipatti in Madurai district from August to June to study the population dynamics of aphids and their correlation with abiotic factors. Aphid incidence showed significant variation between locations. The maximum population (5.28 aphids/3 leaves) was recorded during the third week of April at Kadachanenthal, while the lowest (0.69 aphids/3 leaves) was observed during the second week of October at Vadipatti. Maximum temperature exhibited a significant positive correlation, whereas rainfall showed a negative correlation with aphid population. Two field experiments were conducted to evaluate the efficacy of newer insecticide molecules and biopesticides against aphids in bitter gourd under randomized block design. Among the newer insecticides, Spinosad 45% SC @ 160 ml/ha proved most effective, recording the lowest aphid population (1.56 aphids/3 leaves) and 93.6 per cent reduction over control. Chlorantraniliprole 18.5 SC @ 150 ml/ha was the next best treatment. Among biopesticides, Neem Seed Kernel Extract (NSKE) 5% and neem oil 3% significantly reduced aphid population, recording 84.80 and 82.81 per cent reduction over control, respectively, and were comparable to the standard check, malathion. The study concludes that spinosad is highly effective among newer insecticides, while NSKE 5% offers an eco-friendly and safer alternative for aphid management in bitter gourd, helping to reduce reliance on synthetic insecticides and conserve pollinators.

Keywords: Bitter gourd, Aphids, Spinosad, NSKE

INTRODUCTION

Bitter gourd (*Momordica charantia* L.; Cucurbitaceae), is one of the important cucurbitaceous vegetables grown in India. In terms of nutritive value, it ranks first among cucurbits, being rich in iron, phosphorus and ascorbic acid (Awasthi and Jaiswal, 1986). Numerous medicinal uses have been documented or claimed particularly, with reference to diabetes treatment (Grover *et al.*, 2002) and prevention of breast cancer (Ray *et al.*, 2010). The presence of secondary metabolites such as alkaloids, saponins, tannins, glycosides and cardiac glycosides in the *M. charantia* may contribute to its medicinal value. Bitter gourd has good export potential and its share in export of green vegetable is to the extent of 20 per cent (Anonymous, 1992).

Insect pests are the major constraints for increasing the production and productivity of this crop. It is attacked by several insect pests during different growth stages, which include melon fruit fly, *Dacus cucurbitae* (Coquillett), Hadda beetle, *Henosepilachna vigintioctopunctata* (Fab.), pumpkin beetle, *Aulacophora foveicollis* (Lucas.), pumpkin caterpillar, *Diaphania indica* (Sounders), snake gourd semilooper, *Plusia peponis* (Fab.)., blister beetle, *Mylabris pustulata* (Thunberg), whitefly, *Bemisia tabaci* (Genn.), stink bugs, *Apspongopus* spp. Thunberg and flea beetle, *Phyllotreta* spp. (Goeze), thrips, *Thrips palmi Karny* and mites *Tetranychus urticae* (Koch).

The fruit fly, *D. cucurbitae* which attacks the ultimate economic part, *i.e.* fruits of the crop, is one of the most important biotic limiting factors and alone can inflict yield loss in different cucurbitaceous vegetables ranging from 30-100% depending upon the cucurbit species and the season (Dhillon *et al.*, 2005), (Shooker *et al.*, 2006). *Diaphania indica* is an oligophagous pest of Cucurbitaceae (Ayyar, 1940). Though principally a leaf feeder, the pumpkin caterpillar is also known to infest flowers, new tender shoots and young and mature fruits. Attack on fruits reduces their commercial value, leading to huge crop losses during outbreaks (Choi *et al.*, 1990). *Henosepilachna vigintioctopunctata* is one of the major pests of bitter gourd (Mahalya and Jesudasan, 1996). In case of severe infestation, the grub and adults were reported to cause 45-75 per cent defoliation to this crop (Shukla and Upadhyay, 1987). Among different species of pumpkin beetles, incidence of adult stage of red pumpkin beetle (RPB), *A. foveicollis* on different cucurbits have been reported by various workers (Nath, 1964); (Nath and Thakur, 1965); (Bogawat and Pandey, 1967).) Percent damage rating gradually decreases from 70-15% as the leaf canopy increases (Rahaman and Prodhan, 2007). The role of whitefly is more important as a vector of yellow mosaic virus in bitter gourd than its direct damage as a sucking pest. The disease attains significance because the virus is capable of infecting the crop in all the stages of its growth period (Rajinimala et al., 2005).

Number of aphid species that attack cucurbits including melon aphid *Aphis gossypii*, (Glover), cowpea aphid *Aphis craccivora* (Koch), potato aphid *Macrosiphum euphorbiae* (Venkatesh *et al.* 2023) and green peach aphid *Myzus persicae* (Sulzer) (Napier, 2009). Aphids usually feed on the underside of leaves, but can attack the soft growing tips. Large populations in a seedling crop can cause leaves to curl and premature death of the leaf or growing tip. In older crops vine development is retarded and yield can be reduced. The melon aphid is the main vector of the mosaic virus while the other aphid species are minor vectors.

In order to overcome these escalating insect pest problems farmers solely relay on pesticides. Frequent application and large-scale use of insecticides for the control of these pests led to the endangerment of ecosystem including pollinators.

Many horticultural crops are dependent on insect pollination, and better pollination results in higher yields (McGregor, 1976); (Free, 1993); (Klein *et al.*, 2007), bitter gourd always requires pollinating insects for effective pollination and better fruit and seed setting (Ashworth and Galetto, 2002. Honey bees (*Apis mellifera* and *A. cerana indica*) are the major floral visitors of bitter gourd in the Philippines along with some solitary bees (*Trigona* sp. and *Halictus* sp.) (Rodelina and Cervanica, 2009). So, it is necessary to protect pollinators from hazardous chemical insecticides.

MATERIALS AND METHODS

Survey

Periodic field surveys were conducted at weekly intervals from August to June 2017 - 2018 in the bitter gourd-growing areas of Madurai district, namely Kadachanenthal and Vadipatti. During each survey, the populations of key insect pests and pollinators were recorded from ten randomly selected plants in farmers' fields. Plants were examined starting from seven days after germination till crop maturity. Data on weather parameters, maximum and minimum temperatures (^{0}C) relative humidity (%) and rainfall (mm) was recorded during the study period. Abiotic factors were correlated with incidence of key pests and pollinators. The significant correlation between incidence and weather factors was further subjected for regression analysis. Pest populations were assessed at weekly intervals using pest-specific sampling methods. For leaf-eating caterpillars, the population was recorded as the number of larvae per plant. The populations of red pumpkin beetle and epilachna beetle were assessed by counting the total number of adults present on the entire plant and expressed as number per plant. For melon fruit fly, the population was estimated as the mean number of flies captured per trap per day.

Two field experiments were conducted in the farmer's holdings one at Kadachanenthal and another one at Vadipatti, Madurai District to evaluate the efficacy of newer insecticide molecules against the key pests of bitter gourd. All the agronomic practices were adopted uniformly for all the treatments. The details of the field experiments are as below.

The field experiments were conducted using two hybrids, Akash and Asmita, during two seasons. Field Experiment I was conducted with Akash from August to December 2017 at Kadachanenthal, Madurai East, while Field Experiment II was conducted with Asmita from January to May 2018 at Vadipatti, Madurai West. Eight treatments were evaluated in a Randomized Block Design with three replications, using a spacing of 5 × 3 m.

Treatments

Name of the insecticides	Dosage g/ml/ha	Sources
Chlorantraniliprole 18.5% SC	125	Dupont India pvt ltd.,
Chlorantraniliprole 18.5 % SC	150	Dupont India pvt ltd.,
Spinosad 45 % SC	160	Dow agro sciences India Pvt.ltd.
Imidacloprid 17.8 % SL	250	Insecticides (India) limited
Spiromesifen 22.9 % SC	500	Bayer crop science limited
Thiodicarb 75 % WP	750	Bayer crop science limited
Standard check Malathion 50% EC	500	Hindustan insecticides ltd.,
Untreated check		

The above newer insecticide molecules were purchased from pesticide shop in Madurai.

Time and Method of application

The first spray was given after the new flush formation and when damage by key pests reached ETL level (10–15% of plants infested, or 20–25 aphids per leaf) and thereafter another spray was given at 15 days interval with a high volume sprayer using 500 lit of spray fluid per ha. The control plot was maintained without any spraying. The above observations of insect pests and natural enemies were recorded on prior to spraying and 3rd,7th,10th and 14th days after spraying and the percent reduction over control was worked out using the formula

$$\text{Reduction (\%)} = \frac{\text{Population in the control} - \text{Population in the treatment}}{\text{Population in the control}} \text{ X } 100$$

Assessment of pest damage / population

Aphids *Aphis gossypii*

In each plant, three leaves representing top, middle and lower portions were selected. The total number of nymphs and adults on each leaf was counted and it was computed as mean population per three leaves in randomly selected ten plants.

To evaluate the efficacy of biopesticides against Aphids in Bitter gourd

Two field experiments were conducted in the farmer's holdings one at Vadipatti and another one at Malayalathanpatti, Madurai District to evaluate the efficacy of biopesticides against the key pests of bitter gourd. All the agronomic practices were adopted uniformly for all the treatments. The details of the field experiments are as follows.

The field experiments were conducted using the Asmita hybrid during two seasons. Field Experiment I was conducted from August to December at Vadipatti, while Field Experiment II was conducted from January to May 2018 at Malayalathanpatti. Nine treatments were evaluated in a Randomized Block Design (RBD) with three replications, using a spacing of 5 × 3 m

Treatments

Treatment Details	Sources
Neem Seed Kernel Extract (NSKE) @5%	-
Neem oil 3%	Madras fertilizer limited, Chennai.
Notchi (*Vitex negundo*) leaf extract @ 10%	-

Neem soap @ 10 g/litre of water	IIHR, Bangalore
Pungam Soap @ 10 g/litre of water	IIHR, Bangalore
Bt @ 2g/litre of water	Purchased from Pondicherry KVK
Metarhizium anisopliae -1x10^8 CFU/ ml	Agriya agrotech pvt ltd., (Metalin)
Malathion 50 EC@ 500ml/ha Standard check	Hindustan insecticides ltd., (Hilmala)
Untreated check	

Preparation of Neem Seed Kernel Extract (NSKE) 5%

A pulverizer was used to powder the dry neem kernel. Five kilos of pulverized neem seed powder was soaked in 10 liters water at overnight, filtered through double layered khada cloth and the volume was made up to 5 % by adding water. (NSKE solution was applied through high volume sprayer after adding Teepol 0.1 %.). NSKE 5 per cent were sprayed twice at an interval of fifteen days.

Preparation of Notchi (*Vitex negundo*) leaf extract @10 %

Notchi leaf was dried under shade and powdered by using electric grinder and pass through a 20 mesh sieve and kept in a polypropylene bag. 300g of each powdered material was taken into a 2 litre capacity conical flask and 1000 ml distilled water was added and homogenized for 15 min then allowed to settle for 24 h. The extract was separated using fine muslin cloth and then filtered. This filtrate was sprayed twice at an interval of fifteen days.

RESULTS AND DISCUSSION

Population dynamics of Aphids in Bitter gourd in Madurai district

Aphids

A significant difference was observed on the seasonal incidence of aphids in two locations of Madurai district (Table 1). Maximum population (5.28/ 3 leaves) was recorded during third week of April in Kadachanenthal and minimum (1.18) during first week of May. In Vadipatti maximum population was noticed during first week of June (4.86/ 3 leaves) and lowest during second week of October (0.69/ 3 leaves). Correlation analysis revealed that in Kadachanenthal, maximum temperature had a highly significant positive association with aphid population, whereas rainfall was significantly negatively correlated. In contrast, at Vadipatti, only rainfall exhibited a negative correlation with aphid population, while no significant effects were observed for the other weather parameters (Table 1).

Efficacy of newer molecular insecticides against aphids, *Aphis gossypii* in bitter gourd

The aphid population varied significantly in various treatments at all the periods of observation. On 3 DAS, significantly less aphid population was recorded in plots treated with Chlorantraniliprole 18.5 SC @ 150ml/ha (4.20 no./3 leaves) and Spinosad 45 % SC @ 160 ml/ha (4.40 no./3 leaves) statistically on par with each other. The next treatments in descending order of effectiveness were Chlorantraniliprole 18.5 SC @ 125 ml/ha (6.50 no./3 leaves) and Imidacloprid 17.8 SL @ 250ml/ha (6.85 no./3 leaves). While computing through all periods of observation, Spinosad 45 % SC @ 160 ml/ha was found to be effective in reducing the aphid population (1.71 no. / 3 leaves). The corresponding per cent reduction over control was 93.6. This was followed by Chlorantraniliprole 18.5 SC @ 150ml/ha (1.94 no./ 3 leaves) and Chlorantraniliprole 18.5 SC @ 125 ml/ha (2.73 no./3 leaves) with the corresponding per cent reduction of 89.88 and 89.79 respectively (Table 2).

The overall results revealed that, the treatment Spinosad 45 % SC @ 160 ml/ha was found consistently effective in reducing the aphid population as it harboured 1.56 aphids / 3 leaves as against 29.32 aphids/ 3 leaves in untreated control respectively. In order of effectiveness, Chlorantraniliprole 18.5 SC @ 150ml/ha (2.83 no./ 3 leaves) and Chlorantraniliprole 18.5 SC @ 125 ml/ha (2.95 no./3 leaves) treatments were proved to be the next alternative in field experiment II (Table 3).

Efficacy of biopesticides against aphids in bitter gourd (Field Experiment I and II)

Aphids

The population of aphids differed significantly due to various treatments in all periods of observation (Table 4).

Table 1: Seasonal incidence of key insect pests of bitter gourd in Madurai district

SMW	Month	Mean No. of aphids / 3 leaves	
		Kadachanenthal	Vadipatti
1	Jan 1 to Jan 7	2.43 (1.56)	3.45 (1.86)
2	Jan 8 to Jan 14	2.61 (1.62)	4.29 (2.07)
3	Jan 15 to Jan 21	4.37 (2.09)	1.78 (1.33)
4	Jan 22 to Jan 28	1.89 (1.37)	4.23 (2.06)
5	Jan 29 to Feb 4	3.76 (1.94)	4.64 (2.15)
6	Feb 5 to Feb 11	3.98 (1.99)	4.42 (2.10)
7	Feb 12 to Feb 18	4.77 (2.18)	4.86 (2.20)
8	Feb 19 to Feb 25	5.21 (2.28)	0.98 (0.99)
9	Feb 26 to Mar 4	4.85 (2.20)	2.8 (1.67)
10	Mar 5 to Mar 11	4.72 (2.17)	2.49 (1.58)
11	Mar 12 to Mar 18	4.94 (2.22)	0.98 (0.99)
12	Mar 19 to Mar 25	4.71 (2.17)	1.65 (1.28)
13	Mar 26 to Apr 1	4.65 (2.16)	1.43 (1.20)
14	Apr 2 to Apr 8	4.72 (2.17)	1.29 (1.14)
15	Apr 9 to Apr 15	2.68 (1.64)	1.18 (1.09)
16	Apr 16 to Apr 22	5.28 (2.30)	4.43 (2.10)
17	Apr 23 to Apr 29	1.29 (1.14)	1.86 (1.36)
18	Apr 30 to May 6	1.18 (1.09)	3.96 (1.99)
19	May 7 to May 13	2.35 (1.53)	3.64 (1.91)
20	May 14 to May 20	4.26 (2.06)	2.51 (1.58)
21	May 21 to May 27	3.85 (1.96)	4.55 (2.13)
22	May 28 to June 4	3.39 (1.84)	4.86 (2.20)
23	June 5 to June 11	4.64 (2.15)	4.53 (2.13)
31	Aug 1 to Aug 7	2.39 (1.55)	2.72 (1.65)
32	Aug 8 to Aug 14	1.62 (1.27)	2.37 (1.54)
33	Aug 15 to Aug 21	3.43 (1.85)	3.15 (1.77)
34	Aug 22 to Aug 28	4.21 (2.05)	2.74 (1.66)
35	Aug 29 to Sep 5	4.26 (2.06)	1.25 (1.12)
36	Sep 4 to Sep 10	2.65 (1.63)	1.23 (1.11)
37	Sep 11 to Sep 17	3.64 (1.91)	2.84 (1.69)
38	Sep 18 to Sep 24	3.58 (1.89)	1.19 (1.09)
39	Sep 25 to Oct 1	3.25 (1.80)	2.97 (1.72)
40	Oct 2 to Oct 8	2.64 (1.62)	0.69 (0.83)

41	Oct 9 to Oct 15	3.82 (1.95)	0.72 (0.85)
42	Oct 16 to Oct 22	3.29 (1.81)	2.54 (1.59)
43	Oct 23 to Oct 29	1.37 (1.17)	2.23 (1.49)
44	Oct 30 to Nov 5	1.25 (1.12)	0.72 (0.85)
45	Nov 6 to Nov 12	2.86 (1.69)	4.29 (2.07)
46	Nov 13 to Nov 19	1.22 (1.10)	1.47 (1.21)
47	Nov 20 to Nov 26	4.35 (2.09)	1.68 (1.30)
48	Nov 27 to Dec 3	2.63 (1.62)	0.85 (0.92)
49	Dec 4 to Dec 10	3.92 (1.98)	0.71 (0.84)
50	Dec 11 to Dec 17	1.42 (1.19)	1.29 (1.14)
51	Dec 18 to Dec 24	1.23 (1.11)	1.64 (1.28)
52	Dec 25 to Dec 31	1.88 (1.37)	1.89 (1.37)
	Mean	**3.28**	**2.49**

Computation of overall mean population throughout the periods in field experiment I revealed that application of NSKE 5% and neem oil 3 % recorded the lowest population of 7.92 and 8.85 aphids/ 3 leaves respectively. The corresponding per cent reduction over control was 82.09 and 80.00 per cent respectively. However, the standard check Malathion 35 EC @ 500 ml/ha registered the lowest population (7.56 / 3 leaves). Similar was the trend observed in second field experiment. The highest percent reduction of aphid population over control was recorded in NSKE 5 % (84.80%) and Neem oil 3% (82.81%) treatments and they were significantly different from each other (Table 5).

Population dynamics of aphids in bitter gourd

The results regarding the population build-up of aphids revealed that the maximum temperature exerts a significant positive correlation while rainfall shows negative correlation. This was in alignment with the findings of Chakraborthy, (2011) who studied the incidence of *A. gossypii* and reported that all weather factors showed significant influence on population. Singh *et al.*, (2013), depicted that the population was negatively correlated with the minimum temperature, rainfall and relative humidity is in accordance with our study.

Efficacy of newer insecticide molecules aphids in bitter gourd

In the present study, Spinosad 45 % SC @ 160 ml/ ha was found consistently effective in reducing the aphid population. The next effective treatment was Chlorantraniliprole 18.5 SC @ 150ml/ha. The present findings were partly collaborated with the findings of Patel *et al.* (2014), reported that spinosad 45 SC @ 125 g a.i/ha emerged as most effective treatment to reduce the aphid population (2.09-3.07 per three leaves/plant).

Efficacy of biopesticides against aphids in bitter gourd

Among the biopesticides evaluated, NSKE found superior to all the other treatments. This was in accordance with the findings of (Jadon, 2008) who reported that NSKE found most effective in reducing the population of aphids and also these were found safer to natural enemies. Jadon tested water and ethanol extracts of botanicals, in comparison to oxydemeton methyl and control. Among the plants extracts neem seed kernel extract found most effective in reducing aphid population. All the tested plant extracts were found safer to natural enemies, *C. Septempunctata* and *D. rapae* in comparison to insecticides. The grain yield and number of siliquae also increased significantly by spray of all the plant extracts.

Ten botanicals tested against aphid, *Lipaphis erysimi* on varuna variety of mustard at Kangda (Anonymous, 2001). The minimum number of aphids per plant was observed in Azadirachtin treated plots. However, the differences among the treatment were not significant and *Mentha spicata*, *M. piperate* and *Vitex negundo* gave comparatively better yield than others.

Table 2: Population of *A. gossypii* as influenced by newer molecular insecticides in Bitter gourd -Field experiment I (Aug – Dec 2017)

Treatment	Dosage	Mean No. of aphids(nymphs and adults) / 3leaves*										
		PTC	I Spray				II spray					Reduction over control (%)
			3 DAS	7 DAS	10 DAS	14 DAS	3 DAS	7 DAS	10 DAS	14 DAS	Mean	
Chlorantraniliprole 18.5% SC	125 ml/ha	21.00	6.50 (2.55)[b]	1.20 (1.10)[c]	3.35 (1.83)[c]	5.40 (2.32)[c]	1.30 (1.14)[b]	0.70 (0.84)[c]	1.35 (1.16)[b]	2.00 (1.41)[c]	2.73 (1.65)[c]	89.79
Chlorantraniliprole 18.5 % SC	150ml/ha	21.60	4.20 (2.05)[a]	0.95 (0.97)[b]	2.20 (1.48)[b]	4.50 (2.12)[b]	0.90 (0.95)[a]	0.45 (0.67)[b]	0.80 (0.89)[a]	1.55 (1.24)[b]	1.94 (1.39)[b]	89.88
Spinosad 45 % SC	160ml/ ha	20.50	4.40 (2.10)[a]	0.75 (0.87)[a]	1.95 (1.40)[a]	3.60 (1.90)[a]	0.80 (0.89)[a]	0.20 (0.45)[a]	0.75 (0.87)[a]	1.20 (1.10)[a]	1.71 (1.31)[a]	93.60
Imidacloprid 17.8 % SL	250ml/ha	21.00	6.85 (2.62)[b]	1.50 (1.22)[d]	3.60 (1.90)[d]	5.80 (2.41)[d]	1.75 (1.32)[c]	0.85 (0.92)[d]	1.50 (1.22)[bc]	1.80 (1.34)[d]	2.96 (1.72)[d]	88.93
Spiromesifen 22.9 % SC	500 ml/ha	21.40	13.25 (3.64)[e]	4.20 (2.05)[g]	7.60 (2.76)[g]	9.80 (3.13)[f]	3.00 (1.73)[f]	1.20 (1.10)[f]	1.95 (1.40)[d]	2.85 (1.69)[g]	5.48 (2.34)[f]	79.52
Thiodicarb 75 % WP	750 g/ha	19.50	11.30 (3.36)[d]	1.80 (1.34)[e]	5.20 (2.28)[e]	9.80 (3.13)[f]	2.50 (1.58)[d]	1.00 (1.00)[e]	1.90 (1.38)[d]	2.75 (1.66)[f]	4.53 (2.13)[e]	83.07
Standard check – Malathion50 % EC	400ml/ha	20.25	8.65 (2.94)[c]	2.75 (1.66)[f]	5.95 (2.44)[f]	8.75 (2.96)[e]	2.75 (1.66)[e]	1.00 (1.00)[e]	1.65 (1.28)[c]	2.35 (1.53)[e]	4.23 (2.06)[e]	84.19
Untreated check	-	20.60	21.00 (4.58)[f]	23.50 (4.85)[h]	25.00 (5.00)[h]	27.20 (5.22)[g]	27.50 (5.24)[g]	28.60 (5.35)[g]	29.00 (5.39)[e]	32.30 (5.68)[h]	26.76 (5.17)[g]	-
S.Ed	-	-	0.336	0.018	0.028	0.027	0.033	0.035	0.033	0.014	0.019	-
CD(0.05)	-	-	0.072	0.039	0.061	0.057	0.072	0.075	0.071	0.030	0.041	-

PTC=Pre Treatment Count, DAS= Day(s) after spraying, NS – Non significant
*Each value is the mean of three replications
Figures in parenthesis are square root transformed values
In a column, means followed by same letter(s) are not significantly different by LSD (p= 0.05)

Table 3: Population of *A. gossypii* as influenced by newer molecular insecticides in Bitter gourd -Field experiment II (Jan - Dec 2017)

Treatment	Dosage	Number of nymphs and adults /3 leaves*										Reduction over control (%)
		PTC	I Spray				II Spray					
			3 DAS	7 DAS	10 DAS	14 DAS	3 DAS	7 DAS	10 DAS	14 DAS	Mean	
Chlorantraniliprole 18.5% SC	125 ml/ha	27.20	8.85 (2.97)^{c}	1.50 (1.22)^{b}	3.23 (1.80)^{b}	5.73 (2.39)^{b}	1.00 (1.00)^{b}	0.60 (0.77)^{c}	1.20 (1.10)^{b}	1.50 (1.22)^{c}	2.95 (1.72)^{c}	89.93
T2-Chlorantraniliprole 18.5 % SC	150ml/ha	29.00	7.95 (2.82)^{b}	1.39 (1.18)^{b}	3.25 (1.80)^{b}	4.92 (2.22)^{a}	1.45 (1.20)^{a}	0.50 (0.71)^{b}	1.30 (1.14)^{a}	1.85 (1.36)^{b}	2.83 (1.68)^{b}	90.34
T3-Spinosad 45 % SC	160ml/ ha	26.40	4.25 (2.06)^{a}	0.30 (0.55)^{a}	1.25 (1.12)^{a}	2.00 (1.41)^{a}	1.10 (1.05)^{a}	0.35 (0.59)^{a}	1.40 (1.18)^{a}	1.80 (1.34)^{a}	1.56 (1.25)^{a}	94.67
T4-Imidacloprid 17.8 % SL	250ml/ha	27.20	9.25 (3.04)^{cd}	1.85 (1.36)^{c}	3.32 (1.82)^{b}	6.25 (2.50)^{c}	1.25 (1.12)^{c}	0.85 (0.92)^{d}	1.72 (1.31)^{bc}	1.95 (1.40)^{d}	3.31 (1.82)^{d}	88.71
T5-Spiromesifen 22.9 % SC	500 ml/ha	28.25	12.50 (3.54)^{f}	4.65 (2.16)^{f}	5.40 (2.32)^{d}	6.85 (2.62)^{f}	4.52 (2.13)^{f}	2.35 (1.53)^{f}	3.00 (1.73)^{d}	3.70 (1.92)^{g}	5.37 (2.32)^{f}	81.68
T6-Thiodicarb 75 % WP	750g/ha	28.50	10.45 (3.23)^{e}	3.84 (1.96)^{e}	5.25 (2.29)^{d}	6.59 (2.57)^{e}	3.47 (1.86)^{d}	1.00 (1.00)^{e}	2.35 (1.53)^{d}	2.84 (1.69)^{f}	4.47 (2.12)^{e}	84.75
T7-Standard check – Malathion 50% EC	400ml/ha	24.00	9.64 (3.10)^{d}	3.15 (1.77)^{d}	4.60 (2.14)^{c}	6.38 (2.53)^{d}	2.00 (1.41)^{e}	1.25 (1.12)^{e}	2.15 (1.47)^{c}	2.32 (1.52)^{e}	3.94 (1.98)^{e}	86.56
T8-Untreated check	-	27.50	27.54 (5.25)^{g}	27.59 (5.25)^{g}	28.45 (5.33)^{e}	28.94 (5.38)^{g}	29.65 (5.45)^{g}	30.28 (5.50)^{g}	30.42 (5.52)^{e}	31.68 (5.63)^{h}	29.32 (5.41)^{g}	-
S.Ed	-	-	0.039	0.031	0.024	0.019	0.033	0.035	0.033	0.014	0.019	-
CD(0.05)	-	-	0.083	0.66	0.527	0.040	0.072	0.075	0.071	0.030	0.041	-

PTC=Pre Treatment Count, DAS= Day(s) after spraying, NS – Non significant
*Each value is the mean of three replications
Figures in parenthesis are square root transformed values
In a column, means followed by same letter(s) are not significantly different by LSD (p= 0.05)

Table 4: Population of *A. gossypii as* influenced by Biopesticides in Bitter gourd -Field experiment I (Aug - Dec 2017)

Treatment	Dosage	Number of nymphs and adults / 3 leaves*										
		PTC	I Spray				II Spray				Mean	Reduction over control (%)
			3 DAS	7 DAS	10 DAS	14 DAS	3 DAS	7 DAS	10 DAS	14 DAS		
T1-Neem seed kernel extract	5%	31.54	13.95 (3.73)^{b}	7.82 (2.80)^{a}	9.65 (3.11)^{a}	13.12 (3.62)^{ab}	6.81 (2.61)^{b}	2.43 (1.56)^{a}	3.64 (1.91)^{a}	5.97 (2.44)^{a}	7.92 (2.81)^{a}	82.09
T2-Neem oil	3%	32.93	15.32 (3.91)^{c}	8.61 (2.93)^{c}	10.93 (3.31)^{c}	12.64 (3.56)^{a}	7.27 (2.70)^{b}	3.69 (1.92)^{b}	5.42 (2.33)^{b}	6.88 (2.62)^{b}	8.85 (2.97)^{b}	80.00
T3-Notchi leaf extract	10%	33.52	17.26 (4.15)^{d}	11.54 (3.40)^{f}	14.23 (3.77)^{f}	15.67 (3.96)^{d}	9.21 (3.03)^{c}	6.32 (2.51)^{e}	8.47 (2.91)^{d}	9.89 (3.14)^{c}	11.57 (3.40)^{d}	73.84
T4-Neem soap	10g/l	34.86	16.72 (4.09)^{d}	9.28 (3.05)^{d}	12.06 (3.47)^{d}	14.32 (3.78)^{c}	10.65 (3.26)^{de}	8.42 (2.90)^{f}	6.85 (2.62)^{c}	9.46 (3.08)^{c}	10.97 (3.31)^{c}	75.19
T5-Pungam soap	10g/l	30.65	16.89 (4.11)^{d}	12.43 (3.53)^{g}	15.24 (3.90)^{g}	16.39 (4.05)^{d}	11.74 (3.43)^{f}	4.68 (2.16)^{c}	8.93 (2.99)^{e}	9.95 (3.15)^{c}	12.03 (3.47)^{d}	72.80
T6-*Bacillus thuringiensis*	2g/l	30.25	13.69 (3.94)^{c}	9.81 (3.22)^{e}	12.27 (3.72)^{e}	14.59 (4.03)^{d}	10.53 (3.35)^{ef}	4.26 (2.44)^{d}	5.62 (2.88)^{d}	7.13 (3.26)^{d}	9.74 (3.39)^{d}	77.97
T7-*Metarhizium anisopliae*	1x10^{8} CFU/ml	32.51	15.25 (3.91)^{c}	10.69 (3.27)^{e}	11.84 (3.44)^{e}	13.47 (3.67)^{b}	10.36 (3.22)^{d}	6.28 (2.51)^{de}	8.92 (2.99)^{e}	10.63 (3.26)^{d}	10.93 (3.31)^{c}	75.28
T8-Standard check- Malathion 50 EC	500 ml/ ha	32.23	12.29 (3.51)^{a}	8.23 (2.87)^{b}	10.67 (3.27)^{b}	12.55 (3.54)^{a}	4.57 (2.14)^{a}	2.39 (1.55)^{a}	3.57 (1.89)^{a}	6.21 (2.49)^{a}	7.56 (2.75)^{a}	82.90
T9-Control	-	33.15	35.94 (5.99)^{e}	38.78 (6.23)^{h}	40.15 (6.34)^{h}	42.67 (6.53)^{e}	45.84 (6.77)^{g}	47.68 (6.91)^{g}	50.42 (7.10)^{f}	52.35 (7.24)^{e}	44.23 (6.65)^{e}	-
S.Ed	-	-	0.052	0.028	0.028	0.051	0.047	0.032	0.024	0.045	0.036	-
CD	-	-	0.110	0.060	0.060	0.109	0.100	0.069	0.052	0.095	0.076	-

PTC=Pre Treatment Count, DAS= Day(s) after spraying, NS – Non significant
*Each value is the mean of three replications
Figures in parenthesis are square root transformed values
In a column, means followed by same letter(s) are not significantly different by LSD (p= 0.05)

Table 5: Efficacy of biopesticides on Aphid, *Aphis gossypii* in Bitter gourd- Field experiment II (Jan - May 2018)

Treatment	Dosage	Number of nymphs and adults / 3 leaves*										Reduction over control (%)
		PTC	I Spray				II Spray				Mean	
			3 DAS	7 DAS	10 DAS	14 DAS	3 DAS	7 DAS	10 DAS	14 DAS		
T1-Neem seed kernel extract	5%	33.20	10.50 $(3.24)^{b}$	4.50 $(2.12)^{b}$	6.80 $(2.61)^{b}$	8.20 $(2.86)^{b}$	2.50 $(1.58)^{b}$	1.00 $(1.00)^{b}$	3.40 $(1.84)^{b}$	6.40 $(2.53)^{b}$	5.41 $(2.33)^{ab}$	84.40
T2-Neem oil	3%	32.56	11.25 $(3.35)^{c}$	5.40 $(2.32)^{c}$	7.20 $(2.68)^{b}$	8.50 $(2.92)^{b}$	3.70 $(1.92)^{c}$	1.20 $(1.10)^{c}$	3.60 $(1.90)^{bc}$	6.80 $(2.61)^{bc}$	5.96 $(2.44)^{ab}$	82.81
T3-Notchi leaf extract	10%	34.26	13.20 $(3.63)^{de}$	6.80 $(2.61)^{d}$	9.30 $(3.05)^{c}$	10.60 $(3.26)^{c}$	5.20 $(2.28)^{d}$	1.50 $(1.22)^{d}$	3.80 $(1.95)^{c}$	7.20 $(2.68)^{cd}$	7.20 $(2.68)^{ab}$	79.20
T4-Neem soap	10g/l	33.78	12.80 $(3.58)^{d}$	6.50 $(2.55)^{d}$	9.80 $(3.13)^{cd}$	11.20 $(3.35)^{d}$	6.30 $(2.51)^{e}$	2.00 $(1.41)^{e}$	5.30 $(2.30)^{d}$	7.60 $(2.76)^{de}$	7.69 $(2.77)^{ab}$	77.82
T5-Pungam soap	10g/l	31.64	13.80 $(3.71)^{f}$	10.60 $(3.26)^{f}$	12.20 $(3.49)^{e}$	14.50 $(3.81)^{f}$	9.20 $(3.03)^{g}$	5.40 $(2.32)^{g}$	8.80 $(2.97)^{g}$	10.20 $(3.19)^{g}$	10.59 $(3.25)^{ab}$	69.46
T6-*Bacillus thuringiensis*	2g/l	32.00	13.73 $(3.71)^{ef}$	8.93 $(2.99)^{e}$	10.29 $(3.21)^{d}$	13.68 $(3.70)^{e}$	7.24 $(2.69)^{f}$	4.26 $(2.06)^{f}$	6.13 $(2.48)^{e}$	7.94 $(2.82)^{e}$	9.03 $(3.00)^{ab}$	73.96
T7-*Metarhizium anisopliae*	1x10^{8} CFU/ml	31.90	16.29 $(4.04)^{g}$	11.25 $(3.35)^{g}$	13.68 $(3.70)^{f}$	15.61 $(3.95)^{g}$	7.28 $(2.70)^{f}$	5.63 $(2.37)^{g}$	7.98 $(2.82)^{f}$	9.53 $(3.09)^{f}$	10.91 $(3.30)^{ab}$	68.45
T8-Standard check – Malathion 50 EC	500 ml/ ha	34.20	9.50 $(3.08)^{a}$	4.20 $(2.05)^{a}$	6.00 $(2.45)^{a}$	7.50 $(2.74)^{a}$	2.20 $(1.48)^{a}$	0.68 $(0.50)^{a}$	2.60 $(1.61)^{a}$	4.20 $(2.05)^{a}$	4.53 $(2.13)^{a}$	86.93
T9-Control	-	32.30	32.60 $(5.71)^{h}$	33.40 $(5.78)^{h}$	33.80 $(5.81)^{g}$	34.50 $(5.87)^{h}$	3 5.20 $(5.93)^{h}$	35.50 $(5.96)^{h}$	36.00 $(6.00)^{h}$	36.40 $(6.03)^{h}$	34.68 $(5.89)^{c}$	-
S.Ed	-	-	0.036	0.030	0.044	0.031	0.017	0.035	0.026	0.037	-	-
CD	-	-	0.077	0.064	0.094	0.066	0.037	0.075	0.055	0.078	-	-

PTC=Pre Treatment Count, DAS= Day(s) after spraying, NS – Non significant
*Each value is the mean of three replications
Figures in parenthesis are square root transformed values
In a column, means followed by same letter(s) are not significantly different by LSD (p= 0.05)

Table 6: Correlation coefficients, Regression equations forAphids incidence in Bitter gourd and weather parameters

Locations	Correlation coefficients value #				R^2	Multiple regression equation #
	X_1	X_2	X_3	X_4		
Kadachanenthal	0.497**	0.225 NS	0.072 NS	-0.457**	0.36	$Y = -11.874 + 0.269\ (X_1)^{NS} + 0.093(X_2)^{NS} + 0.055\ (X_3)^{NS} - 0.019\ (X_4)^{NS}$
Vadipatti	0.188 NS	-0.006 NS	0.055 NS	-0.525**	0.41	$Y = -9.732 + 0.295\ (X_1)^{NS} - 0.068(X_2)^{NS} + 0.054\ (X_3)^{NS} - 0.055(X_4)^{NS}$

N = 26 Standard weeks
** Significant at 1 per cent level, * Significant at 5 per cent level, NS - Non Significant
(P <0.05 or P <0.01)
X_1 – Maximum temperature (^{0}C), X_2 – Minimum temperature (^{0}C), X_3 – Relative humidity (%), X_4 – Rainfall (mm)

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AUTHOR'S CONTRIBUTION

Adaikkan Yogapriya **(YA) –** carried out data analysis and manuscript preparation

Janani M **(JM) –** carried out the experiment and data analysis

Balakrishnan Usharani **(BU) –** planning and designing of the experiment and revision of the manuscript

Krishnasamy Suresh **(KS) –** planning and designing of the experiment and revision of the manuscript

CONFLICT OF INTEREST STATEMENT

The authors do not have any conflict of interest.

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