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Research Article

Impact of integrated pest management modules on natural enemies of whiteflies, *Bemisia tabaci* (Genn.) in bitter gourd ecosystem

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Abstract: The impact of eight IPM modules on whitefly *Bemisia tabaci* and its natural enemies were recorded during *kharif* 2016 and 2017, *rabi*-summer 2016-17 and 2017-18. There was a significant difference among the modules in the number of natural enemies per plant. In general, it was found that during *rabi*-summer the population of *B. tabaci* was higher than the *kharif* season on bitter gourd. When modules were compared for the population of *B. tabaci*, module 1 to 4 (sowing maize as a barrier crop, removal of infested leaves and residues from the appearance of pests, erection of solar light trap with yellow pan @ 5 traps/ha for trapping, tying yellow sticky trap to attract whiteflies, spraying neem oil @ 1% and pongam oil @1%) and module 6 (spraying of *Metarhizium anisopliae* (2 x 10^9), *Beauveria bassiana* (2 x 10^8), Neem oil 1% and Pongam oil 1%) which do not include frequent insecticidal applications recorded higher number of coccinellids, syrphids, hymenopterans and spiders than the IPM modules where frequent applications of chemical insecticides were included as a treatment.

Keywords: IPM modules, natural enemies, whiteflies

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INTRODUCTION

Whitefly, *Bemisia tabaci Genn*. (Hemiptera: Aleyrodidae) is a devastating pest of vegetables, fruits, fibre, plantation crops and ornamental crops in tropical and subtropical regions of the world (Oliveira *et al*., 2001). Numerous species of natural enemies are recorded on *B. tabaci* (Gerling *et al*., 2001; Li *et al*., 2011; Torres *et al*., 2014). The natural enemies of *B. tabaci* occur in diversified agro -ecosystems all around the world, different species predators and parasitoids feed and parasitise on *B. tabaci* (Nordlund and Legaspi, 1996; Gerling *et al*., 2001; Palaniswami *et al*., 2001). Several studies have been conducted on the importance of the beneficial fauna attacking *B. tabaci* in agricultural systems (Asiimwe *et al*., 2007; Atuncha *et al*., 2013). In India studies conducted in Andhra Pradesh, Tamil Nadu and Maharashtra states have also added important information on natural enemies of *B. tabaci* (Natarajan, 1990; Kapadia and Puri, 1991; Rao *et al*., 1989). In the present study experiments were conducted to assess the impact of eight integrated pest management (IPM) modules on whitefly *Bemisia tabaci* and its natural enemies in bitter gourd ecosystem during *kharif* 2016 and 2017, *rabi*-summer 2016-17 and 2017-18.

MATERIALS AND METHODS

Except plant protection measures, IPM module included eco-friendly and bio-rational strategies with farmers practice of chemical insecticide sprays (Table 1). Seeds were sown during *kharif* – 2016, 2017 and *rabi*-summer 2016-17 and 2017-18. In all the modules including farmers practice and control, bitter gourd seeds were treated with imidacloprid 17.8 SL before sowing in order to manage the early sucking pests and sprayed imidacloprid 17.8 SL @ 0.35ml/l on the seedlings three hours before transplanting. The pest management interventions were executed when the pest population crossed economic threshold level.

Observations were recorded at 10 days intervals on three leaves each from top middle and bottom of the 5 randomly selected plants in each replication. Similarly, natural enemy population per plant was also recorded on 5 randomly selected plants in each replication and for parasitoids, under surface of the leaves were examined for parasitism with magnifier hand lens (10X), the parasitised whiteflies turned black. The bitter gourd fruit yield was recorded from each module and the data were presented as in kg/ha and benefit cost ratio of each treatment was worked out. Data regarding whitefly damage and viral

Table 1. Details of IPM Modules

No.	Module Treatment Details
M_1	Sowing maize as a barrier crop. Removal of infested leaves and residues from the appearance of pests. Erection of solar light trap with yellow pan @ 5 traps/ha for mass trapping. Tying yellow sticky trap to attract whiteflies.
M_2	Sowing maize as a barrier crop. Removal of infested leaves and residues from the appearance of pests. Erection of solar light trap with yellow pan @ 5 traps/ha for trapping. Tying yellow sticky trap to attract whiteflies. Releasing of *Encarsia guadeloupae* 75,000/ha @ weekly intervals.
M_3	Sowing maize as a barrier crop. Removal of infested leaves and residues from the appearance of pests. Erection of solar light trap with yellow pan @ 5 traps/ha for mass trapping. Tying yellow sticky trap to attract whiteflies. Spraying *Metarhizium anisopliae* (Biomet) ($2x10^9$/ml) @ 3 L/ha and *Beauveria bassiana* (Biorin) ($2x10^9$/ml) @ 3 L/ha (sprayed in the evening hours)
M_4	Sowing maize as a barrier crop. Removal of infested leaves and residues from the appearance of pests. Erection of solar light trap with yellow pan @ 5 traps/ha for mass trapping. Tying yellow sticky trap to attract whiteflies. Spraying Neem oil @ 1% and Pongam oil @1%
M_5	Spraying 1. Neem oil 1% 2. Pongam oil 1% 3. Diafenthiuron 50 WP @ 0.80 g/l and 4. Triazophos 40 EC @ 1.5ml/l
M_6	Spraying 1. *M. anisopliae* ($2x10^9$) 2. *B. bassiana* ($2x10^8$) 3. Neem oil 1% and 4. Pongam oil 1%
M_7	Spraying 1. *M. anisopliae* ($2x10^9$/ml) 2. *B. bassiana* ($2x10^9$/ml) 3. Diafenthiuron 50 WP @ 0.80 g/l and 4. Triazophos 40 EC @ 1.5ml/l
M_8	Spraying 1. Diafenthiuron 50 WP @ 0.80 g/L 2. Triazophos 40 EC @1.5ml/l 3. Buprofezin 25SC @ 0.25ml/l and 4. Imidacloprid 17.8 SL @ 0.35ml/l
M_9	Untreated control

disease infestations were recorded from 10th day after planting and continued up to 110 days. All the data set were subjected to pooled analysis of variance (ANOVA) after appropriate transformations according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The impact of eight IPM modules on natural enemies were recorded for two seasons, *kharif* 2017 and *rabi*-summer 2017-18. Four observations were recorded at 30, 50, 70 and 80 days after planting (DAP). There was a significant difference among the modules in the number of natural enemies per plant on an average. Prominent natural enemies viz. coccinellids (*Coccinella septempunctata* (L.) and *Menochilus sexmaculatus* (Fab.)), syrphid (*Eristalis quinquestriatus*), hymenopteran *Encarsia guadeloupae* (Viggiani) and spiders *Phytoseiulus* sp, *Amblyseius* spp. were recorded during the study (Table 2).

In general, it was found that during *rabi*-summer, the population of *B. tabaci* on bitter gourd was higher compared to *kharif* season it. As a numerical response, the population of natural enemies was also higher compared to the *kharif* season (Table 3). When modules were compared for the *B. tabaci* population, modules 1 to 4 (sowing maize as a barrier crop, removal of infested leaves and residues from the appearance of pests, erection of solar light trap with yellow pan @ 5 traps/ha for trapping, tying yellow sticky trap to attract whiteflies (Plate 1), spraying neem oil @ 1% and pongam oil @1%) and module 6 (Spraying *M. anisopliae* ($2x10^9$), *B. bassiana* ($2x10^8$), Neem oil 1% and Pongam oil 1%) which

Plate 1. Solar light trap with yellow pan and yellow sticky trap used for trapping whiteflies.

Table 2. Natural enemies recorded on whiteflies in bitter gourd ecosystem

Coleopterans	Chrysopids and Syrphids	Hymeno-pterans	Spiders
Coccinellidae: Lady bird beetle, *Coccinella septempunctata* (L.), *Menochilus sexmaculatus* (Fab.) Staphilinidae: Rove beetle, *Paederus fuscipes* (Curtis)	Chrysopidae: Green lace wing, *Chrysoperla zastrowi sillemi* (Esben-Peterson) Syrphidae: Syrphid fly, *Eristalis quinquestriatus* (Fab.)	Parasitoid –*Encarsia guadeloupae* Viggiani	Predatory mites, *Phytoseiulus* sp, *Amblyseius* spp. Phytoseiidae

Table 3. Effect of IPM modules on natural enemies in bitter gourd ecosystem, *kharif* *

Modules	No. of coccinellids / plant					No. of syrphids / plant				
	30 DAP	50 DAP	70 DAP	90 DAP	Mean	30 DAP	50 DAP	70 DAP	90 DAP	Mean
M1	2.22	2.67	2.22	2.22	2.33	1.89	2.11	1.89	1.56	1.86
M2	1.89	2.89	2.22	2.22	2.31	1.78	2.22	1.67	1.67	1.83
M3	2.11	2.56	2.33	2.33	2.33	1.67	2.22	1.78	1.67	1.83
M4	2.33	2.78	2.22	2.22	2.39	1.89	2.33	1.67	1.67	1.89
M5	1.11	1.22	1.22	1.11	1.17	0.89	1.11	0.89	1.11	1.00
M6	2.11	2.56	2.11	2.33	2.28	1.78	2.22	1.67	1.67	1.83
M7	1.11	1.44	1.11	1.11	1.19	1.11	0.89	1.11	0.89	1.00
M8	0.56	0.89	0.67	0.56	0.67	0.56	0.56	0.56	0.44	0.53
M9	2.11	2.78	2.22	2.33	2.36	1.78	2.22	1.78	1.67	1.86
SEM (±)	0.12					0.11				
CD (P=0.05)	0.37					0.34				
CV (%)	12.74					14.71				
Modules	No. of hymenopterans / plant					No. of spiders / plant				
	30 DAP	50 DAP	70 DAP	90 DAP	Mean	30 DAP	50 DAP	70 DAP	90 DAP	Mean
M1	2.11	1.89	1.44	1.11	1.64	2.22	1.89	1.67	1.11	1.72
M2	1.89	1.78	1.44	1.22	1.58	2.11	1.89	1.56	1.22	1.69
M3	2.11	1.89	1.56	1.22	1.69	2.22	1.78	1.67	1.22	1.72
M4	2.22	1.67	1.44	1.33	1.67	2.11	1.89	1.67	1.33	1.75
M5	1.11	1.12	0.89	0.78	0.97	1.11	1.11	1.11	0.78	1.03
M6	2.11	1.89	1.44	1.22	1.67	2.22	1.89	1.89	1.22	1.81
M7	0.89	1.11	0.89	0.89	0.94	0.89	1.22	1.11	0.67	0.97

M8	0.56	0.44	0.22	0.22	0.36	0.33	0.44	0.33	0.44	0.39
M9	2.11	1.89	1.44	1.22	1.67	2.22	1.89	1.67	1.22	1.75
SEM (±)	0.17					0.17				
CD (P=0.05)	0.52					0.54				
CV (%)	24.79					24.33				

*Note: Pooled data of *kharif* for two seasons 2016 and 2017

Table 4. Effect of IPM modules on natural enemies in bitter gourd ecosystem, *rabi*-summer*

Modules	No. of coccinellids/plant					No. of syrphids/plant				
	30 DAP	50 DAP	70 DAP	90 DAP	Mean	30 DAP	50 DAP	70 DAP	90 DAP	Mean
M1	2.44	3.33	3.44	4.33	3.39	2.67	2.56	2.44	2.56	2.56
M2	2.33	3.44	2.89	4.44	3.28	2.78	2.44	2.56	2.56	2.58
M3	2.22	3.44	3.67	4.22	3.39	2.89	2.56	2.33	2.67	2.61
M4	2.33	3.33	3.11	4.56	3.33	2.78	2.56	2.56	2.44	2.58
M5	1.22	1.33	1.33	1.44	1.33	1.11	1.11	0.89	1.33	1.11
M6	2.33	3.22	3.56	4.44	3.39	2.89	2.89	2.67	2.56	2.75
M7	1.23	1.89	1.44	1.33	1.48	1.33	0.89	1.11	1.33	1.17
M8	0.67	0.89	0.78	0.89	0.81	0.67	0.67	0.56	0.56	0.61
M9	2.44	3.44	3.67	4.56	3.53	2.78	2.56	2.78	2.67	2.69
SEM (±)	0.36					0.08				
CD (P=0.05)	1.10					0.25				
CV	26.98					7.60				
Modules	No. of hymenopterans/plant					No. of spiders/plant				
	30 DAP	50 DAP	70 DAP	90 DAP	Mean	30 DAP	50 DAP	70 DAP	90 DAP	Mean
M1	2.56	2.89	3.11	3.11	2.92	2.78	3.89	4.11	4.78	3.89
M2	2.44	2.78	2.78	2.89	2.72	2.56	3.33	4.22	4.89	3.75
M3	2.33	3.11	2.89	3.11	2.86	2.56	3.44	3.78	4.89	3.67
M4	2.44	2.89	3.11	3.11	2.89	2.44	3.78	4.33	4.78	3.83
M5	1.22	1.22	1.44	1.78	1.42	1.11	1.44	1.44	1.67	1.42
M6	2.33	3.11	3.11	3.33	2.97	2.67	3.67	4.44	4.78	3.89
M7	0.89	1.33	1.78	1.89	1.47	0.89	1.33	1.44	1.67	1.33
M8	0.67	0.89	0.78	0.56	0.72	0.56	0.89	0.78	0.67	0.72
M9	2.56	3.11	3.15	3.22	3.01	2.78	3.89	4.54	4.89	4.03

SEM (±)	0.16	0.39
CD (P=0.05)	0.49	1.22
CV	13.77	26.76

*Note: Pooled data of *rabi-summer* for two seasons 2016-17 and 2017-18

do not include frequent insecticidal applications recorded higher number of coccinellids, syrphids, hymenopterans and spiders than the IPM modules where frequent application of chemical insecticides were included as a treatment (Table 4).

Yield and benefit - cost ratio (BCR)

The IPM modules were evaluated for two seasons, *i.e. kharif*- 2016, 2017 and *rabi*-summer 2016 - 17 and 2017 - 18. During *kharif*, all the modules gave significantly higher yields than the control (5.77 t/ha). Module 10 and 6 gave the highest yield of 10. 27 and 10.06 t/ha, followed by Module 5 (9.97 t/ha) and Module 7 and 4 (9.64 and 9.38t/ha), respectively. By considering the economics, Module 6 recorded higher BCR (2.70) and ranked first among all the IPM trials evaluated, followed by Module 4 (2.62). The control gave BCR of 1.77 only (Table. 5). The BCR among all the trials, except control, all modules gave good results and were at-par with each other.

During *rabi*-summer 2017-18, the same set of IPM modules were evaluated. Same trend was observed in all the modules and it gave significantly higher yields than the control (5.97 t/ha). Module 6 gave the highest yield of 10.50 t/ha and followed by 10.39, 10.24 and 10.09 t/ha in modules 8, 5 and 7 respectively. As per the economics, the module 6 recorded higher BCR (2.82), followed by module 44 (2.76) and module 7 (2.67). Control plot gave cost-benefit ratio of 1.83. Overall, based on BCR values obtained from the different modules tested, it was observed that were significantly superior and were at-par with each other except the control.

There were statistical significant differences in the population of natural enemies among the different modules. The IPM modules, where the number of natural enemies was higher, recorded the lower *Bemisia tabaci* infestation and consequently had higher yields. This is a reflection of the action of natural enemies on whitefly population and in turn on the bitter gourd crop yields. The results are in-line with Nisha Lekshmi (2013) who reported the activity of coccinellids was at peak in summer compared to *kharif*. There were statistical significant differences in the population of natural enemies among the different bio-rational modules (Kedar *et al*., 2014). Sardana *et al*., (2006) reported significantly higher populations of coccinellids,

Table 5. Effect of IPM modules on bitter gourd yield

Module No.	Kharif	Rabi-summer	Mean (in tons)/ha	Kharif	Rabi-summer	Mean BCR
	Yield (in tons)/ha	Yield (in tons)/ha		BCR	BCR	
1	8.08e	7.96e	8.02c	2.34	2.30	2.32
2	9.06d	8.78d	8.92c	2.55	2.47	2.51
3	9.78c	9.60c	9.69b	2.55	2.50	2.53
4	9.86bc	9.38c	9.62b	2.76	2.62	2.69
5	10.24	9.97b	10.10ab	2.52	2.45	2.49
6	10.50a	10.06a	10.28a	2.82	2.70	2.76
7	10.09ab	9.64c	9.86ab	2.67	2.56	2.61
8	10.39a	10.27a	10.33a	2.61	2.58	2.60
9	5.97f	5.77f	5.87e	1.83	1.77	1.80
SEm (±)	0.15	0.12	0.14	-	-	-
CV (%)	0.42	0.38	0.39	-	-	-
CD@5%	2.85	2.37	2.52	-	-	-

Modules (Treatments) values in the column with different alphabets are statistically significant (p=0.05)

predatory spiders and *Chrysoperla* in IPM field of bitter gourd plant. Rao *et al*. (1989) on mungbean and urdbean and Gurlaz and Sangha (2016) on chilli, reported that the *B. tabaci* was predated by coccinellids, *Verania vincta, Menochilus sexmaculata*, *Chrysoperla zastrowi sillemi* and the phytoseiid, *Amblyseius* sp. Three coccinellid predators namely, *B. suturalis, S. parcesetosum* and *C. sexmaculata* were observed on whiteflies. Whiteflies are known to be attracted to the yellow range of the natural light. The yellow colour can attract more whiteflies. Chu *et al.* (2000) could prove that the most attractive colours in a wavelength range between 490 to 600 nm for *Bemisia argentifolli* were yellow-green, yellow and spring green respectively. Mutwiwa and Tantau (2005) also reported that the greenhouse whitefly, *Trialeuodes vaporariorum,* were attracted to lamps of the yellow colour.

Hence the present research findings indicate that module 6 (Spraying of *M. anisopliae* (2 x 10^9), *B. bassiana* (2 x 10^8), neem oil 1% and pongam oil 1%) which do not include frequent insecticidal applications recorded higher number of coccinellids, syrphids, hymenopterans and spiders than the IPM modules where frequent applications of chemical insecticides were included as a treatment. Module 6 also gave the highest yield and BCR in all cases.

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