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Evaluation of crop diversification based IPM modules against insect pests of okra

S Gopi, JB Gopali, TB Allolli, Venkateshalu, MA Waseem and Mallikarjun G Awati

S Gopi
Senior M. Sc. (Hort.), Department of Entomology, College of Horticulture, Bagalkot, Karnataka, India

JB Gopali
Professor, Department of Entomology, University of Horticultural Sciences, Bagalkot, Karnataka, India

TB Allolli
Professor, Department of Vegetable Science, University of Horticultural Sciences, Bagalkot, Karnataka, India

Venkateshalu
Professor and Head, Department of Entomology, University of Horticultural Sciences, Bagalkot, Karnataka, India

MA Waseem
Assistant Professor, Department of Entomology, University of Horticultural Sciences, Bagalkot, Karnataka, India

Mallikarjun G Awati
Assistant Professor, Department of Crop Physiology, University of Horticultural Sciences, Bagalkot, Karnataka, India

Correspondence
S Gopi
Senior M. Sc. (Hort.), Department of Entomology, College of Horticulture, Bagalkot, Karnataka, India

Abstract
The investigation on "To evaluate crop diversification based IPM modules against insect pests of okra *viz.*, Leafhoppers, Whiteflies and Shoot and Fruit borers" was carried out at College of Horticulture, Bagalkot, Karnataka, India during summer season of the academic year 2019. The experiment was laid out in randomized completely block design with four treatments and five replications. The treatments included, (T_1) crop diversification based bio-intensive module, (T_2) crop diversification based adoptable module, (T_3) recommended plant protection and (T_4) an untreated check. Observations on pests were recorded on okra crop at ten days intervals starting from 20 days after sowing. Among the different IPM modules evaluated against insect pests of okra, Crop diversification based adoptable module consisting of the components like, two rows of 25 days old maize as barrier crop, one row of 25 days old marigold as trap crop, two rows of cowpea as border crop and okra intercropped with coriander (5:1), seed treatment with imidacloprid 600 FS at 10 ml per kg before sowing, application of neem powder at 2.5 q per ha at the time of ploughing, installation of pheromone traps at 5 per ha for monitoring of fruit borers, setting up of yellow sticky traps at 15 per ha for monitoring of sucking pests, ETL based application of azadirachtin 10,000 ppm at 1.0 ml/l + *Lecanicillium lecanii* (1×10^8 CFU/g) at 5 g/l, tolfenpyrad 15 EC at 1.0 ml, thiamethoxam 25 WG at 0.20 g, cyantraniliprole 10.26 OD at 1.0 ml and chlorantraniliprole 18.5 SC at 0.20 ml exhibited significantly lowest mean leafhoppers (2.24/leaf), whiteflies (0.81/leaf), shoot damage (5.19%), fruit damage by *E. vittella* (6.82%) and fruit borers damage *H. armigera* (6.39%).Further, Crop diversification based adoptable module registered significantly highest yield of (18.15 t ha^{-1}), net returns (Rs. 2,90,340) and highest B:C ratio (5.00) as compared to recommended plant protection measures suggesting crop diversification based adoptable module was more effective, economically feasible and practically adoptable by the farming community.

Keywords: Crop diversification, IPM modules, barrier crop, trap crop, border crop, intercrop, leafhoppers

Introduction
Vegetable crops are the valuable components of horticulture, having great importance in providing food and nutritional security. Among the vegetable crops, okra [*Abelmoschus esculentus* (L.) Moench] is commercial vegetable crop cultivated for domestic consumption and export. Its origin is Africa and belongs to Malvaceae family having chromosome number 2n=130. Okra related to hibiscus and cotton family, often referred to, as "Lady Finger", "bamia" and "gumbo" (Anon., 1995) [1]. China, India and Nigeria are leading okra growing countries in the world. India ranks second in area and production after China. In India, okra is grown in 0.528 million hectares area with 61.46 lakh tons of production and productivity of 11.64 t per ha. In India, major growing states are Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Himachal Pradesh, Jammu and Kashmir, Jharkhand and Karnataka. In Karnataka, major okra growing districts are Bagalkot, Mandya, Belagavi, Haveri, Bengaluru and Vijayapur (Anon., 2017) [2].

Okra production is limited by number of factors, among them insect pest attack is the major one. Okra crop is attacked with as many as 45 species of insect pests throughout its cropping period (Nair, 1984) [3]. Among them, leafhoppers *Amrasca biguttula biguttula* (Ishida), whitefly *Bemisia tabaci* (Gennadius), shoot and fruit borer *Earias vittella* (Fabricius) and fruit borer *Helicoverpa armigera* (Hubner) are most serious and major restraining biotic factors in okra cultivation. The crop loss estimation for major pests are 32.06 to 40.85 per cent by leafhoppers, 90.0 per cent by whiteflies and 3.5 to 90.0 per cent by fruit borers (Nair *et al.*, 1984) [3]. In general, 48.97 per cent economic loss in fruit yield is noticed due to overall damage by insects (Kanwar and Ameta, 2007) [4].

Indiscriminate use of chemical pesticides for management of insect pests of okra, results in pollution of natural resources like water, soil, reduced density of beneficial insects and soil microorganisms, reduction of pollinators and natural enemies like predators and parasitoids, which play a significant role in suppression of pest population. Due to spraying of spurious chemicals on fresh vegetable crops, pesticidal residues remain in the produce, causing health hazards to human beings and also leading to the development of resistance and resurgence in pests. In this contest, crop diversification practices were carried out against the major pests of okra, which includes the integration of barrier, trap, border and intercrops along with the main crop in which border crops act as physical barrier and prevent the movement of sucking pests from one field to another. Further, trap crops attract the insects like fruit borers so as to escape the egg laying or infestation by borers on main crop. Similarly, intercrops during effective flowering period encourages the conservation of natural enemies by providing food source like pollen, nectar and shelter, which making less favorable for pests and more attractive to beneficial insects.

Hence, there is a need to explore alternatives, encompassing available pest control techniques in order to reduce the sole dependence on insecticides. In this context, integrated pest management with special reference to crop diversification seems to be the most appropriate approach to achieve sustainability in okra production.

Materials and Method

The field experiment on to evaluation crop diversification based modules against insect pests of okra was conducted at College of Horticulture, Bagalkot during *summer* season, 2019. The okra seeds were sown at a spacing of 60 cm × 45 cm in a RCBD design with four treatments and five replications in a plot size of 6 m × 4 m. The crop was raised by following the agronomic practices as per the recommended package of practices of UHS, Bagalkot.

Observations on sucking pests

Five okra plants were selected from each replication and tagged randomly for observation. Observations on the population of sucking pests such as leafhoppers and whiteflies were recorded at ten days interval on top three leaves starting from 20 days after sowing till final harvest of the crop.

Observations on shoot and fruit borers

(a) Shoot damage: Total number of shoots along with the infested ones were counted from five okra plants and expressed as per cent shoot infestation using the following formula.

$$\text{Shoot infestation (\%)} = \frac{\text{Number of infested shoots}}{\text{Total number of shoots}} \times 100$$

(b) Fruit damage: Total number of fruits and number of damaged fruits per plant were recorded from selected plants and was expressed as per cent. The observations were recorded at ten days intervals starting from 50 days after sowing. The per cent fruit damage by *H. armigera* and *E. Vittella* calculated using the below formula:

$$\text{Fruit infestation (\%)} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

Fruit yield (t/ha)

Totally, 14 pickings of green tender marketable okra fruits were harvested from each plot and later expressed in terms of fruit tonn yield per hectare basis.

Cost economics

The average market price of green okra fruits was Rs. 20 per kg was considered for calculation. The following formulae were used for the calculation of B:C ratio. The benefit cost ratio of different treatments were worked out by estimating cost of cultivation and gross returns from fruit yield after converting them on hectare basis.

i. Gross returns (Rs/ha) = Yield x Market price of okra
ii. Net Returns = Gross Return - Total Cost of cultivation
iii. B:C ratio = Gross Return / Total Cost

Statistical analysis

The data collected from various experiments were subjected to suitable transformation. Further, the data was subjected to single factor ANOVA using statistical software (WASP-2) and different treatments were compared using Duncan's multiple range test (DMRT).

Table 1: Treatment details for evaluation of crop diversification based IPM modules against insect pests of okra

Sl. No.	Modules	Treatment details
M_1	Crop diversification based bio-intensive module	1. Okra + Border crops (two rows 25 days old maize + one row of 25 days old marigold + two rows of cowpea) + okra intercropped with coriander (5:1) 2. Seed treatment with imidacloprid 600 FS at 10 ml/kg 3. Application of neem powder at 2.5 q/ha 4. *Trichogramma chilonis* one lakh per hectare 5. Pheromone traps five per hectare 6. Yellow sticky traps 15 per hectare 7. Azadirachtin 10,000 ppm at 1.0 ml/l + *Lecanicillium lecanii* (1×10^8 CFU/g) at 5 g/l 8. Spraying of *Bacillus thuringiensis* at 2.0 ml/l 9. Chilli garlic extract at 0.5% 10. Bio-digester at 20%
M_2	Crop diversification based adoptable module	1. Okra + Border crops (two rows 25 days old maize + one row of 25 days old marigold + two rows of cowpea) + okra intercropped with coriander (5:1) 2. Seed treatment with imidacloprid 600 FS 10 ml/kg 3. Application of neem powder 2.5 q/ha 4. Pheromone traps five per hectare 5. Yellow sticky traps 15 per hectare 6. Azadirachtin 10,000 ppm at 1.0 ml/l + *Lecanicillium lecanii* (1×10^8 CFU/g) at 5 g/l 7. Tolfenpyrad 15 EC at 1.5 ml/l 8. Thiamethoxam 25 WG at 0.2 g/l 9. Cyantraniliprole 10.26 OD at 1.0 ml/l

		10. Chlorantraniliprole 18.5 SC at 0.2 ml/l
M_3	Recommended plant protection	1. Dimethoate 30 EC at 1.7 ml/l 2. Imidacloprid 17.8 SL at 0.3 ml/l 3. Thiamethoxam 25 WG at 0.2 g/l 4. Acephate 75 SP at 1.0 g/l 5. Acetamiprid 20 SP at 0.2 ml/l 6. Profenophos 50 EC at 2.0 ml/l 7. Quinalphos 25 EC at 2.0 ml/l 8. Spinosad 45 SC at 0.2 ml/l 9. Chlorantraniliprole 18.5 EC at 0.2 ml/l
M_4	Untreated check	Okra as sole crop

Results and Discussion

Efficacy of modules against sucking pests leafhopper and whitefly

The results revealed that, mean leafhopper population was significantly less in M_2-crop diversification based adoptable module recorded (2.24/leaf) which was at par with M_3-recommended plant protection (3.19/leaf). Next best treatment was M_1-crop diversification based bio-intensive module (8.88/leaf) and the untreated check registered highest population (13.39/leaf) (Table 2).

Among the modules evaluated against whiteflies, the M_2-crop diversification based adoptable module recorded consistently lowest (0.81/leaf) whitefly population which was on par with M_3 (1.12/leaf). Next best treatment was M_1 (2.23/leaf) and the untreated check (3.70/leaf) observed significantly higher number of whiteflies population per leaf (Table 3).

Table 2: To evaluate crop diversification based modules against leaf hopper, *Amrasca biguttula biguttula* in okra

Treatments	Number of leaf hoppers/leaf									Mean
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS	100 DAS	
M_1 - Crop diversification based bio-intensive module	2.73^{b} (1.79)	2.84^{b} (1.82)	4.89^{c} (2.32)	5.91^{bc} (2.51)	8.92^{b} (3.05)	9.27^{b} (3.10)	11.89^{c} (3.51)	21.81^{b} (4.69)	11.70^{b} (3.48)	8.88^{b} (3.04)
M_2 - Crop diversification based adoptable module	1.80^{a} (1.15)	0.83^{a} (1.15)	1.94^{a} (1.56)	4.01^{a} (2.11)	4.55^{a} (2.24)	4.13^{a} (2.14)	1.54^{a} (1.42)	0.70^{a} (1.09)	0.67^{a} (1.08)	2.24^{a} (1.65)
M_3 - Recommended Plant Protection	1.95^{a} (1.56)	0.94^{a} (1.20)	3.02^{b} (1.87)	5.08^{ab} (2.34)	6.01^{a} (2.54)	5.97^{a} (2.50)	2.82^{b} (1.81)	1.98^{a} (1.56)	0.96^{a} (1.20)	3.19^{a} (1.91)
M_4 - Untreated check	2.86^{b} (1.83)	4.29^{c} (2.18)	5.57^{c} (2.46)	7.98^{c} (2.88)	8.99^{b} (3.07)	10.10^{b} (3.24)	21.77^{d} (4.70)	34.99^{c} (5.93)	23.92^{c} (4.92)	13.39^{c} (3.71)
S. Em ±	0.06	0.05	0.07	0.12	0.12	0.13	0.09	0.17	0.10	0.11
C.D. at 5%	0.19	0.17	0.21	0.39	0.36	0.41	0.30	0.52	0.30	0.33

DAS; Days After Sowing, S. Em ±; Standard Error Mean, CD; Critical Difference
Figures in parenthesis indicate square root $\sqrt{(x+0.5)}$ transformed values
In a column, means followed by same alphabet do not differ significantly (P=0.05) by DMRT

Table 3: To evaluate crop diversification based modules against whitefly, *Bemisia tabaci* in okra

Treatments	Number of whiteflies/leaf							Mean
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	
M_1 - Crop diversification based bio-intensive module	1.01^{b} (1.22)	2.25^{c} (1.65)	2.45^{b} (1.71)	3.60^{c} (2.02)	4.10^{b} (2.13)	1.67^{b} (1.46)	0.55^{b} (1.02)	2.23^{b} (1.64)
M_2 - Crop diversification based adoptable module	0.70^{a} (1.09)	0.30^{a} (0.89)	1.15^{a} (1.28)	1.39^{a} (1.37)	1.16^{a} (1.46)	0.30^{a} (0.89)	0.20^{a} (0.83)	0.81^{a} (1.14)
M_3 - Recommended Plant Protection	0.87^{ab} (1.16)	0.79^{b} (1.13)	1.65^{a} (1.46)	2.03^{b} (1.58)	1.50^{a} (1.41)	0.52^{a} (1.01)	0.49^{b} (0.99)	1.12^{a} (1.26)
M_4 - Untreated check	2.11^{c} (1.61)	3.18^{d} (1.91)	3.55^{c} (2.00)	4.20^{c} (2.16)	5.54^{c} (2.45)	6.70^{c} (2.67)	0.60^{b} (1.04)	3.70^{c} (2.04)
S. Em ±	0.03	0.04	0.07	0.05	0.07	0.06	0.02	0.05
C.D. at 5%	0.11	0.14	0.21	0.17	0.22	0.16	0.08	0.16

DAS; Days After Sowing, S. Em ±; Standard Error Mean, CD; Critical Difference
Figures in parenthesis indicate square root $\sqrt{(x+0.5)}$ transformed values
In a column, means followed by same alphabet do not differ significantly (P=0.05) by DMRT

Efficacy of modules against shoot and fruit borers

The M_2-crop diversification based adoptable module registered significantly reduced mean fruit per cent damage of *H. armigera* (6.39%) which was on par with M_3-recommended plant protection (9.28%). Next best module was M_1-crop diversification based bio-intensive module (19.32%) which was at par with M_4-untreated check (23.17%) (Table 4).

Among the modules, M_2-crop diversification based adoptable module emerged as significantly efficient module by recording the lowest shoot damage of *E. Vittella* 5.19 per cent which was on par with M_3-recommended plant protection (5.89%). On the contrary M_1-crop diversification based bio-intensive module (10.73%) was ineffective and highest damage recorded from M_4-untreated check (16.62%) (Table 5).

The M_2-crop diversification based adoptable module was one of the outstanding modules in reducing per cent fruit damage by *E. Vittella* (6.82%) which was on par with the M_3-recommended plant protection (9.70%). However, M_1-crop diversification based bio-intensive module (16.60%) which was at par with the M_4-untreated check (20.79%) registered highest damage (Table 6).

Table 4: To evaluate crop diversification based modules against fruit borer, *Helicoverpa armigera* in okra

Treatments	Fruit damage (%)						Mean
	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS	100 DAS	
M_1 - Crop diversification based bio-intensive module	9.20 [c] (17.55)	17.25 [b] (24.41)	23.90 [b] (29.13)	29.15 [c] (32.54)	25.25 [b] (30.03)	11.15 [b] (19.39)	19.32 [b] (26.28)
M_2 - Crop diversification based adoptable module	4.15 [a] (11.70)	3.25 [a] (10.34)	5.10 [a] (12.99)	10.75 [a] (19.06)	8.06 [a] (16.42)	7.01 [a] (15.28)	6.39 [a] (14.57)
M_3 - Recommended Plant Protection	6.90 [b] (15.15)	4.80 [a] (12.58)	7.95 [a] (16.29)	16.05 [b] (23.85)	10.10 [a] (18.44)	9.45 [ab] (17.81)	9.28 [a] (17.64)
M_4 - Untreated check	11.76 [d] (19.99)	19.25 [b] (25.94)	25.15 [b] (30.02)	32.25 [c] (34.53)	27.25 [b] (31.39)	23.35 [c] (28.82)	23.17 [b] (28.69)
S. Em ±	0.77	0.91	1.12	1.41	1.23	0.99	1.08
C.D. at 5%	2.34	2.74	3.38	4.36	3.70	3.00	3.28

DAS; Days After Sowing, S. Em ±; Standard Error Mean, CD; Critical Difference
Figures in parenthesis indicate arc sine transformed values
In a column, means followed by same alphabet do not differ significantly (P=0.05) by DMRT

Table 5: To evaluate crop diversification based modules against shoot damage caused by *Earias vittella* on okra

Treatments	Shoot damage (%)				Mean
	40 DAS	50 DAS	60 DAS	70 DAS	
M_1 - Crop diversification based bio-intensive module	2.50 [b] (9.04)	10.95 [b] (19.21)	15.95 [b] (23.41)	13.50 [b] (21.43)	10.73 [b] (19.01)
M_2 - Crop diversification based adoptable module	1.15 [a] (6.12)	5.19 [a] (13.11)	9.19 [a] (17.57)	5.22 [a] (13.15)	5.19 [a] (13.11)
M_3 - Recommended Plant Protection	1.71[a] (7.47)	5.90 [a] (13.98)	10.50 [a] (18.81)	5.45 [a] (13.43)	5.89 [a] (13.97)
M_4 - Untreated check	10.56 [c] (18.90)	16.75 [c] (24.08)	20.90 [c] (27.13)	18.25 [c] (25.21)	16.62 [c] (23.98)
S. Em ±	0.49	0.85	1.07	0.89	0.84
C.D. at 5%	1.50	2.58	3.23	2.69	2.55

DAS; Days After Sowing, S. Em ±; Standard Error Mean, CD; Critical Difference
Figures in parenthesis indicate arc sine transformed values
In a column, means followed by same alphabet do not differ significantly (P=0.05) by DMRT

Table 6: To evaluate crop diversification based modules against fruit damage caused by *Earias vittella* in okra

Treatments	Fruit damage (%)						Mean
	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS	100 DAS	
M_1 - Crop diversification based bio-intensive module	15.29 [b] (22.89)	18.27 [b] (25.17)	16.19 [b] (23.59)	19.18 [b] (25.84)	16.49 [c] (23.83)	14.20 [c] (22.09)	16.60 [b] (24.13)
M_2 - Crop diversification based adoptable module	6.25 [a] (14.41)	5.78 [a] (13.85)	7.25 [a] (15.55)	12.51 [a] (20.63)	5.71 [a] (13.76)	3.41 [a] (10.59)	6.82 [a] (15.07)
M_3 - Recommended Plant Protection	8.36 [a] (16.72)	7.71 [a] (16.04)	9.71 [a] (18.06)	12.97 [a] (21.00)	10.25 [b] (18.58)	9.20 [b] (17.56)	9.70 [a] (18.05)
M_4 - Untreated check	21.25 [c] (27.37)	20.15 [b] (26.59)	21.36 [c] (27.45)	23.50 [b] (28.92)	21.25 [d] (27.37)	17.25 [d] (24.49)	20.79 [b] (27.05)
S. Em ±	0.99	1.01	1.03	1.21	1.02	0.74	1.03
C.D. at 5%	3.00	3.07	3.10	3.63	3.10	2.30	3.10

DAS; Days After Sowing, S. Em ±; Standard Error Mean, CD; Critical Difference
Figures in parenthesis indicate arc sine transformed values
In a column, means followed by same alphabet do not differ significantly (P=0.05) by DMRT

Yield and cost economics of IPM modules in okra

All the treatments proved to be superior over untreated check in terms of fruit yield. The fruit yield among the treatments ranged from 10.40 to 18.15 t/ha. Crop diversification based adoptable modules-M_3, registered highest yield (18.15 t/ha), maximum net returns Rs.2,90,340 and highest B:C (5.00) ratio (Table 11). As compared to other modules. Hence, M_2-Crop diversification based adoptable module proved to be more effective, economically feasible and practically adoptable by the farming community.

Table 7: Cost economics of crop diversification based IPM modules in okra

Treatments	Yield (t/ha)	Cost of plant protection (Rs/ha)	Agronomical cost (Rs/ha)	Total cost of production (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C Ratio
M_1 - Crop diversification based bio-intensive module	13.10	12216	51,918	64,134	262000	1,97,866	4.08
M_2 - Crop diversification based adoptable module	18.15	20742	51,918	72,660	363000	2,90,340	5.00
M_3 – Recommended Plant Protection	14.20	8301	51,918	60,219	284000	2,23,781	4.71
M_4 - Untreated check	10.40	0.00	51,918	51,918	208000	1,52,082	4.00

Market price Rs. 20 /kg okra Net returns = Gross returns – Total Cost
B:C ratio = Gross returns / Total cost Gross returns = Yield x Market price of okra (Rs. 20 /kg)

The effectiveness of crop diversification based adoptable module was mainly attributed to adaptation and implementation of excellent crop diversification in different ways such as barrier, trap, border and intercrops which encourages the natural enemies by manipulating ecological crop diversification resulting reduction in okra pest population. Further, maize as barrier crop taller than okra prevents the migration of sucking pests and fruit borers from one plot to another. Especially marigold as trap crop traps the *H. armigera* which avoided egg laying and infestation on main crop. Similarly, border crop cowpea and coriander during effective flowering period encouraged the multiplication of natural enemies by providing food sources like pollen, nectar and shelter. Further, introduction of crop diversification along with seed treatment with imidacloprid, application of neem cake, installation of yellow sticky traps for monitoring of sucking pests, installation of pheromone traps for monitoring of fruit borers, application of bio-pesticides like azadirachtin and bio-agents such as *L. lecanii* based insecticides enhanced the population of parasitoids like tachinids, braconids, *Nepiera* sp., *Neofacydes* sp., predators like coccinellids, crysopids, syrphids, spiders, wasps, reduviid bug and predatory birds like yellow wagtail and cattle egret resulting in reduced incidence of okra leafhoppers, whiteflies and per cent fruit damage by fruit borers. Similarly, ETL based application of green labelled molecules such as chlorantraniliprole 18.5 SC, cyantraniliprole 10.26 OD, thiamethoxam 25 WG and tolfenpyrad 15 EC were better option rather than broad spectrum conventional insecticides which are toxic and detrimental to the natural enemies. Finally, M_2-crop diversification based adoptable module reduced four insecticide sprays as compared to recommended plant protection suggesting cost effective and environmentally safe.

Similar results were corroborated with the findings of Rana *et al.* (2006) [5] where efficacy of imidacloprid seed treatment against sucking pests at the early growth stages of the okra crop has been found most effective. Similarly, Patel *et al.* (2009) [6] observed lowest *B. tabaci* population in IPM module consisting of maize as border crop, seed treatment with imidacloprid, foliar application of neem oil. The present findings were effective principally because of alkaloids like azadiractin, limonoides, triterpenoides and saponins present in neemazal possess antifeedent, repellent and egg deterent activity against insect pests and hence resulted in effective control of whiteflies. Further, results are in conformity with Gupta and Pathak (2009) [7] who reported that, mixed treatment of NSKE (in cow urine) 3% + dimethoate 0.03% were found to be most effective in controlling the incidence of whiteflies.

The present investigations are comparable with observations of Rao *et al.* (2008) [8] and Birah *et al.* (2012) [9] who reported that integration of crop diversification in IPM module is most effective, ecofriendly, economically feasible and practically adaptable. Crop diversification based adoptable module comprised of seed treatment with imidacloprid at 5 g/kg seed, neem cake application at 250 kg/ha at the time of sowing, sowing of maize at the borders as barrier crop, weekly clipping of infested shoots and fruits, erection of pheromone trap at 100 traps/ha for mass trapping, foliar spray of neem seed kernel extract at 30 ml/l, spinosad 45 SC at 0.5 ml/l and karanj oil at 30 ml/l at 45, 60 and 75 days after sowing recorded significantly lower incidence of leafhopper, whiteflies, shoot borer and fruit borer and recorded highest fruit yield. Higher density of predators on okra crop was reported by Preetha and Nadarajan (2011) [10] who recommended integrated module consisting of seed treatment with imidacloprid + release of *T. chilonis* at 6 cc/ac + release of *Chrysoperla* 2000 eggs/acre + Spraying of *B. thuringiensis* (Spicturin FC) at 2.0 ml/l. Border cropping with maize and sorghum might have helped in conserving and augmenting coccinellids by providing shelter, alternate prey and pollen. Selective systemic action of imidacloprid seed treatment retained moderate predator population during the early age of the crop as reported by Nemade *et al.* (2008) [11]. Similarly, more population of predators were spared due to selective toxicity of foliar application by spinosad 45 SC. Earlier workers such as Udikeri *et al.* (2004) [12]; Dhanalakshmi and Mallapur (2008) [13] and Mohanasundarm and Sharma (2011a) [14] reported higher population of spiders and coccinellids on the cotton and okra crop sprayed with spinosad 45 SC. Thus, the IPM modules containing safer chemicals such as seed treatment, neem products and safer new insecticides were ecologically sustainable with effective suppression of the target pests.

Summary and Conclusion

Among different IPM modules evaluated, M_2-crop diversification based adoptable module comprising of crop diversification and bio-agents have been considered to be a sound IPM tool. In the present study, crop diversification based adoptable module comprised of two rows of 25 days old maize as barrier crop, one row of 25 days old marigold as trap crop, two rows of cowpea as border crop and okra intercropped with coriander (5:1), seed treatment with imidacloprid 600 FS 10 at ml/kg, application of neem powder at 2.5 q/ha at the time of sowing, installation of pheromone traps at 5/ha for monitoring of fruit borers, setting up of yellow sticky traps at 15 per ha for monitoring of sucking pests, ETL based application of azadirachtin 10,000 ppm at 1.0 ml + *Lecanicillium lecanii* (1×10^8 CFU/g) at 5 g, tolfenpyrad 15 EC at 1.0 ml/l, thiamethoxam 25 WG at 0.20 g/l, cyantraniliprole 10.26 OD at 1.0 ml/l and chlorantraniliprole 18.5 SC at 0.20 ml/l proved to be significantly effective in reducing the insect pests of okra. Results indicated that, M_2-Crop diversification based adoptable module exhibited significantly lowest mean leafhoppers (2.24/leaf), whiteflies (0.81/leaf), shoot damage (5.15%), fruit damage (6.82%) by *E. vittella* and *H. armigera* fruit damage (6.39%). Further, crop diversification based adoptable module registered significantly highest yield of 18.15 t/ha, net returns (Rs. 2,90,340) and highest B:C ratio (5.00) as compared to recommended plant protection measures suggesting crop diversification based adoptable module more effective, economically feasible and practically adoptable by the farming community.

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