Evaluation of habitat manipulation based IPM modules for encouraging natural enemies against insect pests of okra

Abstract

The investigation on "Evaluation of habitat manipulation based IPM modules for encouragement of natural enemies in okra ecosystem *viz.*, coccinellids, chrysopids, syrphids and spiders was carried out at College of Horticulture, Bagalkot, Karnataka, India. The experiment was laid out in randomized completely block design with four treatments and five replications. The treatments included, (T_1) habitat manipulation based bio-intensive module, (T_2) habitat manipulation based adoptable module, (T_3) recommended plant protection and (T_4) an untreated check. Observations on natural enemies were recorded on okra crop at ten days intervals starting from 20 days after sowing. Among the different IPM modules evaluated for encouragement of natural enemies against insect pests of okra, habitat manipulation based bio-intensive module comprising of 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), seed treatment with imidacloprid 600 FS at 10 ml/kg, Application of neem powder at 2.5 q/ha, releasing of *Trichogramma chilonis* one lakh per hectare, installation of pheromone traps five per hectare and yellow sticky traps 15 per hectare, spraying of azadirachtin 10,000 ppm at 1.0 ml/l + *Lecanicillium lecanii* (1×10^8 CFU/g) at 5 g/l, *Bacillus thuringiensis* at 2.0 ml/l, Chilli garlic extract at 0.5% and Bio-digester at 20% significantly encouraged multiplication of natural enemies like coccinellids (0.37/plant), chrysopids (0.40/plant), syrphids (0.45/plant) and spiders (0.62/plant) as compared to habitat manipulation based adoptive module, recommended plant protection module and control suggesting habitat manipulation based bio-intensive module was more effective, economically feasible and practically adoptable by the farming community.

Keywords: habitat manipulation, IPM modules, barrier crop, trap crop, border crop, intercrop, coccinellids, chrysopids, syrphids and spiders.

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”. 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.

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). Among them, leafhoppers *Amrasca biguttula biguttula* (Ishida), whitefly *Bemisia tabaci* (Gennadius), shoot and fruit borer *Earias vittella* (Fabricius), *Earias insulana* and fruit borer *Helicoverpa armigera* (Hubner) are most serious and major restraining biotic factors in okra cultivation. The crop loss estimation for major pests is 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). In general, 48.97 per cent economic loss in fruit yield is noticed due to overall damage by insects (Kanwar and Ameta, 2007).

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, pesticide 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, habitat manipulation 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 (Gopi *et al*., 2019).

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 habitat manipulation seems to be the most appropriate approach to achieve sustainability in okra production and to encourage the multiplication of native existed natural enemies to control insect pests in okra ecosystem.

Materials and Method

The field experiment on to evaluation habitat manipulation based modules against insect pests of okra was conducted at College of Horticulture, Bagalkot. The okra seeds were sown at a spacing of 60 cm × 45 cm in a Randomized Completely Block Deign (RCBD) design with four treatments and five replications in a plot size of 6 m × 4 m. The crop was raised by following the all agronomic practices as per the recommended package of practices of University of Horticultural Sciences, Bagalkot.

Observations on natural enemies

Total number of natural enemies like coccinellids, chrysoperla, syrphids and spiders per plant were recorded at ten days interval starting from 20 days after sowing till the final harvest of the crop on whole plant basis by visual observation.

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 habitat manipulation based IPM modules for encouraging natural enemies against insect pests of okra

Sl. No.	Modules	Treatment details
M_1	**Habitat manipulation 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	**Habitat manipulation 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**	1. Dimethoate 30 EC at 1.7 ml/l 2. Imidacloprid 17.8 SL at 0.3 ml/l

	protection	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

Abundance of natural enemies

The recommended plant protection registered significantly lowest mean number of coccinellids 0.10 per plant. Whereas, habitat manipulation based adoptable module M_2 0.27 per plant recorded which was on par with untreated check (0.21/plant). The superior module was M_1-habitat manipulation based bio-intensive module (0.37/plant) indicating both are equally effective in encouraging coccinellid population (Table 2).

The chrysopids population varied among different modules in which the M_1-habitat manipulation based bio-intensive module (0.40/plant) recorded the significantly higher population. Second best module was M_2-habitat manipulation based adoptable module (0.31/plant) which was at par with untreated check (0.24/plant). Whereas, M_3-recommended plant protection registered lowest chrysopids (0.13/plant) (Table 3).

Among various treatments, M_1-habitat manipulation based bio-intensive module recorded highest number of syrphids population (0.45/plant) which was in turn statistically at par with M_2-habitat manipulation based adoptable module (0.39/plant) revealing both are equally best in encouraging syrphids population, which was on par with untreated check (0.34/plant). Whereas, recommended plant protection-M_3 (0.14/plant) resulted toxicity to syrphids population (Table 4).

The habitat manipulation based bio-intensive module-M_1 registered highest spider population (0.62/plant) which was statistically on par with both M_2- habitat manipulations based adoptable module registered 0.59 per plant and untreated check (0.55/plant). Whereas, M_3-recommended plant protection registered lowest spiders (0.23/plant) (Table 5).

Table 2: To evaluate habitat manipulation based modules against coccinellids in okra

Treatments	Number of coccinellids/plant								Mean
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**	**100 DAS**	
M1-Habitat manipulation based bio-intensive module	0.10 [a] (0.31)	0.34 [a] (0.57)	0.45 [a] (0.66)	0.46 [a] (0.67)	0.45 [a] (0.66)	0.53 [a] (0.72)	0.39 [a] (0.61)	0.21 [a] (0.45)	**0.37 [a] (0.60)**
M2-Habitat manipulation based adoptable module	0.05 [b] (0.22)	0.21 [b] (0.45)	0.31 [b] (0.55)	0.45 [a] (0.66)	0.35 [ab] (0.58)	0.37 [b] (0.60)	0.30 [ab] (0.54)	0.10 [b] (0.31)	**0.27 [b] (0.51)**
M3-Recommended Plant Protection	0.02 [d] (0.13)	0.10 [c] (0.31)	0.10 [c] (0.31)	0.10 [b] (0.31)	0.13 [c] (0.35)	0.20 [c] (0.44)	0.10 [c] (0.31)	0.07 [b] (0.26)	**0.10 [c] (0.31)**
M4-Untreated check	0.03 [c] (0.17)	0.16 [b] (0.39)	0.25 [b] (0.49)	0.25 [b] (0.49)	0.26 [b] (0.50)	0.35 [b] (0.58)	0.29 [b] (0.53)	0.08 [b] (0.28)	**0.21 [b] (0.45)**
S. Em ±	0.01	0.02	0.02	0.04	0.03	0.02	0.01	0.03	**0.03**
C.D. at 5%	0.04	0.06	0.08	0.13	0.07	0.08	0.05	0.07	**0.07**

DAS; Days After Sowing, S. Em ±; Standard Error Mean, CD; Critical Difference
Figures in parenthesis indicate square root √(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 habitat manipulation based modules against chrysopids in okra**

Treatments	Number of chrysopids/plant								Mean
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**	**70 DAS**	**80 DAS**	**90 DAS**	**100 DAS**	
M1-Habitat manipulation based bio-intensive module	0.15 [a] (0.38)	0.33 [a] (0.57)	0.41 [a] (0.63)	0.55 [a] (0.73)	0.63 [a] (0.78)	0.78 [a] (0.87)	0.20 [a] (0.44)	0.15 [a] (0.38)	**0.40 [a] (0.62)**
M2-Habitat manipulation based adoptable module	0.12 [a] (0.34)	0.25 [b] (0.49)	0.35 [ab] (0.58)	0.50 [ab] (0.70)	0.47 [ab] (0.68)	0.50 [b] (0.70)	0.17 [a] (0.41)	0.13 [ab] (0.35)	**0.31 [b] (0.52)**
M3-Recommended Plant Protection	0.01 [b] (0.10)	0.02 [c] (0.13)	0.21 [c] (0.45)	0.20 [c] (0.44)	0.25 [c] (0.49)	0.30 [c] (0.54)	0.02 [c] (0.13)	0.01 [c] (0.10)	**0.13 [c] (0.35)**
M4-Untreated check	0.01 [b] (0.10)	0.20 [b] (0.44)	0.28 [bc] (0.52)	0.40 [b] (0.63)	0.45 [b] (0.66)	0.35 [c] (0.58)	0.11 [b] (0.33)	0.10 [b] (0.31)	**0.24 [b] (0.51)**
S. Em ±	0.01	0.02	0.03	0.03	0.03	0.03	0.01	0.01	**0.02**
C.D. at 5%	0.05	0.06	0.09	0.10	0.10	0.11	0.05	0.04	**0.07**

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

Table 4: To evaluate habitat manipulation based modules against syrphids in okra

Treatments	Number of syrphids/plant								Mean
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS	100 DAS	
M1-Habitat manipulation based bio-intensive module	0.17 [a] (0.40)	0.22 [a] (0.46)	0.27 [a] (0.51)	0.42 [a] (0.64)	0.73 [a] (0.85)	0.85 [a] (0.91)	0.50 [a] (0.70)	0.40 [a] (0.62)	**0.45 [a] (0.66)**
M2-Habitat manipulation based adoptable module	0.14 [ab] (0.37)	0.20 [a] (0.44)	0.21 [ab] (0.45)	0.31 [b] (0.55)	0.70 [a] (0.83)	0.80 [a] (0.89)	0.41 [ab] (0.63)	0.34 [a] (0.57)	**0.39 [ab] (0.62)**
M3-Recommended Plant Protection	0.10 [c] (0.31)	0.12 [b] (0.34)	0.13 [c] (0.35)	0.12 [d] (0.34)	0.18 [b] (0.42)	0.17 [b] (0.41)	0.16 [c] (0.40)	0.15 [b] (0.38)	**0.14 [c] (0.36)**
M4-Untreated check	0.12 [bc] (0.34)	0.18 [a] (0.42)	0.19 [b] (0.43)	0.20 [c] (0.44)	0.69 [a] (0.82)	0.77 [a] (0.87)	0.39 [b] (0.62)	0.20 [b] (0.44)	**0.34 [b] (0.57)**
S. Em ±	0.01	0.02	0.03	0.02	0.04	0.03	0.01	0.02	**0.02**
C.D. at 5%	0.05	0.06	0.06	0.07	0.12	0.11	0.05	0.08	**0.09**

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

Table 5: To evaluate habitat manipulation based modules against spiders in okra

Treatments	Number of spiders/plant								Mean
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS	100 DAS	
M1-Habitat manipulation based bio-intensive module	0.35 [a] (0.58)	0.50 [a] (0.70)	0.64 [a] (0.79)	0.77 [a] (0.87)	0.85 [a] (0.91)	0.90 [a] (0.94)	0.58 [a] (0.75)	0.40 [a] (0.62)	**0.62 [a] (0.78)**
M2-Habitat manipulation based adoptable module	0.33 [a] (0.57)	0.45 [a] (0.66)	0.60 [a] (0.77)	0.70 [a] (0.83)	0.80 [a] (0.89)	0.87 [a] (0.92)	0.50 [a] (0.70)	0.43 [a] (0.65)	**0.59 [a] (0.76)**
M3-Recommended Plant Protection	0.20 [b] (0.44)	0.30 [b] (0.54)	0.40 [b] (0.63)	0.40 [b] (0.63)	0.10 [b] (0.31)	0.05 [b] (0.22)	0.30 [b] (0.54)	0.05 [b] (0.22)	**0.23 [b] (0.47)**
M4-Untreated check	0.30 [a] (0.54)	0.38 [ab] (0.61)	0.57 [a] (0.75)	0.67 [a] (0.81)	0.78 [a] (0.88)	0.81 [a] (0.89)	0.47 [a] (0.68)	0.38 [a] (0.61)	**0.55 [a] (0.73)**
S. Em ±	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.02	**0.04**
C.D. at 5%	0.10	0.11	0.11	0.11	0.07	0.11	0.10	0.07	**0.12**

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

Discussion

The effectiveness of habitat manipulation based bio-intensive module followed by 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 (Gopi *et al*., 2019). Further, maize as barrier crop, marigold as trap crop, 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* and *Bt* followed by application of chilli garlic extract and bio-digester not affected 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 (Gopi *et al*., 2019). 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_1-habitat manipulation based bio-intensive module followed by M_2-crop diversification based adoptable module reduced four insecticide sprays as compared to recommended plant protection suggesting cost effective and environmentally safe.

The present investigations are comparable with observations of Rao *et al.* (2008) and Birah *et al.* (2012) who reported that integration of crop diversification in IPM module is most effective, eco-friendly, 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) 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). 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); Dhanalakshmi and Mallapur (2008) and Mohanasundarm and Sharma (2011a) 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.

Conclusion:

Among different IPM modules evaluated, M_1-habitat manipulation based bio-intensive module followed by M_2-habitat manipulation based adoptable module comprising of crop diversification and bio-agents have been considered to be a sound IPM tool. In the present study, habitat manipulation based bio-intensive module comprising of 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), seed treatment with imidacloprid 600 FS at 10 ml/kg, Application of neem powder at 2.5 q/ha, *Trichogramma chilonis* one lakh per hectare, Pheromone traps five per hectare, Yellow sticky traps 15 per hectare, Azadirachtin 10,000 ppm at 1.0 ml/l + *Lecanicillium lecanii* (1×10^8 CFU/g) at 5 g/l, Spraying of *Bacillus thuringiensis* at 2.0 ml/l, Chilli garlic extract at 0.5%, Bio-digester at 20% followed by habitat manipulation based adoptable module proved to be significantly effective in encouraging natural enemies in okra ecosystem. Results indicated that, M_1-habitat manipulation based bio-intensive module exhibited significantly encouraged multiplication of natural enemies like coccinellids (0.37/plant), chrysopids (0.40/plant), syrphids (0.45/plant) and spiders (0.62/plant) as compared to recommended plant protection measures suggesting habitat manipulation based bio-intensive module more effective, economically feasible and practically adoptable by the farming community.

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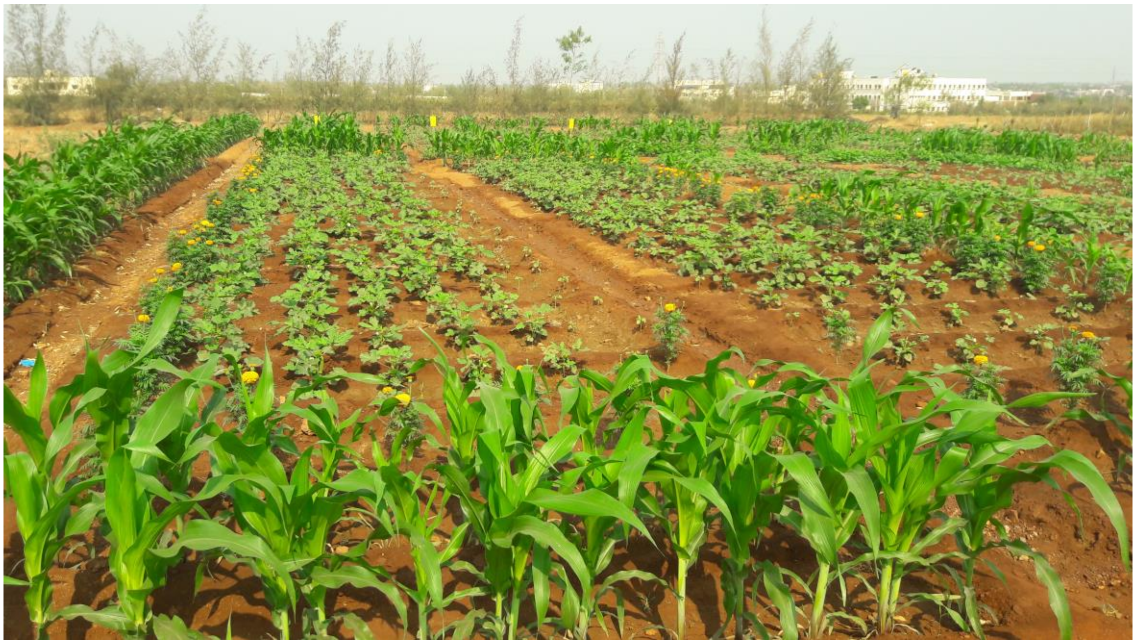


Fig.1. Field view

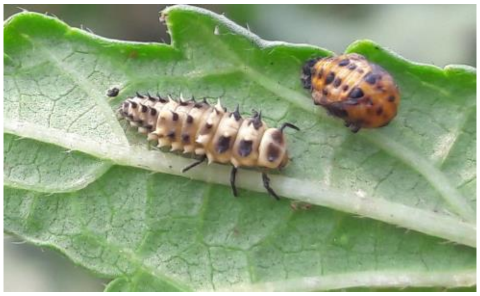
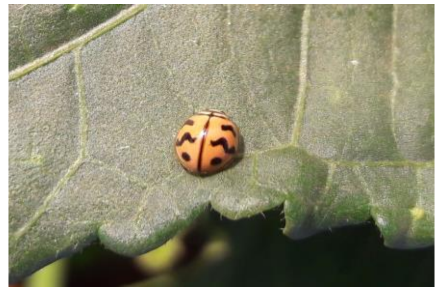
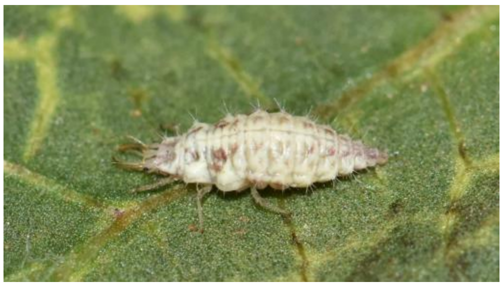
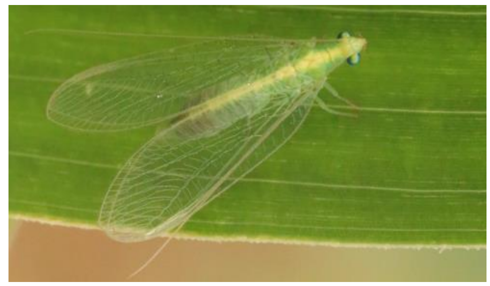
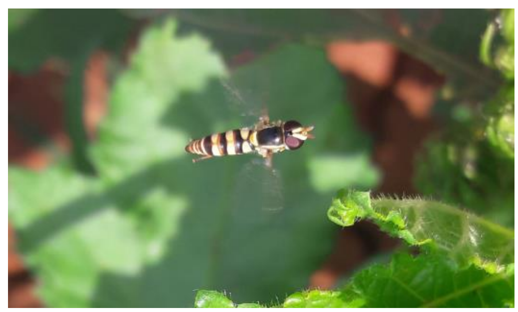
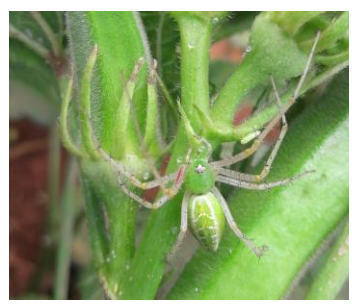
 Coccinellid grub and pupa	 Coccinellid adult
 Chrysoperla grub	 Chrysoperla adult
 Syrphid fly maggot	 Syrphid fly adult
 Spider	 Spider

Fig.2. Predators observed in okra ecosystem

COMPETING INTERESTS DISCLAIMER:
Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.