Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(2): 414-421

Received: 26-01-2017
Accepted: 27-02-2017

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Non-host plant derived kairomone to enhance activity of natural enemies of lepidopteran pests of *Abelmoschus esculentus* (L.) Moench

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Abstract
Vegetational manipulation and use of semio-chemicals in *Abelmoschus esculentus* (L.) Moench eco-system to manage the key lepidopteran pests like *Earias vittella* (Fab.) and *Helicoverpa armigera* (Hübner) were tried by conducting a field experiment during January 2014 at the Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai, Tamil Nadu, India, in which eight intercrops were grown along with *Ab. esculentus* at 1:4 ratios. The average population and shoot and fruit damage caused by *Ea. vittella* and *He. armigera* on *Ab. esculentus* were low when intercropped with cluster bean (*Cyamous tetragocalobe* L.), besides attracting comparatively high population of *Chrysoperla zastrowi sillemi* (Esben-Peterson) and per cent field recovery of *Trichogramma chilonis* Ishii than *Ab. esculentus* as pure crop. Kairomone activity of acetone extract of flowers of *Cy. tetragocalobe* was favourable and enhanced the foraging activity of *Tr. chilonis* and *Ch. zastrowi sillemi* against lepidopteran pests of *Ab. esculentus*.

Keywords: *Abelmoschus esculentus*, *Cyamous tetragocalobe*, habitat manipulation, *Earias vittella*, *Helicoverpa armigera*, semio-chemical, entomophages, management

1. Introduction
The stimuli influencing searching, parasitization, or retention of the parasitoids originate from various sources such as host plant, non-host plant, host insect and long and short chain saturated hydrocarbons [1-5]. Vegetational diversity can also provide support for insect biological control at the local and landscape levels [6, 7, 8]. Non-host plant can directly serve as food sources or provide other ecosystem resources for herbivourous arthropods and indirectly serve carnivourous (beneficial) arthropods by providing food and shelter to their prey [9]. Intercropping, which is the cultivation of two or more species within the same field, is a common method to increase beneficial insect diversity within agro-ecosystems and hence it may provide natural pest management by increasing the abundance and diversity of insect natural enemies in the agro-ecosystems [10, 11]. Several intercropping systems are in vogue at scientists and farmers level which reduced the population of herbivoures through habitat manipulation, besides providing shelter, nectar *etc*., to natural enemies [12-18]. Allelochemicals emanated from non-host plants have been reported to be favourable to natural enemies [19, 20, 14, 21-24]. Using deterring chemical stimuli (push) or trap crops (pull) works well on herbivoures to repel away from the main crop or pull towards the trap crops, besides supporting insect natural enemies and biological control [25, 26]. Flowering plant strips adjacent to main crop fields help support beneficial insect biodiversity in agricultural landscapes [27-30]. The response of *Tetrastichus schoenobii* Ferriere, an egg parasitoid of *Scirpophaga incertulas* (Walker) to flowers of bush mint, *Hyptis suaveolens* L., a common weed in rice fields was noticed [5,10,1]. Flower bud, flower and leaf volatiles of *Tagetes erecta* Linnaeus have been reported to attract *Helicoverpa armigera* (Hübner)) and its parasitoid [34, 35, 57]. The present study was conducted to explore the potential for manipulating the behavior of natural enemies through vegetational diversification of crop habitats and the use of semiochemicals to enhance biological control activity of *Tr. chilonis* and *Ch. zastrowi sillemi* against the lepidopteran pests of *Ab. esculentus*.

2. Materials and Methods

2.1. Intercropping trial

Ab. esculentus hybrid (Cv. No. 55) seeds, purchased from the local Seed Companies, Madurai, Tamil Nadu, India were soaked in 50% salt solution separately to remove diseased/ill-filled seeds and sound seeds were shade dried. They were treated with carbendazim 0.2% @ 2 g/kg of seeds to protect them from soil born diseases. Fungicide treated seeds were dibbled on 10.01.2014 in red loam soil of Insectary, Agricultural College and Research Institute, Madurai, Tamil Nadu, India with weather condition of 25 ^{0}C, 75 RH, photoperiod: 16:8 h L:D. Seeds were dibbled @ 2 seeds/hole in ridges and furrows with spacing of 60 × 30 cm and the plot size was 5 × 4 m and replicated thrice. *Ab. esculentus* was intercropped with *Ricinus communis* L. (local), *Zea mays* (L.) (Cv. Co 6), *Helianthus annuus* L. (local), *Cyamous tetragocalobe* L. (local), *Tagetes erecta* (L.) (Cv. MDU 1), *Pennisetum glaucum* L. R. Br. (Cv. Co7), *Coriandrum sativum* L. (local) and *Vigna unguiculata* (L.) (local) at the ratio of 4:1 with recommended spacing. All agronomic practices were followed as per the Crop Production Guide of Tamil Nadu Agricultural University, Coimbatore, India and they were maintained in unprotected condition to find out cost-effective intercropping system which deter lepidopteran insects of *Ab. esculentus* like *Ea. vittella* and *He.armigera*, besides attracting their entomophages.

The population of *Ea. vittella* and *He. armigera* (number of larvae/10 plants) and per cent shoot damage by *Ea. vittella* (number of bored shoots to healthy shoots in 10 plants) were observed starting from 30 days after dibbling up to 70 days at 10 days interval. Per cent fruit damage by *Ea. vittella* and *He. armigera* (number of bored fruits to healthy fruits) was recorded at each harvest starting from 60 days after dibbling. Number of eggs/grubs of *Ch. zastrowi sillemi* in 10 randomly tagged plants were counted on 40 and 70 days after dibbling. UV irradiated eggs of rice moth, *Corcyra cephalonica* Stainton, pasted in a card size of 7 × 2 cm(approximately 500 eggs/card) were tied @ one card/replication on 18, 38 and 58 days after dibbling. After 48 h exposure, egg cards were collected and incubated at 28 ^{0}C separately to record the per cent recovery of *Tr. chilonis* adults (based on black coloured eggs).

2.2. Maintenance of host insects and natural enemies

2.2.1. *Ea. vittella*

Second instar of *Ea. vittella* were collected from field of *A. esculentus* and reared on *Ab. esculentus* fruits at Insectary, Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai, Tamil Nadu, India, as described by [21]. Fresh and tender *Ab. esculentus* were cut into pieces of 2.5 cm long and placed in 12 well-cavity trays and 2 pieces per well. Using camel hair brush, the larvae were transferred to the fruits. Filter paper of same size as that of tray was placed over the fruits in order to absorb excess moisture thereby preventing the rotting of fruits. The tray was then covered using plastic lid and fastened by a rubber band. Fresh okra fruit pieces were provided on alternate days. The boat shaped cocoons were collected and placed in adult emergence cage (30 × 30 × 30 cm). Newly emerged adults were provided with 10 per cent sugar solution fortified with multivitamin solution in 5 ml glass vial provided with cotton wool wick to prevent moths from drowning. Four to five tender *Ab. esculentus* fruits were kept in cages as oviposition substrates. These fruits were removed on next day of egg laying and observed for hatching. The newly hatched first instars were provided with cut pieces of *Ab. esculentus* fruits. This represented first generation. Similarly, five generations were maintained in the laboratory at 26 ± 1 ^{0}C, RH 75 ± 5% and photoperiod 16:8 h L:D. Second to third instar larvae of sixth generation were used for laboratory experiments.

2.2.2. *He. armigera*

Eggs of *He. armigera* obtained from National Bureau of Agricultural Insects Resources, Bengaluru, Karnataka State, India were reared separately in multi-cavity tray containing chickpea flour based semi-synthetic diet. Two eggs were inoculated per cell and separated as one per cell on 10th day to avoid cannibalism. Old diet was replaced with fresh ones in alternate days. Pre-pupae were collected in vermiculite for pupation. Pupae collected from culture were placed in adult emergence wooden cage measuring 30 × 30 × 30 cm. Five pairs of newly emerged adults were transferred to plastic buckets of seven liter capacity maintaining the sex ratio of 1:3 (female : male) for oviposition. Adults were fed with 10 per cent sugar solution enriched with multivitamin drops. The mouth of the bucket was covered with sterile muslin cloth which served as oviposition substrate. The buckets were kept in a dark place at 25 °C with 75% RH. Muslin cloth along with eggs was collected from third day onwards and used for laboratory experiments.

2.2.3. *Tr. chilonis*

Co. cephalonica obtained from National Bureau of Agricultural Insects Resources, Bengaluru, Karnataka State, India was reared in the laboratory as per the protocol suggested by [36]. The newly emerged *Co. cephalonica* adults were released into oviposition cages of 21 × 25 cm size, with a wire mesh at bottom and lateral sides for ventilation. Adults were provided with 50% honey solution as food. Eggs collected at the bottom on a blotting paper kept in tray were cleaned with sieves or egg scale separator. The cleaned eggs were sprinkled over broken pearl millet grains, at the rate of one cc per 2.5 kg of grains, fortified with ten grams of yeast in a plastic basin (45 × 30 × 10 cm) and covered with khada cloth. Care was taken to maintain the culture free of storage mites and diseases by mixing 5 g of wettable sulphur 80 WP and streptomycin sulphate 0.5%, respectively. The emerged adults were collected and used again for culturing both host (*Co. cephalonica*) and parasitoid (*Tr. chilonis*). The culture was maintained at 26 ± 2 ºC, RH 75 ± 5% with the photoperiod 16:8 h L:D.

The egg parasitoid, *Tr. chilonis* was mass-cultured on the eggs of *Co. cephalonica*. The fresh *Co. cephalonica* eggs were collected in the early morning and sterilized under UV radiation of 15 watts for 20 minutes at a distance of 15 cm to avoid the emergence of *Co. cephalonica* larvae. The sterilized eggs were then pasted on paper cards of 21 × 30 cm size containing 30 rectangular cards (7 × 2 cm). These egg cards were placed in polythene bags along with nucleus card at 6:1 ratio for parasitization by the egg parasitoids at 26 ± 2ºC, R.H. 75 ± 5% and photoperiod 16:8 h L:D. After parasitisation, the egg cards were cut into bits and the three-day-old, cent per cent parasitized eggs (eggs appearing black and plumpy) were used for screening the acetone extracts of various parts of genotypes of *Ab. esculentus*.

2.2.4. *Ch. zastrowi sillemi*

Mass rearing of *Ch. zastrowi sillemi* was carried out with *Co. cephalonica* eggs as feed. Grubs of *Ch. zastrowi sillemi* obtained from National Bureau of Agricultural Insects

Resources, Bengaluru, Karnataka State, India were reared in galvanized iron (GI) basins (28 cm dia) at 250 larvae per basin covered with khada cloth. The UV irradiated eggs of *Co. cephalonica* were provided as feed for the grubs in the laboratory. About 2.5 cc of *Co. cephalonica* eggs per basin were provided on alternate days. After five feedings, the larvae pupated into white coloured round silken cocoon. The cocoons were collected and transferred into one litre plastic container with wire mesh window for the emergence of adults at 26 ± 2 ^{0}C, RH 75 ± 5% and a photoperiod 16:8 h L:D. The adults were collected and transferred to GI troughs (30 cm dia. × 12 cm ht.), wrapped inside with brown sheets for collecting the eggs. The trough was covered with nylon cloth and kept firm with the help of a rubber band. Over the cloth covering, two bits of foam sponge (2.5 cm^2) dipped in water were kept besides an artificial protein rich diet in the form of semi solid paste was smeared. This diet consisted one part of yeast powder + one part of fructose + one part of honey + one part of protinex. Water was mixed to make it just a paste. The adults laid eggs on the brown sheet wrapped inside the trough. The adults were collected daily and allowed into fresh rearing troughs with fresh feed. From the old troughs, the brown paper sheets along with *Ch. zastrowi sillemi* eggs were removed and dislodged and used for screening the acetone extracts of various parts of genotypes of *Ab. esculentus* for the presence of kairomone substances.

2.2.5. Preparation of acetone extracts of various parts of *Cy. tetragocalobe*

Acetone extracts (1% or 10000 ppm) of various plant parts of *Cy. tetragocalobe* (flower, stem and young and old leaves) were prepared. Various parts of *Cy. tetragocalobe* were collected separately and shade dried for 12 h. Young and old leaves collected on 30 and 65th day after dibbling, flowers on 35th day and stem on 40th day, were used for extraction. About 20 g of each sample was weighed and chopped into small pieces. These were transferred to 250 ml conical flask. One hundred ml of acetone (HPLC grade) was poured into the individual conical flask containing chopped plant materials. The mouths of the flasks were covered with non-absorbent cotton and were incubated for 72 h and shacked in water bath (Genuine model) at 28 ^{0}C for two hours followed with 20 minutes at 50 ^{0}C. The plant materials were filtered through Whatman number 1 filter paper. The acetone fraction was subsequently concentrated by vacuum evaporator at 40 ^{0}C (LARK model, Bengaluru). The extracts were stored at -20 ^{0}C in deep freezer (REMI model, Bengaluru) till further use for bioassay studies. A concentration of one per cent (10000 ppm) of the extracts of various parts *Cy. tetragocalobe* was prepared after dilution with acetone and used throughout the experiment.

2.2.6. Preparation of Egg card

Clean, healthy and 0-24 h old eggs of *Ea. vittella* and *He. armigera* sterilized under 4 watt UV light for 45 minutes were washed twice in hexane to remove the traces of scales or natural kairomones present on the surface of eggs and shade dried. These eggs were pasted with pure white gum on dull coloured cardboard, measuring 7 × 2 cm at the rate of 80-100 (*Ea. vittella*) and (*He. armigera*) eggs per piece (egg card). Kairomone extracts (10000 ppm) of various parts of *Cy. tetragocalobe* were used to treat the egg card (5 µl/card) [37] separately and shade dried.

2.2.7. Bio-assay-Choice Test

The treated egg cards were arranged in a circular fashion at equi-distance in a petri-dish (150 × 15 mm dia) and the parasitoids were released at the centre at 6:1 ratios. After 24 h exposure, egg cards were taken in glass tube (7.5 × 2.5 cm) and incubated at 23 ^{0}C and 65% RH. The per cent parasitization was observed on 3rd, 5th and 7th day after exposure. Choice tests were conducted separately for each extract and each insect egg. Similarly, one pre-starved second instar of *Ch. zastrowi sillemi* was released in a glass tube containing one egg card of *Ea. vittella* and *He. armigera* (700-750 numbers/card), treated with various extracts. Per cent predation was estimated 24 h after release. Laboratory experiment was conducted at 23 ± 2 °C, 65 ± 5% RH and light intensity of 160 LUX [25]. Each treatment was replicated eight times and each egg card was considered as one replication.

3. Statistical analysis

Field and laboratory experiments were conducted in a Randomized Block Design. Data on population of *Ea. vittella*, *He. armigera* and *Ch. zastrowi sillemi* were subject to square root transformation while per cent shoot damage, recovery and parasitization by *Tr. chilonis* and predation by *Ch. zastrowi sillemi* were subject to arcsine transformation before subjecting to 2 way ANOVA using IRRSTAT software version 6.5. The difference between the means of various treatments was compared by DMRT test at 5% significance level.

4. Results and Discussion

4.1. Intercropping trial

Population of *Ea. vittella* was low in *Ab. esculentus* (13.22 larvae/10 plants), intercropped with *Cy. tetragocalobe* at 4:1 ratios which was 16.12, 17.89, 18.88 and 19.30 larvae/10 plants on *Ab. esculentus*, raised along with pearl millet, marigold, sunflower and maize, respectively. Population of *Ea. vittella* was maximum (22.90 larvae/10 plants) when *Ab. esculentus* was raised as pure crop (Table 1). Damage to shoot of *Ab. esculentus* caused by *Ea. vittella* was reduced when intercropped with *Cy. tetragocalobe* at 4:1 ratios (16.07%), followed by pearl millet (18.41%) while it was 26.61% in *Ab. esculentus* as pure crop (Table 2). When *Ab. esculentus* was intercropped with *Cy. tetragocalobe* at 4:1 ratios, the population of *He. armigera* was 6.96 larvae/10 plants, followed by pearl millet as intercrop (7.76 larvae/10 plants) in contrast to 14.57 larvae/10 plants in *Ab. esculentus* as pure crop (Table 3). Fruit damage by *Ea. vittella* and *He. armigera* was minimum in *Ab. esculentus* (16.51%), intercropped with *Cy. tetragocalobe* while it was 28.56% in *Ab. esculentus* as pure crop (Table 4). Population of *Ch. zastrowi sillemi* was high in *Ab. esculentus* when intercropped with *Cy. tetragocalobe* at 4:1 ratio, recording 17.69, 9.65, 24.39 and 5.14 numbers/10 plants, respectively while it was 9.49, 6.46, 11.97 and 2.53 numbers/10 plants in *Ab. esculentus* as pure crop (Table 5). Per cent recovery of *Tr. chilonis* in *Ab. esculentus* + *Cy. tetragocalobe* intercropping system was 14.86% while it was 9.33% in *Ab. esculentus* as pure crop (Table 6).

In the present study, cluster bean (*Cy. tetragocalobe*) has been reported to be a best companion crop for *Ab. esculentus* which reduced the population, shoot and fruit damage by *Ea. vittella* and*He. armigera* in *Ab. esculentus* eco-system. Such suppression of population and damage of lepidopteran pests was well demonstrated in several intercropping systems

including cotton + ladies finger, maize + legumes, sorghum + cowpea, cotton + sunflower, groundnut + bajra, sesame + pearl millet and cotton + cluster bean [39-41, 14, 42, 16-18]. Intercropping is one of the important cultural practices in pest management, reducing insect pests by changing micro-climate, physical factors like protection from wind, shading, sheltering, prevention of dispersal, alteration of colour, shape of the stand *etc.,* natural enemies, availability of alternate food [43,12].Allelochemicals emanated from intercrop (*Cy. tetragocalobe*) might be responsible to repel the herbivores of *Ab. esculentus*, as pointed by [15, 44] who reported that the sowing of non-host crops with groundnut repelled and changed the oviposition behaviour of lepidopteran pests.

Average population of *Ch. zastrowi sillemi* and per cent recovery of *Tr. chilonis* were comparatively high in plots of *Ab. esculentus*, intercropped with *Cy. tetragocalobe*. Colonization of natural enemies was reported in many intercropping systems. Average population of *Ch. carnea* and spiders were significantly high on cotton intercropped with lucerne, cowpea and groundnut [45]. In China when cotton intercropped with alfalfa which attracted greater number of lady beetles, lacewings and spiders [46]. Cowpea was a short duration pulse crop which attracted aphids, thus increasing occurrence of coccinellids in groundnut [47]. Coccinellids were significantly more abundant in pigeon pea with sorghum or green gram or groundnut or maize systems [48, 49]. High diversity in predatory insect and parasitoid species was recorded from intercropping system like groundnut + maize and groundnut + pearl millet wherein intercrop supplied pollen and nectar as supplementary feed to the natural enemies [7]. Changing trends in cotton pest management mentioned about the lady beetles and lacewings as important predators in cotton intercropped with different pulse crops [49]. This supplementary food resource increased the parasitoid fecundity, longevity [50] and also favours rapid colonization of generalist predators [51, 52].

4.2. Kairomone activity of extracts of parts of *Cy. tetragocalobe*

The effect of acetone extracts of various parts of *Cy. tetragocalobe* on the parasitization of eggs of *Ea. vittella* by *Tr. chilonis* revealed that flower extract (1% or 10000 ppm) was found to be effective in eliciting highest activity of *Tr. chilonis*, recording 22.5% on 3rd day after introduction of the parasitoids which was significantly different from extracts of young leaves (15.4%), stem (9.3%) and leaves (9.2%) of *Cy. tetragocalobe* when compared to control (5.3%). On 5th and 7th day after introduction of parasitoids, flower extract was found to enhance the activity of parasitoid to the tune of 54.2 and 61.3% while it was 8.6 and 10.3% in control, respectively (Table 7). Acetone extract of *Cy. tetragocalobe* flowers (1%) was found to elicit kairomonal effect on the predation by *Ch. zastrowi sillemi* on the eggs of *Ea. vittella* which was 51.2%, followed by extracts of young leaves (30.2%), stem (24.4%) and old leaves (23.4%) while it was 12.5% in control (Table 8). Level of parasitization of *Tr. chilonis* was enhanced when eggs of *He. armigera*, treated with acetone extract of flowers of *Cy. tetragocalobe* (1%) which was 66.2%, 7th day after introduction of parasitoids while it was 15.6% in control (Table 9). Similarly, the predation by *Ch. zastrowi sillemi* on eggs of *He. armigera* was enhanced to 57.2% due to the application of flower extract, as compared to 12.8% in control (Table 10).

Allelochemicals emanated from non-host plants have been reported to be favourable to natural enemies and the outcome of the present study indicated that acetone extract of flowers of *Cy. tetragocalobe* (1% or 10000 ppm) was favourable to the foraging activity of *Tr. chilonis* and *Ch. zastrowi sillemi* under laboratory condition which enhanced the parasitic activity from 10.3 (hexane treated eggs) to 61.3% and 12.5 (hexane treated eggs) to 51.2% and predatory activity from 15.6 (hexane treated eggs) to 66.5% and 12.8 (hexane treated eggs) to 57.2% on eggs of *Ea. vittella* and *He. armigera*, respectively. Allelochemicals of flower extract of *Cy. tetragocalobe* might be responsible to enhance the activities of *Tr. chilonis* and *Ch. zastrowi sillemi,* as indicated in cluster bean and pearl millet as intercrops [14, 23, 24]. Chemicals like alkaloids, Terpenes, flavanoids, phenolic compounds *etc*. present in flowers of weed, *Hy. suaveolens* in rice eco-system was reported to be attractive to *Te. schoenobii*, an egg parasitoid of *Sc. incertulas* [31,32,33]. Flower bud, flower and leaf extracts of *Ta. erecta* containing benzaldehyde, (*S*)-(−)-limonene, (*R,S*)-(±)-linalool, (*E*)-myroxide, (*Z*)-β-ocimene, phenylacetaldehyde, and (*R*)-(−)-piperitone have been reported to attract *He. armigera* and its parasitoid [54,35,56,57].

Table 1: Population of shoot and fruit borer, *Ea. vittella* in intercropping systems

Intercropping system	Number of larvae of *Ea. vittella*/10 plants*					Mean
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	
Okra + Castor (4 : 1)	14.55 (3.77)^{d}	18.54 (4.28)^{f}	21.41 (4.58)^{c}	24.58 (4.84)^{de}	21.22 (4.59)^{c}	20.06 (4.59)^{e}
Okra + Maize (4 : 1)	12.94 (3.55)^{c}	17.89 (4.14)^{de}	20.56 (4.56)^{c}	24.56 (4.85)^{de}	20.56 (4.56)^{c}	19.30 (4.52)^{de}
Okra + Sunflower (4 : 1)	12.87 (3.64)^{c}	17.52 (4.09)^{d}	20.34 (4.56)^{c}	23.55 (4.79)^{d}	20.12 (4.57)^{c}	18.88 (4.40)^{d}
Okra + Cluster bean (4 : 1)	9.42 (2.94)^{a}	11.82 (3.31)^{a}	13.46 (3.60)^{a}	15.56 (3.86)^{a}	15.84 (4.01)^{a}	13.22 (3.55)^{a}
Okra + Marigold (4 : 1)	12.65 (3.43)^{c}	15.42 (3.86)^{c}	20.42 (3.61)^{c}	22.54 (4.68)^{c}	18.42 (4.38)^{b}	17.89 (4.16)^{c}
Okra + Pearl millet (4 : 1)	11.56 (3.29)^{b}	13.52 (3.59)^{b}	18.42 (4.38)^{b}	20.62 (4.58)^{b}	16.52 (3.98)^{a}	16.12 (3.96)^{b}
Okra + Coriander (4 : 1)	14.87 (3.79)^{d}	18.54 (4.19)^{def}	22.52 (4.67)^{c}	25.64 (5.00)^{f}	22.32 (4.66)^{c}	20.77 (4.53)^{e}
Okra + Cowpea (4 : 1)	14.63 (3.72)^{d}	18.88 (4.23)^{ef}	21.56 (4.61)^{c}	24.57 (4.92)^{ef}	21.45 (4.56)^{c}	20.21 (4.54)^{de}
Okra pure crop	15.65 (3.85)^{e}	20.87 (4.46)^{g}	24.32 (4.90)^{d}	28.12 (5.27)^{g}	25.54 (5.11)^{d}	22.90 (4.69)^{f}
SEd	0.0726	0.0494	0.0573	0.0452	0.0583	0.0721
CD (P=0.05)	0.1538	0.1047	0.1215	0.0959	0.1236	0.1529

*Mean of three replications

Figures in table are original values and subject to square root transformation during statistical analysis

In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 2: Shoot damage of *Ea. vittella* in intercropping systems

Intercropping system	% Shoot damage*					Mean
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	
Okra + Castor (4:1)	16.21 (23.22)^{d}	20.54 (27.26)^{c}	25.22 (30.01)^{d}	24.88 (29.99)^{c}	27.41 (32.06)^{f}	22.85 (28.01)^{cd}
Okra + Maize (4:1)	15.86 (22.75)^{c}	19.86 (26.54)^{b}	25.41 (30.56)^{d}	24.42 (29.44)^{c}	27.63 (31.88)^{ef}	22.63 (28.14)^{cd}
Okra + Sunflower (4:1)	15.56 (22.80)^{c}	19.22 (26.44)^{b}	24.21 (30.05)^{d}	24.12 (29.44)^{c}	26.52 (30.75)^{d}	21.92 (27.53)^{c}
Okra+Cluster bean (4:1)	12.62 (20.80)^{a}	15.24 (23.66)^{a}	17.14 (24.51)^{a}	18.54 (25.00)^{a}	16.84 (23.57)^{a}	16.07 (23.76)^{a}
Okra + Marigold (4:1)	15.22 (20.17)^{c}	18.41 (26.03)^{b}	22.54 (27.91)^{a}	22.54 (27.10)^{b}	24.52 (29.56)^{c}	20.64 (27.45)^{c}
Okra + Pearl millet (4:1)	13.65 (22.62)^{b}	16.54 (24.50)^{b}	19.22 (25.71)^{b}	22.12 (28.26)^{b}	20.55 (26.50)^{b}	18.41 (25.96)^{b}
Okra + Coriander (4:1)	16.42 (20.77)^{d}	20.53 (27.49)^{c}	25.54 (30.22)^{d}	26.52 (31.53)^{d}	27.54 (31.27)^{de}	23.31 (28.54)^{d}
Okra + Cowpea (4:1)	16.55 (23.50)^{d}	20.12 (27.42)^{c}	2542 (29.86)^{d}	26.41 (31.46)^{d}	27.58 (31.33)^{de}	23.21 (28.41)^{d}
Okra pure crop	19.52 (26.80)^{e}	23.36 (28.75)^{d}	28.51 (31.87)^{e}	30.12 (33.59)^{e}	31.54 (33.53)^{g}	26.61 (30.71)^{e}
SEd	0.3638	0.3040	0.3001	0.3827	0.3331	0.3497
CD (P=0.05)	0.7711	0.6444	0.6361	0.8113	0.7061	0.7412

*Mean of three replications
Figures in table are original values and subject to arcsine transformation during statistical analysis
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 3: Population of *He. armigera* in intercropping system

Intercropping system	Number of larvae of *He. armigera*/10 plants*					Mean
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	
Okra + Castor (4 : 1)	7.52 (2.73)^{c}	10.63 (3.14)^{b}	11.14 (3.27)^{c}	11.88 (3.32)^{b}	14.21 (3.73)^{c}	11.07 (3.29)^{e}
Okra + Maize (4 : 1)	6.58 (2.66)^{c}	9.88 (3.13)^{b}	10.56 (3.29)^{c}	11.52 (3.34)^{b}	12.63 (3.44)^{b}	10.23 (3.31)^{d}
Okra + Sunflower (4 : 1)	5.94 (2.49)^{b}	9.54 (3.19)^{b}	10.44 (3.30)^{c}	10.88 (3.34)^{b}	12.84 (3.46)^{b}	9.92 (3.16)^{c}
Okra + Cluster bean (4 : 1)	4.67 (2.23)^{a}	5.17 (2.42)^{a}	7.21 (2.82)^{a}	8.24 (3.01)^{a}	9.55 (3.21)^{a}	6.96 (2.66)^{a}
Okra + Marigold (4 : 1)	5.88 (2.50)^{b}	6.52 (2.50)^{a}	9.58 (3.15)^{bc}	10.15 (3.22)^{b}	10.88 (3.30)^{a}	8.60 (2.86)^{b}
Okra + Pearl millet (4 : 1)	5.11 (2.40)^{b}	5.89 (2.44)^{a}	8.41 (3.04)^{b}	8.87 (3.10)^{a}	10.54 (3.34)^{a}	9.76 (2.76)^{ab}
Okra + Coriander (4 : 1)	8.64 (3.03)^{d}	11.96 (3.31)^{b}	12.63 (3.43)^{d}	14.51 (3.71)^{c}	15.54 (3.97)^{d}	12.65 (3.50)^{f}
Okra + Cowpea (4 : 1)	7.87 (2.88)^{d}	11.85 (3.30)^{b}	12.12 (3.47)^{d}	14.23 (3.75)^{c}	15.23 (3.97)^{d}	12.26 (3.41)^{f}
Okra pure crop	9.65 (3.16)^{e}	13.88 (3.59)^{c}	15.42 (3.97)^{e}	16.52 (3.98)^{d}	17.42 (4.20)^{e}	14.57 (3.77)^{g}
SEd	0.0663	0.0891	0.0745	0.0904	0.0705	0.0751
CD (P=0.05)	0.1406	0.1890	0.1579	0.1916	0.1495	0.1593

*Mean of three replications
Figures in table are original values and subject to square root transformation during statistical analysis
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 4: Per cent fruit damage by *Ea. vittella* and *He. armigera* in intercropping system

Intercropping system	% fruit damage 60 DAS
Okra + Castor (4 : 1)	21.55 (27.27)^{c}
Okra + Maize (4 : 1)	20.78 (27.47)^{c}
Okra + Sunflower (4 : 1)	20.22 (27.18)^{c}
Okra + Cluster bean (4 : 1)	16.51 (24.30)^{a}
Okra + Marigold (4 : 1)	18.56 (25.32)^{b}
Okra + Pearl millet (4 : 1)	25.41 (30.13)^{e}
Okra + Coriander (4 : 1)	24.32 (29.41)^{d}
Okra + Cowpea (4 : 1)	18.21 (29.52)^{b}
Okra pure crop	28.56 (32.00)^{f}
SEd	0.2821
CD (P=0.05)	0.5979

*Mean of three replications
Figures in table are original values and subject to arcsine transformation during statistical analysis
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 5: Population of *Ch. zastrowi sillemi* in intercropping system

Intercropping system	*Chrysoperla* Egg/grub (Nos./10 plants)		Mean
	40 DAS	70 DAS	
Okra + Castor (4 : 1)	2.05 (1.63)^{bc}	2.45 (1.77)^{e}	2.25 (1.67)^{b}
Okra + Maize (4 : 1)	2.11 (1.66)^{bc}	2.89 (1.71)^{e}	2.50 (1.69)^{b}
Okra + Sunflower (4 : 1)	2.85 (1.67)^{b}	4.12 (2.04)^{c}	3.48 (1.76)^{b}
Okra + Cluster bean (4 : 1)	4.88 (2.25)^{a}	5.41 (2.38)^{b}	5.14 (2.20)^{a}
Okra + Marigold (4 : 1)	2.44 (1.69)^{b}	3.15 (1.88)^{d}	2.79 (1.84)^{b}
Okra + Pearl millet (4 : 1)	1.72 (1.46)^{c}	1.89 (1.47)^{f}	1.80 (1.46)^{c}
Okra + Coriander (4 : 1)	1.89 (1.48)^{c}	2.21 (1.63)^{e}	2.05 (1.59)^{b}
Okra + Cowpea (4 : 1)	4.51 (2.28)^{a}	6.11 (2.63)^{a}	5.31 (2.40)^{a}
Okra pure crop	1.52 (1.40)^{c}	3.54 (1.84)^{d}	2.53(1.72)^{b}
SEd	0.0832	0.0761	0.0960
CD (P=0.05)	0.1764	0.1612	0.2036

*Mean of three replications
Figures in table are original values and subject to square root transformation during statistical analysis
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 6: Per cent recovery of *Tr. chilonis* in intercropping system

Intercropping system	% recovery of *Tr. chilonis*			Mean
	20 DAS	40 DAS	60 DAS	
Okra + Castor (4 : 1)	8.12 (17.12)[b]	15.87 (22.79)[d]	8.21 (17.35)[d]	10.73 (19.17)[c]
Okra + Maize (4 : 1)	9.12 (18.18)[c]	15.25 (23.59)[d]	8.41 (17.64)[d]	10.92 (19.46)[c]
Okra + Sunflower (4 : 1)	9.74 (18.49)[c]	17.21 (24.46)[b]	8.55 (17.25)[d]	11.83 (20.24)[c]
Okra + Cluster bean (4 : 1)	10.53 (19.38)[a]	21.48 (27.15)[a]	12.57 (20.15)[d]	14.86 (21.86)[a]
Okra + Marigold (4 : 1)	9.21 (18.44)[c]	16.41 (23.73)[c]	9.21 (18.33)[a]	11.61 (19.58)[c]
Okra + Pearl millet (4 : 1)	7.45 (16.26)[b]	14.21 (21.70)[e]	7.12 (16.47)[d]	9.59 (18.34)[d]
Okra + Coriander (4 : 1)	7.12 (16.34)[b]	14.32 (22.17)[e]	6.54 (15.55)[e]	9.32 (18.69)[d]
Okra + Cowpea (4 : 1)	8.47 (16.68)[b]	18.85 (25.00)[a]	10.67 (19.39)[b]	12.66 (20.10)[b]
Okra pure crop	6.51 (15.38)[d]	14.62 (22.01)[e]	6.87 (15.45)[e]	9.33 (18.34)[d]
SEd	0.2735	0.3701	0.4021	0.5014
CD (P=0.05)	0.5799	0.7846	0.8525	1.0629

*Mean of three replications
Figures in table are original values and subject to arcsine transformation during statistical analysis
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 7: Per cent parasitism by *Tr. chilonis* on eggs of *Ea. vittella*, as influenced by acetone extracts of various parts of cluster bean

Intercrop samples	% parasitization by *Tr. chilonis* after*		
	3rd day	5th day	7th day
Cluster bean			
Flowers	22.54 (27.65)[a]	54.21 (48.01)[a]	61.32 (50.97)[a]
Stem	9.33 (17.95)[c]	19.63 (26.94)[d]	32.54 (34.08)[c]
Young leaves	15.45 (23.22)[b]	34.41 (35.07)[b]	42.65 (44.44)[b]
Old leaves	9.21 (18.34)[c]	22.14 (27.54)[c]	30.56 (33.98)[c]
Control	5.33 (14.18)[d]	8.67 (17.69)[e]	10.33 (18.48)[d]
SEd	0.4954	0.4127	0.3712
CD (P=0.05)	1.0795	0.8992	0.8087

*Mean of eight replications; 100 mg/10 ml of acetone
Figures in parentheses are arcsine transformed values
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 8: Per cent predation by *Ch. zastrowi sillemi* on eggs of *Ea. vittella*, as influenced by acetone extracts of various parts of cluster bean

Intercrop samples	% predation by *Ch. zastrowi sillemi* after 24 h*
Cluster bean	
Flowers	51.25 (45.26)[a]
Stem	24.47 (29.34)[c]
Young leaves	30.21 (33.76)[b]
Old leaves	23.42 (28.12)[d]
Control	12.56 (19.89)[e]
SEd	0.3632
CD (P=0.05)	0.7913

*Mean of eight replications; 100 mg/10 ml of acetone
Figures in parentheses are arcsine transformed values
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 9: Per cent parasitism by *Tr. chilonis* on eggs of *He. armigera*, as influenced by acetone extracts of various parts of cluster bean

Intercrop samples	% parasitization by *Tr. chilonis* after*		
	3rd day	5th day	7th day
Cluster bean			
Flowers	25.58 (29.70)[a]	52.64 (45.80)[a]	66.24 (54.96)[a]
Stem	14.56 (22.01)[c]	25.74 (30.71)[c]	35.68 (35.75)[c]
Young leaves	18.64 (24.78)[b]	35.21 (36.08)[b]	48.23 (43.55)[b]
Old leaves	11.52 (18.98)[d]	25.31 (30.00)[c]	32.47 (34.21)[d]
Control	10.23 (19.33)[d]	12.54 (19.54)[d]	15.64 (22.43)[e]
SEd	0.3809	0.3817	0.4121
CD (P=0.05)	0.8300	0.8318	0.8980

*Mean of eight replications; 100 mg/10 ml of acetone
Figures in parentheses are arcsine transformed values
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

Table 10: Per cent predation by *Ch. zastrowi sillemi* on eggs of *He. armigera*, as influenced by acetone extracts of various parts of cluster bean

Intercrop samples	% predation by *Ch. zastrowi sillemi* after 24 h*
Cluster bean	
Flowers	57.21 (49.34)[a]
Stem	30.85 (33.91)[c]
Young leaves	35.54 (36.54)[b]
Old leaves	29.56 (33.50)[c]
Control	12.87 (19.86)[d]
SEd	0.4256
CD (P=0.05)	0.9273

*Mean of eight replications; 100 mg/10 ml of acetone
Figures in parentheses are arcsine transformed values
In a column means followed by same letter(s) are not significantly different by DMRT (P= 0.05)

5. Conclusion

Utilization of optimal concentrations of non-host kairomone can be exploited to enhance the foraging efficiency of Trichogrammatids and Chrysopids in integrated pest management programme. Identification and documentation of non-host plants including intercrop, trap crop, bund crop, weeds *etc*. in any crop eco-systems and further screening for their attractiveness to entomophages are highly useful in conservative biological control. Maintenance of such non-host plants in main crop would be attractive to the wild and released population of entomophages for the management of herbivoures.

6. Acknowledgement

Authors are thankful to Department of Bio-technology (No. BT/PR 11078/AGR/05/440/2008 (letter 1) dt. 28.07.2011), New Delhi, India for the financial assistance to conduct field and laboratory experiments.

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