Insect Pests of Cucumber (*Cucumis sativus* L.) And Their Bio-rational Management Under Protected Cultivation

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RICHA BANSHIWAL

Thesis

Master of Science in Agriculture

(Entomology)

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DEPARTMENT OF ENTOMOLOGY
RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
UDAIPUR (RAJASTHAN)

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Thesis

Submitted to

Maharana Pratap University of Agriculture and Technology, Udaipur

in partial fulfillment of the requirements for the Degree of

Master of Science in Agriculture

(Entomology)

By

RICHA BANSHIWAL

2018

Maharana Pratap University of Agriculture and Technology

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1. INTRODUCTION

Cucumber (*Cucumis sativus* L. Cucurbitaceae) is a popular and widely grown vegetables all over the country, is reported to have originated in India. It is one of the quickest maturing vine vegetable crops and is the second most widely cultivated cucurbit after watermelon. Cucumber is grown in an area of 74, 000 hectares with the production of 1142, 000 metric tons (Anon., 2017). The immature fruits of cucumber are used as salad and for pickling. The fruits and seed possess cooling properties. The fruit is also used as an astringent and antipyretic. Fruits are good for people suffering from constipation, jaundice and indigestion. It is reported that oil extracted from seed is good for brain and body. Nutritively 100 g of edible portion of cucumber contains 96.3 g moisture, 2.5 g carbohydrates, 0.4 g protein, 0.1 g fat, 0.3 g minerals, 10 mg calcium, 0.4 g fiber and traces of vitamin C and iron.

Commercially it is grown throughout the year in southern states of India while in plains of northern India, it is grown during the summer and rainy season. Production of cucumber in India is more under open field cultivation; nevertheless, biotic and abiotic stresses are the main factors responsible for low yield and poor quality particularly the rainy season crop is always affected by diseases and pests, resulting into low productivity and poor quality of fruits.

The protected vegetable cultivation technology can be utilized for year round production of high value quality vegetable crops, with high yield. Increasing photosynthetic efficiency and reduction in transpiratory loss are added advantages of protected cultivation Protected cultivation of crops provides protection from adverse environmental conditions (Sood *et al*., 2015); nevertheless, such protected environment provides a stable and congenial micro climate favorable for the multiplication of sucking insect pests, which in turn becomes a limiting factor for successful crop production (Kaur *et al*., 2010). In India, about twenty insect and mite species have been recorded to be associated with the crops under protected cultivation (Sood et al., 2006). Thrips, whitefly, leaf miner, aphids, gall midge, mites and nematodes are serious problems on vegetable crops under protected cultivation; however, further studies are required to mitigate the location-specific problems of insect pests and their eco-friendly management.

The whitefly, *Bamicia tabaci* (Gennabuis) (Homoptera:-Aleyrodidae), is one of the most important insect pest on greenhouse cucumber crops throughout the world. Whitefly adult and nymph feed by sucking on the plant foliage. This causes a reduction in growth of the plant and can induce wilting in strong sunlight (O’ Reilley 1974). In addition, honey dew excreted by all stages of whitefly (Hussey *et al.* 1958) accumulate on the foliage and the fruit and becomes sites for the development of sooty molds, these molds reduce photosynthesis and make the fruit unmarketable.

The species of thrips gained the status of major pest of green house grown vegetable. Thrips damage the plant both directly and indirectly (Steiner, 1990; Murai, 1994). Direct damage caused by feeding puncture, results in necrosis of leaves. Indirect damage like fruit malformation and scarring. *Liriomyza trifoli* is very dominating leaf miner species in greenhouse cucumber. In cucumber, the insect damage the crop by making feeding and oviposition punctures on the leaves and then by leaf mining by the maggot. The larvae tunnel inside the mesophyll tissue. When one fourth of the leaf area was mined, photosynthesis decreased by <1% (Martens and Trumble, 1987).

Among the bio-rational methods of pest management, exploitation of insect behaviour can be suitably used under protected cultivation. It is well known that insects are differentially attracted to coloured surfaces; particularly, yellow is known as a general insect attractant. This feature has been exploited by entomologists for collection of Coleoptera, Cicadellidae, aphids, Hymenoptera and Thysanoptera (Riley & Schuster, 1994).The use of sticky traps for population monitoring in commercial greenhouse cultures was introduced, recommendations were blue for monitoring thrips and yellow for whitefly/ alate aphids and other insects. In practice, however, most often yellow sticky traps are used whereby the lower efficiency in monitoring of thrips is generally not considered affecting control decisions (Loomans *et al.* 1995) also other pests may be monitored simultaneously. According to Hara (2000), bio-rational insecticides are synthetic or natural compounds that effectively control insect pests, but have low toxicity to non-target organisms (such as humans, animals and natural enemies) and the environment.

(i) To study the incidence of major insect pests of cucumber under protected cultivation.

(ii) To evaluate the efficacy of bio-rational insecticides against the major insect pests.

2. REVIEW OF LITERATURE

Available literature on aspects related to the research topic entitled, **"Insect pests of cucumber (*Cucumis sativus* Linn.) and their bio-rational management under protected cultivation"** has been reviewed and presented under the following sub heads:

2.1 Major insect pests of commonly cultivated vegetables

2.2 Efficacy of bio-rational insecticides against the major insect pests of vegetables.

2.1 Major insect pests of commonly cultivated vegetables.

2.1.1 Seasonal incidence of major pests of commonly cultivated vegetable in protected cultivation.

Perdikis *et al.* (2008) observed that solanaceous greenhouse crops are susceptible to infestation by a number of insect and mite pests that can cause serious yield losses. The most important of these pests are whiteflies, aphids, leaf-miner, thrips and spider mites.

Kaur *et al.* (2010) observed that red spider mite (*Tetranychus urticae* Koch) was the predominant pest of cucumber. Leaf miner (*Liriomyza trifolii* Burgess) incidence was considerably low, and whitefly (*Bemisia tabaci* Gennadius) was noticed only during the early season. Thrips (*Scirtothrips dorsalis* Hood) were serious pests on cucumber and Tobacco caterpillar (*Spodoptera litura* Fabricius) damage was around 5 per cent on cucumber.

Maklad *et al.* (2012) stated that the population of aphids, whitefly, spider mites and thrips in cucumber was maximum under polythene sheet.

Shalaby *et al.* (2013) conducted an experiment on the relation between pest infestation and the time of planting of cucumber crops under plastic greenhouses and reported that the infestation by *Bamicia tabaci* started in early crop stage and that the infestation of *Aphis gossypii* and *Tetranychus urticae* were observed in later stage of the crop.

Ellaithy *et al.* (2015) reported that the population of sucking pests was minimum in sweet pepper under plastic house with white shade net when compared to polythene cover house.

Nayana *et al.* (2017) found that the tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a recently invaded pest to India and causing havoc in both open field tomatoes and in protected crops. Infestation level of *T. absoluta* both in Kharif and Rabi was low during first crop phenologic cycle. Then *T. absoluta* density increased with age of crop under both polyhouse and field condition.

2.1.2 Seasonal incidence of major pests of commonly cultivated vegetable in open field.

Pareek *et al.* (1986) studied seasonal incidence of insect pests on ten cucurbit species in Udaipur and Jobner. The insect observed on different cucumber were red pumpkin beetle, jassid, whitefly, thrips and leaf miner.

Umeh *et al.* (2005) recorded that the populations of major insect pests and yield of tomato. *Bemisia tabaci, Aphis gossypii* and *Helicoverpa armigera* contributed significantly to yield losses. Some cultivars were less susceptible to attack by these insect pests and had comparatively higher yields compared to other cultivars. There was a negative correlation between the percentage of plants attacked by the insect pests and yield.

Rai *et al.* **(**2013) The field incidence of the serpentine leaf miner, *L. Trifolii* (Burgess) was severe during the fruiting stage of the crop and infestation was higher on lower surface of leaf in comparisons of upper surface.

Sri *et al.* (2017) results revealed that whitefly, aphid and leaf miner were most important insects damaging tomato under open conditions whereas leaf miner and whitefly in poly house. The peak population of these pests was observed during 8 and 9 SMW under both conditions. Pest population and density fluctuation is very low in poly house when compared to open condition expect the leaf miner whose population was high in poly house.

2.1.3 Monitoring of major insect pests of cucumber.

Civelek *et al.* (2004) recorded *Liriomyza huidobrensis* (Blanchard) (Diptera: Agromyzidae) as an important pest in cucumber greenhouses and concluded that using yellow sticky traps would be a healthier and more cost effective practice than using pesticides. Martin *et al*. (2005) determined Colour preference by exposing traps of various colours (red, blue, violet, green, white, and yellow) and materials (cardboard and acetate) to leafminer populations in celery for 24-48 hours. Both sexes of adult pea leafminer were preferentially attracted to yellow opaque or translucent sticky cards.

Hassan *et al*. (2004) was carried out a greenhouse experiment to evaluate the trapping efficiency of various colored traps in cucumber (*cucumis sativus* L.). The insect pests recorded were Thrips *Thrips tabaci* (Lindeman) and the leaf miner *Liriomyza trifolii* (Burgess). Significantly more insect pests were trapped on fluorescent yellow as compared to other traps whereas pink, green and orange colored traps caught significantly lower number of insects and found statistically similar.

Kaas *et al*. (2005) suggested that single type of yellow sticky trap was significantly less efficient than other yellow sticky traps for thrips. Also blue was significantly more attractive to thrips than yellow in one of two tests. Gillespie *et al*. (2014) observed that population of western flower thrips, *Frankliniella occidentalis* on sticky traps was assessed by height, color and sex in commercial greenhouse crops. At 2.4m height, blue traps captured more females than other colors, and yellow captured more males. Results were similar in a trial with commercial yellow sticky traps, except that the catch of females was greatest at 3.0m. Sridhar *et al.* (2015) evaluated different colour sticky traps for the purpose of monitoring chilli thrips, *Scirtothrips dorsalis* Hood on Rose both under open and protected conditions. Among the colour traps used, blue colour attracted highest number of *S. dorsalis* adults followed by yellow and pink.

Ping *et al*. (2009) their result showed that the yellow sticky boards can catch more adults of leafminer in middle and upper part of cucumber , but for *Trialeurodes vaporarium,* the better part is mid lower in greenhouse, the more adult were caught in mid and backside.

Premalatha *et al.* (2011) observed that irrespective of the varieties, yellow chart coated with castor oil harboured more whitefly than on yellow sticky traps.

Lu *et al.* (2012) observed that, in the greenhouse, yellow sticky traps significantly suppressed the population increase of adult and immature whiteflies *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae). The whitefly densities in the greenhouse with traps were significantly lower than the greenhouse without traps, suggesting that yellow sticky traps could be used as an effective method for the control of whiteflies in the greenhouse. Wagan *et al.* (2017) observed that yellow sticky traps were most effective for monitoring and managing whiteflies and thrips in okra.

Sampson *et al*. (2012) studied in semi-protected strawberry crops, mass trapping of *F. occidentalis* using blue sticky roller traps reduced adult thrips numbers per flower by 61% and fruit bronzing by 55%. Devi *et al*. (2017) observed that blue coloured sticky trap attracted more number of thrips over the crop growth period than white, yellow and fluorescent green sticky traps. Blue coloured sticky trap also attracted comparatively less number of beneficial insects and can be used for relative estimate of *T. tabaci* population and also for monitoring and mass trapping as a component of IPM programme.

Bashir *et al*. (2014) results showed that the most attractive and efficient color in monitoring trial was the brown color followed by light blue, dark blue, red, green, yellow and the sticky trap having low population was white.

Bayisa *et al*. (2017) found higher number leaf miners were attracted by sticky traps coated with lavender oil, lemon oil and castor oil and higher number of whiteflies and thrips were attracted by lavender oil and basil oil coated yellow sticky traps, respectively. Therefore, using yellow sticky traps with natural essential oils reduced the pest population and also contributed in the management.

Muthuram *et al*. (2017) used five different coloured sticky boards viz. green, yellow, orange, violet and white of 20 × 15 cm size smeared with sticky material and tested for the efficacy of thrips. Green coloured sticky boards were found effective in attracting *T. tabaci* than other boards.

2.2 Evaluate the efficacy of bio-rational insecticide against the major insect pests.

2.2.1 Bio-efficacy of insecticide under protected cultivation.

Mayoral *et al.* (2006) evaluated the efficacy of *Beaveria bassiana* based bio-insecticide, applied at different doses, against whiteflies on protected tomato and found that all *B. bassiana* treatments, irrespective of the dose (doses tested: 125, 250, and 300 ml/hl), significantly reduced the whitefly infestation compared to the untreated control, with their efficacy ranging from 72.3 to 82.8 per cent.

Nadagouda *et al.* (2010) evaluated different seven insecticides in the laboratory against the maggots of *L. trifolii* collected from the different four locations of dry land areas from cucurbit crops in polyhouses and found that maggots were most sensitive to imidacloprid (0.50 ml./lit water) followed by oxydemeton methyl (1.5 ml/lit water) and Acephate (1 g/lit water) which resulted in considerable higher mortality.

Kaur *et al*. (2014) evaluated the efficacy of an organic salt (Lastrawfi) and an oil based formulation of *Beauveria bassiana* (Myco-Jaalfi) against aphid, thrips and broad mite on sweet pepper under net-house conditions in Punjab, India. Both these compounds at higher doses reduced the thrips population by 80% 84%.

Larew *et al.* (2014) applied crude neem extract (0.4%) as a soil drench to chrysenthemum, which caused significant mortality of late instar maggots and pupae of *Liriomyza trifolii* (Burgess) in both research and commercial greenhouses.

Kashyap *et al*. (2016) conducted a study to investigate the efficacy of insecticides and bio-pesticides against the greenhouse whitefly on tomatoes grown in polyhouses. Results showed that abamectin resulted in the highest mean percent reduction in immatures of *T. vaporariorum*, followed by acetamiprid and buprofezin, Spiromesifen and bifenthrin resulted in moderate levels of efficacy, followed by azadirachtin and mineral oil.

2.2.2 Bio-efficacy of insecticide in open field cultivation.

Pallai *et al.* (1988) did experiments for the control of thrips with neem products. NSKE at 5 and 10 % neem oil at 2% were evaluated for control of thrips in Tamil Nadu. Neem oil at 2% was as effective as phosphamidon and fenthion for controlling rice thrips.

Cloyd *et al.* (2000) reported that spinosad @ 50, 100 and 200 ppm and acephate @ 600 ppm were effective against western flower thrips (*Franklinilla occidentalis*) on gerbera having 94.3, 97.7 and 91.4 per cent control, respectively.

Venkatesh *et al.* (2003) tested the efficacy of fish oil rosin soap (FORS) and neem oil in comparison with insecticides over two consecutive seasons at Tamilnadu. The result revealed that FORS, neem oil and insecticides were significantly effective against both nymphs and adults of *Thrips tabaci*. Dimethoate 0.03 % and endosulfan 0.07 % were equally superior to FORS 2.5 % and neem oil 1 % in reducing the population of nymphs as well as of adults during both the season.

Kumar *et al.* (2007) reported that azadirachtin and abamectin deterred the settling of adult whiteflies on tomato, *Lycopersicon esculentum* Mill (Solanaceae) plants and consequently reduced egg deposition. Effects of azadirachtin were significantly altered if applied to different-aged eggs (1, 3, and 5 d old) per cent nymphal mortality with azadirachtin and spinosad was achieved 6–9 dose post application. Toxicity of Azadirachtin however gradually declined under greenhouse conditions with time (5 d) post application.

Wankhede *et al.* (2007) conducted an experiment to evaluate different insecticides against *L. trifolii* in tomato at Nagpur in Maharashtra. Result showed that Neem oil 1% gave the lowest (4.37%) leaf miner infestation at 14 days after second spray followed by 0.01% spinosad and 5% neem seed extract.

Kontsedalov *et al*. (2008) result showed that adult *B. tabaci* mortality rate after spiromesifen treatment (5mg L−1) was 40%. Treatment with 0.5mg L−1 reduced fecundity per female by more than 80%, and fertility was almost nil. LC50 for eggs was 2.6mg L−1, and for first instar 0.5mg L−1.

Bhatnagar *et al.* (2009) reported that after 10 days of first spray, the least population of thrips was noticed in imidacloprid, followed by acetameprid, thiamethoxam and dimethoate. Among indigenous materials the least count was noticed in NSKE treatment and all other treatments showed no difference compared to untreated control.

Carvalho *et al*. (2012) Suggested that neem (*Azadirachta indica*) oil nanoformulations containing β-ciclodextrin and poli-ε-caprolactone (PCL) as to their control efficiency against eggs and nymphs of *Bemisia tabaci* (Genn.).

Mondol (2016) evaluated the efficacy of insecticides in monitoring the damage caused by *Liriomyza brassicae* on the pea crop var. 'Arpana' in Allahabad. The order of efficacy was dimethoate > cypermethrin > chlorpyriphos > imidacloprid > acephate > endosulfan > emamectin benzoate > control. Dimethoate (0.06%) gave lowest percent larval population after spraying followed by cypermethrin (0.0075%). Chlorpyriphos (0.04%), imidachloprid (0.01%), acephate (0.15%) were found to be statistically at par with each other.

3. MATERIALS AND METHODS

The proposed investigation on, "Insect pests of cucumber (*Cucumis sativus* L) and their bio-rational management under protected cultivation" was carried out at the High-tech Unit of Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur during kharif, 2017. The material used and methodology adopted during these studies are described here in this chapter.

Location of the experimental site:

The experimental site was located at the Horticulture farm, Rajasthan college of agriculture, Udaipur. Geographically Udaipur is situated at 75.40E Latitude and 23.40N Longitude at an elevation of 582.17 MSL in the sub-humid southern region of Rajasthan.

Preparation of nursery for cucumber seedling

For protected cultivation of cucumber, the seedlings were raised on soil-less media in plastic portrays having cells of 1.5" in size. A mixture of coco-peat, vermiculite and perlite @ 3:1:1 was used as a media for raising seedlings. One seed was sown in each cell. Regular watering and plant protection measures were adopted. Nutrients were applied in the form of N:P:K (1:1:1) @ 140 PPM once a week through the fine sprinkler to maintain the uniformity in application of nutrients. The seedlings were ready for transplanting within 20-25 days.

Bed preparation:

The raised beds were prepared about 60 cm above the ground level for the experimental purpose. Basal dose of FYM @250 quintals per hectare was applied and thoroughly mixed in soil one week before transplanting.

Transplanting:

Three weeks old seedlings at 2-3 true leaf stage were transplanted on 20th june 2017 according to the treatment combinations. Transplanting was done in the evening and watering was done thereafter.

3.1 Experimental details:

(i) Incidence of major insect pests of cucumber:

Design = CRD

Number of treatment = Four

Number of replications = Five

Total no. of plots = 20

Plot size = 5.6m X 1m

Spacing = 40cm X 30cm

Variety = Terminator

(ii) Evaluation of bio-rational insecticide against major insect pests of cucumber:

Design = CRD

Number of treatment = Seven

Number of replications = Three

Total no. of plots = 21

Plot size = 4m X 1m

Spacing = 40cm X 30cm

Variety = Terminator

Treatment details: There will be seven treatments in all including control and each treatment will be replicated three times. Two sprays will be given, the first when sufficient pest build-up will be recorded and the second 20 days later.

S. No.	Treatments	Dose (%)
T_1	Spiromesifen (22.9 SC)	0.1
T_2	Acetamiprid (20 SP)	0.02
T_3	Neem oil	1

T_4	*Beauveria bassiana*	0.4
T_5	Difenthiuron(30WP)	0.04
T_6	Acephate(75 SP)	0.2
T_7	Control	-

3.2 Methodology:-

(i) Incidence of major insect pests of cucumber:

The treatments comprised the following traps: yellow sticky trap; blue sticky trap; yellow pan trap; and the blue pan trap.

The sticky traps were made of art paper smeared with sticky glue. During the experiment traps were fixed about 140cm above ground level. The length of blue and yellow sticky traps was 35.56 cm. and 36.83 cm. and width was 24.13 cm. and 24.13 cm. respectively. Observation were taken at weekly interval during early morning from 7 to 9 am. The number of insects per trap was counted using hand held magnifying lens and were replaced every week.

Thrips, whiteflies and leaf miner adults were caught on the cards. Whitefly catch tended to be uniform, but thrips were caught on the bottom half of the cards. One-inch-wide vertical column in the center of each card to estimate the total numbers of insects caught. Cards should be placed just above the crop canopy to more effectively trap insects.

(ii) Evaluation of bio-rational insecticide against major insect pests of cucumber:

The insecticides were applied with the help of manually operated knapsack sprayer. The quantity of spray fluid required for treating the crop per plot was calculated by spraying untreated control plot with water. The quantity of each insecticidal formulation was worked out and mixed in required quantity of water. Care was taken to cover all plant parts thoroughly while spraying and to avoid the drift to the neighbouring plots for which a muslin cloth screen was placed. The treatments were applied two times in the morning, proper care was taken to clean the sprayer with water while changing the insecticide treatment.

Observations:-

Whitefly and thrips:-The population of whiteflies and thrips on cucumber was recorded by counting the number of nymphs and adults on five randomly selected plants from each plots that were maintained without plant protection measures. The observations for sucking pests were recorded during morning hours between 6:30 AM to 8:30 AM. The population of whitefly was recorded from five leaves , two from the middle, two from the lower and one from the upper position from five randomly selected plants. The population of thrips was counted on white piece of paper by finger tapping method from other five randomly selected plant with the help of 10× hand lens.

Leaf miner:- leaf miner damage was estimated by counting the numbers with maggots within leaves, and expressed as maggot percent mortality per plant.

The observations of whitefly, thrips and leaf miner recorded before spraying as pre treatment population and at 3,7 and 10 days after spray.

Statistical analysis:-

The population data thus obtained will be converted to percent reduction in population using the method employed by Henderson and Tilton (1955) and the efficacy of various treatments will be analyzed using analysis of variance.

$$\text{Population reduction (\%)} = 100\{1-(T_a \times C_b / T_b \times C_a)\}$$

Where,

T_a = Number of insect after treatment in treated plot

T_b = Number of insect before treatment in treated plot

C_a = Number of insect in untreated check after treatment

C_b = Number of insect in untreated check before treatment

4. RESULTS

Results of the investigations on **"Insect pests of cucumber (*Cucumis sativus* Linn.) and their bio-rational management under protected cultivation**" carried out at the Horticulture Farm of Rajasthan College of Agriculture, MPUAT, Udaipur with the objectives to study the incidence of major insect pests of cucumber under protected cultivation and to evaluate the efficacy of various insecticides against the major insect pests have been presented here under:

4.1 The incidence of major insect pests of cucumber under protected cultivation.

Evaluation of weather parameter on the incidence of whiteflies, thrips and leaf miner did not show evince any significant influence, Accordingly the coefficient of correlation were not significant.

4.1.1 White fly

The Sticky traps were placed at suitable distances from ground level and whitefly adult counts were taken at an interval of 7 days. The data presented in Table (1) and graphically represented in Fig (1) reveal that mean population of white fly caught in various traps from first week of August (30th SMW) to last week of September (37th SMW) in 2017. The Yellow Sticky Traps was the strongest attractant of adult whiteflies. The maximum mean number of whitefly recorded on YST was 112.20 followed by Blue Sticky Traps with 85 mean number of whitefly per trap. Yellow Pan Traps recorded 18.20 mean number of adult whitefly while the lowest mean population of whitefly was recorded on Blue Pan Traps (13.20). YPT and BPT remained statistically at par with each other.

4.1.2 Leaf miner

The data presented in Table (2) and graphically represented in Fig (2) show that the incidence of leaf miner was first noticed during the first week of August (30th SMW) on YST with a mean count of 4.2 leaf miner per trap while peak incidence was observed during third week of September (37th SMW) on YST and BST that recorded 22.4 and 9.6 mean number of leaf miners, respectively. YST was more effective for trapping leaf miner population and BST was least affective with 12.65 and 3.85 total mean number of leaf miner adults trapped, respectively. No leaf miner was trapped in BPT and YPT.

4.1.3 Thrips

The data presented in Table (3) and graphically represented in Fig (3) reveal that after installation of traps, significantly higher numbers of thrips were trapped on BST as compared to that on YST, YPT and BPT. The maximum mean number of thrips was 15.67 caught on BST followed by 6.97 mean number of thrips trapped on YST while no thrips were trapped on YPT and BPT, indicating that blue was the best trap color for thrips, yellow was less attractive. The pan traps were not effective for trapping thrips as no thrips were trapped in the pan traps.

4.2 Efficacy of different bio-rational insecticides against major insect pests of cucumber under protected cultivation.

4.2.1 Whitefly

Seven different insecticides were evaluated for their bio-efficacy against whitefly infesting cucumber along with control. All the treatments were evaluated based on percent reduction of whitefly population after 3, 7 and 10 days after first as well as second application.

I Spray

The data recorded on reduction of whitefly population after first spray is presented in Table (4). The pre-treatment population of whitefly was uniform in all the plots and varied from 14.07 to 16.20 whitefly/ plant.

3rd day after spray

Three days after first spray among all the insecticidal treatments acetamiprid 20 SP was significantly superior and showed highest reduction per cent as 78.55 in whitefly population, followed by acephate 75 SP (74.80%) and both were statistically found at par with each other. The least effective treatment was neem oil @ 1 percent with 52.01 per cent population reduction and it was at par with *Beauveria bassiana* (54.61%). Spiromesifen 22.9 SC and difenthiuron 30 WP were moderately effective and recorded 67.84 and 65.76 per cent reduction in whitefly population, respectively, being at par with each other.

7th day after spray

The treatment of acetamiprid 20 SP (72.13%) was superior as compared to the other treatments in reducing the population of whitefly. However treatment Acephate 75 SP (70.27%) was at par with acetamiprid. Neem oil (1%) was least effective and recorded 48.08

per cent reduction. It was at par with *Beauveria bassiana* (51.16%). Spiromesifen 22.9 SC and difenthiuron 30 WP showed 62.31 and 60.08 per cent reduction respectively, and were at par with each other.

10th day after spray

The treatment acetamiprid 20 SP was most effective in reducing whitefly population with 66.23 per cent reduction followed by acephate 75 SP (65.08%) and spiromesifen 22.9 SC (62.73%) and were at par with each other. Difenthiuron 30 WP and *Beauveria bassiana* were found moderately effective with 59.80 and 54.53 per cent reduction and neem oil (1%) was least effective (52.00%). All these three treatments were at par with each other.

II Spray

The data recorded on reduction of whitefly population after second spray is presented in Table (5). A day before second spray, the population of whiteflies (PTP) ranged from 10.87 to 23.47 whiteflies/plant showing no significant difference among all the evaluated treatments.

3rd day after spray

Three days after second spray all the treatments were effective to reduce the whitefly population and significantly differed from each other. The data reveal that acetamiprid 20 SP emerged significantly superior and showed highest reduction in whitefly population (75.88%) followed by acephate 75 SP which recorded 70.69 per cent reduction in whitefly population. Spiromesifen 22.9 SC, difenthiuron 30 WP and *Beauveria bassiana* were moderately effective and recorded 64.85, 60.06 and 51.81 per cent reduction of whitefly, respectively. Neem oil (1%) was recorded lowest reduction in whitefly population (46.59%).

7th day after spray

After seven days of second spray the treatment acetamiprid 20 SP was most superior and recorded 67.28 per cent reduction in whitefly population. Acephate 75 SP, spiromesifen 22.9 SC and difenthiuron 30 WP were moderately effective with 64.52, 58.59, 55.91 per cent reduction, respectively and were at par with each other. Neem oil (1%) recorded lowest population reduction (44.30%) and was at par with that for *Beauveria bassiana* (46.21%).

10 day after spray

Ten days after spray acetamiprid 20 SP resulted in max population reduction (62.79%) which was at par with acephate 75 SP (61.53%). Neem oil (1%) was least effective and recorded 48.07 per cent reduction in white fly population. Spiromesifen 22.9 SC, difenthiuron 30 WP and *Beauveria bassiana* recorded 57.39, 54.41 and 51.05 per cent population reduction, respectively. All these treatments were at par with each other and were moderately effective for reducing whitefly population.

4.2.2 Leaf miner

I Spray:

To evaluate the bio efficacy of different bio-rational insecticides against leaf miner on cucumber the observations were taken on 3, 7 and 10 days after treatments application. The first spray was applied on 17 June 2017, after 45 days of sowing. The data recorded on reduction in maggot population of leaf miner after first spray is presented in Table (6). The pretreatment population (PTP) of leaf miner ranged from 3.50 to 3.77 /plant.

3rd day after spray

The data presented in table (6) reveal that after three days of application, all the treatments were significantly effective in reducing the maggot population on cucumber leaves over control. Among the treatments, difenthiuron 30 WP recorded maximum reduction of the maggot population (50.94%) and it was at par with acephate 75 SP (47.14%). Acetamiprid 20 SP and spiromesifen 22.9 SC were moderately effective in reducing the maggot population recording 46 and 42.25 percent reduction, respectively. While *Beauveria bassiana* and neem oil (1%) were less effective as by indicative significantly lower reduction of maggot population being 42.23 and 41.06 per cent, respectively.

7th day after spray

After seven days of application, difenthiuron 30 WP found was effective which recorded significantly higher maggot population reduction (65.82%) was at par with Acephate 75 SP (64.09%) and acetamiprid 20 SP (62.57%). Spiromesifen 22.9 SC and *Beauveria bassiana* recorded 60.48 and 57.04 per cent population reduction of leaf miner while neem oil (1%) was least effective to reducing the maggot population with 55.62 per cent reduction.

10th day after spray

After ten days of spray, the maximum reduction in maggot population was recorded in plots treated with difenthiuron 30 WP with 71.18 per cent reduction and it was significantly at par with Acephate 75 SP (66.55%) and acetamiprid 20 SP (64.89%) Spiromesifen 22.9 SC was also significantly effective against the population of leaf miner maggot with 62.60 per cent reduction. Significantly the lowest reduction in maggot population was recorded for *Beauveria bassiana* (59.15%) and neem oil @ 1 percent (56.75%).

II Spray:

The second spray was applied after twenty days of first spray. The data recorded on reduction in maggot population of leaf miner after second spray is presented in Table (7). The pretreatment population (PTP) of leaf miner varied from 2.43 to 2.90/ leaf.

3rd day after spray

Three days after second spray difenthiuron 30 WP was most effective as it recorded significantly higher reduction in maggot population (54.57%) that rest of the treatments, but it was statistically at par with acephate 75 SP (51.54%) and acetamiprid 20 SP (48.95%). However, *Beauveria bassiana* and neem oil (1%) recorded lower population reduction 43.24 and 42.27 percent being at par with each other similarly Spiromesifen 22.9 SC recorded 45.58 percent reduction in maggot population and was at par with *Beauveria bassiana* and neem oil.

7th day after spray

Among all treatments difenthiuron 30 WP recorded significantly higher population reduction of leaf miner maggot (70.81%) which was at par with Acephate 75 SP (67.40%) and acetamiprid 20 SP (66.80%) after 7 days of second spray. Neem oil % and *Beauveria bassiana* were least effective to reduce the maggot population with 58.44 and 60.07 per cent reduction, respectively, and both were at par with spiromesifen 22.9 SC (63.99%).

10 day after spray

After ten days of second spray difenthiuron 30 WP was more effective over other treatments with 73.52 per cent reduction and was at par with acephate 75 SP (70.75%) and acetamiprid 20 SP (68.14%). Neem oil (1%) was least effective with 60.61 per cent reduction of maggot population and was at par with spiromesifen 22.9 SC (65.76%) and *Beauveria bassiana* (63.17%).

4.2.3 Thrips

I spray

The data recorded on reduction of thrips population after first spray is presented in Table (8). A day before second spray, the pre-treatment population of thrips was more or less uniform in all plots and ranged from 22.27 to 23.07/leaf.

3rd day after spray

Three days after first spray among all the applied treatments acetamiprid 20 SP emerged as significantly superior and showed maximum reduction in thrips population (75.67%), followed by acephate 75 SP and difenthiuron 30 WP with 70.07 and 68.63 per cent reduction being statistically at par with each other. Spiromesifen 22.9 SC was also effective in reducing thrips population with 60.84 per cent reduction. Neem oil (1%) showed lowest population reduction (54.07%), which was at par with *Beauveria bassiana* (56.06%).

7th day after spray

The data recorded at seven days after spray reveals that is maximum reduction in thrips population (70.08%) was observed in the plots treated with acetamiprid 20 SP and was most effective treatment in reducing the thrips population followed by acephate 75 SP and difenthiuron 30 WP with 65.43 and 63.61 per cent population reduction, being at par with each other. Spiromesifen 22.9 SC was moderately effective with 58.41 per cent reduction. Neem oil (1%) and *Beauveria bassiana* were least effective and recorded 49.23 and 51.69 per cent reduction, being at par with each other.

10 day after spray

The treatment acetamiprid 20 SP and acephate 75 SP were superior as compared to the other treatments and recorded 59.46 and 58.09 per cent reduction and both were at par with each other. However, treatments difenthiuron 30 WP, spiromesifen 22.9 SC, *Beauveria bassiana* and neem oil % recorded 55.93, 54.43, 48.49 and 46.35 per cent reduction, respectively, being at par with each other.

II Spray

The data recorded on thrips infestation after second spray is presented in Table (9). A day before second spray, the thrips population ranged from 13.53 to 14 thrips /leaf, showing no significant difference.

3rd day after spray

The data on three days after second spray reveal that the acetamiprid 20 SP recorded highest reduction of thrips population with 70.84 per cent and was significantly superior over other treatments, followed by acephate 75 SP and difenthiuron 30 WP with reduction per cent of 68.22 and 65.73 respectively. The treatments were at par with each other. However, the treatment spiromesifen 22.9 SC was moderately effective with a population of 58.59 per cent. Neem oil (1%) and *Beauveria bassiana* showed lowest reduction 51.71 and 53.24 per cent respectively, and were at par with each other.

7th day after spray

After Seven days of second spray as maximum reduction in thrips population was observed for acetamiprid (67.58%) and was highest effective for control of thrips population followed by acephate 75 SP (63.51%) and difenthiuron 30 WP (60.22%) being at par with each other. Spiromesifen 22.9 SC showed medium range of effectiveness with 55.70 per cent population reduction. While *Beauveria bassiana* and neem oil (1%) were found at par with each other with 50.41 and 48.06 per cent reduction in thrips population.

10 day after spray

The results indicate that treatment with acetamiprid 20 SP was most effective among all treatments and recorded 55.74 per cent reduction, it was at par with acephate 75 SP and difenthiuron 30 WP with 54.31 and 53.25 per cent reduction of thrips population. However, neem oil (1%) recorded lowest population reduction as 45.85 per cent, which was at par with spiromesifen 22.9 SC and *Beauveria bassiana* with reduction per cent of 50.11 and 48.51, respectively.

Table 4: Bio-efficacy of insecticide against whitefly (First spray)

S.No.	Treatment (%)	Pre treatment population	% Mean reduction of whitefly		
			3DAS	7DAS	10DAS
T1	Spiromesifen(0.1)	14.07	67.84[b]	62.31[b]	62.73
T2	Acetamiprid(0.02)	15.60	78.55[c]	72.13[c]	66.23
T3	Neem oil *(A. Indica)* (1)	16.20	52.01[a]	48.08[a]	52.00
T4	*Beauveria bassiana* (0.4)	15.87	54.61[a]	51.16[a]	54.53
T5	Difenthiuron(0.04)	15.07	65.76[b]	60.08[b]	59.80
T6	Acephate(0.2)	15.47	74.80[c]	70.27[c]	65.08
T7	Control	16.14			
	S.Em.±	0.671	1.574	1.928	3.357
	C.D. (P= 0.05)	N S	4.850	5.940	NS

PTP: Pre treatment population numbers per plant of whitefly 1-day before treatments;
NS: Non significant; CD: Critical differences; S.Em: Standard error of mean;
Numbers followed by the same alphabates in each column are not significantly different at 5%

Table 5: Bio-efficacy of insecticide against whitefly (Second spray)

S.No.	Treatment (%)	Pre treatment population	% Mean reduction of whitefly		
			3DAS	7DAS	10DAS
T1	Spiromesifen(0.1)	14.07	64.85[d]	58.59[b]	57.39
T2	Acetamiprid(0.02)	10.87	75.88[f]	67.28[c]	62.79
T3	Neem oil (*A.indica)* (1)	15.40	46.59[a]	44.30[a]	48.07
T4	*Beauveria bassiana* (0.4)	14.87	51.81[b]	46.21[a]	51.05
T5	Difenthiuron(0.04)	13.67	60.06[c]	55.91[b]	54.41
T6	Acephate(0.2)	11.80	70.69[e]	64.52[b]	61.53
T7	Control	23.47			
	S.Em.±	2.518	1.120	1.537	3.330
	C.D. (P= 0.05)	N S	3.450	4.737	NS

PTP: Pre treatment population numbers per plant of whitefly 1-day before treatments;
NS: Non significant; CD: Critical differences; S.Em: Standard error of mean;
Numbers followed by the same alphabates in each column are not significantly different at 5%

Table 6: Bio-efficacy of insecticide against leaf miner (First spray)

S.No.	Treatment (%)	Pre treatment population	% Mean reduction of leaf miner maggot		
			3DAS	7DAS	10DAS
T1	Spiromesifen (0.1)	3.50	42.45[a]	60.48[a]	62.6[a]
T2	Acetamiprid (0.02)	3.60	46.00[a]	62.57[b]	64.89[b]
T3	Neemoil *(A. Indica)*(1)	3.63	41.06[a]	55.62[a]	56.75[a]
T4	*Beauveria bassiana* (0.4)	3.77	42.23[a]	57.04[a]	59.15[a]
T5	Difenthiuron (0.04)	3.57	50.94[b]	65.82[b]	71.18[b]
T6	Acephate (0.2)	3.77	47.14[b]	64.09[b]	66.55[b]
T7	Control	3.60			
	S.Em.±	0.218	1.707	2.519	2.363

	C.D. (P= 0.05)	N S	5.179	7.641	7.168

PTP: Pre treatment population numbers per six leaves of leaf-miner 1-day before treatments;
NS: Non significant; CD: Critical differences; S.Em: Standard error of mean;
Numbers followed by the same alphabates in each column are not significantly different at 5%

Table 7: Bio-efficacy of insecticide against leaf miner (Second spray)

S.No.	Treatment (%)	Pre treatment population	% Mean reduction of leaf miner maggot		
			3DAS	7DAS	10DAS
T1	Spiromesifen(0.1)	2.60	45.58[a]	63.99[a]	65.76[a]
T2	Acetamiprid(0.02)	2.90	48.95[b]	66.80[b]	68.14[b]
T3	Neemoil (*A. indica)* (1)	2.80	42.27 [a]	58.44 [a]	60.61 [a]
T4	*Beauveria bassiana* (0.4)	2.50	43.24 [a]	60.07 [a]	63.17 [a]
T5	Difenthiuron (0.04)	2.43	54.57 [b]	70.81 [b]	73.52 [b]
T6	Acephate(0.2)	2.47	51.54 [b]	67.40 [b]	70.75 [b]
T7	Control	2.70			
	S.Em.±	0.161	2.078	2.607	2.336
	C.D. (P= 0.05)	N S	6.302	7.909	7.086

PTP: Pre treatment population numbers per six leaves of leaf-miner 1-day before treatments;
NS: Non significant; CD: Critical differences; S.Em: Standard error of mean;
Numbers followed by the same alphabates in each column are not significantly different at 5%

Table 8: Bio-efficacy of insecticide against Thrips (First spray)

S.No.	Treatment (%)	Pre treatment population	% Mean reduction of thrips		
			3DAS	7DAS	10DAS
T1	Spiromesifen(0.1)	22.27	60.84[b]	58.41[b]	54.53
T2	Acetamiprid(0.02)	21.07	75.67[d]	70.08[d]	59.46
T3	Neem oil(*A. Indica)* (1)	22.60	54.07[a]	49.23[a]	46.35
T4	*Beauveria bassiana* (0.4)	22.47	56.06[a]	51.69[a]	48.49
T5	Difenthiuron (0.04)	21.40	68.63[c]	63.61[c]	55.93
T6	Acephate(0.2)	22.07	70.07[c]	65.43[c]	58.09
T7	Control	22.70			

	S.Em.±	0.558	1.203	0.866	3.142
	C.D. (P= 0.05)	N S	3.706	2.668	NS

PTP: Pre treatment population numbers per plant of thrips 1-day before treatments;
NS: Non significant; CD: Critical differences; S.Em: Standard error of mean;
Numbers followed by the same alphabates in each column are not significantly different at 5%

Table 9: Bio-efficacy of insecticide against Thrips (Second spray)

S.No.	Treatment (%)	Pre treatment population	% Mean reduction of thrips		
			3DAS	7DAS	10DAS
T1	Spiromesifen(0.1)	13.53	58.59[b]	55.70[b]	50.11
T2	Acetamiprid(0.02)	12.33	70.84[c]	67.58[d]	55.74
T3	Neem oil *(A. Indica)* (1)	13.33	51.71[a]	48.06[a]	45.85
T4	*Beauveria bassiana*(0.4)	12.47	53.24[a]	50.41[a]	48.51
T5	Difenthiuron (0.04)	12.53	65.73[c]	60.22[c]	53.25
T6	Acephate (0.2)	13.20	68.22[c]	63.51[c]	54.91
T7	Control	14.00			
	S.Em.±	0.423	1.989	1.121	2.357
	C.D. (P= 0.05)	N S	6.129	3.454	NS

PTP: Pre treatment population numbers per plant of Thrips 1-day before treatments;
NS: Non significant; CD: Critical differences; S.Em: Standard error of mean;
Numbers followed by the same alphabates in each column are not significantly different at 5%

Table: 1Efficiency of various traps against whitefly

Treatment	**Mean population**
YST	112.20
BST	85.00
YPT	18.20
BPT	13.20
S.Em±	1.859
C.D. (P=0.05)	5.573

Table: 2 Efficiency of various traps against leaf miner

SMW	Mean population	
	YST	BST
02-Aug	4.2	0
09-Aug	6.8	1.4
16-Aug	9.6	1.8
23-Aug	10.8	2.6

30-Aug	13.4	3.8
06-Sep	15.4	5.2
13-Sep	18.6	6.4
20-Sep	22.4	9.6
Mean	12.65	3.85
t-cal.	3.49*	
t	2.41	

* Significant at 5 per cent level of significance

Table: 3 Efficiency of various traps against thrips

SMW	Mean population	
	YST	BST
02-Aug	0.2	7.6
09-Aug	0.4	8.6
16-Aug	1.8	9.8
23-Aug	5.4	12.6
30-Aug	7.8	16.6
06-Sep	10.2	20.6
13-Sep	13.4	23.8
20-Sep	16.6	25.8
Mean	6.97	15.67
t-cal.	|-2.62|*	
t	2.33	

* Significant at 5 per cent level of significance

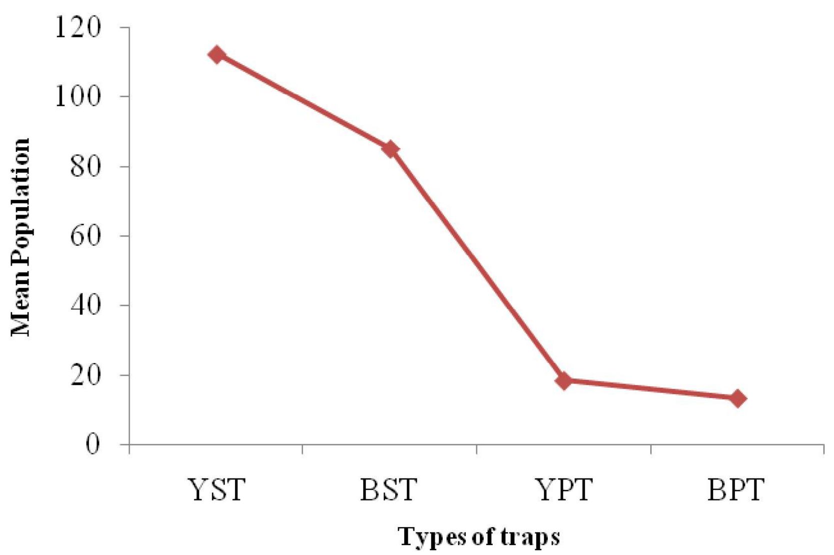

Fig:1 Mean population of whitefly trapped in different traps

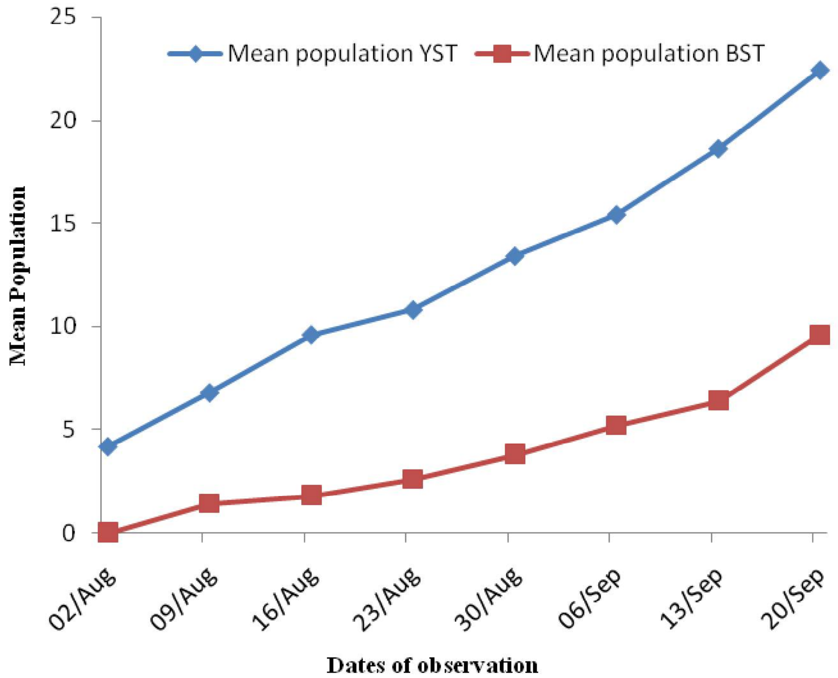

Fig:2 Mean population of leaf miner trapped on different traps

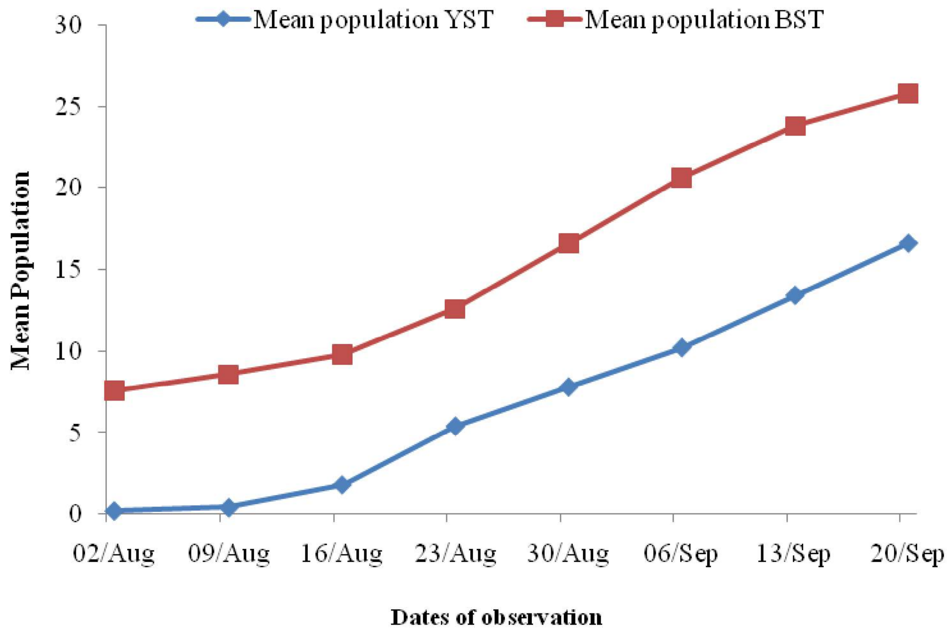

Fig.3: Mean population of thrips trapped in different traps

5. DISCUSSION

The results of investigations on "Insect pests of cucumber (*Cucumis sativus* Linn.) and their bio-rational management under protected cultivation" have been discussed in light of available information and important conclusions have been drawn.

5.1 The incidence of major insect pests of cucumber under protected cultivation

During the present investigation, three insect pests namely whitefly, thrips and leaf miner were observed to infest the crop during the season. The data presented in Table (1) and graphically represented in Fig (1) reveal that the incidence of whitefly was observed from first week of August (30th SMW) they were captured in various traps. The activity of whitefly was observed to be maximum during last week of September (37th SMW) in 2017. Our results reveal that the Yellow Sticky Traps was most attractive to adult whiteflies. The maximum mean number of whiteflies recorded on YST was 112.20 followed by that on Blue Sticky Traps with 85 mean number of whitefly per trap. Yellow Pan Traps recorded 18.20 mean numbers of adult whiteflies while the lowest mean population of whiteflies was recorded on Blue Pan Traps (13.20). YPT and BPT remained statistically at par with each other. Earlier Lu *et al.* (2012) asserted that in the greenhouse, yellow sticky traps significantly suppressed the population increase of adult and immature whiteflies *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) and suggested that yellow sticky traps could be used as an effective method for the control of whiteflies in the greenhouse. Wagan *et al.* (2017) observed that yellow sticky traps were most effective for monitoring and managing whiteflies and thrips in okra. Bayisa *et a*l. (2017) found that higher numbers of whiteflies and thrips were attracted by lavender oil and basil oil coated yellow sticky traps, respectively. While Premalatha *et al.* (2011) observed that yellow chart coated with castor oil harboured more whiteflies than on yellow sticky traps; therefore, using yellow sticky traps with natural essential oils contributed in the pest management of whiteflies.

The data presented in Table (2) and graphically represented in Fig (2) show that the incidence of leaf miner was first noticed during the first week of August (30^{th} SMW) while peak incidence was observed during third week of September (37^{th} SMW) on YST. YST was more effective for trapping leaf miner population and BST was least affective with 12.65 and 3.85 total mean number of leaf miner adults trapped, respectively. No leaf miner was trapped in BPT and YPT. The timing of peak activity of different insect pests appearing on cucumber crop differs depending on crop cultivation under protected condition or field condition and the region where it is cultivated. Similar to our findings Perdikis *et al.* (2008) observed that greenhouse crops were susceptible to infestation by a number of insect pests and the most important of these pests are whiteflies, leaf-miner and thrips. Similarly, Maklad *et al.* (2012) stated that the population of aphids, whitefly, spider mites and thrips in cucumber were maximum under polythene sheet. Kaur *et al.* (2010) observed that leaf miner (*Liriomyza trifolii* Burgess) incidence was considerably low, whitefly (*Bemisia tabaci* Gennadius) incidence was noticed early during the season and thrips (*Scirtothrips dorsalis* Hood) were serious pests on cucumber. Shalaby *et al.* (2013) also reported that the infestation by *Bemicia tabaci* started early on the crop. Nayana *et al.* (2017) found that the tomato leaf miner, *Tuta* *absoluta* (Meyrick) caused havoc in both open field tomatoes and under protected cultivation and observed that the *T. absoluta* density increased with age of crop under both polyhouse and field condition.

The data presented in Table (3) and graphically represented in Fig (3) show that after installation of traps; significantly higher numbers of thrips were trapped on BST as compared to that on YST, YPT and BPT. The maximum mean number of thrips was 15.67 captured on BST followed by 6.97 mean number of thrips trapped on YST while no thrips were trapped on YPT and BPT, indicating that blue colour was the best for thrips, while yellow was less attractive. The pan traps were not effective for trapping thrips as no thrips were trapped in the pan traps. Similar findings were noted by Sridhar *et al.* (2015) who evaluated different colour sticky traps for the purpose of monitoring chilli thrips, *Scirtothrips dorsalis* Hood on Rose both under open field and protected conditions. Among the colour traps used, blue colour attracted highest number of *S. dorsalis* adults followed by yellow and pink. Similarly, Kaas *et al*. (2005) observed that blue sticky trap was significantly more attractive to thrips than yellow in one of two tests. Gillespie *et al*. (2014) observed that at 2.4m height, blue traps captured more females than other colors, and yellow captured more males of western flower thrips, *Frankliniella occidentalis*. The efficiency of blue sticky traps used in our trials was in conformity with the findings of Devi et al. (2017), who observed that blue coloured sticky trap attracted more number of thrips over the crop growth period than white, yellow and fluorescent green sticky traps. Sampson et al. (2013) revealed that in semi-protected strawberry crops, mass trapping of *F. occidentalis* using blue sticky roller traps reduced the number of adult thrips per flower by 61 per cent and fruit bronzing by 55 per cent. Muthuram *et al*. (2017) used five different coloured sticky boards viz. green, yellow, orange, violet and white for testing their efficiency against thrips and found that green coloured sticky boards were most effective in attracting *T. tabaci* than other boards. Hassan et al. (2004) also carried out a greenhouse experiment to evaluate the trapping efficiency of various coloured traps in cucumber (*Cucumis sativus* L.) against thrips, *Thrips tabaci* (Lindeman) and the leaf miner *Liriomyza trifolii* (Burgess) and recorded significantly more insect pests on fluorescent yellow as compared to other traps whereas, pink, green and orange colored traps caught significantly lower number of insects and were found statistically at par.

Our findings show that YST was more effective for trapping leaf miner population and BST was least affective for trapping leaf miner adults. No leaf miner was trapped in BPT and YPT. Earlier, Civelek et al. (2004) recorded Liriomyza huidobrensis (Blanchard)

(Diptera: Agromyzidae) as an important pest in cucumber greenhouses and concluded that using yellow sticky traps would be a healthier and more cost effective practice than using pesticides. Ping et al. (2009) also recorded that the yellow sticky boards can catch more adults of leafminer in middle and upper part of cucumber. Similarly, Martin et al. (2005) also determined colour preference by exposing traps of various colours (red, blue, violet, green, white, and yellow) and materials (cardboard and acetate) to leafminer populations in celery for 24-48 hours and found that both sexes of adult pea leafminer were preferentially attracted to yellow opaque or translucent sticky cards. Bayisa et al. (2017) found higher number leaf miners were attracted by sticky traps coated with lavender oil, lemon oil and castor oil. It was concluded that yellow sticky traps were most effective to attract the adults of whiteflies and leaf miners while blue sticky traps to attract the thrips in a protected crop and was a good tactic towards monitoring and management of flying insect pests in cropping area.

5.2 Efficacy of different bio-rational insecticides against major insect pests of cucumber under protected cultivation

In view of the indiscriminate use of chemical pesticides and public concerns, the new generation insecticides provide an alternative to reduce the ill effects of conventional insecticides like destruction of natural enemies, pest resurgence and outbreak, environmental pollution, residue and other issues. Keeping these points in view the bio-rational insecticide molecules with novel mode of action were evaluated to find out a viable option for sustainable management against major insect pests of cucumber under protected cultivation.

In the present investigation, six insecticides namely difenthiuron 30 WP, acephate 75 SP, acetamiprid 20 SP, spiromesifen 22.9 SC, *Beauveria bassiana* and neem oil (1%) were evaluated against insect pests of cucumber in protected cultivation and it was observed that all the treatment schedules were significantly superior over the control. Based on the percent reduction of pest population after treatment the performance of acetamiprid 20 SP was observed to be significantly superior in controlling whitefly population, followed by acephate 75 SP however, both were statistically at par with each other. The least effective treatment was neem oil @ 1 percent and it was at par with *Beauveria bassiana*. While spiromesifen 22.9 SC and difenthiuron 30 WP were moderately effective to control the whitefly population, respectively, being at par with each other. The results are similar to those of

Kontsedalov *et al*. (2008) who showed that adult *B. tabaci* mortality rate after spiromesifen treatment (5mg L−1) was 40 per cent. While Kashyap *et al.* (2016) conducted a study to investigate the efficacy of insecticides and bio-pesticides against the greenhouse whitefly on tomatoes grown in polyhouses and found that abamectin 1.9% EC resulted in the highest mean percent reduction in immatures of *T. vaporariorum*, followed by acetamiprid and buprofezin, spiromesifen and bifenthrin resulted in moderate levels of efficacy, followed by azadirachtin and mineral oil. Mayoral *et al.* (2006) also observed that all *B. bassiana* treatments, irrespective of the dose (doses tested: 125, 250, and 300 ml/hl), significantly reduced the whitefly infestation on protected tomato compared to the untreated control.

During the investigations, among the all treatments evaluated difenthiuron 30 WP recorded maximum reduction of the maggot population and it was at par with acephate 75 SP. Acetamiprid 20 SP and spiromesifen 22.9 SC were moderately effective in reducing the maggot population, respectively. While *Beauveria bassianan* and neem oil (1%) were least effective as indicative by significantly lower reduction of maggot population of leaf miner. The results are similar to those of Mondol (2016) who evaluated the efficacy of insecticides in monitoring the damage caused by *Liriomyza brassicae* on pea crop and found that imidachloprid (0.01%) followed by, acephate (0.15%) gave lower percent larval population after spraying but were found to be statistically at par with each other. Wankhede *et al.* (2007) conducted an experiment to evaluate different insecticides against *L. trifolii* in tomato crop and showed that Neem oil 1% gave the lowest (4.37%) leaf miner infestation at 14 days after second spray followed by 0.01% spinosad and 5% neem seed extract. Larew *et al.* (2014) applied crude neem extract (0.4%) as a soil drench to chrysanthemum, which caused significant mortality of late instar maggots and pupae of *Liriomyza trifolii* (Burgess) in both research and commercial greenhouses.

In the present experiment the treatment of acetamiprid 20 SP was significantly superior and showed maximum reduction in thrips population followed by acephate 75 SP and difenthiuron 30 WP but being statistically at par with each other. Spiromesifen 22.9 SC was also effective in reducing thrips population. Neem oil (1%) showed lowest population reduction, which was at par with *Beauveria bassiana*. Our results are supported by the findings of Cloyd *et al.* (2000) who reported that acephate @ 600 ppm was effective against western flower thrips (*Franklinilla occidentalis*) on gerbera. Bhatnagar *et al.* (2009) reported that after 10 days of first spray, the least population of thrips was noticed in imidacloprid 17.8% SL followed by acetamiprid 20% SP, thiamethoxam 25% WG and dimethoate 30EC.

Among indigenous materials the least count was noticed in NSKE treatment. Venkatesh *et al.* (2003) tested the efficacy of neem oil in comparison with insecticides over two consecutive seasons at Tamilnadu and the result revealed that neem oil (1%) and insecticides were significantly effective against both nymphs and adults of *Thrips tabaci*. Similarly, Pallai *et al.* (1988) did experiments for the control of thrips with neem products and found that neem oil (2%) was as effective as phosphamidon and fenthion for controlling rice thrips.

6. SUMMARY

The results of the present investigation on **"**Insect pests of cucumber and their bio-rational management under protected cultivation" that was carried out at the High-tech Unit of Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur during *kharif* 2017, have been summarized and detailed as under:

The whiteflies, leaf miner and thrips were captured in various traps during first week of August (30th SMW) to last week of September (37th SMW) in *kharif* 2017 under protected conditions of cucumber cultivation. The maximum mean numbers of whiteflies were recorded on Yellow Sticky Traps (112.20) and minimum on Blue Pan Traps (13.20); likewise, the mean numbers of thrips captured were 15.67 on Blue Sticky Traps and 6.97 on Yellow Sticky Traps; and the maximum leaf miners were captured on Yellow Sticky Traps (12.65) and minimum on Blue Sticky Traps (3.85). On the blue and yellow pan traps no leaf miners and thrips got trapped.

Seven different insecticides were evaluated for their bio-efficacy against the whiteflies, leaf miners and thrips infesting cucumber. All the treatments were evaluated based on number of adult whiteflies, thrips and the numbers of leaf miner maggots present on the leaves after 3, 7 and 10 days after the first as well as second application. Observation after te first spray application indicated that acetaprimid 20 SP (0.02%) was most effective against whiteflies and thrips causing 78.55 and 75.67 per cent population reduction respectively after 3 days; 72.13 and 70.08 per cent population reduction respectively after 7 days; and 66.23 and 59.46 per cent population reduction after 10 days. The application of neem oil (1%) was least effective with 52.01 and 54.07 per cent, reduction in the population of whiteflies and thrips, respectively 3 days after spray; similarly, 48.08 and 49.23 per cent reduction respectively after 7 days; and 52.00 and 46.35 per cent reduction after 10 days of treatment.

Quite similarly, the maximum reduction in the population of whiteflies (75.88%) and thrips (70.84%) after three days of second spray was observed in acetamiprid 20 SP (0.02%); while, neem oil (1%) treatment resulted in lowest reduction being 46.59 and 49.23 per cent reduction in the population of whiteflies and thrips, respectively. Likewise, after seven days, acetamiprid 20 SP (0.02%) was most superior and recorded 67.28 and 67.28 per cent population reduction, while neem oil (1%) recorded 44.30 and 48.06 per cent reduction in the population of whiteflies and thrips, respectively. After ten days of second spray acetamiprid 20 SP (0.02%) resulted in maximum population reduction (62.79 and 55.74% for whiteflies and thrips), while neem oil (1%) caused the minimum reduction being 48.07 and 45.85 per cent for whiteflies and thrips, respectively.

In the case of leaf miner, after 3 days of first spray difenthiuron 30 WP (0.04%) recorded maximum reduction of the maggot population (50.94%), while neem oil (1%) recorded lowest reduction of maggot population (41.06%). After seven days of spray difenthiuron 30 WP (0.04%) recorded 65.82 reduction per cent, while neem oil (1%) recorded the minimum reduction (55.62%). After ten days also difenthiuron 30 WP (0.04%) had maximum reduction (71.18%) and neem oil (1%) resulted in 56.75 per cent population reduction. Similarly, after the second spray, 3, 7 and 10 days later difenthiuron 30 WP (0.04%) recorded maximum reduction in maggot population with the values being 54.57, 70.81 and 73.52 per cent; while the least reduction was observed in neem oil treatment with 42.27, 58.44 and 60.61 per cent maggot population reduction.

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Insect pests of cucumber (*Cucumis sativa* L.) and their bio-rational management under protected cultivation

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ABSTRACT

The investigations on major insect pests of cucumber and their bio-rational management under protected cultivation were carried out at the High-tech Unit of Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur during *kharif* season, 2017 with an aim to monitor the populations of whiteflies, thrips and leaf miners using yellow sticky trap (YST), blue sticky trap (BST), yellow pan trap (YPT) and blue pan trap (BPT) and evaluate the bio-efficacy of insecticides against these pests.

The whiteflies, leaf miners and thrips were captured in the different traps from first week of August (30^{th} SMW) through the last week of September (37^{th} SMW) and their mean numbers per plant on YST were 112.20, on BST 85.00, on YPT 18.20 and on BPT 13.20. The quantum of leaf miners trapped were 12.65 on YST and 3.85 on BST; and 15.67 and 6.97 caught on BST and YST for thrips. Leaf miner and thrips were not trapped in YPT and BPT.

Among the insecticides evaluated the most effective against whiteflies and thrips was acetaprimid (20 SP @ 0.02%) 3, 7, and 10 days after the first as well as the second spray. While in case of leaf miner maximum reduction of maggot population was observed in difenthiuron 30 WP (0.04%) and neem oil @ 1 per cent was observed least effective in reducing the per cent population of whitefly, leaf miner and thrips.

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APPENDIX-1

ANOVA for efficiency of various traps against whitefly

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	3	36274.2	12091.4	699.9	3.239	5.292
Error	16	276.40	17.27			
Total	19					

APPENDIX-2

ANOVA for bio-efficacy of various insecticides at PTP against whitefly (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	9.849	1.642	1.214	2.848	4.456
Error	14	18.923	1.352			
Total	20					

APPENDIX-3

ANOVA for bio-efficacy of various insecticides 3 DAS against whitefly (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	1688.512	337.702	45.442	3.106	5.064
Error	12	89.179	7.432			
Total	17					

APPENDIX-4

ANOVA for bio-efficacy of various insecticides 7 DAS against whitefly (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	1426.154	285.231	25.581	3.106	5.064
Error	12	133.801	11.150			
Total	17					

APPENDIX-5

ANOVA for bio-efficacy of various insecticides 10 DAS against whitefly (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	497.903	99.581	2.945	3.106	5.064
Error	12	405.792	33.816			
Total	17					

APPENDIX-6

ANOVA for bio-efficacy of various insecticides at PTP against whitefly (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	305.142	50.857	2.673	2.848	4.456
Error	14	266.356	19.025			

Total	20					

APPENDIX-7

ANOVA for bio-efficacy of various insecticides at 3DAS against whitefly (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	1861.223	372.245	98.985	3.106	5.064
Error	12	45.127	3.761			
Total	17					

APPENDIX-8

ANOVA for bio-efficacy of various insecticides at 7DAS against whitefly (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	1317.113	263.423	37.158	3.106	5.064
Error	12	85.070	7.089			
Total	17					

APPENDIX-9

ANOVA for bio-efficacy of various insecticides at 10DAS against whitefly (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	505.466	101.093	3.038	3.106	5.064
Error	12	399.307	33.276			
Total	17					

APPENDIX-10

ANOVA for bio-efficacy of various insecticides at PTP against leaf miner (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	0.180	0.030	0.210	2.848	4.456
Error	14	2.000	0.143			
Total	20					

APPENDIX-11

ANOVA for bio-efficacy of various insecticides at 3DAS against leaf miner (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	215.870	35.978	4.114	2.848	4.456

Error	14	122.439	8.746			
Total	20					

APPENDIX-12

ANOVA for bio-efficacy of various insecticides at 7DAS against leaf miner (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	1191.848	198.641	10.434	2.848	4.456
Error	14	266.534	19.038			
Total	20					

APPENDIX-13

ANOVA for bio-efficacy of various insecticides at 10DAS against leaf miner (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	1492.634	248.772	14.848	2.848	4.456
Error	14	234.565	16.755			
Total	20					

APPENDIX-14

ANOVA for bio-efficacy of various insecticides at PTP against leaf miner (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	0.570	0.095	1.215	2.848	4.456
Error	14	1.093	0.078			
Total	20					

APPENDIX-15

ANOVA for bio-efficacy of various insecticides at 3DAS against leaf miner (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	372.216	62.036	4.791	2.848	4.456
Error	14	181.286	12.949			
Total	20					

APPENDIX-16

ANOVA for bio-efficacy of various insecticides at 7DAS against leaf miner (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	1247.952	207.992	10.198	2.848	4.456
Error	14	285.546	20.396			
Total	20					

APPENDIX-17

ANOVA for bio-efficacy of various insecticides at 10DAS against leaf miner (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	1526.554	254.426	15.537	2.848	4.456
Error	14	229.250	16.375			
Total	20					

APPENDIX-18

ANOVA for bio-efficacy of various insecticides at PTP against thrips (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	8.691	1.448	1.552	2.848	4.456
Error	14	13.062	0.933			
Total	20					

APPENDIX-19

ANOVA for bio-efficacy of various insecticides at 3DAS against thrips (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	1097.605	219.521	50.582	3.106	5.064
Error	12	52.079	4.340			
Total	17					

APPENDIX-20

ANOVA for bio-efficacy of various insecticides at 7DAS against thrips (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	994.253	198.851	88.423	3.106	5.064
Error	12	26.986	2.249			
Total	17					

APPENDIX-21

ANOVA for bio-efficacy of various insecticides at 10DAS against thrips (spray-1)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	417.446	83.489	2.819	3.106	5.064
Error	12	355.380	29.615			
Total	17					

APPENDIX-22

ANOVA for bio-efficacy of various insecticides at PTP against thrips (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	6	689.096	114.849	214.384	2.848	4.456
Error	14	7.500	0.536			
Total	20					

APPENDIX-23

ANOVA for bio-efficacy of various insecticides at 3DAS against thrips (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	968.109	193.622	16.315	3.106	5.064
Error	12	142.417	11.868			
Total	17					

APPENDIX-24

ANOVA for bio-efficacy of various insecticides at 7DAS against thrips (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	862.658	172.532	45.760	3.106	5.064
Error	12	45.244	3.770			
Total	17					

APPENDIX-25

ANOVA for bio-efficacy of various insecticides at 10DAS against thrips (spray-2)

S.V.	d.f.	SS	MSS	F(cal)	Ftab5%	Ftab1%
Treatment	5	226.101	45.220	2.713	3.106	5.064
Error	12	200.033	16.669			
Total	17					

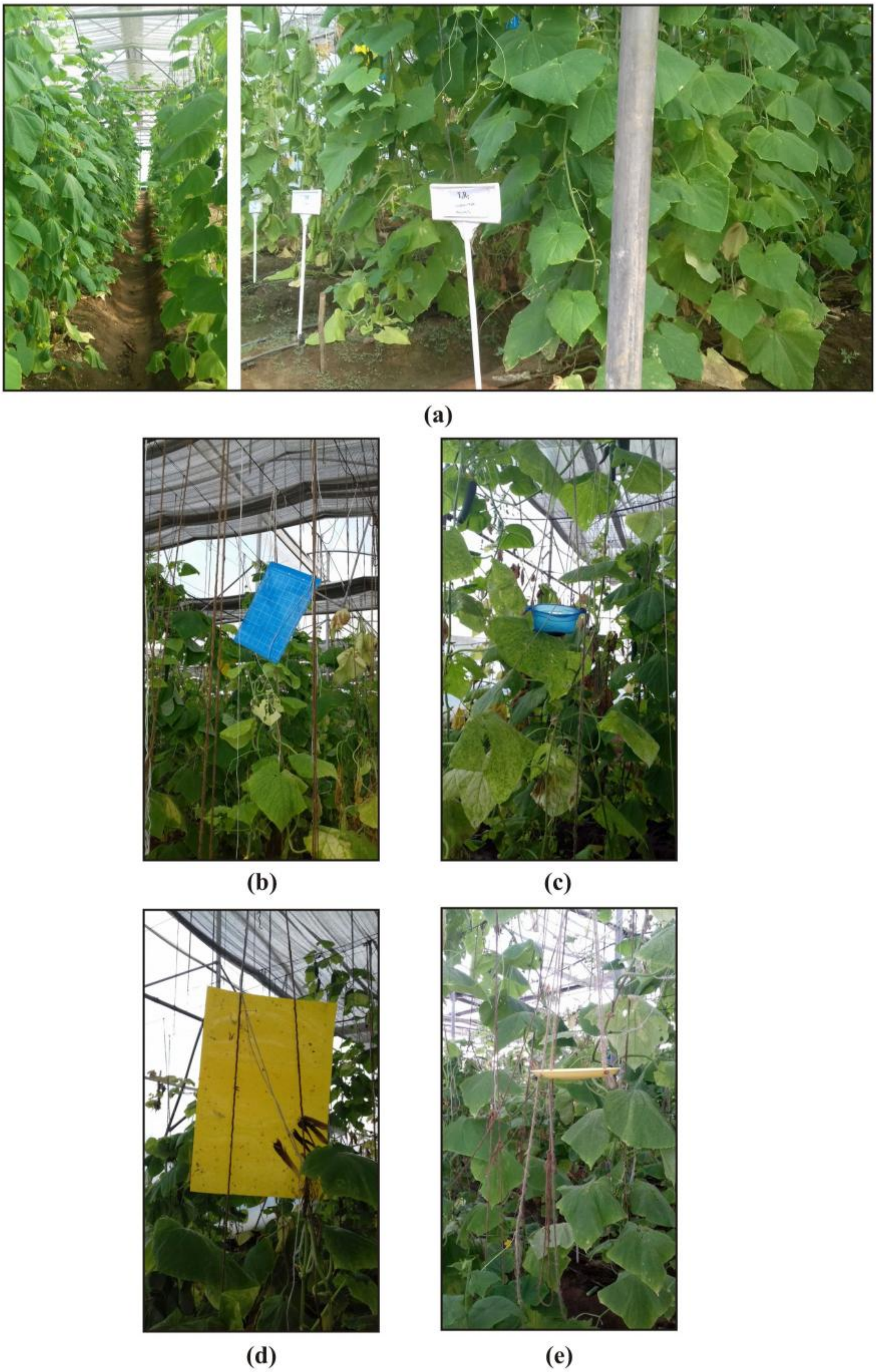
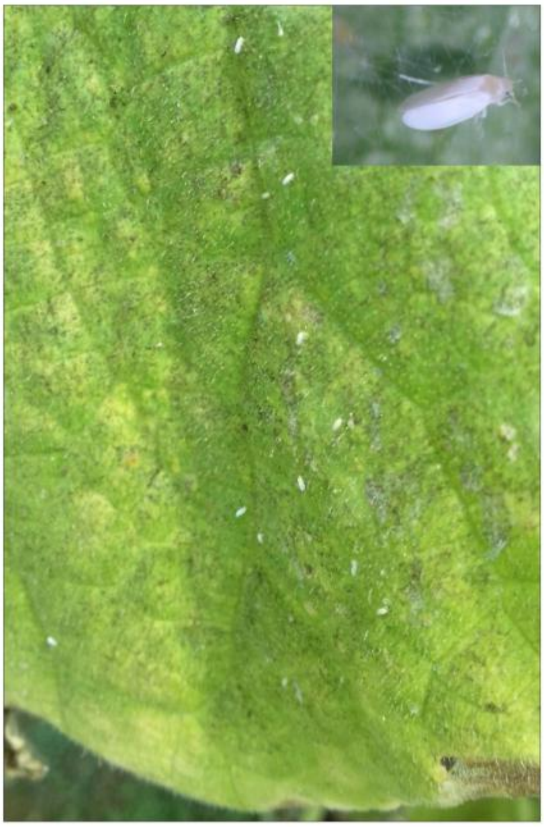


Plate 1. (a) General view of experimental view of cucumber; (b) Installation of Blue sticky trap; (c) Blue pan trap;(d) Yellow sticky trap; (e) Yellow pan trap



(a)

(b)

Plate 2. (a) Leaf damaged by whitefly (b) Leaf damaged by leaf miner