

**“EVALUATION OF DIFFERENT MODULES AGAINST MAJOR PESTS
OF CUCUMBER (*Cucumis sativus* L.)”**

by

Miss. Boraste Arati Anandrao
(Reg. No. 017/152)

A thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA**

in partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY



DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

**POST GRADUATE INSTITUTE
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2019

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

Place: MPKV, Rahuri.

(A. A. Boraste)

Date: / /2019

Prof. S. A. Pawar

Jr. Entomologist,
AICRP on Vegetable Crops,
Department of Horticulture,
MPKV, Rahuri -413 722.

CERTIFICATE

This is to certify that the thesis entitled,“ **EVALUATION OF DIFFERENT MODULES AGAINST MAJOR PESTS OF CUCUMBER (*Cucumis sativus* L.)**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of a piece of bonafide research work carried out by **Miss. BORASTE ARATI ANANDRAO**, under my guidance and supervision and that no part of the thesis has been submitted to any other University for Degree or Diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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Date: / /2019

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Place: M.P.K.V., Rahuri.

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Place : M.P.K.V., Rahuri.

Date : / /2019

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Place : MPKV, Rahuri

(Boraste A. A.)

Date : / /2019

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LIST OF ABBREVIATIONS AND SYMBOLS

%	:	Per cent
/	:	Per
@	:	at the rate of
+	:	Plus
X	:	Multiply
a.i.	:	Active ingredient
a.m.	:	Ante meridian (before noon)
C.D.	:	Critical difference
Cm	:	Centimetre (s)
cm ²	:	Square centimetre (s)
DAS	:	Days after Sowing
EC	:	Emulsifiable concentrate
e.g.	:	Exempli gratia, For example
<i>et al.</i>	:	And others (et alli)
etc.	:	<i>Et cetera</i> , and so on
FYM	:	Farm Yard Manure
Fig.	:	Figure
G	:	Gram (s)
G	:	Granule (s)
Ha	:	Hectare (s)
Hr	:	Hour (s)
i.e.	:	Id est, That is
IPM	:	Integrated Pest Management
Kg	:	Kilogram (s)
L	:	Litre (s)
M	:	Metre (s)
m ²	:	Square metre
Mg	:	Milligram (s)
MPKV	:	Mahatma Phule Krishi Vidyapeeth
MW	:	Meteorological week
NSE	:	Neem Seed Extract
Q	:	Quintal (s)
No.	:	Number
S.E.	:	Standard error
p.m.	:	Post meridian (after noon)
Rs.	:	Rupee (s)
SC	:	Suspension concentrate
T	:	Tones
<i>viz.,</i>	:	Videlicet (Namely)
WG	:	Water dispersible granules
WP	:	Weightable powder

ABSTRACT

EVALUATION OF DIFFERENT MODULES AGAINST MAJOR PESTS OF CUCUMBER (*Cucumis sativus* L.)

By

Miss. Boraste Arati Anandrao

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

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AGRICULTURAL ENTOMOLOGY

Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722

2019

Research Guide : **Prof. S. A. Pawar**

Department : **Agricultural Entomology**

An experiment entitled "Evaluation of different modules against major pests of cucumber (*Cucumis sativus* L.)" was conducted at the All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist: Ahmednagar (Maharashtra) during *kharif* 2018. During the course of study, three pest management modules viz., Chemical, Bio-intensive and IPM module consisting spraying of different pesticides as well as biopesticides were evaluated with untreated control in Randomized Block Design (RBD) with five replications. The seasonal incidence of pests of cucumber was also studied.

The incidence of thrips, whitefly and aphid was observed throughout the season with varying degree of intensity. Maximum number was recorded in 36th meteorological week (11.65 thrips/leaf) in the month of September. The correlation studies revealed that non-significant negative correlation existed between thrips population and maximum temperature ($r = -0.180$) as well as minimum temperature ($r = -0.090$). The incidence of thrips was non-significantly positively correlated with evening RH ($r = 0.090$) and non-significantly negatively correlated with morning RH ($r = -0.045$). The maximum build-up of whitefly was found in 32nd meteorological week in the month of August (12.23 whitefly/leaf). The correlation studies revealed that a non-significant negative correlation existed between the whitefly incidence and maximum temperature ($r = -0.186$) and non-significant positive correlation with minimum temperature ($r = 0.059$). There existed a positive non-significant correlation between the whitefly incidence and morning and evening RH ($r = 0.031$ and 0.176 , respectively). Maximum number of aphids was recorded in the 32nd (12.37 aphids/leaf) and 36th (12.37 aphid/leaf) meteorological week in the month of August and September respectively. The incidence of aphids showed non-significant negative correlation with maximum ($r = -0.01$) and minimum ($r = -0.079$) temperature. Also, it showed a non-significant negative correlation with morning ($r = -0.273$) and evening ($r = -0.063$) RH. The studies on evaluation of pest management modules for major pests of cucumber revealed that in case of control of whitefly, aphids and leaf miner the IPM module observed 3.80 whitefly, 3.90 aphids/3 leaves/plant and 21.15 % damaged leaves by leaf miner, respectively. This module found to be significantly superior and also at par with the Chemical module which has been observed with 4.86 whitefly, 4.43 aphids/3 leaves/plant and 25.94 % damaged leaves by leaf miner, respectively.

Abstract contd.....

Ms. Boraste A. A.

Whereas, in case of thrips and fruit fly pest, the IPM module was significantly superior module and observed 4.31 thrips/3 leaves/plant and 10.84% damaged fruits, respectively and it was followed by Chemical module which observed 5.11 thrips/3 leaves/plant and 18.12 % damaged fruits, respectively.

Effect of different strategies on predatory coccinellids showed that the Bio-intensive module recorded the highest grub population per plant i.e 3.85 grubs/plant and was at par with the IPM module which recorded 3.36 grubs/plant indicating their relative safety to the grubs of lady bird beetles. Whereas, the chemical module recorded least population i.e 1.37 grubs/plant at different intervals after each of four spraying taken in chemical module which indicated its toxic effects on the grubs.

The highest yield of cucumber fruits 230q/ha was registered from the IPM module with highest ICBR 1:13.86 as against 160 q/ha in untreated control followed by Chemical module with 225 q/ha and ICBR 1:10.66, while in the Bio-intensive module the yield recorded was 200 q/ha with lowest ICBR 1:62.

The above findings are based on the results of experimentation for only one season, which may be considered as merely indicative and further investigation is necessary to arrive at definite conclusion.

1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the oldest amongst cultivated vegetable crops belong to the family *cucurbitaceae*. Cucumber is said to be indigenous to India, from where it spread to Asia, Africa and Europe. It is one of the most popularly grown vegetable during *kharif* and summer season in all parts of the country including hilly part of the north India. In Maharashtra state, cucumber is grown in all the districts. However, more than 60% area is concentrated in Western Maharashtra and Konkan region.

In India, cucumber is grown over an area of 82,000 ha and annual production of 12,60,000 MT (Anonymous., 2017-18). In Maharashtra, cucumber is grown over an area of 44700 hectares with the annual production of 5,89,500 tones and productivity of 14 tones/ha (Anonymous., 2017-18).

The major insect pests recorded on cucumber are whitefly (*Bemisia tabaci* Gennadius), Leaf hopper (*Amrasca biguttula biguttula* Ishida), aphids (*Aphis gossypii* Glover and *Myzus persicae* Sulzer), Thrips (*Thrips palmi* Karny), fruit fly (*Bactrocera cucurbitae* Coq), American serpentine leaf miner (*Liriomyza trifolii* Burgess) and red pumpkin beetle (*Raphidopalpa foveicollis* Lucas). Out of these, American serpentine leaf miner (*L. trifolii*) and fruit fly (*B. cucurbitae*) recorded to be the most destructive pests.

American serpentine leaf miner (*L. trifolii*) (Agromyzidae: Diptera) is minute golden agromyzid fly, easily identified in adult stage. In India, Agromyzid, *Liriomyza* species were reported for first time in Karnataka in 1990-91 (Viraktamath *et al.*, 1993). Severe outbreak was noticed during 1992 in Maharashtra state on cucurbits (Wakchaure, 1998). Locally, it is called as 'Nag ali'. It has spread widely in Andhra Pradesh, Maharashtra, Gujarat and Delhi. Control of leaf miner with insecticides usually difficult because of its biology i.e. short life cycle, smaller in size and high mobility of adults, relatively long pupal stage in soil, high reproductive capability i.e. fecundity and concealed larval stages.

The fruit flies constitute an important group of pests infesting cucurbit vegetables. Two species namely *Bactrocera cucurbitae* (Coquillett) and *Bactrocera tau* (Walker) commonly called as melon fruit flies are the major species found infesting cucurbits. Besides, they have been found feeding on solanaceous crops like tomato and brinjal (Kapoor and Agarwal 1983). Whereas, in India Singh *et al.* (2000) reported fruit infestation 31.27 per cent infestation on bitter gourd and 28.55 per cent on water melon.

The melon fruit flies have more than 80 hosts and their economic importance cannot be evaluated entirely from the stand point of the direct damage to the various crops affected. About 50 per cent of cucurbits are partially or completely damaged by fruit flies in India (Gupta and Verma 1992).

Although several species of aphids may be found on cucumbers, the melon aphid (also known as the cotton aphid) is the most important as a pest. Melon aphids vary in size and colour. Most are approximately 1/16th of an inch long and light yellow to green to black in colour. They have black eyes, leg joints, and cornicles (“tailpipes”). Aphids usually start to colonize cucumber plants after the plants start to form runners. Aphids are typically found on the undersides of leaves where they feed by inserting a straw-like mouthpart, called a stylet, into, the leaves to suck out plant sap. This feeding can result in leaf distortions, including twisting, puckering, and cupping. Eventually, colonized leaves will turn brown and die. Aphids excrete honeydew on the leaves, which gives the leaves a glossy appearance. The honeydew provides nutrients for the growth of sooty mold fungi, which can cover leaves and fruit with dark brown fungal growth that is difficult to remove from fruit and reduces the plant’s ability to photosynthesize. The melon aphid can also transmit several viruses, including *Cucumber mosaic virus*.

Several species of whitefly can be found on cucumbers, with the silver leaf and greenhouse whitefly causing the most damage. Accurate identification is important to avoid treating whitefly species that do not cause significant yield losses. A hand lens is required for identification. Silver leaf whitefly (*Bemisia tabaci*) typically hold their wings vertically tilted, like a pitched roof on a house, and the wings do not meet over the back. By contrast, greenhouse whitefly (*Trialeurodes vaporariorum*) hold their wings flatter with no space visible between the wings where they meet at the back. Whitefly are usually found on the undersides of leaves where they feed on plant sap. Feeding by large populations of whitefly can result in plant desiccation, and infested plants become weak with reduced fruit production. Like aphids, whitefly produce honeydew that coats plant surfaces and results in the growth of sooty mold fungi that reduces fruit quality and photosynthesis.

Thrips are small slender insect with sucking and rasping mouth parts. Species, such as the western flower thrips, feed on plants, which can cause damage and yield reductions if population is high. However, the western flower thrips also eats spider mites, so it can also act as a beneficial insect.

These insect pests reduce the quality as well as quantity of cucurbit fruits and adversely affect the growth of plants. The infested fruits become unfit for human consumption and hence unmarketable

Several chemical insecticides have been recommended and are being extensively used by the farmers to control these sap sucking pests. However, considering economics and bioefficacy of pesticidal treatments, satisfactory control could not be obtained in many instances due to misuse of insecticides, resistance developed by pests and faulty application techniques.

Furthermore, heavy doses of insecticides has posed problems of residue in the fruits which cause human hazards upon consumption and also cause pest resurgence, insecticide resistance and destruction of natural enemies. However, the chemical pesticides can be minimized by integrating

it with botanical and microbial pesticides for producing healthy and good quality crop. Recently, new molecules of pesticides are introduced in the market which are comparatively safe to natural enemies of the pest. Some promising chemical are integrated in the present study to test the pest management modules against pests of cucumber with following objectives:

1. To study the seasonal incidence of pests of cucumber.
2. To evaluate pest management modules for major pests of cucumber.

2. REVIEW OF LITERATURE

The cucumber crop suffered mainly due to infestation of sucking pests viz; whitefly, leaf hoppers, aphids, thrips, serpentine leaf miner, red pumpkin beetle and fruit fly. Out of these, serpentine leaf miner (*Liriomyza trifolii*) and fruit fly (*Bactrocera cucurbitae*) recorded to be the most destructive pests. Severe outbreak was noticed during 1992 in Maharashtra state on cucurbits (Wakchaure, 1998). About 50 per cent of cucurbits are partially or completely damaged by fruit flies in India. (Gupta and Verma, 1992).

The pertinent literature on evaluation of management strategies against pests of cucumber (*Cucumis sativus* L.) have been reviewed under the following heads:

1. Seasonal incidence of sucking pests of cucumber.
2. Efficacy of insecticides against pests of cucumber.
3. Impact of the pest management strategies on natural enemies.

2.1 Seasonal incidence of sucking pests of cucumber

Attia *et al.* (1986) studied the seasonal abundance of aphids infesting cowpea in Egypt during 1985-86. Three species, *Aphis craccivora* Koch, *A. gossypii* Glover and *Acyrtosiphon pisum* (Harris) have been found infesting cowpea. However, *A. craccivora* remained the most damaging species. The absolute counts of *A. craccivora* were recorded at the beginning of the season. The pest was found active from mid May to the end of September reaching peak in mid July. Parasitism of the pest by a species of braconid occurred in June and July and reached to peak in July.

Slosser *et al.* (1998) studied abiotic and biotic regulation of aphid populations in Texas rolling plains and showed peak population of aphids in August was related to high temperatures and it reached to 15 aphids per leaf in mid September.

Yano *et al.* (1989) observed that the population growth rate of greenhouse whitefly in tomato was strongly affected by temperature.

Abdel *et al.* (1998) reported that temperature had a significant effect on both egg and nymphal populations of white fly on tomato while, relative humidity had no significant effect.

Arnal *et al.* (1998) observed that the adult white fly (*Bemisia tabaci*) were present through the growing period in the course of the study in tomato field and concluded that their population was higher at the end of rainy season.

Watson *et al.* (2003) conducted research on whitefly and the problem of sticky cotton and reported that the temperature above 30°C increased the rate of egg laying and temperature above 40°C reduced the length of life cycle of *B. tabaci* to less than two weeks.

Barde (2006) studied the seasonal incidence of white fly on tomato and reported that it appeared during second week of January and remained active until the crop was harvested. Peak

population was observed during the last week of February when maximum and minimum temperature was 30.5 and 16.8°C, respectively, 61.5 percent average relative humidity and 162 mm rainfall.

Choudhary (2006) studied the population buildup of insect pests of green gram, viz., jassids, whitefly and thrips. The infestation of these pests started in the last week of July and reached to peak in the first week of September when maximum and minimum temperature was 33.5 and 23.8°C, respectively with 78 per cent relative humidity. The maximum temperature showed significant negative correlation whereas minimum temperature and relative humidity showed significant positive correlation with the population of pests.

Krishna Kumar *et al.* (2006) conducted seasonal incidence of thrips and bud necrosis virus in watermelon and reported the population of thrips increased from three to six weeks after sowing of watermelon.

Lin *et al.* (2007) recorded that the at least 14 species of plants on which *B. tabaci* fed during the winter and spring. *Lycopersicon esculentum* Mill, *Brassica alboglabra* Bailey, *Ficus carica* L., *Euphorbia pulcherrima* Wild, and *Hemelia patens* Haence were the main host plants. Further research on the population dynamics of *B. tabaci* on three major greenhouse hosts; tomato, cucumber, and melon, indicated that densities remained at a low level during the winter, but increased steadily from February to March until migration into field crops in April. It is concluded that the control of the insect in greenhouse in winter and spring can play an important role for seasonal management of this pest.

Vennila *et al.* (2007^a and 2007^b) reported that high temperature and scanty rainfall aggravate the severity of sucking pests on cotton and reported that *Thrips tabaci* has population peaks during dry spell with high temperature and low humidity which are optimum for population build up.

Meena *et al.* (2009) studied the seasonal incidence of leafhopper and whitefly on okra and concluded that maximum temperatures are positively correlated with the population dynamics of sucking pests.

Ashfaq *et al.* (2010) studied the correlation of abiotic factors in *Bt* cotton with whitefly and reported that the whitefly population was positively correlated with mean temperature and negatively correlated with mean relative humidity. The positive correlation between the temperature and whitefly population can be attributed to the enhanced rate of development and reproduction of whitefly. The relatively higher temperatures can be conducive for rapid multiplication and activity of *B. tabaci*.

Mathur *et al.* (2012) conducted research on seasonal incidence and effect on abiotic factors on population dynamics of major insect pests on brinjal crop and reported that results on correlation analysis between weather parameters and abundance of *B. tabaci* revealed that

maximum temperature was positively correlated with the population of whitefly, minimum temperature was found to be negatively correlated with the population of whitefly, sunshine hours was positively correlated while, evening relative humidity and rainfall were negatively correlated.

Kandakoor *et al.* (2012) studied the incidence and abundance of sucking pests on groundnut and observed that correlation analysis of weather parameters with thrips, leafhoppers and aphids showed negative correlation with rainfall -0.106, -0.056 and -0.134, respectively. Thrips showed positive correlation to maximum and minimum temperature with 0.277 and 0.087 respectively and positive correlation (0.072) with sunshine hours. In aphids, negative correlation was observed (-0.211) with maximum temperature and positive correlation (0.165) with minimum temperature and positive correlation (0.017) for evening RH.

Lekshmi *et al.* (2014) conducted research on pest succession and population dynamics of major pests of bitter melon and reported that maximum and minimum temperature were significantly and negatively correlated with the population build-up of whitefly.

Shukla (2014) studied the seasonal incidence and relation to weather parameters of aphid and their natural enemies on okra and reported that correlation coefficient between different weather parameters and population of sucking aphids revealed that maximum temperature showed significant negative correlation with population of aphid ($r = -0.456$). Minimum temperature showed a significant negative correlation with population of aphid ($r = -0.250$).

Singh and Singh (2015) studied effect of temperature on the life history traits of aphids on bitter melon and reported that *A. gossypii* populations were well adapted to temperatures between 20 and 30°C, showing a high capita growth rate within this temperature change. Temperatures below or above this range result in drastically reduced population growth and temperatures over 30°C are lethal to nymphs of the aphids.

Satar *et al.* (2015) studied the effect of temperature on development and fecundity of aphid on bitter melon and reported that developmental time of aphid significantly decreased with increasing constant temperature ranging from 10.8 days at 15° C to 4.1 days at 30° C and 32.5° C. the constant temperature of 35° C was lethal to early instar of the cotton aphid.

Sunil *et al.* (2017) conducted studies on seasonal incidence of sucking insects pests on bitter melon during the *khariif* season 2014-15. The correlation studies between seasonal incidence of aphids and different weather parameters revealed that a weak positive correlation existed between incidence of aphids and maximum temperature ($r = 0.08$). Whereas, negative correlation existed between minimum temperature ($r = -0.49$), maximum RH ($r = -0.005$) and minimum RH ($r = -0.40$). During *khariif*, a non-significant negative correlation existed between the thrips incidence and maximum temperature ($r = -0.22$), minimum temperature ($r = -0.01$), maximum relative humidity ($r = -0.04$), minimum relative humidity ($r = -0.12$) and rainfall ($r = -0.03$). During *khariif*, a non-significant positive correlation existed between incidence of whitefly and maximum

temperature ($r = 0.39$), minimum temperature ($r = 0.05$) and rainfall ($r = 0.23$). While, non-significant negative correlation was observed with maximum RH ($r = -0.35$) and minimum RH ($r = -0.12$).

Tamilnayagan *et al.* (2017) conducted experiment on seasonal incidence of sucking pests of ash gourd in Tamil Nadu results on correlation analysis between weather parameters and abundance of *B. tabaci* revealed that maximum temperature was positively correlated with the population of whiteflies ($r = 0.708$), minimum temperature was found to be negatively correlated with the population of whiteflies ($r = -0.158$). Sunshine hours was positively correlated ($r = 0.646$), while, evening relative humidity and rainfall were negatively correlated with the r value of -0.528 and -0.197 , respectively. Correlation between weather parameters and population of *M. persicae* revealed that maximum temperature was positively correlated with the population of aphids ($r = 0.641$) and was found to be statistically significant at 1 per cent level. Sunshine was positively correlated with the population of aphids with the ($r = 0.723$) and was found to be statistically significant at 5 per cent level. Evening relative humidity and rainfall were negatively correlated with the r value of -0.476 and -0.168 , respectively.

Javed *et al.* (2017) studied the seasonal incidence and impact of abiotic factors on sucking pests of brinjal and reported that aphid population has highly significant and positive correlation with the maximum temperature ($r = 0.70$), highly significant and negative correlation with the rainfall ($r = -0.74$) and significant with negative correlation was showed by Relative humidity II ($r = -0.59$). Relative humidity I ($r = -0.36$) and wind speed ($r = -0.28$) showed non-significant negative correlation, whereas minimum temperature ($r = 0.09$), sunshine hours ($r = 0.54$) and evaporation ($r = 0.46$) showed non-significant positive correlation with aphid population.

Sharma *et al.* (2017) conducted research on seasonal dynamics and management of whitefly in tomato and concluded that the correlation studies between whitefly population and various abiotic factors showed a significant (Pearson correlation r , at $p \leq 0.05$) positive correlation with temperature (both maximum and minimum) and a positive but non-significant correlation with sunshine hours. Whereas, a significant negative correlation was observed with relative humidity (maximum and minimum) and a negative, but non-significant correlation was observed with rainfall.

Ghosh (2017) studied seasonal incidence of aphid (*Aphis gossypii* G.) infesting tomato and reported that correlation studies between aphid population and environmental parameters revealed that the population had a non-significant positive correlation with temperature (maximum, minimum and average); while non-significant negative correlation with rainfall (weekly total). On the other hand significant positive correlation was found between aphid population and relative humidity (average), temperature (difference) while significant negative correlation was found

between aphid population and relative humidity (maximum and minimum). This indicates that activity of aphid population increases with the rise of temperature and average relative humidity.

Bade *et al.* (2017) conducted research on seasonal incidence and bioefficacy of newer insecticides and biopesticides against aphids on okra and reported that the activity of aphid population was initiated on okra crop during second week of August (0.60 aphids/3 leaves). There was a gradual increase in aphid population up to third week of September and subsided next two weeks. The peak activity again resumed during first week of October (13.40 aphids/3 leaves). Correlation coefficient between different weather parameters and aphid population on okra revealed that maximum temperature recorded non-significant but positive correlation with population of aphids ($r=+0.1706$). Minimum temperature showed significant but negative correlation with population of aphids ($r=-0.6445$). However, evening relative humidity had significant positive correlation with aphids ($r=+0.4891$). The rainfall showed negative correlation on aphids ($r=-0.4720$).

Potai *et al.* (2018) conducted studies on seasonal incidence of major insect pests and their correlation with weather parameters and reported that aphid population was noticed negative non-significant correlation with maximum temperature ($r=-0.16$) and minimum temperature ($r=-0.02$) and significant positive correlation with morning RH ($r=0.64^*$) and negative non-significant correlation with evening RH ($r=-0.09$). On the other hand positive correlation with rainfall ($r=0.41$) and negative non-significant correlation with wind velocity ($r=-0.7$), respectively. Whitefly incidence had positive but non-significant correlation with maximum temperature ($r = 0.13$) and positive higher significant correlation with minimum temperature ($r = 0.82^{**}$), on the other hand positive higher significant correlation with rainfall ($r = 0.75^{**}$) and positive significant correlation with morning ($r = 0.67^*$) and evening ($r = 0.59^*$) RH and non-significant negative correlation with wind velocity ($r = -0.03$), respectively.

Alasady and Abdul (2018) recorded five new thrips species on cucumber in Iraq, *Thrips palmi*, *Thrips tabaci*, *Frankiniella schultzie*, *Haplothrips sp.*, and *Eremiothrips sp.* Out of that *Thrips palmi* was the most dominant species which recorded 76% out of all the thrips.

2.2 Efficacy of insecticides against pests of cucumber

Cu-lure and ENT 31812 lures were placed on the ground and at 2 and 5 feet above the ground to evaluate the effect on the response of *B. cucurbitae*. Both the attractants were found at least as attractive at ground level as at higher levels and cu-lure was found more attractive than ENT 31812 (Hart *et al.* 1967).

Singh and Srivastava (1983) reported that neem oil extract (5%) effectively prevented the oviposition in *B. cucurbitae*.

According to Metcalf *et al.* (1983), *B. cucurbitae* was extremely responsive to cu-lure, but non responsive to methyl eugenol. Whereas, *B. dorsalis* extremely responsive to methyl eugenol, but non-responsive to cu-lure.

Green *et al.* (1985) reported that abamectin applied weekly @ 45 ppm before infestation gave excellent control of *L. trifolii*. Doubling of this concentration was suggested for even better control of younger plants. The abamectin was recommended as prophylactic treatment against Agromyzid on Chrysanthemum, Gerbera and Gypsophila grown as greenhouse crop.

Albrecht and Sherman (1987) tested avermectin B1 against three fruit fly species *in vitro* and reported that its high dosages resulted in high mortality in the adults of all the three species. They concluded that it might be superior to malathion for the control of fruit fly species although slow acting, but was highly toxic and has definite suppressive effect on fecundity particularly in *B. cucurbitae*.

Schuster and Taylor (1987) observed that single application of abamectin @ 4.54 g a.i./378.5 liters of water, control the *Liriomyza trifolii* on tomato in the field. They applied abamectin to tomato in the field and treated foliage was bioassayed in the laboratory against *Liriomyza trifolii*. Surface residues on leaflets increased adult mortality only when bioassay on the day of treatment. Oviposition and larval abundance were reduced even when leaflets were bioassayed 7 days after treatment. Leaf puncturing by female was reduced for 3 days after treatment. A single application of abamectin at a comparable dose controlled *Liriomyza trifolii* on tomato in the field for at least a week.

Grafius and Hayden (1988) according to them, abamectin caused high mortality of all larval stages with adult emergence. Thiocyclam caused high mortality of all larvae but did not affect emergence. Cyromazine acted most strongly against early instar larvae, before visible mines were present and caused little direct mortality of larger larvae, but prevented successful adult emergence.

Azam (1991) studied toxicity of neem oil (0.5, 0.75, 1.0, 1.25 and 1.5 %) to larvae of *Liriomyza trifolii* on cucumber leaves. More than 60 % mortality of larvae and pupae were recorded at 1.0 to 1.25 % concentration. While less than 1 % conc. it was less effective and at 1.5 % it did not caused a significant increase in mortality in the laboratory.

Saito (1991) conducted a field trial of an entomopathogenic fungus *Beauveria bassiana* for the control of *Thrips palmi* Karny on cucumber and his reports revealed that *Thrips palmi* Karny was successfully controlled by using EPF.

In an experiment in melon field, commercially produced attractants Flycide C (80% cu-lure content), Eugelure 20 (20%), Eugleure DB (8%), cu-lure (80%) + naled cu-lure (80%) + diazinon and cu-lure (90%) + naled were tested against *B. cucurbitae* showed no significant difference in captured flies (Iwaizumi *et al.* 1991).

Pawar *et al.* (1991) used cu-lure (sex attractant) and tephrit lure (food attractant) for the monitoring of *B. cucurbitae* and found cu-lure traps more efficient in trapping fruit flies as compared to tephrit lure.

Lima and Machado (1994) reported that spraying abamectin with 1.8 EC @ 50, 75 and 100 ml/ 100 liter, gave best protection against leaf miner and there were no significant difference between cartap hydrochloride 50 SP @ 180 g/100 liter, gave the good plant protection against the pest.

Borah and Nath (1995) evaluated an insecticidal schedule on incidence of whitefly and reported that the application of dimethoate @ 0.03% at 15 and 30 days after germination significantly reduced the whitefly population and significantly lowest incidence of yellow vein mosaic, followed by dimethoate 0.03% at 15 days after germination + malathion 0.05% at 25 and 30 days after germination as well as malathion 0.05% at 15 days after germination + dimethoate 0.03% at 25 and 30 days after germination.

Dimetry *et al.* (1996) revealed that the bioactivity of different formulations of neem seed extracts against *Bemisia tabaci* was assayed in semi-field trials during 1992. Tomato plants (variety UC-97) were cultivated in pots and left to become naturally infested with *B. tabaci* in an open field and were sprayed with various concentrations of each extract. The high concentration of all the extracts tested exhibited activity. Also, the different treatments reduced the population density of the adults compared with the (untreated) control.

Chen *et al.* (1996) studied the deterrent effect of neem seed kernel extract on oviposition of oriental fruit fly, *B. dorsalis* and revealed that guava fruits treated with neem seed kernel extract (0.2 to 0.4%) resulted in reduction in oviposition preference (87.5 to 99.2%) over the untreated check fruits.

Ranganath *et al.* (1997) tested a number of botanicals and chemical insecticides against *B. cucurbitae* on cucumber and ridge gourd in Southern Andaman, India and reported that neem oil (1.2%) was the most effective in reducing the damage in cucumber and recorded 6.2 per cent infestation over 39.0 per cent in the control.

Ragumoorthi *et al.* (1998) tested five neem formulations against Moringa fruit fly, *Gotina distigma* (Meigon) and observed that nimbecidine (1500 ppm) was the most effective with high anti-oviposition effect as 15.33 eggs per female were observed compared to 54.67 in untreated check.

Krishna Kumar (1998) reported that NSKE 4% sprays was found to be the most effective in controlling *L. trifolii*. It was revealed that NSKE was not an ovipositional deterrent, but killed first instar *L. trifolii* larvae.

Hassan (1998) tested neem seed kernel extract on persimmon for its efficacy against developing stages of the Queensland fruit fly and found it significantly effective @ 120-140 mg per liter of water against 1st and 2nd instar larvae.

Apte (2001) reported average efficacy 66.95, 51.95 and 48.04% on azadirachtin, fipronil and quinalphos against *Liriomyza trifolii* on gerbera respectively.

Gahbiche (2001) who tested the toxicity of spinosad against *L. trifolii* and reported that it gave 100 per cent mortality of first instar larvae and 89.3 per cent mortality of third instar larvae.

Galande (2002) conducted experiment to evaluate the efficacy of selected insecticides from different groups. Chlorpyrifos + cypermethrin (0.05 %) was found most effective and ranked top in controlling *Liriomyza trifolii* and recorded maximum yield. Next promising treatments were NSKE 5%, Azadirachtin (0.0075 %) and Lufenuron (0.0025 %). In sequential application of insecticides, all the sequence of insecticides tested were equally effective against *Liriomyza trifolii* on cucumber. The treatment with chlorpyrifos + cypermethrin- chlorpyrifos + cypermethrin- Azadirachtin and Lufenuron – chlorpyrifos + cypermethrin – Azadirachtin were highly promising in reducing the incidence of *Liriomyza trifolii* on cucumber.

Rajkumar *et al.* (2002) reported that the treatments were: fish oil insecticidal soap (FOIS; Na-based) 2.5%; FOIS (K-based) 2.5%; FOIS (K) + tobacco extract (2.5%); FOIS (Na) + tobacco extract (2.5%); Nimbecidine (0.2%); garlic extract (2.5%) + Nimbecidine [*Azadirachta indica*] (0.2%); quinalphos (0.05%); and control. Among the biorationals evaluated, FOIS (Na) 2.5% + tobacco extract (2.5%) significantly reduced the damage caused by thrips.

Eswarareddy *et al.*, (2004) reported that abamectin 1.4 ml/ L was most effective in controlling *Liriomyza trifolii* on tomato. Abamectin 1.05 ml/ L and neem seed powder 7 % also gave satisfactory control of pest.

Thomas *et al.* (2005) evaluated two para pheromones *viz.*, cu-lure and methyl eugenol for their attraction to *B. cucurbitae* in a bitter gourd field and revealed that melon flies were attracted to only cu-lure traps.

Response of fruit flies to the traps which differed in size, shape and colour containing methyl eugenol were evaluated in mango orchard by Ranjitha and Viraktamath (2005) and observed that fruit flies showed greater response to spheres than bottles and cylinders. However, response to different colours varied among different species.

Sharma and Sinha (2009) evaluated seven insecticides for the control of *B. cucurbitae* and revealed that three foliar sprays of alphamethrin (20 g a.i./ha) at fortnight interval proved most effective followed by emamectin benzoate (15 g a.i./ha) and neem ban (1 ml/liter of water).

Vargas *et al.* (2009) evaluated various traps with methyl eugenol and cu-lure for capturing fruit flies and observed that *B. dorsalis* was captured in methyl eugenol traps and *B. cucurbitae* in cu-lure traps.

In Nepal, application of locally made botanical pesticide Jholmal, a mixture of leaf extract of many plants including neem was found superior in terms of quality, size, yield and reduced fruit fly infestation in squash (Sapkota *et.al* 2010).

Ganapathy *et al.* (2010) reported that among the botanicals tested on cowpea, NSKE @ 5% was most effective against the larval instars with a mean larval mortality of 53.4 % and low damage level of 25.5 %. Among the insecticides chlorpyrifos 20 EC, 0.05 % was highly effective with higher larval mortality (74.9%) followed by triazophos 40 EC @ 0.04 % (37.3 %) leaf damage was also low in chlorpyrifos 20 EC, 0.05 % (21.9 %) followed by triazophos 40 EC @ 0.04 % (23.9 %) compare to control (42.9 %).

Moreau and Isman (2011) studied comparison of greenhouse whitefly responses to trap crops and yellow sticky traps and reported that yellow sticky traps were effective at trapping adult whiteflies and significantly reduced adult populations on the main crops (peppers) compared with the control.

Mondal and Mondal (2012) evaluated in field alternate uses of insecticides against chilli thrips. A package of treatments comprising sprays of difenthiuron 50WP @ 1 g/l followed by acetamiprid 20 SP @ 1 g/l at 10 days interval 30 days after transplanting of the crop, was found to be superior over all other packages in terms of significantly lower thrips population count and highest per cent reduction of curly leaves with significantly higher yields over untreated control.

Pawar and Patil (2013), evaluated number of new insecticides against cucumber leaf miner and found that amongst the insecticides, abamectin 1.9 EC at (0.00057%) significantly reduced maggot population of leaf miner by 65.68, 71.90 and 75.26 per cent mortality on 7th days after application of each spray at 1st, 2nd and 3rd spray ,respectively followed by cartap hydrochloride 50 SP at 0.05 per cent (62.40, 68.66 and 73.68%) and it was at par with abamectin. The rest of the treatments *viz.*, NSKE 5% (60.06, 64.43 and 67.55%), fipronil 5 SC at 0.0075 per cent (59.76, 65.86 and 70.40%) , spinosad 45 SC at 0.018 per cent (57.28,64.06 and 67.66%), triazophos 40 EC at 0.08 per cent (57.03,61.93 and 65.59%), imidacloprid 17.8 SL at 0.0071 per cent (56.48, 59.35 and 59.30%) and carbosulfan 25 EC at 0.025 per cent (53.21%)also effective in minimizing the pest population on 7th days after each spray application *i.e.* 1st, 2nd and 3rd spray, respectively.

Annamalai *et al.* (2014) studied the bioefficacy of *Beauveria bassiana* and *Lecanicillium lecanii* and reported that *B. bassiana* and *L. lecanii* significantly decrease the *T. tabaci* infestations in onion crop under the greenhouse as well as field conditions.

Ghosh (2017) conducted experiment on management of aphids (*Aphis gossypii* G.) infesting tomato using botanical insecticides and found that among the bio-pesticides combination of neem and *Spilanthes* gave higher control (77.58%) very closely followed by neem (71.63%) over control and recommended use of biopesticides in IPM programme against aphids on tomato plants.

Bade *et al.* (2017) conducted research on seasonal incidence and bioefficacy of newer insecticides and biopesticides against aphids on okra and their effect on natural enemies and reported that insecticidal treatments with acetamiprid 20 SP @ 15 g a.i./ha followed by *Lecanicillium lecanii* @ 2.5 kg/ha, acetamiprid 20 SP @ 15 g a.i./ha and thiamethoxam 25 WG @ 25 g a.i./ha were found most effective treatment against aphids after four sprays. The use of *L. lecanii* @ 2.5 kg/ha alone was found effective in controlling population of aphids on okra with minimum mortality of lady bird beetles as compared to other insecticides. At 10 days after sprays, the treatment with *L. lecanii* recorded highest population of 4.49 lady bird beetles/plant and it was superior over all the treatments except, untreated control.

2.3 Impact of the pest management strategies on natural enemies

Hara (1986) reported that cyromazine and abamectin were the most efficacious insecticides against *Liriomyza trifolii* (Burgess) on potted- and cut chrysanthemums. Oxamyl, oxamyl plus methomyl (tankmix), and permethrin plus micro-encapsulated methyl parathion (tank-mix) were also effective against *L. trifolii*. No adverse effects of tested insecticides to the leaf miner parasitoids, *Diglyphus imermedius* (Girault) and *Ganaspidium hunieri* (Crawford) were observed.

Johnson (1987) conducted survey of parasites and per cent parasitization of *L. sativae* and *L. trifolii* in watermelon. The eulophid, *Chrysonotomyia punctiventris* (45.2%) and the pteromalid, *Halticoptera circulus* (22.4%) were predominant parasites reared from foliage collected in spring plantings. In summer plantings, importance of the eucoilid, *Ganaspidium hunter* (43.8%) increased and that of *C. punctiventris* (29.6%) decreased. Although insecticides were occasionally applied for secondary pests, the mean percentage of maximum leaf miner parasitism was about 75.1%.

Hoelmer *et al.* (1990) observed that the commercial neem insecticide was not toxic to adult coccinellid predators.

Banken and Stark (1997) found that azadirachtin (Neemix) was virtually non-toxic to larvae of *Coccinella septempunctata* Linn. exposed to direct sprays in the laboratory.

Darvas and Polgar (1998) alleged that insecticides that disrupt the parasitoid food chain by killing leaf miners would always have a negative effect on their natural enemies. A field trial showed that methomyl could encourage pest growth through the disturbance of the parasitoid guilds, and that methamidophos was safer than methomyl to the natural enemies.

Gahbiche and Aoun (1999) tested the efficiency of spinosad on larvae and pupae of *L. trifolii* on pepper and observed that spinosad had significant effect on larvae (54%) and pupae (78%) with a persistency effect of 15 days recording efficiency of 75% on larvae for a week and an efficiency of 67% on pupae. Spinosad did not had any adverse effects on larval parasitoids of leaf miner for a week of application but was fatal for pupae and larval pupal parasitoids after 15 days following application.

Weintraub (2001) evaluated different insecticides and observed that methomyl, methamidophos, abamectin showed higher densities of the leaf miner parasitoid *Diglyphus isaea* on treated potatoes compared to cyromazine.

Acharya *et al.* (2002) suggested that newer molecules *viz.* acetamiprid (20 g a.i./ha), thiamethoxam (25 g a.i./ha), imidacloprid (25 g a.i./ha), NACLFMOA (20 g a.i./ha) and abamectin(20 g a.i./ha) were relatively safe to the predatory lady bird beetle.

Hidrayani *et al.* (2005) studied the effects of profenofos, carbosulfan, and abamectin. They observed that profenofos, and carbosulfan reduced parasitism by *Hemiptarsenus varicornis*, *Opius chromatomyiae* and *C. humilis*, and abamectin did not reduce parasitism.

Kaspi and Parrella (2005) studied the compatibility of the widely used abamectin insecticide with the commercially available parasitoid *D. isaea*. Topical applications greatly affected parasitoid survival. Abamectin residue on plants also negatively affected *D. isaea* survival up to 5 days after application. Parasitism of treated leaf miner larvae was lethal for the natural enemy. However, application of insecticide after the leaf miner was parasitized and parasitoid larvae started feeding, did not affect *D. isaea* emergence and longevity

Seal *et al.* (2006) tested six insecticides against *S. dorsalis* on pepper plants and the effects on adults of *Cryptolaemus sp.* They found imidacloprid and cyfluthrin to be very harmful. Chlorfenapyr was moderately harmful and spinosad slightly harmful to the Australian lady bird beetle on paper plant.

The effects of neem (azadirachtin), abamectin and spinosad to *Neochrysocharis formosa* and *Opius chromatomyiae* were summarized by Hossain and Poehling (2006). Neem-Azal-U was used for soil applications, and it caused low mortality on *O. chromatomyiae* when the parasitized *L. sativae* pupae came in contact with this insecticide; longevity of the emerged parasitoids was unaffected. The foliar formulations of azadirachtin, spinosad and abamectin were all highly toxic to *O. chromatomyiae*. The application of spinosad and abamectin to parasitized leaf miner larvae by *N. formosa* had strong negative effects on its emergence. However, NeemAzal- T/S (azadirachtin) had no detrimental effects on the parasitoid observed.

Thania and Thomas (2013) found that spiromesifen was the safest insecticide against natural enemies *viz.*, predatory mites, coccinellid beetles and spiders. Whereas, the organophosphate insecticide dimethoate 30 EC @ 300 g a.i /ha was unsafe to natural enemies.

Bade *et al.* (2017) investigated the effect of newer insecticide and biopesticides on okra and the insecticidal sprays with acephate 75 SP, acetamiprid 20 SP, diafenthiuron 50 WP, thiacloprid 21.7 SC, thiamethoxam 25 WG and *Lecanicillium lecanii* were found safer to the lady bird beetle population in okra crop.

3. MATERIALS AND METHODS

The present investigation entitled “Evaluation of different modules against major pests of cucumber (*Cucumis sativus* L.) were carried to evaluate effective module for the management of major pests of cucumber *viz.*, thrips, whitefly, aphids, leafminer and fruit fly and their natural enemies under field conditions.

The field experiment on evaluation of pest management modules against pests of cucumber was conducted at the Research Farm of AICRP on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra during the *Kharif* 2018. The details of the material used and methods adopted during the course of investigations are described in this chapter.

3.1 Experiment on seasonal incidence of pests

3.1.1 Method of recording observation of sucking pests

The seasonal incidence of various sucking pests *viz.*, thrips, whitefly and aphids was noted as stated below. In order to know the intensity of each sucking pest, count of nymph and adults were taken in to account.

Observations on sucking pests such as thrips, whitefly and aphids were recorded on five randomly selected plants from each replication. Total number of thrips, whitefly and aphids were recorded from three leaves of each selected plant. The observation were recorded at a particular day in a week.

3.1.2 Observation on meteorological parameters

In order to study the incidence of climatic condition on the incidence of pests, meteorological parameters *viz.*, maximum and minimum temperature ($^{\circ}\text{C}$), relative humidity at morning and afternoon (%), sunshine period (hr) and rainfall (mm) were taken into account to study the correlation. The meteorological data were obtained from the meteorological observatory located at the central campus Farm of MPKV, Rahuri for the period of July 2017 to October 2018. The correlation coefficient (r) between climatic parameters and incidence of pests was worked out by following standard statistical procedure (Gomez and Gomez, 1984).

3.2 Evaluation of pest management modules for major pests of cucumber

Evaluation of pest management modules against major pests of cucumber was studied by conducting field trial.

3.2.1 Material

A. Seeds

The seed of cucumber (*Cucumis sativus*.L) variety ‘Gypsy’ was obtained from the local market of Rahuri.

B. Insecticides

All the chemical insecticides required for the field experiment were obtained from All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, MPKV, Rahuri. All the biopesticides were obtained from Bicontrol Laboratory, Department of Agricultural Entomology, PGI, MPKV, Rahuri. The technical information of all the pesticides and biopesticides included in the present research work *viz.*, common name, trade formulation and source is given in Table 3.1.

C. Equipments

The equipments such as sprayer (High volume knapsack spray pump of ASPEE make), measuring cylinder, weighing balance and other materials such as labels, thread and iron pegs were obtained from All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, MPKV, Rahuri for conducting the field experiment.

3.2.2 Methods

The soil selected for experiment was medium black and well drained. The land was ploughed, harrowed once and furrows were made. The seeds were dibbled and irrigated immediately after sowing. All the recommended agronomical practices were followed in raising the crop and uniform plant population was maintained.

3.2.3 Treatment details:

I. Chemical Module:

1. Spraying of chlorantraniliprole 18.5 SC 0.3 ml/l at 30 DAS followed by
2. Spraying of emamectin benzoate 5 WG @ 0.4 g/l at 45 DAS followed by
3. Spraying of spinosad 45 SC @0.3 ml/l at 60 DAS followed by
4. Spraying of abamectin 1.9 EC 0.3 ml/l at 75 DAS.

II. Bio-intensive Module:

1. Seed treatment with cow dung slurry and *Trichoderma viride*, soil application of neem cake @ 250 kg/ha at the time of sowing.
2. Spray of Neem oil (300 ppm) @ 5 ml/l at 30 DAS.
3. Installation of yellow sticky traps @ 25/ha
4. Installation of Cu-lure traps @ 12/ha.
5. Spraying of Pongamia oil @ 1% at 45 DAS.
6. Spraying of *Lecanicillium lecanii* @ 5g/l @ 60 DAS.
7. Spraying of NSE @ 5% at 75 DAS.

Table 3.1. Details of pesticides and bio-pesticides against pest management under chemical, bio-intensive and IPM modules of cucumber

Sr.no	Insecticides/biopesticides with their formulations	Trade name	Dose (g or ml/l)	Source
1	Chlorantraniliprole 18.5 SC	Coragen	0.3	M/S. Dow Agro-Sciences India Pvt. Ltd. Mumbai
2	Emamectin benzoate 5 WG	Volvox	0.4	M/S. Indofil Industries Ltd. Pune
3	Spinosad 45 SC	Tracer	0.3	M/S. Dow Agro-sciences India Pvt. Ltd. Mumbai
4	Abamectin 1.9 EC	Temprano	0.3	M/S. Temprano chemptura India Pvt. Ltd. Mumbai
5	<i>Trichoderma viride</i>	Phule Trichoderma		Biocontrol lab, Mahatma Phule Krishi Vidyapeeth, Rahuri
6	Neem oil 300 ppm	Neem Gold	5	M/s. SPIC India Ltd., Chennai
7	Pongamia oil 1%	Karanj tel		M/s. Vijay Agro Industries, Sangamner, Dist.-Ahmednagar
8	<i>Lecanicillium lecanii</i> 1.15 WP	Phule Bugicide	5.0	Biocontrol lab, Mahatma Phule Krishi Vidyapeeth, Rahuri.
9	<i>Metarhizium anisopliae</i>	Phule Metarhiza	5.0	Biocontrol lab, Mahatma Phule Krishi Vidyapeeth, Rahuri
10	NSE @ 5%			Neem seeds collected locally and extract prepared.

3.2.3.1 Experimental details

1	Crop	Cucumber
2	Variety	Gypsi
3	Design	(Randomized Block Design)RBD
4	Replications	05
5	No. of treatments	04
6	Plot size	4 x 3m
7	Spacing	1.5 x 0.5m
8	Type of bed	Broad bed furrows
9	Type of Irrigation	Drip irrigation
10	Manures and Fertilizers	FYM @ 20t/ha N:P:K @ 100:50:50 kg/ha
11	Date of Sowing	25 July 2018
12	Date of Spraying	26 August 2018 10 September 2018 25 September 2018 11 October 2018
13	Date of Pickings	13 September 2018 19 September 2018 24 September 2018 2 October 2018 8 October 2018

III. Integrated Pest Management Module:

1. First spray of *Metarhizium anisopliae* @ 5 g/l of water at 30 DAS.
2. Installation of yellow sticky traps @ 25/ha.
3. Installation of Cu-lure traps @ 12/ha.
4. Spraying of spinosad 45 SC @ 0.3 ml/l at 45 DAS.
5. Spraying of *Lecanicillium lecanii* @ 5g/l @ 60 DAS.
6. Spraying of neem oil (300 ppm) @ 5 ml/l at 75 DAS.

IV. Untreated control.

3.2.4 Method of preparation of insecticide solution

3.2.4.1 Preparation of Neem Seed Extract (NSE 5%)

For preparing 5% NSE solution 500 gram of neem seed were taken and grinded. It was soaked in 1 litre of water for overnight. Next day it was filtered and squeezed by giving 2-3 washings and finally 10 liter of volume was made by adding water. The soap was used as spreading agent at the rate of 1g/L of solution.

3.2.4.2 Calibration and Preparation of spray fluid of insecticides

The quantity of spray fluid required for a plot of 4 x 3m size plot worked out by spraying untreated control plot with water. By using the following formula, the quantity of each insecticide was computed. The measured volume of the insecticide was dissolved in small quantity of water, mixed well using wooden stick and required concentration of spray solution was prepared by adding clean water to it.

$$\text{Quantity of insecticidal formulation required} = \frac{\text{Desired strength}}{\% \text{ of insecticide in formulation}} \times \text{Quantity of water required}$$

3.2.4.3 Method of insecticides sprays applications

Spraying was under taken in the morning hours (7.00- 9.00 a.m.) using manually hand operated knapsack sprayer. Five replications of each treatment were sprayed at a time by avoiding drift of spray solution on neighboring plots. Four sprays in each module were given at fortnightly interval starting from 30 DAS.

3.3 Methods of recording observations

3.3.1 Per cent damaged leaves of cucumber

Observations on per cent damaged leaves were recorded on randomly selected plants in each replication. For this purpose five plants per plot were tagged. The observations were recorded

by counting total number of leaves per plant and number of leaf miner infested leaves. Pretreatment count of *L. trifolii* damage was recorded one day before the insecticides application and subsequent observations for post treatment counts were recorded on 15, 30, 45, 60 and 75 DAS.

The per cent damage of leaves was expressed as below.

$$\text{Per cent damage of leaves} = \frac{\text{No. of leaf miner infested leaves}}{\text{Total number of leaves}} \times 100$$

3.3.2 Sucking pests

Observations on sucking pests such as whitefly, thrips and aphids were recorded on 5 randomly selected plants from each replication. Total number of whitefly, thrips and aphids were recorded from three leaves of each selected plant. The observation were recorded at 15, 30, 45, 60 and 75 DAS.

3.3.3 Fruit infestation

At plucking, the entire marketable size fruits of the crop irrespective of healthy and infested fruits were plucked and infested and healthy fruits were sorted out to calculate the per cent fruit infestation as:

$$\text{Per cent fruit infestation} = \frac{\text{No. of infested fruits}}{\text{Total number of fruits}} \times 100$$

3.3.4 Natural enemies

Adult coccinellid beetles were counted per five plants in each replication at 15, 30, 45, 60 and 75 DAS.

3.3.5 Computation of Incremental cost benefit ratio

The procedure used for working out the Incremental cost benefit ratio (ICBR) of the different treatments are given below.

A) Gross monetary benefit

Gross monetary benefit was calculated by multiplying the additional yield over untreated control with prevailing average local market price of cucumber @ Rs. 20 per kg.

B) Cost of treatments

Cost of various insecticides were taken as per market price and labour charges were calculated at prevailing rate of Rs. 290 per day. The total cost of spraying was calculated on the basis labour requirement per hectare per day. Market price of insecticides and labour charges were summed up to worked out the total cost of application of each treatment. This cost was taken as an additional cost required for treatment against pest.

C) Net monetary return

This was calculated by subtracting the additional cost required for treatment (as worked out under B) from the monetary benefit for each treatment separately (as worked out under A).

D) Incremental Cost benefit ratio

The Incremental cost benefit ratio (ICBR) was calculated by dividing the net monetary return (C) by total additional cost due to treatment (B).

3.3.6 Harvesting

The data on yield of cucumber fruits from each plot was recorded at the time of each picking and then total yield from the plot (kg/plot) was converted to quintals per hectare.

3.3.7 Statistical Analysis

The data on average survival population of pests were translated into square root formation ($\sqrt{x + 0.5}$) as well as data on the per cent infestation caused by the pests was transformed into arcsine formation and then subjected to statistical analysis as suggested by Panse and Sukhatme (1985). The Standard error (S.E) and critical difference (C.D) at 5% level of probability were calculated to determine efficacy of each insecticide. The yield data was subjected to statistical analysis. Finally Incremental Cost Benefit Ratio (ICBR) was worked out for each treatment.

4. RESULTS AND DISCUSSION

Studies on evaluation of different modules against major pest of cucumber (*Cucumis sativus* L.) were conducted at the Research Farm of AICRP on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra state during *kharif* 2018. The results obtained during the course of investigation are presented under the following heads and discussed in the line of earlier findings.

- Population dynamics of sucking pests of cucumber under field conditions.
- Evaluation of different modules against major pests of cucumber.
- Work out incremental cost benefit ratio (ICBR).

As per set objectives of the research studies the data generated from the different modules conducted during *kharif* 2018 is approximately compiled and results based on the same are explained in the chapter.

4.1 Population dynamics of sucking pests of cucumber under field conditions

Observations on seasonal incidence of thrips, whitefly and aphids were recorded on five plants of untreated plot from each replication at an interval of one week. The weekly data on pest incidence for the period of July to October 2018 are presented in Table 4.1 and depicted in figure 4.1. Corresponding weekly data on meteorological parameters *viz.*, temperature ($^{\circ}\text{C}$), relative humidity (%), rainfall (mm) and sunshine period (hr) are presented in Table 4.1 and correlation analysis in Table 4.2. The fluctuation in pest infestation and corresponding weather parameters during cucumber season is shown graphically in Fig 4.1. The pest wise results are explained as follows.

4.1.1 Thrips

The incidence of thrips was observed throughout the season with varying degree of intensity. Maximum number was recorded in 36th meteorological week (11.65 thrips/leaf) in the month of September as against lowest (5.10 thrips/leaf) in 30th meteorological week in the month of July.

The correlation studies revealed that non-significant negative correlation existed between thrips population and maximum temperature ($r = -0.180$) as well as minimum temperature ($r = -0.090$). The incidence of thrips was non-significantly positively correlated with evening RH ($r = 0.090$) and non-significantly negatively correlated with morning RH ($r = -0.045$).

4.1.2 Whitefly

The incidence of whitefly was observed in varying degree throughout the season. The maximum build-up of whitefly was found in 32nd meteorological week in the month of August (12.23 whitefly/leaf) which declined steadily afterwards with minor fluctuation till October.

The correlation studies revealed that a non-significant negative correlation existed between the whitefly incidence and maximum temperature ($r = -0.186$) and non-significant positive correlation with minimum temperature ($r = 0.059$). There existed a positive non-significant correlation between the whitefly incidence and morning and evening RH ($r = 0.031$ and 0.176 , respectively).

4.1.3 Aphid

The incidence of aphids was noticed throughout the season except up to the month of July. Maximum number was recorded in the 32nd (12.37 aphids/leaf) and 36th (12.37 aphid/leaf) meteorological week in the month of August and September, respectively.

The incidence of aphids showed non-significant negative correlation with maximum ($r = -0.01$) and minimum ($r = -0.079$) temperature. Also, it showed a non-significant negative correlation with morning ($r = -0.273$) and evening ($r = -0.063$) RH.

These results are in agreement with the findings of Sunil *et.al.* (2017) who conducted studies on seasonal incidence of sucking insects pests on bitter gourd and reported that the correlation studies between seasonal incidence of aphids and different weather parameters revealed that a weak positive correlation existed between incidence of aphids and maximum temperature ($r = 0.08$). Whereas, negative correlation existed between minimum temperature ($r = -0.49$), maximum RH ($r = -0.005$) and minimum RH ($r = -0.40$). During *kharif*, a non-significant negative correlation existed between the thrips incidence and maximum temperature ($r = -0.22$), minimum temperature ($r = -0.01$), maximum relative humidity ($r = -0.04$), minimum relative humidity ($r = -0.12$) and rainfall ($r = -0.03$). During *kharif*, a non-significant positive correlation existed between incidence of whitefly and maximum temperature ($r = 0.39$), minimum temperature ($r = 0.05$) and rainfall ($r = 0.23$). While, non-significant negative correlation was observed with maximum RH ($r = -0.35$) and minimum RH ($r = -0.12$). The results are also in support with the findings of Potai and Chandrakar (2018) who reported that aphid population was noticed negative non-significant correlation with maximum temperature ($r = -0.16$) and minimum temperature ($r = -0.02$) and significant positive correlation with morning RH ($r = 0.64^*$) and negative non-significant correlation with evening RH ($r = -0.09$). On the other hand positive correlation with rainfall ($r = 0.41$) and negative non-significant correlation with wind velocity ($r = -0.7$), respectively. Whitefly incidence had positive but non-significant correlation with maximum temperature ($r = 0.13$) and positive higher significant correlation with minimum temperature ($r = 0.82^{**}$), on the other hand positive higher significant correlation with rainfall ($r = 0.75^{**}$) and positive significant correlation with morning ($r = 0.67^*$) and evening ($r = 0.59^*$) RH and non-significant negative correlation with wind velocity ($r = -0.03$), respectively.

Table 4.1. Seasonal incidence of thrips, whitefly and aphids on cucumber

Meteorological week	Date of observations	Incidence of pest per leaf of			Weather parameters						
					Temperature (°C)		Relative Humidity (%)		Wind (km/hr)	Sunshine (hrs)	Rainfall (mm)
		Thrips	Whitefly	Aphids	Max.	Min.	Morning	Evening			
30	29/07/2018	5.10	7.54	0.0	32.0	20.9	77	55	7.0	5.2	0.0
31	03/08/2018	6.40	9.00	9.20	31.6	23.9	67	54	7.6	3.4	0.0
32	11/08/2018	10.57	12.23	12.37	30.4	22.4	74	69	7.6	3.4	0.0
33	18/08/2018	10.73	11.98	12.31	26.0	22.4	79	77	0.9	0.0	0.0
34	25/08/2018	10.98	11.39	12.25	29.0	21.5	81	68	4.4	6.6	0.0
35	01/09/2018	11.23	11.30	12.34	30.2	20.9	71	65	4.2	6.2	0.0
36	08/09/2018	11.65	11.24	12.37	29.2	19.4	66	50	4.0	4.9	0.0
37	15/09/2018	11.42	11.58	12.03	31.2	20.3	66	46	0.3	6.1	0.0
38	22/09/2018	11.24	11.79	11.79	32.8	24.9	71	48	5.4	4.3	0.0
39	29/09/2018	11.01	11.58	11.81	34	23.3	66	42	1.8	9.2	0.0

40	6/10/2018	10.65	10.80	11.30	34.0	19.9	61	51	1.1	5.5	0.0
41	13/10/2018	9.86	9.86	10.98	34.0	16.9	44	32	1.3	8.2	0.0

Table 4.2 Correlation of weather parameters with incidence of sucking pests

Sr. No.	Weather Parameters	Correlation Coefficient (r)		
		Thrips	Whitefly	Aphids
1	Maximum temperature (°C)	-0.180	-0.186	-0.010
2	Minimum temperature (°C)	-0.090	0.059	-0.079
3	Morning relative humidity (%)	-0.045	0.031	-0.273
4	Evening relative humidity (%)	0.090	0.176	-0.063
5	Wind (km/hr)	-0.485	-0.393	-0.482
6	Sunshine (hrs)	-0.046	0.205	-0.047
7	Rainfall (mm)	--	--	--

Significant at 5% level=0.575*

4.2 Evaluation of different modules against major pests of cucumber

The pest management modules *viz.*, Chemical (M1), Bio-intensive (M2) and IPM (M3) and untreated check (M4) consisting spraying of different pesticides and bio-pesticides were given at 15 days interval starting from 30 days after sowing. The observations on different pests *viz.*, whitefly, thrips, aphids, leafminer and fruitfly was recorded at 15, 30, 45, 60 and 75 DAS. The means of surviving population of whitefly, aphids and thrips as well as per cent damage leaves and fruits were worked out to determine the effectiveness of each strategy and also overall mean of all these were computed to study the performance of different strategies for their effectiveness against pests of cucumber.

4.2.1 Thrips, (*Thrips palmi* Karny)

The data pertaining to effect of different modules on infestation of thrips on cucumber is presented in Table 4.3 and depicted in fig.4.2.

The thrips population recorded at 15 DAS was lowest in the IPM module with 4.41 thrips/3 leaves/plant followed by 6.1 thrips in Chemical module while in Bio-intensive module the thrips population recorded was 6.43 thrips. Whereas, highest population was recorded in the untreated module with 10.57 thrips/3 leaves/plant.

At 30 DAS, the IPM module recorded lowest infestation of thrips with 4.51 thrips/3 leaves/plant followed by Chemical module which recorded with 5.67 thrips. However, in Bio-

intensive module the population observed was 6.39 thrips and the untreated control recorded highest thrips population (10.98 thrips/3 leaves/plant).

At 45 DAS the same trend was observed. IPM module showed lowest population of thrips with 4.36 thrips/3 leaves/plant followed by Chemical module with 4.72 thrips. Thrips population recorded in the Bio-intensive module was 6.26 thrips. While the untreated control has the highest population of thrips (11.65 thrips/3 leaves/plant).

Table 4.3 Effect of different modules on thrips (*Thrips palmi* Karny) population

Module	Number of thrips/3 leaves/plant on					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean
M1	6.1 (2.57)	5.67 (2.48)	4.72 (2.28)	4.59 (2.26)	4.45 (2.22)	5.11 (2.36)
M2	6.43 (2.63)	6.39 (2.62)	6.26 (2.60)	5.45 (2.44)	5.45 (2.44)	6.00 (2.55)
M3	4.41 (2.22)	4.51 (2.24)	4.36 (2.20)	4.46 (2.23)	3.81 (2.08)	4.31 (2.19)
M4	10.57 (3.33)	10.98 (3.39)	11.65 (3.49)	11.24 (3.43)	10.98 (3.39)	11.08 (3.40)
SE(±)	0.05	0.06	0.06	0.06	0.06	0.30
CD	0.17	0.18	0.18	0.20	0.20	0.09

*Average of five observations taken at 15, 30, 45, 60 and 75 DAS.

(Figures in the parathenses indicates $\sqrt{x + 0.5}$ values)

M1 =Chemical Module

M3 = Integrated Pest Management Module

M2= Bio-intensive module

M4= Untreated module

At 60 and 75 DAS observed least population of thrips in the IPM module and it was in the range (3.81- 4.46 thrips/3 leaves/plant). However, the chemical module was found at par with IPM module and recorded the thrips population in the range (4.45-4.59 thrips). Whereas, untreated control observed maximum population of thrips and it was in the range (10.98- 11.24 thrips/3 leaves/plant).

The overall results states that IPM module (4.31 thrips/3 leaves/plant) was effective in controlling the thrips on cucumber followed by Chemical module (5.11 thrips) as against 11.08 thrips/3 leaves/plant in untreated control.

The present investigation is in agreement with the results of Rajkumar *et al.* (2002) who reported that Nimbecidine (*Azadirachta indica*) significantly reduced the damage caused by thrips. The present results are also in support with the findings of Annamalai *et al.* (2014) who reported that *B. bassiana* and *L. lecanii* significantly decrease the *T. tabaci* infestations in onion crop under the greenhouse as well as field conditions.

4.2.2 Whitefly, (*Bemisia tabaci* Gennadius)

The data pertaining to effect of different modules on incidence of whitefly on cucumber is presented in Table 4.4 and depicted in fig 4.3.

Table 4.4 Effect of different modules on whitefly (*B. tabaci* Gennadius) population

Module	Number of whitefly/3 leaves/plant on					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean
M1	4.82 (2.32)	4.97 (2.33)	5.27 (2.40)	4.65 (2.27)	4.64 (2.26)	4.86 (2.32)
M2	6.25 (2.60)	5.95 (2.54)	5.78 (2.51)	5.60 (2.47)	5.37 (2.42)	5.37 (2.51)
M3	4.43 (2.22)	4.23 (2.17)	4.49 (2.23)	3.87 (2.09)	3.80 (2.07)	3.80 (2.16)
M4	12.23 (3.57)	11.39 (3.46)	12.24 (3.51)	11.79 (3.51)	11.75 (3.50)	11.75 (3.52)
SE(±)	0.04	0.05	0.06	0.06	0.07	0.06
CD	0.15	0.18	0.21	0.21	0.22	0.20

*Average of five observations taken at 15, 30, 45, 60 and 75 DAS.

(Figures in the parathenses indicates $\sqrt{x + 0.5}$ values)

M1 =Chemical Module

M3 = Integrated Pest Management Module

M2= Bio-intensive module

M4= Untreated module

At 15 DAS the incidence of whitefly recorded was lowest in the IPM module (4.43 whitefly/3 leaves/plant) followed by (4.82 whitefly) in Chemical module. Both IPM and Chemical module were found at par with each other. In Bio-intensive pest management module population of whiteflies recorded (6.25 whitefly). Whereas, the highest incidence was recorded in the untreated module (12.23 whitefly/3 leaves/plant).

At 30 DAS, IPM module showed lowest population of whitefly (4.23 whitefly) and was found at par with Chemical module which recorded (4.97 whitefly) In Bio-intensive pest management module the population was (5.95 whitefly). Whereas, the untreated control recorded population of whitefly (11.39 whitefly/3 leaves/plant).

At 45 DAS, IPM module showed the lowest infestation of whitefly with 4.49 whitefly followed by Chemical module with 5.27 whitefly. Whitefly population recorded in the Bio-intensive module was 5.78 whitefly while the treatment untreated control was highly infested by whitefly (12.24 whitefly/ 3 leaves/plant).

At 60 and 75 DAS, the whitefly population was in the range (3.80- 3.87 whitefly/3 leaves/plant) in IPM module. Whereas, the chemical module was found at par with IPM module and observed the whitefly population in the range (4.64- 4.65 whitefly). The Bio-intensive module also observed 5.60 and 5.37 whitefly at 60 and 75 DAS, respectively. In untreated control the population of whitefly population remain more or less similar at 60 and 75 DAS.

The overall results indicates that IPM module (3.80 whitefly/3 leaves/plant) was effective in controlling the whitefly infestation on cucumber and was found at par with Chemical module (4.86 whitefly). The least intensity of whitefly was observed in Bio-intensive module (5.37 whitefly).

The present investigation is in agreement with findings of Dimetry *et al.* (1996) who revealed that the bioactivity of different formulations of neem seed extracts against *Bemisia tabaci* reduced the population density of the adults compared with the (untreated) control. The present investigation is also in support of results of Moreau and Isman (2011) who reported that yellow sticky traps were effective at trapping adult whiteflies and significantly reduced adult populations on the main crops (peppers) compared with the control.

4.2.3 Aphids, (*Aphis gossypii* Glover)

The data pertaining to effect of different modules on population of aphids on cucumber is presented in Table 4.5 and depicted in fig 4.4.

The aphid intensity was recorded at 15 DAS and the IPM module noticed the lowest 4.02 aphids/3 leaves/plant followed by 4.59 aphids in Chemical module. Both IPM and Chemical module are at par with each other. In Bio-intensive module recorded population was 6.04 aphids. Whereas highest population was recorded in the untreated module with 12.20 aphids/3 leaves/plant.

At 30 and 45 DAS, the IPM module recorded lowest population of aphids and it was in the range (3.59-3.70 aphids/3 leaves/plant). Whereas, the chemical module was found at par with IPM module and observed aphid population in the range (4.27-4.34 aphids) as against (12.25-12.37 aphids/3 leaves/plant) in untreated control.

At 60 DAS, the lowest aphid population was recorded in IPM module with 4.04 aphids/3 leaves/plant which found at par with Chemical module and observed 4.52 aphids/leaf. Bio-intensive module recorded 5.86 aphids. Whereas, untreated control recorded highest population of aphids 12.45 aphids/3 leaves/plant.

At 75 DAS, IPM module observed lowest aphids population (4.15 aphids) followed by 4.42 aphids in chemical module followed by 5.58 aphids in Bio-intensive module. IPM and Chemical module found at par with each other.

The overall results indicates that IPM module (3.90 aphids/3 leaves/plant) was effective in controlling the aphids on cucumber and was found at par with Chemical module (4.43 aphids).

Table 4.5 Effect of different modules on number of aphids (*Aphis gossypii* Glover) population

Module	Number of aphids/3 leaves/plant on					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean
M1	4.59 (2.25)	4.34 (2.19)	4.27 (2.18)	4.52 (2.24)	4.42 (2.21)	4.43 (2.22)
M2	6.04 (2.55)	5.53 (2.45)	5.79 (2.51)	5.86 (2.52)	5.58 (2.47)	5.76 (2.50)
M3	4.02 (2.12)	3.70 (2.04)	3.59 (2.02)	4.04 (2.13)	4.15 (2.15)	3.90 (2.10)
M4	12.20 (3.56)	12.25 (3.57)	12.37 (3.59)	12.45 (3.60)	12.78 (3.64)	12.41 (3.59)
SE(±)	0.05	0.06	0.07	0.06	0.06	0.05
CD	0.17	0.20	0.22	0.18	0.18	0.17

*Average of five observations taken at 15, 30, 45, 60 and 75 DAS.

(Figures in the parathenses indicates $\sqrt{x + 0.5}$ values)

M1 =Chemical Module

M3 = Integrated Pest Management Module

M2= Bio-intensive module

M4= Untreated module

The present investigation is in agreement with the findings of Ghosh (2017) who reported that among the bio-pesticides combination of neem and *Spilanthes* gave higher control (77.58%) very closely followed by neem (71.63%) over control and recommended use of biopesticides in IPM programme against aphids on tomato plants. The findings of Bade *et al.* (2017) who reported that insecticidal treatments with *Lecanicillium lecanii* @ 2.5 kg/ha was found most effective treatment against aphids after four sprays also support the present investigation.

4.2.4 Leaf miner, (*Liriomyza trifolii* Burgess)

The data pertaining to effect of different modules on population of leaf miner on cucumber is presented in Table 4.6 and depicted in fig 4.5.

At 15 DAS, the IPM module recorded least per cent (24.06 %) damaged leaves followed by 27.5 per cent damaged leaves in Chemical module. Both IPM and Chemical module were found at par with each other. Bio-intensive module observed 33.90 per cent damaged leaves. Whereas, highest per cent damaged leaves was recorded in the untreated module with 47.08 per cent.

At 30 DAS, IPM module recorded lowest per cent damaged leaves with 23.94 per cent and was found at par with Chemical module which recorded 25.31 per cent damaged leaves. In Bio-intensive module the per cent damage leaves recorded 33.01 per cent and the untreated control recorded highest 46.14 per cent damaged leaves.

The IPM module showed lowest per cent damaged leaves (23.68 %) followed by Chemical module with 27.20 per cent damaged leaves at 45 DAS. The Bio-intensive module observed 29.68 per cent damaged leaves. While, the untreated control has the highest 45.98 per cent damaged leaves.

The IPM and Chemical module were found at par with each other in respect of per cent damage of leaves at 60 and 75 DAS and these modules observed per cent damage leaves in the range (21.15-24.21 %) and (23.33- 26.37 %), respectively.

The overall results seems that IPM module (21.15 % damaged leaves) was effective in controlling the leaf miner on cucumber and found at par with Chemical module (25.94 % damaged leaves).

The present results are in agreement with the findings of Schuster and Taylor (1987) who observed that single application of abamectin @ 4.54 g a.i./378.5 liters of water, control the *Liriomyza trifolii* on tomato in the field and concluded that single application of abamectin at a suitable dose controlled *Liriomyza trifolii* on tomato in the field for at least a week.

Table 4.6 Effect of different modules on incidence of leaf miner (*Liriomyza trifolii* Burgess)

Module	Incidence of leaf miner (Per cent damaged leaves) on					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean
M1	27.5 (31.63)	25.31 (30.20)	27.2 (31.44)	26.37 (30.90)	23.33 (28.88)	25.94 (30.61)
M2	33.9 (35.61)	33.01 (35.07)	29.68 (33.01)	28.76 (32.41)	28.03 (31.97)	30.68 (33.62)
M3	24.06 (29.37)	23.94 (29.29)	23.68 (29.12)	24.21 (29.47)	21.15 (27.38)	21.15 (28.93)
M4	47.08 (43.33)	46.14 (42.79)	45.98 (42.69)	43.71 (41.30)	42.14 (40.48)	42.14 (42.13)
SE(±)	0.67	0.78	0.88	0.88	0.83	0.35
CD	2.07	2.41	2.73	2.73	2.64	1.53

*Average of five observations taken at 15, 30, 45, 60 and 75 DAS.

(Figures in the parathenses indicates arcsine transformed values)

M1 =Chemical Module

M3 = Integrated Pest Management Module

M2= Bio-intensive module

M4= Untreated module

The present investigation are also in agreement with findings of Apte (2001) who reported that average efficacy of 66.95, 51.95 and 48.04% on azadirachtin, fipronil and quinalphos against *Liriomyza trifolii* on gerbera respectively as well as Gahbiche (2001) who tested the toxicity of spinosad against *L. trifolii* and reported that it gave 100 per cent mortality of first instar larvae and 89.3 per cent mortality of third instar larvae.

4.2.5 Fruit fly (*Bactrocera cucurbitae* Coq.)

The data pertaining to effect of different modules on population of fruit fly on cucumber is presented in Table 4.7 and depicted in fig 4.6.

The cucumber fruits were harvested in five pickings and the harvested fruits were categorized as infested fruits and healthy fruits. Average fruits damaged by fruit fly were recorded.

At the time of first picking the per cent damage of fruits was low in IPM module (11.20% damaged fruits) followed by 19.60% damaged fruits in Chemical module. In Bio-intensive module

the per cent damaged fruits observed 35.80%. Whereas highest per cent damaged fruits was recorded in the untreated module with 51.60%.

At second picking, IPM module also recorded lowest per cent damaged fruits (10.60%) followed by Chemical module which recorded 19.20% damaged fruits. In Bio-intensive module the per cent damage fruits observed 35.80% as against 51.40% damaged fruits in untreated control.

At third harvesting, IPM module showed lowest per cent damaged fruits of 10.80% followed by Chemical module with 18.20% damaged fruits. Per cent damaged fruits recorded in the Bio-intensive module was 33.80% while the untreated control has the highest 48.80% damaged fruits.

At fourth and fifth picking, the IPM module observed least per cent damage of fruits and it was in the range (10.00-10.84%) followed by Chemical module which also observed the damage of fruits in the range (16.40-17.20%). Whereas, in the Bio-intensive module the per cent damage fruits was observed high as compare to IPM and Chemical module and it was in the range (33.00 -35.80%).

Table 4.7 Effect of different modules on incidence of Fruit fly (*Bactrocera cucurbitae* Coq.)

Module	Per cent fruits damaged by fruit fly on picking					
	I	II	III	IV	V	Mean
M1	19.60 (26.28)	19.20 (25.99)	18.20 (25.25)	17.20 (24.50)	16.40 (23.89)	18.12 (25.18)
M2	35.80 (36.75)	35.80 (35.73)	33.80 (35.55)	33.00 (35.06)	35.80 (36.75)	34.84 (36.17)
M3	11.20 (19.55)	10.60 (19.00)	10.80 (19.19)	11.60 (19.91)	10.00 (18.43)	10.84 (19.22)
M4	51.60 (45.92)	51.40 (45.80)	48.80 (44.31)	48.80 (43.74)	48.00 (43.85)	43.85 (44.72)
SE(±)	1.03	1.04	1.03	1.07	1.11	0.31
CD	3.19	3.21	3.18	3.30	3.44	0.95

*Average per cent infestation taken at five harvesting.

(Figures in the parathenses indicates arcsine transformed values)

M1 =Chemical Module

M3 = Integrated Pest Management Module

M2= Bio-intensive module

M4= Untreated module

The overall results indicates that IPM module (10.84 % damaged fruits) was effective in controlling the fruit fly on cucumber followed by Chemical module (18.12 % damaged fruits). In Bio-intensive module least control of fruit fly was observed (34.84% damaged fruits).

The present investigation are in support with Ranganath *et al.* (1997) who tested a number of botanicals and chemical insecticides against *B. cucurbitae* on cucumber and ridge gourd in Southern Andaman, India and reported that neem oil (1.20%) was the most effective in reducing the damage in cucumber and recorded 6.20 per cent infestation over 39.00 per cent in the control.

The present results also support findings of Vargas *et al.* (2009) who evaluated various traps with methyl eugenol and cu-lure for capturing fruit flies and observed that *B. dorsalis* was captured in methyl eugenol traps and *B. cucurbitae* in cu-lure traps. The present investigation is also in agreement with the findings of Sharma and Sinha (2009) who reported that for the control of *B. cucurbitae* most effective insecticide was emamectin benzoate (15 g a.i./ha) followed by neem ban (1 ml/liter of water).

4.2.6 Effect of different modules on natural enemies

The data pertaining to effect of different modules on population of natural enemies on cucumber is presented in Table 4.8 and depicted in fig 4.7. The number of coccinellid grubs/plant were recorded in all modules on randomly selected five plants during the investigation.

In the Bio-intensive module, 15 DAS the coccinellids population observed 3.70 grubs/plant. Whereas, IPM module also found at par with this module and observed 3.36 grubs/plant. The maximum population of grubs observed in untreated control. The lowest population of grubs observed in Chemical control.

At 30 DAS, Bio-intensive observed population of coccinellids (3.61 grubs/plant) and was found at par with IPM module which recorded with (3.24 grubs/plant). In Chemical module the population recorded was 1.45 grubs/plant.

The Bio-intensive module showed highest population of coccinellids with 3.60 grubs/plant followed by IPM module with 3.19 grubs/plant at 45 DAS. Lowest coccinellids population was observed in Chemical module which recorded 1.11 grubs/plant.

At 60 and 75 DAS, the Bio-intensive module observed significantly good number of coccinellid population and it was in the range (3.85- 4.51 grubs/plant). However, the IPM module also found at par with this module and recorded the grub population in the range (3.26- 3.75 grubs/plant). In Chemical control least number of coccinellid grubs were observed. Whereas, untreated control observed maximum number of grubs and it was in the range (5.33-5.65 grubs/plant).

Table 4.8 Effect of different modules on coccinellids per plant

Module	Number of coccinellids (grubs/plant)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean
M1	2.19 (1.64)	1.45 (1.40)	1.11 (1.27)	1.30 (1.34)	0.81 (1.14)	1.37 (1.36)
M2	3.70 (2.05)	3.61 (2.03)	3.60 (2.02)	3.85 (2.09)	4.51 (2.24)	3.85 (2.09)
M3	3.36 (1.96)	3.24 (1.93)	3.19 (1.92)	3.26 (1.93)	3.76 (2.09)	3.36 (1.98)
M4	4.27 (2.18)	4.40 (2.21)	4.93 (2.33)	5.33 (2.41)	5.65 (2.48)	4.92 (2.32)
SE(±)	0.06	0.05	0.05	0.06	0.05	0.05
CD	0.18	0.15	0.17	0.20	0.18	0.15

*Average of five observations taken at 15, 30, 45, 60 and 75 DAS.

(Figures in the parathenses indicates $\sqrt{x + 0.5}$ values)

M1 =Chemical Module

M3 = Integrated Pest Management Module

M2= Bio-intensive module

M4= Untreated module

The overall results indicates that Bio-intensive module (3.85 grubs/plant) was most favourable and safest module for coccinellids on cucumber and was found at par with IPM module (3.36 grubs/plant). The chemical module that was found most toxic to natural enemies and recorded least coccinellids population (1.37 grubs/plant).

The present investigation are in agreement with the findings of Hoelmer *et al.* (1990) who observed that the commercial neem insecticide was not toxic to adult coccinellid predators. The results of present investigation support findings of Kaspi and Parrella (2005) who reported that abamectin residues on plants negatively affect the natural enemies. The findings of Bade *et al.* (2017) who reported that the use of *L. lecanii* @ 2.5 kg/ha recorded highest population of 4.49 lady bird beetles/plant and it was superior over all the treatments for control of aphid except, untreated control also support the present investigation.

4.2.7 Effect of different modules on yield of cucumber

The data pertaining to effect of different modules on yield of cucumber is presented in Table 4.9 and depicted in fig 4.8.

Amongst the modules, the IPM module obtained maximum (230.00 q/ha) yield of marketable fruits of cucumber as against (160.00 q/ha) in untreated control. Whereas, the Chemical module which was found at par with IPM module and recorded (225.00 q/ha) yield of cucumber fruits. The Bio-intensive module observed less yield (200.00 q/ha) as compared to IPM module and Chemical control.

Table 4.9 Effect of different modules on yield of cucumber

Module	Yield of cucumber fruits (kg)						q/ha
	R I	R II	R III	R IV	R V	Mean (Kg/plot)	
M1	25.00	28.00	29.00	27.00	26.00	27.00	225.00
M2	24.00	26.00	25.00	23.00	22.00	24.00	200.00
M3	28.00	27.00	29.00	26.00	28.00	27.60	230.00
M4	20.00	21.00	18.00	17.00	20.00	19.20	160.00
					SE(±)	0.61	5.08
					CD	1.88	15.66

*Average taken at five harvesting.

M1 =Chemical Module

M3 = Integrated Pest Management Module

M2= Bio-intensive module

M4= Untreated module

4.3 Economics of different modules for the control of pests of cucumber

An additional yield, additional returns, net returns and incremental cost benefit ratio (ICBR) of different modules were calculated and presented in Table 4.10

The data on additional returns over control Table 4.10 shows that maximum additional income of Rs. 1,40,000.00 and net returns Rs. 1,30, 580.00 per hectare was gained from the IPM module. The next best module was chemical module with an additional income of Rs. 1,30,000.00 and net returns of Rs.1,18,870.00, respectively.

The highest incremental cost benefit ratio (ICBR 1:13.86) was recorded in the IPM module. Whereas, the next module in order of ICBR is Chemical module which observed (1:10.66) ICBR. The Bio-intensive module (1:5.96) recorded comparatively less ICBR (1:6.12) as this module is more costly to that of others.

Considerable yield advantages due to effective control of pests of cucumber particularly through the use of IPM was observed in the present investigation is in agreement with Gundannavar (2007) and Pandey and Satpathy (2009), Mondal and Mondal (2012) and Tripathy *et al.* (2013). These workers reported IPM to be effective in controlling pests in various crops with highest yield. Thus, the observations of earlier workers in respect of these strategies influencing yield of crops could support the findings of present investigation.

Table 4.10 Effect of modules on yield of Cucumber and Incremental Cost Benefit Ratio (ICBR)

Sr. No.	Modules	Yield (qt/ha)	Additional yield over control (qt/ha)	Additional returns over control (Rs) (A)	Additional cost of insecticide and spraying (Rs) (B)	Net returns per ha (Rs) (C)	ICBR (C/B)
1	Chemical Module	225.00	65.00	1,30,000	11,150	1,18,850	1:10.66
2	Bio-intensive module	200.00	40.00	80,000	11,235	68,765	1:6.12
3	Integrated pest management module	230.00	70.00	1,40,000	9420	1,30,580	1:13.86
4	Untreated module	160.00	-	-			

Price of cucumber = Rs.2000/q

Table 4.11 Cost of insecticides and sprayings

Sr.no	Module	Chemical	Quantity required for 1 spray	Rate (kg or L)	Cost (Rs/ha)	Application Charges (Rs/ha)	Total cost of (insecticide and spraying)
1	Chemical	Chlorantroniliprole 18.5 SC	150 ml	26666	4000	2900	11150
		Emamectin benzoate 5 WG	200 g	3200	640		
		Spinosad 45 SC	150 ml	17066	2560		
		Abamectin 1.9 EC	150 ml	7000	1050		
2	Bio-intensive	Cow dung+ <i>Trichoderma viride</i>	--	--	--	2900	11235
		Neem cake	250 Kg	10	2500		
		Neem oil 300 ppm	2.5 L	400	1000		
		Yellow sticky traps	25 (Nos.)	50 Rs/trap	1250		
		Cu-lure traps	12 (Nos.)	80 Rs/trap	960		
		Pongamia oil 1%	5 L	400	2000		
		<i>L. lecanii</i>	2.5 Kg	150	375		
		NSE 5%	25 Kg crude neem seed	10	250		

3	IPM	<i>M. anisopliae</i>	2500	150	375	2900	9420
		Yellow sticky traps	25 (Nos.)	50 Rs/trap	1250		
		Cu-lure traps	12 (Nos.)	80 Rs/trap	960		
		Spinosad 45 SC	150 ml	17066	2560		
		<i>L. lecanii</i>	2.5 Kg	150	375		
		Neem oil 300 ppm	2.5 L	400	1000		

5. SUMMARY AND CONCLUSION

Cucumber (*Cucumis sativus* L.) is one of the most popular vegetables in the world. The crop, however, is attacked by a number of pests, amongst whitefly (*Bemesia tabaci* Gennadius), thrips (*Thrips palmi* Karny), aphids (*Aphis gossypii* Glover), leaf miner (*Liriomyza trifolii* Burgess) and fruit fly (*Bactrocera cucurbitae* Coq.) are most important. In the Maharashtra state, these pests has posed a serious threat to the cucumber cultivation and the attack of these pests is the major bottleneck in achieving higher yield.

The present investigation were undertaken for “Evaluation of different modules against major pests of cucumber (*Cucumis sativus* L.) at the research farm of AICRP on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri during *kharif* 2018. The findings of the present investigation are summarized in this chapter.

5.1 Summary

The pest management modules *viz.*, Chemical control, Bio-intensive, IPM were tested against the major pests of cucumber under field conditions and compared with untreated control. The untreated control was chosen as the seasonal incidence plot and observations were recorded weekly on a particular day. The treatment application with spraying of pesticides and bio-pesticides were given at 15 days interval starting from 30 days after sowing. Observations were taken at 15 days interval.

5.1.1 Seasonal incidence of sucking pests of cucumber

Incidence of thrips, whitefly and aphids were studied from July to October during throughout the cucumber season. Observations were recorded weekly on five plants from each replication on a particular day.

The incidence of thrips was observed throughout the season with varying degree of intensity. Maximum number was recorded in 36th meteorological week (11.65 thrips/leaf) in the month of September as against lowest (5.10 thrips/leaf) in 30th meteorological week in the month of July.

The correlation studies revealed that non-significant negative correlation existed between thrips population and maximum temperature ($r = -0.180$) as well as minimum temperature ($r = -0.090$). The incidence of thrips was non-significantly positively correlated with evening RH ($r = 0.090$) and non-significantly negatively correlated with morning RH ($r = -0.045$).

The incidence of whitefly was observed in varying degree throughout the season. The maximum build-up of whitefly was found in 32nd meteorological week in the month of August (12.23 whitefly/leaf) which declined steadily afterwards with minor fluctuation till October.

The correlation studies revealed that a non-significant negative correlation existed between the whitefly incidence and maximum temperature ($r = -0.186$) and non-significant positive correlation with minimum temperature ($r = 0.059$). There existed a positive non-significant correlation between the whitefly incidence and morning and evening RH ($r = 0.031$ and 0.176 , respectively).

The incidence of aphids was noticed throughout the season except, up to the month of July. Maximum number was recorded in the 32nd (12.37 aphids/leaf) and 36th (12.37 aphid/leaf) meteorological week in the month of August and September, respectively.

The incidence of aphids showed non-significant negative correlation with maximum ($r = -0.01$) and minimum ($r = -0.079$) temperature. Also, it showed a non-significant negative correlation with morning ($r = -0.273$) and evening ($r = -0.063$) RH.

5.1.2 Evaluation of pest management modules against major pests of cucumber

5.1.2.1 Whitefly (*Bemisia tabaci* Gennadius)

All the pest management modules were found significantly superior over untreated control in reducing the whitefly population. The observations were recorded at 15 days interval at 15, 30, 45, 60 and 75 DAS in each module comprising different treatments taken in between these days. Among all the three strategies tested, IPM module was found significantly better for controlling whitefly over other modules and registered 3.80 whitefly/3 leaves/plant and found to be at par with chemical module which recorded 4.86 whitefly. The Bio-intensive module recorded 5.37 whitefly. Therefore the best module for controlling whitefly was IPM module followed by Chemical control.

5.1.2.2 Thrips, (*Thrips palmi* Karny)

All the modules were found significantly superior over untreated control in reducing thrips population. The results indicated that IPM module was found significantly superior over all other modules in reducing thrips (4.31 thrips/3 leaves/plant) population. The next best module was Chemical module which recorded 5.11 thrips. The least control of thrips was found in Bio-intensive module in which observed 6.00 thrips/. Thus for control of thrips in cucumber, IPM module was effective treatment followed by Chemical module and Bio-intensive module was the least effective module against thrips on cucumber.

5.1.2.3 Aphids, (*Aphis gossypii* Glover)

For the control of aphids on cucumber all the modules showed significant result over the untreated control. The results stated that among all the three management modules IPM module was found significantly superior for reducing aphid population with minimum survived population observed (3.90 aphids/3 leaves/plant) and it was found at par with the chemical module with surviving population 4.43 aphids. It is therefore the best module for control of aphids on cucumber was IPM module followed by Chemical.

5.1.2.4 Leaf miner, (*Liriomyza trifolii* Burgess)

All the pest management modules were found significantly superior over untreated control in reducing the leaf miner infestation. Among all the three strategies tested so far, IPM module was found significantly better for controlling leaf miner infestation over other modules and observed average (21.15%) damaged leaves and found to be at par with Chemical module which recorded 25.94 per cent damaged leaves. Accordingly the best module for controlling leaf miner infestation was IPM module followed by Chemical control.

5.1.2.5 Fruit fly, (*Bactrocera cucurbitae* Coq.)

All the pest management modules were found significantly superior over untreated control in reducing the fruit fly infestation. The observations were recorded at each picking in each module comprising different treatments. Total of five pickings were done. Among all the three strategies tested, IPM module was found significantly better for reducing fruit fly infestation over other modules and registered 10.84% damaged fruits. The next best module after IPM was Chemical module in which 18.12% damaged fruits were recorded. In Bio-intensive module 34.84% damaged fruits were recorded. Hence the best module for reducing fruit fly infestation was IPM module followed by Chemical control.

5.1.2.6 Effect of different pest management modules on natural enemies on cucumber

It is seen from the data that maximum number of grubs of coccinellids (4.92 grubs/plant) were recorded in untreated control plot of cucumber. The Bio-intensive module recorded higher grub population of 3.85 grubs/plant than the remaining modules and it was followed by IPM module with 3.36 grubs/plant indicating their less toxic effects on to the coccinellids after the sprays taken in these respective modules. Whereas the chemical control recorded least population of grubs 1.37 grubs/plant at different intervals of observations at each of the four sprays taken in Chemical module which exhibited its toxic effects on the grubs. Therefore it can be concluded that the least toxic module for coccinellids is Bio-intensive followed by IPM. Whereas, the most toxic effects were shown by Chemical module.

5.1.2.7 Effect of different pest management modules on yield of cucumber

The observations on yield were recorded at each picking in each module comprising different treatments. Total of five pickings were done. Among all the three modules tested, IPM module showed higher yield of cucumber fruits over other modules and registered 230.00 q/ha marketable fruit yield of cucumber. The Chemical module was found at par with IPM module in which 225.00 q/ha fruit yield was observed. In Bio-intensive module 200.00 q/ha cucumber fruit yield was recorded. Therefore, the module with higher yield was IPM module followed by Chemical control.

5.1.2.8 Economics of different modules for control of major pests of cucumber

The yield of cucumber fruits was recorded from each treatment plot which was then converted into quintals per ha. The highest yield of cucumber was obtained from the IPM treated module (230.00 q/ha) with 1: 13.86 ICBR. However, it was at par with Chemical control (225.00 q/ha) with ICBR 1:10.66. The lowest yield was noticed in Bio-intensive module (200.00 q/ha) with ICBR 1:6.12, respectively. Thus, IPM module was effective in controlling major pests of cucumber as well as gaining higher ICBR ratio.

5.2 Conclusion:

Following conclusions can be drawn from the present investigation.

5.2.1 Seasonal incidence of sucking pests of cucumber

1. The incidence of sucking pests of cucumber was not significantly correlated with weather parameters.
2. The incidence of thrips, whitefly and aphids was observed throughout the season with varying degree of intensity. Maximum number of thrips was recorded in 36th meteorological week (11.65 thrips/leaf) in the month of September. Whereas, the maximum build-up of whitefly was found in 32nd meteorological week in the month of August (12.23 whitefly/leaf).
3. Maximum number of aphids was recorded in the 32nd (12.37 aphids/leaf) and 36th (12.37 aphid/leaf) meteorological week in the month of August and September respectively.

5.2.2 Evaluation of different modules against major pests of cucumber

1. Among the four management modules for controlling pests of cucumber, the Integrated Pest Management module was found to be most effective for the suppression of whitefly, thrips, aphids leaf miner and fruit fly on cucumber.
2. The Bio-intensive pest management strategy was observed to be less toxic to predatory coccinellids, while Chemical control showed toxic effects on the coccinellids on cucumber.
3. Among the different pest management strategies, IPM was found effective for the control of whitefly, thrips, aphids, leaf miner and fruit fly with good marketable yield of cucumber i.e (230 qt/ha) with 1:13.86 ICBR.

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APPENDIX

MW	Date of observations	Weather parameters						
		Temperature °C		Relative Humidity (%)		Wind (km/hr)	Sunshine (hrs)	Rainfall (mm)
		Max.	Min.	Mor	Eve			
30	29/07/2018	32.0	20.9	77	55	7.0	5.2	0.0
31	03/08/2018	31.6	23.9	67	54	7.6	3.4	0.0
32	11/08/2018	30.4	22.4	74	69	7.6	3.4	0.0
33	18/08/2018	26.0	22.4	79	77	0.9	0.0	0.0
34	25/08/2018	29.0	21.5	81	68	4.4	6.6	0.0
35	01/09/2018	30.2	20.9	71	65	4.2	6.2	0.0
36	08/09/2018	29.2	19.4	66	50	4.0	4.9	0.0
37	15/09/2018	31.2	20.3	66	46	0.3	6.1	0.0
38	22/09/2018	32.8	24.9	71	48	5.4	4.3	0.0
39	29/09/2018	34	23.3	66	42	1.8	9.2	0.0
40	6/10/2018	34.0	19.9	61	51	1.1	5.5	0.0
41	13/10/2018	34.0	16.9	44	32	1.3	8.2	0.0

8. VITAE

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MASTER OF SCIENCE (AGRICULTURE)
in
AGRICULTURAL ENTOMOLOGY
2019

Title of thesis		:	“Evaluation of different modules against major pests of cucumber (<i>Cucumis sativus</i> L.)”
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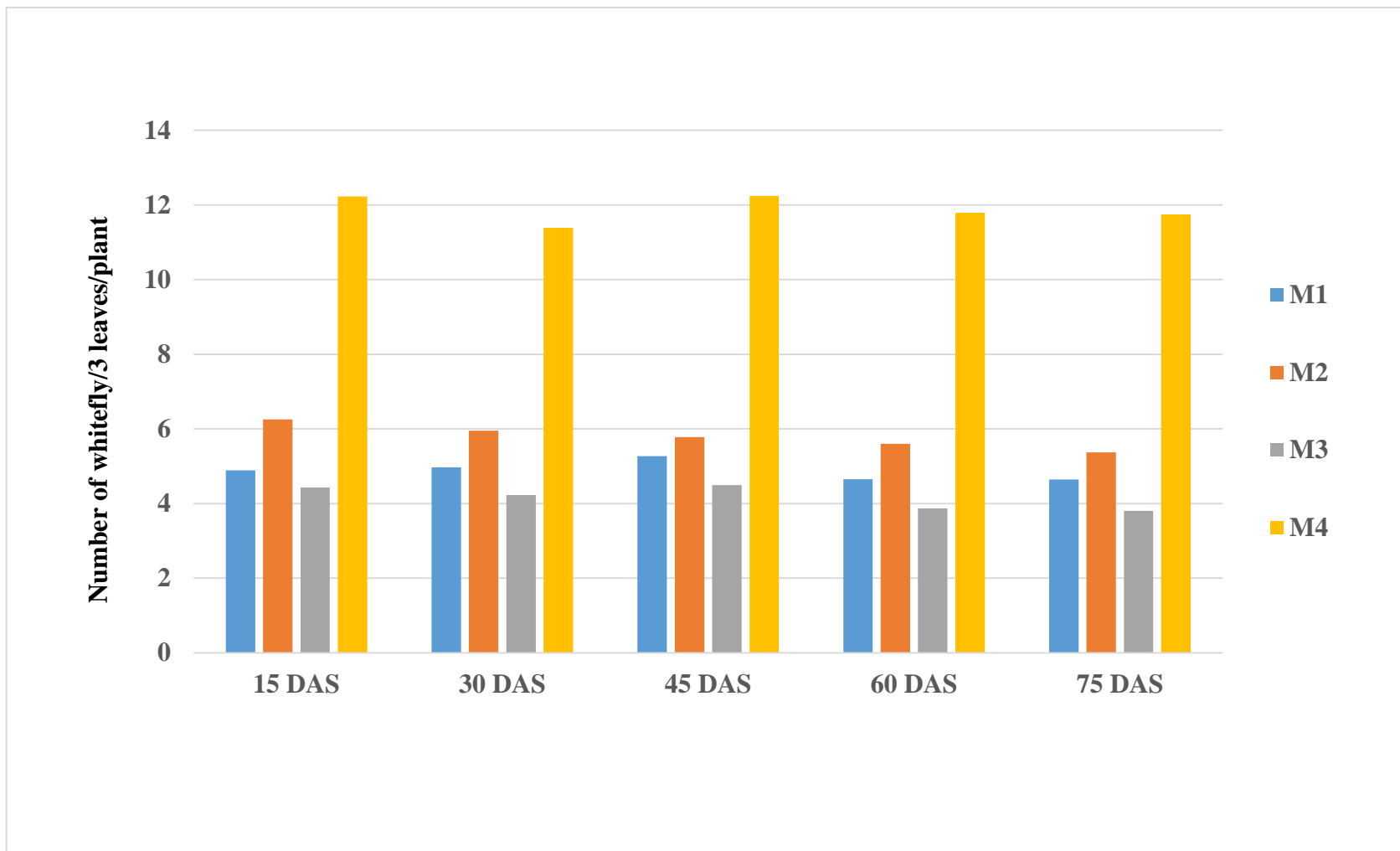


Fig 4.3 Effect of different modules on whitefly (*Bemesia tabaci* Gennadius.) population

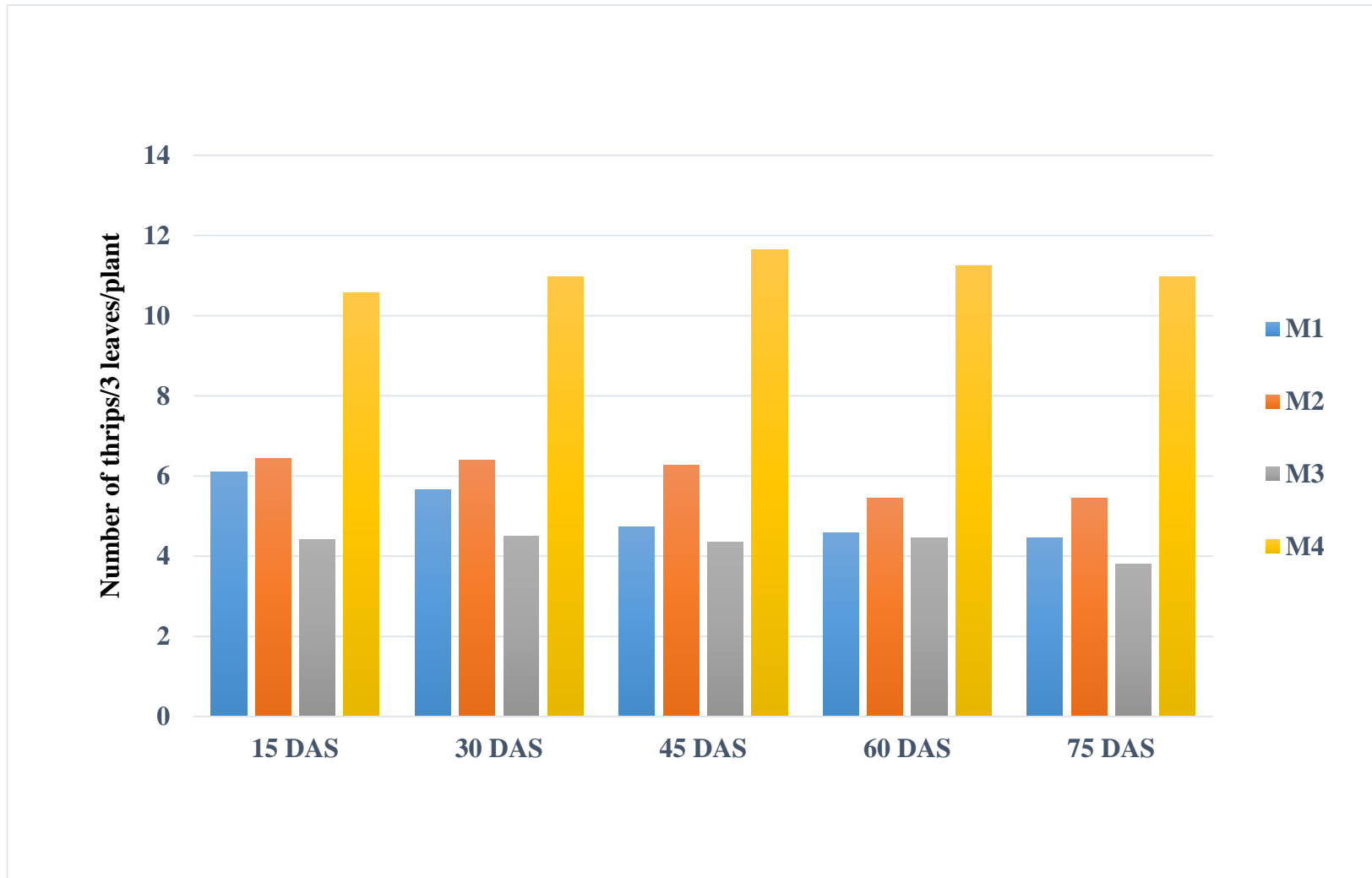


Fig. 4.2 Effect of different modules on thrips (*Thrips palmi* Karny.) population

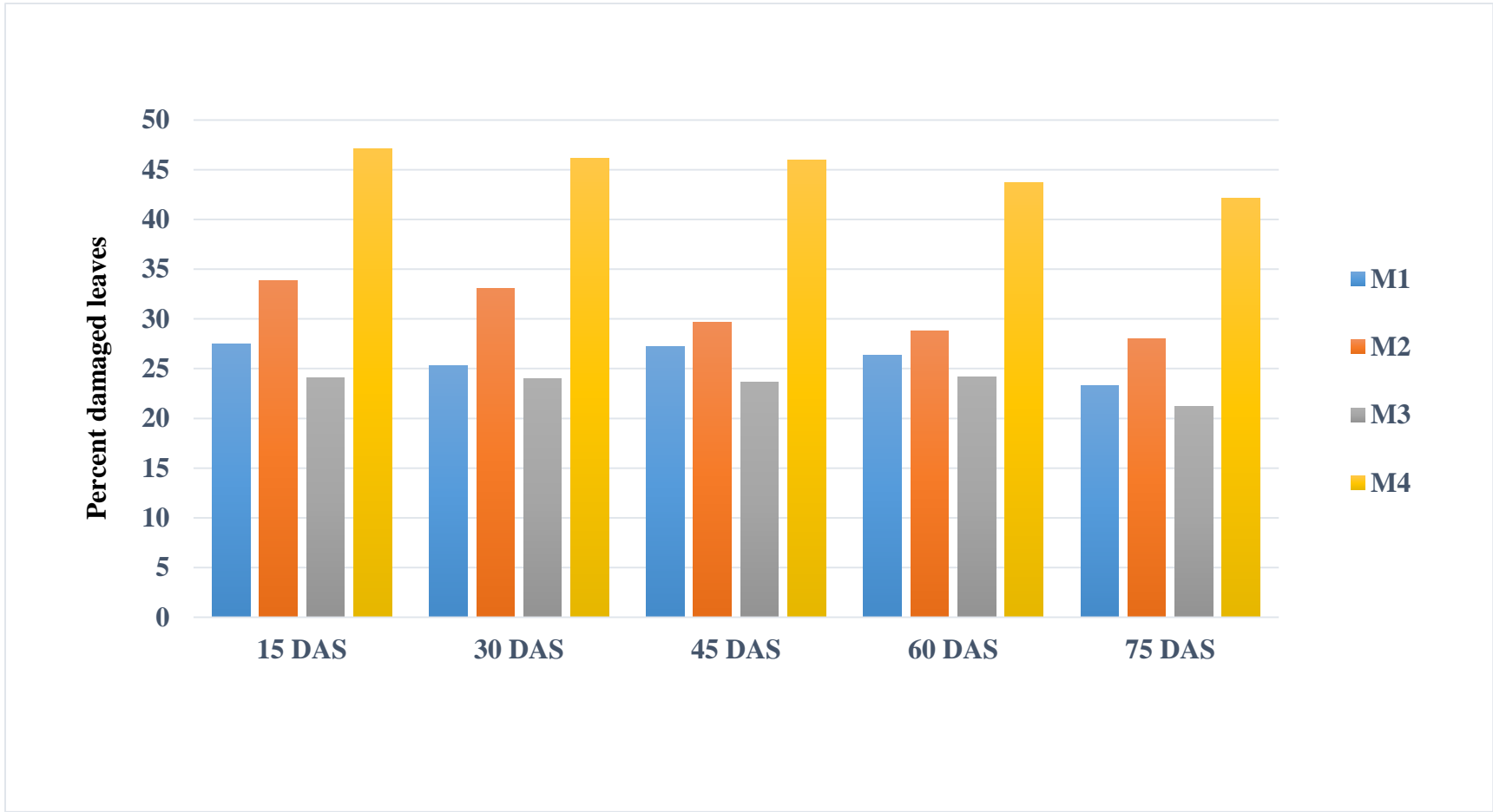


Fig 4.5 Effect of different modules on incidence of leaf miner (*Liriomyza trifolii* Burgess.)

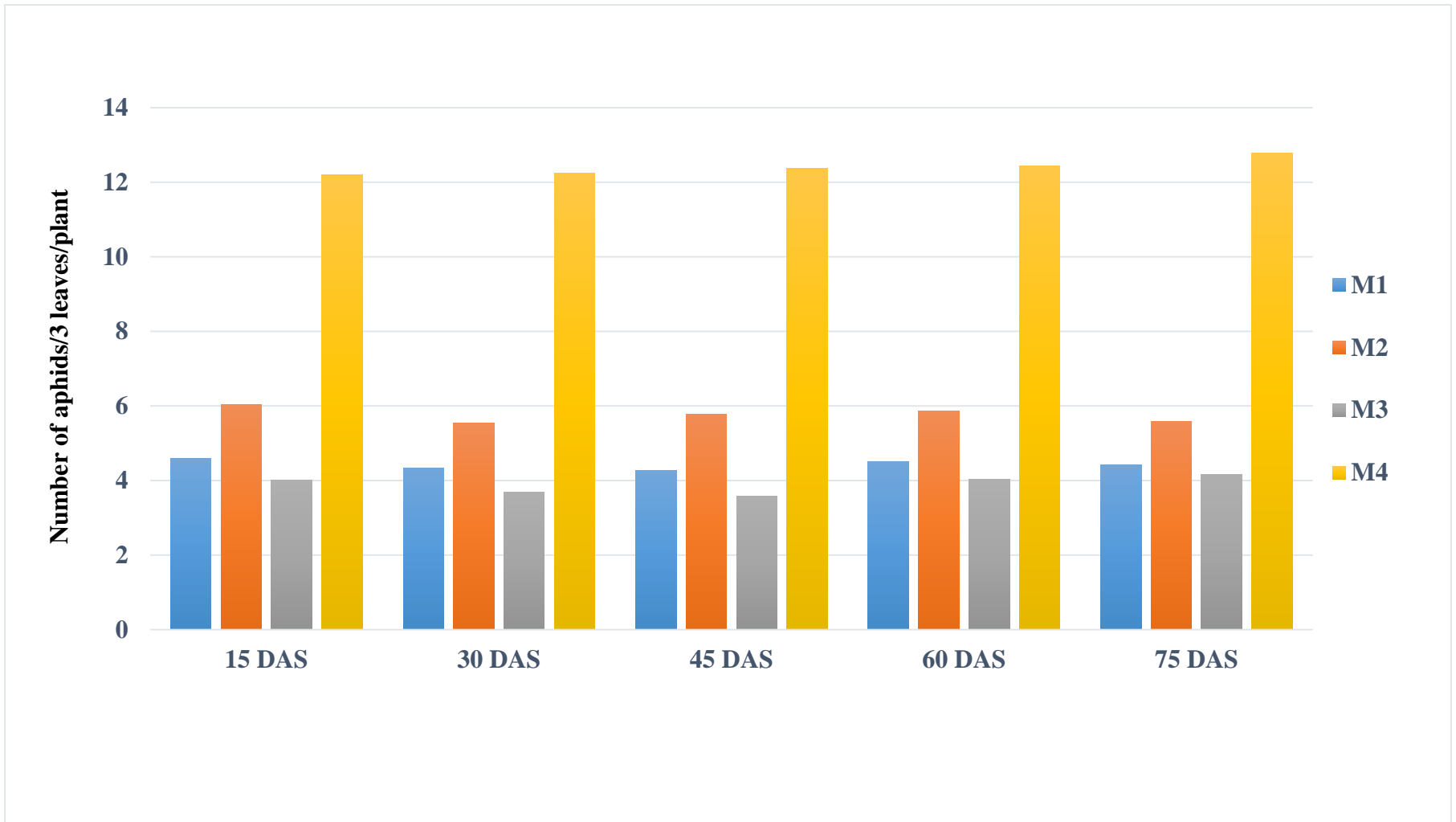


Fig. 4.4 Effect of different modules on number of aphids (*Aphis gossypii* G.) population

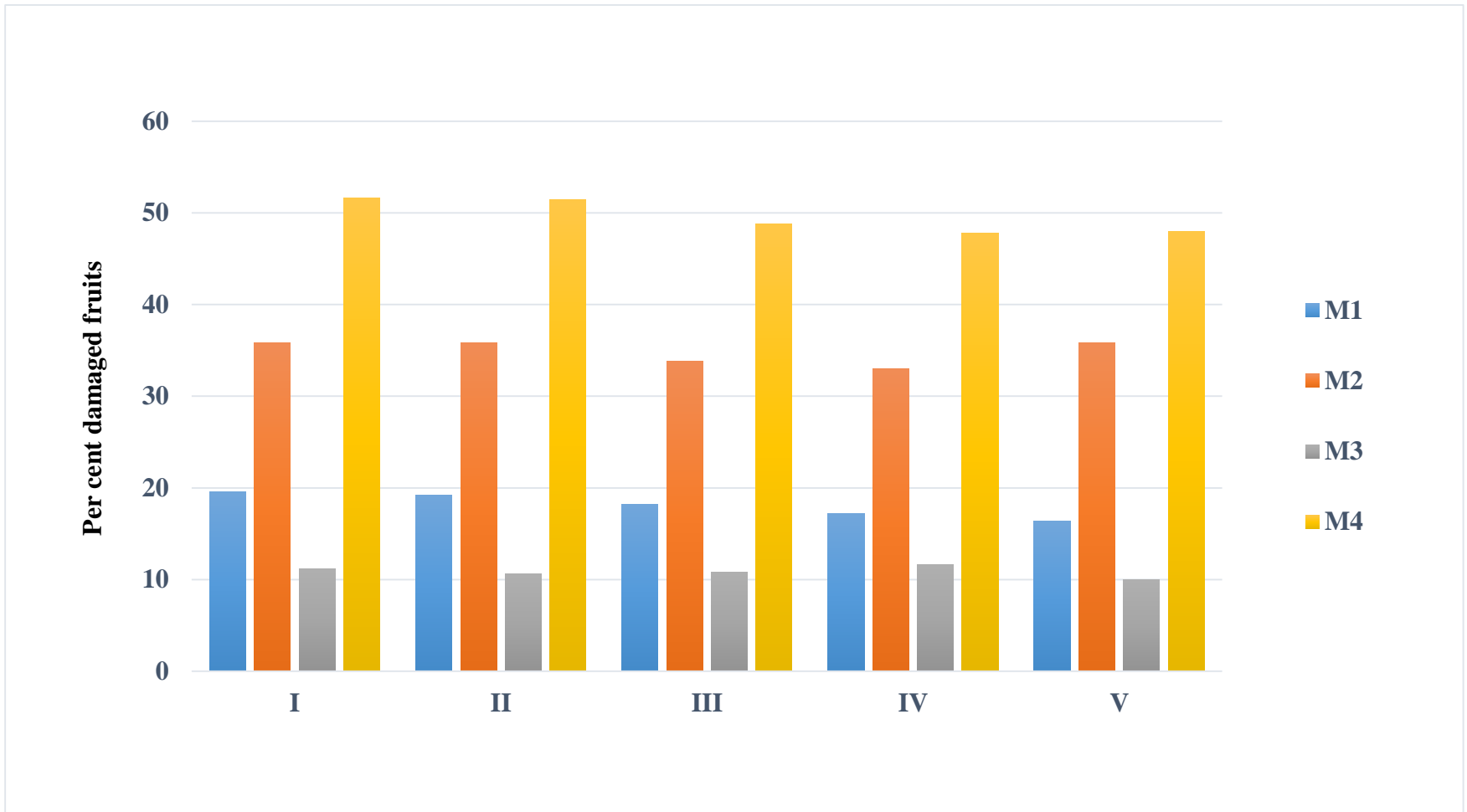


Fig.4.6 Effect of different modules on incidence of fruit fly (*Bactrocera cucurbitae* Coq.)

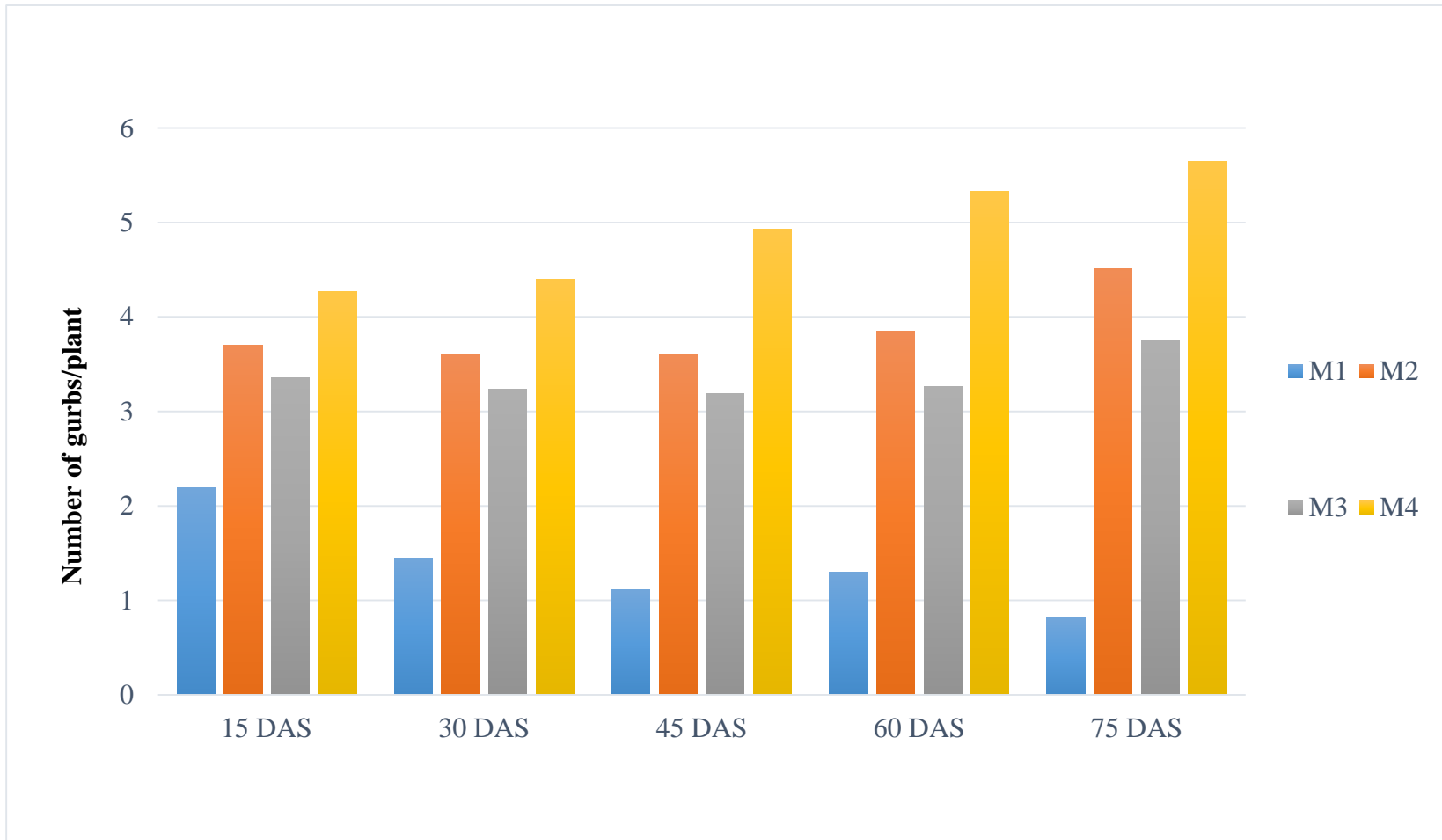


Fig. 4.7 Effect of different modules on coccinellids per plant

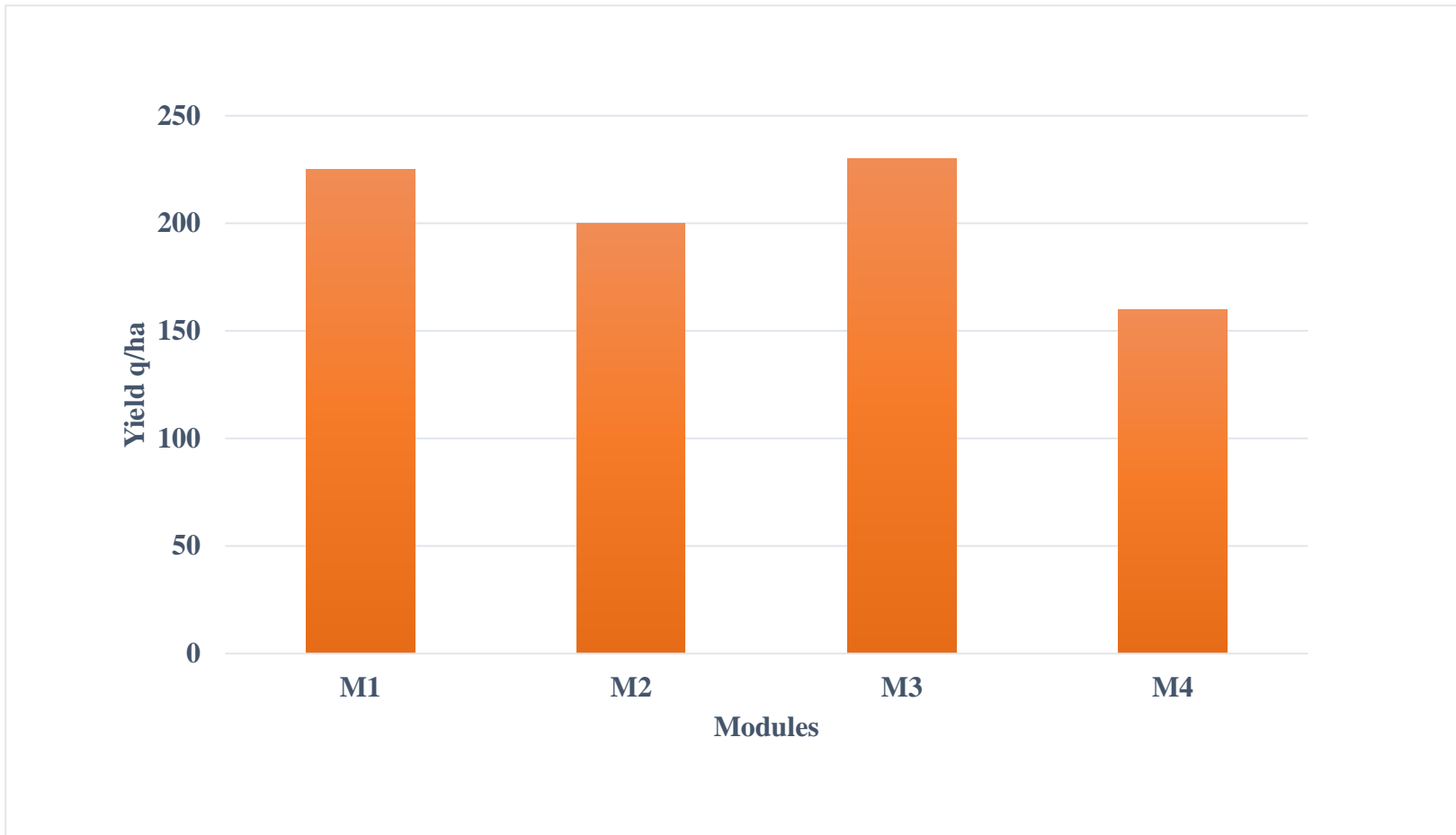


Fig 4.8 Effect of different modules on yield of cucumber

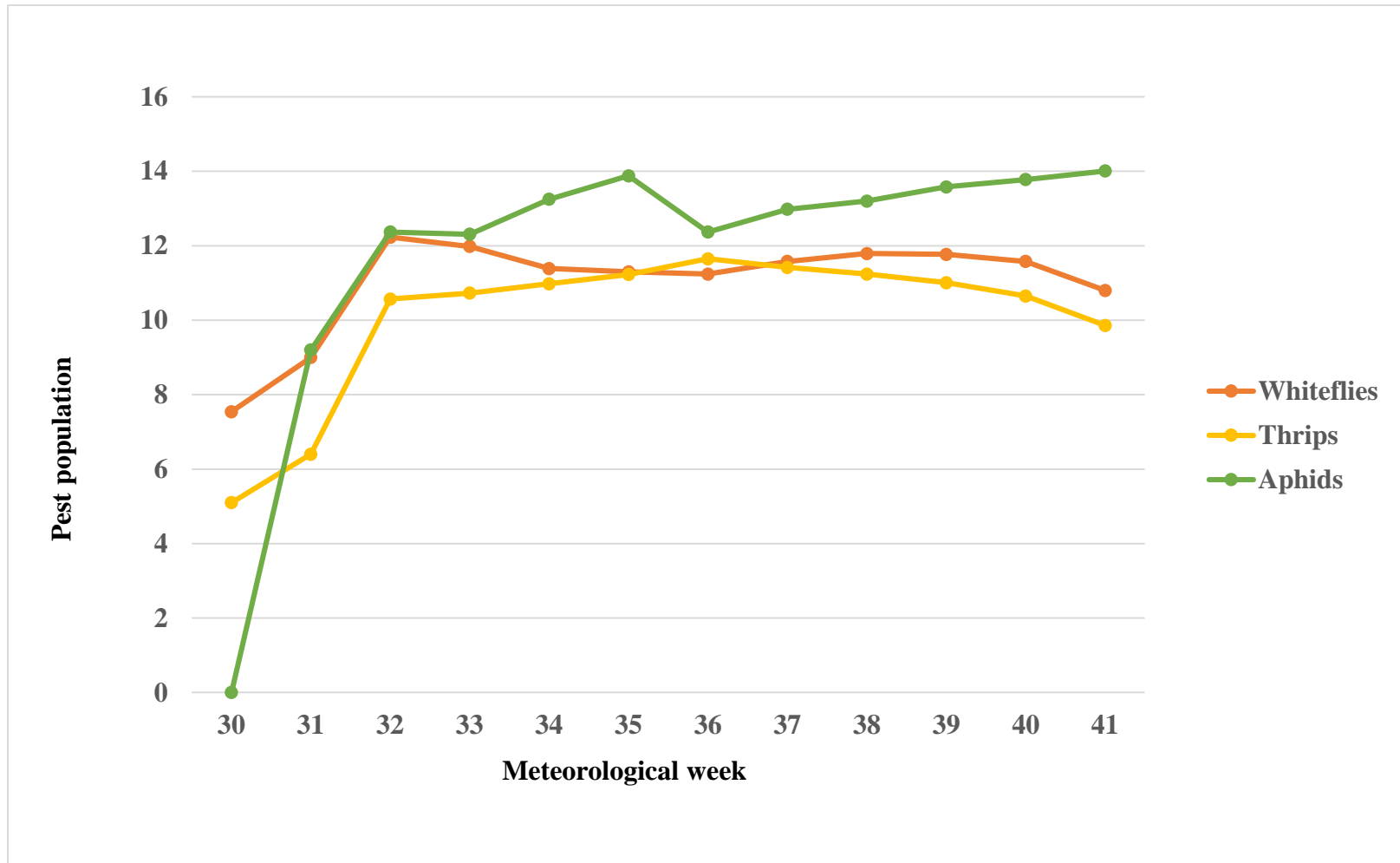


Fig. 4.1 Population dynamics of sucking pests of cucumber under field conditions during *Kharif* 2018

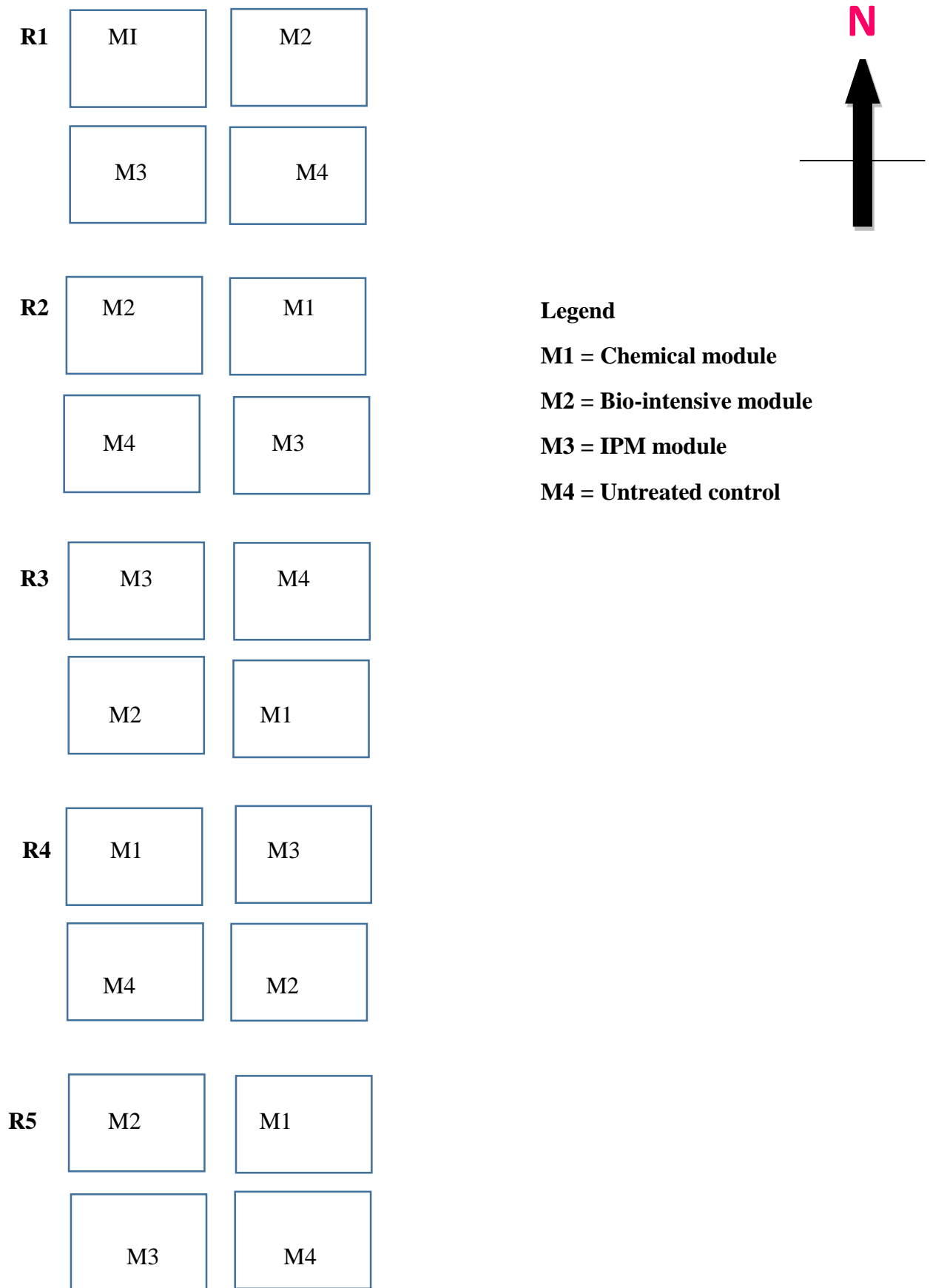


Fig.3.1. Layout of Experimental field



Plate 3.1 General view of Experimental plot



Plate 3.2 Chemical module plot



Plate 3.3 Bio-intensive module plot



Plate 3.4 Integrated Pest Management Module plot



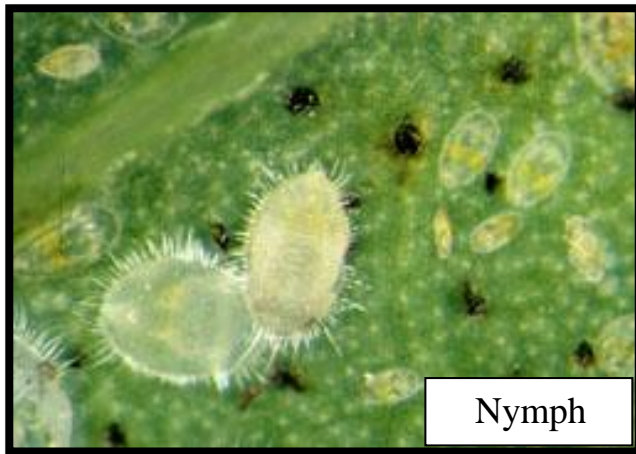
Plate 3.5 Yellow sticky trap and cu-lure trap in IPM module



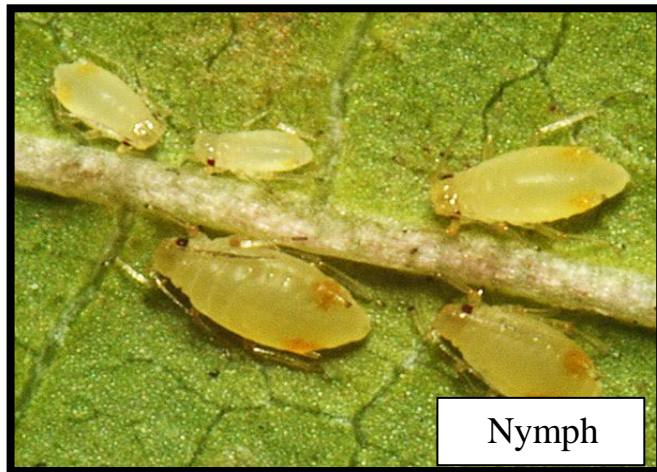
Plate 3.6 Untreated control and seasonal incidence plot of sucking pests of cucumber



Thrips



Whitefly



Aphid

Plate 4.1 Nymph and Adult stages of sucking pests of cucumber



Plate 4.2 Mines on leaves of cucumber plant due to leaf miner attack.



Plate 4.3 Fruit fly adults trapped in cu-lure traps



Plate 4.4 Fruit fly infestation to cucumber fruits



Fruits infested by Fruit fly



Healthy fruits

Plate 4.5 Infested and healthy cucumber fruits



Grub



Adult

Plate 4.6 Grub and adult stage of lady bird beetle.