# Evaluation of various pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench

*A*
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*Odisha University of Agriculture and Technology*
*in partial fulfilment of the requirements for the degree of*
*Doctor of Philosophy in Agriculture*
*(Entomology)*


*By*
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**DEPARTMENT OF ENTOMOLOGY**

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# CERTIFICATE - I

This is to certify that the thesis entitled **"Evaluation of various pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench"** submitted in partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE (ENTOMOLOGY)** to the Odisha University of Agriculture and Technology, Bhubaneswar is a faithful record of bona fide and original research work carried out by **SWAPNALISHA MOHAPATRA, Adm. No. 18123F01** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

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# CERTIFICATE-II

This is to certify that the thesis entitled **"Evaluation of various pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench"** submitted by **SWAPNALISHA MOHAPATRA, Adm. No. 18123F01** to the Odisha University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE (ENTOMOLOGY)** has been approved by the students' advisory committee and the external examiner.

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# ABBREVIATIONS

| ABBREVIATIONS | DESCRIPTION |
|---|---|
| a.i | : Active ingredient |
| *et al.* | : And others |
| @ | : At the rate |
| bp | : Base pair |
| B:C ratio | : Benefit: Cost ratio |
| cm | : Centimetre |
| CTAB | : Cetyl trimethyl ammonium bromide |
| C.D. | : Critical difference |
| DAS | : Days after sowing |
| °C | : Degree Celsius |
| DNA | : Deoxyribonucleic acid |
| EC | : Emulsifiable concentrate |
| etc | : Et. cetera |
| EDTA | : Ethylene diamide tetraacetic acid |
| Fig. | : Figure |
| FS | : Flowable concentrate |
| g | : Gram |
| ha | : Hectare |
| hrs. | : Hours |
| HCl | : Hydrochloric acid |
| *i.e.* | : (*Id est.*) That is |
| IPM | : Integrated Pest Management |
| kg | : Kilogram |
| l | : Litre |
| $MgCl_2$ | : Magnesium chloride |
| µl | : Microlitre |
| ml | : Mililitre |
| mM | : Milimolar |
| mg | : Milligram |
| MT | : Million tonnes |
| min | : Minute |
| MtCOI | : Mitochondrial cytochrome oxidase-I |
| M | : Molar |
| nm | : Nanometer |
| No. | : Number |

| ABBREVIATIONS | DESCRIPTION |
|---|---|
| OUAT | : Odisha University of Agriculture and Technology |
| ppm | : Parts per million |
| % | : Per cent |
| q | : quintal |
| rpm | : Revolution per minute |
| NaCl | : Sodium Chloride |
| SL | : Soluble concentrate |
| sp. | : Species |
| Sq.m | : Square metre |
| $SE_m$ | : Standard Error of Mean |
| SMW | : Standard Meteorological week |
| $H_2SO_4$ | : Sulphuric acid |
| SC | : Suspension Concentrate |
| t | : tonne |
| TAE | : Tris-Acetate EDTA |
| TBE | : Tris-Borate EDTA |
| TE | : Tris-EDTA |
| *Viz.* | : Videlicet (namely/that is to say) |
| WG | : Water dispersible granule |
| WS | : Water dispersible solution |
| SP | : Water soluble powder |
| WP | : Wettable Powder |

# ABSTRACT

Field and laboratory experiments on "Evaluation of various pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench" was conducted in the premises of Central Research Station, Department of Entomology and different laboratories of Odisha University of Agriculture and Technology, Bhubaneswar during *kharif* 2019, 2020 and summer, 2021. Okra crop was found to be attacked severely by sucking pests like leafhopper, *Amrasca biguttula biguttula* (Ishida), whitefly, *Bemisia tabaci* (Gennadius), aphid, *Aphis gossypii* Glov. during the early crop growth stages in the present study whereas, the shoot and fruit borer, *Earias vittella* (Fabricius) and two spotted spider mite, *Tetranychus urticae* Koch dominated during mid and later crop growth stages. Among the natural enemies, four species of ladybird beetles i.e., *Coccinella transversalis* (Fab.), *Micraspis discolor* (Fab.), *Cheilomenes sexmaculata* (Fab.) and *Brumoides suturalis* (Fab.) and mixed population of spiders were found associated with their prey. Efficacy of three pest management modules along with untreated control was tested against major insect pests of okra, their effect on natural enemies population, incidence and intensity of vector borne viral diseases and on fruit quality was studied. Both integrated module comprising of seed treatment with imidacloprid 600 FS @ 9 ml/kg seed + yellow sticky trap (@ 20/ ha) at 25 DAS + pheromone trap (@ 5/ ha) at 30 DAS + azadirachtin 0.03 % @ 5 ml/l after 30 DAS + flonicamid 50WG @ 0.4 g/l at 10 DAFiS + spinetoram 11.7 % SC @ 0.5 ml/l at10 DASS and chemical module (Seed treatment with imidacloprid 600 FS @ 9 ml/kg seed + flonicamid 50WG @ 0.4 g/l after pest appearance + diafenthuron 50 WP @ 1 g/l at 10 DAFiS + spiromesifen 22.9 SC @ 1.25 ml/l at 10 DASS + emamectin benzoate 5 % SG @ 0.4 g/l at10 DATS) were found superior in managing *A. biguttula biguttula*, *B. tabaci* and *A. gossypii* during all the three seasons of study. Integrated module was superior with highest per cent reduction over control in fruit damage both in number and weight basis. The population of coccinellids and spider were significantly lower in chemical module compared to good number of these natural enemies witnessed in other pest management modules and untreated control. Among several viral diseases, okra yellow vein mosaic disease was prevalent in all three seasons. The lowest incidence and intensity of yellow vein mosaic virus was also recorded in integrated and chemical module with the highest incidence being recorded in bio-intensive module. Molecular characterization of both yellow vein mosaic virus and whiteflies collected from virus infected plants were also done by conducting PCR followed by gel electrophoresis of isolated DNA samples which revealed that the whiteflies from Bhubaneswar grouped phylogenetically with the whitefly isolates from Indonesia, Thailand and China. In case of viruses, okra enation leaf curl virus from Bhubaneswar clustered with *Mungbean yellow mosaic virus* (MYMV) from Raichur and Hyderabad. The effect of pest management modules on fruit quality *viz*., total soluble solids, sugar, ascorbic acid, phenol, crude fibre and dry matter content revealed that none of the module had any significant effect on fruit quality during all the three seasons. Integrated module recorded the highest yield with maximum avoidable yield loss which was followed by chemical module. Among the pest management modules evaluated against major insect pests of okra, integrated module was found to be highly cost effective with highest incremental cost benefit ratio during all the three seasons.

(DAS-Days after sowing, DAFiS- Days after first spraying, DASS- Days after second spraying, DATS- Days after third spraying)

# INTRODUCTION

Vegetables are indispensable part of our diet and thus play an immense role in human nutrition (Kalloo and Pandey, 2002). India stands second in production of vegetables [19, 17, 69, 000 metric tonnes (MT)] next to China accounting for about 10 per cent of the total production under a total area of 1, 03, 53, 000 hectares (ha) during 2019-20 (Annonymous, 2019). The per capita consumption of vegetables is also much more than in the western countries due to lower cost of the common vegetables compared with non-vegetarian products besides religiously vegetarian food habit of a huge population. Due to some of these reasons concentration has been switched to grow more vegetables to meet the increasing demand.

Amongst the various vegetables grown, okra, *Abelmoschus esculentus* (L.) Moench commonly known as bhindi or lady's finger (Family: Malvaceae) is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. This crop is said to be originated from Ethiopia (Vavilov, 1951) and is commercially cultivated in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia and Southern United States. In India it is mostly grown as a kitchen garden crop as well as on large high-tech commercial farms and is cultivated commercially under a total area of 0.53 million ha with a total annual production of 6.46 million tonnes (FAOSTAT, 2021).

Okra provides an important source of vitamins, calcium, potassium and other mineral matters which often lacks in the diet of developing countries (IBPGR, 1990). The average nutritive value of okra is higher than that of tomato, eggplant and most of the cucurbits, except bitter gourd. It contains carbohydrate (6.40 %), protein (1.90 %), fat (0.20 %), minerals (0.70 %) and moisture (89.60 %). Besides being a vegetable, it also acts as clarifying agent in jaggery preparation (Chauhan, 1972). The canned, dehydrated or frozen forms are used for off-season consumption (Neeraja *et al.*, 2004). Its ripe seeds are roasted, ground and used as a substitute for coffee in Turkey (Mehta, 1959). Fruits are very useful against genito-urinary disorders, spermatorrhoea and chronic dysentery (Nandkarni, 1927).

Due to tenderness and succulence nature of vegetables they are quite easily invaded by insect pests,which is same in case of okra.This crop is also known to harbour many insect pests and diseases which require special attention to combat with at proper time and manner. The crop, soon after germination to harvesting is attacked by about 72 species of insect pests (Dangi and Ameta, 2005). The major insect pests are shoot and fruit borer, *Earias insulana* (Boisd.), *Earias vittella* (Fab.); leafhopper, *Amrasca biguttula biguttula* (Ishida); leaf roller, *Sylepta derogata* Fab; whitefly, *Bemisia tabaci* (Genn.); Aphid, *Aphis gossypii* Glov. and mite, *Tetranychus cinnabarinus* (Boisd.) and considered as major restraining biotic factors in okra cultivation (Meena and Kanwat, 2005). Besides, red cotton bug, *Dysdercus cingulatus* (Fabricius) and blister beetle, *Mylabris pustulata* (Thunberg) are also most important damaging pests of okra in many regions of the country (Sharma *et al.*, 1964). In case of red cotton bug both the adults and nymphs feed on the developing fruits, affecting the crop yield and quality of fruits thereby reducing the market value (Critchley, 1997); while the adult blister beetle feeds on the reproductive parts of the plants (flower) causing significant yield losses. Some natural enemies *viz.*, *Encarsia* sp., *Chrysoperla* sp., ants and coccinellids are also associated in okra ecosystem along with these insects causing reduction in population of insect pest of okra (Solangi and Lohar, 2007).

The shoot and fruit borer (*E. insulana* and *E. vittella*) is one of the most serious pests of okra. The larvae bore into the terminal growing shoots, floral parts and fruits of okra, resulting in withering and drying of infested shoots, tender leaves and heavy shedding of floral buds and flowers. The infested fruits become malformed and are rendered unfit for human consumption as well as for procurement of the seeds. It is reported that 69.00 per cent losses were observed in marketable yield due to attack of okra shoot and fruit borer (Rawat and Sahu, 1973). The borer has been reported to cause 24.60 to 26.00 per cent damage to okra shoots (Zala *et al.*, 1999) and 40.00 to 100.00 per cent loss to fruits (Shinde *et al.*, 2007).

Sucking pests play a major role in causing significant yield losses in okra in the process of feeding through sap sucking from the leaves and tender growing tips resulting in removal of sufficient amount of chlorophyll reducing vital function of plants (photosynthesis). Jassids cause cupping, yellowing and bronzing of okra leaves affecting growth of the crop adversely (Mahal *et al.*, 1994) and the losses in yield due to this pest have been reported to vary from 32.06 to 40.84 per cent (Singh and Brar, 1994). Whitefly apart from causing direct damage through sap sucking, also acts as a vector of a viral disease i.e., okra yellow vein mosaic, as a result the plant completely debilitates with losses to the extent of 90 per cent in fruit yield. High population of aphids also results in reduction of the vitality of plant. Adults and nymphs of red spider mite, *Tetranychus urticae* Koch causing 7.00 to 48.00 per cent loss in fruit yield in severe infestation (Kumaran *et al.*, 2007).

In order to check insect pest infestation and to produce a quality crop, it is necessary to manage them at appropriate time with suitable control measures. The chemical control has been suggested by many workers since years ago to combat with the insect pests of okra (Manjanaik *et al.,* 2002) but due to some reasons, it could not become wholesome in protection of the crop. According to Kabir *et al.* (1994) the use of insecticides have undoubtedly resulted in maximizing the production, but over reliance and injudicious use of synthetic pesticides over the last five decades has resulted in many negative consequences in the name of 3 R (resistance, resurgence and residue problems) inclusive of health hazards. Additionally, their jumbled use has resulted in curtailing biodiversity of natural enemies, food contamination and breakdown of food webs in ecosystem (Krishnamurthy, 1999). Although use of insecticides cannot be omitted all at once as they form the mainstay of pest management strategies, yet their role can be limited by utilizing safer techniques of pest management. Thus, schedule based application of various insecticides and managing their injudicious use is the need of the hour.

The concept of Integrated Pest Management (IPM) is although old, but it is acceptable and practicable approach all over the world where the objective is to maintain the pest below economic threshold level rather than exterminate it. This approach stand up for an integration of all possible known control measures (cultural control, physical control, biological control, mechanical control etc.) with or without insecticides which leads to achieve the best insect management in terms of economics and maintenance of pest population below the economic injury level (Govindachari, 1992). The farmers growing okra usually go for 10 to 12 sprays in a season to mitigate the losses due to okra shoot and fruit borer. Thus the fruits harvested at short intervals are likely to retain unavoidably high level of pesticide residues which may be highly hazardous to consumers. The use of insecticides also reported to affect the fruit quality and nutritional parameters like the acids, sugar content and some other parameters which in turn affect the flavour (Lawyer and Hartz, 1965).

The success of a pest management module depends on the ecological condition of a locality. Hence it is necessary to evolve suitable pest management packages for a particular region according to pest population dynamics, availability of the inputs, economic viability and social acceptability.

Keeping these facts in view the study has been undertaken with the following objectives:

- Efficacy of different pest management modules on insect pests and their natural enemies in okra
- Impact of different pest management modules on the incidence/intensity of vector borne viral diseases in okra
- Effect of pest management modules on fruit quality
- Assessment of economics of pest management modules

# REVIEW OF LITERATURES

The present study entitled "Evaluation of various pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench" was carried out at experimental field, Department of Entomology, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar during *kharif*, 2019; *kharif*, 2020 and summer, 2021. The literature pertaining to insect pests associated with okra and their natural enemies, incidence/intensity of vector borne viral diseases, fruit quality and incremental cost benefit ratio towards evaluation of different pest management modules have been collected and embodied in the following paragraphs.

## 2.1 Evaluation of various pest management modules on insect pests and their natural enemies

Prior to evaluation of the pest management modules there is an obvious need to know the prevailing status of the pest complex and natural enemies during the study period. Very scanty information on the novel insecticidal molecules included in various pest management modules of present study is available. The correlation of insect pests with natural enemies and abiotic factors are presented here under.

### 2.1.1 Insect pests and natural enemies associated with okra crop and their relation to weather parameters

Okra is commonly infested with sucking insect pests *viz.*, whitefly, *Bemisia tabaci* (Genn.), leafhopper, *Amrasca bigutulla bigutulla* Ishida, aphid, *Aphis gossypii* Glov. and borer pests *viz.*, shoot and fruit borer, *Earias vittella* Fab. as stated by Singh *et al.* (2013). Due to ecological differences from region to region there is variation in seasonal activity of different pests of okra and so also the damage caused by them. Most of the pest activity is severe during warmer and rainy season i.e. from June to August (Kashyap and Verma, 1982).

#### 2.1.1.1 Incidence of leafhopper and their relation to abiotic factors

Uthamasamy (1988) stated that in okra, leafhopper (*A. b. biguttula*) population was the highest on 25$^{th}$ and the lowest on 35$^{th}$ days after sowing (DAS) at Coimbatore (Tamil Nadu). There was a significant positive correlation between leafhopper infestation and the hopper burn symptoms (r= 0.430) and the per cent hopper burn damage showed a negative correlation (r= -0.570) with the yield parameter.

Patel *et al.* (1997) revealed that there was significant positive correlation between leafhopper population and maximum temperature (r= 0.760) as well as with bright sunshine hours (r= 0.820).

Ghosh *et al.* (1999) reported that *A. b. biguttula* attained its peak population in middle of June (21.36/ leaf).

According to Kumar and Singh (2002), Arka Anamika variety of okra harboured relatively lesser population of leafhopper (1.98/ leaf) and showed minimum leaf injury (12.61%).

Preetha and Nadarajan (2007) recorded a non significant negative effect of maximum temperature on leafhopper population.

Anitha and Nandihalli (2008) recorded the leafhopper population of okra in summer season and cited that their incidence started from first week of April (4.33/ 3 leaves) and the peak reached during last week of June (18.44/ 3 leaves).

Leafhopper infestation usually started in 21 days old okra crop (3.53/ leaf) and reached its peak (17.33/ leaf) when the crop was about 63 days old and thereafter its population declined (Kumari *et al.*, 2009).

Selvaraj *et al.* (2010) stated that maximum and minimum temperature had significant positive effect on leafhopper population in Tamil Nadu.

At Mizoram the infestation of *A. biguttula biguttula* on okra commenced from last week of May and remained till the final harvest i.e., first week of August with peak activity of 0.12 leafhopper per leaf during first week of July i.e., $12^{th}$ week after sowing (Boopathi *et al.*, 2011).

Weather parameters play an important role in incidence of sucking pests of okra as evidenced from the findings of Mohanasundaram and Sharma (2011) who observed that mean relative humidity (r = -0.673) showed significant negative correlation with leafhopper population while sunshine hours showed a significant positive correlation (r = 0.685).

As per the reports of Singh *et al.* (2013) leafhopper population showed negative correlation with mean temperature and relative humidity whereas positive correlation with rainfall.

Kumar *et al*., 2014 recorded the first incidence of okra leafhopper from third week of sowing ($27^{th}$ SMW) and reached its peak activity at $34^{th}$ standard meteorological week (SMW) i.e., tenth week of sowing.

The activity of *A. b. biguttula* on okra crop started at the early stages, attaining peak population of 19.70 nymphs per leaf after 60 DAS at $34^{th}$ SMW (third week of August). Among the abiotic factors, evening relative humidity and rainfall showed a significant positive correlation with leafhopper population whereas bright sunshine hours exhibited a significant negative effect (Kumaranag, 2015).

Khating *et al.* (2016) studied on seasonal incidence of sucking pests of okra along with their natural enemies in *kharif* season. Their study revealed that incidence of leafhopper reached its peak activity (23.00 leafhoppers/ 3 leaves/ plant) during the second week of September.

Leafhopper incidence noticed from $24^{th}$ SMW i.e., second fortnight of June with 0.33 nymphs per leaf and it reached the highest activity with 22.42 nymphs per leaf in the first week of August at $31^{st}$ SMW as stated by Sandhi and Sindhu (2018).

Burade *et al.* (2019) reported the peak incidence of leafhopper (20.00/ three leaves) at $21^{st}$ SMW at Parbhani, Maharashtra. The correlation of leafhopper with both maximum and minimum temperature and wind velocity was positively significant whereas morning relative humidity had negative effect.

Jat and Singh (2019) witnessed that the leafhopper infestation in summer okra crop started from second week of March ($11^{th}$ SMW) and reached to its highest activity in the first week of May and third week of April in two consecutive seasons i.e., of 2017 and 2018.

The maximum activity of leafhopper (23.00/ six leaves) was observed at $47^{th}$ SMW i.e., third week of November and the pest has no significant correlation with abiotic factors (Challa *et al.*, 2020).

Lal *et al.* (2020) reported that the incidence of leafhopper was observed about 15 to 16 days after germination in *kharif* season (August) and remain active till second week of November. Correlation study revealed that leafhopper had significantly positive correlation with maximum temperature and evaporation but did not exhibit any significant correlation with minimum temperature, morning and evening relative humidity and rainfall.

Sindhu *et al.* (2020) reported the maximum (8.80/ leaf) and minimum (0.20/ leaf) incidence of leafhopper at $31^{st}$ and $39^{th}$ SMW, respectively at Hisar. The leafhopper population had significant and positive correlation with evening relative humidity and rainfall whereas it was negative with maximum temperature.

Patel *et al*. (2022) reported the infestation of leafhopper in okra crop from 12 to 14 days after sowing and the population reached the peak at $17^{th}$ SMW with 19 leafhoppers per three leaves.

**2.1.1.2 Incidence of whitefly and their relation to abiotic factors**

Ghosh *et al.* (1999) confirmed that *B. tabaci* reached peak at the end of growth period of okra (*kharif*) i.e., in fourth week of July with a population of 2.80 whitefly per leaf.

At Faisalabad (Pakistan), the whitefly population showed significant negative correlation with relative humidity (Safdar *et al.*, 2005). Similar result was also noticed by Singh *et al*., 2013 in India i.e., both average temperature and relative humidity were negatively correlated with whitefly population where as rainfall had a positive effect.

Selvaraj *et al*. (2010) observed the peak incidence of *B. tabaci* from $33^{rd}$ to $36^{th}$ SMW (mid August to mid September) and a positive significant correlation between the pest and both maximum and minimum temperature.

According to Mohansundaram and Sharma (2011) whitefly showed significant positive correlation with minimum temperature (r= 0.994) while maximum temperature had non significant effect.

The activity of *B. tabaci* on okra crop started at the early stages, attaining peak population of 6.20 per leaf on $29^{th}$ SMW (third week of July) and had positive correlation with maximum and minimum temperature as well as wind speed (Kumaranag, 2015).

Khating *et al.* (2016) from their study revealed that incidence of whitefly reached its peak activity during the second week of September with (21.00/ 3 leaves/ plant).

Burade *et al.* (2019) from their study revealed that the maximum activity of whitefly was at 21st SMW with 25.00 whiteflies per three leaves. There was significant positive correlation between whitefly population and maximum and minimum temperature whereas it was negative with relative humidity (morning and evening).

Whitefly had significant and positive correlation with maximum temperature and evaporation but did not show any significant effect with minimum temperature, morning and evening relative humidity and rainfall (Lal *et al.,* 2020).

Whitefly reached the peak activity at 17th SMW with a population of 17.00 per three leaves during summer season as per Patel *et al.*, 2022. Maximum temperature had significant positive (r= 0.738) correlation with the pest population while relative humidity had negative (r= -0.752) effect.

Sapkal *et al.* (2022) reported the first incidence of whitefly on 11th SMW on okra and attained the maximum population (5.80/ leaf) at early growth stages i.e., at 14th SMW.

**2.1.1.3 Incidence of aphid and their relation to abiotic factors**

According to Kandoria *et al.* (1989) *A. gossypii* was active on okra crop during the months of September to October and there was decline in population from mid May to the end of June due to high temperature (40 to 45°C).

Ghosh *et al.* (1999) confirmed that during *kharif* season *A. gossypii* reached peak at the end of growth period of okra i.e., in fourth week of July with 39.85 aphids per leaf.

At Alexandria (Egypt), *A. gossypii* activity on okra started in July and reached its peak (1343.38 aphids/ 10 plants) in late August (Al Eryan *et al.*, 2001).

Aphid incidence on okra started from first week of May and continued till the first week of September with a peak population of 450.40 and 393.65 aphids per plant in the last week of July. The abiotic factors such as the average sunshine hours and wind speed had significantly positive correlation whereas average relative humidity and total rainfall showed significant negative correlation with aphid density on the host plant (Shah *et al.,* 2009).

The aphid population showed negative correlation with mean temperature, relative humidity and rainfall whereas it was having positive correlation with maximum temperature and coccinellids (Singh *et al.,* 2013)

Shukla (2014) indicated that incidence of *A. gossypii* has reached to its peak level (27.17 aphids/ 3 leaves) during $14^{th}$ week after sowing (first week of July) and maximum activity was recorded during that month. It was confirmed from the correlation studies that aphids showed positive correlation with rainfall (r= 0.261) and both morning and evening relative humidity(r= 0.295 and 0.401, respectively) where as significant negative correlation was observed with maximum temperature (r= -0.456).

Aarwe *et al.* (2016) highlighted two distinct peak levels of *A gossypii* consecutively at $36^{th}$ and $37^{th}$ SMW with 46.50 and 44.50 aphids per three leaves, respectively.

Khating *et al.* (2016) reported that in *kharif* okra the peak incidence of aphid was noticed in the first week of September (43.30 aphids/ 3 leaves/ plant).

Potai and Chandrakar (2018) reported the maximum activity of okra aphid at $40^{th}$ SMW with 39.24 aphids per plant.

Thara *et al.* (2019) reported that the abundance of insect pests of okra were more during August to November. Among the insect pests, aphid population exhibited positive correlation with minimum temperature but having negative correlation with maximum temperature, rainfall and maximum and minimum relative humidity. Following the trend with aphid, its predators like coccinellids appeared more or less with aphid population.

The maximum activity of aphid (36.50/ six leaves) was observed on third week of November i.e., at $47^{th}$ SMW and it had significant negative correlation (r= -0.510) with rainfall (Challa *et al.,* 2020).

Lal *et al.* (2020) reported that the incidence of aphid was observed at about 15 to 16 days after germination in *kharif* season (August) and remain active till $2^{nd}$ week of November. Correlation with weather parameters revealed that aphid had significantly positive correlation with maximum temperature and evaporation but did not show any significant correlation with minimum temperature, morning and evening relative humidity and rainfall.

Accotrding to Sonawane *et al*. (2021), the first incidence of aphid during kharif season was noticed at 29$^{th}$ SMW and attained the highest population of 34.70 per three leaves at 37$^{th}$ SMW.

Patel *et al*. (2022) stated a significant positive and negative correlation between maximum temperature (r= 0.747) and relative humidity (r= - 0.720) with aphid population, respectively.

**2.1.1.4 Incidence of red spider mite and their relation to abiotic factors**

As reported by Sugeetha (1998) mite incidence in okra was first witnessed from 60 to 100 days old crop in *kharif* season (mid November to last week of December) whereas in summer this pest appeared much earlier (50 DAS) and attained the highest activity from 65 to 95 DAS (mid April to end of May).

In *kharif* season mite population was highest in the month of October (29.25 mites/ 3 leaves), after which there was a gradual decline (Gulati, 2004). However in summer season more number of mites was recorded as compared to winter crop.

Mohansundaram and Sharma (2011) observed the incidence of two spotted spider mite on okra between mid August and first week of September and it reached its maximum activity during last week of September.

On okra the maximum population of *Tetranychus urticae* was observed during first fortnight of June (352.50 mites/ 3 leaves) when the average atmospheric temperature was 35.53 $^{0}$C with relative humidity of 33.00 per cent and no rainfall, while minimum population of *T. urticae* was recorded during first fortnight of March (7.20 mites/ 3 leaves) when average atmospheric temperature was 21.7 $^{0}$C with relative humidity of 61.70 per cent and rainfall of 6.40 mm (Tripathi *et al.*, 2013).

Ghosh (2013) from West Bengal studied the activity of *T. urticae* on okra. He reported that the mite incidence has occurred throughout the crop growing season with a peak population of 6.18/ leaf and 7.56/ leaf during 23$^{rd}$ SMW (last week of May) in summer crop and 42$^{nd}$ SMW (first week of October) in *kharif* crop, respectively.

### 2.1.1.5 Incidence of shoot and fruit borer and their relation to abiotic factors

Okra shoot and fruit borer (*E. vittella*) is one of the major pests on all okra grown areas of Maharashtra and this pest infested the okra crop soon after the fruit set causing maximum damage of 69.91 per cent after 3 to 4 weeks. Thereafter the population declined (Mote, 1977).

Kadam and Khaire (1995) reported that in summer season the highest incidence of *E. vitella* (50.63 %) was recorded at $20^{th}$ SMW and there was significant negative correlation between the pest incidence with relative humidity and rainfall.

An experiment was conducted by Gupta *et al.* (1998) at Samastipur (Bihar) to forecast the okra shoot and fruit borer damage (weight basis) in relation to weather factors. The findings revealed that the minimum (3.20 %) and maximum (32.10 %) incidence was recorded in last week of May and in fourth week of July, respectively. According to their result there was significant positive relationship with the minimum temperature (r= 0.824), total rainfall (r= 0.338) and significant negative correlation with maximum temperature (r= -0.619).

Zala *et al.,* 1999 cited the infestation of *E vitella* in okra started on 3 to 4 weeks old crop and retained their activity till the maturity of crop. Moreover, bright sunshine hour and both maximum and mean temperature showed significant positive correlation with the larval population, whereas relative humidity had significant negative effect.

Naresh *et al.* (2003) conducted a field experiment with okra variety Arka Anamika at Mohanpur, West Bengal. According to their findings, shoot and fruit borer infestation occurred on three and six weeks old crop. They noticed two peaks of the pest, one at the vegetative stage (second fortnight of August) accounting for 14.87 per cent shoot damage and another at reproductive stage (second week of September) attributing 31.25 per cent fruit damage.

Selvaraj *et al.* (2010) cited that both *E. vitella* and *Helicoverpa armigera* is major borer pest of okra fruit with the peak incidence of *E. vitella* observed at $37^{th}$ SMW and this pest showed a significant positive correlation with maximum temperature.

Sharma *et al.* (2010) from Udaipur (Rajasthan) confirmed that in *kharif* sown okra crop, shoot and fruit borer infestation started from $29^{th}$ SMW and maximum shoot damage (91.60 %) was observed during 45th SMW whereas in 42nd SMW, highest number of larvae (7.50 larvae/ 10 plants) was recorded. According to them 18 weeks old crop exhibited maximum percentage of damaged fruits both on number basis and on weight basis which was 54.30 per cent and 54.70 per cent, respectively.

Mohanasundaram and Sharma (2011) reported that the peak incidence of *E. vittella* with 56.60 per cent fruit damage was observed during third week of September in *kharif* okra. The incidence of fruit borer was significantly and negatively correlated with relative humidity and significantly and positively correlation with bright sunshine hours.

The maximum incidence of *H. armigera* was observed in 37th SMW (1.20 larvae/ plant) and 38th SMW (1.00 larvae/ plant) in okra and showed a significant positive correlation with rainfall whereas *E. vittella* caused maximum fruit damage of 43.52 per cent during 41st SMW (Nath *et al.*, 2011). Another report by Mani and Singh (2012) suggested that the maximum shoot and fruit damage of 20.20 and 30.90 per cent by *E. vitella* were noticed at 13th and 16th SMW, respectively.

Pal *et al.* (2013) experimented on seasonal incidence of shoot and fruit borer of okra and reported that the borer population was observed from 14th standard week i.e. second week of April. Initially the borer population increased slowly in vegetative stage of crop (4.99 to 8.66 % shoot damage) but soon after fruit development the population rapidly increased causing 43.42 per cent fruit damage just one week after fruiting initiation (16th SMW). Among the abiotic factors, maximum temperature (r= 0.736), minimum temperature (r= 0.623), rainfall (r= 0.014) and sunshine (r= 0.640) had positive correlation with mean insect population while relative humidity had negative correlation (r= -0.312).

Fruit infestation by shoot and fruit borer (*E. vittella*) in *kharif* season started from fourth week of August (five weeks old plants) and continued until fourth week of October (14 week old plants) but the highest population of 5.40 larvae per plant was observed in the third week of September (Singh *et al.*, 2015).

According to Padwal and Sharma (2015) *E. vittella* population was positively correlated with the maximum temperature (r= 0.473) and sunshine hours (r= 0.876) but negatively correlated with humidity (r= -0.286) and rainfall (r = -0.564).

Raju *et al.* (2017) recorded the incidence of okra shoot and fruit borer in *kharif* season and they found that the peak larval population and shoot infestation was about 6.40 per 10 plants and 30.63 per cent, respectively. Fruit infestation both on number and weight basis was about 58.32 and 33.42 per cent, respectively. The larval population, fruit damage both on number and weight basis were significantly and negatively correlated with maximum temperature but non-significantly and negatively correlated with minimum temperature, relative humidity and rainfall. Incidence of shoot damage was significantly correlated with maximum temperature and minimum temperature and non-significantly negatively correlated with rainfall and relative humidity.

Kumar *et al.* (2017) indicated that *E. vittella* population had built up from third week of July and continued till first week of October in *kharif* season. The peak population of the pest was recorded during last week of August resulting 25.00 per cent shoot damage with average temperature and relative humidity of 30.15 ºC and 83.20 per cent, respectively.

The correlation between *E. vitella* and temperature (maximum and minimum) and wind velocity was positively significant whereas both morning and evening relative humidity had negative effect. Rainfall and bright sunshine hour had positive but non significant effect with the borer incidence (Burade *et al.*, 2019).

According to Vastav and Yadav (2019) shoot infestation of *E. vittella* in okra commenced after three weeks after sowing in *kharif* i.e. 3rd week of September (2.77 % infestation), which gradually increased and reached to peak (25.00 %) in the fourth week of October whereas the fruit infestation started in the 1st week of October (9.25 % infestation) which gradually increased and reached peak (22.64 %) in the 2nd week of November. It was confirmed from the correlation study that this insect showed positive correlation with minimum temperature and negative correlation with evening humidity, wind speed, bright sunshine hours/day while remaining abiotic factors showed no significant effect.

Challa *et al*. (2020) studied the effect of abiotic factors on major pests of okra. Wind velocity and maximum temperature had significantly positive (r= 0.600) and negative (r= - 0.890) effect on shoot and fruit borer of okra, respectively.

The incidence of okra shoot and fruit borer was recorded from 28$^{th}$ to 39$^{th}$ SMW at Pantnagar, Uttarakhand with the maximum incidence of 5.90 larvae per plant at 37$^{th}$ SMW (Rawat *et al*., 2020).

**2.1.1.6 Incidence of natural enemies and their relation to abiotic factors**

Eight species of aphidophagus predators *viz.,* of which five coccinellids, two of syrphids and one of hemerobiid were found associated with aphid in okra crop (Shah *et al.*, 2009).

Meena and Kanwat (2010) studied the seasonal incidence of coccinellid beetle on okra and observed their population build up from first week of August (1.80/ plant) and reached the maximum activity (6.20/ plant) in the first week of October. Further, minimum temperature and relative humidity had negative correlation with the coccinellid population.

Natural enemies *viz.,* coccinellids were associated more or less with aphid and leafhopper population and showed negative correlation with both maximum and minimum temperature, rainfall and relative humidity as stated by Singh *et al.* (2013).

Spiders are major group of arthropod natural enemies associated with sucking pests of okra and persisted throughout the entire cropping season (Singh *et al.*, 2013) and they showed a significant positive correlation with both morning and evening relative humidity (Sahito *et al.*, 2013).

The abundance of predators *viz.*, spiders (1.00 spider/ plant) and coccinellids (0.90 coccinellid/ plant) was at its peak between 33$^{rd}$ and 34$^{th}$ SMW (second and third week of August), respectively and had significant positive correlation with morning relative humidity and rainfall (Kumaranag, 2015).

Khating *et al.* (2016) stated that the peak activity of predatory lady bird beetle was reported during second week of September (26.00 lady bird beetles/ plant), coinciding with the peak population of sucking pests. The minimum temperature had positive non-significant correlation with leafhoppers and positive significant correlation with aphids.

Potai and Chandrakar (2018) reported two species of coccinellids *viz., Menochilus sexmaculata* and *Coccinella septumpunctata* as major predators in okra with their maximum activity (1.27/ plant) in the third week of September ($38^{th}$ SMW).

With the incidence of sucking pests the populations of coccinellid beetles were built up and its peak population (1.80 coccinellids/ plant) synchronized with the peak of aphid (12.40/ six leaves/ plant). Coccinellid beetles had significantly positive correlation with maximum temperature and evaporation but did not show any significant correlation with minimum temperature, morning and evening relative humidity and rainfall. The coccinellid beetle was also positively associated with aphid population (Lal *et al.,* 2020).

Gaikwad *et al.* (2020) reported that in okra the peak population of grubs and adults of coccinellids (2.90/ plant), larvae of green lacewing (3.56/ plant) and spiders (1.02/ plant) were observed in $40^{th}$ meteorological week (first week of October) in 2017-18.

### 2.1.2 Efficacy of various pest management modules on insect pests and their natural enemies

Paulraj and Ignacimuthu (2005) reported that the installation of 10 pheromone traps per acre along with release of *Trichogramma chilonis* Ishii at 25 DAS and release of *Chrysoperla carnea* were effective in managing insect pests of okra.

Sardana *et al.* (2005) experimented on efficacy of five pest management modules *viz.,* bio-intensive (module-I), cultural + mechanical + bio-intensive (module-II), cultural + mechanical + bio-intensive + chemical (module-III), farmers practices (module-IV) and untreated control (module-V). Module III comprising of releases of egg parasitoid, *T. chilonis* @ 1 lakh/ha based on monitoring of pest population using pheromone trap, three spray of neem seed kernel extract (NSKE) @ 5% intermittently with need based application of chemical pesticides and periodic removal of borer and disease affected plants had proved superior among the modules tested in managing the pest complex of okra.

Preetha and Nadarajan (2007) stated that both bio intensive module and the insecticide module were at par in managing the major sucking pests of okra like leafhopper (*A. b. biguttula*) and aphids (*A. gossypii*) while the chemical module was the most effective one against red spider mite.

Nemade *et al*. (2008) studied the effectiveness of new insecticides against natural enemies of *Earias vittella* and stated that imidacloprid seed treatments were safer for natural enemies of *E. vittella* in okra field.

In Andhra Pradesh a module comprising of sorghum as a border crop + seed treatment with imidacloprid @ 5 g/kg of seed + spray of neem seed kernel extract @ 5 % (NSKE) alternated with the neem oil 5 % elicited lower incidence of shoot damage (1.05 %), fruit damage (16.40 %) and more fruit yield (43.50 q/ha) as compared to untreated control, which registered 13.40 and 52.40 per cent incidence of shoot and fruit borer damage with fruit yield of 30.50 q/ha, respectively (Rao *et al.*, 2008).

Sharma and Kaushik (2010) reported the effectiveness of emamectin benzoate 5 SG @ 140 g a.i/ha against two spotted spider mite in okra.

Shabozoi *et al.* (2011) from Pakistan quoted that bio pesticides are safe to natural enemies and integration of bio pesticides along with natural enemies have a good impact on crop yield parameters also.

Birah *et al.* (2012) experimented on efficacy of different pest management practices at Andaman and Nicobar islands against pest complex of okra and noticed that among different modules tested *viz.*, biointensive module ($M_1$) comprising of neem cake application @ 250 kg/ha at the time of sowing, sowing of maize at the borders as barrier crop, weekly clipping of infested shoots and fruits, erection of pheromone trap @ 100 traps/ha for mass trapping, foliar spray of NSKE @ 30 ml/l, aqueous leaf extracts of cloves (*Syzygium aromaticum*) @ 250 g/l, karanj oil @ 30 ml/l at 45, 60 and 75 DAS, respectively; integrated module ($M_2$) including seed treatment with imidacloprid @ 5g/kg seed, sowing of maize at the borders as barrier crop, weekly clipping of infested shoots and fruits, erection of pheromone trap @ 100 traps/ha for mass trapping, foliar spray of NSKE @ 30 ml/l, spinosad 45 SC @ 0.5ml/l and karanj oil @ 30 ml/l at 45 at 45, 60 and 75 DAS, respectively and Farmer's practice module ($M_3$) having foliar spray of endosulfan @ 2 ml/l, cypermethrin @ 1.5 ml/l and deltamethrin @ 1.5 ml/l at 45, 60 and 75 DAS, respectively and untreated control ($M_4$). Both integrated module and bio-intensive module recorded significantly lower leafhopper population of 3.32 leafhopper/ leaf and 4.27 leafhopper/ leaf, respectively than farmer's practices (5.31 leafhopper/ leaf) and untreated control (10.12 leafhopper/ leaf). Less shoot damage (4.23 %) and fruit damage (5.64 %) and more fruit yield (8.66 t/ha) was recorded in integrated module as compared to untreated control i.e., 13.42 per cent, 16.85 per cent and fruit yield of 5.25 t/ha, respectively.

Spiromesifen @ 150 g a.i/ha was the best treatment in reducing the whitefly population recording only 4.10 whiteflies per 3 leaves per plant as compared to other conventional insecticides (Anand *et al*., 2013).

Alam *et al.* (2014) from West Bengal reported that spiromesifen 240 SC @ 150 g a.i/ha was the best treatment reducing red spider mite infestation up to 96.68 per cent in tomato whereas acephate 75 SP @ 375 a.i/ha proved to be the best treatment in reducing whitefly population to the tune of 84.84 per cent reduction followed by spiromesifen 240 SC @ 150 g a.i./ha (70.25 %).

According to Kumawat *et al.* (2014) two modules i.e $M_2$ comprising of seed treatment with imidacloprid + *Beauveria bassiana* (Bals.) + spinosad + destruction of infested shoots and fruits (DISF) and $M_1$ (imidacloprid + *B. bassiana* + spinosad) were proven as the most effective module against leafhopper and whitefly and other modules such as $M_4$ (*B. bassiana* + NSKE + acephate+ *Bacillus thuringiensis kurstaki* (*Btk*) + DISF) and $M_7$ (*Metarhizium anisopliae* (Metsch.) + NSKE + acephate + *T. chilonis* + DISF) were effective against mite. They reported that, module $M_8$ (*M. anisopliae*+ NSKE + spinosad + *Btk* + DISF) and $M_3$ (*B. bassiana* + NSKE + spinosad + *T. chilonis* + DISF) were better against shoot and fruit borer than other modules.

Sarkar *et al.* (2016) evaluated the efficacy of several biopesticides against sucking pests of okra in West Bengal. Imidacloprid 17.8 % SL (0.3 ml/l) was the best treatment followed by karanjin 2 % EC (2 ml/l) and azadirachtin 1% EC (2 ml/l) in reducing the population of whitefly (3.91, 4.16, 5.16 per 15 leaves, respectively) and leafhopper (15.27, 33.91, 40.38 per 15 leaves, respectively). They also stated that *B. bassiana* and *Lecanicillium lecaii* (Zimm.) each at 5 g/l was relatively less effective in managing the population of sucking pests.

Kodandaram *et al.* (2017) carried out an experiment in IIVR, Varanasi on three pest management modules *viz.*, biointensive module ($M_1$), integrated module ($M_2$), chemical module ($M_3$) and control ($M_4$) against major insect pests of okra including leafhopper (*A. biguttula biguttula*), whitefly (*B. tabaci*) and shoot and fruit borer (*E. vittella* and *E. insulana*). The integrated module ($M_2$) comprising sprayings of chlorantraniliprole 18.5 % SC @ 0.15 ml/l at 25 DAS, NSKE 4% at 35 DAS, emamectin benzoate 5 % SG @ 0.5 g/l at 45 DAS, *Bt* @ 2 ml/l at 55 DAS and nimbecidine @ 5 ml/l at 65 DAS and their need based rotation was most effective in reducing the fruit borer damage (71.74 %) and yellow vein mosaic disease (17.75 %) with significant increase in the yield (177.7 q/ha) over control. However, in case of okra leafhopper, chemical module ($M_3$) consisting of several insecticidal components such as seed treatment with imidacloprid 70 % WS @ 3 g/kg seeds followed by spraying of thiamethoxam (Actara 25 % WG) @ 0.5 g/l at 25 DAS followed by spraying of indoxacarb (Kare 14.5 % SC) @ 0.5 ml/l at 35 DAS followed by spraying of dimethoate (Tafgor 30 % EC) @ 2 ml/l at 45 DAS followed by spraying of emamectin benzoate 5 % SG @ 0.5 g/l at 55 DAS followed by spraying of cypermethrin (Cyperguard 25 % EC) @ 1 ml/l at 65 DAS proved as the most effective with 74.26 per cent reduction over control.

Thrice application of *L. lecanii* 1.15 % WP + *Metarhizium anisopliae* 1.15 % WP (5 g/l each) was the most effective treatment in suppressing aphid population in okra recording only 6.73 aphids per leaf per plant (Palthiya and Nakat, 2017).

Roy and Sarkar (2017) investigated field effectiveness of different pest management modules [M-1: bio-intensive (application of neem cake at final land preparation and 3 weeks after sowing (WAS) @ 240 kg/ha, neem oil 0.3 % @ 2.5 ml/l at 6 WAS, *Bt* @ 2 g/l at 8 WAS, karanja oil @ 2 ml/l at 10 WAS); M-2: farmers' conventional package of practice (acephate 75 SP @ 0.75 g/l at 3 WAS, thiamethoxam 25 WG @ 0.3 g/l at 5 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 6 WAS, flubendiamide 35.39 SC @ 0.3 ml/l at 8 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 10 WAS); M-3: proposed IPM compatible bio-rational module (acephate 75 SP @ 0.75 g/l at 3 WAS, thiamethoxam 25 WG @ 0.3 g/l at 5 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 6 WAS, flubendiamide 35.39 SC @ 0.3 ml/l at 8 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 10 WAS) and M-4: adaptable package of practice (imidacloprid 17.8 SL @ 0.3 ml/l at 3 WAS, neemazol TS 5 % @ 2 ml/l at4 WAS, acetamiprid 20 SP @ 0.3 g/l at 5 WAS, methomyl 40 SP @ 1 ml/l at 6 WAS, indoxacarb 14.5 SC @ 0.75 ml/l at 8 WAS, lambda cyhalothrin 5 EC @ 0.75 ml/l at 10 WAS)] against major insect pests of okra and their impact on prevailing natural enemies. Mean per cent reduction of leafhopper population was the highest in $M_3$ followed by $M_4$ accounting for 59.33 and 42.84 per cent, respectively while, in case of whitefly, $M_3$ recorded the lowest number of nymphs and adults (2.01/ leaf) followed by $M_2$ (2.79/ leaf). $M_3$ registered the lowest mean population of *H. armigera* (0.17 larvae/ plant) along with lowest mean fruit damage (3.22 %) and highest yield (13.69 t/ha). Highest mean numbers of natural enemies *viz.,* coccinellids and spiders were encountered in $M_3$ (0.32 and 0.31/ plant, respectively).

Field experiment conducted by Vishnupriya and Muthukrishnan (2017) in two seasons revealed that three sprayings of spinetoram at fortnightly interval @ 45 g a.i/ha reduced the fruit borer damage to the tune of 81.60 and 82.20 per cent, respectively while the same toxicant applied at 54 g a.i/ha reduced the damage percentage to the extent of 83.90 and 83.60 per cent, respectively.

IPM modules comprising the components like seed treatment with 5 % NSKE, manual hoeing at 30, 50 and 70 DAS, two weekly foliar application of NSKE, one subsequent foliar applications of 5 per cent bitter apple extract, two foliar applications of emamectin benzoate with 10 days interval, one subsequent foliar application of indoxacarb, five releases of *T. chilonis* cards with 10 days interval from 40 DAS were quite effective in managing the shoot and fruit borer infestation in okra resulting a minimum of 6.76 and 2.89 per cent of shoot and fruit infestations, respectively as compared to the control plots (19.86 and 15.63 %, respectively) and farmers routine modules (seed treatment with imidacloprid @ 5 g/kg of seed, manual hoeing at 30, 50 and 70 DAS, three foliar applications of chlorpyrifos with 10 days interval, two foliar applications of deltamethrin with 10 days interval) resulted in 13.91 and 10.83 per cent infestations, respectively (Javed *et al.,* 2019).

Amongst the various modules tested by Mohod *et al.* (2019), three modules *viz.,* $M_1$ comprising of seed treatment with imidacloprid 48 FS @ 9 ml/kg seed, soil application neem cake @ 250 kg/ha at time of sowing, Installation of yellow sticky trap at 15 DAS (30 x 15cm size of foam sheet) at 2 opposite corner along crop canopy and 15 cm above crop canopy, cypermethrin 25 EC @ 0.4 ml/l at 30 DAS, followed by triazophos 40 EC @ 2 ml/l at 45 DAS, followed by fenpropathrin 30 EC @ 0.35 ml/l at 60 DAS, followed by acephate 75 SP @ 1.6 g/l+ spiromesifen 22.9 SC @ 1 ml/l at 75 DAS; $M_2$ including seed treatment with imidacloprid 48 FS @ 9 ml/kg seed, soil application neem cake @ 250 kg/ha at time of sowing, installation of yellow sticky trap at 15 DAS (30 × 15 cm size of foam sheet) at 2 opposite corner along crop canopy and 15 cm above crop canopy, cypermethrin 25 EC @ 0.4 ml + dimethoate 30 EC @ 2 ml/l at 30 DAS, followed by fenpropathrin 30 EC @ 0.35 ml/l at 45 DAS, followed by ethion 50 EC @ 2.5 ml/l + quinalphos 25 EC @ 2 ml/l at 60 DAS, followed by lambda cyhalothrin 5 EC @ 1ml/l at 75 DAS and $M_3$ having soil application of neem cake @ 250 kg/ha at time of sowing, installation of yellow sticky trap at 15 DAS (30 × 15cm size of foam sheet) at 2 opposite corner along crop canopy and 15 cm above crop canopy, thiamethoxam 25 WG @ 0.2 g/l at 30 DAS, followed by fenpropathrin 30 EC @ 0.35 ml/l at 45 DAS, followed by lambda cyhalothrin 5 EC @ 1 ml/l at 60 DAS, followed by triazophos 40 EC @ 2 ml/l + dicofol 18.5 EC @ 2.7 ml/l at 75 DAS were found effective. $M_1$, $M_2$ and $M_3$ witnessed 5.07, 5.31 and 5.79 leafhoppers per leaf, respectively.

Patil *et al.* (2020) experimented on efficacy of several IPM modules in Dharwad, Karnataka. Among all the modules tested, the chemical module (azardirachtin 10000 ppm @ 1 ml/l, dimethoate @ 1.7 ml/l, thiamethoxam 25 WG @ 0.2 g/l, chlorantrinilipole 20 SC @ 0.25 ml/l) recorded significantly lesser fruit infestation (7.24 %). The IPM module comprising azardirachtin 10000 ppm @ 1 ml/l, *L. lecani* @ 5 g/l, chlorantrinilipole 20 SC @ 0.25 ml/l recorded 14.14 tonnes/ha fruit yield with highest B:C ratio of 3.71 against shoot and fruit borer.

Nath *et al.* (2020) reported that application of malathion 50 EC @ 0.05 % along with yellow sticky trap was the most effective in Assam condition in reducing both whitefly and leafhopper population to 2.08 and 3.98 per leaf, respectively after three weeks of appearance of the initial pest population.

According to Borkakati and Saikia (2020) minimum fruit damage of 8.17 per cent was obtained in chemical control plots including six sprays of deltamethrin (Decis 2.8 EC) @ 0.5 ml/l as against 9.06 per cent in IPM plot (installation of yellow sticky traps @ 1/ 30 $m^2$ at 15 DAS against *B. tabaci* and *A. b. biguttula*; three releases of *T. chilonis* @ 50,000/ ha/ week against fruit borer at bud initiation stage; installation of light trap @ 1/ 500 sq.m at 15 DAS of okra against adult lepidopteran pests; removal and destruction of infested fruits/shoots, rouging of yellow vein mosaic infested plants and need based application of insecticides i.e. two sprays of malathion 50 EC @ 2 ml/l).

*M. anisopliae* and *B. bassiana* both at $1 \times 10^8$ concentrations were quite promising in reducing the population of aphid (54.60 and 48.20 %, respectively) and leafhopper (90.6 % and 100 %, respectively) after ten days of spraying in okra and also there was no harmful effect on their coccinellid predators (Ebadah *et al.*, 2020).

Spinotetram 0.8 % GR @ 70 g a.i/ha reported to be the best treatment against rice yellow stem borer, with 86.52 and 88.43 per cent reduction in dead heart and white ear head, respectively and it was at par with its median dose of 65 g a.i/ha with 80.86 and 84.75 per cent reduction, respectively (Kumar *et al.*, 2020).

Spiromesifen 22.9 % @ 500 ml/ha showed very good performance in Punjab condition with least mite population (1.41/ 2cm$^2$ leaf area) and it was at par with its median (375 ml/ha) and lowest doses (250 ml/ha) with mite population of 1.71 and 1.93 per 2 cm$^2$ leaf area, respectively (Singh *et al.*, 2020).

Yadav *et al.* (2020) reported that insecticide in combination with entomopathogenic fungi (acetamiprid + *B. bassiana* + spinosad + destruction of infested shoots and fruits) was the best treatment in managing the leafhopper (1.51/ three leaves) and whitefly (1.85/ three leaves) population whereas, use of only biopesticides in combination with bio control agents (*B. bassiana* + NSKE + spinosad + *T. chilonis* + destruction of infested shoots and fruits) had proved as the best treatment in reducing the infestation by shoot and fruit borer with 1.38 per cent shoot damage and 2.26 per cent fruit damage, respectively.

According to Krishnan and Sreekumar (2021) spiromesifen 22.9 SC @ 96 g a.i/ ha was most effective and had persistent action in the field against mite whereas, pongamia oil soap reported an immediate control over the pest but its effectiveness declined with time and concentration. Among the botanicals tested pongamia oil soap @ 3 per cent was found most effective and followed by the pongamia oil soap @ 2 per cent with 5.44 and 6.94 mites per top 6 leaves per plant after 7 days, respectively after which the population of mite built up again.

## 2.2 Impact of various pest management modules on incidence and intensity of vector borne viral diseases of okra

### 2.2.1 Incidence of viral diseases in okra

More than 27 begomoviruses infect okra [Singh and Dutta (1986); Venkataravanappa, 2008]. Among them okra yellow vein mosaic disease (OYVMD) and okra enation leaf curl disease (OELCD) are major viral diseases. These two diseases are getting transmitted by an insect vector i.e., whitefly (*Bemisia tabaci* Gen) in semi-persistent manner. Both of the viruses belong to the genus *Begomovirus*, family Geminiviridae (Sanwal *et al.*, 2014).

### 2.2.2 Viral transmission by vector

*Bemisia tabaci* is one of the serious global pests that affect many agricultural crops, ornamental plants and weed species in addition to act as the sole vector of begomoviruses (Varma and Malathi, 2003).

A minimum of ten numbers of whiteflies required inducing cent per cent infection; though a single whitefly can transmit the OYVMD effectively. The female whiteflies are more efficient than the male whiteflies in transmitting the virus (Sanwal *et al.*, 2014).

### 2.2.3 Biotypes of *Bemisia tabaci*

Rosell *et al*. 1997 reported difficulty in differentiating species within the *B. tabaci* complex using morphological characteristics.

*B. tabaci* is a cryptic species complex (Perring, 2001) as they are morphologically indistinguishable but have distinctive biological, physiological and genetic variation.

The invasive biotype-B was first discovered in South India by Banks *et al.* (2001). As a result there was change in epidemiology of tomato leaf curl disease with year round severe infection in Karnataka.

Different methods used to identify and name the populations *viz.*, phylogenetic analysis of sequences of the 18S rRNA gene (Campbell *et al*., 1994), mitochondrial cytochrome oxidase subunit one (mtCOI) gene (Boykin *et al.*, 2007) and nuclear DNA ribosomal ITS1 regions (De Barro *et al.*, 2000).

Liu *et al*. (2012) stated that in *B. tabaci* more than 30 ‘biotypes’ have been named based on esterase profiles and biological assays *viz.*, mating compatibility and virus transmission ability.

Amongst several genetic groups only biotype-B was prevalent in tomato, okra, beans and cabbage at some places of Karnataka as cited by Reddy *et al*., 2012.

The B- biotypes have an increased host range of more than 600 plant species. As a result they spread the begomovirus rapidly to the new host crops which were previously unaffected (Sanwal *et al.,* 2014). Thus, understanding the population structure of *B. tabaci* is required to manage its spread and prevent the types of damage caused by its different populations.

### 2.2.4 Molecular characterization of *B. tabaci* and vector borne viral diseases in okra

According to Singh *et al.* (2012) mtCOI gene based phylogenetic analysis on whiteflies showed the presence of both Asia 1 and Asia 2 genetic groups from North India.

Sohrab *et al.* (2013) confirmed the presence of both yellow vein mosaic virus (YVMV) and enation leaf curl virus (ELCV) of okra in southern India which was caused by a begomovirus associated with DNA-β. They also stated that the plants showing yellow vein mosaic symptoms never develop leaf curl symptom and vice versa.

Emmanuel *et al*. (2020) revealed that the begomovirus isolates shared 98.2 to 99.7 per cent identity with enation leaf curl virus. Two distinct alpha satellite species, okra enation leaf curl alpha satellite and okra yellow vein mosaic alpha satellite were also identified in leaf samples showing enation leaf curl symptom.

Saravana *et al*. (2021) confirmed the presence of only Asia 1 genotype of *B. tabaci* throughout Tamil Nadu okra growing regions which was responsible for okra yellow vein mosaic disease.

Venkataravanappa *et al*. (2022) stated that okra enation leaf curl virus was a major disease in okra, brinjal and pointed gourd where the Asia-1 and China-3 cryptic species of *B. tabaci* was associated.

### 2.2.5 Effect of pest management modules on vector borne viral disease of okra

Ali *et al.* (2005) experimented on efficacy of three products i.e., neem extracts, effective microbes and imidacloprid for the control of *Bemisia tabaci* and OYVMD on okra. Among all the treatments, imidacloprid proved to be the best in controlling whitefly population (1.00/ leaf) and recorded 7.20 per cent disease incidence (PDI). They observed a significant positive correlation between okra yellow vein mosaic disease with minimum temperature and relative humidity.

Magar and Madrap (2010) studied the performance of different okra genotypes towards yellow vein mosaic virus in three seasons (*kharif*, *rabi* and summer) and noticed that Arka Anamika variety of okra was highly resistant to OYVMD in summer season whereas moderately resistant and susceptible in *rabi* and *kharif* season, respectively.

Yellow vein mosaic disease of okra resulted in yield loss ranging between 50 and 94 per cent (Ali *et al.*, 2012) whereas okra enation leaf curl disease (OELCD) caused yield loss between 80 and 90 per cent. The natural transmission of both the diseases occured through whitefly, *Bemisia tabaci*.

In Arka Anamika variety of okra the per cent disease incidence was mild with 26.50 per cent (*kharif*) of infection in Hyderabad condition (Vijaya and Joshi, 2013). This variety is highly resistant to OYVMD in summer season whereas in rainy season it was found to be moderately succeptible as reported by Solankey *et al*. (2014).

Chaudhary *et al*. (2016) evaluated the toxicity of four botanicals [*Azadirachta indica* A. Juss. (neem), *Allium sativum* L. (garlic), *Zingiber officinale* Rosc. (ginger) *Allium cepa* L. (onion)] against OYVMD and whitefly, *B. tabaci. Azadirachta indica* (neem) at 5 % concentration was the most effective as compared to other extracts in reducing the whitefly and OYVMV disease incidence under field condition.

Saurabh *et al.* (2016) screened several okra varieties against OYVMD at Ranchi, Jharkhand. As per their report, in *kharif* season Arka Anamika variety showed 16.47 and 57.26 per cent disease incidence during pre-flowering and post-flowering stage, respectively and thereby showing susceptible reaction to the virus whereas the same variety showed resistant reaction in summer season.

Rajesh *et al.* (2018) screened several hybrids of okra in Allhabad agroclimatic region where Arka Anamika was found to be resistant with a severity of 16.67 per cent but the rate of development of disease was much faster.

According to Bora *et al*. (2018) the incidence of okra yellow vein mosaic disease in Arka Anamika was 30 per cent in *kharif* season.

Poudel *et al.* (2018) screened several okra genotypes against yellow vein mosaic virus under different management practices at Nepal and witnessed the effectiveness of azadirachtin and imidacloprid with 50.29 and 40.18 per cent PDI, respectively.

Arka Anamika variety showed moderartely resistant reaction to OYVMD during summer season in Bihar condition with 41.93 per cent disease incidence. In the crop tenure, the incidence is higher particularly during April and May due to high temperature coupled with high rainfall (Kumari *et al*., 2018).

Neonicotinoids *viz.,* thiamethoxam 70 WS, imidacloprid 70 WS as seed treatment and spinosad 45 SC as foliar spray were quite effective in management of whitefly vector and thereby OYVMV in okra. (Manju *et al*., 2018)

Patra *et al.* (2018) stated that Arka Anamika variety was tolerant to OYVMD with 24.64 to 36.90 per cent incidence at 45 to 60 DAS.

In summer season, there was highly significant positive correlation ($p < 0.01$) between OYVMD incidence and maximum and minimum temperature. However, relative humidity (maximum) was negatively correlated with the disease incidence in Arka Anamika variety of okra (Sree *et al*., 2018). They also reported that there was an increase in per cent incidence towards the maturity of the crop.

Sarkar *et al.* (2019) from Bhubaneswar, Odisha cited 38.20 and 31.80 per cent disease incidene in Arka Anamika variety of okra in summer 2015-16 and 2017-18, respectively. In both the seasons this variety was referred as showing moderately susceptible reaction with coefficient of infection of 28.70 and 23.90, respectively.

According to the experimental results of Jamir *et al.* (2020) Arka Anamika variety was severely infested with OYVMD (75.00 %) in *kharif* rendering in severe yield loss.

Mandal *et al.* (2020) evaluated efficacy of suitable pest management module for management of OYVMD under west central table zone of Odisha. Seed treatment with imidacloprid 600FS @ 5 ml/kg of seed, installation of yellow sticky trap @ 50/ ha and spraying of acetamiprid 20 SP @ 0.3 g/l was found most promising among other modules to control whitefly population so as the OYVMD.

Panigrahi *et al.* (2020) experimented on effect of pest management module for management of yellow vein mosaic virus in okra under mid-central table land zone of Odisha. Seed treatment with imidacloprid 600FS @ 5 ml/kg of seed, installation of yellow sticky trap @ 50 traps/ ha and spraying of diafenthiuron 50 % WP @ 1 g/l resulted lowest mean population of whitefly (3.74/ 3 leaves) and also lowest OYVMD infected plant (3.70 %) with 41.74 per cent increase in yield over other treatments.

Hossain *et al.* (2021) studied the efficacy of various insecticides *viz.,* [imidacloprid 20 SL (Imitaf) @ 2.5 ml/10 liters water; profenophos 50 EC (Protect) @ 2.5 ml/l water; imidacloprid 70 WDG (Tiddo Plus) @ 0.2 g/l water and chlorpyriphos + cypermethrin 50 EC (Terbine) @ 0.2 ml/l] against whitefly in okra. Minimum number of whitefly per leaf (4.00, 4.33, 5.00) was recorded in the plots sprayed with Terbine @ 0.2 ml/l after 40, 60 and 80 DAS respectively. The lowest disease incidence was reported from plots treated with Imitaf 20 SL @ 2.5 ml/10 liters water (0, 15.01, 32.21 %) after 40, 60 and 80 DAS, respectively.

As per the reports of Patel *et al.* (2021) yellow vein mosaic virus and enation leaf curl virus were the two major viral diseases of okra affecting the fruit yield.

Saravana *et al.* (2021) used Arka Anamika variety as susceptible check in screening of several okra genotypes and reported that this variety was highly susceptible to OYVMD with more than 70 per cent disease incidence along with highest numbers of whitefly (8.05) per plant.

**2.3 Effect of different pest management modules on fruit quality of okra**

Biochemical parameters like crude protein content, reducing and non reducing sugars can be used as marker traits for resistance against *Earias* sp (Aziz *et al*., 2012).

Gautam *et al.* (2013) studied on the morphological and biochemical parameters of fruit against shoot and fruit borer of okra and reported that ascorbic acid and carbohydrate showed a positive non significant correlation with the infestation whereas phenol and potassium had negative significant effect. The ascorbic acid content and phenol content among different germplasms varied between 11.78-15.75 mg/ 100g and 2.38-6.01 mg/100g, respectively.

According to Dar *et al.* (2014) the brinjal cultivars which showed maximum shoot infestation by shoot and fruit borer, *Leucinodes orbonalis* Guenee also have maximum content of total moisture and minimum content of total ash, lignin and crude fibre.

Role of physico-morphic and biochemical characters of different okra genotypes with respect to population of okra shoot and fruit borer, *Earias vittella* was studied by Halder *et al.* (2015) at Indian Institute of Vegetable Research, Varanasi and as per their findings the total phenol content showed negative correlation with the borer incidence.

Vishnupriya and Muthukrishnan (2017) studied on the phytotonic and phytotoxic effect of spinetoram 12 SC on Okra, Brinjal and Tomato. They revealed that spinetoram 12 SC treated plants at 36, 45 and 54 g a.i/ha were significantly superior which registered the maximum plant height, chlorophyll content, stem girth and number of fruits per plant on okra, brinjal and tomato and lycopene content in tomato fruits. But there was no significant difference for crude fibre content in okra and brinjal fruits.

The total soluble solid (TSS) and ascorbic acid content of Arka Anamika variety of okra was 6.30 °Brix and 10.93 mg/100g, respectively at Lucknow condition (Kumar *et al.*, 2018).

According to Kovalikova *et al*. (2019) there was an increase in ascorbic acid content in white cabbage after the damage caused by flea beetle.

Different quality attributes of Arka Anamika variety was tested by Walling *et al.* (2020) in Nagaland condition. The results indicated that the ascorbic acid content was 22.30 mg/100g which was the maximum among the genotypes. Among other attributes tested, crude fibre and dry matter content was reported as 12.33 and 15.05 per cent, respectively.

Muhammad *et al.* (2021) reported that the resistant varieties in cotton possess relatively less soluble sugars, soluble proteins and more phenolics and flavonids as compared to the susceptible ones. Among sucking pests of cotton, thrips and leafhopper population had a significant and negative correlation with above mentioned four biochemical traits. However, whitefly shows significant positive correlation with total soluble sugar and soluble proteins and negative correlation with phenols, tannins and flavonoids.

## 2.4 Economics of pest management modules in okra

Yadav *et al.* (2008) evaluated the efficacy of biopesticides against pest complex of okra. The application of *B. thuringiensis* (*Bt*), azadirachtin, endosulfan, *Trichogramma* each at 15 days interval proved as the best treatment against shoot and fruit borer with maximum yield (79.70 q/ha).

Gosalwad and Wadnerkar (2009) conducted a field experiment to study the economics of several insecticides *viz.*, abamectin, spinosad, fipronil and endosulfan in managing insect pests of okra. They concluded that the highest net return was obtained with fipronil @ 11.25 g a.i./ha with a cost benefit ratio of 1:10.89.

Shabozoi *et al.* (2011) studied the effect of neem and tobacco based synthetic insecticides and use of natural enemies on insect pests of okra and reported maximum benefit-cost ratio in case of biosal application (4.13) followed by natural enemies (*Chrysoperla* + *Trichogramma*) (1.55) as compared to the application of synthetic insecticides (1.21).

Bio-efficacy of different insecticides and miticides was tested by Parmar *et al.* (2013) against pest complex of okra. Among the treatments, imidacloprid resulted highest yield (105.22 q/ha) followed by acetamiprid (100.16 q/ha) and deltamethrin + triazophos (89.78 q/ha). They concluded that the highest cost benefit ratio was registered in imidacloprid (1:22.08) followed by deltamethrin (1:14.22) and deltamethrin + triazophos (1:12.70).

Kumawat *et al.* (2014) worked on bioefficacy and economics of pest management modules against pest complex of okra. He concluded that among the modules tested, highest benefit-cost ratio was obtained in module comprising of alternate sparaying with dimethoate and endosulfan (28.52) followed by spraying with acephate + *M. anisopliae* + spinosad (19.24) whereas the lowest was obtained with spraying of *B.bassiana* + NSKE + spinosad + *T. chilonis* + destruction of infested shoots and fruits (6.90).

Singh and Gupta (2014) evaluated several modules against major insect pests of okra particularly jassids and shoot and fruit borer. The maximum marketable fruit yield (72.33 q/ha) with maximum cost benefit ratio (1:10.78) was recorded in farmers' practices module where only chemicals were sprayed.

Emamectin benzoate yielded maximum okra fruit (89.16 q/ha) followed by spinosad (85.0 q/ha) as per the report of Laichattiwar and Meena (2014). However, the maximum cost: benefit ratio was obtained from plots treated with fipronil (1:11.76) followed by spinosad (1:8.77).

According to the experiment conducted by Rajashekhar *et al.* (2016) the highest benefit cost ratio (3.91) was observed in NCIPM recommended module comprising of components *viz.*, sowing of OYVMV resistant hybrid MH-10, growing sorghum/maize on border, setting up yellow sticky traps @ 15/ acre, erection of bird perches @ 10/ acre, giving two sprays of NSKE @ 5 % , spraying imidacloprid 17.8 SL @ 40 g a.i/ha, installation of pheromone traps @ 2/ acre, releasing of egg parasitoid and need based application of chemical pesticides imidacloprid 17.8 SL @ 40 g a.i/ha, cypermethrin 25 EC @ 200 g a.i/ha, quinolphos 25 EC @ 0.05 %, propargite 57 EC @ 850 g a.i/ha.

Amongst several modules evaluated by Pazhanisamy *et al.* (2019) two modules *viz.*, $M_1$ comprising of soil incorporation of neem cake @ 250 kg/ha, growing maize as a border crop, spraying of NSKE 5 % + panchagavya 3 % at 35 DAS, spraying of *Bt* (dipel) @ 0.3 % at 45 DAS, spraying of spinosad 45 % SC @ 120 ml/ha at 55 DAS, release of trichocard @ 2.5 lakhs/ ha at 60 and 75 DAS and pheromone funnel traps @ 15/ ha and $M_2$ including seed treatment with imidacloprid 70 WP @ 5 g/kg of seed, spraying of imidacloprid 17.8 SL @ 0.5 ml/l at 35 DAS, flubendiamide 39.35 % SC @ 200 g/ha at 50 DAS and emamectin benzoate 5 % SG @ 250 g/ha at 65 DAS were most effective against shoot and fruit borer of okra. $M_1$ and $M_2$ documented maximum fruit yield (10.95 and 10.55 t/ha, respectively) and the highest benefit cost ratio (3.55 and 3.22, respectively).

The IPM module comprising of installation of yellow sticky traps @ 1 / 30 $m^2$ at 15 DAS, three releases of *T. chilonis* @ 50,000/ ha/ week at bud initiation stage, installation of light trap @ 1/ 500 sq.m at 15 DAS, removal & destruction of infested fruits/shoots, rouging of YVMV infested plants and need based application of malathion 50 EC @ 2 ml/l and the farmer's practice module (only chemical control) registered maximum fruit yield of okra (102.2 q/ha and 98.57 q/ha, respectively) with highest cost benefit ratio of 8.46 and 7.98, respectively (Borkakati and Saikia, 2020).

Seed treatment with imidacloprid 600 FS @ 5 ml/kg of seed, installation of yellow sticky trap @ 50/ ha and spraying of acetamiprid 20 SP @ 0.3 g/l. yielded more okra fruits with highest benefit cost ratio (1.93) as stated by Mandal *et al.* (2020).

According to Patil *et al.* (2020) highest B:C ratio of 3.71 was recorded in IPM based module comprising of azardirachtin 10000 ppm @ 1.0 ml/l, *L. lecani* @ 5 g/l, chlorantriniliprole 20 SC @ 0.25 ml/l followed by chemical module including spraying of azardirachtin 10000 ppm @ 1.0 ml/l, dimethoate 30 % EC @ 1.7 ml/l, thiamethoxam 25 WG @ 0.2 g/l, chlorantriniliprole 20 SC @ 0.25 ml/l (3.55) and bio-intensive module containing azardirachtin 10000 ppm @1.0 ml/l, *L. lecani* @ 5 g/l, *Bt* @ 1 ml/l, *B. bassiana* @ 5 g/l (1.91).

# MATERIALS AND METHODS

The current investigation for the dissertation entitled "Evaluation of various pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench" was conducted in the premises of Central Research Station affiliated to Odisha University of Agriculture and Technology, Bhubaneswar in the district Khordha, Odisha. The crop was raised following the norms standardised by standard package of practices. The materials used and the methodologies adopted during the course of investigation to study the efficacy of different pest management modules on insect pests and their natural enemies, incidence/ intensity of vector borne viral diseases, fruit quality and to assess the economics are elaborated in this chapter.

**3.1 Location, soil characteristics and weather condition of experimental site**

The designated experimental plot was located at field site of Department of Entomology, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar. The experimental plot was situated in a medium land area of the Central Research Station (20$^{\circ}$ 15'' N, longitude of 85$^{\circ}$ 52''E) at an elevation of 25.9 m above mean sea level and at 64 km west of Bay of Bengal. The plot possessed sandy loam textured soil recording an average pH of 6.9. The plot had proper access to irrigation facilities and was well endowed with drainage facilities. The climate of Bhubaneswar is sub-tropical and the city experiences an average annual rainfall of 1500 mm. Monsoon generally coincides with the second week of July in the *kharif* season with its peak during August to September. The maximum temperature of 34 to 40 $^{\circ}$C remains for a period of two months during May and June and from 13 to 15 $^{\circ}$C during December to January. However, high temperature of around 42 $^{\circ}$C persists in the month of May. The relative humidity ranges from 57.5 to 91.5 per cent. The detailed meteorological data of the locality during the experimental period is presented in Appendix-I.

**3.2 Agronomical practices**

The experimental plot was thoroughly tilled using a power tiller before the commencement of the experimental work. This served as the primary tillage operation which led to the pulverisation of larger clods which imparted a change in the structure of the experimental plot. After thorough tillage operation in the land, one cart load of well decomposed FYM (farm yard manure) was applied uniformly in the main plot. This was again followed by last round of ploughing to ensure thorough mixing of manure and soil.

Thereafter it was followed by levelling. Plots were divided with the size dimensions of 5 m long and 4 m width keeping furrows between treatments to function as irrigation cum drainage channel. A total of 20 sub plots were prepared to accommodate plants on which three pest management modules were applied along with a control plot in five replications (Fig. 1). The recommended fertilizer dose of 100:60:80 NPK kg/ha was applied in the form of urea, single super phosphate and muriate of potash, respectively. Half dose of recommended N and full dose of $P_2O_5$ and $K_2O$ was applied as basal dose along with need based irrigation. Then sowing was done in third and first week July in *kharif*, 2019 and 2020, respectively, whereas in the summer sowing was completed in the third week of March, 2021. The intercultural operations like weeding and top dressing (21 DAS) were done at appropriate crop growth period.

### 3.3 Harvesting

The fruits were harvested after 45 to 60 days after sowing (DAS). Pods were picked when they were still immature and green and have attained edible size. Every alternate days picking was done.

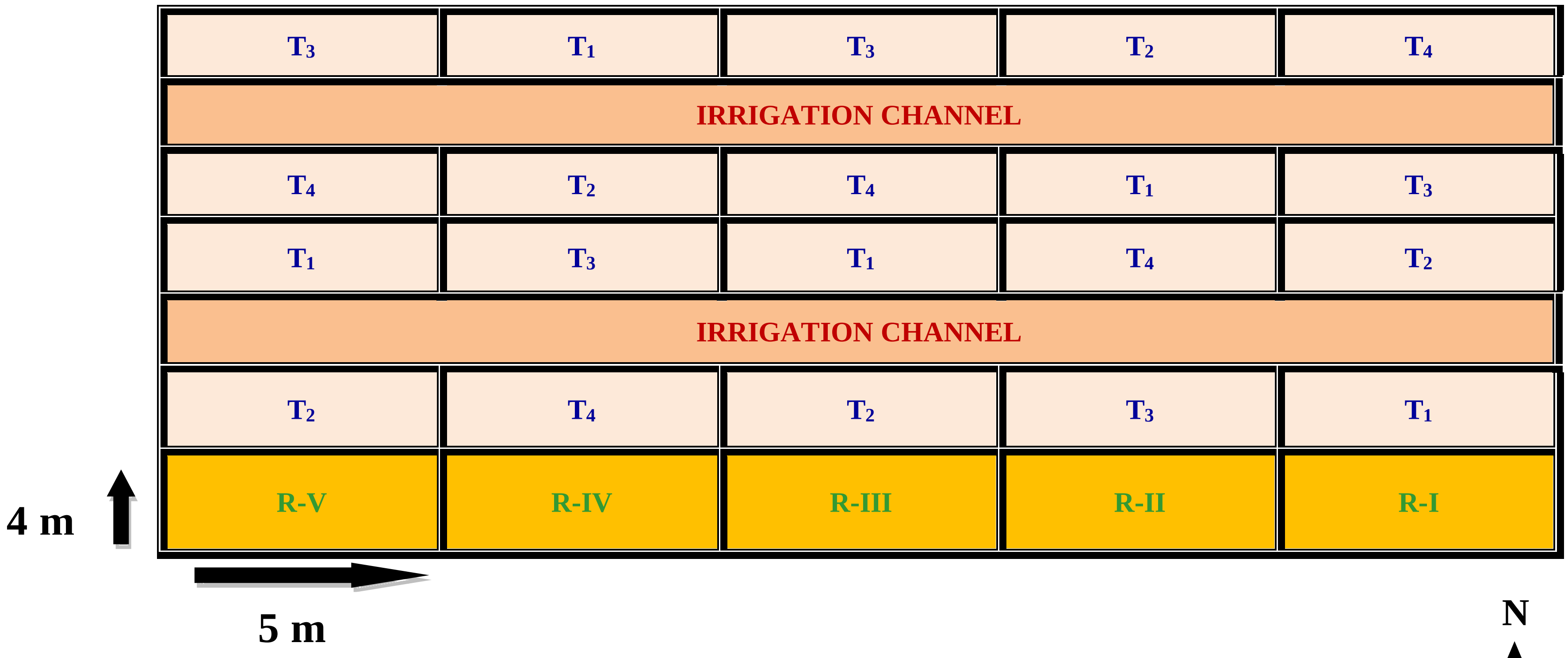
### 3.4 Experimental details

| | | |
|---|---|---|
| Crop | : | Okra |
| Season | : | *Kharif* (2019 and 2020) and summer, 2021 (Fig. 2 to Fig. 4) |
| Design | : | Randomized Complete Block Design (RCBD) |
| Replications | : | 5 |
| Treatments | : | 4 |
| Variety | : | Arka Anamika (Hybrid) |
| Spacing | : | 45 cm X 30 cm |
| Plot size | : | 5 m X 4 m |
| Fertilizer | : | 100 kg N, 60 kg $P_2O_5$ and 80 kg $K_2O$ |

Due to the pandemic Covid-19, the experiment during summer, 2020 could not be taken up for which it was taken up during summer, 2021. The details of the treatments are presented in Table 1 and Fig. 7 to 9.

### 3.5 Crop variety

During all the three seasons, okra hybrid variety "Arka Anamika" was taken as the test cultivar. Fruits were lush green, tender, long and free from spines having five to six ridges with delicate aroma. The crop duration was 130 to 135 days and resistant to okra yellow vein mosaic virus.



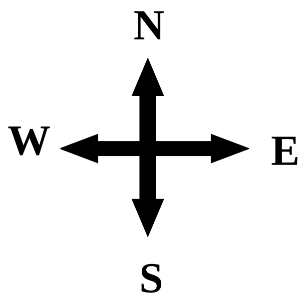




**Fig 1. Layout plan of the experiment**

**Table 1. Details of the treatments used in the experiment**

| Treatment no. | Treatment details |
|---|---|
| $T_1$ ($M_1$: Integrated Module) | Seed treatment with imidacloprid 600 FS @ 9 ml/kg seed<br>+ yellow sticky trap (@ 20/ ha) at 25 DAS<br>+ pheromone trap (@ 5/ ha) at 30 DAS<br>+ azadirachtin 0.03 % @ 5 ml/l after 30 DAS<br>+ flonicamid 50WG @ 0.4 g/l at 10 DAFiS<br>+ spinetoram 11.7 % SC @ 0.5 ml/l at10 DASS |
| $T_2$ ($M_2$: Bio-intensive Module) | Neem soap @ 10 g/l after pest appearance<br>+ pongamia soap @ 10 g/l at 10 DAFiS<br>+ NSKE 5 % @ 50 g/l at 10 DASS<br>+ *Lecanicillium lecanii* @ 5 g/l at 10 DATS<br>+ *Beauveria bassiana* @ 5 g/l at 10 DAFoS |
| $T_3$ ($M_3$: Chemical Module) | Seed treatment with imidacloprid 600 FS @ 9 ml/kg seed<br>+ flonicamid 50WG @ 0.4 g/l after pest appearance<br>+ diafenthiuron 50 WP @ 1 g/l at 10 DAFiS<br>+ spiromesifen 22.9 SC @ 1.25 ml/l at 10 DASS<br>+ emamectin benzoate 5 % SG @ 0.4 g/l at10 DATS |
| $T_4$ (Untreated Control) | |

(DAS-Days after sowing, DAFiS- Days after first spraying, DASS- Days after second spraying, DATS- Days after third spraying, DAFoS- Days after fourth spraying)

**Fig 2. A view of field experiment during *kharif*, 2019**

**Fig 3. A view of field experiment during *kharif*, 2020**

**Fig 4. A view of field experiment during summer, 2021**

### 3.6 Pests encountered

The efficacy of integrated pest management modules were evaluated against the major insect pests of okra like leafhopper, *Amrasca biguttula biguttula* (Ishida), whitefly, *Bemisia tabaci* (Genn.), aphids, *Aphis gossypii* Glov., red spider mite, *Tetranychus urticae* (Koch) and shoot and fruit borer *Earias vittella* (Fab.). The sucking pests are considered to be the most destructive during early growth period of okra and in later stage the crop is severely affected by the borers especially destroying the economic product meant for human consumption i.e., the fruits. The taxonomic position of these pests is mentioned in Table 2 and Fig. 5.

### 3.7. Natural enemies observed

During the course of investigation several natural enemies were recorded. The taxonomic position of these natural enemies is mentioned in Table 3 and Fig. 6.

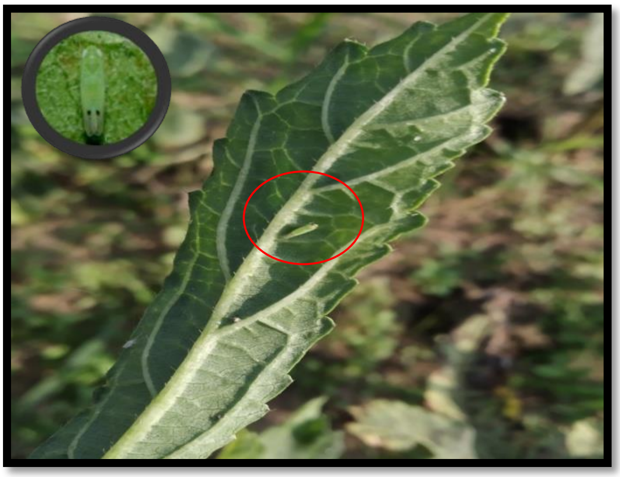
### 3.8 Installation of yellow sticky traps and pheromone traps

The yellow sticky traps (25 X 25 cm) were installed on 25 DAS at 30 cm above the crop canopy for monitoring of sucking pests *viz.*, whiteflies and aphids. The sticky traps were procured from Good Earth Nursery, Bhubaneswar (Fig. 11).

The pheromone traps were installed for monitoring of *E. vittella* adults in the field. The Ervit lure was procured from Gaiagen Technologies Private Limited, Bengaluru, Karnataka and installed @ 5 traps per hectare. The trap was installed on 30 DAS at 30 cm above the crop canopy and the data on the population of the *E.vittella* adults were recorded at weekly intervals. The height of the pheromone traps were adjusted according to the plant height periodically (Fig. 12).

### 3.9 Method of pesticide application

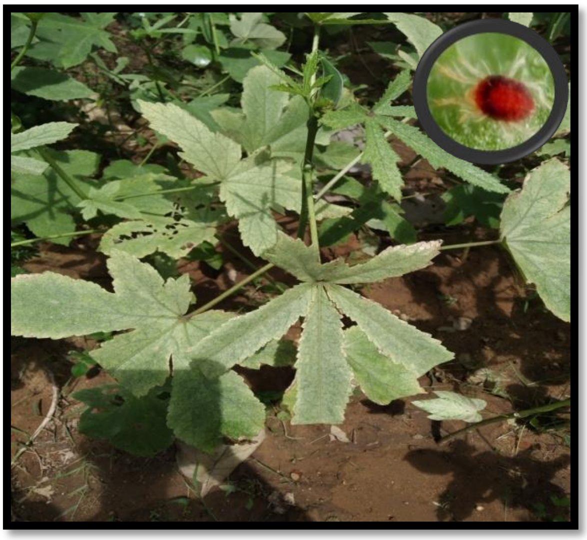
All the pesticides except seed treatment were applied in specified dosages in the form of foliar spray with the help of a 15 litre knapsack sprayer fitted with hollow cone nozzle. These were applied starting from 30 DAS up to fruit formation stage of the crop based on economic threshold level of the pest (Table 4). During application care was taken to obtain uniform coverage of pesticide in each plot and on each plant so as to avoid drifting of pesticides while spraying (Fig. 10).



**Leafhopper**

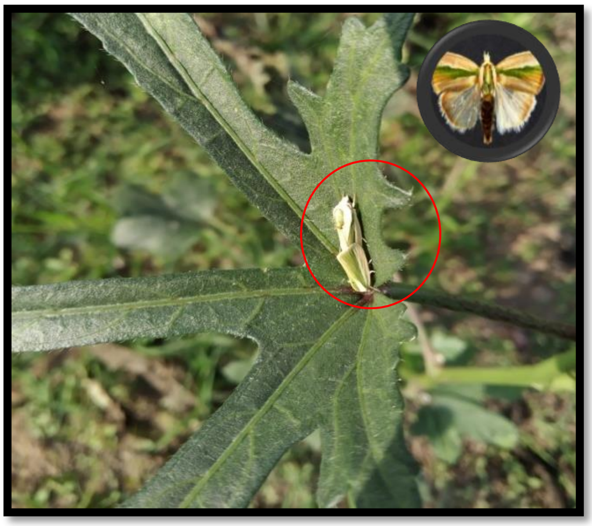
**Whitefly**

**Aphid**



**Two spotted spider mite**

**Shoot and fruit borer larvae**



**Shoot and fruit borer adults**

**Fig 5. Insect pests encountered during the experimental seasons**

*Micraspis discolor*

*Coccinella transversalis*

*Cheilomenes sexmaculata*

*Brumoides suturalis*

**Mixed population of spiders**

**Fig 6. Natural enemies encountered during the experimental seasons**


**Fig 7. Insecticides and biopesticides used in the experiment**

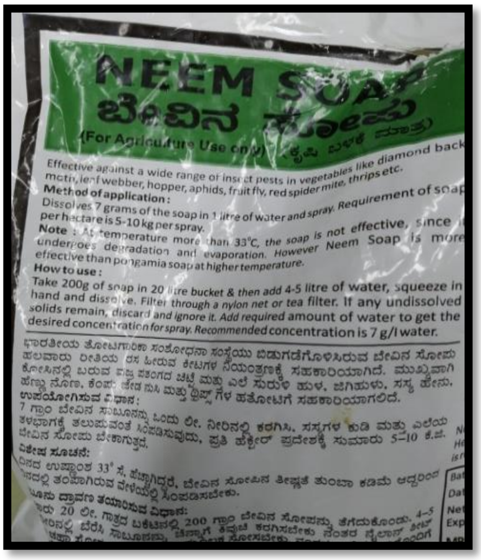




**Fig 8. Pongamia soap**

**Fig 9. Neem soap**

**Fig 10. Spraying of insecticides**

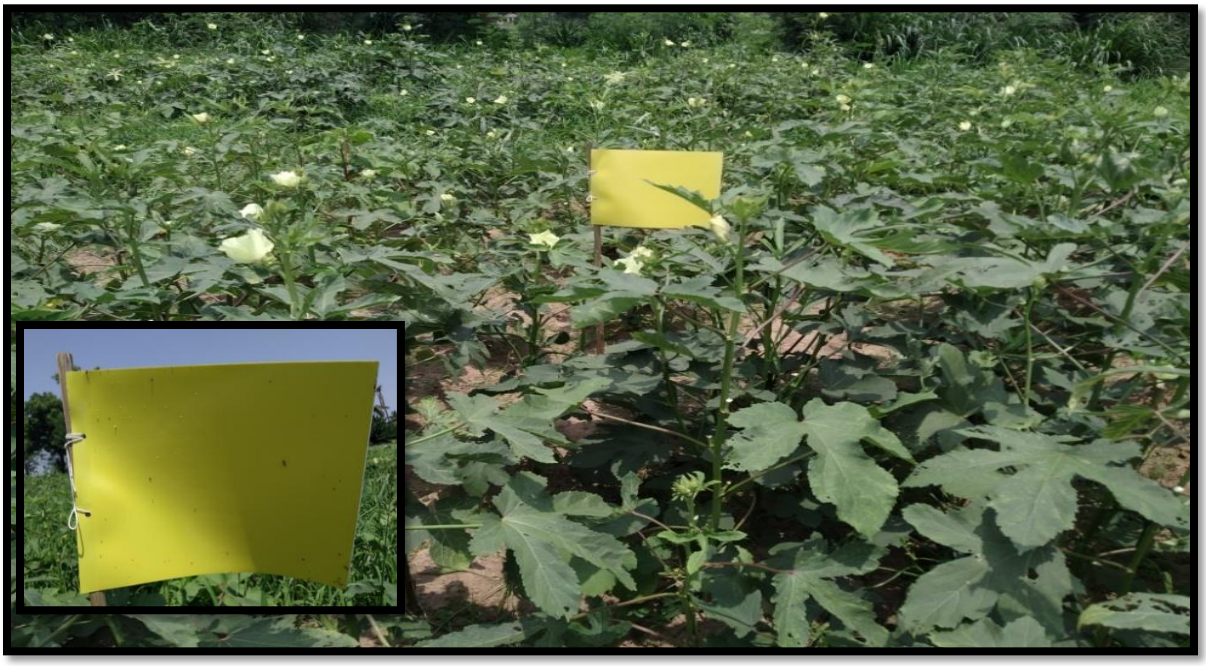


**Fig 11. Installation of yellow sticky trap in okra**


**Fig 12. Installation of pheromone trap (Ervit lure) in okra**

**Table 2. Taxonomic position of the insect pests encountered during the study period**

| Sl No. | Common name | Scientific Name | Family | Order |
|---|---|---|---|---|
| 1 | Leafhopper | *Amrasca biguttula biguttula* (Ishida) | Cicadellidae | Homoptera |
| 2 | Whitefly | *Bemisia tabaci* (Genn.) | Aleyrodidae | Homoptera |
| 3 | Aphid | *Aphis gossypii* Glov. | Aphididae | Homoptera |
| 4 | Shoot and fruit borer | *Earias vittella* (Fab.) | Noctuidae | Lepidoptera |
| 5 | Two spotted spider mite | *Tetranychus urticae* Koch | Tetranychidae | Acarina |

**Table 3. Taxonomic position of the natural enemies observed during the study period**

| Sl No. | Common name | Scientific Name | Family | Order |
|---|---|---|---|---|
| 1 | Ladybird beetle | *Coccinella transversalis* (Fab.) | Coccinellidae | Coleoptera |
| 2 | Ladybird beetle | *Micraspis discolor* (Fab.) | Coccinellidae | Coleoptera |
| 3 | Ladybird beetle | *Cheilomenes sexmaculata* (Fab.) | Coccinellidae | Coleoptera |
| 4 | Ladybird beetle | *Brumoides suturalis* (Fab.) | Coccinellidae | Coleoptera |
| 5 | Spider | Unidentified | | |

**Table 4. Economic threshold level (ETL) of major insect pests of okra**

| **Pest** | **ETL (**DPPQS, 2001**)** |
|---|---|
| Leafhopper | 2.5 nymphs/ leaf |
| whitefly | 4 adults/ leaf |
| Shoot and fruit borer | One infested plant/ metre row |
| Spider mite | 2 mites/ leaf |

### 3.10 Method of recording observations

Different techniques were employed for estimating the pest population. Incidence of different insect pests and the natural enemies were recorded at weekly interval from randomly selected 5 plants in the untreated control plot leaving behind the border rows. The observations were initiated after germination and continued up to the availability of insects until the crop attained maturity.

#### 3.10.1 Sucking pests:

Lower side of selected leaves were carefully examined for the presence of nymphs and adults of leafhopper, whitefly and aphid. The sampling technique for leafhoppers was given by Singh and Kaushik (1990) who examined five different population sampling techniques of cicadellids. According to them the best method out of the examined methods was to take the samples from three leaves, one each from the top, middle and bottom canopy, of five randomly selected plants for the sampling concerned with the sucking pests infesting the crops.

##### 3.10.1.1 Leafhopper and aphid

The population of nymphs and adult were recorded from five randomly selected plants per plot. Thereafter from each selected plant three leaves (one upper, one middle and one lower) were observed for the presence of leafhoppers and aphids. Pre-treatment observations and number of leafhoppers and aphids surviving beyond 5 and 10 days after treatment were recorded from each treatment. The procedure was repeated after each application of insecticide.

##### 3.10.1.2 Whitefly

Population of whitefly was also recorded in a similar fashion. The treated plots were observed during morning hours (before 8.00AM) at pre-treatment stage and at 5 and 10 days after each treatment.

##### 3.10.1.3 Mite

Similarly, the population of the two spotted spider mite, *Tetranychus urticae* Koch was recorded on three leaves each from the top, middle and bottom canopy of each plant by using 1 $cm^2$ windows made on the card board and at three places on each leaf and was expressed as number of mites per $cm^2$ (Nain *et al*., 2017) at pre-treatment stage and at 5 and 10 days after each treatment.

### 3.10.2 Shoot and fruit borer

Fruit infestation of shoot and fruit borer (*Earias vittella*) was estimated by counting the healthy fruits and damaged fruits (having symptoms like tiny fruits with holes, curved fruits with holes and excrement filled fruit). The per cent fruit borer infestation was computed by using the following formula.

$$\text{Per cent fruit damage (number basis)} = \frac{\text{Number of damaged fruits}}{\text{Total number of fruits observed}} \times 100$$

$$\text{Per cent fruit damage (weight basis)} = \frac{\text{Weight of damaged fruits}}{\text{Total weight of fruits observed}} \times 100$$

After recording of each observation, the damaged fruits were removed and destroyed. The observations were initiated after first symptom of pest and continued till the maturity of the crop. The per cent population reduction over control for shoot and fruit borer *Earias vittella* was calculated using the formula as given by Roy *et al*., 2014.

$$\text{Per cent reduction over control} = \frac{C - T}{C} \times 100$$

Where,
T = Population in treatment
C = Population in untreated control

### 3.10.3 Natural enemy

During the course of investigation, natural enemies like coccinellid beetles and spiders were recorded which were counted from five randomly selected plants per plot one day before and 5 and 10 days after each spray. Specimen encountered in field were collected and brought to the laboratory for identification.

### 3.11 Meteorological factors and their association:

Meteorological factors such as maximum and minimum temperature, morning and evening relative humidity, rainfall, bright sunshine hours and wind velocity that prevailed during the experimental period were recorded from the meteorological observatory of Odisha University of Agriculture and Technology, Bhubaneswar.

Correlation studies were carried out with the population of pests as well as with natural enemies to study the influence of meteorological factors on their population build up.

### 3.12 Observation on vector borne viral diseases

Soon after germination vigilant watch on any viral diseases was kept. Observations were taken at ten days interval after the incidence of first viral symptom. Ten plants were selected randomly from a plot and severity values of these plants were averaged to constitute the severity value of that particular plot. The impact of different pest management modules on vector-borne viral diseases i.e., okra yellow vein mosaic disease (OYVMD) (Fig. 13 to Fig. 15) had been assessed based on per cent disease incidence (PDI) and disease severity in each plot. PDI and disease severity was calculated using the methodology as suggested by Gangopadhyay *et al.* (2017).

$$\text{Per cent disease incidence (PDI)} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100$$

$$\text{Per cent disease severity/ intensity} = \frac{\text{Number of leaves showing symptom}}{\text{Total number of leaves}} \times 100$$

In order to know the transmission of OYVMD, whiteflies and infected diseased leaves were collected and subjected for molecular characterization.

### 3.13 Collection of insect vectors

The whiteflies were collected from the okra plants in the experimental field using an aspirator and killed by using cotton plugs dipped in ethyl acetate. The samples collected in the field were transferred to 5 ml vials containing 3/4$^{th}$ volume of 70 per cent ethyl alcohol. Then the vials were labelled and sealed with parafilm to prevent leakage of alcohol. These samples were stored at 4 °C until further use.

### 3.14 Collection of leaf samples infected with okra yellow vein mosaic disease (OYVMD)

Young leaves of okra showing characteristic yellow vein mosaic symptoms were collected in sterile polythene bags, labelled and stored at 4 °C until further use.

Fig 13. Young leaves infested with OYVMD

Fig 14. Whole plant infected with OYVMD

**Fig 15. Fruits harvested from OYVMD infected plants**

### 3.15 Molecular characterization of *Bemisia tabaci* and OYVMD infecting okra

#### 3.15.1 Preparation of sample for DNA isolation

The insects were removed from alcohol using a camel hair brush and sterilized in 10 per cent sodium hypochlorite solution followed by sterile distilled water and then placed on parafilm strip.

#### 3.15.2 DNA isolation from whitefly samples

- Whiteflies (10 nos.) were grounded in 100 µl of extraction buffer containing 2 per cent CTAB , 100mM Tris-HCl (pH-8.0), 1.4 M sodium chlorite, 20mM EDTA and 0.1 per cent of 2- mercaptoethanol using a sterile micropestle in a 1.5ml micro centrifuge tube.
- The samples were incubated at 56 °C for 2 hour followed by gentle swirling.
- Proteinase-K (2 µl) was added and incubated at 37 °C for 10 minutes.
- Equal volume of chloroform and isoamyl alcohol in the ratio of (24: 1) was added and mixed by inverting.
- The suspension was centrifuged at 10000 rpm for 10 min at 8 °C. The aqueous layer was collected and transferred to a fresh microcentrifuge tube.
- DNA was precipitated by adding an equal volume of chilled isopropanol and centrifuged at 10000 rpm for 10 min.
- The supernatant was discarded and DNA pellets were washed with 70 per cent alcohol and then the dried pellets were dissolved in 20 µl TE buffer.
- The dissolved DNA was stored at -20 °C.
- The quality of the DNA was assessed on 0.8 per cent agarose gel by loading 2 µl of DNA sample on above prepared agarose gel and allowed it to run at 90 volts for 30 min. Thereafter, the DNA bands were visualized under ultraviolet light.

#### 3.15.3 DNA extraction from virus infected plant leaves

- The CTAB extraction buffer (2%), 1.4M NaCl, 20mM EDTA, 100mM Tris-HCl (Ph-8.0), 1 % PVP and 1 % (v/v) 2-mercaptoethanol was preheated to 60 °C for 10 min.
- Approximately 0.5 g of diseased leaf tissue was grounded using liquid nitrogen in mortar and pestle. Mixed with three times (900 µl) of CTAB buffer and samples were heated at 60 °C for 10 to 30 min.
- Equal volume of choloform : isoamyl alcohol (24: 1) mixture added to the samples and mixed gently.
- The sample was centrifuged at 9500 rpm for 10 min.

- The top aqueous layer was transferred in to a micro centrifuge tube.
- 0.8 volume of cold (-20 °C) isopropanol was added and incubated at -20 °C at least for 2 hr.
- Again centrifuged at 4 °C for 15 min.
- The supernatant was discarded and then the pellets were washed in 0.5 ml (500 µl) of 70 per cent ethanol and finally the pellets were dried.
- Then pellets were suspended in 100 µl of 1× TE buffer and added 4 µl RNAse and kept it for 40 min at 37 °C.
- Equal volume of chloroform: isoamyl alcohol (24: 1) was added and centrifuged at 9500 rpm for 10 min.
- The supernatant was collected and pellets were discarded.
- Then 1/10$^{th}$ volume 7.5 M ammonium acetate and two volumes of 75 per cent ethanol added and stored at -20 °C.
- Centrifuged at 13000 rpm at 4 °C for 30 min and the supernatant was discarded and the pellets were dried.
- The pellets were suspended in 100 µl 1× TE buffer or sterile distilled water and stored at -20 °C.

**3.16 Polymerase chain reaction (PCR) amplification**

The genomic DNA of whitefly sample and OYVMV infected samples were diluted to a working concentration of 25 ng per µl and subjected to PCR amplification using following primers given in the Table 5 The DNA amplification was carried out in PCR thermocycler in 25 µl volume containing 2 µl genome DNA, 1 µl of 25 mMdNTP, 0.5 µl of 20 pM primer, 2.5 µl of 10 × PCR buffer, 2 µl of 25 mM $MgCl_2$ and 0.5 µl of 2 unit of Taq DNA polymerase. The amplification was carried out with the following programme. The amplicons were resolved in 1.5 % agarose gel using 0.5X tris-acetate-EDTA (TAE) buffer.

| | | |
|---|---|---|
| 95 °C for 5 min | Pre-denaturation | |
| 95 °C for 30 sec | Denaturation | 39 cycles |
| 58°C for 45 sec | Annealing | 39 cycles |
| 72°C for 1 min | Extension | 39 cycles |
| 72°C for 7 min | Final extension | |

**Table 5. List of primers used for amplification of *B. tabaci* and OYVMV**

| Specimen | Primer | Sequences 5’ to 3’ |
|---|---|---|
| *Bemisia tabaci* | MtCOI C1-J-2195<br>MTCOI L2-N-3014 | 5´ TTGATTTTTTGGTCATCCAGAAGT 3´<br>5´ TCCAATGCACTAATCTGCCATATTA 3´ |
| Okra yellow vein mosaic virus | BMf-783<br>BMr-784 | 5´ CCCCTGTGCGTGAATCCGT 3´<br>5´ SDVTBCMGCTGCGCGGCC 3´ |

**3.17 Agarose Gel Electrophoresis**

**3.17.1 Reagents and buffers**

**TBE buffer, pH 8.3 (5 X stock)**

| | |
|---|---|
| 0.45 M Tris base | 54.0 g |
| 0.45 M Boric acid | 27.5 g |
| 0.5 M EDT A, pH 8.0 | 20.0 ml |
| Distilled water | 500 ml |

The solution prepared after mixing was adjusted for the pH 8.3, sterilized by autoclaving and stored at room temperature

**Sample or loading buffer (6 X loading Dye):**

Bromophenol blue (0.25%)

Xylene cynol FF (0.25 %)

Glycerol (30 %)

**Ethidium bromide (0.5 mg/ml)**

Dissolved 0.5 mg of ethidium bromide in 1 ml of distilled water and stored at 4 °C in dark coloured bottle.

**Agarose gel (0.8 per cent)**

0.8 g of agarose in 0.5 × TBE

Gel frames and combs

UV trans illuminator (230-280 m)

**3.17.2 Protocol**

Agarose gel (0.8%) was prepared according to Lee *et al*. (2012). Agarose powder (0.8 g) was dissolved in 100 ml Tris Borate EDTA (1X TBE) buffer by boiling in a microwave oven until the agarose got dissolved completely. Agarose dissolved in water was allowed to cool and then 0.5 mg per ml of ethidium bromide was added prior to pouring in the casting tray. Gel casting tray and comb was washed with water and wiped with 70 per cent alcohol. The two open ends of the gel casting tray were sealed with cello tape to avoid leakage. After solidification of the agarose, the comb and cello tape was removed carefully and the casted gel was placed in the electrophoresis unit with wells facing towards the cathode and submerged with IX TAE buffer to a depth of about one cm.

### 3.17.3 Loading the DNA samples

A piece of paraflim was placed on the solid surface and 5 µl of genomic DNA was pipetted out on to a paraflim. Loading dye (bromophenol blue) 2 µl was added to the DNA samples and mixed thoroughly by pipetting up and down two to three times gently. The contents were loaded into wells carefully with the help of micropipette. 1 kb DNA ladder (Fermentas, Thermo Fisher Scientific, USA) was loaded as a standard marker. Cathode and anode were connected to a power pack and gel was run at the constant voltage (70 V). The gel was run for 60 min. until the tracking dye reached half of the gel and bands were visualized and documented in the gel documentation system.

## 3.18 PCR product purification

PCR products were purified using a DNA purification kit (HiPura™) according to the manufacturer's protocol.

| **Reagents** | **Volume** |
|---|---|
| PCR Binding Solution (SPB) | 280 µl |
| Wash Solution Concentrate (HPE) | 700 µl |
| Elution Buffer (ET) | 50 µl |

### 3.18.1 Procedure for DNA purification

- In a 2.0 ml capped collection tube 280 µl of PCR Binding Solution (SPB) to 50 µl of the PCR sample was added and mixed well by pipetting.
- The mixture was centrifuged at 12000 rpm for 1 min.
- The flow-through was discarded and replaced the column in the same collection tube.
- 700 µl diluted wash solution (HPE) was added to the column and centrifuged for one minute at 12000 rpm.
- The flow-through was discarded and replaced the column in the same collection tube.
- It was centrifuged at 12000 rpm for 1 min. To remove excess ethanol and transferred the column to a clean 2 ml uncapped collection tube.

- 50 µl of Elution Buffer was added to the column and incubated at room temperature for 1 minute.
- After incubation, the elute was transferred to a fresh capped 2 ml collection tube

### 3.19 DNA sequencing

The purified DNA of the mtCOI genes was sequenced using the facilities of a commercial firm (Heredity Lifesciences Pvt. Ltd., Bhubaneswar).

### 3.20 Analysis of mtCOI gene sequences

The mtCOI gene sequences similarity searches were performed by comparing sequence to mtCOI gene sequences of different insects available at the NCBI (National Center for Biotechnology Information, San Diego, CA, USA) by using the BLAST programme (Altschul *et al.*, 1990). Sequences showing more homology with mtCOI gene sequence characterized in the present study were retrieved from the database. Further, the multiple alignments were made using CLUSTAL-X (Thompson *et al.*, 1997) and a phylogenetic tree was generated using MEGA-11 software (Kumar *et al.*, 2016) by neighbour joining method with 1000 bootstrap replications estimate evolutionary distances between all pairs of sequences.

### 3.21 Observation on fruit quality

After application of all the treatments in a module the harvested fruits were taken to the laboratory of Department of Fruit Science and Horticulture Technology, Odisha University of Agriculture and Technology where analysis on total soluble solids (TSS), sugars (reducing sugar, non-reducing sugar) and ascorbic acid was done. The analysis on dry matter content and crude fibre content was carried out in the laboratory of Department of Entomology and Department of Soil Science, respectively. Total phenol content of the fruit sample was computed in laboratory of Central Horticulture Experiment Station (CHES)-IIHR, Bhubaneswar.

#### 3.21.1 Total soluble solids (TSS)

Total soluble solids content of matured fruit (Fig. 16) were determined with the help of Hand refractometer and values were expressed in terms of °Brix at room temperature.

### 3.21.2 Sugars

Sugar was estimated by Fehling 'A' and 'B' solution method for which ten grams of fruit pulp was macerated with small amount of distilled water and filtered through muslin cloth and volume was made up to 100 ml (Fig. 18).

#### 3.21.2.1 Total sugar

Ten ml of juice was hydrolyzed by adding 1N HCl and was transferred to 250 ml volumetric flask followed by addition of 30 ml distilled water to it. Then entire content was heated for 4 to 5 minutes over gas burner and was cooled by placing it in the water bath. Then in a 250 ml conical flask the entire content was transferred followed by addition of 2 to 3 drops of phenolphthalein indicator. Then the entire solution was titrated with 1N NaOH solution placed in a burette. The appearance of light pink colour indicates the end point which signifies the conversion of non-reducing sugars to reducing sugar present in the sample. Then the entire content was transferred to a burette and the same procedure was repeated as in case of estimation of reducing sugar. The total sugar was calculated by following the Shaffer Shomogi method as described by Ranganna (1977).

$$\text{Total sugar (\%)} = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre value} \times \text{Volume of sample}} \times 100$$

#### 3.21.2.2 Reducing sugars

Ten ml of filtered juice of okra fruit was taken in 100 ml volumetric flask and volume was made up to 100 ml by adding distilled water. The entire content was then transferred to a 100 ml burette. Then 5 ml of each Fehling's solution A and B was taken in a 250 ml conical flask to which 40 ml of distilled water was added. The flask containing solution was placed on electric heater for boiling. On appearance of first bubble 2-3 drops of methylene blue indicator were dropped. The Fehling's solution was then titrated against fruit juice. The appearance of brick red colour indicates the end point. The reducing sugar was calculated by following the Shaffer Shomogi method as described by Ranganna, (1977).

$$\text{Reducing sugar (\%)} = \frac{0.05 \times \text{Volume}}{\text{Titre value} \times 10} \times 100$$

Non reducing sugar (%) = (Total sugar – Reducing sugar) × 0.95

### 3.21.3 Ascorbic acid

Ascorbic acid was estimated by volumetric method using 2, 6- dichlorophenol indophenol dye according to procedure suggested by Ranganna (1977) and expressed as mg/ 100 g pulp. Five gram fruit pulp was dissolved in 3 per cent metaphosphoric acid and volume was maintained up to 100 ml to determine the ascorbic acid. Five mililitre aliquot were titrated against standardized 2,6- dichlorophenol indophenol dye. The end point marked by the appearance of pink colour which persisted at least 15 seconds. The ascorbic acid was expressed as mg of ascorbic acid per 100 g pulp of sample.

$$\text{Ascorbic acid (mg/ 100g pulp)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up (100 ml)}}{\text{Aliquot of extract for estimation} \times \text{Weight of sample}}$$

### 3.21.4 Total Phenol

Estimation of total phenols in okra fruits was done by using Folin-Ciocalteau reagent (FC reagent) as per the procedure outlined by Malick and Singh (1980). A sample of 0.5 g of fruit tissue was taken and grinded in 10 ml of ethanol with the help of pestle and mortar and the solution was filtered using filter paper from which one ml filtered solution was taken in a test tube and boiled at 100 °C till the solution was evaporated. One ml of distilled water was added to the test tube and from this 0.5 ml of solution was taken into another test tube to which 2.5 ml of distilled water, one ml of FC (Folin–Ciocalteu) reagent and 2 ml of sodium carbonate was added, cooled and finally absorbance was measured at 650 nm by using spectrophotometer. Total phenol content was calculated with the help of standard graph and expressed in microgram per g of fruits.

### 3.21.5 Crude fibre

Crude fibre content was analysed using the procedures suggested by Ranganna (1977). Two gram of dried material was boiled with 200 ml of sulphuric acid for 30 minutes with bumping chips to determine the crude fibre (Fig. 17). Then it was filtered through muslin cloth and washed with boiling water until washings were no longer acidic. Then it was again filtered with muslin cloth and washed with 25 ml of boiling 1.25 per cent $H_2SO_4$, three 50 ml portions of water and 25 ml alcohol. The residue was removed and transferred to ashing dish (Preweighed dish as $W_1$). Then the residue was dried for 2 hr at 130 ± 2°C and the ashing dish was then cooled in a desiccator and

**Fig 16. Fruit samples for analysis of Total soluble sugar**


**Fig 17. Crude fibre extraction**


**Fig 18. Sample preparation for analysis of Sugar**

weighed as $W_2$. Then it was again ignited for 30 minutes at 600 ± 15°C, cooled and reweighed as $W_3$.

$$\text{Crude fibre in ground sample (\%)} = \frac{\text{Loss in weight on ignition } (W_2\text{-}W_1) - (W_3\text{-}W_1)}{\text{Weight of the sample}} \times 100$$

**3.21.6 Dry matter content**

Dry matter content was determined by drying a known weight of the sample in an oven at 60 ± 5°C to a constant weight. The final weight of the sample after drying was weighed and expressed as per cent dry matter content (AOAC, 1984).

$$\text{Dry matter Content (\%)} = \frac{\text{Final dry weight}}{\text{Initial fresh weight}} \times 100$$

**3.22 Fruit yield**

The plot wise yield of healthy fruits was recorded at each picking from each of the treatments. The data of different pickings from each treatment was then pooled and the final plot yield was expressed in tonnes/ hectare (t/ ha). The per cent yield increase over control and avoidable yield loss percentage were calculated using the following formula:

$$\text{Increase in yield over control (\%)} = \frac{\text{Yield in treated plot} - \text{Yield in control plot}}{\text{Yield in control plot}} \times 100$$

$$\text{Avoidable yield loss (\%)} = \frac{\text{Yield in treated plot} - \text{Yield in control plot}}{\text{Yield in treated plot}} \times 100$$

**3.23 Economics of the treatments**

The incremental cost benefit ratio (ICBR) of each treatment were calculated taking into account the prevailing market price of inputs (labour charges for spraying and cost of insecticides) and outputs (selling price of produce).

**3.24 Statistical analysis**

To study the influence of meteorological factors on the population build up, correlation studies were carried out with the insect pests. The coccinellids and spiders observed during the period of investigation were correlated with weather parameter and also with aphid and leafhopper population.

Correlation coefficient was calculated with the following formula:

$$r = \frac{\sum xy - \frac{\sum x . \sum y}{N}}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{N}\right)\left(\sum y^2 - \frac{(\sum y)^2}{N}\right)}}$$

Where, r = Co-efficient of correlation

N = Number of observations

x = Mean

y = Independent variables

Then the correlation co-efficient (r) was tested for significance or non-significance by using the formula:

$$t = \frac{r}{\sqrt{(1 - r^2)}} \times \sqrt{n-2} \text{ with } (n - 2) \text{ d.f.}$$

The data on insect pests and natural enemies population, incidence/ intensity of vector borne viral diseases, several quality parameters and yield were subjected to statistical analysis following the procedures laid out by the Fischer's analysis of Variance technique given by Panse and Sukhatme (1967) at 5 % level of significance. The data were suitably transformed following Gomez and Gomez (1984), analyzed statistically to arrive at meaningful conclusion.

# RESULTS

The investigation on "Evaluation of various pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench" was carried out at Central Research Station, Odisha University of Agriculture and Technology, Bhubaneswar, Khordha, Odisha. Field and laboratory experiments were conducted during the course of investigation. The results so obtained from various experiments have been presented in this chapter under pertinent headings and sub headings.

Prior to evaluation of the pest management modules the incidence of insect pests and natural enemies associated with the crop and their relation to the weather parameters during the study period has been recorded and detailed below.

## 4.1. Seasonal incidence of major insect pests of okra and their natural enemies in relation to weather factors

### 4.1.1 Leafhopper, *Amrasca biguttula biguttula* (Ishida)

The activity of *A. biguttula biguttula* on okra crop was observed throughout the cropping period during *kharif*, 2019. The pest was initially noticed on the crop on first week of August (31$^{st}$ SMW) with a population density of 0.53 per leaf. The leafhopper population increased with the advancement of crop growth stage with a highest population count of 8.14 leafhoppers per leaf during 35$^{th}$ SMW (fifth week of August) and remained at moderate densities (1.43 to 7.98 leafhoppers per leaf) in the rest of the experimental period with a declined trend towards the crop maturity stage (Table 6).

Similar trend was noticed as regards to leafhopper population which was observed between 29$^{th}$ and 40$^{th}$ SMW during *kharif*, 2020. The peak activity (11.88 leafhoppers/ leaf) was recorded on 36$^{th}$ SMW i.e., first week of September on 60 days old crop (Table 7).

The incidence of leafhopper on the crop commenced from first week of April, which rapidly increased and attained its peak at 22$^{nd}$ SMW (last week of May) with a mean population density of 14.30 leafhoppers per leaf (Table 8) during summer, 2021. Thereafter, the population started declining slowly with a mean leafhopper density of 9.76 per leaf observed in third week of June (25$^{th}$ SMW).

The correlation analysis between different weather parameters and *A. biguttula biguttula* population (Table 9 to Table 11) showed that during *kharif*, 2019 the leafhoppers had positive but non-significant correlation with maximum temperature whereas during *kharif*, 2020 and summer, 2021 it was having negative correlation. The minimum temperature had negative but non-significant correlation with leafhoppers during *kharif*, 2019 and *kharif*, 2020 whereas in summer, 2021 it exhibited positive significant (r= 0.577) correlation. Morning relative humidity had positive and non-significant correlation with leafhopper population during *kharif*, 2020 and summer, 2021 however, during *kharif*, 2019 it had negative effect. However, leafhopper had a significant positive correlation with evening relative humidity (r = 0.618) during summer, 2021 and non significant positive correlation during *kharif*, 2019 and 2020, respectively. Rainfall exhibited a positive but non-significant correlation in all the three seasons. *A. biguttula biguttula* population had positive non-significant correlation with bright sunshine hours during *kharif*, 2019 and negative non significant effect during *kharif*, 2020 and summer, 2021. Wind speed showed a significant negative correlation (r= -0.688 and r= -0.667) during *kharif*, 2019 and *kharif*, 2020, respectively but it was non-significant in summer, 2021.

**4.1.2 Whitefly, *Bemisia tabaci* (Gennadius)**

*B. tabaci* infestation on okra initiated at 15 DAS during first week of August (31$^{st}$ SMW). The peak population of the pest (7.80/ leaf) was recorded in the second week of September (37$^{th}$ SMW) and started declining thereafter recording a minimum population of 1.69 per leaf on 42$^{nd}$ SMW (third week of October) during *kharif*, 2019 (Table 6).

The whitefly infestation appeared at 15 DAS during *kharif*, 2020 and similar trend in incidence was noticed as recorded during *kharif*, 2019. The population of whiteflies ranged from 0.24 to 7.92 per leaf during 29$^{th}$ to 40$^{th}$ SMW (Table 7). The population was as high as 7.92 adult whiteflies per leaf on 35$^{th}$ SMW (last week of August), which then declined towards crop maturity with a population of 1.85 per leaf at the final harvest i.e., on 40$^{th}$ SMW (first week of October).

The crop season summer, 2021 witnessed very high activity of whiteflies on the crop particularly during the early growth stages of the crop (35 to 55 DAS) with the population ranging from 0.20 to 8.46 whiteflies per leaf from 14$^{th}$ to 25$^{th}$ SMW (1$^{st}$ week of April to 3$^{rd}$ week of June). The peak activity was observed on 19$^{th}$ SMW (8.46 whiteflies/ leaf) and remained very active for the subsequent three SMWs and thereafter it started declining (Table 8).The correlation between different weather parameters and *B. tabaci* population was worked out (Table 9 to Table 11). The whiteflies had no significant correlation with any of the weather parameters.

**4.1.3 Aphids, *Aphis gossypii* (Glover)**

The aphids were active on okra from 32$^{nd}$ to 42$^{nd}$ SMW i.e., from second week of August to third week of October (Table 6) during *kharif*, 2019. The pest appeared during second week of August (2.37 aphids/ leaf) which showed a variable trend. Maximum population of aphids i.e., of 26.37 per leaf was recorded during fifth week of August. Then again the population reached to 15.51 and 18.82 per leaf during 37$^{th}$ and 38$^{th}$ SMW, respectively after which a declining trend was observed. Again the population reached to 11.72 per leaf during 40$^{th}$ SMW (first week of October) and thereafter it declined.

During *kharif*, 2020 the activity of pest initiated from 29$^{th}$ SMW i.e., third week of July (1.33 aphids/ leaf) to 40$^{th}$ SMW i.e., first week of October (1.32 aphids/ leaf). The highest population of 28.62 per leaf of the pest was recorded during 36$^{th}$ SMW. Beyond that, the population pursued a decreasing trend although the activity did not stop altogether and the pest was present in sizeable numbers (Table 7).

During summer, 2021 the incidence of aphids commenced from second week of April, which rapidly increased and attained its peak on 20$^{th}$ and 21$^{st}$ SMW (second and third week of May) with a mean population of 14.05 and 14.60 aphids per leaf, respectively (Table 8). Thereafter, the population declined to a mean of 5.65 aphids per leaf during third week of June (25$^{th}$ SMW).

The simple correlation coefficient values (Table 9 to Table 11) suggested that, minimum temperature showed a noteworthy positive effect on pest population (r = 0.579) during *kharif*, 2020. However, rainfall had a significant negative effect (r= -0.609 and r= -0.633) on the population of aphid during *kharif*, 2019 and *kharif*, 2020, respectively. The bright sunshine hour had significant positive impact (r= 0.593) on the aphid population during *kharif*, 2020 while remaining weather factors did not show any significant influence on aphids during the cropping seasons of *kharif*, 2019 and *kharif*, 2020. In summer, 2021 none of the weather parameter showed any significant effect on the population build up of aphids.

### 4.1.4 Two spotted spider mite, *Tetranychus urticae* Koch

The infestation of *T. urticae* was initially noticed at 55 DAS during 37$^{th}$ SMW (second week of September) with a lowest density of 2.16 mites per cm$^2$ of leaf during *kharif,* 2019. The pest population remained at moderate densities in the succeeding weeks, which increased rapidly and attained its peak at 40$^{th}$ SMW (first week of October) with a population density as high as 8.21 mites per cm$^2$ of leaf (Table 6).

The mite population, during *kharif*, 2020, was noticed from 34$^{th}$ SMW (fourth week of August) with population density of 3.10 mites per cm$^2$ of leaf, appearing two weeks early compared to previous season. Thereafter, the mite population increased to

**Table 6. Incidence of insect pests and natural enemies in okra along with the abiotic factors during *kharif*, 2019**

| Month | SMW | leafhopper/leaf | whitefly/leaf | aphid/leaf | Two spotted spider mite/$cm^2$ leaf | coccinellid/plant | spider/plant | % fruit borer damage |
|---|---|---|---|---|---|---|---|---|
| July | 29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| August | 31 | 0.53 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 32 | 1.43 | 1.25 | 2.37 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 33 | 3.84 | 3.61 | 9.82 | 0.00 | 0.16 | 0.00 | 0.00 |
| | 34 | 5.54 | 3.88 | 5.25 | 0.00 | 0.12 | 0.00 | 0.00 |
| | 35 | 8.14 | 5.62 | 26.37 | 0.00 | 1.04 | 0.28 | 0.00 |
| September | 36 | 7.50 | 6.76 | 5.02 | 0.00 | 0.16 | 0.40 | 0.00 |
| | 37 | 7.06 | 7.80 | 15.51 | 2.16 | 0.56 | 0.24 | 1.82 |
| | 38 | 6.07 | 6.72 | 18.82 | 5.10 | 0.80 | 0.56 | 4.92 |
| | 39 | 7.98 | 5.56 | 1.39 | 5.48 | 0.16 | 0.24 | 6.24 |
| October | 40 | 7.54 | 4.89 | 11.72 | 8.21 | 0.52 | 0.36 | 8.81 |
| | 41 | 6.72 | 2.76 | 8.74 | 7.76 | 0.44 | 0.32 | 12.46 |
| | 42 | 6.56 | 1.69 | 4.31 | 6.78 | 0.52 | 0.36 | 13.55 |

**Table 7. Incidence of insect pests and natural enemies in okra along with the abiotic factors during *kharif*, 2020**

| Month | SMW | leafhopper/leaf | whitefly/leaf | aphid/leaf | Two spotted spider mite/$cm^2$ leaf | coccinellid/plant | spider/plant | % fruit borer damage |
|---|---|---|---|---|---|---|---|---|
| July | 27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 29 | 0.38 | 0.24 | 1.33 | 0.00 | 0.04 | 0.00 | 0.00 |
| | 30 | 1.58 | 1.32 | 7.24 | 0.00 | 0.12 | 0.08 | 0.00 |
| August | 31 | 3.94 | 3.33 | 2.95 | 0.00 | 0.08 | 0.00 | 0.00 |
| | 32 | 5.16 | 4.48 | 8.30 | 0.00 | 0.16 | 0.16 | 0.00 |
| | 33 | 6.88 | 5.95 | 3.82 | 0.00 | 0.24 | 0.44 | 0.00 |
| | 34 | 7.35 | 6.96 | 2.61 | 3.10 | 0.28 | 0.64 | 0.00 |
| | 35 | 8.41 | 7.92 | 18.29 | 7.56 | 0.76 | 0.32 | 0.00 |
| September | 36 | 11.88 | 6.16 | 28.62 | 14.33 | 1.20 | 0.72 | 3.11 |
| | 37 | 11.10 | 5.20 | 20.47 | 10.30 | 0.88 | 0.48 | 7.85 |
| | 38 | 10.21 | 3.09 | 3.90 | 10.50 | 0.28 | 0.48 | 11.30 |
| | 39 | 10.33 | 2.09 | 8.64 | 13.91 | 0.44 | 0.36 | 12.81 |
| October | 40 | 9.98 | 1.85 | 1.32 | 14.42 | 0.20 | 0.32 | 17.06 |

**Table 8. Incidence of insect pests and natural enemies in okra along with the abiotic factors during summer, 2021**

| Month | SMW | leafhopper/leaf | whitefly/leaf | aphid/leaf | Two spotted spider mite/ $cm^2$ leaf | coccinellid/plant | spider/plant | % fruit borer damage |
|---|---|---|---|---|---|---|---|---|
| March | 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| April | 14 | 0.41 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 15 | 0.83 | 0.69 | 0.73 | 0.00 | 0.08 | 0.00 | 0.00 |
| | 16 | 3.52 | 3.94 | 4.13 | 0.00 | 0.16 | 0.00 | 0.00 |
| | 17 | 5.90 | 4.94 | 5.85 | 0.00 | 0.28 | 0.32 | 0.00 |
| | 18 | 8.14 | 5.65 | 8.61 | 3.52 | 0.48 | 0.24 | 0.00 |
| May | 19 | 8.81 | 8.46 | 11.14 | 5.05 | 0.80 | 0.36 | 0.00 |
| | 20 | 11.42 | 7.85 | 14.05 | 11.57 | 0.84 | 0.40 | 0.00 |
| | 21 | 11.32 | 5.55 | 14.60 | 16.28 | 1.04 | 0.56 | 0.00 |
| | 22 | 14.30 | 6.33 | 10.66 | 13.81 | 1.08 | 0.60 | 3.03 |
| June | 23 | 11.48 | 4.28 | 10.09 | 12.59 | 0.96 | 0.48 | 6.53 |
| | 24 | 10.62 | 3.28 | 5.52 | 12.49 | 0.60 | 0.60 | 13.95 |
| | 25 | 9.76 | 2.28 | 5.65 | 12.26 | 0.52 | 0.48 | 11.76 |

14.33 mites per $cm^2$ of leaf at 36th SMW (first week of September) and attained its peak population of 14.42 mites per $cm^2$ of leaf at 40th SMW (first week of October) (Table 7).

The incidence of *T. urticae* was recorded between 18th and 25th SMW with the population density ranging between 3.52 and 12.26 mites per $cm^2$ of leaf during summer, 2021. Maximum mite population of 16.28 per $cm^2$ of leaf was witnessed during 21st SMW (third week of May) after which there was a decline towards the end of cropping period (Table 8).

The correlation between *T. urticae* and weather parameters (Table 9 to Table 11) during *kharif*, 2019 revealed that mite population had significant negative correlation with minimum temperature (r= -0.811) and wind speed (r= -0.867) whereas rest of the weather parameters had non significant effect in all the three seasons.

**4.1.5 Shoot and fruit borer, *Earias vittela***

During the period of investigation shoot damage by *E. vittela* was not observed in any of the seasons. However, fruit damage was observed from second week of September (37th SMW) with 1.82 per cent damage in weight basis which increased gradually afterwards. Maximum damage of 13.55 per cent was recorded during third week of October (42nd SMW) during *kharif*, 2019 (Table 6); whereas during *kharif*, 2020 it was observed at 36th SMW with 3.11 per cent damage in weight basis which increased progressively and reached maximum of 17.06 per cent at the final harvest during 40th SMW (first week of October) (Table 7).

However, in summer, 2021 the damage percentage was relatively less compared to the two *kharif* seasons (Table 8). The fruit damage was noticed from last week of May i.e., 22nd SMW with 3.03 per cent damage in weight basis which reached its peak with 13.95 per cent damage in the 24th SMW.

The correlation analysis between the weather parameters and per cent fruit damage (Table 9 to Table 11) revealed that both maximum (r= -0.926) and minimum (r= -0.880) temperature had significant negative correlation with the shoot and fruit borer damage during *kharif*, 2020, respectively whereas during *kharif*, 2019 only minimum temperature (r= -0.913) had negative effect. Bright sunshine hours had also significant negative correlation (r= -0.995) whereas morning relative humidity had significant positive correlation (r= 0.939) during *kharif*, 2020. Both minimum temperature (r= 0.974) and wind speed (r= 0.955) had significant negative correlation with the damage of fruits in summer, 2021. Rest of the weather parameter had no significant effect on fruit damage.

**Table 9. Correlation analysis between weather parameters and insect pest population during *kharif*, 2019**

| Insect pest | *Kharif*, 2019 | | | | | | |
|---|---|---|---|---|---|---|---|
| | T (max) | T (min) | RH (M) | RH (E) | RF | BSH | Wind speed |
| **Leafhopper** | 0.069 | -0.346 | -0.022 | 0.131 | 0.001 | 0.199 | -0.688* |
| **Whitefly** | 0.070 | 0.264 | 0.099 | 0.165 | 0.100 | 0.026 | -0.231 |
| **Aphid** | 0.273 | 0.386 | -0.219 | -0.203 | -0.609* | 0.114 | -0.232 |
| **Two spotted spider mite** | 0.313 | -0.811* | -0.500 | -0.096 | -0.187 | 0.274 | -0.867* |
| **Shoot and fruit borer** | 0.191 | -0.913* | -0.207 | -0.232 | -0.268 | 0.380 | -0.654 |

***Significant at 5 % level**

**Table 10. Correlation analysis between weather parameters and insect pest population during *kharif* , 2020**

| Insect pest | *Kharif*, 2020 | | | | | | |
|---|---|---|---|---|---|---|---|
| | T (max) | T (min) | RH (M) | RH (E) | RF | BSH | Wind speed |
| **Leafhopper** | -0.247 | -0.063 | 0.389 | 0.201 | 0.015 | -0.088 | -0.667* |
| **Whitefly** | -0.143 | 0.175 | -0.030 | 0.086 | 0.141 | -0.102 | -0.270 |
| **Aphid** | 0.450 | 0.579* | -0.481 | -0.570 | -0.633* | 0.593* | -0.554 |
| **Two spotted spider mite** | 0.330 | 0.071 | 0.061 | -0.286 | -0.489 | 0.377 | -0.615 |
| **Shoot and fruit borer** | -0.926* | -0.880* | 0.939* | 0.915 | 0.572 | -0.995** | 0.848 |

***Significant at 5 % level   **Significant at both 5 % and 1 % level**

**Table 11. Correlation analysis between weather parameters and insect pest population during summer, 2021**

| Insect pest | Summer, 2021 | | | | | | |
|---|---|---|---|---|---|---|---|
| | T (max) | T (min) | RH (M) | RH (E) | RF | BSH | Wind speed |
| **Leafhopper** | -0.568 | 0.577* | 0.201 | 0.618* | 0.473 | -0.151 | -0.194 |
| **Whitefly** | 0.107 | 0.435 | -0.478 | 0.026 | -0.008 | 0.460 | 0.345 |
| **Aphid** | -0.083 | 0.434 | -0.159 | 0.220 | 0.143 | 0.342 | 0.396 |
| **Two spotted spider mite** | -0.580 | 0.485 | 0.679 | 0.571 | 0.412 | -0.456 | -0.058 |
| **Shoot and fruit borer** | -0.570 | -0.974* | 0.940 | 0.791 | 0.828 | -0.851 | -0.955* |

***Significant at 5 % level**

### 4.1.6 Coccinellids

Four species of coccinellids *viz.*, *Coccinella transversalis* Fabricius, *Cheilomenes sexmaculata* Fabricius, *Micraspis discolour* Fabricius and *Brumoides suturalis* Fabricius were found associated with sucking pests of okra crop. They were observed at very low densities during the early growth stages of the crop however, their population was found synchronising corresponding to their prey population. The coccinellids appeared from 33$^{rd}$ SMW with an initial density of 0.16 per plant (Table 6). Peak population of 1.04 coccinellids per plant was recorded at 35$^{th}$ SMW during *kharif,* 2019. Thereafter, the population started decreasing towards the crop maturity stage.

The coccinellids appeared from 29$^{th}$ SMW and remained throughout the cropping period at lower densities ranging from 0.04 to 1.20 coccinellids per plant during *kharif,* 2020. The highest population of 1.20 coccinellids per plant was observed during first week of September i.e., on 36$^{th}$ SMW (Table 7).

The coccinellids were observed between 15$^{th}$ and 25$^{th}$ SMW with population ranging from 0.08 to 1.08 per plant during summer, 2021. The highest population of 1.08 coccinellid per plant was recorded during 22$^{nd}$ SMW (fourth week of May) and thereafter the population declined (Table 8).

Among the different weather parameters, rainfall had significant negative effect (r= -0.665) on coccinellid population during *kharif,* 2019. Rest of the weather parameter had no significant effect on population during any of the cropping season. However, the correlation between aphid population showed a significant positive influence on the population build up of coccinellids in all the seasons i.e., *kharif,* 2019 (r= 0.877), *kharif,* 2020 (r=0.951) and summer, 2021 (r= 0.876) (Table 12 to Table 14).

### 4.1.7 Spiders

Predatory spiders preying upon sucking insects and soft bodied larvae were found associated in the okra crop. They were observed at very low densities during the cropping season but their abundance increased with corresponding increase in their prey population. The spiders appeared from 35$^{th}$ SMW with an initial density of 0.28 per plant (Table 6) reaching their peak population of 0.56 spiders per plant at 38$^{th}$ SMW during *kharif,* 2019. Thereafter the population declinedtowards the crop maturity stage.

**Table 12. Correlation analysis between weather parameters, natural enemies and their prey population during *kharif*, 2019**

| Natural enemy | *Kharif*, 2019 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **T (max)** | **T (min)** | **RH (M)** | **RH (E)** | **RF** | **BSH** | **Wind speed** | **Aphid** | **Leaf hopper** |
| Coccinellid | 0.346 | 0.106 | -0.426 | -0.483 | -0.665* | 0.410 | -0.255 | 0.877** | 0.370 |
| Spider | 0.668 | 0.164 | -0.354 | -0.530 | -0.335 | 0.639 | -0.119 | 0.139 | -0.659 |

***Significant at 5 % level   **Significant at both 5 % and 1 % level**

**Table 13. Correlation analysis between weather parameters, natural enemies and their prey population during *kharif*, 2020**

| Natural enemy | *Kharif*, 2020 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **T (max)** | **T (min)** | **RH (M)** | **RH (E)** | **RF** | **BSH** | **Wind speed** | **Aphid** | **Leaf hopper** |
| Coccinellid | 0.268 | 0.430 | -0.287 | -0.363 | -0.476 | 0.457 | -0.544 | 0.951** | 0.714** |
| Spider | -0.247 | -0.005 | 0.239 | 0.256 | 0.038 | -0.049 | -0.398 | 0.422 | 0.758** |

****Significant at both at 5 % and 1 % level**

**Table 14. Correlation analysis between weather parameters, natural enemies and their prey population during summer, 2021**

| Natural enemy | Summer, 2021 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **T (max)** | **T (min)** | **RH (M)** | **RH (E)** | **RF** | **BSH** | **Wind speed** | **Aphid** | **Leaf hopper** |
| Coccinellid | -0.422 | 0.493 | 0.135 | 0.528 | 0.303 | 0.045 | 0.039 | 0.876** | 0.922** |
| Spider | -0.788* | 0.268 | 0.677* | 0.746* | 0.535 | -0.654 | -0.328 | 0.092 | 0.767* |

***Significant at 5 % level   **Significant at both 5 % and 1 % level**

The spiders appeared from 30th SMW and remained throughout the cropping period at lower densities ranging from 0.08 to 0.72 spiders per plant during *kharif*, 2020. The highest population of 0.72 spiders per plant was observed during first week of September (36th SMW) (Table 7). However, at 31st SMW (first week of August) the incidence was nil and started increasing thereafter.

The spiders were observed between 17th and 25th SMW with population ranging from 0.32 to 0.60 per plant during summer, 2021. The peak population of 0.60 spider per plant was recorded both on 22nd SMW (fourth week of May) and 24th SMW (second week of June) and thereafter the population declined (Table 8).

Amongst different weather parameters, the maximum temperature had significant negative influence on spider population with r= -0.788 in summer, 2021. However, morning (r=0.677) and evening (r=0.746) relative humidity had significant positive effect on spider population in summer, 2021. Rest of the weather parameter had no significant effect on population during any of the cropping season. The correlation between leafhopper population showed a significant positive influence on the population build up of spiders during *kharif*, 2020 (r=0.758) and summer, 2021 (r= 0.767) but had no significant influence during *kharif*, 2019 (Table 12 to Table 14).

## 4.2 Effect of pest management modules against insect pests and natural enemies of okra

### 4.2.1 Leafhopper, *Amrasca biguttula biguttula* (Ishida)

A perusal of data presented in Table 15 showed that the pest management modules have significant effect on leafhopper population. During *kharif*, 2019 at 30 DAS both the chemical and integrated modules recorded lower leafhopper population of 2.32 and 2.41/ leaf, respectively, as compared to the population in biointensive module (3.44/ leaf) and untreated control (3.01/ leaf). Lesser number of leafhopper population was observed after five days of first spray at 35 DAS in all the treatments as compared to untreated control. Leafhopper population crossed the economic threshold level (ETL) in all the modules at ten days after first spray i.e., at 40 DAS. Five days after second spray i.e., at 45 DAS significant differences in population of *A. biguttula biguttula* among the modules was evident with the integrated and chemical modules recording lesser population of 2.38 and 2.82/ leaf, respectively, which were at par with each other while biointensive module was the least effective with higher population of 4.05 leafhoppers per leaf. At 50 DAS i.e., 10 days after second spray, chemical module recorded the lowest number of leafhoppers (3.94/ leaf), followed by integrated and biointensive module and the untreated control with population of 4.06, 5.45 and 7.24/ leaf, respectively. Similar trend in leafhopper population across different treatments was observed at 55 DAS (5 days after third spray).

There was an increasing trend in population of leafhopper after 60 DAS (10 days after third spray) ranging from 5.74 to 6.53 till 75 DAS in integrated module. The population increased to 9.37 per leaf in untreated control followed by 6.78 per leaf in biointensive module at 60 DAS. The incidence of leafhopper did not decline afterwards and remained active till the maturity stage of the crop. Five days after fourth spray i.e., at 65 DAS, chemical module retained its superiority by recording the lowest leafhopper population of 6.10 per leaf as against 10.10 in untreated control. Leafhopper population declined onwards from 70 DAS (10 days after fourth spray) across the treatments including untreated control. The biointensive module witnessed 7.86 and 5.68 leafhoppers per leaf at 75 (5 days after fifth spray) and 80 DAS (10 days after fifth spray), respectively. Based on mean leafhopper population, chemical module was superior to others except the integrated module with the minimum leafhopper population (4.18/ leaf) and the untreated control exhibited the maximum population of 7.11 leafhoppers per leaf. However, all the modules recorded lower population than untreated control.

Population of *A. biguttula biguttula* also differed significantly among the treatments during *kharif*, 2020 (Table 16). Lower population of leafhoppers i.e., 2.35, 2.46 and 3.32 per leaf was observed at 30 DAS in integrated, chemical and biointensive module, respectively as against untreated control recording the highest population of 3.58 leafhoppers per leaf. However, after five days of first spray at 35 DAS, the lowest population of leafhoppers (1.49 leafhoppers/ leaf) was noticed in chemical module followed by integrated module (2.26 leafhoppers/ leaf), which were significantly superior to biointensive module (3.08 leafhoppers/ leaf). All the modules varied significantly among themselves at 40 DAS i.e., ten days after first spray with chemical module recording the lowest leafhopper population of 2.45 per leaf. However, at 45 DAS (5 days after second spray), both chemical and integrated module were at par with each other recording 2.16 and 2.60 leafhoppers per leaf, respectively, and were superior to others. Ten days after second spray i.e., at 50 DAS, leafhopper population both in chemical and integrated module was following similar trend, which varied significantly with biointensive module. A similar but increased trend in leafhopper population was observed after 50 DAS in both integrated and chemical module as regarded to suppression of leafhopper population which continued up to 55 DAS i.e., five days after third spray.

As evidenced in the previous season the leafhopper population increased after 60 DAS in integrated module. The lowest population of 3.80 leafhoppers per leaf was recorded in chemical module as against the highest in untreated control (11.82/ leaf) at 60 DAS (10 days after third spray). Substantially higher leafhopper population was recorded at 65 DAS (5 days after fourth spray) in chemical module (4.72/ leaf) whereas, the population reduced to 7.10 per leaf in biointensive module as compared to 60 DAS. Biointensive module was the least effective among the modules tested at ten days after fourth spray (70 DAS) with a population of 7.29 leafhoppers per leaf. Similar trend in efficacy of biointensive modules was noticed even five days after fifth spray at 75 DAS. The mean leafhopper population harboured was 7.54 per leaf in the biointensive module after ten days of fifth spray at 80 DAS. Based on the cumulative mean leafhopper population, the chemical and integrated modules were superior to others by harbouring lower population of 3.66 and 4.32 leafhoppers per leaf as against 7.92 per leaf in untreated control.

Considering the pooled effect from both the experiments during *kharif* seasons (Table 17), all the modules tested significantly lowered the leafhopper population. Integrated and chemical modules exerted significant control on leafhopper population by recording 2.34 and 2.44 leafhoppers per leaf at 30 DAS and 2.03 and 1.73 per leaf at 35 DAS (5 days after first spray), respectively. The chemical module was most effective after ten days of first spray (40 DAS) with the lowest population of 2.69 leafhoppers per leaf and varied significantly with integrated module (3.44 leafhoppers/ leaf) and biointensive module (4.20 leafhoppers/ leaf). Significant difference in reduction of leafhopper population was also observed between integrated and biointensive module at 40 DAS. The integrated (2.49 leafhoppers/ leaf) and chemical module (2.49 leafhoppers/ leaf) were quite effective in managing the leafhopper population below ETL after five days of second spray i.e., at 45 DAS as compared to the biointensive module (4.35 leafhoppers/ leaf). Leafhopper population was quite fluctuating throughout the seasons and integrated module (3.84 leafhoppers/ leaf) and chemical module

**Table 15. Effect of pest management modules against leafhopper population during *kharif*, 2019**

| Treatment details | Average number of leafhopper nymphs and adults per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 2.32 (1.82) | 1.80 (1.67) | 3.12 (2.03) | 2.38 (1.84) | 4.06 (2.25) | 3.90 (2.21) | 5.74 (2.59) | 6.41 (2.72) | 6.53 (2.74) | 6.09 (2.65) | 4.68 (2.38) | 4.28 (2.26) |
| $T_2$: Bio-intensive module | 3.44 (2.10) | 2.65 (1.90) | 3.69 (2.16) | 4.05 (2.25) | 5.45 (2.54) | 4.96 (2.44) | 6.78 (2.78) | 8.08 (3.01) | 7.86 (2.97) | 7.86 (2.97) | 5.68 (2.57) | 5.50 (2.52) |
| $T_3$: Chemical module | 2.41 (1.84) | 1.96 (1.71) | 2.93 (1.98) | 2.82 (1.96) | 3.94 (2.22) | 3.65 (2.15) | 5.29 (2.50) | 6.10 (2.66) | 6.44 (2.72) | 5.84 (2.61) | 4.55 (2.33) | 4.18 (2.24) |
| $T_4$: Untreated control | 3.01 (2.00) | 3.81 (2.19) | 5.10 (2.47) | 6.29 (2.70) | 7.24 (2.86) | 7.86 (2.97) | 9.37 (3.22) | 10.10 (3.33) | 9.66 (3.25) | 9.28 (3.20) | 6.50 (2.73) | 7.11 (2.81) |
| SE (m) ± | **0.071** | **0.064** | **0.046** | **0.040** | **0.048** | **0.060** | **0.077** | **0.081** | **0.118** | **0.077** | **0.126** | |
| CD (0.05) | **0.22** | **0.20** | **0.14** | **0.12** | **0.15** | **0.18** | **0.24** | **0.25** | **0.36** | **0.24** | **0.39** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 16. Effect of pest management modules against leafhopper population during *kharif*, 2020**

| Treatment details | Average number of leafhopper nymphs and adults per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 2.35 (1.82) | 2.26 (1.80) | 3.75 (2.18) | 2.60 (1.89) | 3.61 (2.14) | 3.78 (2.18) | 4.62 (2.37) | 5.46 (2.54) | 6.66 (2.77) | 5.82 (2.61) | 6.60 (2.76) | 4.32 (2.28) |
| $T_2$: Bio-intensive module | 3.32 (2.08) | 3.08 (2.02) | 4.70 (2.39) | 4.65 (2.37) | 6.32 (2.70) | 5.56 (2.56) | 7.28 (2.87) | 7.10 (2.84) | 7.29 (2.88) | 6.64 (2.76) | 7.54 (2.92) | 5.77 (2.58) |
| $T_3$: Chemical module | 2.46 (1.86) | 1.49 (1.57) | 2.45 (1.85) | 2.16 (1.77) | 3.21 (2.04) | 2.93 (1.98) | 3.80 (2.19) | 4.72 (2.38) | 5.77 (2.60) | 5.16 (2.48) | 6.12 (2.67) | 3.66 (2.13) |
| $T_4$: Untreated control | 3.58 (2.13) | 4.00 (2.23) | 6.44 (2.73) | 7.38 (2.89) | 7.89 (2.98) | 9.14 (3.18) | 11.82 (3.58) | 9.84 (3.29) | 10.37 (3.37) | 8.24 (3.04) | 8.40 (3.06) | 7.92 (2.95) |
| SE (m) ± | **0.065** | **0.057** | **0.050** | **0.071** | **0.071** | **0.049** | **0.061** | **0.078** | **0.065** | **0.048** | **0.052** | |
| CD (0.05) | **0.20** | **0.18** | **0.15** | **0.22** | **0.22** | **0.15** | **0.19** | **0.24** | **0.20** | **0.15** | **0.16** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 17. Effect of pest management modules against leafhopper population during *kharif*, 2019 and *kharif*, 2020 (Pooled)**

| Treatment details | Average number of leafhopper nymphs and adults per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 2.34 (1.82) | 2.03 (1.74) | 3.44 (2.11) | 2.49 (1.87) | 3.84 (2.20) | 3.84 (2.20) | 5.18 (2.48) | 5.94 (2.63) | 6.60 (2.76) | 5.96 (2.63) | 5.64 (2.57) | 4.30 (2.27) |
| $T_2$: Bio-intensive module | 3.38 (2.09) | 2.87 (1.96) | 4.20 (2.28) | 4.35 (2.31) | 5.89 (2.62) | 5.26 (2.50) | 7.03 (2.83) | 7.59 (2.93) | 7.58 (2.93) | 7.25 (2.87) | 6.61 (2.75) | 5.64 (2.55) |
| $T_3$: Chemical module | 2.44 (1.85) | 1.73 (1.64) | 2.69 (1.92) | 2.49 (1.87) | 3.58 (2.13) | 3.29 (2.07) | 4.55 (2.35) | 5.41 (2.52) | 6.11 (2.66) | 5.50 (2.55) | 5.34 (2.51) | 3.92 (2.19) |
| $T_4$: Untreated control | 3.30 (2.07) | 3.91 (2.21) | 5.77 (2.60) | 6.84 (2.80) | 7.57 (2.92) | 8.50 (3.08) | 10.60 (3.40) | 9.97 (3.31) | 10.02 (3.31) | 8.76 (3.12) | 7.45 (2.90) | 7.51 (2.88) |
| SE (m) ± | **0.050** | **0.043** | **0.035** | **0.039** | **0.043** | **0.039** | **0.050** | **0.057** | **0.064** | **0.046** | **0.064** | |
| CD (0.05) | **0.14** | **0.12** | **0.10** | **0.11** | **0.12** | **0.11** | **0.14** | **0.16** | **0.19** | **0.13** | **0.19** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 18. Effect of pest management modules against leafhopper population during summer, 2021**

| Treatment details | Average number of leafhopper nymphs and adults per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 2.82 (1.95) | 2.14 (1.77) | 3.31 (2.07) | 2.52 (1.87) | 3.88 (2.21) | 3.50 (2.12) | 4.79 (2.40) | 6.08 (2.65) | 5.32 (2.51) | 5.34 (2.51) | 7.02 (2.83) | 4.25 (2.26) |
| $T_2$: Bio-intensive module | 3.41 (2.10) | 3.16 (2.03) | 4.80 (2.40) | 4.73 (2.39) | 6.48 (2.73) | 5.71 (2.59) | 8.46 (3.06) | 9.23 (3.19) | 7.28 (2.88) | 6.30 (2.69) | 8.27 (3.04) | 6.17 (2.65) |
| $T_3$: Chemical module | 2.44 (1.85) | 1.96 (1.71) | 2.89 (1.97) | 2.32 (1.81) | 3.15 (2.03) | 3.18 (2.03) | 4.56 (2.36) | 5.30 (2.51) | 5.62 (2.57) | 5.14 (2.47) | 6.85 (2.80) | 3.95 (2.19) |
| $T_4$: Untreated control | 3.56 (2.13) | 5.88 (2.62) | 7.71 (2.95) | 9.82 (3.29) | 10.53 (3.39) | 11.21 (3.49) | 12.20 (3.63) | 12.92 (3.73) | 11.90 (3.59) | 10.00 (3.31) | 8.60 (3.10) | 9.48 (3.20) |
| SE (m) ± | **0.056** | **0.068** | **0.085** | **0.060** | **0.064** | **0.082** | **0.101** | **0.081** | **0.060** | **0.103** | **0.044** | |
| CD (0.05) | **0.17** | **0.21** | **0.26** | **0.18** | **0.20** | **0.25** | **0.31** | **0.25** | **0.18** | **0.32** | **0.14** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

(3.58 leafhoppers/ leaf) were at par at 50 DAS i.e., ten days after second spray recording lower leafhopper population as compared to the biointensive module (5.89 leafhoppers/ leaf). A similar but increasing trend in leafhopper population was observed after 50 DAS.

Substantially higher leafhopper population was recorded in all the modules at 60 DAS (10 days after third spray) with the least population of 4.55 per leaf in chemical module, which was at par with integrated module (5.18/ leaf). Five days after fourth spray at 65 DAS leafhopper population increased to 7.59 and 5.41 per leaf in biointensive and chemical module, respectively. Similar trend was observed in chemical and biointensive modules at 70 DAS i.e., ten days after fourth spray. However, integrated module recorded lesser leafhopper population (6.60/ leaf) as compared to biointensive module (7.58/ leaf). Thereafter the population decreased in all the modules. In biointensive module the leafhopper population was reduced to 7.25 and 6.61 per leaf at five and ten days after fifth spraying i.e., 75 and 80 DAS, respectively. The seasonal mean leafhopper population indicated that chemical and integrated module were at par with each other in restricting the population by recording 3.92 and 4.30 leafhoppers per leaf, respectively, followed by biointensive module with 5.64 leafhoppers per leaf.

Similar trend in seasonal mean population among the modules was observed during summer, 2021 (Table 18). Chemical module with mean leafhopper population of 3.95 per leaf was best in keeping the population of leafhopper under check and the integrated module recorded a seasonal mean population of 6.17 per leaf. Integrated and chemical modules recorded 2.82 and 2.44 leafhoppers per leaf, respectively at 30 DAS which was reduced to 2.14 and 1.96 leafhoppers per leaf, respectively at 35 DAS (5 days after first spray). The chemical module was most effective after ten days of first spraying at 40 DAS with lowest population of 2.89 leafhoppers per leaf followed by integrated module (3.31 leafhoppers/ leaf) which were statistically on par with each other and both the modules were better than biointensive module (4.80 leafhoppers/ leaf). Five days after second spray i.e., at 45 DAS, leafhopper population crossed ETL in biointensive module recording 4.73 leafhoppers per leaf along with untreated control (9.82 leafhoppers/ leaf). Similar trend in leafhopper population was observed after ten days of second spray i.e., at 50 DAS. The population reduced to 5.71 and 3.50 per leaf in biointensive module and integrated module, respectively at 55 DAS (5 days after third spray).

Integrated module (4.79 leafhoppers/ leaf) and chemical module (4.56 leafhoppers/ leaf) were at par with each other at 60 DAS i.e., ten days after third spray and differed significantly from biointensive module (8.46 leafhoppers/ leaf). However, after five days of fourth spray at 65 DAS the leafhopper population increased to 5.30 and 9.23 per leaf in chemical and biointensive module, respectively. The leafhopper population ranged from 5.32 to 11.90 per leaf in different treatments at 70 DAS (10 days after fourth spray) which was lowered to 6.30 per leaf after five days of fifth spray at 75 DAS in biointensive module. Afterwards the population increased to 8.27 per leaf in biointensive module at 80 DAS (ten days of fifth spray). Incidence of leafhopper remained active up to 80 DAS and chemical module recorded the lowest population of 6.85 per leaf and the next best effective module was integrated module with 7.02 leafhoppers per leaf.

#### 4.2.2 Whitefly, *Bemisia tabaci* (Gennadius)

Among the various pest management modules tested against whiteflies, integrated and chemical modules proved to be superior to others by recording lower seasonal mean population of whiteflies (2.23 and 2.26/ leaf, respectively) against biointensive module (3.73 whiteflies/ leaf) during *kharif*, 2019 (Table 19). Integrated and chemical modules recorded 1.60 and 1.65 whiteflies per leaf, respectively, at 30 DAS, which was reduced to 1.34 and 1.06 per leaf, respectively after five days of first spray i.e., at 35 DAS. However, ten days after first spraying at 40 DAS the integrated module recorded the lowest population of 2.47 whiteflies per leaf. The integrated and chemical modules were at par with each other recording 1.38 and 1.83 whiteflies per leaf, respectively at 45 DAS (5 days after second spray). The chemical module witnessed the lowest whitefly population of 3.71 per leaf closely followed by integrated module (3.98 whiteflies/ leaf) at 50 DAS (10 days after second spray) whereas at 55 DAS i.e., five days after third spray, chemical module (2.75/ leaf) was the most effective but was at par with integrated module (3.25/ leaf).

Whitefly population reduced gradually and ranged from 1.53 to 2.87 per leaf during 60 to 80 DAS in integrated module. The chemical module with 3.20 whiteflies per leaf was better than biointensive module (5.52 whiteflies/ leaf) at 60 DAS (10 days after third spray). Five days after fourth spray i.e., at 65 DAS, chemical module also recorded the lowest whitefly population of 2.37 per leaf as against the highest population of 5.66 per leaf in untreated control. Similar efficiency in controlling the whitefly population was noticed at 70 DAS i.e., ten days after fourth spray. However, the biointensive module at 75 (5 days after fifth spray) and 80 DAS (10 days after fifth spray) experienced relatively higher whitefly population of 2.59 and 2.16 per leaf among the modules tested. Further, at 80 DAS there were no significant differences among the modules though they all varied significantly from untreated control.

Whitefly population varied significantly among the modules at 30 DAS during *kharif*, 2020 (Table 20). The integrated and chemical modules recorded less whitefly population of 2.92 and 3.22 per leaf, respectively as compared to the biointensive module with 4.09 whiteflies per leaf. Lesser whitefly population was observed after the first spray at 35 DAS (5 days after first spray) in all the modules as compared to untreated control. Similar trend in efficacy was observed at 40 DAS (10 days after first spray) while whitefly population crossed ETL only in untreated control (4.97whiteflies/ leaf). Whereas, at 45 DAS (5 days after second spray) significant differences in population of *B. tabaci* was evident among the modules with chemical module recording 1.17 whiteflies per leaf, which was significantly lower than the integrated (1.88/ leaf) and biointensive modules (3.61/ leaf). However, ten days after second spraying at 50 DAS integrated module (1.51 whiteflies/ leaf) retained its supremacy over other modules. All the modules worked efficiently to contain the whitefly population below economic threshold level but biointensive module with 4.92 whiteflies per leaf crossed ETL at 55 DAS i.e., five days after first spray but the integrated and chemical modules never crossed ETL during the cropping season.

The whitefly population reduced gradually and ranged from 0.74 to 2.80 during 60 to 80 DAS in integrated module. The chemical module with 1.54 whiteflies per leaf was superior to biointensive module (3.06 whiteflies/ leaf) at 60 DAS (10 days after third spray). Five days after fourth spray i.e., at 65 DAS, chemical and biointensive modules recorded 2.77 and 3.80 whiteflies per leaf, respectively. Biointensive module with 4.27 whiteflies per leaf was the least effective at 70 DAS (10 days after fourth spray). Similar trend was noticed for biointensive module even at 75 and 80 DAS i.e., five and ten days after fifth spraying. Based on mean whitefly population, biointensive module with 3.46 whiteflies per leaf was also the least effective one. However, both chemical (2.11 whiteflies/ leaf) and integrated (2.16 whiteflies/ leaf) modules were statistically at par with each other.

Considering the pooled effect of different modules over both the *kharif* seasons (2019 and 2020), it was evident that integrated and chemical modules recorded lower whitefly adults (2.19 each/ leaf) followed by biointensive module (3.60/ leaf) throughout the season (Table 21). The integrated (2.75 whitefly/ leaf) and chemical (3.17 whitefly/ leaf) modules managed the whitefly population so effectively that it didn’t cross the ETL throughout the cropping period, whereas, the biointensive module with 4.88 whiteflies

**Table 19. Effect of pest management modules against whitefly population during *kharif*, 2019**

| Treatment details | Average number of whitefly adults per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 1.60 (1.60) | 1.34 (1.53) | 2.47 (1.86) | 1.38 (1.54) | 3.98 (2.23) | 3.25 (2.06) | 2.87 (1.96) | 2.65 (1.91) | 1.84 (1.68) | 1.53 (1.58) | 1.62 (1.61) | 2.23 (1.78) |
| $T_2$: Bio-intensive module | 2.41 (1.84) | 1.97 (1.72) | 4.01 (2.24) | 3.74 (2.18) | 5.85 (2.62) | 5.45 (2.54) | 5.52 (2.55) | 4.15 (2.26) | 3.21 (2.04) | 2.59 (1.89) | 2.16 (1.77) | 3.73 (2.15) |
| $T_3$: Chemical module | 1.65 (1.63) | 1.06 (1.43) | 3.48 (2.11) | 1.83 (1.67) | 3.71 (2.16) | 2.75 (1.93) | 3.20 (2.05) | 2.37 (1.83) | 1.90 (1.70) | 1.31 (1.51) | 1.60 (1.61) | 2.26 (1.78) |
| $T_4$: Untreated control | 2.54 (1.88) | 3.69 (2.16) | 5.28 (2.50) | 5.80 (2.61) | 7.18 (2.86) | 7.94 (2.98) | 6.79 (2.79) | 5.66 (2.56) | 4.63 (2.37) | 4.00 (2.23) | 3.28 (2.06) | 5.16 (2.46) |
| SE (m) ± | **0.048** | **0.053** | **0.051** | **0.071** | **0.074** | **0.082** | **0.069** | **0.102** | **0.082** | **0.080** | **0.072** | |
| CD (0.05) | **0.15** | **0.16** | **0.16** | **0.22** | **0.23** | **0.25** | **0.21** | **0.32** | **0.25** | **0.25** | **0.22** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 20. Effect of pest management modules against whitefly population during *kharif*, 2020**

| Treatment details | Average number of whitefly adults per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 2.92 (1.98) | 1.65 (1.62) | 2.78 (1.94) | 1.88 (1.69) | 1.51 (1.57) | 2.96 (1.98) | 2.80 (1.94) | 2.69 (1.92) | 2.30 (1.81) | 1.50 (1.57) | 0.74 (1.31) | 2.16 (1.76) |
| $T_2$: Bio-intensive module | 4.09 (2.26) | 2.85 (1.96) | 3.22 (2.04) | 3.61 (2.14) | 3.90 (2.20) | 4.92 (2.43) | 3.06 (2.00) | 3.80 (2.19) | 4.27 (2.29) | 2.84 (1.95) | 1.54 (1.59) | 3.46 (2.10) |
| $T_3$: Chemical module | 3.22 (2.05) | 1.54 (1.59) | 2.94 (1.98) | 1.17 (1.47) | 2.62 (1.90) | 2.70 (1.92) | 1.54 (1.59) | 2.77 (1.94) | 2.50 (1.87) | 1.84 (1.66) | 0.41 (1.19) | 2.11 (1.74) |
| $T_4$: Untreated control | 3.95 (2.22) | 4.18 (2.27) | 4.97 (2.44) | 4.36 (2.31) | 5.98 (2.63) | 7.25 (2.85) | 5.76 (2.60) | 5.00 (2.45) | 5.45 (2.54) | 3.60 (2.14) | 2.18 (1.77) | 4.79 (2.38) |
| SE (m) ± | **0.053** | **0.079** | **0.076** | **0.057** | **0.089** | **0.080** | **0.084** | **0.066** | **0.066** | **0.087** | **0.074** | |
| CD (0.05) | **0.16** | **0.24** | **0.23** | **0.18** | **0.27** | **0.25** | **0.26** | **0.20** | **0.20** | **0.27** | **0.23** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 21. Effect of pest management modules against whitefly population during *kharif*, 2019 and *kharif*, 2020 (pooled)**

| Treatment details | Average number of whitefly adults per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 35 DAS | 40DAS | 45 DAS | 50DAS | 55DAS | 60DAS | 65DAS | 70DAS | 75DAS | 80DAS | Mean |
| $T_1$: Integrated module | 2.26 (1.79) | 1.49 (1.57) | 2.63 (1.90) | 1.63 (1.62) | 2.75 (1.90) | 3.11 (2.02) | 2.83 (1.95) | 2.67 (1.91) | 2.07 (1.75) | 1.52 (1.58) | 1.18 (1.46) | 2.19 (1.77) |
| $T_2$: Bio-intensive module | 3.25 (2.05) | 2.41 (1.84) | 3.61 (2.14) | 3.68 (2.16) | 4.88 (2.41) | 5.19 (2.48) | 4.29 (2.28) | 3.98 (2.22) | 3.74 (2.17) | 2.71 (1.92) | 1.85 (1.68) | 3.60 (2.12) |
| $T_3$: Chemical module | 2.44 (1.84) | 1.30 (1.51) | 3.21 (2.05) | 1.50 (1.57) | 3.17 (2.03) | 2.73 (1.93) | 2.37 (1.82) | 2.57 (1.88) | 2.20 (1.78) | 1.57 (1.58) | 1.01 (1.40) | 2.19 (1.76) |
| $T_4$: Untreated control | 3.25 (2.05) | 3.94 (2.22) | 5.12 (2.47) | 5.08 (2.46) | 6.58 (2.74) | 7.60 (2.92) | 6.27 (2.69) | 5.33 (2.51) | 5.04 (2.45) | 3.80 (2.19) | 2.73 (1.92) | 4.98 (2.42) |
| SE (m) ± | **0.036** | **0.047** | **0.045** | **0.045** | **0.058** | **0.058** | **0.054** | **0.060** | **0.052** | **0.059** | **0.052** | |
| CD (0.05) | **0.10** | **0.14** | **0.13** | **0.13** | **0.17** | **0.17** | **0.16** | **0.17** | **0.15** | **0.17** | **0.15** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 22. Effect of pest management modules against whitefly population during summer, 2021**

| Treatment details | Average number of whitefly adults per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 35 DAS | 40DAS | 45 DAS | 50DAS | 55DAS | 60DAS | 65DAS | 70DAS | 75DAS | 80DAS | Mean |
| $T_1$: Integrated module | 1.61 (1.61) | 1.19 (1.48) | 2.58 (1.89) | 1.11 (1.45) | 2.39 (1.84) | 2.60 (1.90) | 4.02 (2.24) | 2.73 (1.93) | 1.38 (1.54) | 1.62 (1.62) | 1.96 (1.72) | 2.11 (1.75) |
| $T_2$: Bio-intensive module | 2.48 (1.86) | 1.77 (1.66) | 3.34 (2.08) | 2.74 (1.93) | 4.24 (2.29) | 3.62 (2.14) | 5.55 (2.56) | 5.78 (2.60) | 2.56 (1.88) | 2.01 (1.73) | 2.37 (1.83) | 3.31 (2.05) |
| $T_3$: Chemical module | 2.15 (1.77) | 0.90 (1.37) | 1.46 (1.57) | 1.13 (1.45) | 2.41 (1.84) | 1.46 (1.57) | 3.49 (2.12) | 2.17 (1.78) | 1.54 (1.59) | 1.95 (1.71) | 2.16 (1.77) | 1.89 (1.69) |
| $T_4$: Untreated control | 2.76 (1.94) | 3.66 (2.16) | 4.56 (2.36) | 6.33 (2.70) | 7.05 (2.83) | 6.02 (2.64) | 7.29 (2.87) | 7.43 (2.90) | 4.08 (2.24) | 3.98 (2.22) | 3.73 (2.17) | 5.17 (2.46) |
| SE (m) ± | **0.049** | **0.051** | **0.052** | **0.061** | **0.063** | **0.059** | **0.061** | **0.065** | **0.071** | **0.083** | **0.053** | |
| CD (0.05) | **0.15** | **0.16** | **0.19** | **0.19** | **0.20** | **0.18** | **0.19** | **0.20** | **0.22** | **0.25** | **0.16** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

per leaf crossed the ETL at an early crop growth stage of 50 DAS i.e., ten days after second spraying. Similar trend in efficacy of the modules was witnessed up to 60 DAS (10 days after third spraying). Thereafter the population declined. Considering the mean whitefly population per leaf at 80 DAS the chemical (1.01 whiteflies/ leaf) and integrated (1.18 whiteflies/ leaf) modules were superior to biointensive module (1.85 whiteflies/ leaf). However, all the modules varied with each other and were superior to untreated control (2.73 whiteflies/ leaf).

Various pest management modules significantly reduced the whitefly population (Table 22) during summer, 2021. Both integrated and chemical modules recorded lower whitefly population (1.61 and 2.15/ leaf, respectively) at 30 DAS. Lesser whitefly population was observed after five days of first spray at 35 DAS in all the modules, whereas at 40 DAS (10 days after first spraying) significant differences in population of whitefly among the modules was evident with chemical module recording the lowest whitefly population of 1.46 per leaf followed by integrated (2.58/ leaf) and biointensive (3.34/ leaf) modules. Further, at 45 DAS (five days after second spray) the highest population reduction was achieved in integrated module (1.11 whiteflies/ leaf) closely followed by chemical module (1.13/ leaf). Integrated module was the most efficient after ten days of second spraying at 50 DAS. The whiteflies maintained a peak population of 7.43 per leaf at 65 DAS in untreated control. Chemical module with 1.46 whiteflies per leaf was the best after five days of second spray at 55 DAS.

Whitefly population crossed ETL in biointensive (5.55/ leaf) and integrated (4.02/ leaf) modules at 60 DAS i.e., ten days after third spraying. Thereafter in integrated module the whitefly population declined towards maturity. Chemical module was superior with only 2.17 whiteflies per leaf at 65 DAS i.e., five days after fourth spray. Similar trend in efficacy of chemical module was observed at 70 DAS (10 days after fourth spraying). However, at 75 and 80 DAS the whitefly population declined to 2.01 and 2.37 per leaf, respectively in biointensive module. Based on mean whitefly population at 80 DAS, there were no significant differences among the modules but all were better than the untreated control. The seasonal mean indicated the superiority of chemical module by recording the lowest seasonal mean population of 1.89 whiteflies per leaf followed by integrated and biointensive modules.

### 4.2.3 Aphids, *Aphis gossypii* (Glover)

Aphids were active on okra in the initial stages of the crop growth during *kharif*, 2019 (Table 23). The integrated module recorded the lowest population (3.06/ leaf) and was superior to chemical and biointensive modules with population of 4.90 and 6.13 per leaf, respectively at 30 DAS. Five days after first spray i.e., at 35 DAS both the chemical and integrated modules recorded lower aphid population of 2.14 and 3.13 per leaf, respectively as compared to the population in biointensive module (6.55/ leaf). Substantially higher aphid population was recorded in all the modules at 40 DAS (10 days after first spray). Biointensive module with 10.01 aphids per leaf was the least effective at 45 DAS i.e., 5 days after second spraying. The population declined exceptionally in both chemical and integrated modules registering only 3.08 and 3.10 aphids per leaf, respectively at 50 DAS (10 days after second spray). Similar trend with increasing population across different treatments was noticed at 55 DAS i.e., five days after third spray.

Chemical module proved significantly better (4.28 aphids/ leaf) over other modules after ten days of third spray at 60 DAS. Similar trend in efficiency of chemical module was witnessed after five and ten days of fourth spray i.e., at 65 and 70 DAS, respectively. The aphid population in biointensive module was 3.30 and 4.86 per leaf at 5 and 10 days of fifth spraying i.e., at 75 and 80 DAS, respectively. No significant differences were observed at 80 DAS among the modules and untreated control with respect to *A. gossypii* population. Based on the overall mean aphid population, chemical and integrated modules were superior by harbouring lower population of 4.18 and 4.61 per leaf, respectively which was followed by biointensive module with7.12 aphids per leaf.

Similar trend in seasonal mean aphid population among the modules was observed during *kharif*, 2020 (Table 24). Chemical module with mean aphid population of 4.62 per leaf was the best in keeping the population of aphid under check and it was statistically on par with integrated module, which recorded a seasonal mean population of 5.44 per leaf. Both integrated and chemical modules recorded the lowest population of 1.95 and 2.05 aphids per leaf, respectively, which were at par with each other and varied significantly with biointensive module (2.60 aphids/ leaf). Similar efficiency of integrated and chemical modules in controlling the aphid population was noticed at 35

DAS (5 days after first spray). Further, at 40 DAS i.e., 10 days after first spray both chemical and integrated modules had lower aphid population of 3.32 and 3.44 per leaf, respectively which was significantly superior over biointensive module (5.21/ leaf) while after five days of second spray i.e., at 45 DAS, biointensive module recorded higher population of 6.12 aphids per leaf, followed by chemical (4.99 aphids/ leaf) and integrated (4.21 aphids/ leaf) modules. Similar trend with relatively lower aphid population was observed amongst the modules at ten days after second spraying (50 DAS). Five days of third spraying i.e., at 55 DAS the chemical module with 5.25 aphids per leaf stood best amongst the modules tested.

Chemical module (6.54 and 10.64 aphids/ leaf, respectively) registered the lowest population at 60 (10 days after third spray) and 65 (5 days after fourth spray) DAS while biointensive module with 15.80 and 19.66 aphids per leaf was the inferior one. Similar trend was followed at 70 DAS (10 days after fourth spray). Aphid population reduced to 3.05 and 5.59 per leaf in biointensive module after five and ten days of fifth spray at 75 and 80 DAS, respectively.

Considering the pooled effect of different modules over both the *kharif* seasons (Table 25), it was evident that aphid population was fluctuating throughout the seasons attending the highest activity in the early crop growth stage i.e., at 45 DAS (16.46 aphids/ leaf) and later during 55 to 65 DAS with population ranging between 17.49 to 19.96 aphids per leaf in untreated control. Aphid population was lower both in integrated and chemical modules with population of 4.29 and 4.86 aphids per leaf and varied significantly with biointensive module (5.23 aphids/ leaf) at 80 DAS. Considering the seasonal mean population of aphid, the chemical module was the most effective one in reducing the aphid population followed by integrated and biointensive module, respectively.

Aphid incidence during summer, 2021 was relatively less in number in comparison to the previous two *kharif* seasons (Table 26). There was significant difference with respect to the aphid population among the modules at 30 DAS, as integrated module recorded the lowest population of 2.32 aphids per leaf. Both chemical and integrated modules recorded significantly lower aphid population of 1.84 and 2.02 per leaf, respectively as compared to biointensive module (4.04 aphids/ leaf) at 35 DAS i.e., five days after first spraying. Similar trend was followed amongst the modules at 40

DAS (10 days after first spraying). Biointensive module was inferior recording the highest aphid population of 5.81 per leaf at 45 DAS i.e., five days after second spray amongst the modules tested. Both integrated and chemical modules registered lower aphid population of 3.89 and 3.36 per leaf, respectively and were statistically at par with each other at 50 DAS (10 days after second spray). Chemical module was the most effective with 4.94 aphids per leaf and varied significantly with all other modules at 55 DAS (5 days after third spray).

Both chemical and integrated modules proved significantly superior (3.13 and 3.87 aphids/ leaf, respectively) over biointensive module (6.70/ leaf) at ten days after third spraying i.e., at 60 DAS. Similar trend in efficacy of modules was noticed at 65 (5 days after fourth spray) and 70 (10 days after fourth spray) DAS. The aphid population declined to 3.62 and 2.88 per leaf after five and ten days of fifth spray i.e., at 75 and 80 DAS, respectively in biointensive module. There was no significant difference among the modules at 80 DAS with respect to aphid population but all were superior over untreated control. Based on the overall mean aphid population of the season, chemical and integrated modules were superior with 2.74 and 3.36 aphids per leaf, respectively, which was followed by biointensive module with 5.52 aphids per leaf.

#### 4.2.4 Two spotted spider mite, *Tetranychus urticae* Koch

The data pertaining to effect of pest management modules against two spotted spider mite is presented in Table 27. During *kharif*, 2019 the first mite incidence was noticed at 55 DAS i.e., five days after third spraying with 0.28, 0.97 and 0.21 mites per $cm^2$ in integrated, biointensive and chemical module, respectively. The chemical and integrated module retained its supremacy at 60 DAS i.e., ten days after third spraying with 0.76 and 0.87 mites per $cm^2$, respectively. Mite population gradually increased in all the modules at 65 DAS (5 days after fourth spray). However, chemical module with the lowest mite population of 2.01 mites per $cm^2$, was effective in suppressing the population compared to biointensive module (3.76 mites/ $cm^2$). Similarly, at 70 DAS (10 days after fourth spray) chemical module retained its efficiency with 3.98 mites per $cm^2$. The mite population increased to 6.02 and 8.44 per $cm^2$ at 75 and 80 DAS i.e., five and ten days after fifth spraying, respectively in biointensive module. Chemical module was significantly differed from untreated control registering 7.66 mites per $cm^2$ at 80 DAS. Considering the seasonal mean population of mites, the chemical module was the

**Table 23. Effect of pest management modules against aphid population during *kharif,* 2019**

| Treatment details | Average number of aphids per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 3.06 (2.01) | 3.13 (2.02) | 8.25 (3.04) | 5.32 (2.50) | 3.10 (2.02) | 7.65 (2.93) | 5.72 (2.59) | 4.04 (2.24) | 3.36 (2.08) | 2.62 (1.90) | 4.48 (2.33) | 4.61 (2.33) |
| $T_2$: Bio-intensive module | 6.13 (2.66) | 6.55 (2.73) | 14.62 (3.94) | 10.01 (3.31) | 5.50 (2.55) | 9.80 (3.27) | 7.00 (2.83) | 5.63 (2.57) | 4.92 (2.42) | 3.30 (2.06) | 4.86 (2.42) | 7.12 (2.80) |
| $T_3$: Chemical module | 4.90 (2.43) | 2.14 (1.76) | 8.88 (3.14) | 4.98 (2.44) | 3.08 (2.02) | 5.64 (2.57) | 4.28 (2.29) | 2.54 (1.87) | 3.12 (2.01) | 1.52 (1.58) | 4.86 (2.41) | 4.18 (2.23) |
| $T_4$: Untreated control | 6.33 (2.70) | 9.85 (3.29) | 16.80 (4.22) | 25.22 (5.12) | 7.08 (2.84) | 17.57 (4.30) | 15.10 (4.01) | 14.70 (3.96) | 6.38 (2.72) | 4.46 (2.33) | 5.58 (2.56) | 11.73 (3.46) |
| SE (m) ± | **0.080** | **0.094** | **0.107** | **0.087** | **0.088** | **0.114** | **0.060** | **0.093** | **0.091** | **0.066** | **0.075** | |
| CD (0.05) | **0.25** | **0.29** | **0.33** | **0.27** | **0.27** | **0.35** | **0.18** | **0.29** | **0.28** | **0.20** | **0.23** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed value

**Table 24.Effect of pest management modules against aphid population during *kharif,* 2020**

| Treatment details | Average number of aphids per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 1.95 (1.71) | 2.51 (1.87) | 3.44 (2.10) | 4.21 (2.27) | 2.83 (1.96) | 6.97 (2.82) | 8.73 (3.11) | 14.88 (3.98) | 7.62 (2.93) | 2.62 (1.90) | 4.10 (2.26) | 5.44 (2.44) |
| $T_2$: Bio-intensive module | 2.60 (1.89) | 7.69 (2.94) | 5.21 (2.49) | 6.12 (2.67) | 4.46 (2.32) | 10.73 (3.42) | 15.80 (4.09) | 19.66 (4.53) | 9.68 (3.25) | 3.05 (2.01) | 5.59 (2.56) | 8.24 (2.93) |
| $T_3$: Chemical module | 2.05 (1.74) | 3.21 (2.05) | 3.32 (2.07) | 4.99 (2.43) | 3.17 (2.03) | 5.25 (2.49) | 6.54 (2.74) | 10.64 (3.40) | 4.56 (2.35) | 2.22 (1.80) | 4.85 (2.42) | 4.62 (2.32) |
| $T_4$: Untreated control | 3.54 (2.13) | 12.49 (3.67) | 6.65 (2.76) | 7.69 (2.95) | 6.02 (2.65) | 17.40 (4.29) | 21.78 (4.77) | 25.21 (5.10) | 15.10 (4.01) | 4.31 (2.30) | 5.36 (2.52) | 11.41 (3.38) |
| SE (m) ± | **0.060** | **0.072** | **0.086** | **0.095** | **0.094** | **0.075** | **0.123** | **0.179** | **0.103** | **0.053** | **0.067** | |
| CD (0.05) | **0.18** | **0.22** | **0.27** | **0.29** | **0.29** | **0.23** | **0.38** | **0.55** | **0.32** | **0.16** | **0.21** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 25.Effect of pest management modules against aphid population during *kharif*, 2019 and *kharif*, 2020 (pooled)**

| Treatment details | Average number of aphids per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 2.51 (1.86) | 2.82 (1.95) | 5.85 (2.57) | 4.77 (2.39) | 2.97 (1.99) | 7.31 (2.88) | 7.23 (2.85) | 9.46 (3.11) | 5.49 (2.51) | 2.62 (1.90) | 4.29 (2.30) | 5.03 (2.39) |
| $T_2$: Bio-intensive module | 4.37 (2.28) | 7.12 (2.84) | 9.92 (3.22) | 8.07 (2.99) | 4.98 (2.44) | 10.27 (3.35) | 11.40 (3.46) | 12.65 (3.55) | 7.30 (2.84) | 3.18 (2.04) | 5.23 (2.49) | 7.68 (2.86) |
| $T_3$: Chemical module | 3.48 (2.09) | 2.68 (1.91) | 6.10 (2.61) | 4.99 (2.44) | 3.13 (2.03) | 5.45 (2.53) | 5.41 (2.52) | 6.59 (2.64) | 3.84 (2.18) | 1.87 (1.69) | 4.86 (2.42) | 4.40 (2.27) |
| $T_4$: Untreated control | 4.94 (2.42) | 11.17 (3.48) | 11.73 (3.49) | 16.46 (4.04) | 6.55 (2.75) | 17.49 (4.30) | 18.44 (4.39) | 19.96 (4.53) | 10.74 (3.37) | 4.39 (2.32) | 5.47 (2.54) | 11.57 (3.42) |
| SE (m) ± | **0.050** | **0.057** | **0.071** | **0.067** | **0.064** | **0.064** | **0.064** | **0.096** | **0.067** | **0.043** | **0.053** | |
| CD (0.05) | **0.14** | **0.16** | **0.21** | **0.20** | **0.19** | **0.19** | **0.19** | **0.28** | **0.20** | **0.12** | **0.15** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 26. Effect of pest management modules against aphid population during summer, 2021**

| Treatment details | Average number of aphids per leaf | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 2.32 (1.80) | 2.02 (1.73) | 4.80 (2.41) | 2.72 (1.93) | 3.39 (2.09) | 6.74 (2.78) | 3.87 (2.20) | 3.22 (2.05) | 2.85 (1.95) | 2.14 (1.77) | 2.85 (1.96) | 3.36 (2.06) |
| $T_2$: Bio-intensive module | 3.91 (2.20) | 4.04 (2.24) | 6.46 (2.73) | 5.81 (2.60) | 7.98 (2.98) | 10.46 (3.38) | 6.70 (2.76) | 4.95 (2.44) | 3.93 (2.21) | 3.62 (2.15) | 2.88 (1.97) | 5.52 (2.51) |
| $T_3$: Chemical module | 2.66 (1.88) | 1.84 (1.68) | 3.13 (2.03) | 2.17 (1.78) | 3.86 (2.19) | 4.94 (2.44) | 3.13 (2.03) | 2.26 (1.80) | 1.66 (1.63) | 1.82 (1.67) | 2.68 (1.91) | 2.74 (1.91) |
| $T_4$: Untreated control | 4.63 (2.36) | 4.86 (2.42) | 8.17 (3.03) | 9.20 (3.19) | 13.32 (3.78) | 14.25 (3.90) | 9.35 (3.22) | 9.60 (3.25) | 8.34 (3.05) | 7.54 (2.92) | 3.69 (2.16) | 8.45 (3.03) |
| SE (m) ± | **0.146** | **0.076** | **0.072** | **0.064** | **0.095** | **0.090** | **0.098** | **0.085** | **0.070** | **0.066** | **0.067** | |
| CD (0.05) | **0.45** | **0.23** | **0.22** | **0.20** | **0.29** | **0.28** | **0.30** | **0.26** | **0.21** | **0.20** | **0.21** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

most effective in reducing the mite population throughout the season followed by integrated and biointensive module, respectively.

As evidenced from Table 28, the mite infestation during *kharif,* 2020 started at 55 DAS (5 days after third spray) with the lowest population of 1.64 mites per $cm^2$ in chemical module which was at par with integrated module with 2.18 mites per $cm^2$ but varied significantly with biointensive module (4.92 mites/ $cm^2$). Similar trend in mite population was recorded amongst the modules even at 60 DAS (10 days after third spray). Biointensive module was ineffective with 7.68 mites per $cm^2$ and was at par with untreated control (8.58 mites/ $cm^2$) at 65 DAS (5 days after fourth spray). Chemical module was found to be superior with lesser number of mites (6.21 mites/ $cm^2$) at ten days after fourth spraying i.e., at 70 DAS. The biointensive module registered 7.73 and 11.50 mites per $cm^2$ after five and ten days of fifth spraying i.e., at 75 and 80 DAS, respectively. Based on the overall mean mite population of the season, both chemical and integrated modules were superior with 5.73 and 6.29 mites per $cm^2$ leaf whereas, biointensive module was the least effective one harbouring 7.80 mites per $cm^2$ leaf.

Considering the pooled effect of two *kharif* seasons on mite population it was evident that the mite infestation started late in the seasons with relatively lower population (Table 29). Amongst the modules tested chemical module was proved as the best with 8.65 mites per $cm^2$ leaf at 80 DAS and varied significantly with integrated (9.62 mites/ $cm^2$ leaf) and biointensive (9.97 mites/ $cm^2$ leaf) module. At the same time untreated control plots recorded 10.70 mites per $cm^2$ leaf. The seasonal mean mite population was the lowest in chemical module (6.53 mites/ $cm^2$ leaf) followed by integrated and biointensive module registering seasonal average mite population of 7.04 and 8.44 mites per $cm^2$ leaf, respectively.

During summer, 2021 the mite infestation started earlier at 40 DAS (Table 30). Significantly lower mite population was recorded at 40 DAS (10 days after first spray) in integrated (1.37 mites/ $cm^2$), chemical (1.11 mites/ $cm^2$) and biointensive (1.98 mites/ $cm^2$) module as compared to untreated control (4.83 mites/ $cm^2$). Mite population gradually increased in all the modules at 45 DAS (5 days after second spray). Integrated module recorded the lowest mite population of 4.69 per $cm^2$ and was at par with chemical (4.96 mite/ $cm^2$) and biointensive (5.72 mites/ $cm^2$) module at 50 DAS (10 days after second spray). However, at 55 DAS i.e., five days after third spray, chemical module proved superior with 5.17 mites per $cm^2$.

Further, at 60 DAS (10 days after third spray) both integrated and chemical modules retained its efficiency by recording significantly lower mite population (5.17 and 5.05 mites/ $cm^2$) which was followed by biointensive module with 7.20 mites per $cm^2$. The mite population gradually increased towards maturity stage. Similar efficiency of chemical module was retained at 65 DAS (5 days after fourth spray) with mite population of 5.33 per $cm^2$ and it varied significantly with other modules. Chemical module witnessed mite population of 5.57 per $cm^2$ at 70 DAS (10 days after fourth spray). Biointensive module witnessed 7.17 and 12.32 mites per $cm^2$ after five and ten days of fifth spraying i.e., at 75 and 80 DAS, respectively. The seasonal mean population indicated that biointensive module was the least effective one in checking the mite population but it was superior over untreated control.

### 4.2.5 Shoot and fruit borer (*Earias vittela* Fab.)

The data presented in Table 31 depicted per cent fruit infestation (number and weight basis) by shoot and fruit borer (*Earias vittela* Fab.) during *kharif*, 2019, *kharif*, 2020 and summer, 2021. Integrated module was the best module against shoot and fruit borer with the lowest fruit damage (number basis) of 5.34 and 5.13 per cent during *kharif*, 2019 and *kharif*, 2020, respectively with an average value of 5.24 per cent (48.24 % less than the control). The corresponding data on weight basis was 5.33 and 4.80 per cent with the average of 5.06 per cent having the highest per cent reduction over control (50.34 %). The second best treatment was chemical module which recorded 6.48 and 5.96 per cent pooled mean damage with 35.92 and 41.51 per cent reduction over control based on number and weight basis, respectively. Biointensive module was relatively less effective in managing the per cent fruit damage and recorded 8.58 and 8.47 per cent pooled fruit damage with 15.20 and 16.89 per cent reduction over control based on number and weight basis, respectively.

Similar trend in fruit damage was obtained in summer, 2021 also. Integrated module was the best module against shoot and fruit borer recording the lowest per cent fruit damage both in number and weight basis (3.86 and 2.79 %, respectively) with the highest per cent reduction over control of 47.89 and 61.57, respectively. The second best

**Table 27. Effect of pest management modules against two spotted spider mite population during *kharif,* 2019**

| Treatment details | Average number of mites per $cm^2$ leaf | | | | | | |
|---|---|---|---|---|---|---|---|
| | **55 DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 0.28 (1.11) | 0.76 (1.28) | 2.24 (1.79) | 4.56 (2.35) | 4.90 (2.42) | 8.29 (3.05) | 3.51 (2.00) |
| $T_2$: Bio-intensive module | 0.97 (1.34) | 2.15 (1.68) | 3.76 (2.16) | 5.28 (2.50) | 6.02 (2.65) | 8.44 (3.07) | 4.44 (2.23) |
| $T_3$: Chemical module | 0.21 (1.09) | 0.87 (1.31) | 2.01 (1.69) | 3.98 (2.22) | 4.96 (2.43) | 7.66 (2.94) | 3.28 (1.95) |
| $T_4$: Untreated control | 1.20 (1.45) | 3.92 (2.21) | 4.69 (2.37) | 6.84 (2.80) | 7.81 (2.96) | 8.95 (3.15) | 5.57 (2.49) |
| SE (m) ± | **0.139** | **0.194** | **0.144** | **0.109** | **0.090** | **0.060** | |
| CD (0.05 | **NS** | **0.60** | **0.44** | **0.34** | **0.28** | **0.18** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 28. Effect of pest management modules against two spotted spider mite population during *kharif,* 2020**

| Treatment details | Average number of mites per $cm^2$ leaf | | | | | | |
|---|---|---|---|---|---|---|---|
| | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 2.18 (1.72) | 5.50 (2.54) | 6.20 (2.68) | 6.48 (2.72) | 6.41 (2.72) | 10.95 (3.45) | 6.29 (2.64) |
| $T_2$: Bio-intensive module | 4.92 (2.41) | 6.69 (2.77) | 7.68 (2.94) | 8.26 (3.03) | 7.73 (2.95) | 11.50 (3.53) | 7.80 (2.94) |
| $T_3$: Chemical module | 1.64 (1.50) | 5.48 (2.54) | 5.26 (2.50) | 6.21 (2.68) | 6.16 (2.67) | 9.63 (3.26) | 5.73 (2.53) |
| $T_4$: Untreated control | 6.55 (2.75) | 8.06 (3.01) | 8.58 (3.09) | 10.12 (3.32) | 10.75 (3.41) | 12.45 (3.66) | 9.42 (3.21) |
| SE (m) ± | **0.184** | **0.080** | **0.078** | **0.149** | **0.109** | **0.076** | |
| CD (0.05) | **0.57** | **0.25** | **0.24** | **0.46** | **0.34** | **0.23** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 29.Effect of pest management modules against two spotted spider mite population during *kharif*, 2019 and *kharif*, 2020 (pooled)**

| Treatment details | | Average number of mites per $cm^2$ leaf area | | | | | |
|---|---|---|---|---|---|---|---|
| | 55 DAS | 60DAS | 65DAS | 70DAS | 75DAS | 80DAS | Mean |
| $T_1$: Integrated module | 1.23 (1.42) | 3.13 (1.91) | 4.22 (2.24) | 5.52 (2.54) | 5.66 (2.57) | 9.62 (3.25) | 7.04 (3.13) |
| $T_2$: Bio-intensive module | 2.95 (1.88) | 4.42 (2.23) | 5.72 (2.55) | 6.77 (2.77) | 6.88 (2.80) | 9.97 (3.30) | 8.44 (3.41) |
| $T_3$: Chemical module | 0.93 (1.30) | 3.18 (1.93) | 3.64 (2.10) | 5.10 (2.45) | 5.56 (2.55) | 8.65 (3.10) | 6.53 (3.03) |
| $T_4$: Untreated control | 3.88 (2.10) | 5.99 (2.61) | 6.64 (2.73) | 8.97 (3.14) | 8.80 (3.11) | 10.70 (3.41) | 10.27 (3.75) |
| SE (m) ± | **0.113** | **0.097** | **0.079** | **0.091** | **0.071** | **0.048** | |
| CD (0.05 | **0.33** | **0.28** | **0.23** | **0.27** | **0.20** | **0.14** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 30. Effect of pest management modules against two spotted spider mite population during summer, 2021**

| Treatment details | Average number of mites per $cm^2$ leaf area | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40DAS | 45 DAS | 50DAS | 55DAS | 60DAS | 65DAS | 70DAS | 75DAS | 80DAS | Mean |
| $T_1$: Integrated module | 1.37 (1.48) | 2.66 (1.85) | 4.69 (2.38) | 5.70 (2.59) | 5.17 (2.48) | 5.49 (2.54) | 5.45 (2.54) | 5.04 (2.45) | 10.85 (3.44) | 5.16 (2.42) |
| $T_2$: Bio-intensive module | 1.98 (1.68) | 3.42 (2.08) | 5.72 (2.59) | 6.42 (2.71) | 7.20 (2.86) | 7.21 (2.86) | 7.18 (2.85) | 7.17 (2.85) | 12.32 (3.65) | 6.51 (2.68) |
| $T_3$: Chemical module | 1.11 (1.38) | 2.68 (1.90) | 4.96 (2.44) | 5.17 (2.48) | 5.05 (2.46) | 5.33 (2.51) | 5.57 (2.56) | 5.25 (2.50) | 9.40 (3.22) | 4.95 (2.38) |
| $T_4$: Untreated control | 4.83 (2.38) | 6.53 (2.73) | 9.94 (3.30) | 10.10 (3.32) | 9.28 (3.20) | 12.96 (3.73) | 10.45 (3.36) | 9.53 (3.22) | 13.58 (3.82) | 9.69 (3.23) |
| SE (m) ± | **0.216** | **0.185** | **0.090** | **0.100** | **0.072** | **0.105** | **0.093** | **0.130** | **0.079** | |
| CD (0.05) | **0.67** | **0.57** | **0.28** | **0.31** | **0.22** | **0.32** | **0.29** | **0.40** | **0.24** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

treatment was chemical module which recorded 5.64 and 4.76 per cent mean fruit damage with 23.99 and 34.29 per cent reduction over control based on number and weight, respectively. Biointensive module was the least effective in managing the per cent fruit damage and recorded 6.91 and 6.09 fruit damage with 6.81 and 15.99 per cent reduction over control based on number and weight, respectively.

### 4.2.6 Abundance of coccinellids

The data on impact of pest management modules on the abundance of coccinellids was presented in Table 32. Initially the density of coccinellids population among the treatments was uniform between 30 to 40 DAS (10 days after first spray) during *kharif* 2019. Significantly lower population of coccinellids (0.04 coccinellids/ plant) was recorded in chemical module compared to 0.68 coccinellids per plant in untreated control at five days after second spray i.e., 45 DAS. Both integrated and biointensive modules have moderate effect on coccinellids with recorded population of 0.16 and 0.44 per plant, respectively. Similar trend was evident after ten days of second spray at 50 DAS where the chemical module showed not a single activity of coccinellids while 0.44 and 0.12 coccinellids per plant were noticed in biointensive and integrated module, respectively in comparison to untreated control with 0.36 coccinellids per plant. All the modules except chemical module (0.04/ plant) recorded uniform coccinellid density (0.60 to 0.68/ plant) and were comparable with population observed in untreated control (0.96/ plant) at 55 DAS (5 days after third spray).

The population varied between 0.08 to 1.20 coccinellids per plant in different treatments at 60 DAS (10 days after third spray) with the lowest population observed in chemical module and the highest in untreated control. Similarly, the highest coccinellid population was recorded in biointensive module (1.24/ plant) at 65 DAS (5 days after fourth spray). The population of coccinellids ranged from 0.08 to 1.28 per plant with the former observed in chemical module and later in untreated control at 70 DAS (10 days after fourth spray). Gradual decrease in the population of coccinellid was observed in biointensive module at 75 DAS (five days after fifth spray). All the modules except chemical module were at par with each other at 80 DAS. The seasonal average coccinellid population was relatively more in untreated control which was closely followed by biointensive and integrated module with population of 0.61 and 0.41 per plant, respectively indicating their safety to the coccinellid population. Chemical module

**Table 31. Effect of pest management modules on per cent fruit damage (number basis and weight basis) on okra during *kharif*, 2019 and 2020 and summer, 2021**

| **Treatments** | **Fruit damage percentage (number basis)** | | | | **Per cent reduction over control in pooled *kharif* seasons (%)** | **Per cent reduction over control during summer 2021 (%)** | **Fruit damage percentage (weight basis)** | | | | **Per cent reduction over control in pooled *kharif* seasons (%)** | **Per cent reduction over control during summer, 2021 (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *kharif*, 2019 (mean of 15 pickings) | *kharif*, 2020 (mean of 13 pickings) | Pooled over 2 *kharif* seasons | summer, 2021 (mean of 10 pickings) | | | *kharif*, 2019 (mean of 15 pickings) | *kharif*, 2020 (mean of 13 pickings) | Pooled over 2 *kharif* seasons | summer, 2021 (mean of 10 pickings) | | |
| $T_1$: Integrated Module | 5.34 (2.51) | 5.13 (2.68) | 5.24 (2.50) | 3.86 (2.20) | 48.24 | 47.89 | 5.33 (2.51) | 4.80 (2.41) | 5.06 (2.46) | 2.79 (1.93) | 50.34 | 61.57 |
| $T_2$: Biointensive Module | 8.30 (3.04) | 8.86 (3.14) | 8.58 (3.09) | 6.91 (2.81) | 15.20 | 6.81 | 8.76 (3.12) | 8.18 (3.02) | 8.47 (3.07) | 6.09 (2.66) | 16.89 | 15.99 |
| $T_3$: Chemical Module | 6.75 (2.78) | 6.22 (2.48) | 6.48 (2.73) | 5.64 (2.57) | 35.92 | 23.99 | 6.61 (2.75) | 5.32 (2.50) | 5.96 (2.62) | 4.76 (2.39) | 41.51 | 34.29 |
| $T_4$: Untreated control | 9.69 (3.27) | 10.55 (3.39) | 10.12 (3.33) | 7.42 (2.89) | - | - | 10.26 (3.35) | 10.12 (3.33) | 10.19 (3.34) | 7.25 (2.87) | - | - |
| **SE(m)±** | **0.070** | **0.080** | **0.078** | **0.086** | **-** | **-** | **0.092** | **0.087** | **0.096** | **0.089** | **-** | **-** |
| **CD (0.05)** | **0.23** | **0.25** | **0.23** | **0.27** | **-** | **-** | **0.28** | **0.27** | **0.28** | **0.27** | **-** | **-** |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

recorded the lowest seasonal mean population of coccinellids (0.05/ plant).

A similar trend in coccinellid population as influenced by different pest management modules was observed during *kharif*, 2020 (Table 33). Initially the population of coccinellids did not vary significantly among the treatments from 30 to 40 DAS (10 days after first spray). Integrated, biointensive, chemical module and untreated control recorded 0.32, 0.48, 0.08 and 0.64 coccinellids per plant, respectively at 45 DAS i.e., five days after second spray. Nevertheless, significant differences in coccinellid density between modules were evident after ten days of second spraying at 50 DAS with chemical module registering no coccinellid population as against higher coccinellid population in the range of 0.28 to 0.44 per plant recorded in other modules and untreated control. Similarly, after five days of third spray at 55 DAS, significant negative effects of constituent insecticidal sprays of chemical module were notable with minimum population of 0.08 coccinellid per plant against the highest population (1.04 coccinellids/ plant) recorded in untreated control.

Coccinellid population ranging from 0.12 to 1.00 per plant was recorded at 60 DAS (10 days after third spray) in different treatments with the highest population recorded in untreated control and the lowest in chemical module. However, at 65 DAS (5 days after fourth spray) the highest population was recorded in biointensive module with 0.96 per plant and the lowest was witnessed in chemical module (0.08/ plant). Similar trend was registered for 70, 75 and 80 DAS. The seasonal average coccinellid population was more in untreated control (0.61/ plant) followed by biointensive and integrated module with a population of 0.59 and 0.41 per plant, respectively.

Considering the pooled effect of two *kharif* seasons (Table 34) on effect of different pest management modules on coccinellid population it was evident that the higher cooccinellid population was fluctuating in between the biointensive module and untreated control but relatively lower in integrated module which did not vary significantly with biointensive module. But there was very few coocinellids in the chemical module and it varied significantly with other modules. The mean coccinellid population at 80 DAS was 0.66, 0.60, 0.56 and 0.18 per plant in biointensive module, untreated control, integrated and chemical module, respectively. The seasonal average coccinellid population was more in untreated control which was closely followed by biointensive and integrated module whereas, chemical module recorded the lowest seasonal mean population of coccinellids.

Similar to the previous *kharif* seasons chemical module was proved to be harmful to coccinellids as evidenced by lowest seasonal mean population of coccinellids (0.08/ plant) during summer, 2021 (Table 35). In contrast, the highest coccinellid population was recorded in case of untreated control (0.73/ plant) which was followed by biointensive and integrated module with seasonal average of 0.72 and 0.46 per plant, respectively. At the early stages of crop growth i.e., at 30 and 35 DAS coccinellid population was uniform among all the treatments. However, there was no population build up of coccinellids in chemical module up to 35 DAS (5 days after first spray). The population of coccinellids varied significantly between chemical module (0.04/ plant) and untreated control (0.48/ plant) at 40 DAS i.e., ten days after first spraying. Further, at the same time integrated and biointensive module recorded 0.24 and 0.32 coccinellids per plant. Integrated and chemical module recorded 0.12 and 0.04 coccinellids per plant, respectively which varied significantly with biointensive module (0.76 coccinellids/ plant) and untreated control (0.88 coccinellids/ plant) at 45 DAS (5 days after second spray). The population of coccinellids increased at 50 DAS (10 days after second spray) in integrated module (0.60 coccinellids/ plant) and was at par with biointensive module and untreated control with 0.96 and 1.08 coccinellids per plant, respectively. The highest coccinellid population at 55 DAS (5 days after third spray) was recorded in biointensive module with 1.24 per plant which was followed by untreated control (1.04/ plant), integrated (0.68/ plant) and chemical (0.12/ plant) module, respectively.

Similar trend in effect of pest management modules on coccinellid population was noticed at 60 DAS (10 days after third spray). Coccinellid population of 0.04 per plant was witnessed in chemical module which was the lowest where as the biointensive module with 1.04 coccinellids per plant registered the highest population at 65 DAS i.e., five days after fourth spray. All the modules except chemical module along with untreated control did not vary significantly among themselves at 80 DAS.

### 4.2.7 Abundance of spiders

The population build up of spiders did not occur at 30 DAS and after that the population did not vary significantly among the treatments between 35 (5 days after first spray) to 45 (5 days after second spray) DAS during *kharif*, 2019 (Table 36). Integrated, biointensive, chemical module and untreated control recorded 0.28, 0.48, 0.00 and 0.52 spiders per plant, respectively at 50 DAS (10 days after second spray).

Similar pattern in the abundance of spiders in different treatments was observed throughout the observation period. The spider population at 60 DAS (10 days after third spray) was of 0.32, 0.52, 0.08 and 0.72 per plant in integrated, biointensive, chemical module and untreated control, respectively. Similar trend in observations regarding the spider population between different modules were recorded at 65 DAS (5 days after fourth spray) with significant reduction in population of spiders observed in chemical module. The treatments except chemical module did not differ significantly with almost similar pattern in spider population among themselves at 70 (10 days after fourth spray) and 75 (5 days after fifth spray) DAS. During 80 DAS, spiders population varied in between 0.12 to 0.44 per plant, with chemical module (0.12 spiders/ plant) registering the lowest population and untreated control (0.44 spiders/ plant) witnessed the highest population. The seasonal mean spider population was the lowest in chemical module with 0.05 spiders per plant compared to the highest population of 0.41 per plant in untreated control.

The difference in the spider population among the treatments was not significant between 30 to 40 DAS during *kharif*, 2020 (Table 37). Significantly lower population of spider (0.04/ plant) was recorded in chemical module compared to other modules and untreated control after five days of second spray at 45 DAS (5 days after second spray). Similar trend was evident at 50 DAS (10 days after second spray). Five days after third spraying at 55 DAS, no spider population was observed in chemical module in comparison with the highest in untreated control (0.44/ plant). The population varied between 0.08 to 0.64 spiders per plant in different treatments at 60 DAS (10 days after third spray) with the lowest population observed in chemical module and the highest in untreated control. Similar trend in spider population was observed from 65 (5 days after fourth spray) to 75 (5 days after fifth spray) DAS. Population of spiders ranged from 0.16 to 0.56 per plant at 80 DAS with the former recorded in chemical module and the later was recorded from untreated control. Based on the seasonal mean population of spiders it can be concluded that integrated and biointensive module with 0.32 and 0.39 spider per plant, respectively were relatively safer as against chemical module with 0.06 spider per plant.

**Table 32. Effect of pest management modules against coccinellid population during *kharif*, 2019**

| Treatment details | Average number of coccinellids per plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 0.00 (1.00) | 0.04 (1.02) | 0.20 (1.09) | 0.16 (1.07) | 0.12 (1.06) | 0.60 (1.26) | 0.80 (1.34) | 0.80 (1.32) | 0.72 (1.30) | 0.56 (1.24) | 0.56 (1.24) | 0.41 (1.18) |
| $T_2$: Bio-intensive module | 0.08 (1.04) | 0.12 (1.06) | 0.24 (1.11) | 0.56 (1.24) | 0.44 (1.19) | 0.68 (1.29) | 1.08 (1.44) | 1.24 (1.48) | 0.96 (1.38) | 0.68 (1.29) | 0.64 (1.28) | 0.61 (1.25) |
| $T_3$: Chemical module | 0.00 (1.00) | 0.00 (1.00) | 0.04 (1.02) | 0.04 (1.02) | 0.00 (1.00) | 0.04 (1.02) | 0.08 (1.04) | 0.08 (1.04) | 0.08 (1.04) | 0.04 (1.02) | 0.16 (1.07) | 0.05 (1.02) |
| $T_4$: Untreated control | 0.04 (1.02) | 0.16 (1.07) | 0.40 (1.18) | 0.68 (1.29) | 0.36 (1.16) | 0.96 (1.38) | 1.20 (1.47) | 0.92 (1.38) | 1.28 (1.50) | 0.60 (1.25) | 0.56 (1.24) | 0.65 (1.27) |
| SE (m) ± | **0.016** | **0.028** | **0.052** | **0.063** | **0.035** | **0.062** | **0.059** | **0.074** | **0.075** | **0.060** | **0.040** | |
| CD (0.05) | **0.05** | **0.09** | **0.16** | **0.19** | **0.11** | **0.19** | **0.18** | **0.23** | **0.23** | **0.20** | **0.12** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 33. Effect of pest management modules against coccinellid population during *kharif*, 2020**

| Treatment details | Average number of coccinellids per plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 0.04 (1.02) | 0.04 (1.02) | 0.28 (1.12) | 0.32 (1.13) | 0.28 (1.13) | 0.60 (1.26) | 0.76 (1.32) | 0.68 (1.29) | 0.60 (1.26) | 0.44 (1.20) | 0.56 (1.25) | 0.41 (1.18) |
| $T_2$: Bio-intensive module | 0.08 (1.04) | 0.16 (1.07) | 0.36 (1.15) | 0.48 (1.21) | 0.32 (1.15) | 1.00 (1.41) | 0.96 (1.39) | 0.96 (1.40) | 0.96 (1.38) | 0.56 (1.25) | 0.68 (1.29) | 0.59 (1.25) |
| $T_3$: Chemical module | 0.00 (1.00) | 0.00 (1.00) | 0.04 (1.02) | 0.08 (1.04) | 0.00 (1.00) | 0.08 (1.04) | 0.12 (1.06) | 0.08 (1.04) | 0.12 (1.06) | 0.04 (1.02) | 0.20 (1.09) | 0.07 (1.03) |
| $T_4$: Untreated control | 0.04 (1.02) | 0.20 (1.09) | 0.28 (1.13) | 0.64 (1.28) | 0.44 (1.20) | 1.04 (1.42) | 1.00 (1.41) | 0.88 (1.35) | 0.92 (1.38) | 0.68 (1.29) | 0.64 (1.28) | 0.61 (1.26) |
| SE (m) ± | **0.024** | **0.037** | **0.064** | **0.053** | **0.032** | **0.047** | **0.072** | **0.064** | **0.071** | **0.041** | **0.044** | |
| CD (0.05) | **0.07** | **0.11** | **0.20** | **0.16** | **0.10** | **0.15** | **0.22** | **0.20** | **0.22** | **0.13** | **0.13** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 34.Effect of pest management modules against coccinellid population during *kharif*, 2019 and *kharif*, 2020 (Pooled)**

| Treatment details | Average number of coccinellids per plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 0.02 (1.01) | 0.04 (1.02) | 0.24 (1.11) | 0.24 (1.10) | 0.20 (1.10) | 0.60 (1.26) | 0.78 (1.33) | 0.74 (1.31) | 0.66 (1.28) | 0.50 (1.22) | 0.56 (1.25) | 0.42 (1.18) |
| $T_2$: Bio-intensive module | 0.08 (1.04) | 0.14 (1.07) | 0.30 (1.13) | 0.52 (1.23) | 0.38 (1.17) | 0.84 (1.35) | 1.02 (1.42) | 1.10 (1.44) | 0.96 (1.38) | 0.62 (1.27) | 0.66 (1.29) | 0.60 (1.25) |
| $T_3$: Chemical module | 0.00 (1.00) | 0.00 (1.00) | 0.04 (1.02) | 0.06 (1.03) | 0.00 (1.00) | 0.06 (1.03) | 0.10 (1.05) | 0.08 (1.04) | 0.10 (1.05) | 0.04 (1.02) | 0.18 (1.08) | 0.06 (1.03) |
| $T_4$: Untreated control | 0.04 (1.02) | 0.18 (1.08) | 0.34 (1.16) | 0.66 (1.29) | 0.40 (1.18) | 1.00 (1.40) | 1.10 (1.44) | 0.90 (1.37) | 1.10 (1.44) | 0.64 (1.27) | 0.60 (1.26) | 0.63 (1.26) |
| SE (m) ± | **0.014** | **0.025** | **0.039** | **0.039** | **0.025** | **0.039** | **0.046** | **0.046** | **0.053** | **0.039** | **0.028** | |
| CD (0.05) | **0.04** | **0.07** | **0.11** | **0.11** | **0.07** | **0.11** | **0.13** | **0.13** | **0.15** | **0.11** | **0.08** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 35. Effect of pest management modules against coccinellid population during summer, 2021**

| Treatment details | Average number of coccinellids per plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 0.04 (1.02) | 0.12 (1.06) | 0.24 (1.11) | 0.12 (1.06) | 0.60 (1.26) | 0.68 (1.29) | 0.72 (1.30) | 0.56 (1.24) | 0.68 (1.29) | 0.64 (1.27) | 0.64 (1.27) | 0.46 (1.20) |
| $T_2$: Bio-intensive module | 0.08 (1.04) | 0.12 (1.06) | 0.32 (1.15) | 0.76 (1.32) | 0.96 (1.40) | 1.24 (1.49) | 1.12 (1.45) | 1.04 (1.42) | 0.80 (1.34) | 0.72 (1.31) | 0.76 (1.32) | 0.72 (1.30) |
| $T_3$: Chemical module | 0.00 (1.00) | 0.00 (1.00) | 0.08 (1.04) | 0.04 (1.02) | 0.08 (1.04) | 0.12 (1.06) | 0.12 (1.06) | 0.04 (1.02) | 0.08 (1.04) | 0.04 (1.02) | 0.24 (1.11) | 0.08 (1.04) |
| $T_4$: Untreated control | 0.04 (1.02) | 0.24 (1.11) | 0.48 (1.21) | 0.88 (1.37) | 1.08 (1.43) | 1.04 (1.42) | 0.84 (1.35) | 0.92 (1.38) | 0.96 (1.39) | 0.88 (1.36) | 0.68 (1.29) | 0.73 (1.30) |
| SE (m) ± | **0.024** | **0.028** | **0.047** | **0.036** | **0.059** | **0.061** | **0.063** | **0.049** | **0.065** | **0.068** | **0.048** | |
| CD (0.05) | **0.07** | **0.09** | **0.14** | **0.11** | **0.18** | **0.19** | **0.19** | **0.15** | **0.20** | **0.21** | **0.15** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

Considering the pooled effect of two *kharif* seasons (Table 38) on effect of different pest management modules on spider population it was evident that the higher spider population was varying in between the biointensive module and untreated control but relatively lower in integrated module though it did not vary significantly with biointensive module. But there were very few spiders in the chemical module and it varied significantly with other modules. The mean spider population at 80 DAS was 0.50, 0.46, 0.40 and 0.14 in untreated control, followed by biointensive, integrated and chemical module, respectively. The seasonal average spider population was more in untreated control and it was closely followed by biointensive and integrated module where as chemical module recorded the lowest population of spiders.

Similarly, during summer, 2021 the lowest seasonal average spider population was observed in chemical module (0.05 spider/ plant) compared to the highest population of 0.43 per plant recorded in untreated control (Table 39). The population build up of spiders started at 35 DAS (5 days after first spray) and it was quite fluctuating in chemical module throughout the season. There was no population of spiders in chemical module at 40 DAS (10 days after first spray). Moreover, integrated module (0.08 spiders/ plant) and untreated control (0.32 spiders/ plant) differed significantly. Spider population in integrated, biointensive, chemical module and untreated control was 0.16, 0.32, 0.04 and 0.44 per plant, respectively at 45 DAS i.e., after 5 days of second spray. Chemical module with 0.04 spiders per plant differed significantly with integrated (0.28 spiders/ plant) and biointensive module (0.32 spiders/ plant) along with untreated control (0.48 spiders/ plant) at 50 DAS (10 days after second spray). Again after five days of third spraying at 55 DAS there was no spider population in chemical module.

The population at 60 DAS (10 days after third spray) varied between 0.08 to 0.60 spiders per plant in different treatments with the lowest population observed in chemical module and the highest in untreated control. Similar trend in spider population was noticed at 65 (5 days after fourth spray) and 70 DAS (10 days after fourth spray). Population of spiders ranged from 0.04 to 0.64 per plant at 75 DAS (5 days after fifth spray) with the highest being recorded in untreated control and the lowest recorded in chemical module. Further, at 80 DAS (10 days after fifth spray) higher density of 0.64 and 0.52 spider per plant was witnessed in untreated control and biointensive module, respectively.

**Table 36. Effect of pest management modules against spider population during *kharif*, 2019**

| Treatment details | Average number of spider per plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 0.00 (1.00) | 0.04 (1.02) | 0.08 (1.04) | 0.12 (1.06) | 0.28 (1.12) | 0.36 (1.16) | 0.32 (1.15) | 0.40 (1.18) | 0.32 (1.15) | 0.52 (1.23) | 0.36 (1.16) | 0.25 (1.12) |
| $T_2$: Bio-intensive module | 0.00 (1.00) | 0.00 (1.00) | 0.20 (1.09) | 0.24 (1.11) | 0.48 (1.21) | 0.36 (1.16) | 0.52 (1.23) | 0.56 (1.25) | 0.52 (1.23) | 0.56 (1.24) | 0.40 (1.18) | 0.35 (1.16) |
| $T_3$: Chemical module | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.04 (1.02) | 0.00 (1.00) | 0.04 (1.02) | 0.08 (1.04) | 0.12 (1.06) | 0.04 (1.02) | 0.12 (1.06) | 0.12 (1.06) | 0.05 (1.02) |
| $T_4$: Untreated control | 0.00 (1.00) | 0.04 (1.02) | 0.16 (1.07) | 0.36 (1.16) | 0.52 (1.23) | 0.40 (1.18) | 0.72 (1.31) | 0.68 (1.29) | 0.56 (1.25) | 0.68 (1.29) | 0.44 (1.20) | 0.41 (1.18) |
| SE (m) ± | **0.000** | **0.014** | **0.032** | **0.042** | **0.044** | **0.027** | **0.038** | **0.031** | **0.031** | **0.045** | **0.031** | |
| CD (0.05) | **0.00** | **0.04** | **0.10** | **0.13** | **0.13** | **0.08** | **0.12** | **0.10** | **0.10** | **0.14** | **0.10** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 37. Effect of pest management modules against spider population during *kharif*, 2020**

| Treatment details | Average number of spider per plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | **35 DAS** | **40DAS** | **45 DAS** | **50DAS** | **55DAS** | **60DAS** | **65DAS** | **70DAS** | **75DAS** | **80DAS** | **Mean** |
| $T_1$: Integrated module | 0.00 (1.00) | 0.12 (1.06) | 0.24 (1.11) | 0.32 (1.15) | 0.44 (1.20) | 0.36 (1.17) | 0.36 (1.16) | 0.44 (1.20) | 0.40 (1.18) | 0.44 (1.20) | 0.44 (1.20) | 0.32 (1.15) |
| $T_2$: Bio-intensive module | 0.00 (1.00) | 0.16 (1.07) | 0.20 (1.09) | 0.44 (1.20) | 0.52 (1.23) | 0.40 (1.18) | 0.52 (1.23) | 0.52 (1.23) | 0.48 (1.21) | 0.56 (1.25) | 0.52 (1.23) | 0.39 (1.17) |
| $T_3$: Chemical module | 0.00 (1.00) | 0.00 (1.00) | 0.04 (1.02) | 0.04 (1.02) | 0.08 (1.04) | 0.00 (1.00) | 0.08 (1.04) | 0.04 (1.02) | 0.08 (1.04) | 0.12 (1.06) | 0.16 (1.07) | 0.06 (1.03) |
| $T_4$: Untreated control | 0.12 (1.06) | 0.20 (1.09) | 0.32 (1.15) | 0.48 (1.21) | 0.68 (1.29) | 0.44 (1.20) | 0.64 (1.28) | 0.56 (1.25) | 0.56 (1.24) | 0.60 (1.26) | 0.56 (1.24) | 0.47 (1.21) |
| SE (m) ± | **0.018** | **0.031** | **0.044** | **0.037** | **0.046** | **0.039** | **0.034** | **0.036** | **0.036** | **0.040** | **0.045** | |
| CD (0.05) | **0.06** | **0.09** | **0.14** | **0.11** | **0.14** | **0.12** | **0.11** | **0.11** | **0.11** | **0.12** | **0.14** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 38. Effect of pest management modules against spider population during *kharif*, 2019 and *kharif*, 2020 (Pooled)**

| Treatment details | Average number of spider per plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 35 DAS | 40DAS | 45 DAS | 50DAS | 55DAS | 60DAS | 65DAS | 70DAS | 75DAS | 80DAS | Mean |
| $T_1$: Integrated module | 0.00 (1.00) | 0.08 (1.04) | 0.16 (1.08) | 0.22 (1.11) | 0.36 (1.16) | 0.36 (1.17) | 0.34 (1.16) | 0.42 (1.19) | 0.36 (1.17) | 0.48 (1.22) | 0.40 (1.18) | 0.29 (1.13) |
| $T_2$: Bio-intensive module | 0.00 (1.00) | 0.08 (1.04) | 0.20 (1.09) | 0.34 (1.16) | 0.50 (1.22) | 0.38 (1.17) | 0.52 (1.23) | 0.54 (1.24) | 0.50 (1.22) | 0.56 (1.25) | 0.46 (1.21) | 0.37 (1.16) |
| $T_3$: Chemical module | 0.00 (1.00) | 0.00 (1.00) | 0.02 (1.01) | 0.04 (1.02) | 0.04 (1.02) | 0.02 (1.01) | 0.08 (1.04) | 0.08 (1.04) | 0.06 (1.03) | 0.12 (1.06) | 0.14 (1.07) | 0.05 (1.03) |
| $T_4$: Untreated control | 0.06 (1.03) | 0.12 (1.06) | 0.24 (1.11) | 0.42 (1.19) | 0.60 (1.26) | 0.42 (1.19) | 0.68 (1.30) | 0.62 (1.27) | 0.56 (1.25) | 0.64 (1.28) | 0.50 (1.22) | 0.44 (1.19) |
| SE (m) ± | **0.007** | **0.014** | **0.025** | **0.028** | **0.032** | **0.025** | **0.025** | **0.025** | **0.025** | **0.032** | **0.028** | |
| CD (0.05) | **0.02** | **0.04** | **0.07** | **0.08** | **0.09** | **0.07** | **0.07** | **0.07** | **0.07** | **0.09** | **0.08** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

**Table 39. Effect of pest management modules against spider population during summer, 2021**

| Treatment details | Average number of spider per plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 35 DAS | 40DAS | 45 DAS | 50DAS | 55DAS | 60DAS | 65DAS | 70DAS | 75DAS | 80DAS | Mean |
| $T_1$: Integrated module | 0.00 (1.00) | 0.04 (1.02) | 0.08 (1.04) | 0.16 (1.07) | 0.28 (1.13) | 0.32 (1.15) | 0.36 (1.17) | 0.32 (1.15) | 0.32 (1.15) | 0.28 (1.13) | 0.40 (1.18) | 0.23 (1.11) |
| $T_2$: Bio-intensive module | 0.00 (1.00) | 0.08 (1.04) | 0.28 (1.13) | 0.28 (1.13) | 0.32 (1.15) | 0.56 (1.24) | 0.48 (1.21) | 0.36 (1.16) | 0.40 (1.18) | 0.40 (1.18) | 0.52 (1.23) | 0.33 (1.15) |
| $T_3$: Chemical module | 0.00 (1.00) | 0.04 (1.02) | 0.00 (1.00) | 0.04 (1.02) | 0.04 (1.02) | 0.00 (1.00) | 0.08 (1.04) | 0.08 (1.04) | 0.08 (1.04) | 0.04 (1.02) | 0.20 (1.10) | 0.05 (1.03) |
| $T_4$: Untreated control | 0.00 (1.00) | 0.12 (1.06) | 0.32 (1.15) | 0.44 (1.20) | 0.48 (1.21) | 0.52 (1.23) | 0.60 (1.26) | 0.56 (1.25) | 0.44 (1.19) | 0.64 (1.28) | 0.64 (1.28) | 0.43 (1.19) |
| SE (m) ± | **0.000** | **0.024** | **0.034** | **0.036** | **0.030** | **0.036** | **0.040** | **0.036** | **0.031** | **0.025** | **0.039** | |
| CD (0.05) | **0.00** | **0.07** | **0.10** | **0.11** | **0.09** | **0.11** | **0.12** | **0.11** | **0.09** | **0.08** | **0.12** | |

*Figures in Parentheses are $\sqrt{n+1}$ transformed values

### 4.3 Effect of pest management modules on vector-borne viral diseases

During the study period of *kharif*, 2019 and 2020 and summer, 2021 in okra, only yellow vein mosaic viral disease was prevalent. The disease infected at all the stages of crop growth and severely reduced crop growth.

#### 4.3.1 Observation of symptoms

During our study period some plants exhibited yellow vein mosaic symptom. The infection started with yellowing of entire networks of veins in the leaf blade. The veins of the leaves were cleared by the virus and interveinal area became completely yellow. In severe infection, the younger leaves turned yellow. During *kharif*, 2019 the infection pronounced late in the season i.e., at 70 DAS, whereas during *kharif*, 2020 and summer, 2021 the incidence pronounced earlier at 40 DAS. Flowering and fruiting reduced drastically in highly infected plants. The affected plants produced harder fruits of yellow to white colour which were not fit for marketing. However, none of the plants could show enation leaf curl virus symptoms.

#### 4.3.2 PCR and Gel electrophoresis of DNA isolated from whiteflies and the virus infected plants

PCR followed by gel electrophoresis of DNA isolated from whiteflies collected from the virus infected plants of okra showed the presence of amplicon of ~850 bp specific to mtCOI gene whereas PCR of total DNA isolated from the virus infected leaves using universal primers specific to begomoviruses followed by gel electrophoresis indicated the amplicon of ~550 bp (Fig. 19).

#### 4.3.3 DNA sequencing and phylogenetic analysis

After sequencing of amplicons specific to whiteflies and begomoviruses, the number of nucleotides was found to be 839 and 565 nucleotides, respectively. In BLAST analysis available at NCBI, sequences specific to whiteflies showed maximum homology with the sequences of mtCOI gene of whitefly isolates from New Delhi (Accession Number-MN193060), Andhra Pradesh (Accession Number-MK420036) and Pakistan (Accession Number-HG315654) available in GeneBank with ~ 91 % identity (Appendix-II). DNA sequence of amplicon specific to begomoviruses, the maximum homology was displayed with okra enation leaf curl virus (OELCV) strains from New Delhi (Accession Number-MK069437) and Karnataka (Accession Number-KT390311) with ~ 94 per cent identity (Appendix-III).

Sequences of these two amplicons were subjected for BLAST analysis and the sequences showing homology with our sequences which were retrieved from gene bank and were subjected to phylogenetic analysis. It was observed that the whiteflies from Bhubaneswar grouped phylogenetically with the whitefly isolates from Indonesia, Thailand and China however, the Bhubaneswar isolate of whitefly was placed singly in a separate sub-cluster (Fig 20) whereas isolates from Indonesia, Thailand and China showing closeness with the Bhubaneswar isolate were together placed in another sub-cluster. In case of viruses, okra enation leaf curl virus (OELCV) from Bhubaneswar clustered with mungbean yellow mosaic virus (MYMV) from Raichur and Hyderabad (Fig 21). These three viruses i.e., OELCV under the study and two different isolates from Raichur and Hyderabad grouped together with tomato leafcurl virus (ToLCV) from Bangalore and chilli leaf curl virus (ChiLCV) from Ahmedabad and Gonda.

An attempt was also taken to detect the virus particle from whiteflies after DNA isolation. However, it was unable to detect the presence of virus within whitefly.

### 4.3.4 Effect of pest management modules on incidence and intensity of okra yellow vein mosaic disease (OYVMD) during *kharif*, 2019

Incidence of OYVMV noticed late in the season at 50 DAS during *kharif*, 2019 (Table 40). However, at 70 DAS the disease spread throughout the field resulting in significantly higher incidence in untreated control (4.34 %) with the minimum incidence of 0.95 per cent in integrated module. However, the chemical module recorded lower disease incidence of 1.98 per cent at 80 DAS. At 90 DAS, there was no significant difference among the modules, but the incidence in all the modules was less as compared to untreated control.

Considering the per cent intensity of the disease at 70 DAS (Table 40), untreated control plots recorded the highest intensity of 8.46 per cent as compared to the lowest in integrated module (3.55 %). The intensity increased steadily to 80 DAS with integrated, biointensive, chemical module and untreated control recording 7.60, 12.10, 8.96 and 14.53 per cent, respectively. Similar efficiency of pest management modules was observed at 90 DAS.

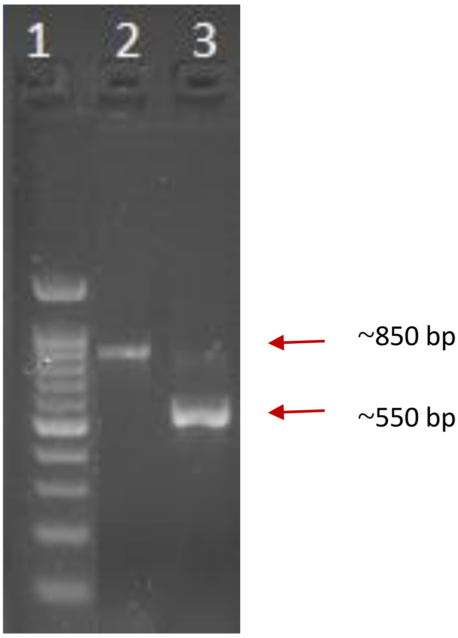



**Fig 19. Gel picture showing the PCR based detection of whiteflies and OELCV in symptomatic leaves using MtCOI specific and begomovirus specific primers, respectively**

**Lane 1: 100 bp ladder**
**Lane 2: Whitefly sample**
**Lane 3: OELCV sample**

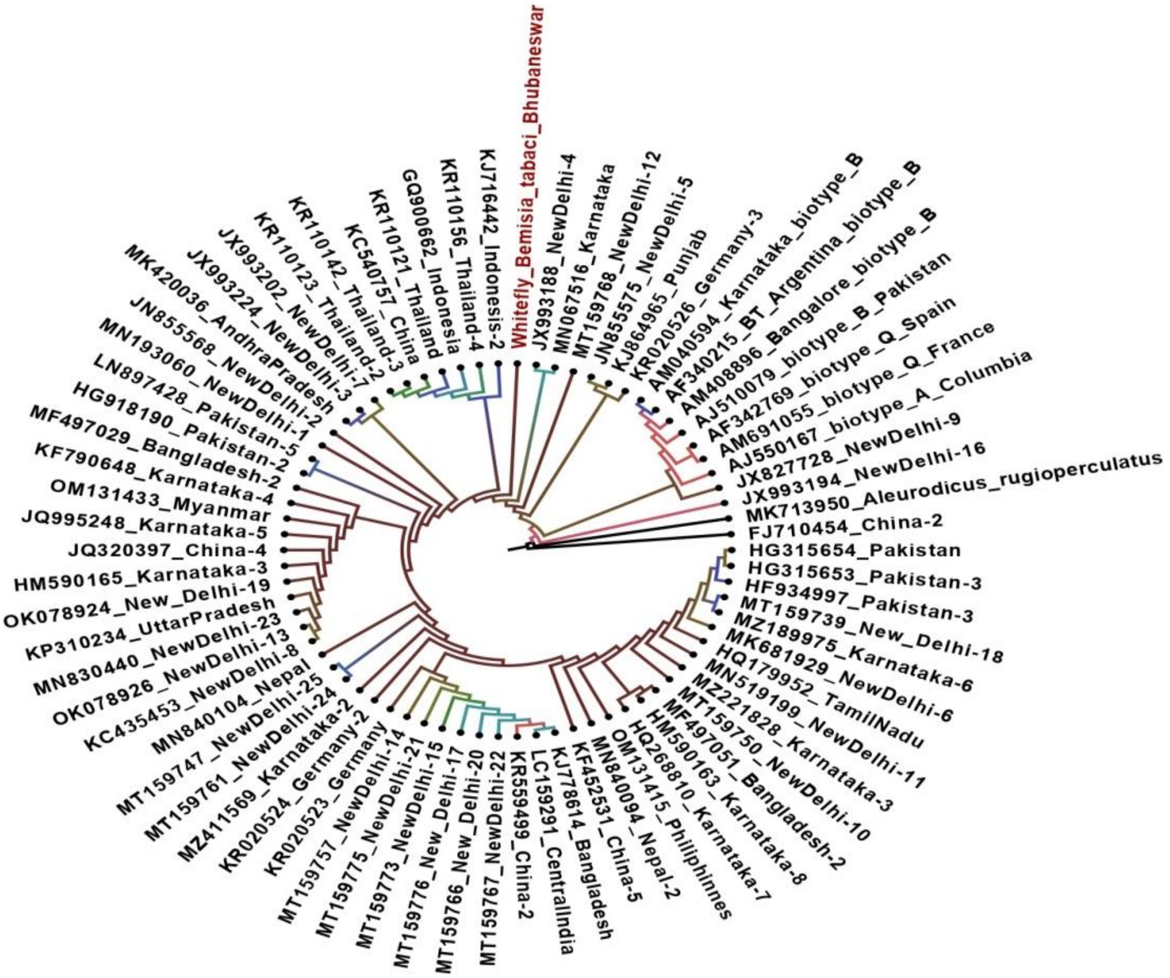



**Fig 20: Phylogenetic tree constructed from partial genome sequence of mtCOI gene of *Bemisia tabaci* with other isolates by MEGA 11 using neighbor joining algorithm**

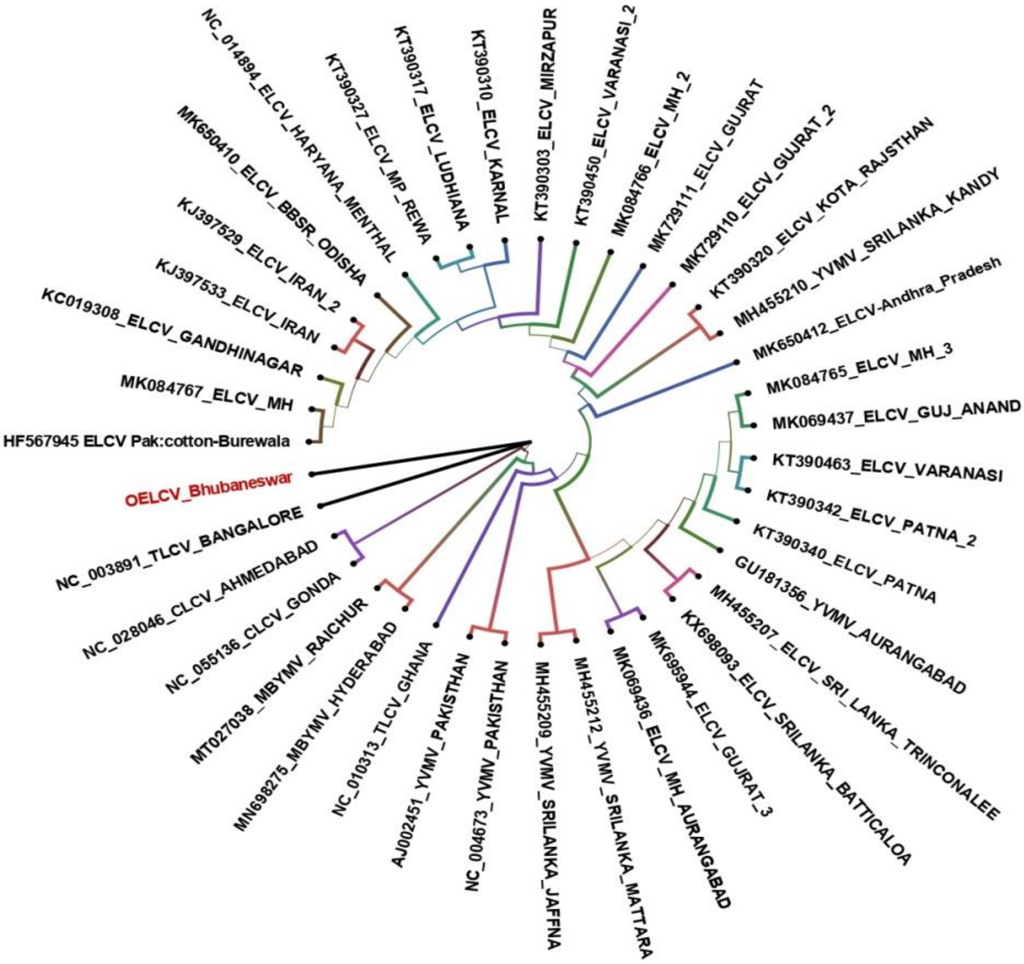


**Fig 21: Phylogenetic tree constructed from partial genome sequence of okra enation leaf curl virus with other strains by MEGA 11 using neighbour joining algorithm**

**Table 40. Effect of pest management modules on incidence and intensity of okra yellow vein mosaic disease during *kharif*, 2019**

| Treatment details | Disease Incidence (%) | | | Disease Intensity (%) | | |
|---|---|---|---|---|---|---|
| | 70 DAS | 80DAS | 90DAS | 70 DAS | 80DAS | 90DAS |
| $T_1$: Integrated Module | 0.95 (5.49) | 2.31 (8.55) | 3.07 (10.03) | 3.55 (10.87) | 7.60 (15.99) | 7.68 (16.04) |
| $T_2$: Biointensive Module | 2.02 (7.95) | 3.38 (10.41) | 4.47 (12.03) | 7.19 (15.54) | 12.10 (20.31) | 12.85 (20.98) |
| $T_3$: Chemical Module | 1.27 (6.26) | 1.98 (7.86) | 2.86 (9.63) | 5.10 (13.04) | 8.96 (17.40) | 8.89 (17.31) |
| $T_4$: Untreated control | 4.34 (11.87) | 6.65 (14.89) | 8.56 (16.94) | 8.46 (16.87) | 14.53 (22.37) | 14.46 (22.32) |
| **SE (m) ±** | **0.886** | **0.785** | **0.830** | **0.401** | **0.637** | **0.585** |
| **CD (5%)** | **2.73** | **2.42** | **2.56** | **1.24** | **1.96** | **1.80** |

*Figures in parentheses are angular transformed values

**Table 41. Effect of pest management modules on incidence and intensity of okra yellow vein mosaic disease during *kharif*, 2020**

| Treatment details | Disease Incidence (%) | | | | | | Disease Intensity (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40DAS | 50DAS | 60DAS | 70DAS | 80DAS | 90DAS | 40DAS | 50DAS | 60DAS | 70DAS | 80DAS | 90DAS |
| $T_1$: Integrated Module | 3.18 (10.08) | 6.81 (15.13) | 14.04 (22.00) | 16.38 (23.84) | 21.97 (27.94) | 25.78 (30.50) | 5.09 (12.98) | 14.52 (22.33) | 23.12 (28.73) | 26.46 (30.94) | 30.44 (33.46) | 35.90 (36.82) |
| $T_2$: Biointensive Module | 5.34 (13.32) | 10.01 (18.32) | 17.24 (24.47) | 22.37 (28.20) | 28.78 (32.43) | 32.66 (34.85) | 8.10 (16.50) | 19.59 (26.24) | 28.84 (32.42) | 35.68 (36.62) | 39.88 (39.12) | 40.38 (39.39) |
| $T_3$: Chemical Module | 2.55 (9.10) | 7.72 (16.07) | 14.95 (22.76) | 18.00 (25.08) | 23.01 (28.65) | 27.48 (31.61) | 6.31 (14.52) | 16.91 (24.27) | 25.89 (30.54) | 30.21 (33.28) | 38.64 (38.44) | 43.70 (41.38) |
| $T_4$: Untreated control | 6.08 (14.15) | 13.60 (21.65) | 20.83 (27.14) | 26.26 (30.80) | 32.10 (34.49) | 35.02 (36.27) | 11.79 (20.06) | 23.57 (29.03) | 37.26 (37.59) | 44.33 (41.74) | 47.73 (43.70) | 55.84 (48.38) |
| **SE (m) ±** | **0.887** | **0.785** | **0.555** | **0.734** | **0.603** | **0.571** | **0.552** | **0.742** | **1.081** | **1.461** | **1.222** | **1.561** |
| **CD (5%)** | **2.73** | **2.42** | **1.71** | **2.26** | **1.86** | **1.76** | **1.70** | **2.29** | **3.33** | **4.50** | **3.77** | **4.81** |

*Figures in parentheses are angular transformed values

### 4.3.5 Effect of pest management modules on incidence and intensity of okra yellow vein mosaic disease (OYVMD) during *kharif*, 2020

Incidence of OYVMV started early during *kharif,* 2020 i.e., at 30 DAS and quickly spread to entire field at 40 DAS with maximum incidence of 6.08 per cent in untreated control (Table 41). Subsequently the disease spread rapidly with 13.60 per cent incidence at 50 DAS. At this stage the incidence was the lowest in integrated module (6.81 %) being at par with chemical module (7.72 %). Similar trend was noticed at 60 DAS. The rate of incidence of the disease was also increased with the age of the crop. At 70 DAS the biointensive module was the least effective resulting in 22.37 per cent incidence as compared to the other modules. At 80 DAS similar trend in efficiency of modules were recorded. Integrated module was the most effective followed by chemical module, biointensive module and the untreated control at 90 DAS in order with corresponding disease incidence of 25.78, 27.48, 32.66 and 35.02 per cent, respectively.

Similarly, during *kharif,* 2020 the per cent intensity at 40 DAS (Table 41) was the highest in untreated control (11.79 %) and the lowest was with integrated module (5.09 %). At 50 DAS a quick spread in the disease occurred with per cent intensity ranging from 14.52 to 23.57 where the intensity was the lowest in integrated module and the highest in untreated control. Similar efficiency of the modules was recorded at 60 DAS. The lowest per cent disease intensity was recorded in integrated module (26.46 %) and the highest in untreated control (44.33 %) at 70 DAS. Integrated module was the most effective at 80 DAS with 30.44 per cent intensity of the disease as compared to chemical module and biointensive module with 38.64 and 39.88 per cent intensity, respectively and as against 47.73 per cent in untreated control. Similar trend was observed at 90 DAS with the integrated module having the lowest incidence of 35.90 per cent.

### 4.3.6 Effect of pest management modules on incidence and intensity of okra yellow vein mosaic disease (OYVMD) during summer, 2021

During summer, 2021 the incidence of OYVMD started early like *kharif*, 2020 with the maximum incidence of 1.70 per cent in biointensive module (Table 42). Subsequently, the disease spread rapidly. The lowest incidence was noticed in chemical module (2.75 %) being different from integrated module and biointensive module with respective incidence of 3.61 and 4.78 per cent at 50 DAS. Incidence of the disease ranged between 4.66 and 11.75 per cent at 60 DAS with the maximum in the untreated control as against the lowest in the chemical module. Among the modules, the biointensive module was least effective resulting in 12.44 per cent incidence as compared to the other modules at 70 DAS. Similar trend in efficiency of modules was recorded at 80 DAS. Chemical module was the most effective followed by integrated module, biointensive module and the untreated control with 12.06, 15.75, 19.89 and 26.93 per cent incidence, respectively at 90 DAS.

The per cent intensity during summer, 2021 (Table 42) indicates the highest infection in untreated control (5.67 %) and the lowest (2.92 %) in chemical module at 40 DAS. The per cent intensity of the disease increased to 6.55 per cent in chemical module at 50 DAS which was followed by integrated (8.31 %) and biointensive module (10.99 %). A quick spread in the disease occurred at 60 DAS with per cent intensity ranging from 14.89 to 21.39 where the lowest intensity was in chemical module and the highest in untreated control. Integrated module (24.45 %) was the most effective and closely followed by chemical module with 24.52 per cent intensity at 70 DAS. Similar trend in efficiency was followed during 80 and 90 DAS.

### 4.4 Effect of pest management modules on fruit quality

#### 4.4.1 Total Soluble Solid (TSS)

The total soluble solid content of the okra fruit ranged from 4.82 to 5.10 °Brix with the lowest in chemical module and the highest in untreated control during *kharif,* 2019 (Table 43). Similarly, during *kharif,* 2020 the TSS was 4.86, 4.96, 4.98 and 5.02 °Brix in the chemical, integrated, biointensive module and untreated control, respectively (Table 44). The highest TSS content was 5.12 °Brix in untreated control with the lowest in integrated module (4.98 °Brix) in the summer, 2021 (Table 45). The difference amongst the treatments in all the three seasons was not significant.

#### 4.4.2 Sugar

Like TSS, the sugar content in okra fruit was also not significant among the pest management modules (Table 43 to 45). However, the total sugar content in descending order was 1.51, 1.50, 1.45 and 1.44 per cent in the untreated control, biointensive, chemical and integrated modules, respectively during *kharif,* 2019. The total sugar content during *kharif,* 2020 and summer, 2021 was maximum in untreated control (1.54 and 1.68 %, respectively) whereas it was minimum in chemical module (1.48 and 1.62 %, respectively).

**Table 42. Effect of pest management modules on incidence and intensity of okra yellow vein mosaic disease during summer, 2021**

| Treatment details | Disease Incidence (%) | | | | | | Disease Intensity (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **40DAS** | **50DAS** | **60DAS** | **70DAS** | **80DAS** | **90DAS** | **40DAS** | **50DAS** | **60DAS** | **70DAS** | **80DAS** | **90DAS** |
| $T_1$: Integrated Module | 0.55 (4.22) | 3.61 (10.86) | 6.71 (14.90) | 8.90 (17.25) | 13.26 (21.29) | 15.75 (23.37) | 3.33 (10.53) | 8.31 (16.65) | 16.84 (24.27) | 24.45 (29.59) | 36.60 (37.21) | 39.63 (39.01) |
| $T_2$: Biointensive Module | 1.70 (7.36) | 4.78 (12.58) | 8.27 (16.65) | 12.44 (20.65) | 16.97 (24.29) | 19.89 (26.46) | 8.40 (16.80) | 10.99 (19.31) | 18.57 (25.51) | 30.95 (33.79) | 42.54 (40.66) | 47.73 (43.70) |
| $T_3$: Chemical Module | 0.47 (3.90) | 2.75 (9.54) | 4.66 (12.42) | 7.55 (15.94) | 10.46 (18.72) | 12.06 (20.36) | 2.92 (9.80) | 6.55 (14.83) | 14.89 (22.61) | 24.52 (29.64) | 39.70 (38.75) | 40.85 (39.70) |
| $T_4$: Untreated control | 1.35 (6.49) | 5.19 (13.11) | 11.75 (20.01) | 17.19 (24.48) | 24.03 (26.26) | 26.93 (31.26) | 5.67 (13.76) | 13.26 (21.31) | 21.39 (27.51) | 38.49 (38.33) | 56.02 (48.48) | 60.20 (50.90) |
| **SE (m) ±** | **0.558** | **0.440** | **0.636** | **0.573** | **1.322** | **0.665** | **0.533** | **0.467** | **0.895** | **0.991** | **1.692** | **0.888** |
| **CD (5%)** | **1.72** | **1.36** | **1.96** | **1.77** | **4.07** | **2.05** | **1.64** | **1.44** | **2.76** | **3.05** | **5.21** | **2.74** |

*Figures in parentheses are angular transformed values

The difference among the treatments in reducing sugar content of fruits in all the three seasons was not significant (Table 43 to 45). Reducing sugar content of the okra fruits in the integrated, biointensive, chemical modules and the untreated control was 0.92, 0.94, 0.91 and 0.94 per cent respectively during *kharif*, 2019. The content of reducing sugar during *kharif*, 2020 ranged from 0.88 to 0.98 per cent with the lowest in chemical module and the highest in untreated control. In summer, 2021 the highest reducing sugar content was obtained in integrated module treated fruits (1.22 %) and the lowest in untreated control (1.19 %).

The effect of the modules on non reducing sugar content was also not significant (Table 43 to 45). The non reducing sugar content of the okra fruits was highest in untreated control (0.54 %) and the lowest in integrated module (0.50 %) during *kharif*, 2019. Similar trend was recorded during *kharif*, 2020. However, during summer, 2021 the lowest non reducing sugar content was recorded from chemical module (0.39 %).

**4.4.3 Ascorbic acid**

The effect of pest management modules on ascorbic acid content of okra fruits was not significant in all the seasons (Table 43 to 45). During *kharif*, 2019 the highest ascorbic acid content of 18.20 mg/100 g was recorded in the fruits harvested from integrated module where as the lowest (16.46 mg/100 g) was recorded in untreated control. Similar trend was observed during *kharif,* 2020. The ascorbic acid content was relatively low in the fruits harvested from different modules in summer 2021 and was in descending order of 16.72, 15.58, 15.20 and 14.82 mg per 100 g in integrated, biointensive, chemical modules and the untreated control, respectively.

**4.4.4 Phenol**

There was very less variation in the phenol content of fruits harvested from different treatments. The phenol content varied marginally between 1.08 and 1.12 mg/g with the former in the untreated control and later in integrated module during *kharif*, 2019 (Table 43). Similar trend was noticed during *kharif*, 2020 also (Table 44). The phenol content was 1.08, 1.05, 1.06 and 1.05 mg per 100 g in integrated, biointensive, chemical modules and the untreated control, respectively during summer, 2021.

**4.4.5 Crude Fibre**

Different pest management modules also did not influenced the crude fibre content of okra fruits (Table 43 to 45). The crude fibre content of integrated,

**Table 43. Effect of pest management modules on fruit quality of okra during *kharif*, 2019**

| Treatment details | TSS (°Brix) | Total sugar (%) | Reducing Sugar (%) | Non reducing sugar (%) | Ascorbic acid (mg/100g) | Phenol (mg/g) | Crude Fibre (%) | Drymatter content (%) |
|---|---|---|---|---|---|---|---|---|
| $T_1$: Integrated Module | 4.94 | 1.44 | 0.92 | 0.50 | 18.20 | 1.12 | 9.70 | 12.87 |
| $T_2$: Biointensive Module | 4.98 | 1.50 | 0.94 | 0.53 | 17.70 | 1.09 | 8.30 | 12.66 |
| $T_3$: Chemical Module | 4.82 | 1.45 | 0.91 | 0.51 | 17.14 | 1.10 | 8.40 | 13.11 |
| $T_4$: Untreated control | 5.10 | 1.51 | 0.94 | 0.54 | 16.46 | 1.08 | 8.00 | 12.24 |
| **SE(m)±** | **0.118** | **0.036** | **0.038** | **0.046** | **0.583** | **0.024** | **0.416** | **0.982** |
| **CD(5%)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**Table 44. Effect of pest management modules on fruit quality of okra during *kharif*, 2020**

| Treatment details | TSS (°Brix) | Total sugar (%) | Reducing Sugar (%) | Non reducing sugar (%) | Ascorbic acid (mg/100g) | Phenol (mg/g) | Crude Fibre (%) | Drymatter content (%) |
|---|---|---|---|---|---|---|---|---|
| $T_1$: Integrated Module | 4.96 | 1.50 | 0.94 | 0.52 | 19.60 | 1.09 | 8.70 | 13.08 |
| $T_2$: Biointensive Module | 4.98 | 1.53 | 0.97 | 0.55 | 18.90 | 1.06 | 8.50 | 12.27 |
| $T_3$: Chemical Module | 4.86 | 1.48 | 0.88 | 0.53 | 18.48 | 1.05 | 8.90 | 12.45 |
| $T_4$: Untreated control | 5.02 | 1.54 | 0.98 | 0.57 | 17.50 | 1.04 | 8.40 | 12.09 |
| **SE(m)±** | **0.064** | **0.034** | **0.045** | **0.040** | **1.367** | **0.025** | **0.453** | **0.639** |
| **CD(5%)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**Table 45. Effect of pest management modules on fruit quality of okra during summer, 2021**

| Treatment details | TSS (°Brix) | Total sugar (%) | Reducing Sugar (%) | Non reducing sugar (%) | Ascorbic acid (mg/100g) | Phenol (mg/g) | Crude Fibre (%) | Drymatter content (%) |
|---|---|---|---|---|---|---|---|---|
| $T_1$: Integrated Module | 4.98 | 1.65 | 1.22 | 0.41 | 16.72 | 1.08 | 9.50 | 14.34 |
| $T_2$: Biointensive Module | 5.10 | 1.66 | 1.20 | 0.43 | 15.58 | 1.05 | 8.40 | 12.37 |
| $T_3$: Chemical Module | 5.08 | 1.62 | 1.21 | 0.39 | 15.20 | 1.06 | 9.60 | 13.17 |
| $T_4$: Untreated control | 5.12 | 1.68 | 1.19 | 0.46 | 14.82 | 1.05 | 8.40 | 12.12 |
| **SE(m)±** | **0.101** | **0.029** | **0.009** | **0.032** | **0.681** | **0.019** | **0.390** | **1.057** |
| **CD(5%)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

biointensive, chemical modules and the untreated control was 9.70, 8.30, 8.40 and 8.00 per cent, respectively during *kharif,* 2019. Similarly, during *kharif,* 2020 the crude fibre content was the highest in chemical module (8.90 %) and the lowest in untreated control (8.40 %). The trend was similar in summer, 2021.

### 4.4.6 Dry matter content

Various pest management modules also failed to influence the fruit dry matter in all the three seasons (Table 43 to 45).The dry matter content in fruits from integrated, biointensive, chemical modules and the untreated control was 12.87, 12.66, 13.11 and 12.24 per cent, respectively during *kharif,* 2019. The same ranged from 12.09 to 13.08 per cent during *kharif,* 2020 with the lowest under untreated control and the highest in integrated module. Similar but relatively higher amount of dry matter content was recorded during summer, 2021.

## 4.5 Effect on fruit yield

The fruit yield during *kharif*, 2019, *kharif*, 2020 and summer, 2021 are presented in Table 46. The marketable fruit yield was significantly higher under different pest management modules (7.70 to 8.75 t/ha) as compared to untreated control (6.93 t/ha). Integrated module recorded the highest yield of 8.75 t/ha which was 26.19 per cent higher than untreated control during *kharif*, 2019. The next highest yield (8.11 t/ha) was recorded from chemical module which was 17.03 per cent more than untreated control. However, biointensive module recorded the lowest yield (7.70 t/ha) with only 11.04 per cent increase over control.

During *kharif*, 2020 integrated module produced the highest fruit yield of 9.17 t/ha with 28.07 per cent increase over untreated control (7.16 t/ha) but was at par with chemical module producing 8.79 t/ha i.e., 22.70 per cent increase over untreated control. Both these two modules were superior to biointensive module which recorded the lowest yield among the modules i.e., of 8.20 t/ha and 14.55 per cent increase over untreated control.

However, considering the pooled mean of both the *kharif* seasons, the mean marketable yield with different modules (7.95 to 8.96 t/ha) was significantly higher than untreated control (7.04 t/ha). The yield was highest in the integrated module i.e., of 8.96 t/ha registering 27.24 per cent yield increase over untreated control and differed significantly from chemical (8.79 t/ha) and biointensive module (8.20 t/ha) with 19.99 and 12.90 per cent increase in yield over untreated control, respectively. Pooled over *kharif* seasons avoidable yield loss was the highest in integrated module (21.41 %) followed by chemical (16.66 %) and biointensive (11.43 %) modules.

The same trend in yield was observed in summer, 2021 though the yield was relatively lower. The yield was highest in the integrated module i.e., of 7.89 t/ha with 34.64 per cent increase over untreated control which was at par with chemical module (7.51 t/ha) with 28.08 per cent increase in yield over untreated control. Among the modules, the lowest marketable yield was recorded in biointensive module (5.86 t/ha) with only 17.41 per cent yield advantage over untreated control.

In the summer, 2021, the avoidable yield loss was also found to be the highest in integrated module (25.73 %) followed by chemical (21.92 %) and biointensive (14.83 %) module.

**4.6 Economics of pest management modules**

The incremental cost benefit analysis for the *kharif,* 2019 and *kharif,* 2020 (pooled) was calculated for different modules and is depicted in Table 47. The highest incremental cost benefit ratio (ICBR) of 1: 3.31 was obtained with integrated module with an incremental benefit of Rs 44,245/- per ha followed by chemical module with an ICBR of 1:1.52 and incremental benefit of Rs 25, 530/- per ha. The biointensive module recorded the lowest ICBR of 1:0.76 with incremental benefit of only Rs 11,800/- per ha.

The trend was similar in summer, 2021. It was observed that integrated module resulted in highest ICBR of 1: 3.56 with incremental benefit of Rs 47,545/- per ha followed by chemical module with ICBR of 1: 1.95 and incremental benefit of Rs 32,730/- per ha. The biointensive module produced the lowest ICBR of 1: 0.97 and incremental benefit of Rs 15,100/- per ha (Table 48).

**Table 46. Effect of pest management modules on the fruit yield (t/ha) of okra during *kharif*, 2019 and 2020 and summer, 2021**

| Treatment details | *Kharif*, 2019 | | *Kharif*, 2020 | | Pooled mean fruit yield of 2 *kharif* (t/ha) | Pooled increase in yield over control (%) | Avoidable yield loss (%) | Summer, 2021 | | Avoidable yield loss (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marketable fruit yield (mean of 15 pickings) (t/ha) | Increase in yield over control (%) | Marketable fruit yield (mean of 13 pickings) (t/ha) | Increase in yield over control (%) | | | | Marketable fruit yield (mean of 10 pickings) (t/ha) | Increase in yield over control (%) | |
| $T_1$: Integrated Module | 8.75 | 26.19 | 9.17 | 28.07 | 8.96 | 27.24 | 21.41 | 7.89 | 34.64 | 25.73 |
| $T_2$: Biointensive Module | 7.70 | 11.04 | 8.20 | 14.55 | 7.95 | 12.90 | 11.43 | 6.88 | 17.41 | 14.83 |
| $T_3$: Chemical Module | 8.11 | 17.03 | 8.79 | 22.70 | 8.45 | 19.99 | 16.66 | 7.51 | 28.08 | 21.92 |
| $T_4$: Untreated control | 6.93 | | 7.16 | | 7.04 | | | 5.86 | | |
| **SE(m)±** | **0.203** | | **0.210** | | **0.150** | | | **0.170** | | |
| **CD (0.05)** | **0.62** | | **0.65** | | **0.43** | | | **0.52** | | |

**Table 47. Incremental cost-benefit analysis of pest management modules against major insect pests in okra during *kharif*, 2019 and 2020 (pooled)**

| Tr. No. | Details of treatment | Dose gm or ml a.i/ha | Quantity of treatment required for single spray (g/ml/ha) | Cost of treatments for single spray (Rs) [1] | Labour charges for single spray (Rs/ha) [2] | Total cost{[1]+[2]+ cost of seed treatment with imidacloprid 600FS-Rs 580 + cost of yellow stickytrap (@20/ha) and pheromone trap (@5/ha)- Rs 650} [A] | Yield (kg/ha) | Increase in yield over control (kg/ha) | Value of increased yield (Rs/ha) [B] | Incremental benefit (Rs/ ha) [C=B-A] | ICBR 1: [C/A] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | Azadirachtin 0.03 % | 0.75 | 2500 | 1175 | 2025 | 1985 | 8960 | 1920 | 57600 | 44245 | 1: 3.31 |
| | Flonicamid 50 WG | 100 | 200 | 2000 | 2025 | 2810 | | | | | |
| | Spinetoram 11.7 % SC | 28.75 | 250 | 2875 | 2025 | 3685 | | | | | |
| | | | | | **Total** | **13355** | | | | | |
| $T_2$ | Neem soap @ 10 g/l | | 5000 | 1000 | 2025 | 1810 | 7950 | 910 | 27300 | 11800 | 1: 0.76 |
| | Pongamia soap @ 10 g/l | | 5000 | 1000 | 2025 | 1810 | | | | | |
| | NSKE 5 % | 1250 | 25000 | 875 | 2025 | 1685 | | | | | |
| | *Lecanicillium lecanii* @ 5g/l | | 2500 | 1250 | 2025 | 2060 | | | | | |
| | *Beauveria bassiana* @ 5g/l | | 2500 | 1250 | 2025 | 2060 | | | | | |
| | | | | | **Total** | **15500** | | | | | |
| $T_3$ | Flonicamid 50 WG | 75 | 200 | 2000 | 2025 | 2810 | 8450 | 1410 | 42300 | 25530 | 1: 1.52 |
| | Diafenthuron 50 WP | 250 | 500 | 2200 | 2025 | 3010 | | | | | |
| | Spiromesifen 22.9 SC | 143 | 625 | 3250 | 2025 | 4060 | | | | | |
| | Emamectin benzoate 5 % | 10 | 200 | 640 | 2025 | 1450 | | | | | |
| | | | | | **Total** | **16770** | | | | | |
| $T_4$ | Untreated Control | - | - | - | - | - | 7040 | - | - | - | - |

| | | | | |
|---|---|---|---|---|
| **Cost of treatments** (per commercial unit) | azadirachtin= Rs 470/ l | Spinetoram=Rs 1150/100 ml | Emamectin benzoate=Rs 320/100 g | Diafenthuron=Rs 110/25 g |
| | Flonicamid= Rs 300/30 g | Neem soap= Rs 200/ l | **Average market price of okra**= Rs 30 /kg | Spiromesifen =Rs 260/50 ml |
| | Pongamia soap= Rs 200/ l | Neem seed kernel= Rs 35/ kg | **ICBR= Incremental Cost Benefit Ratio** | *Lecanicillium lecanii*= Rs 500/ l |
| **Cost of Imidacloprid 600 FS** = Rs 580/100 ml | **Labour charge for spraying of chemicals**= Rs 405.00/day (5 nos. Of workers required/day/ha) | | Cost of yellow sticky trap= Rs 200/ 20 nos Cost of Pheromone funnel trap=Rs 250/5 nos. | *Beauveria bassiana*= Rs 500/ l |
| | | | | Cost of Ervit lure= Rs 200/5 nos. |

**Table 48. Incremental cost-benefit analysis of pest management modules against major insect pests in okra during summer, 2021**

| Tr. No. | Details of treatment | Dose gm or ml a.i/ha | Quantity of treatment required for single spray (g/ml/ha) | Cost of treatments for single spray (Rs) [1] | Labour charges for single spray (Rs/ha) [2] | Total cost{[1]+[2]+ cost of seed treatment with imidacloprid 600FS-Rs 580 + cost of yellow stickytrap (@20/ha) and pheromone trap (@5/ha)- Rs 650} [A] | Yield (kg/ha) | Increase in yield over control (kg/ha) | Value of increased yield (Rs/ha) [B] | Incremental benefit [C=B-A] | ICBR 1: [C/A] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | Azadirachtin 0.03 % | 0.75 | 2500 | 1175 | 2025 | 1985 | 7890 | 2030 | 60900 | 47545 | 1: 3.56 |
| | Flonicamid 50 WG | 100 | 200 | 2000 | 2025 | 2810 | | | | | |
| | Spinetoram 11.7 % SC | 28.75 | 250 | 2875 | 2025 | 3685 | | | | | |
| | | | | | **Total** | **13355** | | | | | |
| $T_2$ | Neem soap @ 10 g/l | | 5000 | 1000 | 2025 | 1810 | 6880 | 1020 | 30600 | 15100 | 1: 0.97 |
| | Pongamia soap @ 10 g/l | | 5000 | 1000 | 2025 | 1810 | | | | | |
| | NSKE 5 % | 1250 | 25000 | 875 | 2025 | 1685 | | | | | |
| | *Lecanicillium lecanii* @ 5 g/l | | 2500 | 1250 | 2025 | 2060 | | | | | |
| | *Beauveria bassiana* @ 5 g/l | | 2500 | 1250 | 2025 | 2060 | | | | | |
| | | | | | **Total** | **15500** | | | | | |
| $T_3$ | Flonicamid 50 WG | 75 | 200 | 2000 | 2025 | 2810 | 7510 | 1650 | 49500 | 32730 | 1: 1.95 |
| | Diafenthuron 50 WP | 250 | 500 | 2200 | 2025 | 3010 | | | | | |
| | Spiromesifen 22.9 SC | 143 | 625 | 3250 | 2025 | 4060 | | | | | |
| | Emamectin benzoate 5 % | 10 | 200 | 640 | 2025 | 1450 | | | | | |
| | | | | | **Total** | **16770** | | | | | |
| $T_4$ | Untreated Control | - | - | - | - | - | 5860 | - | - | - | - |

| | | | | |
|---|---|---|---|---|
| **Cost of treatments** (per commercial unit) | azadirachtin= Rs 470/ l | Spinetoram=Rs 1150/100 ml | Emamectin benzoate=Rs 320/100 g | Diafenthuron=Rs 110/25 g |
| | Flonicamid= Rs 300/30 g | Neem soap= Rs 200/ l | **Average market price of okra**= Rs 30/ kg | Spiromesifen =Rs 260/50 ml |
| | Pongamia soap= Rs 200/ l | Neem seed kernel= Rs 35/ kg | **ICBR= Incremental Cost Benefit Ratio** | *Lecanicillium lecanii*= Rs 500/ l |
| **Cost of Imidacloprid 600 FS** = Rs 580/100 ml | **Labour charge for spraying of chemicals** = Rs 405.00/day (5 nos. Of workers required/day/ha) | | Cost of yellow sticky trap= Rs 200/ 20 nos<br>Cost of Pheromone funnel trap=Rs. 250/ 5 nos. | *Beauveria bassiana*= Rs 500/ l<br>Cost of Ervit lure= Rs 200/5 nos. |

# DISCUSSION

Various field and laboratory experiments relating to the dissertation entitled "Evaluation of pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench" was conducted during *kharif*, 2019 through 2020 and summer, 2021 at Central Research Station, Odisha University of Agriculture and Technology, Bhubaneswar. The results obtained during the course of investigation have been presented in the previous chapter and are critically discussed in this chapter.

## 5.1 Seasonal incidence of major insect pests of okra and their natural enemies in relation to weather factors

### 5.1.1 Leafhopper, *Amrasca biguttula biguttula* (Ishida)

The studies on incidence of leafhopper, *Amrasca biguttula biguttula* affirmed that it was one of the major sucking pests of okra and prevailed throughout the year irrespective of the cropping seasons. Anitha and Nandihalli (2008) and Mohanasundaram and Sharma (2011) also observed the infestation of okra leafhopper throughout the cropping season in their localities.

The pest was initially noticed on the crop during first week of August ($31^{st}$ SMW) with a population density of 0.53 per leaf in *kharif*, 2019. The population of the pest increased with the advancement of crop growth stage reaching the highest number (8.14 leafhoppers/leaf) that coincided with $35^{th}$ SMW (fifth week of August) and also maintained an active population till the final harvest of the crop (6.56 leafhoppers/ leaf). This may be due to rain induced succulence of the leaves at early stage crop. Further, increase in population might have been caused due to increase in sucking area, high leaf growth and vein growth and thickness. Also, as the plant age increased, there was proportional increase in size of leaf lamina and decrease in hair density, which also might have favoured the leafhopper population increase. Our finding is in confirmatory with Sindhu *et al.*, 2020 who reported that the leafhopper attained the peak activity at $31^{st}$ SMW (8.80/ leaf) i.e., five weeks after the incidence of the pest in Haryana condition in the *kharif* season. The activity of the pest might be related to the crop growth stage irrespective of the sowing time.

Similarly, in the *kharif* season of 2020, the infestation of *A. biguttula biguttula* on the okra crop was observed between $29^{th}$ and $40^{th}$ SMW in a higher magnitude compared to previous season with a population of 11.88 per leaf during its peak activity on $36^{th}$

SMW (first week of September). Sandhi and Sidhu (2018) observed the initiation of pest from 24$^{th}$ SMW with 0.33 leafhoppers per leaf and reaching its maximum at 31$^{st}$ SMW (22.42 leafhoppers/ leaf). Similar findings were also observed by Kumar *et al*. (2014). The population increased continuously during the entire cropping period due to congenial weather condition.

During 2021 summer, the incidence of leafhopper commenced from first week of April, which rapidly increased and attained its peak at 22$^{nd}$ SMW (fourth week of May) with a mean population density of 14.30 leafhoppers per leaf which was probably because of the higher evening relative humidity (63.00 %). However, this pest remained active in high numbers from 20$^{th}$ SMW (11.42/ leaf) to 24$^{th}$ SMW with a population of 10.62 per leaf. Patel *et al.* (2022) also observed the activity of *A. biguttula biguttula* from March to May with peak on fourth week of April with a population of 19 leafhoppers per three leaves. Similarly Jat and Singh (2019) reported the infestation of leafhopper from second week of March and attended a peak population in the first week of May. The slight differences in the incidence might be attributed due to the difference in sowing date of the crop and climatic factors of the region.

The correlation studies showed that population of *A. biguttula biguttula* was not affected by maximum temperature. The maximum temperature showed a non significant positive effect on *A. biguttula biguttula* population build up during *kharif*, 2019 whereas, in *kharif*, 2020 and summer, 2021 the effect was negative. The minimum temperature exhibited negative non significant effect during both the *kharif* seasons but the effect was positive and significant during summer, 2021. These findings are in agreement with the observations of Preetha and Nadarajan (2007) and Singh *et al*. (2013) who recorded a non significant negative effect of maximum temperature and mean temperature on *A. biguttula biguttula* population. Patel *et al.,* 2022 observed a significant positive correlation between leafhopper population and minimum temperature in summer season in okra crop. The leafhopper population was significantly and positively correlated with evening relative humidity in summer, 2021. This observation is in partial akin with Burade *et al*. (2019) who reported the correlation between leafhopper population and evening relative humidity was positive but not significant. Rainfall had positive but non-significant effect on leafhopper population in all the seasons. Here present findings differed with Mohansundaram and Sharma (2011) and Selvaraj *et al*. (2010) who showed that maximum temperature had positive impact whereas, rainfall and relative humidity had negative effect on leafhopper population. The observed differences may be attributed to different ecological conditions of the study area. Further, the leafhopper population showed a significant negative effect with wind speed during both the *kharif* seasons. Present findings are in agreement with the observation recorded by Sindhu *et al.* (2020) and Challa *et al.* (2020). However, it is in contradicts with the results of Selvaraj *et al*. (2010) as they observed a positive correlation between leafhopper population and wind speed. The *A. biguttula biguttula* population was positively correlated with bright sunshine hours during *kharif,* 2019 but it was negative during *kharif,* 2020 and summer, 2021 though these correlations were non-significant in all the seasons.

**5.1.2 Whitefly**

Whitefly incidence was noticed on fifteen days old crop during first week of August in *kharif*, 2019 (31$^{st}$ SMW) and attained peak during 37$^{th}$ SMW (second week of September). In the present study the okra crop witnessed relatively low activity of adult whiteflies during early growth stages of crop. This observation is in contradiction with Mohansundaram and Sharma (2011) who reported the peak population of adult whiteflies during early growth stages of okra. This variation may be attributed to changes in agro climatic condition as this pest require high temperature and low rainfall for rapid multiplication and continuous rainfall during the present study period might have affected the growth and multiplication of the insect.

The infestation of whitefly on the okra crop was observed during third week of July (29$^{th}$ SMW) with the highest population observed during fifth week of August (35$^{th}$ SMW) and it remained very active up to second week of September (37$^{th}$ SMW) in *kharif,* 2020. The present findings are in partial akin with the observation of Khating *et al*. (2016) who reported that whitefly incidence was started in last week of July and reached the peak in second week of September. Selvaraj *et al*., 2010 reported the peak activity of whitefly from 33$^{rd}$ to 36$^{th}$ SMW. The slight difference in incidence might be attributed due to the difference in sowing dates.

The incidence of whitefly during summer, 2021 commenced from first week of April (14$^{th}$ SMW) after 15 DAS which rapidly increased and attained the highest population on 19$^{th}$ SMW (first week of May) with a mean population density of 8.46 whitefly per leaf. Usually, when the temperature rises to more than 30 $^{\circ}$C, it favours the fecundity of this pest (Singh *et al.*, 2013) and in the present study duration, the temperature was more than 30 $^{\circ}$C throughout which favoured rapid multiplication. However, the population of whitefly remained fully active during the month of May, thereafter it declined. This observation is in accordance with the findings of Patel *et al*., 2022 who reported that the whitefly population in okra started from 11th SMW and it gradually increased attending a peak population of 17 whiteflies per three leaves on 17th SMW. However, the present finding is not in agreement with the reports of Sapkal *et al*. (2022) who reported that the whitefly population reached the highest population very quickly i.e., only three weeks after the first incidence.

The present findings revealed that the maximum temperature had a positive effect on *B tabaci* population in *kharif*, 2019 and summer, 2021. However, the relation was negative in *kharif*, 2020. Minimum temperature had positive but non-significant effect on population build up of whitefly. This result is in partial confirmation with the findings of Burade *et al.* (2019) who cited that whitefly had significant positive correlation with both maximum and minimum temperature. Morning relative humidity had positive correlation with *B tabaci* in *kharif*, 2019 however in *kharif*, 2020 and summer, 2021 this relationship was negative. Evening relative humidity had positive correlation with *B tabaci* population. Rainfall had positive non significant effect on whitefly population in both the *kharif* seasons but it was negative in summer, 2021. The present findings did not agree with those of Singh *et al.*, 2013 who reported negative correlation with maximum and minimum temperature, morning and evening relative humidity while the relation was positive with rainfall. The bright sunshine hours exhibited positive effect on whitefly in *kharif*, 2019 and summer, 2021 but negative in *kharif*, 2020. Further, wind speed exhibited negative correlation with *B. tabaci* population in both the *kharif* seasons but positive in summer, 2021. However, all the weather parameters had non-significant effect on *B. tabaci* population in the present findings.

**5.1.3 Aphid**

The pest appeared on crop during second week of August (32nd SMW) with 2.37 aphids per leaf in *kharif*, 2019. The aphid population was quite fluctuating in the season might be due to intermittent heavy rainfall. Maximum population of aphid (26.37/ leaf) was recorded during fifth week of August (35th SMW) and then followed a declining trend afterwards with a population of 4.31 per leaf at the final harvest of the crop. This finding is in partial accordance with the findings of Singh *et al.*, 2013. They reported that the aphid population on okra crop started from 36th SMW and reached the peak activity at 41st SMW (second week of October). The slight variation might be attributed to changes in ecological conditions and sowing dates.

During *kharif*, 2020 the incidence of aphids on the crop commenced from third week of July (29th SMW) with a population of 1.33 per leaf. However, the population remained low till fourth week of August (34th SMW) and then suddenly the population increased and remained active for the next three weeks with the peak population of 28.62 per leaf at 36th SMW i.e., at first week of September. The population declined to 1.32 at 40th SMW (first week of October). Sonaware *et al.,* 2021 reported the initiation of aphid in the third week of July and touching the peak during second week of September (37th SMW) with 34.70 aphid per three leaves.

Two peak populations of 14.05 and 14.60 aphids per leaf were recorded during 20th and 21st SMW in the summer, 2021. However, the population was less as compared to the *kharif* seasons. Beyond that the population decreased although the activity did not stop altogether and the pest was present in sizeable number (5.65/ leaf) during 25th SMW (third week of June). The findings of Aarwe *et al*., 2016 is in complete accordance with the present result who reported two peak activity of *A gossypii* at 36th and 37th SMW. Similarly Patel *et al.* (2022) reported that the incidence of aphid started from first week of March i.e., at 10th SMW and continued up to the crop termination at last week of May reaching the peak activity in third week of April i.e., 17th SMW with a population of 16.20 per three leaves. The slight difference might be due to change in sowing date and the ecological conditions of the locality.

The maximum temperature had positive but non-significant correlation with aphid population in both the *kharif* seasons. However, it exerted negative effect in summer, 2021. The minimum temperature in *kharif*, 2020 had significant positive effect on the population build up of *A gossypii*. The present finding is in agreement with Patel *et al*. (2022) but differ with the findings of Sonawane *et al*. (2021) and Potai and Chandrakar (2018) who reported a negative relationship between aphid population and minimum temperature. The present findings suggested that there was no significant relation between aphid population and relative humidity. Rainfall exhibited a significant negative effect with the population build up of aphids in *kharif* seasons whereas, bright sunshine hours in *kharif*, 2020 had positive significant effect. The results are in line with the observations of Challa *et al*., 2020 who reported a significant negative and positive effect of rainfall and bright sunshine hours, respectively on aphid population as heavy rainfall might wash away the aphids.

**5.1.4 Two spotted spider mite**

During *kharif*, 2019 infestation of *T. urticae* was initially noticed on 60 days old crop at 37th SMW (second week of September) with a lowest density of 2.16 per $cm^2$ leaf. The mite population occurred moderately with peak population of 8.21 per $cm^2$ leaf at 40$^{th}$ SMW (first week of October). As per the findings of Sugeetha (1998) in okra the mite incidence was noticed between 60 to 100 days old crop in *kharif* season.

Similarly during *kharif,* 2020 the mite incidence started relatively early in the season i.e., at 34$^{th}$ SMW (fourth week of August) on 50 days old crop with sizeable population of 3.10 per cm$^2$ leaf. Then with the age of the crop mite infestation increased attending relatively higher population at 36$^{th}$ and 40$^{th}$ SMW with 14.33 and 14.42 mites per cm$^2$ leaf, respectively.

The mite population in the okra crop during summer, 2021 was noticed from 18$^{th}$ SMW (fifth week of April) with population density of 3.52 per cm$^2$ leaf with early appearance by one week compared to *kharif,* 2020. This result is in confirmatory with the findings of Sugeetha, 1998 who reported that mite appeared on summer okra crop much earlier i.e., in mid April (50 DAS) and reached the peak from end of April to end of May (65-95 DAS). Thereafter the mite population increased at an accelerated pace in the succeeding weeks to reach peak of 16.28 per cm$^2$ leaf at 21$^{st}$ SMW. Similar trend in population fluctuation of mite was reported by Gulati, 2004 who stated that the incidence of mite started from April and reached the peak in the month of May.

Maximum temperature exerted a positive effect on the population of two spotted spider mite in both the *kharif* seasons whereas, minimum temperature exhibited significant negative effect only in *kharif*, 2019. However, in summer, 2021 this effect was vice versa. The present observation is in agreement with the results of Gulati (2004) and Mohansundaram and Sharma (2011) who reported negative effect of minimum temperature on population build up of two spotted spider mite. Morning relative humidity had negative effect on the population of *T. urticae* in *kharif*, 2019. However the effect was positive in *kharif*, 2020 and summer, 2021. Evening relative humidity and rainfall had negative influence on growth of two spotted spider mite in both the *kharif* seasons. Similar effect of evening relative humidity was observed by Gulati (2004). However all the weather parameters had non-significant effect on the mite population throughout the experimental period.

**5.1.5 Shoot and fruit borer**

The per cent fruit damage commenced from second week of September (37$^{th}$ SMW) with 1.82 per cent fruit damage on weight basis and its peak with cumulative fruit damage of 13.55 per cent recorded during 42$^{nd}$ SMW (third week of October) during *kharif*, 2019. The present findings are contradictory with the findings of Challa *et al.*, 2020 who reported early fruit infestation by *E vittella* i.e., 5 weeks after sowing (49$^{th}$

SMW). This variation might be due to change in ecological condition and difference in cultivar chosen.

The fruit damage initiated one week later to the previous year i.e., on 60 days old crop in *kharif*, 2020 with infestation of 3.11 per cent at 36$^{th}$ SMW (first week of September). The infestation by the borer increased gradually with a highest figure of 17.06 per cent on the final fruit harvest stage i.e., at 40$^{th}$ SMW (first week of October). Our result is similar with the findings of Rawat *et al.*, 2020 where the peak incidence of *E. vittella* occurred on 37$^{th}$ SMW with maximum of 5.7 larvae per plant.

In summer, 2021 the incidence of *E. vittella* started very late in the season with the per cent fruit infestation of 3.03 at 22$^{nd}$ SMW (fourth week of May) when the maximum temperature was 33.5 °C, morning RH of 92 per cent, 28.50 mm rainfall and 6.20 kmph wind velocity. Thereafter the infestation increased attending a peak of 13.95 per cent damage at 24$^{th}$ SMW (second week of June). These findings contradicts with Kadam and Khaire (1995) who reported the infestation of *E. vittella* was the highest from 7$^{th}$ to 20$^{th}$ SMW. Burade *et al.*, 2019 reported that *E. vittella* attended peak population at 15$^{th}$ SMW after five weeks of first incidence on okra crop.

The variation in per cent damaged fruits across the season may be attributed to variation in ambient weather condition. Temperature had a significant effect on the incidence and damage by *E. vittella* population. Maximum temperature had significant negative effect on the population of shoot and fruit borer during *kharif*, 2020. Similarly, minimum temperature had significant negative effect in all the three seasons. The results of Zala *et al.*, 1999 support the present findings as they have reported significant negative correlation between minimum temperature and the fruit damage inflicted by *E. vittella*. However, the studies of Selvaraj *et al.* (2010) and Mohansundaram and Sharma (2011) highlighted significant positive effect of minimum temperature on fruit damage. Morning relative humidity in *kharif*, 2020 had significant positive effect on the fruit damage caused by the shoot and fruit borer. The present finding is not in agreement with the results of Mohansundaram and Sharma (2011) who reported significant negative correlation between fruit damage and relative humidity. The observed variation might be due to change in agro climatic conditions and cultivars used for the study. The fruit damage was non-significantly and positively correlated with rainfall during *kharif*, 2020 and summer 2021 though the effect was negative during *kharif*, 2019. However, bright sunshine hour and wind speed had significant negative effect on the fruit damage in *kharif*, 2020 and summer, 2021, respectively. It can be inferred from the present studies that the per cent fruit damage decreased with increase in temperature, bright sunshine hour and wind speed.

**5.1.6 Coccinellids**

In the present studies four species of coccinellids namely *Coccinella transversalis, Cheilomenes sexmaculata, Micraspis discolor* and *Brumoides suturalis* were found associated with sucking pests of okra. Similar result with respect to coccinellid fauna on okra crop were reported by Singh *et al.*, 2013 from Madhya Pradesh and Potai and Chandrakar, 2018 from Raipur, Chhattisgarh. The appearance of coccinellids started after 30 DAS i.e., third week of August (33$^{rd}$ SMW) and 15 DAS i.e., third week of July (29$^{th}$ SMW) in *kharif,* 2019 and *kharif,* 2020, respectively. The peak activity coincided with the peak population of aphid on 35$^{th}$ SMW and 36$^{th}$ SMW in *kharif*, 2019 and *kharif*, 2020, respectively. Similar incidence in coccinellid abundance was recorded by Potai and Chandrakar (2018). However, in summer, 2021 the highest activity of coccinellid synchronized with the peak activity of leafhopper at 22$^{nd}$ SMW (fourth week of May).

The correlation studies indicated that coccinellids were adversely affected by maximum temperature in summer, 2021. However, both maximum and minimum temperature had a positive effect on the population build up of these predators in *kharif* season. The present findings are in conformity with findings of Meena and Kanwat (2010) as they also observed non significant positive correlation of maximum temperature with coccinellids. Both morning and evening relative humidity had negative effect in the *kharif* season but this effect was positive in summer season. Rainfall had significant negative correlation with the coccinellid population. These predators have significant positive correlation with the population build up of aphid and leafhopper. These findings are in line with the results of Khating *et al.*, 2016 and Lal *et al.*, 2020 who stated positive significant correlation between sucking pests and predatory ladybird beetle.

**5.1.7 Spiders**

Spiders are important group of arthropod natural enemies associated with insect pests in okra ecosystem (Singh *et al.*, 2013). The spider population reached its peak at 38$^{th}$ and 36$^{th}$ SMW in *kharif,* 2019 and *kharif* 2020, respectively. The peak activity of the spiders in *kharif,* 2020 synchronized with the highest activity of leafhopper, aphid and mite. In summer 2021, the highest activity of spider was noticed on fourth week of May (22$^{nd}$ SMW) which coincided with the highest activity of leafhopper.

The maximum temperature had significant negative influence on the population build up of predatory spiders in summer, 2021. However the relative humidity had significant positive effect as already reported by Sahito (2013). Rest of the weather parameters had no significant effect on the population of these predators. The spiders had significant positive correlation with leafhopper population in *kharif*, 2020 and summer, 2021.

## 5.2 Efficacy of pest management modules against insect pests and natural enemies in okra

### 5.2.1 Leafhopper

The various components of the pest management modules had significant influence on leafhopper population as evident from the data presented in Table 15 to 18. All the modules recorded significantly lower population as against higher population observed in case of untreated control. Amongst the modules, significantly lower population was recorded in integrated and chemical module. Biointensive module with higher seasonal mean leafhopper population was the least effective one in managing the leafhopper. The low level of leafhopper infestation in integrated and chemical module in the early stages of crop growth at 30 DAS could be attributed to seed treatment with imidacloprid (Gaucho 600 FS) @ 9 ml/kg seed. A number of workers *viz*., Rao *et al*., 2008, Birah *et al*., 2012, Kumawat *et al.*, 2014, Sarkar *et al*., 2016, Javed *et al*., 2019, and Mohod *et al*., 2019 in the past reported the efficacy of imidacloprid seed dressing in controlling leafhopper for variable period in okra which supports the present findings. Further, in chemical module application of Flonicamid 50 WG at 30 DAS suppressed the leafhopper population below ETL after five days of spraying though, the population increased after ten days of application. Foliar application of diafenthiuron and spiromesifen at 40 and 50 DAS, respectively was moderately effective in managing the leafhopper population. However, the chemical module proved its worth by recording the lowest leafhopper population in comparison to other modules. Recently, Kodandaram *et al.,* 2017 reported the efficacy of chemical module comprised of seed treatment with imidacloprid 70 % WS @ 3g/ kg seeds followed by spraying of thiamethoxam 25 % WG @ 0.5 g/l at 25 DAS, indoxacarb 14.5 % SC @ 0.5 ml/l at 35 DAS, dimethoate 30 % EC @ 2 ml/l at 45 DAS, emamectin benzoate 5 % SG @ 0.5 g/l at 55 DAS followed by spraying of cypermethrin 25 % EC @ 1 ml/l at 65 DAS explained the trend observed during the present study.

Similarly, in integrated module the seed treatment with imidacloprid suppressed the leafhopper population in initial stages of okra crop up to 45 DAS. Further, application of azadirachtin 0.03 % and flonicamid 50 WG at 30 and 40 DAS, respectively acted in tandem with imidacloprid seed treatment in reducing the leafhopper infestation in okra in integrated module. Previously, Sarkar *et al.*, 2016 had reported the efficacy of azadirachtin in reducing the population of leafhopper. Roy and Sarkar (2017) reported the efficacy of IPM compatible biorational modules with several components like acephate 75 SP @ 0.75 g/l at 3 weeks after sowing (WAS), thiamethoxam 25 WG @ 0.3 g/l at 5 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 6 WAS, flubendiamide 35.39 SC @ 0.3 ml/l at 8 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 10 WAS was the best in managing leafhopper population. It can be concluded that the effective and sustainable management of leafhopper in okra can be done by integrating seed treatment with imidacloprid along with foliar application of one biopesticide and need based application of relatively safer synthetic insecticide.

**5.2.2 Whitefly**

Adult whitefly population was significantly lower in all pest management modules compared to untreated control during all three seasons of study. Integrated and chemical modules both performed better over biointensive module in minimizing the whitefly infestation on okra crop. Seed treatment with imidacloprid 600 FS, installation of yellow sticky trap, application of azadirachtin 0.03 %, flonicamid 50 WG and spinetoram 11.7 SC might have significantly influenced the incidence of whitefly population in integrated module. Likewise, seed treatment with imidacloprid 600 FS followed by application of flonicamid 50 WG, diafenthiuron 50 WP, spiromesifen 22.9 SC and emamectin benzoate 5 SG each at 10 days interval probably kept the whitefly population under control in chemical module. The seed treatment with imidacloprid in integrated and chemical modules regulated the population of whiteflies during the early stages of crop growth up to 40 DAS which has been previously illustrated by Kumawat *et al.*, 2014. Integrated module adopted in the present investigation proved effective in suppression of whitefly population on okra crop which is in line of agreement with the observations of Birah *et al*. (2012) who recorded significantly lower whitefly population in integrated pest management module comprising seed treatment with imidacloprid @ 5 g/kg of seed, sowing maize at the borders as barrier crop, foliar spray of neem seed kernel extract @ 30 ml/l, spinosad 45 SC @ 0.5 ml/l and karanj oil @ 30 ml/l. The efficiency of yellow sticky trap in managing whitefly in okra has previously cited by Mohod *et al*., 2019; Borkakati and Saikia (2020) and Nath *et al*., 2020.

The efficiency of seed treatment with imidacloprid in containing the whitefly population in chemical module was augmented by the application of flonicamid 50WG, diafenthiuron 50WP, spiromesifen 22.9 SC and emamectin benzoate 5 SG at 30, 40, 50 and 60 DAS, respectively. The results are in agreement with observations recorded by Roy and Sarkar (2017) as they recorded minimum whitefly infestation on okra crop in both chemical (acephate 75 SP @ 0.75 g/l at 3 WAS, thiamethoxam 25 WG @ 0.3 g/l at 5 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 6 WAS, flubendiamide 35.39 SC @ 0.3 ml/l at 8 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 10 WAS) and integrated pest management (acephate 75 SP @ 0.75 g/l at 3 WAS, thiamethoxam 25 WG @ 0.3 g/l at 5 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 6 WAS, flubendiamide 35.39 SC @ 0.3 ml/l at 8 WAS, chlorpyrifos + cypermethrin 16 % + 5 % EC @ 1 ml/l at 10 WAS) module. Further, in the present experiment application of new insecticidal molecule like spiromesifen 22.9 SC has proved effective in managing whitefly as has been already reported by Anand *et al*., 2013, Alam *et al.*, 2014 and Mohod *et al*., 2019. Thus, whitefly population on okra seed crop can be effectively managed by seed treatment with imidacloprid in the early stages followed by installation of yellow sticky trap from 25 DAS, application of azadirachtin 0.03 % alternated with flonicamid 50WG or spiromesifen 22.9 SC in the later stages of crop growth.

**5.2.3 Aphid**

In the present study, all the pest management modules were quite effective in restricting aphid population in comparison to untreated control during all three crop seasons. Among the modules, the maximum reduction of *A. gossypii* population was recorded in chemical and integrated modules followed by biointensive module. The application of flonicamid 50WG, diafenthiuron 50 WP, spiromesifen 22.9 SC and emamectin benzoate 5 SG at 30, 40, 50 and 60 DAS, respectively reduced the aphid population effectively in chemical module. The efficacy of chemical module against aphid population in the present study was in partial corroboration with the observations recorded by Preetha and Nadarajan (2007) who reported both chemical and biointensive module were at par in managing aphid population in okra. However, in our study biointensive module comprising of foliar spray with neem and pongamia soap, NSKE 5 % and application of entomopathogenic fungi such as *L. lecanii* and *B. bassiana* each at

10 days interval was least effective one. This might be due to higher efficacy of integrated and chemical modules to restrict the aphid population for further rise. Moreover, efficiency of yellow sticky trap of integrated module could be instrumental in trapping alate form in managing aphid in okra (Nath *et al*., 2020).

**5.2.4 Two spotted spider mite**

In the present study, all the pest management modules recorded significantly lower mite population in comparison to higher population level recorded in untreated control during all three crop seasons. Among the modules, the maximum reduction of *T. urticae* population was recorded in chemical and integrated modules followed by biointensive module. Towards the end of cropping season the biointensive module with higher mean population was ineffective in managing the pest population. The application of flonicamid 50 WG, diafenthiuron 50 WP, spiromesifen 22.9 SC and emamectin benzoate 5 SG at 30, 40, 50 and 60 DAS, respectively reduced the *T. urticae* population effectively in chemical module. The efficacy of emamectin benzoate 5 SG against mite population in the present study was in corroboration with observations recorded by Sharma and Kaushik (2010) who recorded lowest population of *T. urticae* on okra crop sprayed with emamectin benzoate 5 SG @ 140 g/ha. Further, spiromesifen 22.9 SC acts as good acaricide in Punjab condition as reported by Singh *et al*., 2020. Krishnan and Sreekumar (2021) witnessed the efficacy of spiromesifen 22.9 SC @ 96 g a.i/ ha with minimum mite, *Polyphagotarsonenus latus* population on chilli crop. The superiority of integrated module in reducing the population of *T. urticae* may be attrbuted to spraying the crop with azadirachtin 0.03 %, flonicamid 50WG and spinetoram 11.7 SC at 30, 40 and 50 DAS, respectively. Azadirachtin due to its repellent, oviposiional deterrent and ovicidal activity might have resulted in the reduction in the population of *T. urticae*.

**5.2.5 Shoot and fruit borer**

The superiority of integrated module in containing the larval population had direct bearing on the resultant fruit damage caused by *Earias vittella*. The pooled fruit damage in integrated module (both on number and weight basis) varied between 5.24 and 5.06 per cent, respectively as against 10.12 and 10.19 per cent, respectively observed in untreated control. Remaining modules which recorded fruit damage in the range of 6.48 to 8.58 per cent were moderately effective in managing the incidence of *E. vittella*. The effective integration of the seed treatment, monitoring by installation of pheromone trap and bio-rational insecticides achieved the maximum reduction in the incidence of fruit borer on okra crop in integrated module. The present findings are in agreement with the observations recorded by Birah *et al*. (2012) who recorded minimum fruit damage in okra plots treated with IPM modules comprising of seed treatment with imidacloprid @ 5 g/kg seed, sowing of maize at the borders as barrier crop, weekly clipping of infested shoots and fruits, erection of pheromone trap @ 100 traps/ha for mass trapping, foliar spray of NSKE @ 30 ml/l, spinosad 45 SC @ 0.5 ml/l and karanj oil @ 30 ml/l at 45, 60 and 75 DAS, respectively. Further, field efficacy of three sprayings of spinetoram at fortnight interval @ 45 g a.i/ha in two seasons reduced the fruit borer damage to the tune of 81.60 and 82.20 per cent, respectively which has been proved by Vishnupriya and Muthukrishnan (2017). The fruit damage in other modules was quite higher probably due to failure of some components like NSKE, entomopathogenic fungi like *Beauveria bassiana* in regulating the larval population. Weather conditions might have rendered these strategies ineffective as reported by Sardana *et al*. (2005). Fruit damage by *Earias spp*. on the okra seed crop can be effectively managed by blending components like seed treatment with imidacloprid, foliar application with spinetoram 11.7 SC and emamectin benzoate 5 SG along with installation of pheromone traps.

**5.2.6 Coccinellids and spiders**

In the present investigation, the components of pest management modules significantly influenced the abundance of spiders and coccinellids on okra. Maximum reduction in the population of these predators was noticed in chemical module. Biointensive and integrated modules were safer to natural enemies as coccinellid and spider population were relatively more at different sampling intervals during the entire study period. Foliar application of flonicamid 50 WG, diafenthiuron 50 WP, spiromesifen 22.9 SC at 30, 40 and 50 DAS, respectively at the early crop growth stages and the use of emamectin benzoate 5 SG at 60 DAS having persistent contact toxicity at the mid and later growth stages of crop might have significant negative effect on spider and coccinellids population in chemical module. The harmful effects of intensive insecticide use in okra ecosystem influenced the population of predator fauna to a great extent as witnessed by Sardana *et al*. (2005). They observed no predatory spiders in farmers practices, which included 13 sprays of broad spectrum insecticides without due consideration to economic threshold level compared to higher spider population recorded in bio-intensive and IPM modules.

Higher densities of both the predators in integrated module may be due to use of relatively safer components *viz*., seed treatment with imidacloprid, installation of yellow sticky trap and pheromone trap, foliar application with azadirachtin 0.03 %, flonicamid

50 WG and spinetoram 11.7 SC at 30, 40 and 50 DAS, respectively. Similar higher densities of predators on okra crop was reported by Preetha and Nadarajan (2007) in an integrated module consisting of seed treatment with imidacloprid + release of *Trichogramma chilonis* @ 6 cc/ac + release of *Chrysoperla* 2000 eggs/acre + spraying of *Bacillus thuringiensis* (Spicturin FC) @ 2 ml/l. Selective systemic action of neonicotinoid seed treatment retained moderate predator population during the early age of the crop as reported by Nemade *et al.* (2008). The safety of neem product to spiders and coccinellids by their unique mode of action witnessed higher population of these predators in the integrated and biointensive module. Similarly, in integrated module, more number of predators was noticed due to incorporation of biopesticides *viz*., foliar spraying of neem soap, pongamia soap, NSKE 5%, *Lecanicillium lecanii* and *Beauveria bassiana* at 30, 40, 50, 60 and 70 DAS, respectively as proved by Roy and Sarkar, 2017. Further, Shabozoi *et al*., 2011 mentioned that bio pesticides are safe to natural enemies and integration of bio pesticides along with natural enemies have a good impact on crop yield.

### 5.3 Molecular characterization of whitefly and virus associated with okra yellow vein mosaic disease (OYVMD)

In order to know the transmission of observed viral disease i.e., OYVMD by means of whitefly it is essential to identify the insect vector as well as the virus. Therefore, attempt was made to characterize the whitefly and associated virus with the infected plants at molecular level.

Whitefly, *Bemisia tabaci* is a cryptic species complex with distinct biological, physiological and genetic variation as reported earlier by Perring (2001). So, it is difficult to develop sustainable approaches for managing whitefly and whitefly transmitted diseases due to the species composition and diversity within it. The genetic structure of most prevalent members of this complex species has been well studied. In the present investigation the whitefly samples from the Central Research Station, Department of Entomology, OUAT, Bhubaneswar were characterized based on mtCOI gene and the phylogenetic analysis showed that the whitefly sequences from our locality showed maximum homology with the sequences of mtCOI gene of whitefly isolates from New Delhi (Accession Number-MN193060), Andhra Pradesh (Accession Number-MK420036) and Pakistan (Accession Number-HG315654) available in GeneBank. Partial sequences of mtCOI gene along with the sequences retrieved from GeneBank were subjected to phylogenetic analysis where it was observed that the whiteflies from

Bhubaneswar grouped with the whitefly isolates from Indonesia, Thailand and China. However, the Bhubaneswar isolate of whitefly was placed singly in a separate sub-cluster (Fig. 20) whereas isolates from Indonesia, Thailand and China exhibiting closeness with the Bhubaneswar isolate were placed together in another sub-cluster. The present study is in line with the findings of Venkataravanappa *et al*. (2022) who reported that *B. tabaci* associated with okra enation leaf curl disease in India grouped with Asia-I and China-3 cryptic species group. Further, it is required to conduct complete sequencing of mtCOI gene (full genome sequencing) to know exactly the cryptic species group in which the whitefly from our locality is associated.

During the course of present investigation symptoms typical to yellow vein mosaic disease was noticed. In spite of that, DNA sequence of amplicon specific to begomoviruses revealed maximum homology (~ 94 % identity) was displayed with okra enation leaf curl virus (OELCV) strains from New Delhi (Accession Number-MK069437) and Karnataka (Accession Number-KT390311). OELCV from Bhubaneswar clustered with mungbean yellow mosaic virus (MYMV) from Raichur and Hyderabad (Fig. 21). These three viruses i.e., OELCV under the study and two different isolates of MYMV from Raichur and Hyderabad grouped together with tomato leafcurl virus (ToLCV) from Bangalore and chilli leaf curl virus (ChiLCV) from Ahmedabad and Gonda. Earlier study on okra yellow vein mosaic disease and its causal agent revealed that this disease is caused by a complex consisting of a begomovirus, okra yellow vein mosaic virus and a beta satellite molecule. Both the viruses i.e., okra yellow vein mosaic virus and okra enation leaf curl virus could be present but plants were able to exhibit symptom typical to only one virus (OYVMV). This result is in confirmatory with the findings of Sohrab *et al.* (2013) who also reported that a single plant never show both types of leaf curl and yellow vein mosaic symptoms i.e., OYVMV and OELCV of okra show either yellow vein mosaic or leaf curl symptom. Emmanuel *et al*. (2020) from Sri Lanka revealed that the begomovirus isolates shared 98.2-99.7% nucleotide identity with okra enation leaf curl virus. Moreover, repeated attempts should be made to check the presence of both the viruses. Based on 565 bp sequences, ~ 94 per cent homology was observed with OELCV, however, it could also display ~ 92 per cent homology with OYVMV. In future full genome sequencing of the virus is needed for exact identification.

Attempt to identify virus within whitefly was not successful and the reason could be the randomly chosen whiteflies for the purpose of DNA isolation was non-virulent (non acquisition of virus particle). Further, systemic experiments are required to unravel the exact scenario of the begomoviruses present there in and their transmission by whitefly.

**5.4 Effect of pest management modules on vector borne viral diseases of okra**

Yellow vein mosaic disease of okra noticed during *kharif,* 2019, 2020 and summer, 2021 in the present study is a major disease of okra that affects the crop yield and it was earlier stated by Patel *et al.,* 2021. Though it is a viral disease there is no specific management practice to reduce the disease incidence and one of the best measure to reduce the disease was to manage its vectors. All the pest management modules that has been tested, recorded significantly lower incidence of the disease in comparison to higher incidence recorded in untreated control during all three crop seasons. Integrated and chemical modules both performed better over biointensive module in minimizing the OYVMV and this might be due to reduced population of whitefly that acts as a vector of the diseases which is previously illustrated by Ali *et al.,* 2005 and Sanwal *et al.,* 2014. Seed treatment with imidacloprid 600 FS, installation of yellow sticky trap, application of azadirachtin 0.03 % and flonicamid 50 WG and spinetoram 11.7 SC might have significantly influenced the incidence of whitefly population in integrated module and thereby the incidence and intensity of the disease. Likewise, seed treatment with imidacloprid 600 FS followed by application of flonicamid 50 WG, diafenthiuron 50 WP, spiromesifen 22.9 SC and emamectin benzoate 5 SG each at 10 days interval probably kept the whitefly population under control in chemical module. During *kharif,* 2019 the incidence of OYVMV started late in the season and that could be due to the prevailing weather condition which attributed for late disease development. The seed treatment with imidacloprid in integrated and chemical modules regulated the population of whiteflies during the early stages of crop as a result the per cent disease incidence is low in the modules where seed treatment was a component. Our result is in line with Ali *et al.,* 2005 and Manju *et al.,* 2018 who reported effectiveness of imidacloprid in controlling whitefly population (1.00/ leaf) and recorded 7.20 per cent disease incidence (PDI) of OYVMV. Further, in integrated module, installation of yellow sticky trap from 25 DAS and application of azadirachtin 0.03 per cent at 30 DAS and flonicamid 50 WG at 40 DAS and spinetoram 11.7 SC at 50 DAS synergized seed treatment in reducing the whitefly population on okra seed crop. The effectiveness of yellow sticky trap along with other treatments in reducing the whitefly and thereby OYVMV was previously reported by Mandal *et al.,* 2020. The efficiency of azadirachtin was previously tested by Poudel *et al.*, 2018 against OYVMV and their result is in accordance to the present result showing reduction in whitefly population and thereby the incidence of OYVMV. The efficiency of seed treatment with imidacloprid in containing the whitefly population in chemical module was augmented by the application of flonicamid 50 WG, diafenthiuron 50 WP, spiromesifen 22.9 SC and emamectin benzoate 5 SG at 30, 40, 50 and 60 DAS, respectively and this result is in corroboration with the results obtained by Panigrahi *et al.,* 2020 who reported seed treatment with imidacloprid 600 FS @ 5 ml/kg of seed, installation of yellow sticky trap @ 50 traps/ ha and spraying of diafenthiuron 50 % WP @ 1 g/l resulted lowest mean population of whitefly (3.74/ 3 leaves) and also lowest OYVMD infected plant (3.70 %). The failure of biointensive module in reducing the per cent disease incidence might be attributed to the components used which failed in managing the whitefly population as a result the disease spread rapidly. However, irrespective of the treatments in different modules the disease incidence increased towards maturity of the crop which was previously cited by Sree *et al*., 2018.

### 5.5 Effect of pest management modules on fruit quality

The data on effect of pest management modules on fruit quality *viz.*, total soluble solids, sugar, ascorbic acid, phenol, crude fibre and dry matter content revealed that none of the module had any significant effect on fruit quality during all the three seasons of study. Earlier report by Visnupriya and Muthukrishnan (2017) indicated that insecticides besides controlling the target pests also induce growth promoting effects (phytotonic effect) such as increase in plant height, chlorophyll content and yield in various vegetables. Hence, the present study was carried with a motive of studying the effect of pest management modules on various biochemical parameters of the plant. The present result is partially confirmatory with the findings of Visnupriya and Muthukrishnan (2017) who studied the phytotonic effect of Spinetoram 12 SC on okra and witnessed non-significant effect of spinetoram on crude fibre content of okra.

### 5.6 Economics of pest management modules

Different pest management modules were evaluated against the major insect pests of okra and among them integrated module found to be highly cost effective with highest yield and incremental cost benefit ratio (ICBR) during all the three seasons. Chemical module was the next best modules with higher monetary returns per rupee invested on plant protection measures. Biointensive module was the least economically feasible with lower economic returns per unit of input cost. In spite of higher fruit yield in chemical module, the lower incremental cost benefit ratio was due to higher cost involved of insecticides such as flonicamid 50 WG, diafenthiuron 50 WP, spiromesifen 22.9 SC and emamectin benzoate 5 SG. The present result is contradictory to the findings of Singh and Gupta (2014) who reported maximum yield and cost benefit ratio from farmer's practice module where only insecticides were applied. This variation might be due to the involvement of newer insecticide molecules in the present study which were relatively costlier. However, the present finding is in conformity with the results obtained from Rajashekhar *et al.* (2016) where maximum benefit cost ratio (3.91) was obtained from NCIPM recommended module comprising of components *viz.*, sowing of OYVMV resistant hybrid MH-10, growing sorghum or maize on border, setting up of yellow sticky traps @ 15/ acre, erection of bird perches @ 10/ acre, giving two sprays of NSKE @ 5 % , spraying imidacloprid 17.8 SL @ 40 g a.i/ha, installation of pheromone traps @ 2/ acre, releasing of egg parasitoid and need based application of chemical pesticides imidacloprid 17.8 SL @ 40 g a.i/ha, cypermethrin 25 EC @ 200 g a.i/ha, quinolphos 25 EC @ 0.05 %, propargite 57 EC @ 850 g a.i/ha. The present findings are also in line with Borkakati and Saikia (2020) and Patil *et al.*, 2020 who reported maximum benefit cost ratio from integrated modules.

# SUMMARY AND CONCLUSION

The effect of pest management modules on insect pest complex of okra under field trials (*kharif*, 2019, *kharif*, 2020 and summer, 2021) was conducted at the Central Research Farm, Department of Entomology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar. The details of the conduct of various experiments, results obtained and validation of the result through discussion have already been presented in previous chapters. The summary of the entire experiment and the conclusion derived is presented in this chapter.

Okra crop was found to be attacked severely by sucking pests like leafhopper, *Amrasca biguttula biguttula* (Ishida), whitefly, *Bemisia tabaci* (Gennadius), aphid, *Aphis gossypii* Glov. during the early crop growth stages in the present study. Whereas, the shoot and fruit borer, *Earias vittella* (Fabricius) and two spotted spider mite, *Tetranychus urticae* Koch dominated during mid and later crop growth stages. Among the natural enemies, four species of ladybird beetles i.e., *Coccinella transversalis* (Fab.), *Micraspis discolor* (Fab.), *Cheilomenes sexmaculata* (Fab.) and *Brumoides suturalis* (Fab.) and mixed population of spiders were found associated with their prey.

The incidence of major insect pests and natural enemies associated with the crop and their relation to the weather parameters during the experimental period were studied prior to evaluation of the pest management modules. Arka Anamika variety of okra crop was sown in 400 $m^2$ area during third and first week July in *kharif*, 2019 and 2020, respectively whereas, in the summer sowing was completed in the first week of March, 2021 following all the agronomic practices except plant protection measures. The population counts of different pests and natural enemies were recorded at weekly interval till crop maturity. The results revealed that the activity of *A. biguttula biguttula* was first noticed on 15 days old crop at 31$^{st}$ SMW (first week of August), 29$^{th}$ SMW (third week of July) and at 14$^{th}$ SMW (first week of April) during *kharif*, 2019, *kharif*, 2020 and summer, 2021, respectively. The population increased gradually and attained its peak at 35$^{th}$ SMW (fifth week of August) during *kharif*, 2019. Likewise, during *kharif*, 2020 and summer, 2021 the highest activity was witnessed during 36$^{th}$ SMW (first week of September) and 22$^{nd}$ SMW (fourth week of May), respectively. The correlation studies between leafhopper and abiotic factors revealed that wind speed exerted significant negative effect during both the *kharif* seasons whereas, minimum temperature and evening relative humidity had significant positive effect during summer, 2021. The peak population of *B. tabaci* was observed during 37th (second week of September) and 35th (fifth week of August) SMW during *kharif*, 2019 and *kharif*, 2020, respectively while during summer, 2021 the maximum activity was noticed at 20th SMW (second week of May). The correlation with weather parameters revealed that none of the abiotic factors had any significant effect on whitefly population in all the three seasons. The maximum activity of aphid was recorded at 35th (fifth week of August) and 36th (first week of September) SMW through *kharif*, 2019 and *kharif*, 2020, respectively and in summer the highest activity was during 21st SMW (third week of May). Rainfall exhibited significant negative effect during both the *kharif* seasons though both minimum temperature and bright sunshine hours had significant positive effect during *kharif*, 2020 only. The infestation of two spotted spider mite was commenced on 55 to 60 days old crop at 38th SMW during *kharif*, 2019. The highest population during *kharif*, 2020 and summer, 2021 was observed at 36th (first week of September) and 21st SMW (third week of May), respectively. Among the abiotic factors only minimum temperature had significant negative effect on the mite population during *kharif*, 2019. The natural enemies such as coccinellids and spiders reached their maximum activity during 35th (fifth week of August) and 38th (third week of September) SMW, respectively during *kharif*, 2019. Furthermore, during *kharif* 2020 and summer 2021 the highest activity of both the predators was recorded during 36th (first week of September) and 22nd (fourth week of May) SMW, respectively. Rainfall had significant negative effect on the population build up of coccinellids during *kharif*, 2019. Likewise, during summer, 2021 both morning and evening relative humidity had significant positive effect on spider population but this effect was negative with maximum temperature. Both the predators had significant positive effect with their prey population during all the three seasons. The shoot damage by *E. vittella* was absent in all three seasons in the present investigation. However, fruit infestation was present with maximum infestation at 42nd (third week of October) and 40th (first week of October) SMW during *kharif*, 2019 and *kharif*, 2020, respectively whereas, during summer, 2021 the highest fruit infestation was recorded during second week of June (24th SMW). The correlation studies revealed that minimum temperature had significant negative effect in all the three seasons. Moreover, during *kharif*, 2020 maximum temperature and bright sunshine hours also exerted significant negative effect on fruit infestation by *E. vittella* though the effect was positive with morning relative humidity. Similarly, during summer, 2021 wind speed exhibited significant negative effect.

The efficacy of pest management modules along with untreated control was tested against major insect pests of okra and their effect on natural enemies population during *kharif*, 2019, *kharif*, 2020 and summer, 2021. The results revealed that both integrated module comprising of seed treatment with imidacloprid 600 FS @ 9 ml/kg seed + yellow sticky trap (@ 20/ ha) at 25 DAS + pheromone trap (@ 5/ ha) at 30 DAS + azadirachtin 0.03 % @ 5 ml/l after 30 DAS + flonicamid 50 WG @ 0.4 g/l at 10 DAFiS + spinetoram 11.7 % SC @ 0.5 ml/l at10 DASS and chemical module (Seed treatment with imidacloprid 600 FS @ 9 ml/kg seed + flonicamid 50 WG @ 0.4 g/l after pest appearance + diafenthiuron 50 WP @ 1 g/l at 10 DAFiS + spiromesifen 22.9 SC @ 1.25 ml/l at 10 DASS + emamectin benzoate 5 % SG @ 0.4 g/l at10 DATS) were found superior in managing *A. biguttula biguttula*, *B. tabaci* and *A. gossypii* during all the three seasons of study. The higher population of *Tetranychus urticae* was observed in bio-intensive module [Neem soap @ 10 g/l after pest appearance + pongamia soap @ 10 g/l at 10 DAFiS + NSKE 5 % @ 50 g/l at 10 DASS + *Lecanicillium lecanii* @ 5 g/l at 10 DATS + *Beauveria bassiana* @ 5 g/l at 10 DAFoS] compared to the lower population recorded in integrated and chemical module. Among the modules tested, integrated module was superior with highest per cent reduction over control in fruit damage both in number and weight basis which was followed by chemical module and bio-intensive module, respectively during all the three seasons. The population of coccinellids and spider were significantly lower in chemical module compared to good number of these natural enemies witnessed in other pest management modules and untreated control.

The pest management modules were also evaluated against incidence and intensity of vector borne viral diseases of okra. Among several viral diseases, okra yellow vein mosaic disease was prevalent in all the three seasons though the incidence pronounced lately during *kharif*, 2019. This disease was transmitted by whitefly, *B. tabaci*. The lowest incidence and intensity of yellow vein mosaic virus was also recorded in integrated and chemical module with the highest incidence being recorded in bio-intensive module. Molecular characterization of both yellow vein mosaic virus and whiteflies collected from virus infected plants were also done by conducting PCR followed by gel electrophoresis of isolated DNA samples. The whiteflies from Bhubaneswar grouped phylogenetically with the whitefly isolates from Indonesia, Thailand and China. In case of viruses, OELCV from Bhubaneswar clustered with *Mungbean yellow mosaic virus* (MYMV) from Raichur and Hyderabad.

The effect of pest management modules on fruit quality *viz*., total soluble solids, sugar, ascorbic acid, phenol, crude fibre and dry matter content revealed that none of the module had any significant effect on fruit quality during all the three seasons

Integrated module recorded the highest yield with maximum avoidable yield loss which was followed by chemical module. Bio-intensive module recorded the lowest yield though it was superior over control. Among the pest management modules evaluated against major insect pests of okra, integrated module was found to be highly cost effective with highest incremental cost benefit ratio during all the three seasons. Chemical module was the next best modules with higher monetary returns per rupee invested on plant protection measures. Bio-intensive module was the least economically feasible with lower economic returns per unit of input cost.

From the entire investigation it can be concluded that integrated module [seed treatment with imidacloprid 600 FS @ 9 ml/kg seed + yellow sticky trap (@ 20/ ha) at 25 DAS + pheromone trap (Ervit lure @ 5/ ha) at 30 DAS + azadirachtin 0.03 % @ 5 ml/l after 30 DAS + flonicamid 50 WG @ 0.4 g/l at 10 DAFiS + spinetoram 11.7 % SC @ 0.5 ml/l at10 DASS] and chemical module [Seed treatment with imidacloprid 600 FS @ 9 ml/kg seed + flonicamid 50 WG @ 0.4 g/l after pest appearance + diafenthiuron 50 WP @ 1 g/l at 10 DAFiS + spiromesifen 22.9 SC @ 1.25 ml/l at 10 DASS + emamectin benzoate 5 % SG @ 0.4 g/l at10 DATS] were most effective in managing *A. biguttula biguttula*, *B. tabaci*, *A. gossypii*, *T. urticae*, and *E.vittella* during all the three seasons of study. The highest natural enemies *viz*., coccinellids and spiders were recorded in bio-intensive module [Neem soap @ 10 g/l after pest appearance + pongamia soap @ 10 g/l at 10 DAFiS + NSKE 5 % @ 50 g/l at 10 DASS + *Lecanicillium lecanii* @ 5 g/l at 10 DATS + *Beauveria bassiana* @ 5 g/l at 10 DAFoS] and untreated control. Also the integrated and chemical modules had significant effect with minimum per cent incidence and intensity of okra yellow vein mosaic disease during all the three seasons of study. However, none of the module had any significant effect on fruit quality such as total soluble solids, sugar, ascorbic acid, phenol, crude fibre and dry matter content. The highest ICBR of 3.31 and 3.56 was obtained from the plots treated with integrated module during *kharif* 2019 and 2020 (pooled) and summer 2021, respectively.

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**ANNEXURE-I**

**Meteorological data during *kharif*, 2019**

| Month | SMW | Temperature (°C) | | RH (%) | | Rainfall (mm) | BSH (hours) | Wind velocity (kmph) |
|---|---|---|---|---|---|---|---|---|
| | | Max | Min | Morning | Afternoon | | | |
| July | 29 | 29.20 | 26.30 | 91.00 | 63.00 | 24.20 | 8.40 | 1.10 |
| | 30 | 31.90 | 25.60 | 95.00 | 77.00 | 94.60 | 4.40 | 1.10 |
| August | 31 | 31.20 | 26.00 | 93.00 | 77.00 | 48.90 | 1.50 | 1.40 |
| | 32 | 32.60 | 26.00 | 93.00 | 74.00 | 101.50 | 4.20 | 1.70 |
| | 33 | 32.30 | 26.00 | 95.00 | 80.00 | 73.10 | 2.70 | 1.30 |
| | 34 | 32.50 | 26.00 | 96.00 | 81.00 | 87.30 | 3.00 | 0.40 |
| | 35 | 32.00 | 26.20 | 94.00 | 77.00 | 9.80 | 2.50 | 0.30 |
| September | 36 | 32.30 | 26.10 | 95.00 | 77.00 | 108.70 | 3.00 | 1.00 |
| | 37 | 32.10 | 26.20 | 94.00 | 77.00 | 40.30 | 4.10 | 1.50 |
| | 38 | 33.60 | 26.00 | 92.00 | 72.00 | 23.20 | 7.10 | 0.60 |
| | 39 | 29.90 | 24.40 | 96.00 | 89.00 | 234.30 | 1.20 | 0.50 |
| October | 40 | 34.00 | 24.40 | 87.00 | 73.00 | 7.40 | 5.80 | 0.50 |
| | 41 | 32.20 | 23.90 | 94.00 | 83.00 | 38.60 | 4.80 | 0.30 |
| | 42 | 33.00 | 23.70 | 92.00 | 66.00 | 2.00 | 7.60 | 0.70 |

**<u>Meteorological data during *kharif*, 2020</u>**

| Month | SMW | Temperature (°C) | | RH (%) | | Rainfall (mm) | BSH (hours) | Wind velocity (kmph) |
|---|---|---|---|---|---|---|---|---|
| | | Max | Min | Morning | Afternoon | | | |
| July | 27 | 34.40 | 27.00 | 94.00 | 72.00 | 76.50 | 4.50 | 0.60 |
| | 28 | 33.50 | 26.20 | 96.00 | 70.00 | 34.40 | 3.40 | 0.80 |
| | 29 | 34.60 | 26.60 | 92.00 | 68.00 | 26.60 | 7.50 | 1.70 |
| | 30 | 34.40 | 26.10 | 92.00 | 64.00 | 13.20 | 5.20 | 0.70 |
| August | 31 | 35.40 | 26.50 | 92.00 | 68.00 | 169.40 | 6.50 | 1.10 |
| | 32 | 33.30 | 26.50 | 94.00 | 72.00 | 61.10 | 3.80 | 0.40 |
| | 33 | 32.80 | 26.20 | 95.00 | 78.00 | 150.40 | 2.20 | 0.80 |
| | 34 | 31.00 | 25.60 | 95.00 | 86.00 | 195.10 | 0.60 | 1.00 |
| | 35 | 33.50 | 26.50 | 92.00 | 66.00 | 25.70 | 6.20 | 1.10 |
| September | 36 | 35.20 | 26.70 | 92.00 | 64.00 | 8.60 | 8.60 | 0.10 |
| | 37 | 34.40 | 26.90 | 93.00 | 68.00 | 13.70 | 6.40 | 0.30 |
| | 38 | 33.30 | 26.30 | 95.00 | 73.00 | 175.40 | 4.80 | 0.50 |
| | 39 | 33.60 | 26.10 | 94.00 | 71.00 | 27.40 | 4.30 | 0.80 |
| October | 40 | 30.60 | 25.20 | 97.00 | 86.00 | 116.50 | 1.50 | 0.60 |

**Meteorological data during summer, 2021**

| Month | SMW | Temperature (°C) | | RH (%) | | Rainfall (mm) | BSH (hours) | Wind velocity (kmph) |
|---|---|---|---|---|---|---|---|---|
| | | Max | Min | Morning | Afternoon | | | |
| March | 12 | 38.50 | 23.50 | 92.00 | 30.00 | 0.00 | 3.70 | 3.70 |
| | 13 | 39.70 | 24.60 | 93.00 | 55.00 | 75.00 | 6.30 | 5.90 |
| April | 14 | 37.60 | 25.50 | 92.00 | 46.00 | 3.50 | 6.80 | 6.90 |
| | 15 | 37.00 | 24.80 | 89.00 | 50.00 | 3.70 | 4.60 | 6.60 |
| | 16 | 38.80 | 26.00 | 90.00 | 42.00 | 0.00 | 8.00 | 8.20 |
| | 17 | 39.90 | 26.60 | 89.00 | 37.00 | 0.00 | 7.30 | 7.10 |
| | 18 | 37.30 | 25.00 | 87.00 | 47.00 | 5.60 | 7.60 | 7.50 |
| May | 19 | 37.40 | 25.50 | 85.00 | 60.00 | 58.20 | 8.10 | 6.70 |
| | 20 | 37.10 | 27.30 | 91.00 | 51.00 | 31.20 | 8.90 | 7.90 |
| | 21 | 34.90 | 25.60 | 89.00 | 67.00 | 105.30 | 4.40 | 9.40 |
| | 22 | 33.50 | 27.60 | 92.00 | 63.00 | 28.50 | 5.60 | 6.20 |
| June | 23 | 36.60 | 26.70 | 92.00 | 60.00 | 21.80 | 7.70 | 5.40 |
| | 24 | 32.20 | 25.40 | 94.00 | 72.00 | 113.80 | 0.50 | 3.60 |
| | 25 | 32.20 | 26.20 | 94.00 | 78.00 | 165.80 | 1.80 | 3.20 |

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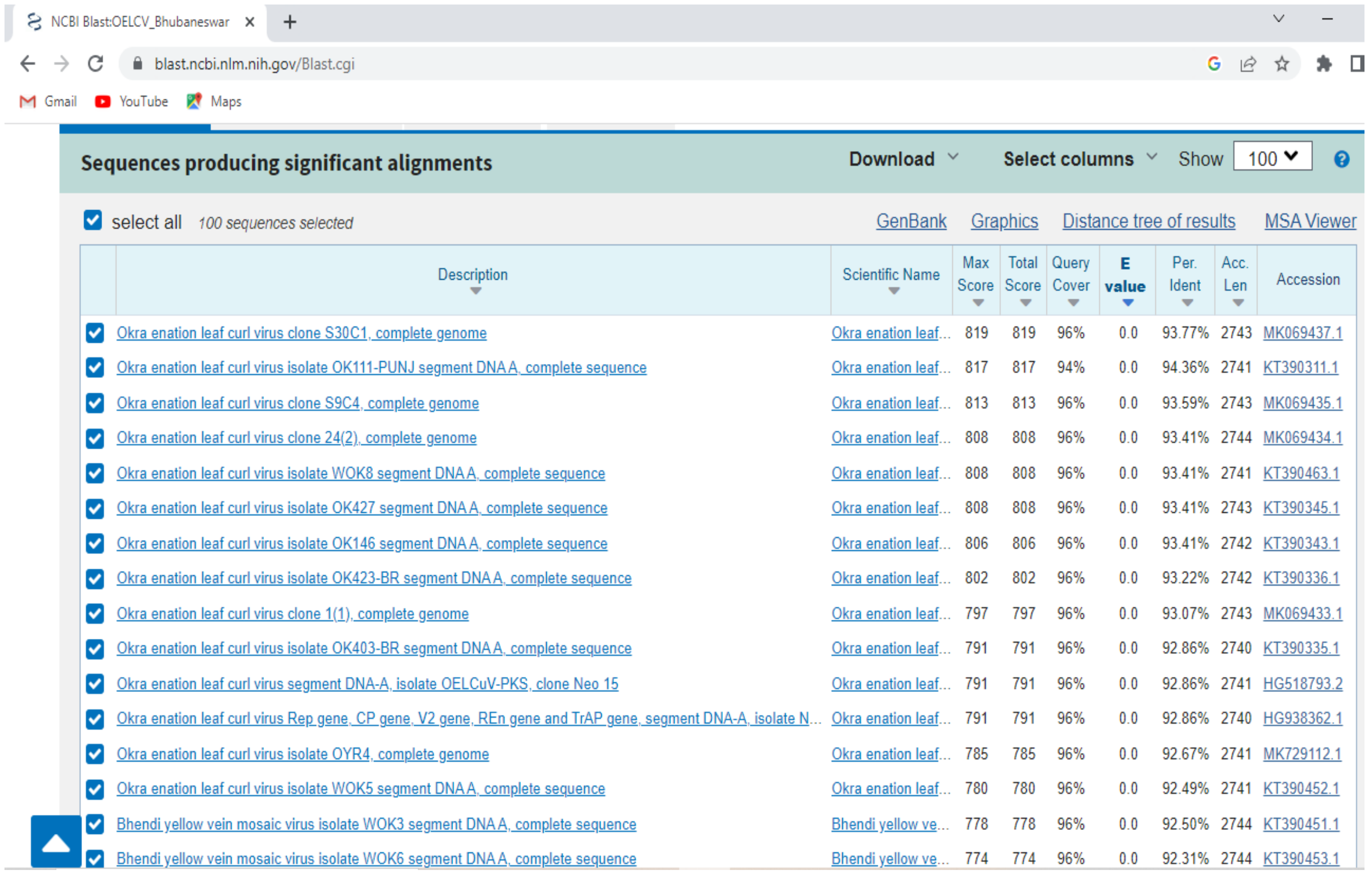
|---|---|---|---|---|---|---|---|---|---|
| ☑ | Bemisia tabaci isolate GL2 cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1511 | 1511 | 100% | 0.0 | 99.17% | 858 | MN193060.1 |
| ☑ | Bemisia tabaci isolate CBEBRI cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1511 | 1511 | 100% | 0.0 | 99.17% | 867 | MH374141.1 |
| ☑ | Bemisia tabaci mitochondrial partial COI gene for cytochrome oxidase subunit 1, isolate P-376 | Bemisia tabaci | 1511 | 1511 | 100% | 0.0 | 99.17% | 867 | HG918196.1 |
| ☑ | Bemisia tabaci isolate Amravati cytochrome oxidase subunit 1 (co1) gene, partial cds; mitochondrial | Bemisia tabaci | 1511 | 1511 | 100% | 0.0 | 99.17% | 867 | JN855568.1 |
| ☑ | Bemisia tabaci isolate X-92 cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 868 | MN566917.1 |
| ☑ | Bemisia tabaci cytochrome oxidase subunit I gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 867 | MK420036.1 |
| ☑ | Bemisia tabaci cytochrome oxidase subunit I gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 867 | MK420035.1 |
| ☑ | Bemisia tabaci mitochondrial partial COI gene for cytochrome oxidase subunit 1, isolate P-208 | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 866 | HG315654.1 |
| ☑ | Bemisia tabaci mitochondrial partial COI gene for cytochrome oxidase subunit 1, isolate P-204 | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 865 | HG315652.1 |
| ☑ | Bemisia tabaci mitochondrial partial COI gene for cytochrome oxidase subunit 1, isolate P-76 | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 866 | HF934996.1 |
| ☑ | Bemisia tabaci isolate Uttarkannada cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 867 | JX993224.1 |
| ☑ | Bemisia tabaci isolate Bangalore III cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 867 | JX993193.1 |
| ☑ | Bemisia tabaci isolate Birbhum I cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 867 | JX993190.1 |
| ☑ | Bemisia tabaci isolate Belgaum cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 867 | JX993188.1 |
| ☑ | Bemisia tabaci isolate Bapatla I cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 867 | JX993184.1 |
| ☑ | Bemisia tabaci isolate Amravati cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial | Bemisia tabaci | 1506 | 1506 | 100% | 0.0 | 99.05% | 867 | JX993182.1 |

**Fig 22.Nucleotide BLAST alignment of *B. tabaci* from Bhubaneswar**



Sequences producing significant alignments — Download — Select columns — Show 100

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| Description | Scientific Name | Max Score | Total Score | Query Cover | E value | Per. Ident | Acc. Len | Accession |
|---|---|---|---|---|---|---|---|---|
| Okra enation leaf curl virus clone S30C1, complete genome | Okra enation leaf... | 819 | 819 | 96% | 0.0 | 93.77% | 2743 | MK069437.1 |
| Okra enation leaf curl virus isolate OK111-PUNJ segment DNA A, complete sequence | Okra enation leaf... | 817 | 817 | 94% | 0.0 | 94.36% | 2741 | KT390311.1 |
| Okra enation leaf curl virus clone S9C4, complete genome | Okra enation leaf... | 813 | 813 | 96% | 0.0 | 93.59% | 2743 | MK069435.1 |
| Okra enation leaf curl virus clone 24(2), complete genome | Okra enation leaf... | 808 | 808 | 96% | 0.0 | 93.41% | 2744 | MK069434.1 |
| Okra enation leaf curl virus isolate WOK8 segment DNA A, complete sequence | Okra enation leaf... | 808 | 808 | 96% | 0.0 | 93.41% | 2741 | KT390463.1 |
| Okra enation leaf curl virus isolate OK427 segment DNA A, complete sequence | Okra enation leaf... | 808 | 808 | 96% | 0.0 | 93.41% | 2743 | KT390345.1 |
| Okra enation leaf curl virus isolate OK146 segment DNA A, complete sequence | Okra enation leaf... | 806 | 806 | 96% | 0.0 | 93.41% | 2742 | KT390343.1 |
| Okra enation leaf curl virus isolate OK423-BR segment DNA A, complete sequence | Okra enation leaf... | 802 | 802 | 96% | 0.0 | 93.22% | 2742 | KT390336.1 |
| Okra enation leaf curl virus clone 1(1), complete genome | Okra enation leaf... | 797 | 797 | 96% | 0.0 | 93.07% | 2743 | MK069433.1 |
| Okra enation leaf curl virus isolate OK403-BR segment DNA A, complete sequence | Okra enation leaf... | 791 | 791 | 96% | 0.0 | 92.86% | 2740 | KT390335.1 |
| Okra enation leaf curl virus segment DNA-A, isolate OELCuV-PKS, clone Neo 15 | Okra enation leaf... | 791 | 791 | 96% | 0.0 | 92.86% | 2741 | HG518793.2 |
| Okra enation leaf curl virus Rep gene, CP gene, V2 gene, REn gene and TrAP gene, segment DNA-A, isolate N... | Okra enation leaf... | 791 | 791 | 96% | 0.0 | 92.86% | 2740 | HG938362.1 |
| Okra enation leaf curl virus isolate OYR4, complete genome | Okra enation leaf... | 785 | 785 | 96% | 0.0 | 92.67% | 2741 | MK729112.1 |
| Okra enation leaf curl virus isolate WOK5 segment DNA A, complete sequence | Okra enation leaf... | 780 | 780 | 96% | 0.0 | 92.49% | 2741 | KT390452.1 |
| Bhendi yellow vein mosaic virus isolate WOK3 segment DNA A, complete sequence | Bhendi yellow ve... | 778 | 778 | 96% | 0.0 | 92.50% | 2744 | KT390451.1 |
| Bhendi yellow vein mosaic virus isolate WOK6 segment DNA A, complete sequence | Bhendi yellow ve... | 774 | 774 | 96% | 0.0 | 92.31% | 2744 | KT390453.1 |

**Fig 23. Nucleotide BLAST alignment of okra ELCV from Bhubaneswar**

# Evaluation of various pest management modules for insect pest complex in okra, *Abelmoschus esculentus* (L.) Moench

*by* Swapnalisha Mohapatra

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