EVALUATION OF IPM MODULE FOR THE MANAGEMENT OF KEY INSECT PESTS IN CHILLIES

ABSTRACT

Chilli is an important tropical and subtropical crop grown all over India as versatile spice as well as vegetable crop. Among the plethora of constraints in chilli cultivation, the crop attack by a multitude of pests and mite at different crop stages is of utmost concern. Field experiments were laid out at Kuttiyagoundanur village of Kolathur block of Salem District to find out the best integrated management practices of key pests in a randomized block design with the following three modules. The results of IPDM capsule for the management of major pest and diseases including viral diseases in chillies revealed that pre-treatment count on thrips/leaf was non-significant in all treatments including the untreated control and it was ranged from 7.20 to 8.40 thrips/leaf. The thrips infestation in leaf ranged from 3.20 to 9.46, 2.60 to 11.58 ,~~and~~ 3.82 to 16.42 and~~,~~ 2.10 to 13.46 in 5, 7, 9 and 11 WAT respectively. Among the treatments, farmers practice of chemical control recorded less infestation of 2.93 thrips/leaf followed by IPM module recorded 3.60 thrips/leaf. The pre-treatment count of mite/leaf was ranged from 17.09 to 19.23 mite/leaf. The mite infestation in leaves ranged from 7.01 to 19.21 and 3.64 to 21.42 in 13 and 15 WAT respectively. Among the treatments, IPM module recorded less infestation of 5.32 mite/leaf followed by farmers practice recorded 12.90 mite/leaf. The pretreatment count of fruit borer was ranged from 3.20 to 3.72 larvae/plant. The fruit borer infestation in plant ranged from 0.21 to 3.92, 0.13 to 4.54 larvae/plant in 13 and 15 WAT respectively. Among the treatments, chemical control recorded less infestation of fruit borer and fruit damage 0.17 larva/plant and 1.40 % followed by IPM module that is ~~recorded~~ 1.17 larvae/plant and 4.91%. The leaf curl infection was low in farmers practice 10.82 per cent followed by IPM module recorded 15.26 per cent. Maximum fruit yield 11200 kg/ha with comfortable B:C ratio of 2.96 was obtained in IPM module followed by Farmers practice with B:C ratio of 2.91.

Keywords: Chillies, thrips, insecticides, mite

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INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important economical spice as well as popular vegetable crop grown all over India which is essential ingredient of Indian curry and tempted by

Comment [VV1]: Mention the modules or rephrase the sentence

Comment [VV2]: Use single abbreviation in whole document (IPM or IPDM) characterized colour and titillating pungency having immense commercial dietary and therapeutic values and grown throughout the year (1). It is a native of tropical America and was introduced in India by the Portuguese in 19th century. At present, India is the second largest producer of chillies in the world, which contributes about one fourth of the world's production. Chilli has been reported as a commercial spice crop in tropical and sub-tropical parts of the India. –In India, chilli is an important agricultural crop, not only because of its economic importance, but also for the nutritional value of its fruits which are excellent source of natural colours and antioxidant compounds (2). The attractive colour is because of presence of a pigment known as 'Capsanthin' and the pungency due to an alkaloid "capsaicin".

Comment [VV3]: Add supporting figures of area and production if possible. Consult NHB database.

Comment [VV4]: Add 2-3 highest nutritional element present in chilli. Give value in per 100gm

Although, the crop has got great export potential besides huge domestic requirement, a number of limiting factors have been attributed for low productivity. The pest spectrum of chilli crop is complex with more than 293 insects and mite species debilitating the crop in the field as well as in storage (3, 4). Amongst these, aphids, *Myzus persicae* Sulzer., *Aphis gossypii* Glover., thrips, *Scirtothrips dorsalis* Hood., yellow mite, *Polyphagotarsonemus latus* Banks and fruit borer, *Helicoverpa armigera* Hubner (5), of which *S. dorsalis*, *A. gossypii*, *P. latus* and *H. armigera* are mainly responsible for inflicting yield loss up to 75% or more in Indian sub-continent (6) and these are the most vital production constraints (7, 8). During the last two decades insecticidal control of chilli pests in general and especially in irrigated crop characterized by high pesticide usage. Over use of pesticides have often leads to the development of undesirable problems like destruction of natural enemies, pest resurgence and failure of control strategies results in outbreak of leaf curl in chilli. In addition, the presence of pesticide residues in chillies (9) has been more concerned for export of chillies to developed countries. The yield losses due to aphid and whitefly are approximately 50% (10). The loss caused by the thrips is reported ranging from 50–90% and fruit borers to an extent of 90% (11). In this context, it is therefore necessary to develop effective non-chemical pest management strategies against sucking pests for sustained crop management and production of healthy food. In view of this indiscriminate use of chemical pesticides and public concerns, the rise of new generation insecticides provides an alternative to reduce the ill effects of conventional insecticides (9, 12). The new insecticides are more tissue-specific, activated in unique ways inside the target cells of insects resulting in reduced threat to other organism. Selective toxicity to insects and safety to natural enemies have made the new class of insecticides more user and eco-friendly. In order to prevent the infestation of the insect pests and to produce a quality crop, it is essential to manage the pest population at appropriate time with suitable measures (13).

In order to tackle the increasing menace of the pest, farmers have a habit of resorting excessive and often indiscriminate use of insecticides which pushes up the cost of production and at the same time inviting the problem of resistance to commonly used insecticides in chilli (14). Besides this, insecticidal residues in chillies have been reported by various workers in India (15). Now-a-days, the pesticide residues in chilli are a major non-tariff barrier for export of chillies to developed countries. It, therefore, is imperative to resort to other non-chemical pest management strategies such as use of organic amendments, use of newer molecules, along with some conventional insecticides may be helpful in population management of the insect with little disturbance of the agro-ecosystem. Keeping this background information in view, a detailed study was undertaken with the following objectives.

Comment [VV5]: Objectives are missing. Please mention clearly.

As chillies are harvested at multiple times ~~picked at short intervals~~ maintenance of insecticidal film is both uneconomical and hazardous. Furthermore, the uncontrolled use of insecticides has weakened sustainability, resulting in chemical residue buildup, pesticide resistance, comeback, and secondary outbreaks of these pests. Pesticide use, in addition to increasing production costs, has significant environmental and human health consequences due to excessive chemical residues (16). ~~Besides the indiscriminate use of insecticides has eroded sustainability and resulted in the buildup of pesticide residues, resistance to pesticides, resurgence, and the secondary outbreak of these pests. Besides increasing the cost of production, the use of pesticides has negative effects on the environment and human health, which is attributed to high chemical residues (16). So, the~~ The use of insecticides for the control of these pests is highly criticized for various reasons and therefore switching from insecticides to trap cropping might be a sustainable control measure,~~.~~ which ~~Trap crop~~ provides protection by ~~preventing~~ restricting the pests from entering the main crop and ~~the pests are diverted away from the main crop~~ checked or concentrated the movements in certain pockets of the field where they are easily ~~arrested or~~ controlled. Trap crops have an important attribute that ~~it~~ is distinctly more attractive to the pests than the main crop and have additional function for natural enemies. Intercropping and strip cropping reduce pest pressure on the cash crop through either a push (deterrent from cash crop) or pull (attraction to other species) approach. Researchers concluded that the use of the perimeter trap crop technique as part of Integrated Pest Management. (IPM) or organic program can help improve crop quality and overall farm profitability while reducing pesticide use and the possibility of secondary pest outbreaks (17). In tomato field using marigold (3:1 combination) as trap crop reduced 81–89% in the larval population of tomato fruit borer (18). Grain sorghum could serve as a successful trap crop for corn earworm in cotton (19). The effects of push-pull strategy was assessed with trap crops in cotton and showed *H. armigera* showed resistance against insecticides (20); while under trap cropping system, the *H. armigera* reduced on cotton and this insect showed preference on other minor crops. Insect pests showed disturbance with the cultivation of trap crops such as corn, beans, sunflower, pigeon pea, and cowpea (21); where whereas, it was observed that the losses in the main crop due to insect pests infestation reduced considerably due to trap cropping as compared to control. Trap cropping is the planting of a trap crop to protect the main cash crop from a certain pest or several pests (22). The trap crop can be from the same or different family group, than that of the main crop, as long as it is more attractive to the pest. The trap crop minimizes the cost and use of pesticides, lesser the use of pesticide, lowers the pesticide cost, preserves the indigenous natural enemies, improves the crop's quality and helps conserve the soil and the environment. trap cropping was reviewed as an IPM tool for controlling insect pests and concluded that trap crops can be arranged in various spatial patterns and the choice of design will depend on target pest, pest pressures, and garden or farm size (23). The insect pests on chilli may be reduced by using trap crops on the borers or at the alternate rows (24).

Intercropping is the agronomic practice of growing two or more crops in the same field at the same time (25). Crops may be planted without regard to rows (mixed intercropping), in alternating rows, or with different crops alternating within the same row. Relay intercropping refers to the planting of one intercrop species before another so that their life cycles partially overlap (26). Intercropping also encompasses combining crops and weeds intentionally and combining crops with beneficial non crop plants, such as cover crops or nursery crops (27). Mixtures of crop cultivars in their definition of intercropping, because such combinations may possess some of the advantages associated with conventional intercropping (28). In agricultural areas where labour is the primary resource and reduction of risk the primary concern, polyculture systems have been developed that give higher and more secure yields than monoculture (29). Successful intercropping systems often are characterized by greater efficiency in the use of solar radiation, nutrients, and soil moisture when compared with monocropped production under the same conditions (26, 30, 31). In India, (32) proposed three ways by which intercropping might reduce pest damage: (1) individual plants might be more difficult to find because they are usually more dispersed in intercropped systems; (2) certain plant species might serve as trap crops, diverting pests from other crops; and (3) some crops might have a repellent effect on herbivores. Conventional agricultural practices have harmful effects on the environment, human health and food security, including pesticide contamination of food, insect pest resistance to insecticides and the harm of non-target organisms, including pollinators and beneficial insects resulting in a shift to alternative management strategy such as intercropping and trap cropping for insect pests management (33, 34 and 35). This study was therefore undertaken to evaluate the best integrated management practices of thrips on chillies.

Comment [VV6]: Rewrite the whole paragraph as there is so much grey area between the sentences. Please try to co-relate the previous sentence with the next one.

MATERIALS AND METHODS

Field experiments were laid out at Kuttiyagoundanur village of Kolathur block of Salem District, Tamil Nadu to know the effect of IPM module against key insect pests of chillies and to find out the efficacy of IPM module for key insect pest in chillies in a randomized block design with the following three modules as treatments and replicated seven times with a Chilli Local Variety.

Comment [VV7]: If there is name then mention it..!

T1- Module 1:

Comment [VV8]: Graphical representation/ layout if added would be much more helpful to understand.

Seed treatment with Bacillus @ 2 g/lit; Barrier crop with two rows of maize; Intercropping of cluster bean @ 6:1 ratio; mulching with silver plastic mulch; Yellow sticky traps @ 50/ha placed at 30cm to 60cm above ground level to trap adult thrips ; Basal soil application of micronutrient mixture @ 2.5kg / ha each ferrous sulphate, zinc sulphate, copper sulphate, manganese sulphate and borax along with the foliar application of micronutrient mixture (0.2 per cent of each ferrous sulphate, zinc sulphate, copper sulphate, manganese sulphate and 0.1 per cent borax) @ 30 and 45 DAS ; Traps for fruit flies – 12 Nos/ ha ; ETL based (5 thrips/leaf) application of Imidacloprid 17.8 SL @ 3.0 ml/10 lit followed by pyriproxifen @ 0.1% at 10 days interval

T2- Farmers practice:

- Five sprays of thiodicarb 75 WP @ 0.5 g/lit at 3 WAT, 5 WAT, 7 WAT, 9 WAT and 11 WAT

T3- Module 3:

- Untreated control

The experimental plot was prepared with four ploughings and cross ploughings was followed to break the clods as well as to level the soil. The weeds and stubbles of previous crops were collected and removed from the soil of experimental plot. Thirty-five days old seedlings of chilli were transplanted in main field - experimental plots of size 5 x 4 m with spacing of 60 x 60 cm. The seeds of border crop of maize and intercrops such as cluster beans were sown and fifteen days old agathi seedlings at the time of chilli transplanting at different row proportions between the main crop – Chilli.

All the management practices were followed as per recommended package of practices of Tamil Nadu Agricultural University Horticultural Crops Production guide except the plant protection measures against target pest – Thrips. Yellow sticky traps @ 50/ha placed at 30 cm to 60 cm above ground level to trap adult thrips in the treatment Module 1.

Observation on thrips

The population of both adults and nymphs of thrips, *Scirtothrips dorsalis* (Hood) were counted. For counting the population, five chilli plants were selected randomly in each plot and tagged. The population count of thrips were taken from top, middle and bottom leaves and expressed as number of thrips per leaf until the population crosses ETL of 5 thrips / leaf at 30, 60 days after transplanting (DAT). ETL based (5 thrips / leaf) spraying of insecticides was done in all the treatments. First spraying of Imidacloprid 17.8 SL @ 3.0 ml/10 lit followed by pyriproxifen @ 0.1% at 10 days interval for the treatment module 1. For the treatment module 2, thiodicarb 75 WP @ 0.5 g/lit of water was used for five sprayings at 3 WAT, 5 WAT, 7 WAT, 9 WAT and 11 WAT. The insecticides were sprayed with the help of a knapsack sprayer fitted with hollow cone nozzle. The insecticides were sprayed with a volume of water at the rate of 500 l/ha. The target insect was chilli thrips *S. dorsalis*. To study the efficacy of different agro-chemicals, observation on population thrips was recorded one day before each spraying as pre-treatment count(PTC) as well as 3, 7 and 14 days after spraying. These data were subjected to analysis of variance after making necessary transformation (36) for comparison of treatment means.

Observation on Mites

The mite along with the leaf were collected from top, middle and bottom and kept in the perforated polythene bag of size 16 x 18 cm and the samples were brought to laboratory and examined under 20x magnification binocular microscope. Total number of mites from each leaf were counted and expressed in terms of number of mites per leaf.

Observation on fruit borer

The observation of larval population of chilli fruit borer, H. armigera was made on five randomly selected plants from each treatment at 16 and 18 WAT. Three different treatments were attempted.

Observation on Leaf Curl index

Ten plants were selected randomly in each plot and scored visually for leaf curling index (LCI) at 70 and 100 DAT following the 0–4 scale (37).

Where, 0 = absence of symptoms,

1 = 1–25% leaves/plant showing curling,

2 = 26–50% leaves/plant showing curling moderately damaged,

3 = 51–75% leaves/plant showing curling, heavily damaged, malformation of growing points, reduction in plant height, and

4 = more than 75% leaves/plant showing curling severe to complete destruction of growing point, drastic reduction in plant height, defoliation, severe malformation.

The population distribution of natural enemies includes both nymphs and adults of coccinellid beetles, chrysopids and spiders. These predators were recorded by visual observation on five randomly selected plants in each treatment. Later, the population densities of natural enemies were recorded based on the observations on number of Coccinellids, Spiders and *Chrysopa* per plant. For counting the population, five plants were selected randomly in each plot and tagged and observed at 60 and 90 DAT. In this field experiment, per cent reduction over control, Green chillie yield and BC ratio were also calculated. The reduction of thrips population over untreated control were calculated using the following formula (38)

Per cent reduction of abundance over control =

$$\frac{\text{Abundance in control plot - Abundance in treated plot}}{\text{Abundance in control plot}} \times 100$$

First harvesting was carried out at 90 DAT and successive plucking was made at an interval of 5-7 days. Fruit yield of each plot was taken from whole population separately and total yield of each treatment was calculated by cumulating the successive plucking from respective plots. Thereafter, yield per plot was computed to kilogram per hectare. To compare the yield performance of chilli in different treatments, analysis of variance was carried out in randomized block design. The per cent increase of yield in treatment over control was calculated from the following formula (39).

The increase in yield over control in various treatments was calculated by using the following formula,

$$\text{Increase of Yield (\%)} = \frac{\text{Yield of treated plot} - \text{Yield of Control plot}}{\text{Yield of Control plot}} \times 100$$

Dry chilli fruit yield

Totally two pickings of red chilli was done during 2020 *kharif* season. The total fruit yield from each plot was taken and expressed in terms of dry chilli fruit yield per hectare basis and subjected for statistical analysis.

Cost economics

The fruit yield per plot was recorded and computed to quintal per hectare. The data thus tabulated, pooled and ranked on the basis of their yield performance. The benefit cost ratio (B:C ratio) of different modules was worked out by estimating different cost of cultivation and return from fruit yield after converting them to one hectare of land. The average market price of dry chilli (Cv. Byadgi dabbi) was rupees 140 per Kg during the experimentation.

The following formulae were used for calculation of B:C ratio.

1. Gross return = Yield x Market price of Byadgi dabbi (Rs. 14000/q)
2. Net Returns = Gross Return - Total Cost
3. B:C ratio = Gross Return / Total Cost

The data on mean population of sucking pests, natural enemies and fruit borer were transformed to $\sqrt{x+1}$ and per cent damage was transformed to arcsine transformation and then subjected to ANOVA using M-STATC ® software package. The treatment effect was compared by following Duncan's Multiple Range Test (DMRT).

Analysis of benefit-cost ratios (BCR) was carried out to find out the cost effective treatment. The analysis was done by estimating different cost of cultivation and return from fruit yield in each treatment after converting them to one hectare of land.

Results and Discussion

Thrips

Results (Table 1) indicated that the pre-treatment count on thrips/leaf was non-significant in all treatments including the untreated control and it was ranged from 7.20 to 8.40 thrips/leaf. The thrips infestation in leaf ranged from 3.20 to 9.46, 2.60 to 11.58 and 3.82 to 16.42, 2.10 to 13.46 in 5, 7, 9 and 11 WAT respectively. During the vegetative stage (5 WAT) IPM module – { Seed treatment with Bacillus @ 2 g/lit; Barrier crop with two rows of maize; Intercropping of cluster bean @ 6:1 ratio; mulching with silver plastic mulch; Yellow sticky traps @ 50/ha placed at 30cm to 60cm above ground level to trap adult thrips ; Basal soil application of micronutrient mixture @ 2.5kg / ha each ferrous sulphate, zinc sulphate, copper sulphate, manganese sulphate and borax along with the foliar application of micronutrient mixture (0.2 per cent of each ferrous sulphate, zinc sulphate, copper sulphate, manganese sulphate and 0.1 per cent borax) @ 30 and 45 DAS ; Traps for fruit flies – 12 Nos/ ha ; ETL based (5 thrips/leaf) application of Imidacloprid 17.8 SL @ 3.0 ml/10 lit followed by pyriproxifen @ 0.1% at 10 days interval was effective in reducing the thrips population (3.20/leaf) followed by farmers practice { Five sprays of thiodicarb 75 WP @ 0.5 g/lit at 3 WAT, 5 WAT, 7 WAT, 9 WAT and 11 WAT} (4.60/leaf) and highest population of thrips (9.46/leaf) was observed in untreated control. Similarly 7WAT data indicated that the IPM module found to be effective in reducing the thrips population (2.60/leaf) followed by farmers practice (3.22/leaf) and highest population of thrips (11.58/leaf) was observed in untreated control. Results after 9 WAT showed that the IPM module was found to be superior over farmers practice and untreated control

After 11 WAT IPM module was found to be effective in reducing the thrips population (3.82/leaf) which was followed by farmers practice (4.26/leaf) and untreated control (16.42/leaf). The mean of four observations recorded that IPM module recorded 2.93/leaf followed by farmers practice (3.60/leaf).Highest thrips population (12.73/leaf) was observed in untreated control.

Mite

The pretreatment count of mite/leaf was ranged from 17.09 to 19.23 mite/leaf. The mite infestation in leaves ranged from 7.01 to 19.21 and 3.64 to 21.42 in 13 and 15 WAT respectively. During the vegetative stage (5 WAT) IPM module – { Seed treatment with Bacillus @ 2 g/lit; Barrier crop with two rows of maize; Intercropping of cluster bean @ 6:1 ratio; mulching with silver plastic mulch; Yellow sticky traps @ 50/ha placed at 30cm to 60cm above ground level to trap adult thrips ; Basal soil application of micronutrient mixture @ 2.5kg / ha each ferrous sulphate, zinc sulphate, copper sulphate, manganese sulphate and borax along with the foliar

Comment [VV9]: Check again as first one was for 11 WAT and then 9 WAT

Comment [VV10]: Mention the table no. with the data.

application of micronutrient mixture (0.2 per cent of each ferrous sulphate, zinc sulphate, copper sulphate, manganese sulphate and 0.1 per cent borax) @ 30 and 45 DAS ; Traps for fruit flies – 12 Nos/ ha ; ETL based (5 thrips/leaf) application of Imidacloprid 17.8 SL @ 3.0 ml/10 lit followed by pyriproxifen @ 0.1% at 10 days interval was effective in reducing the mite population (7.01/leaf) followed by farmers practice { Five sprays of thiodicarb 75 WP @ 0.5 g/lit at 3 WAT, 5 WAT, 7 WAT, 9 WAT and 11 WAT} (14.60/leaf) and highest population of mite (19.21/leaf) was observed in untreated control. After 15 WAT IPM module was found to be effective in reducing the mite population (3.64/leaf) which was followed by farmers practice (11.21/leaf) and untreated control (21.42/leaf). The mean of two observations recorded that IPM module recorded 5.32/leaf followed by farmers practice (12.90/leaf).Highest thrips population (21.42/leaf) was observed in untreated control.

Leaf Curl Index

Comment [VV11]: Data table is missing?

The results revealed that the lowest leaf curl index (10.82 %) was recorded from the IPM module { Seed treatment with Bacillus @ 2 g/lit; Barrier crop with two rows of maize; Intercropping of cluster bean @ 6:1 ratio; mulching with silver plastic mulch; Yellow sticky traps @ 50/ha placed at 30cm to 60cm above ground level to trap adult thrips ; Basal soil application of micronutrient mixture @ 2.5kg / ha each ferrous sulphate, zinc sulphate, copper sulphate, manganese sulphate and borax along with the foliar application of micronutrient mixture (0.2 per cent of each ferrous sulphate, zinc sulphate, copper sulphate, manganese sulphate and 0.1 per cent borax) @ 30 and 45 DAS ; Traps for fruit flies – 12 Nos/ ha ; ETL based (5 thrips/leaf) application of Imidacloprid 17.8 SL @ 3.0 ml/10 lit followed by pyriproxifen @ 0.1% at 10 days wherein the farmers practice the leaf curl reduction of 15.26. However maximum leaf curl index (35.90%) was recorded in the untreated control. Based on the extent of leaf curl index, the treatments could be grouped in the order of IPM module, Farmers practice and untreated control.

Fruit borer larvae and fruit damage %

The mean data pertaining to fruit borer infestation indicated that significantly lower number of larvae noticed in IPM module (0.17/plant) which was followed by farmers practice (1.17/plant). However, farmers practice recorded relatively higher larval population (1.17/plant), but superior to untreated control (4.23/plant). Further results on fruit damage indicated that IPM module recorded comparatively lowest fruit damage of 1.40 %. Whereas, farmers practice was next best in reducing the fruit damage (4.91%). Unquestionably, untreated control recorded highest fruit damage (13.60%). The results on fruit yield showed that IPM module registered significantly highest yield of 11200 kg/ha. Further, farmers practice recording the yield of 10300 kg/ha superior to untreated control (6100 kg/ha) from (Table 3).

Population of Natural Enemies

It appears that the concept of border cropping and intercropping fits into the ecological framework of habitat manipulation of an agroecosystem for pest management. Many other methods alter the habitat as part of IPM strategy. However, in the present study, different inter crops were grown to attract insects or other organisms to protect target crops from pest attack, preventing the pests from reaching the crop or concentrating them in a certain part of the field, where they can be economically destroyed. Among intercrops, clusterbeans reported significantly less thrips population, compared to other crops with the border crop of Maize. It might be because of preference by the pest to clusterbeans as either a food source or oviposition site than the main crop, thus preventing or making less likely the arrival of the pest to the main crop and/or concentrating it in the intercrop where it can be economically destroyed. The population of coccinellids ranged from 2.85 to 3.74 coccinellids/plant. A significantly higher number of coccinellids of 3.74 coccinellids/plant was observed in the treatment IPM module which was followed by the untreated control (3.14 coccinellids /plant), whereas the lowest number of coccinellids (2.85 coccilnellids/plant) was recorded from the Farmers practice. The increase of the coccinellid population over Farmers practice was high in from the treatment IPM module wherein the Border crop – closely spaced three rows of maize; Intercropping of cluster bean @ 6:1 ratio and Border crop – closely spaced three rows of maize**;** Intercropping of Agathi @ 10:1 ratio with observation of 31.23% and 10.18%, respectively. These results revealed that chilli protected by intercropping with different crops contributed a significant role in conserving and enhancing the population of coccinellids.

The population of spiders ranged from 3.15 to 5.25 spiders / plant. A significantly higher number of spiders of 5.25 spiders / plant was observed in the treatment IPM module which was followed by the treatment untreated control (4.34 spiders /plant), whereas the lowest number of spiders (3.15 spiders /plant) was recorded from the Farmers practice. The increase of the spiders population over Farmers practice was high in from the treatment IPM module wherein the Border crop – closely spaced three rows of maize; Intercropping of cluster bean @ 6:1 ratio and Border crop – closely spaced three rows of maize**;** Intercropping of Agathi @ 10:1 ratio with observation of 66.67% and 37.78%, respectively. These results revealed that chilli protected by intercropping with different crops contributed a significant role in conserving and enhancing the population of spiders.

Similar trend was observed in Chrysopids also. The population of Chrysopids ranged from 1.19 to 2.47 Chrysopids /plant. A significantly higher number of Chrysopids of 2.47 Chrysopids /plant was observed in the treatment IPM module which was followed by the treatment untreated control (1.98 Chrysopids /plant), whereas the lowest number of Chrysopids (1.19 Chrysopids /plant) was recorded from the Farmers practice. The increase of the Chrysopids population over Farmers practice was high in from the treatment IPM module wherein the Border crop – closely spaced three rows of maize; Intercropping of cluster bean @ 6:1 ratio and Border crop – closely spaced three rows of maize**;** Intercropping of Agathi @ 10:1 ratio with observation of 107.56% and 66.39%, respectively. These results revealed that chilli protected by intercropping with different crops contributed a significant role in conserving and enhancing the population of Chrysopids. These results revealed that chilli protected by intercropping with different crops and border cropping of Maize contributed a significant role in conserving and enhancing the population of coccinellids and thus served as an ecological pest management attribute.

Effect of IPM module on yield and economics of Chillies

The effect of different intercrops on yield and economics of chilli is presented in Table 2. Green chilli yield was more in IPM module to the tune of 11,200 kg per hectare followed by farmers practice (10,300 kg) while in untreated control it was 6,100 kg. Highest BC ratio (2.96) was recorded in IPM module followed farmers practice (2.91) while in untreated control it was 2.50. From the results of this experiment, IPM module can be recommended for the effective management of key insect pest of chillies (40, 41, and 42) reported that benefits of trap crop system include erosion control, reduced leaching of nutrients, balanced distribution of labour and higher economic returns and serves as eco-friendly pest management attribute than sole cropping.

Conclusion

From the present findings it may be concluded that IPM module can be recommended for the effective management of chilli thrips which revealed that chilli protected by intercropping with clusterbeans and border cropping of Maize contributed a significant role in conserving and enhancing the population of predators and thus served as an ecological pest management attribute.

Comment [VV12]: Elaborate more as what your finding are and how u can make it as a sustainable and cost-effective approach for future.

Table 1. Population dynamics of thrips under different treatments

Treatments	PTC No. of Thrips/leaf	No. of Thrips/leaf				Mean	Per cent reduction over control
		5WAT	7 WAT	9WAT	11WAT		
T1 *IPDM module*	7.90 (2.98)	3.20 (2.04)	2.60 (1.89)	2.10 (1.75)	3.82 (2.18)	2.93 (1.96)	76.98
T2 *Farmers practice*	7.20 (2.86)	4.60 (2.35)	3.22 (2.04)	2.30 (1.81)	4.26 (2.28)	3.60 (2.12)	71.72
T3 Untreated control	8.40 (3.06)	9.46 (3.22)	11.58 (3.53)	13.46 (3.78)	16.42 (4.15)	12.73 (3.67)	-
CD (5%)	0.005	0.078	0.115	0.14	0.13	0.11	
SE(m)	0.002	0.025	0.038	0.04	0.04	0.03	
SE(d)	0.003	0.036	0.053	0.06	0.06	0.05	
CV%	0.17	2.82	4.26	5.55	4.37	4.25	

Table 2. Population dynamics of mites under different treatments

Treatments	PTC mite/leaf	Chilli mite/leaf			Per cent reduction over control	Leafcurl Index %	Per cent reduction over control
		13WAT	15WAT	Mean			

T1 *IPDM module*	19.23 (4.47)	7.01 (2.82)	3.64 (2.14)	5.32 (2.48)	73.80	10.82 (19.11)	69.86
T2 *Farmers practice*	18.99 (4.45)	14.60 (3.93)	11.21 (3.48)	12.90 (3.70)	36.48	15.26 (22.89)	57.49
T3 Untreated control	17.09 (4.23)	19.21 (4.47)	21.42 (4.71)	20.31 (4.59)	-	35.90 (36.70)	
CD (5%)	0.016	0.10	0.15	0.12	-	1.34	
SE(m)	0.005	0.03	0.05	0.04	-	0.43	
SE(d)	0.007	0.04	0.07	0.05	-	0.61	
CV%	0.32	2.50	4.19	3.34	-	4.71	

Table 3. Population dynamics of fruit borer larvae and its damage under different treatments

Treatments	PTC Fruit borer larvae/plant	Fruit borer larvae/plant				
		13WAT	15WAT	Mean	Per cent reduction over control	Fruit damage %
T1 *IPDM module*	3.72 (2.16)	0.21 (1.10)	0.13 (1.06)	0.17 (1.08)	95.98	1.40 (6.76)
T2 *Farmers practice*	3.20 (2.04)	1.60 (1.61)	0.74 (1.31)	1.17 (1.46)	72.34	4.91 (12.74)
T3 Untreated control	3.40 (2.09)	3.92 (2.21)	4.54 (2.34)	4.23 (2.27)		13.60 (21.54)

CD (5%)	0.008	0.08	0.10	0.09		0.88
SE(m)	0.003	0.02	0.03	0.02		0.28
SE(d)	0.004	0.04	0.04	0.04		0.40
CV%	0.37	4.91	6.05	5.48		5.96

Table 4. Natural enemies' population and yield

IPM modules	**Population (Numbers/Plant)**			**Per cent increase of Natural enemies population over Farmer's Practice**			Yield (Kg/ha)	B:C Ratio
	Coccinellids	**Spiders**	**Chrysopids**	**Coccinellids**	**Spiders**	**Chrysopids**		
T1 *IPDM module*	3.74 (2.176)	5.25 (2.499)	2.47 (1.862)	31.23	66.67	107.56	11200	2.96
T2 *Farmers practice*	2.85 (1.962)	3.15 (2.037)	1.19 (1.481)	-	-	-	10300	2.61
T3 Untreated control	3.14 (2.035)	4.34 (2.312)	1.98 (1.728)	10.18	37.78	66.39	6100	1.60
C.D.	0.005	0.007	0.006	-	-	-	594.73	
SE(m)	0.002	0.002	0.002	-	-	-	194.19	
SE(d)	0.002	0.003	0.003	-	-	-	274.63	
C.V.	0.212	0.249	0.294	-	-	-	5.97	

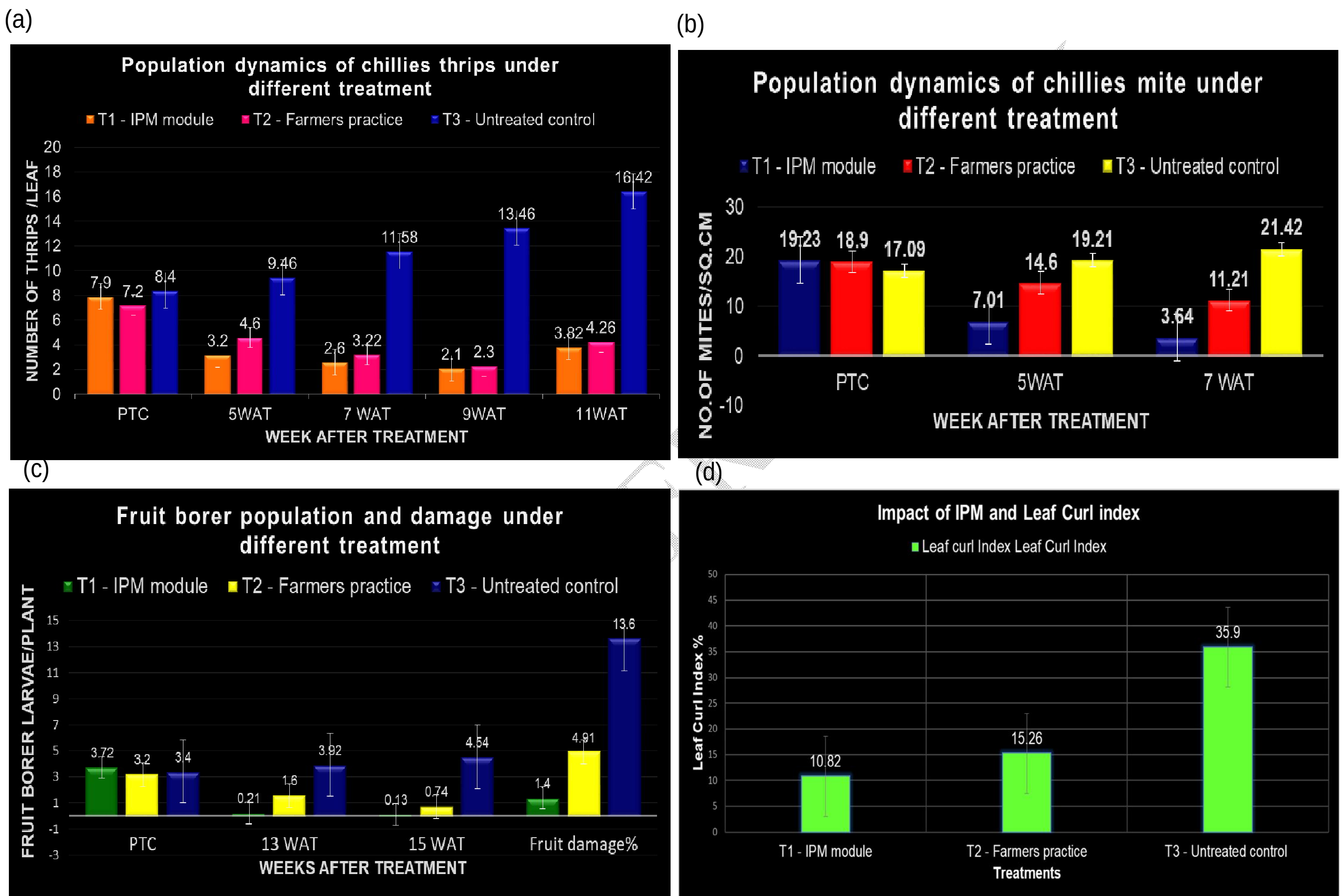
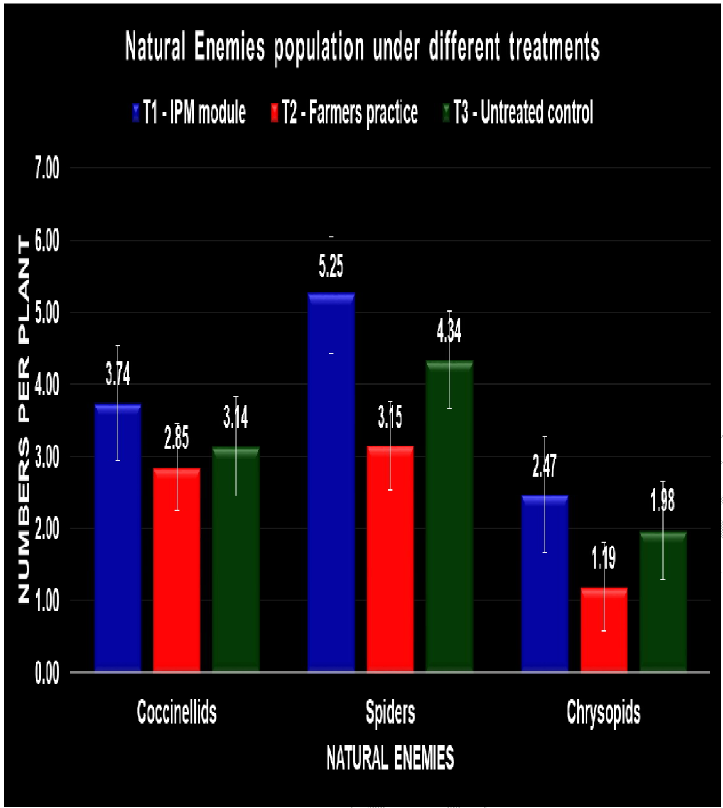


Figure 1 Population dynamics of key insect pest of chillies under different treatments (a) Chillies thrips (b) Chillies mite (c) Fruit borer (d) Leaf Curl Index

(a)



(b)

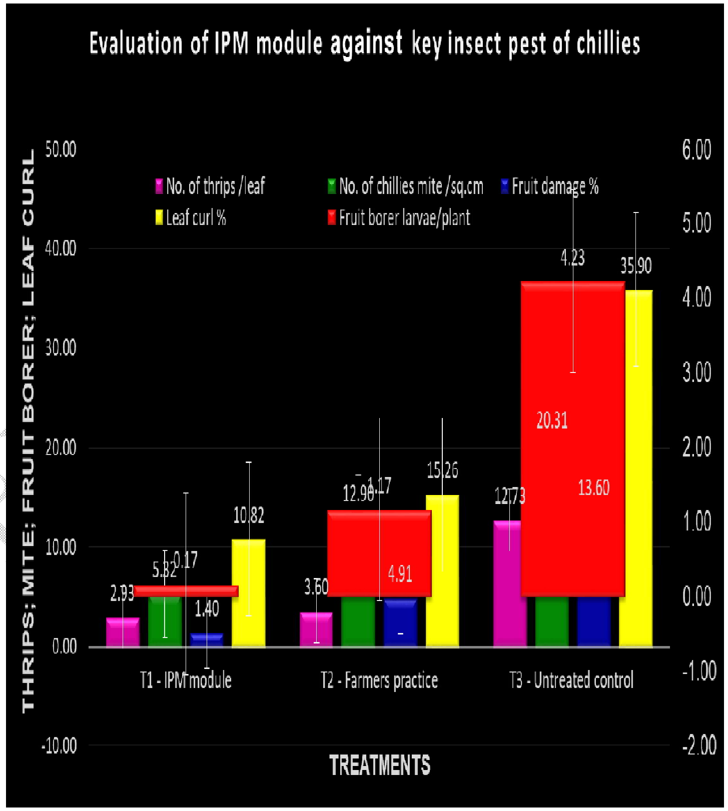


Figure 2 Scenario of natural enemies and key insect pest of chillies (a) Natural enemies (b) Key insect pests of chillies

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