MANAGEMENT OF MAJOR INSECT PESTS OF SOYBEAN THROUGH SOME IPM PACKAGES

MST. TANIA SULTANA

INSTITUTE OF SEED TECHNOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

MST. TANIA SULTANA
REGISTRATION NO. 14-05874
Mobile No. +880193566721
Email:ta718349@gmail.com

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Approved By:

Dr. S. M. Mizanur Rahman Professor Supervisor	**Dr. Mohammed Ali** Professor Co-Supervisor

Prof. Dr. Md. Ismail Hossain
Chairman, Examination Committee
&
Director, Institute of Seed Technology
Sher-e-Bangla Agricultural University

Dr. S. M. Mizanur Rahman
Professor
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka-1207, Bangladesh
Mobile: +880171212707
Email: smmizanur@gmail.com

CERTIFICATE

*This is to certify that the thesis entitled, "**MANAGEMENT OF MAJOR INSECT PESTS OF SOYBEAN THROUGH SOME IPM PACKAGES**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **SEED TECHNOLOGY**, embodies the result of a piece of bonafide research work carried out by **MST.. TANIA SULTANA**, Registration No. **14-05874** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed during the course of this investigation has duly been acknowledged.

Dated: June, 2022
Place: Dhaka, Bangladesh

Dr. S. M. Mizanur Rahman
Professor
Supervisor

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MANAGEMENT OF MAJOR INSECT PESTS OF SOYBEAN THROUGH SOME IPM PACKAGES

ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the management of major insect pests of soybean through some IPM packages during the period from November 2021 to February 2022 in the *Rabi* season. The experiment was laid out in Randomized block design with five different IPM packages *viz.,* T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers practice and T_5 : Untreated control, for the management of major insect pests of soybean with three replications for each treatment. Experimental result showed that in the experimental field, nineteen insect pests from sixteen families and six orders attacked soybean. The majority of them belonged to the Orders Lepidoptera, Hemiptera, and Coleoptera. Among the major pests of soybean, whitefly, jassid, pod borer and leaf roller were more damaging than other pests on soybean research field. The occurrence of these pests varied significantly due to the use of various IPM packages. Among the treatments, T_2 treatment reduced the incidence of these insect pests on soybean plant at different days after sowing. The highest number of healthy pods plant^{-1} (27.53), 1000-seed weight (115.67 g) and seed yield (2.25 t ha^{-1}) were also recorded in T_2 treatment. On the other hand, the lowest seed yield (0.89 t ha^{-1}) was found in untreated control plot (T_5). The T_2 treatment performed as the best treatment in terms of benefit cost ratio (4.72) compared to other treatments. Based on the investigation of the above results, it may be concluded that among all integrated pest management packages, the T_2 treatment demonstrated the best performance in terms of managing the major insect pests of soybean as well as growth and yield among all IPM packages used in this study.

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LISTS OF ABBREVIATIONS

Abbreviations	Full word
^0C	Degree Celsius
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
CV%	Percentage of Coefficient of Variance
DAT	Days after Transplanting
et al.,	And others
FAO	Food and Agriculture Organization
G	Gram (s)
ha^{-1}	Per hectare
Kg	Kilogram
LSD	Least Significant Difference
Max	Maximum
Min	Minimum
MOP	Muriate of Potash
N	Nitrogen
NPK	Nitrogen, Phosphorus and Potassium
NS	Not significant
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TSP	Triple Super Phosphate
wt.	Weight

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L.) is the most widely cultivated legume around the world because of its versatile uses and economic importance (Liu *et al.,,* 2020). Soybean is one of the most multipurpose, nutritionally and economically important legumes due to its unique seed composition (Shea *et al*., 2020). Soybean seed contains about 18 to 22% oil and 38 to 56% vegetable protein with favorable amino acid (USDA, 2018). It is a prominent source of proteins and edible oil, it has valuable uses as food, feed and oil seed crop (Liu *et al*., 2020). Globally, soybean is responsible for about 61% of total international oilseed production and occupied 6% of the world's cultivable area (SoyStat, 2019). According to USDA (2021), about 391.40 million tons of soybean produced around the world, from the cultivated area of 121.69 million hectares with an average yield of 2.76 ton ha^{-1}. The United States, Brazil and Argentina are the leading soybean producing countries in the world and responsible for 81% of the total production. In Bangladesh, 0.986 million tons of soybean produced in 59,445 hectares land area (USDA, 2021). BBS (2021) reported that the total soybean cultivated area was 57646.26 hectares and total production was 91176.59 M. tons in Bangladesh. In our country, the demand for soybean as poultry feed was 1.8-2 million tons in 2021 (BBS, 2021). There are 80 oil refineries with a total production capacity of 2.9 million tons In Bangladesh. But only 48% of production capacity is utilized, so there is a huge demand for soybean in these industries (USDA, 2017).

The soybean yield is restricted due to many abiotic and biotic stresses like drought, weeds, insect pests and diseases (Mammadov *et al*., 2018). Among these, insect pests often pose a serious threat to soybean production by increasing cost of cultivation and impairing quality of produce in many ways. The crop is ravaged by many species of insect and non-insect pests (Heinrichs and Muniappan, 2018). The luxuriant crop growth, soft and succulent foliage attracts many insects and provides unlimited source of food, space and shelter. About 380 species of insects have been reported on soybean crop from various parts of the world (Patel and Rahul, 2020). Out of these, only two dozen insects are of economic importance causing serious losses. On the basis of feeding habit, soybean insects can be categorized into six groups i.e., seed and seedling feeders, stem borer, foliage feeders, sap suckers, flower and pod borers and storage insects (Biswas, 2013). The major insects causing significant reduction in seed yield of soybean include the girdle beetle, *Oberiopsis brevis* (Swed.); semilooper, *Chrysodeixis acuta*(Wlk.); *Diachrysia orichalcea* (Fab.); stem fly, *Melanagromyza sojae* (Zehnt); gram pod borer, *Helicoverp aarmigera* (Hub.), blue beetle, white fly, *Bemisia tabaci* (Genn); jassid, *Amrasca biguttula* (Ishida); tobacco caterpillar, *Spodoptera litura* (Fab.); leaf roller, *Lamprosema indicata* F. and stink bug, *Nezara viridula* (L.) (Motaphale *et al*., 2019). The increasing population of these insect pest complex may cause severe yield losses upto 50% (Abudulai *et al*., 2012). To overcome these losses caused by insect pests, various control measures have been recommended, of which chemical control measures are reported to be more effective. However, indiscriminate use of insecticides has led to problems like insecticide resistance, pest resurgence and environmental pollution besides upsetting the natural ecosystem (Egambaram, 2019). In this regard the utilization of botanical and bio-pesticides for controlling the crop pests can serve as an alternative means over the chemical pesticides. But they are not very target specific. Though bio pesticides do not harm beneficial insects, they are also not target specific. This causes problems on a broader level. Unlike their counterparts, biopesticides are generally slow in nature. They take a lot of time to act on the pests and diseases. At times, this might cause damage to the crop because of the additional life that the pest and diseases gets (Lengai and Muthomi, 2018).

In view of above problems, faced by the application of insecticides for the management of the insect pests there is a need to manage these by safer and eco-friendly approach so that the least disturbance to the environment could happen. To maintain the intermediate- and long-term sustainability of agriculture in Bangladesh, an alternative to prophylactic pest control is integrated pest management (IPM), which endeavors to employ the rational use of insecticides as well as the harmonious integration of different control strategies such as cultural, physical, mechanical and biological method of pest control (Lundin *et al*., 2021). Thus, looking into the overall scenario of soybean crop production and rising environmental issues IPM comes out to be the best alternative for pest management in soybean field (Bueno *et al*., 2011). Although, IPM is the best strategy in crop production programme, yet this practice could not reach to the farmers' field. The extent of adoption of IPM practices among farmers is not very encouraging.

Therefore by considering the above facts, the present study entitled, "Management of major insect pests of soybean through some IPM packages" was undertaken with the following objectives:

- to observe the incidence of insect pests on soybean;
- to evaluate some approaches of IPM packages against major insect pest of soybean; and
- to find out the best IPM package(s) to obtain maximum yield of soybean.

CHAPTER II

REVIEW OF LITERATURE

Soybean [*Glycine max* (L.) Merrill] is a globally important and well-known oil seed and grain legume crop. Several insect pests cause both qualitative and quantitative crop losses in the soybean field. Pests cause damage to Bangladesh every year, either sporadically or in epidemic form. Therefore the literature so far available pertaining to the present study entitled "Management of major insect pests of soybean through some IPM packages" are being presented under the following headings:

2.1 Incidence of insect pests in soybean

2.2 Estimation of losses due to insect pests in soybean

2.3 Effect of different integrated pest management packages on insect pest suppression

2.1 Incidence of insect pests in soybean

Marabi *et al*. (2021) studied first appearance of whitefly on soybean was observed on 7 days old crop (DOC) and was available up to 105 DOC. The overall mean population of whitefly recorded was 2.45 adult whiteflies/plant during the *Rabi* season.

Bhardwaj *et al*. (2019) conducted field experiment during kharif crop season 2015-16 at college of agriculture, Indore (M.P.) on cultivar RVS 2001-4 to assess the effect of weather factors on the trend of blue beetle and tobacco caterpillar activities. The crop was sown in second week of June, 2015-16 in an area of 200 (20×10m) square meters following the recommended agronomical practices with the spacing of 40 ×10 cm rows and plants, respectively. The observations on the appearance of major insect pests were recorded from germination to harvest of the crop at weekly intervals at 10 different sites in 1 meter row length from each site once in a week and correlation was worked out. For blue beetle per cent infestation and for tobacco caterpillar, larval population was counted. Blue beetle infestation started in 26th Meteorological Standard Weeks (MSW) with 1.3% damage. The infestation increased and reached its peak as 7.5 % in 32th Standard Meteorological Weeks (SMW) ending 31th August. After that the infestation decreased slowly in next two weeks and noted least as 3.1% in 33th SMW ending 7th September. The occurrence of tobacco caterpillar started with 2.5% insects in 29th SMW ending 10th august. The population fluctuated and reached its peak as 14.5% in 35th SMW ending 21st September.

Motaphale *et al.,* (2019) observed that the population of *Spodoptera litura, Helicoverpa armigera, Aproaerema modicella, Obereopsis brevis* and *Melanagromyza sojae* were ranged from 0-4, 0-2.2 ,0-2.4, 0-0.3, 5.20-19.66, and 14.9- 27.2 and it was 3.9-20.4 , 6.8-26.2, 3.2-16.0, 0-5.5, 2.9-24.7 and 10-25.7 during 2011-12, respectively. In conclusion leaf miner (*A. modicella*), defoliators, stem fly (*M. sojae*) and girdle beetle (*O. brevis*) were found to be major pests of soybean.

Parul *et al.,* (2018) reported the density of defoliators *i.e. Spodoptera litura* and *Spilosoma obliqua* increased gradually to a peak of 12.5 and 3.9 larva/meter row length during the last week of August and *Thysanoplusia orichalcea* with 6.1 larva/mrl during first week of September and exhibit positive correlation with maximum temperature and RH%. The peak density of sucking pest (*Bemisia tabaci* and *Aphis gossypii*) was observed during mid of August and exhibit positive correlation with maximum temperature, RH% and evaporation. Stem fly infestation persisted till maturity of the crop. Natural enemies *i.e. Coccinella septumpunctata* and *Eocanthecona furcellata* occurred during third week of August. Results revealed that temperature, relative humidity and evaporation act as limiting factor for population buildup of insect pests in soybean ecosystem.

Sarvesh *et al.,* (2018) studied about seasonal incidence of pre-dominant lepidopteran insect-pests in soybean crop the soybean leaf folder (*Omiodes indicata* Fab.), tobacco caterpillar (*Spodoptera litura* Fab.), green semilooper (*Chrysodexis acuta* Walker), leaf webber (*Anarsia ephippias* Mullar) and pod borer (*Helicoverpa armigera* Hub.) were major defoliator insect causing damage at various growth stages of the soybean crop. The peak activity of *Omiodes indicata* Fab. (1.67 larvae/mrl) and *Spodoptera litura* Fab. (1.47 larvae/mrl) were observed during third week of September. Whereas, *Chrysodeixis acuta* (1.0 larvae/mrl), *Anarsia ephippias* (0.6 larvae/mrl) and *Helicoverpa armigera* (0.67

larvae/mrl) were recorded during first week of September, third week of August and fourth week of August, respectively.

Kalyan and Ameta (2017) revealed that the maximum incidence of tobacco caterpillar in soybean crop was recorded during 41st SMW and 42nd SMW, respectively.

Marabi *et al*. (2017) reported that the temperature and evaporation were found to be significantly positively correlated with whitefly population during kharif season.

Mangang *et al*., (2017) reported similar findings at par with present results that evening R.H. showed positive correlation but morning R.H. and sunshine hours showed negative correlation, statistically non-significant with peak aphid infestation.

Ahirwar *et al.,* (2016) reported that the major insect-pest observed attacking soybean variety JS- 335 were girdle beetle, O*bereopsis brevis*; tobacco caterpillar, *Spodoptera litura*; green semilooper, *Chrysodeixis acuta;* whitefly, *Bemisia tabaci* and jassids*, Empoasca kerri*.

Ahirwar *et al.,* (2015) recorded girdle beetle, *Obereopsis brevis*; tobacco caterpillar, *Spodoptera litura*; green semilooper, *Chrysodeixis acuta*; whitefly, *Bemisia tabaci* and *Empoas Ca kerri* as a major pests of soybean. The peak activity of girdle beetle (1.0 damaged plant per meter row) was observed during first week of October. Whereas the peak activity of caterpillar pests that is, *S. litura* (2.5 larvae per meter row) and *C. acuta* (0.7 larvae per meter row) was recorded during second fortnight of August. While, *B. tabaci* (3.2 whiteflies per plant) and *E. kerri* (3.4 jassids/plant) was recorded during last week of August and second week of August, respectively.

Ahirwar *et al.,* (2014) recorded larvae of green semilooper, *Chrysodeixis acuta* with mean population of 9.97 larvae/meter row length during 34th SMW when maximum and minimum temperature were 32°C and 28.2°C, respectively. No significant correlation was exhibited between the larval population and weather parameters. They also recorded appearance and peak period of activity of *Spodoptera litura* during 31st and 37th SMW, with 71.6 and 100 per cent foliage damage, respectively.

Raghuvanshi *et al.,* (2014) reported the activity of blue beetle and white fly was started from 14 days after sowing (DAS) and remained up to first week of September with its peak population during first week of August at 35 DAS. Infestation of green semilooper and tobacco caterpillar was started from third week of July and second week of August, respectively. The infestation of girdle beetle started from second week of august to till harvest.

Raju *et al.,* (2014) reported incidence of green semi looper during last week of July with mean population of 0.9larva/mrl. The pest disappeared during 1st week of October.

Biswas (2013) investigated Soybean Insect Pests (*Glycine max* L.), the nature of their damage, and their succession with crop stages. Thirty-nine insect pest species were discovered infesting soybean crops at various stages of development in the Noakhali region of Bangladesh between January and May of 2010 and 2011. Six pest species were identified as major pests, namely the hairy caterpillar, Spilarctia obliqae (Walker); leaf roller, Lamprosema indicata F; common cutworm, Spodoptera litura F; pod borer, Helicoverpa armigera (Hubner); stem fly, Ophiomyia phaseoli (Tryon); and white fly, Bemisia tabaci Genn. While the rests were of minor importance on the basis of population densities per plant, nature and extent of damages and yield reductions.

Netam *et al.,* (2013) recorded girdle beetle, *Obereopsis brevis,* tobacco caterpillar, *Spodoptera litura*, green semilooper, *Chrysodeixis acuta*, jassids, *Empoasca kerri* and white flies, *Bemisia tabaci* as the major pests of soybean. The activity of girdle beetle increased gradually in the last week of August with 3.2 damaged plants per meter row with seasonal mean of 1.73 damaged plants. The density of caterpillars increased gradually with peak population of 5.0 larvae per meter row during the last week of August and seasonal mean was 3.22 larvae per meter row. Among the sucking pests, whitefly was observed in higher numbers than jassids. The peak density of sucking pests was observed during 3rd week of September with 4.4 sucking pests/plant with seasonal mean of 3.62 white flies and jassids per plant.

Rai and Singh (2012) studied the effects of climatic factors on the incidence of jassid (*Amrasca biguttula biguttula*) on okra (cv. Kashi Pragati) in Uttar Pradesh, India during the summer and rainy seasons of 2008 and 2009. The jassid was initially observed on the second week of April (mean density of 4.8 per 3 larvae), and its population peaked on the fourth week of May (mean density of 22.3 per 3 larvae). The population density was positively correlated with maximum temperature, and negatively correlated with relative humidity. Minimum temperature, minimum relative humidity, rainfall and sunshine hours were not significant correlated with the jassid population.

Kumar *et al.,* (2012) reported that maximum population of green semilooper was observed during vegetative stage, while tobacco caterpillar was more frequent during flowering and pod stages. The order of frequency of pests at vegetative stage was green semilooper (1.2) > tobacco caterpillar (0.8) > grass hoppers (0.4) >, girdlebeetle and *Helicoverpa*sp. (0.2 each)> white fly (0.1). The order of frequency ofpests of flowering stage was, tobacco caterpillar (3.25) > green semilooper, *Helicoverpa* sp. and grass hopper (0.8 each) > girdle beetle (0.6) > white fly (0.4) >Bihar hairy caterpillar (0.3) > pollen feeder (0.2), while the frequency order at podstages was tobacco caterpillar (2.75) > *Helicoverpa* sp. and grasshoppers (0.8 each) >girdle beetle and hairy caterpillar (0.5 each) > pollen feeder (0.4) > white fly (0.2).

Pillai and Agnihotri (2011) reported that the incidence of *E. furcellata* was positively correlated with maximum and minimum temperature and evening R.H.

Netam (2010) observed that density of lepidopterous caterpillars increased gradually with peak population of 5 larvae per meter row during the last week of August. The defoliators, *Spodoptera litura* and *Chrysodeixis acuta* recorded their peak activity during last week of August (3.2 larvae per meter row) and during third week of August (1.2 larvae per meter row) with a seasonal mean of 1.58 and 0.40 larvae per meter row respectively.

Sutaria *et al.,* (2010) conducted field experiments in Gujarat, India, during 2007-08 *kharif* season, to determine the seasonal abundance of *Empoasca kerri* infesting soybean and study the impact of different weather factors (temperature, relative humidity and rain) on the pest incidence. Results showed that the pest was active throughout the season.

Chaudhary (2009) reported the dispersion of *Spilosoma oblique* (Walker) and *Spodoptera litura* (F.) on soybean crop from August to October.

Harish (2008) reported that the maximum larval population of *Spodoptera litura* and *Thysanoplusia orichalcea* (7.80, 12.00, 12.80 and 6.50, 6.20 and 8.60 larvae, respectively) were noticed on the crop sown on 08-06-06, 27- 06-06 and 08-07-06 dates, respectively. Early sown crop recorded lower incidence of *Spodoptera litura, Thysanoplusia orichalcea* and *Spilosoma obliqua* compared to that of late sown crop.

Madrap *et al.,* (2007) recorded the seasonal incidence of insect pests of soybean during *Kharif* season at Parbhani. The studies revealed that the infestation of leaf miner and semilooper was less during the season. However, the infestation of *S. litura* and girdle beetle was more, up to 6.8 and 5.6 per cent, respectively.

Choudhary (2006) reported higher population density of *Spilosoma obliqua* (Wlk.) and *Spodoptera litura* (F.) during second half of October. However, density of *Thysanoplusia orichalcea* (F.) was higher during later part of September or early October.

Meena and Sharma (2006) reported the minimal larval population of 1.42 larvae per mrl in early sown crop (25th June), followed by mid sown crop and late sown crop which recorded 1.67 and 1.87 larvae per mrl, respectively at Udaipur, Rajasthan.

Seema *et al*. (2004) studied the life cycle of *Spodoptera litura* and reported that larval development of *Spodoptera litura* varied greatly depending on host plants and temperature, and development was prolonged under low or high temperatures.

Patil (2002) reported that soybean was attacked by 48 phytophagous species, among these the seedling borers. *Melanagromyza sojae* (Zehnter), *Obereopsis brevis* (Swed) leaf eating caterpillar, semiloopers, *Spodoptera litura* (Feb.) and pod borer, *Cydia ptychora*mey rick were key pests during *kharif.*

Chattopadhyay *et al.,* (2002) studied sensitivity of the incidence of leaf minor (*Aproaerema modicella*) on soybean to the different meteorological parameters. The month of July-September was the peak period of the infestation. Dry weather conditions along with low relative humidity (morning:<=80% afternoon: <=55%) and increase in maximum temperature (>=28˚C for Bangalore and >=32˚Cfor Parbhani) under clear sky condition (sunlight of >=8 h) were favourable for the multiplication of the pest. Weather-based information generated from this study could possible be made to predict leaf miner infestation on soybean and ultimately save the damage of the crop.

Negoyen (2001) reported that lepidopteran defoliators like *S. litura, T. orichalcea* and *L. indicata* were observed from 21 days after growth, of which *H. armigera* was a major pest. *Spodoptera litura* (F.) was recorded from 21 to 49 days after growth with fewer incidences, *T. orichalcea* was observed from 21 to 77 days after growth and population was more at 42 and 49 days after growth.

Singh *et al.,* (2000) reported three hundred species of insect pests infesting soybean. Of which blue beetle, grey semilooper, green semilooper and stem fly are major insect pests in Madhya Pradesh.

Das (1998) identified two major pests that cause the most damage to soybeans: the hairy caterpillar and the stem fly.

2.2 Estimation of losses due to insect pests in soybean

Ahirwar *et al.,* (2014) reported the avoidable seed yield losses in soybean due to insect pests. They recorded 14.84 q ha^{-1} yield in unprotected plots as compared to 21.47 q ha^{-1} in protected plots. It clearly showed that when the crop was protected from insect pest complex, the yield losses may be avoided up to 30.8 percent.

Choudhary and Patidar (2014) reported that girdle beetle caused more losses when soybean crop is infested at early stage than infestation occurred in later stage. At 30 percent infestation level the yield losses was 21.9 per cent at 35 days after germination whereas same infestation level at 56 days after germination caused only 8.1 percent yield loss.

Lal *et al.,* (2014) studied the yield losses in terms of reduction in number of pods, number of seeds and seed weight on the basis of girdle formation. They also studied that losses caused by girdle beetle were influenced by crop stage and different infestation levels. Up to 10 per cent infestation level by girdle beetle did not seem to have much yield reduction at all the crop stages but the crop between 37 and 44 days after germination appeared to be most vulnerable to girdle beetle infestation. The severe yield reduction (40.0 percent) was observed in infested plant by girdle beetle in last week of August followed by first and second week of September *i.e.* 37.6 and 32.3per cent, respectively. The plants infested during 4th week of September and 1st week of October did not show more yield reduction.

Musser *et al.,* (2014) estimated 3.86 per cent yield losses due to the insect pests in soybean.

Jadhav *et al.,* (2013) conducted field experiments to assess the crop loss due to stem fly in soybean under two sowing dates. In first date of sowing the avoidable crop loss was more, which ranged from 27.16 to 33.40 per cent as compared to recommended package of practice (5.91 per cent) whereas in second date of sowing 40.81 per cent avoidable crop loss was recorded in comparison to 24.56 per cent in Relative Pollination Potential (RPP).

Abudulai *et al.,* (2012) estimated the yield losses at different stages of crop by the two major insect pest guilds in soybean *viz.* defoliators and pod feeders. They reported that yield loss ranged between 25.8 and 42.8% in untreated plots, 11.1 and 34.3% in protected plots at the vegetative stage, and 5.2 and 11.3% in plots that were protected at the reproductive stage. There was a consistent negative correlation between yield and numbers of pod-sucking bugs as well as pod and seed damage. These results showed that pod-sucking bugs that attack soybean at the reproductive stage were the most important insect pests limiting soybean yield in Ghana.

Jain and Sharma (2011) reported 5.42 and 21.40 per cent infestation in protected and unprotected condition, respectively in soybean variety JS-335 due to girdle beetle.

Meena and Sharma (2006) observed that in soybean the mean numbers of grains per plant in protected and unprotected were 146.62 and 100.46, 151.69 and 99.23 during 2002 and

2003, respectively. The plants under protection had on an average 46.15 number more grains per plant than unprotected plants. The plants under protection gave significantly higher yield than the unprotected plants. The mean yield per plant in protected and unprotected plants during 2002 was 17.69 and 12.03 g, respectively, whereas, in 2003 it was 18.76 and 11.87 g, respectively.

Gyawali (2005) reported yield losses due to leaf roller, *Apoderus cyaneus* Hope in soybean were 36.2, 45.2, and 58.0 during vegetative and 37.5, 48.5 and 66.0 during reproductive stages from the insect population of 25, 50 and 100, respectively. Yield reduction was higher (260 and 108 mg per day) from each adult beetle at lower population level (25) during vegetative and reproductive stages of soybean.

Chechani *et al.,* (1999) estimated avoidable losses due to surface feeder in PK-472 variety of soybean. The infestation of insect pests on the crop significantly affected number of pods per plant, number of grains per plant, test weight and weight of grains per plot. In protected plots these values were 110.52, 205.56, 124.8 and 3187.5 g, respectively while, in unprotected plots these values were 100.47, 185.06, 113.0 and 1903.75g, respectively. No significant difference in plant height was obtained in protected and unprotected plots. The difference in the net yield from protected and unprotected plots was 40.27 percent.

Gupta *et al.,* (1997) studied the losses in soybean yield due to the insect pest complex and estimated 24 and 18 per cent losses in sole crop and when intercropped with maize, respectively.

Kundu *et al.,* (1995) reported that the average yield loss due to insect pests in different soybean varieties ranged from 2.3 to 5.1 q ha^{-1} due to stem fly.

Venkatesan and Kundu (1994) estimated the losses caused by larvae of *Melanagromyza sojae,* and quantify the loss in terms of soybean yield and yield contributing characters. The stem tunneling ranged from 10 to 20 per cent per plant caused a loss of 24.83 to 33.96 per cent per plant or a loss in pod weight of 5.16-7.09 g or a grain yield loss of 2.75-3.81 g $plant^{-1}$.

2.3 Effect of different integrated pest management packages on insect pest management

Yadav *et al*. (2018) resulted from their investigation on effectiveness of some insecticides against larval population of soybean that Indoxacarb 14.5 SC was found to be superior in reduction of larval population of green semilooper and tobacco caterpillar than other treatments.

Kushram *et al*. (2017) conducted experiment during *kharif* season and evaluated different plant products reported that NSKE (Neem Seed Kernal Extract) 5% was most effective in controlling soybean defoliators, *S. litura* and *C. acuta*.

Motaphale *et al*. (2017b) evaluated IPM modules for effective management of stem fly and girdle beetle on soybean crop. Results revealed that MAU IPM module (cultural control, mechanical control, biological control and chemical control) was found to be effective in reducing the girdle beetle and stem fly infestation (6.30%) and (7.95%), respectively. The higher CB ratio (1:7.65) was observed in MAU IPM module.

Motaphale *et al*. (2017a) conducted field experiments in Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra) and reported that significantly highest population (1.70 LB/5 plants) of *C. septempunctata* and (1.60 spiders/5 plants) of spider were observed in untreated control and were at par with MAU IPM module (cultural control, mechanical control, biological control and chemical control). Significant lowest population was observed in chemical control treatments.

Ingle *et al*. (2016) evaluated different modules against insect pest of soybean and resulted that chemical module gave maximum yield (1383.70 Kg/ha) as compared to other modules.

Sharma *et al.,* (2016) studied ecofriendly techniques for the pest management with special reference to *Spodoptera litura* in soybean crop and reported that all the integrated pest management practices *i.e.* intercropping, trap cropping, bird perches, and IPM modules recorded lowest pest population as 11.41, 13.13, 14.59 and 6.64, respectively and were superior over untreated control and netted plots which recorded larval population of 16.53 and 18.04 larvae/10 plants, respectively.

Singh and Singh (2015) studied IPM modules for mungbean (seed treatment with Imidacloprid 600 FS) and resulted significantly less incidence of whitefly, jassids and thrips. It also proved that IPM practices gave superior results than farmer practices.

Baskaran *et al*. (2014) evaluated the field efficacy of two modules tested during December 2011 to March 2012 for the management of major insect pests of groundnut study revealed that bio-intensive module for groundnut [vermicompost 2 t ha^{-1} + neem cake 250 kg ha^{-1} + bio-fertilizers 2 kg ha^{-1} + NPK (8.5: 34: 54 kg ha^{-1}); *Crysoperla zastrowi* @ 50,000 eggs ha^{-1} (3 releases on 20, 30, 40 DAS); *Trichogramma chilonis* + *T. japonicum* @6.25 cc ha^{-1} (3 releases on 37, 47, 67 DAS), *Helicoverpa armigera* NPV and *Spodoptera litura* NPV @ 500 ml ha^{-1} (4 sprays 40, 50, 60, 70 DAS); neem gold 0.15% @ 1.5 ml lit^{-1} (4 sprays 25, 40, 55, 70 DAS) was effective in reducing the incidence of both the sucking pests (aphids & leafhopper) and defoliators (leaf miner, *S. litura* & *H. armigera*) of groundnut and recorded the highest yield of 1836 kg wet pods ha^{-1}.

Byrappa *et al*. (2012) evaluated various biopesticides in the field bean ecosystem against pod borers. Among the biopesticides treated plots, the sequential application of NSKE-HaNPV- Bt recorded a lower seed yield (10.01 q/ha), whereas the treatment package (inorganic plot) recorded 11.37 q ha^{-1}.

Chaudhary *et al*. (2012) developed organic modules to evaluate against insect pest of soybean and resulted that module comprising of spray of *B. thuringenesis* showed higher reduction in population of semilooper and girdle beetle infestation with increase in yield (1160 Kg/ha) and ICBR (1:4.54) as compare to other modules.

Gorakh and Keshav (2011) reported that the foliar application of neem plant part and neem based pesticide with vermiwash obtained from buffalo dung with barley bran/vegetable wastes for management various pests injurious to the crop. The combinations of neem plant parts and neem based pesticides (Nimbecidine, Achook and multineem) have significant effect on the growth, flowering, productivity and their pest's infestation. The combination of aqueous extract of neem oil with vermiwash of buffalo dung has maximum effect on the growth, flowering, productivity and their pest infestation of Soybean crop. The use of combination of vermi-wash and biopesticides are eco-friendly.

Yambhatnal *et al*. (2011) found that the IPM module consisting variety of groundnut GPBD-4 resistant to late leaf spot and rust, seed treatment with *Trichoderma* 4 g/kg, foxtail millet as intercrop (7:1), installation of pheromone traps @ 2 traps/ acre for monitoring of *Spodoptera litura*, spray of emamectin benzoate 5 SG @ 0.2 g/l at 45 and 60 days after sowing was an effective module in obtaining higher yield of groundnut (39.95 q/ha) and cost effective with cost benefit ratio 1:5 in comparison to module-I and module-II (Farmers practice).

Ahirwar *et al*. (2010) tested efficacy of indeginous neem based products against sucking pest of sesame and reported that NSKE in cow urine followed by neem leaf extract in cow urine solution and neem oil proved superior in control of whitefly with ICBR of 22.6, 16.6 and 6.8, respectively.

Singh *et al*. (2010) conducted a survey of groundnut crop before implementation of IPM module in the area of Vallabhnagar dist. Udaipur, Rajasthan in *kharif* 2007 selected 40 randomiy farmers. As per the survey 85% farmers knew that white grub, collar rot and leaf blight were the key pests of the area. 8% farmers use seed treatment with fungicides and only 15% farmers use pesticide spray. Only 12.5% farmers agree that pesticide spray is effective and useful. 5% farmers have heard about IPM but only 7.5% use bio-pesticides as a component of IPM. After analysis of surveyed data of farmers IPM module was developed and synthesized for this location/specific area. IPM technology was implemented on the concept of Farmers Field School. After implementation of IPM module in the village farmers obtained 12.8 q ha^{-1} yield in year 2008 and 15.26 q/ha in year 2009 while in Non-IPM, yield obtained only 7.16 q ha^{-1} and I1.57 q ha^{-1}, respectively and they also got more net profit from IPM groundnut crop.

Ranganatha (2009) conducted the preliminary laboratory study and their results revealed that nimbicidine (0.5 %) recorded 82.67, 85.00 and 76.67 per cent larval mortality of *S. litura*, *T. Orichalcea* and *Cydia ptychora* after 72 hrs. of treatment, respectively. The next best treatments were NSKE (5 %) and Cristol 74 GL (1 %). Further studied the bioefficacy of organic components and nimbicidine (0.5 %) recorded maximum larval reduction of *S. litura* and *T. orichalcea* (72.74, 85.11 and 73.43, 86.50 % respectively) after first and second spray and least per cent pod damage (24.80 %) and seed damage (16.37 %) with higher seed yield (21.71 q/ha) and B:C ratio (2.96). The next best treatments were NSKE (5 %) and cristol 74 GL (1 %) in soybean.

Gedia *et al*. (2008) tested the efficacy of various commercially available bio pesticides, *viz. Bacillus thuringiensis var. kurstake* (*Bt.k*), Nuclear Polyhydrosis Virus (NPV) alone and in combination with reduced dose of insecticides *viz.*, endosulfan, chloropyriphos to evaluate dynamics of *Spodoptera litura* on castor under field conditions and reported that efficacy and economics of various bio pesticides alone and in combination with conventional insecticides treatments are equally effective.

Pande *et al*. (2008) reported that soybean crop was attacked by various pest among which whitefly was considered as a key pest. The data recorded on population indicated that triazophos and NSKE 5% reduced the whitefly population, considerably. They also reported that spraying of NSKE 5% with dipel increased its efficacy.

Choudhary and Shrivastava (2007) conducted a field experiment at Zonal Agricultural Station (JNKVV), Powarkheda, Madhya Pradesh, on soybean. Six neem-based products and quinalphos (0.04%) were evaluated to assess the efficacy and economics of managing *S. litura* in soybean. Among the neem-based products, application of neem seed kernel extract (NSKE) at 5% + neem leaf extract (NLE) at 10% reduced the maximum larval population (51.59%) and recorded a seed yield of 987.66 kg/ha. However, the incremental cost-benefit ration (ICBR) showed that the application of NSKE at 5% (2.44) proved economically most viable amongst the neem-based treatments, followed by NLE at 5% (2.20).

Singh and Yadav (2007) conducted field trials to test the efficacy of indoxacarb, spinosad, thiamethoxam, endosulfan, three *Bt*. Products and neem formulations. They concluded that indoxacarb caused maximum larval mortality after one week of two sprayings i.e. 99.4% and 98.3 % and resulted in maximum grain yield (1425 kg/ ha) with minimum pod damage (12.5%) and C:B ratio to be 1: 12.387 but higher C: B ratio was recorded in spinosod (1: 15.45).

Rajesekhar *et al*. (2007) reported that, use of B. t. k.+ NSKE 2.5 per cent decreases *H. armigera* larval population (53.2 %) and 1593 kg / ha seed yield in sunflower. Further endosulfone 0.07 per cent, NSKE 5 per cent, *Annona* seed extract 5 per cent, *B. t. k.* + NSKE 2.5 per cent provided a cost benefit ratio of 1:3.9, 1:2.9, 1:2.5 and 1:2.2, respectively.

Patil (2006) reported that the per cent infestation of girdle beetle was significantly reduced in the treatment with *Bt* @ 1 l ha^{-1} + thiamethoxam 25 WG@ 100 g/ha and it was however at par with *Bt* @ 1 l ha^{-1} + methomyl 40 SP@ **1** kg ha^{-1} and *Bt*@ 1 l ha^{-1} + monocrotophos 36 SC@ 0.08l ha^{-1}.

Jagadish *et al*. (2006) carried out an IPM module experiment consisting of seed treatment with imidacloprid 70WS (5 g/kg) + two NSKE spray (5 per cent) and HaNPV spray at 250 LE/ha at 40 and 55 DAS. Results at 55 and 65 DAS revealed a substantial reduction in the population of all sucking pests and defoliators, in addition to a greater incidence of predators, also reported the highest grain yield and Cost: benefit ratio (1:2.32) and superior to chemical control in sunflower.

Bharati (2005) reported that organic treatment as FYM (4 t/ha), Green leaf manure (2.5 t/ha), vermicompost (1 t/ha) and neem cake (500 g/ha) recorded significantly less number of aphids, leaf hoppers, thrips, *S. litura* compared to integrated nutrient management (INM) and inorganic treatment in soybean ecosystem. Also, it was seen that plots of organic treatment recorded significantly higher number of predators and natural enemies followed by INM and inorganic treatment.

Reddy *et al*. (2005) discovered spray application of *B. t. k.* + indoxacarb and indoxacarb+ lufenuron against *S. litura* would give highest general mean effectiveness values (68.1 and 69.9 per cent, decrease in larval population, respectively) and yields (1600 and 1656 kg ha^{-1}, respectively). The use of insecticides in conjunction with *B. t.* k. at reduced doses was more efficient in regulating *S. litura* and increased sunflower yield relative to individual insecticidal sprays at greater doses.

Singh *et al*. (2005) studied the IPM module, consisting seed treatment with *Trichoderma viride* Pers. @ 4g/kg, foliar spray of neem seed kernel extract (5%) applied at 30 days after sowing, foliar spray of sorghum leaf extract (10%) at 20 and 30 DAS installation of pheromone traps @ 10 ha^{-1} each for the monitoring of *H. armigera* and *S. litura*, installation of "T" shaped bamboo bird perches @ 60 ha^{-1} and need based application of SlNPV (Spodoptera littoralis nucleopolyhedrosis virus) spray @ 250 LE ha^{-1} was effective pest management option for groundnut + sunflower based production system.

Ameta *et al*. (2004) validated integrated pest management technology at farmer's field and reported that IPM technology significantly reduced the population of sucking pests and bollworm over non-IPM practices.

Ladaji (2004) carried field investigations to test efficacy of the indigenous materials and reported that pongamia leaf extract (10%) + NSKE (10%) + aloe (5%) + cow urine (30%) recorded maximum reduction in larval population.

Patil and Kulkarni (2004) observed that seed treatment with thiamethoxam @ 3 g/kg seed was found most effective and recorded significantly lower per cent (6.30 %) stem fly and lower per cent girdle beetle infested plant over other seed dressing chemicals whereas it was on par with imidacloprid, phorate and carbofuran treatment at 30 days after sowing.

Singh and Singh (2004) reported *B. thuringiensis* var. *Kurstaki* was most efficient in regulating capitulum borer, *H. armigera* (0.58 larvae/5 crops) in sunflower compared to 2.82 larvae per 5 plants in untreated control plot.

Virkar (2004) evaluated the effectiveness of different insecticides against major pests of soybean and reported that thiamethoxam 25 WG @ 100 g/ha (3.70 %) was the most effective treatment in reducing tunnel length due to stem fly. He also reported that in field testing of chemical insecticides and biopesticides, chlorpyriphos 20 EC @ 1.5 l ha^{-1} were found most superior in reducing per cent leaf damage due to leaf miner 3 days after first spraying. However, it was at par with triazophos 40 EC @ 0.80 l ha^{-1} and *Bacillus thuringiensis*@ 1.0 l ha^{-1}.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the management of major insect pests of soybean through some IPM packages. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from November 2021 to February 2022 in the *Rabi* season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted both in the Central laboratory and Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meters above sea level (Biswas, 2013).

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. For a better understanding, the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I (Biswas, 2013).

3.2.3 Soil

The soil of experimental plot was medium deep black having uniform topography. In order to know the physiochemical properties of the experimental site the soil sample to the depth of 0-30 cm were randomly collected from the experimental site before planting and further analyzed. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in Appendix-II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April, and the monsoon period from May to October (Edris *et al.,*, 1979). Meteorological data related to the temperature, relative humidity, and rainfall during the experiment period was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Planting material

BARI Soybean-6 was used as planting materials for this experiment. The important characteristics of BARI Soybean-6 variety was mentioned below:

BARI Soybean-6

BARI Soybean-6 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh through Exotic germplasm collected from AVRDC, Taiwan and released in 2009. The plant height is between 50-55 cm, capsules/plant 50-55, length of capsule 3-3.5 cm, maximum seed/capsule 2-3, seed coat cream color medium size, 100 seed weight 10-12g, crop duration 100-110 days, are the main characteristics of this variety. This variety is cultivated throughout the country in rabi and kharif season. In rabi season Mid December to mid-January suitable time for sowing and kharif season July suitable time for sowing. BARI Soybean-6 is tolerant to yellow mosaic virus (YMV). It can produce seed yield of 1.80-2.40 t ha^{-1} and content 20-21% oil and 42-44% protein.

3.4 Land preparation

Initially the field was prepared with the help of tractor drawn implement. After giving one deep ploughing the experimental field was cross harrowed and leveled properly to break the clods and bring the soil to the desired tilth. The plots were prepared manually for sowing seeds of the subsequent crops of the experimental study. Land preparation was done at 22 November 2021.

3.5 Experimental treatment

There was single factor in this experiment namely different IPM packages for management of major insect pests of soybean as mentioned below:

T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water

T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water

T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water

T_4 : Farmers practice: Application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water

T_5 : Untreated (Control)

3.6 Experimental details

The present experiment was laid out by using Randomized block design with three replications. The layout consisted of 15 experimental units in three replications with 5 experimental units in each replication. The unit plot size was 5.4 m^2 (2.7 m × 2 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.The layout of the experimental field was done at 25 November 2021 and shown in Appendix -IV.

3.7 Seed collection

For conducting the present experiment the seeds of the test crop *i.e*., BARI Soybean-6 was collected from Bangladesh Agriculture Research Institute (BARI), Gazipur.

3.8 Fertilizer management

Different fertilizers *viz;* Urea, TSP, Mop, Gypsum and boron acid were used as the source of Nitrogen, Phosphorus, Potassium, Sulphur and Boron and were required @ 50, 150, 100,80 and 8 kg ha^{-1} (BARI, 2019). All the fertilizer were applied as basal application during final land preparation according with par treatment requirement.

3.9Seed sowing

BARI Soybean-6 variety seeds were used for sowing. Dibbling was done by maintaining 45 cm inter-row and 5 cm intra-row distance and 30 cm inter-row and 10 cm intra-row distance. It was done at 25 November 2021.

3.10 Germination of seeds

After the sixth day of seed sowing, the seed began to germinate. More than 85% of seeds germinated on the 7^{th} day, and nearly all young plants emerged from the soil on the fifth day.

3.11 Gap filling

Gap filling was done 20 DAS by dibbling the seeds wherever the previous dibbled seeds did not germinate in order to achieve the required plant population in experimental plot.

3.12 Intercultural operations

3.12.1 Thinning

For appropriate development and to avoid a crowded environment, only healthy seedling were preserved per plot. When necessary, thinning was carried out for this.

3.12.2 Weeding

Two hand weeding were given during the growth period of soybean for control of weeds and better aeration in the soil.

3.12.3 Application of pesticides

i. Preparation of spray fluid

The amount of spray solution required was determined by spraying water on the control plots. For preparation of spray solution, the measured quantity of pesticides was taken in a bucket and mixed thoroughly with known quantity of water, agitated and then poured into the tank of sprayer. After each spraying, the sprayer was rinsed by passing clean water through the lance.

ii. Method of foliar application

Knapsack sprayer was used for spraying of pesticides. Sprayings were done generally during morning hours at the time of silent condition to avoid drift due to heavy wind. Three applications of insecticidal and bio pesticidal spraying were under taken after seven weeks of sowing at an interval of 15 days.

3.12.4 Irrigation

Two irrigation were given. First irrigation was given at 25 DAS whereas the second irrigation given at 55 DAS.

3.13 Harvesting

At maturity, the crop was harvested manually. After complete drying of biomass, threshing was done manually and after winnowing clean seeds was collected separately and their weights were recorded in kg plot^{-1} along with biomass. It was harvested at 24 February, 2022.

3.14 Monitoring of insect pest and data collection

For data collection five plants per plot were randomly selected and tagged. Data collection was started at seedling stage to harvest. The results are presented as an average value of the five tagged plants. The data were recorded on different parameters. The following parameters were considered during data collection:

i. Pest complex of soybean field
ii. Number of insect pests and reduction percentage of plant parts
iii. Plant height (cm)
iv. Number of branches plant^{-1}
v. Number of infested pods plant^{-1}
vi. Number of healthy pods plant^{-1}
vii. Seeds pod^{-1} (no.)
viii. 1000-seed weight (g)
ix. Seed yield (t ha^{-1})
x. Correlation between insect pest and seed yield of soybean

3.15 Procedure of recording data

i. Pest complex of soybean field

Insect found in untreated control were recorded according to their incidence and severity and listed with their common name, scientific name main characteristic of them. Observations were recorded at 15 days intervals starting from 15 days of germination up to harvesting

ii. Number of insect pests and reduction percentage of plant parts

Pest insect populations (jassid, pod borer, and leaf roller) were counted at intervals of 15 days. To gather data, five plants were chosen at random. The number of insects was counted at intervals of 15 days starting with the first occurrence and continuing up to 5 times in the morning. The reduction percentage was also calculated by using data from untreated control plants, where the greatest number of major pest attacks occurred. The reduction percentage was calculated using the formula below:

$$\text{Reduction (\%)} = \frac{\text{No. of pest in untreated control-No. of pest per treated plot}}{\text{No. of pest in untreated control}} \times 100$$

iii. Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant at harvest. Mean plant height of soybean plant were calculated and expressed in cm.

iv. No. of branches plant^{-1}

The primary branch plant^{-1} was counted from five randomly sampled plants. It was done by counting the total number of branches of all sampled plants then the average data were recorded at harvest.

v. Number of infested pods plant^{-1}

The average pod number was calculated after counting the number of infested pods per plant from the 5 selected plant samples.

vi. Number of healthy pods plant^{-1}

The number of healthy pods per plant was counted from the 10 selected plant samples, and the average pod number was calculated.

vii. Number of seeds pod^{-1}

The number of seeds pod^{-1} was counted randomly from selected pods at the time of harvest. Data were recorded as the average of 10 pods from each plot.

viii. 1000-seed weight

One thousand cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

xi. Seed yield

Seed yield was recorded from each plot were sun dried properly. The weight of seeds was taken and converted the yield in kg ha^{-1}.

3.16 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This section contains a presentation and discussion of the study's findings on the management of major insect pests of soybean through some IPM packages. The information was presented in various tables and figures. The findings had been discussed, and possible interpretations were provided under the headings listed below:

4.1 Pest complex of soybean

During 2021-22, nineteen insect pest species belonging to sixteen families and six orders were noticed and recorded to infest the various growth stages of the soybean crop at the SAU experimental field (Table 1). The majority of the insect pests belonged to one of three orders (Lepidoptera, Hemiptera, and Coleoptera), with leaf feeding and sucking insect pests dominating. Of these, four species namely, whitefly (*Bemisia tabaci* Genn.), jassid (*Amrasca biguttula* biguttula [Ishida]), pod borer (*Helicoverpa armigera* Hub.) and leaf roller (*Lamprosema indicata* F.) respectively caused 90-100%, 70-80%, 50-60%, and 30-40% plant infestation (Table 2). The population density of whitefly, jassid, pod borer and leaf roller were 1.73-8.96, 0.4-4.20, 0.40-3.46 and 0.45-1.73 per plant, respectively. These insect pests attacked vegetative to pod formation stage of soybean. Pod borer larvae bore soybean pods, Leaf roller larvae roll leaves and feed on leaves, but jassid and whitefly nymphs and adults sucked cell sap from various parts of the plant (Table 1). The result was quite similar with the findings of Motaphale *et al.,* (2019) who observed that the population of *Spodoptera litura, Helicoverpa armigera, Aproaerema modicella, Obereopsis brevis* and *Melanagromyza sojae* were ranged from 0-4, 0-2.2 ,0-2.4, 0-0.3, 5.20-19.66, and 14.9- 27.2 and it was 3.9-20.4 , 6.8-26.2, 3.2-16.0, 0-5.5, 2.9-24.7 and 10-25.7 during 2011-12, respectively. In conclusion leaf miner (*A. modicella*), defoliators, stem fly (*M. sojae*) and girdle beetle (*O. brevis*) were found to be major pests of soybean. Ahirwar *et al.,* (2016) reported that the major insect-pest observed attacking soybean variety JS- 335 were girdle beetle, O*bereopsis brevis*; tobacco caterpillar, *Spodoptera litura*; green semilooper, *Chrysodeixis acuta;* whitefly, *Bemisia tabaci* and jassids*, Empoasca kerri*.

Table1. Insect pests recorded from soybean crop ecosystem during 2021-2022 at SAU experimental field

Sl. No.	Common Name	Order	Family	Feeding behavior
01.	Aphid	Hemiptera	Aphididae	Nymph and adult suck cell sap
02.	Epilachna beetle	Coleoptera	Coccinellidae	Larvae and adult feed on leaves
03.	Flower thrips	Thysanoptera	Thripidae	Nymph and adult suck cell sap
04.	Green grasshopper	Orthoptera	Acrididae	Nymph and adult feed on leaves
05.	Green stinkbug	Hemiptera	Pentatomidae	Nymph and adult suck cell sap
06.	Grey weevil	Coleoptera	Curculionidae	Adult feed on leaves
07.	Hairy caterpillar	Lepidoptera	Erebidae	Larvae feed on leaves
08.	Jassid	Hemiptera	Jassidae	Nymph and adult suck cell sap
09.	Leaf beetle	Coleoptera	Chrysomelidae	Adult and larvae feed on leaves
10.	Leaf miner	Lepidoptera	Gelechiidae	Larvae mine and feed on leaves
11.	Leaf roller	Lepidoptera	Crambidae	Larvae roll and feed on leaves
12.	Long horned grass hopper	Orthoptera	Tettigoniidae	Nymph and adult feed on leaves
13.	Mealybug	Hemiptera	Pseucoccidae	Nymph and adult suck cell sap
14.	Podborer	Lepidoptera	Noctuidae	Larvae bore pod
15.	Pumpkin beetle	Coleoptera	Chrysomelidae	Adult feed on leaves
16.	Semilooper	Lepidoptera	Noctuidae	Larvae feed on leaves
17.	Stemfly	Diptera	Agromyzidae	Larvae bore stem
18.	Tobacco caterpillar	Lepidoptera	Noctuidae	Larvae cut and feed on leaves
19.	Whitefly	Hemiptera	Aleyrodidae	Nymph and adult suck cell sap

Table 2. Incidence of some important soybean insect pests and their infestation level in control plot during 2021-2022 at SAU experimental field

Name of in sects	% plant infestation	No. of insect plant^{-1}	Stage of infestation
Whitefly	90-100	1.73-8.96	Vegetative - Pod formation
Jassid	70-80	0.4-4.20	Vegetative - Pod formation
Pod borer	50-60	0.40-3.46	Vegetative - Pod formation
Leaf roller	30-40	0.45-1.73	Vegetative - Pod formation

Data were recorded from 10 soybean plants in each replication

4.2 Incidence of whitefly and reduction percentage on soybean

Whitefly is a major pest of soybean production. The collecting results during the experiment had a significant influence on the number of whitefly incidences and their percent reduction over the control at all stages of production. The untreated control (T_5) had the highest number of whitefly occurrences (4.73, 6.43, 8.96 and 5.87 at30, 45, 60, and 75 DAS, respectively), while the other treatments had lower numbers. Whereas T_2 (IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water) treatment on soybean plant as an integrated pest management recorded the lowest incidence of whitefly (2.40, 2.47, 3.26 and 1.73 at30, 45, 60, and 75 DAS, respectively) and the reduction percentage was maximum (62.07 %) than other treatments. Among the treatments where the IPM packages were used the highest incidence of whitefly and their minimum reduction (33.32 %) were observed in T_1 treatment over the untreated control (Table 3). The result was quite similar with the findings of Yadav *et al.* (2018) who resulted from their investigation on effectiveness of some insecticides against larval population of soybean that Indoxacarb 14.5 SC was found to be superior in reduction of larval population of green semilooper and tobacco caterpillar than other treatments.

Table 3. Effect of different IPM packages on the incidence and reduction of whitefly on soybean at different days after sowing

Treatments	Number of whitefly at				Mean	% Reduction over control
	30 DAS	45 DAS	60 DAS	75 DAS		
T_1	2.73 b	3.73 c	6.20 b	4.67 b	4.33	33.32
T_2	2.40 c	2.47 d	3.26 e	1.73 e	2.47	62.07
T_3	2.73 b	3.73 c	4.60 d	3.40 d	3.62	44.38
T_4	2.66 b	3.93 b	5.40 c	3.93 c	3.98	38.76
T_5	4.73 a	6.43 a	8.96 a	5.87 a	6.50	
$LSD_{(0.05)}$	0.08	0.07	0.41	0.36		
CV(%)	1.47	1.07	3.85	4.97		

In a column, means having similar letter(s) are statistically identical at 5% level of significance. Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

4.3 Incidence of jassid and reduction percentage on soybean

Table 4 shows the incidence of jassid where different IPM packages were used to suppress the pest. The maximum number of jassid (3.53, 2.67, 4.20 and 3.00 at 30, 45, 60 and 75 DAS, respectively) was found in control treatment (T_5). While application of different IPM packages significantly reduces incidence of jassid at different days after sowing of soybean. The minimum incidence (1.53, 0.73, 1.27 and 0.47 at 30, 45, 60 and 75 DAS, respectively) with maximum reduction percentage (70.14%) was observed it T_2 treatment. Among the treatments where the IPM packages were used the highest incidence of whitefly and their minimum reduction (43.80 %) were observed in T_4 treatment over the untreated control (Table 4). Based on the observations of the incidence of jassid and their control by different treatments, it was discovered that the T2 treatment on the soybean research field reduced the number of jassid. In comparison to the control treatment, all other IPM packages reduce the number of jassid from all stages of production. Other treatments' results showed an intermediate percent incidence of jassid compared to the highest and lowest incidences (Table 4). Singh and Singh (2015) studied IPM modules for mungbean (seed treatment with Imidacloprid 600 FS) and resulted significant less incidence of whitefly, jassids and thrips. It also proved that IPM practices gave superior results than farmer practices.

Table 4. Effect of different IPM packages on the incidence and reduction of jassid on soybean at different days after sowing

Treatments	Number of Jassid at				Mean	% Reduction over control
	30 DAS	45 DAS	60 DAS	75 DAS		
T_1	1.86 b	1.27 c	1.40 d	1.34 c	1.47	56.19
T_2	1.53 c	0.73 d	1.27 d	0.47 e	1.00	70.14
T_3	1.86 b	1.80 b	1.74 c	0.80 d	1.55	53.73
T_4	1.73 b	1.80 b	2.40 b	1.60 b	1.88	43.80
T_5	3.53 a	2.67 a	4.20 a	3.00 a	3.35	
$LSD_{(0.05)}$	0.16	0.08	0.26	0.07		
CV(%)	4.14	2.62	6.42	3.10		

In a column, means having similar letter(s) are statistically identical at 5% level of significance. Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

4.4 Incidence of pod borer and reduction percentage on soybean

The results in (Table 5) revealed significant variations due to the effect of different IPM packages on the incidence and percent reduction of pod borer. Among the IPM packages on management of pod borer, T_2 (IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml/L of water) treatment had the best control against pod borer, while T_1 (IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC) @ 1.2 ml/L of water) treatment had the worst. Pod borer is another major pest that is highly destructive to soybean production. Application of T_2 treatment reduced the maximum pod borer attack (0.46 and 0.40 at 60 and 75 DAS, respectively), resulting in a greater reduction (85.17%) of pod borer and supported to make sure the more yield of soybean. It was discovered that the untreated control (T_5) had the highest number of pod borer (3.46 and 2.33 at 60 and 75 DAS, respectively) occurrences. Motaphale *et al.* (2017b) reported that different IPM modules significantly reduced insect pest infestation in soybean plant comparable to control treatment.

Table 5. Effect of different IPM packages on the incidence and reduction of pod borer on soybean at different days after sowing

Treatments	Number of pod borer at		Mean	% Reduction over control
	60 DAS	75 DAS		
T_1	1.60 b	0.66 b	1.13	61.03
T_2	0.46 c	0.40 c	0.43	85.17
T_3	0.53 c	0.66 b	0.60	79.48
T_4	1.46 b	0.33 d	0.90	68.96
T_5	3.46 a	2.33 a	2.90	
$LSD_{(0.05)}$	0.16	0.04		
CV(%)	5.95	2.44		

In a column, means having similar letter(s) are statistically identical at 5% level of significance. Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

4.5 Incidence of leaf roller and reduction percentage on soybean

The results of the experimental data showed a significant impact on the number of leaf roller incidences and their percent reduction over the control at different days after sowing. Leaf roller occurrences were highest in the (T_5) untreated control (1.63 and 1.73 at 60 and 75 DAS, respectively), while the other treatments had lower numbers. T_2 (IPM package-2: hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water) treatment on soybean plant as an integrated pest management recorded the lowest incidence of leaf roller (0.45 and 0.78 at 60 and 75 DAS, respectively) and the highest reduction percentage (63.39%) over untreated control. Among the treatments where the IPM packages were used the highest incidence of leaf roller and their minimum reduction (50.30 %) were observed in T_4 treatment over the untreated control (Table 6). Ameta *et al*. (2004) validated integrated pest management technology at farmer's field and reported that IPM technology significantly reduced the population of sucking pests and bollworm over non-IPM practices in cotton.

Table 6. Effect of different IPM packages on the incidence and reduction of leaf roller on soybean at different days after sowing

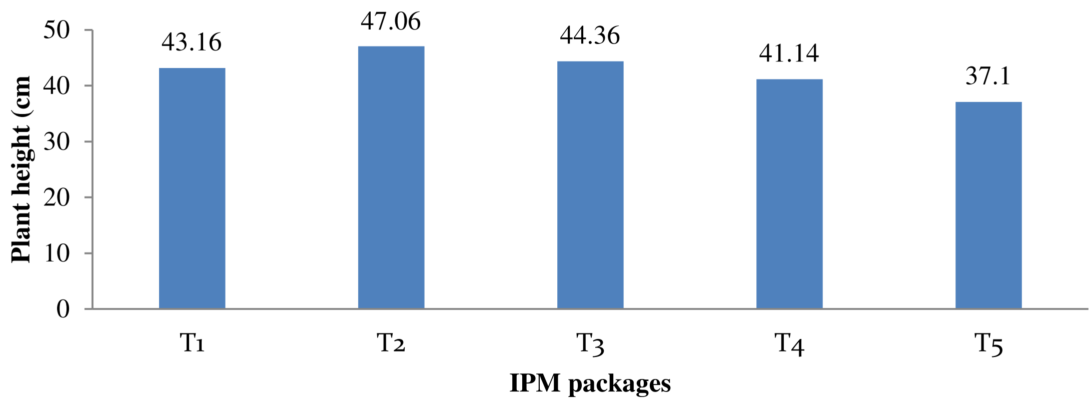
Treatments	Number of leaf roller at		Mean	% Reduction over control
	60 DAS	75 DAS		
T_1	0.46 b	0.80 c	0.63	62.5
T_2	0.45 b	0.78 c	0.62	63.39
T_3	0.46 b	1.06 b	0.76	54.76
T_4	0.47 b	1.20 b	0.84	50.30
T_5	1.63 a	1.73 a	1.68	
LSD(0.05)	0.03	0.16		
CV(%)	2.04	7.78		

In a column, means having similar letter(s) are statistically identical at 5% level of significance. Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

4.6 Effect of different IPM packages on growth and yield of soybean

4.6.1 Plant height (cm)

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants (Fig. 1). At harvest plant height of soybean was significantly influenced by different IPM packages. Experimental result showed that among the treatments the maximum plant height (47.06 cm) was observed in T_2 treatment where minimum number of pest was recorded which was closely followed by T_1 (43.16 cm) and T_3 (44.36 cm) treatment. The untreated control, on the other hand, recorded the lowest plant height (37.10).

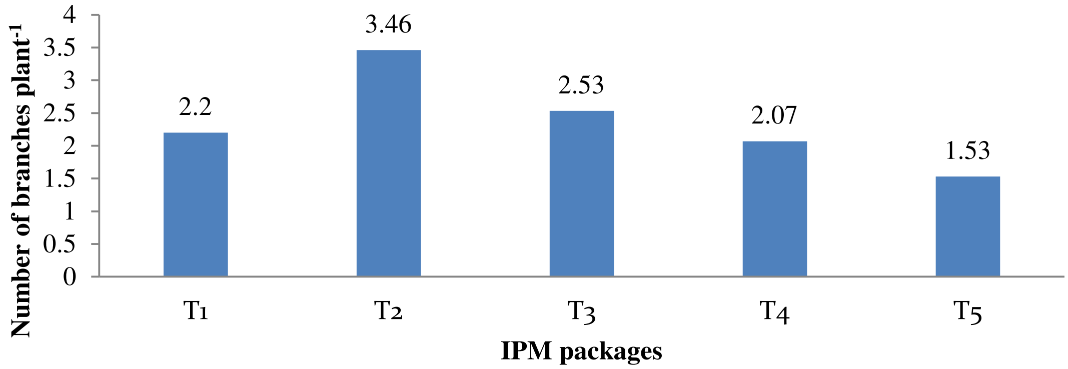


Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

Fig. 1. Effect of different IPM packages on plant height of soybean

4.6.2 Number of branches plant^{-1}

Different IPM packages significantly influenced the number of branches plant^{-1} of soybean at harvest (Fig. 2). The experimental results revealed that the T_2 treatment had the highest number branches plant^{-1} of soybean (3.46) where minimum number of pest was recorded. The untreated control, on the other hand, had the lowest number branches plant^{-1} of soybean (1.53).

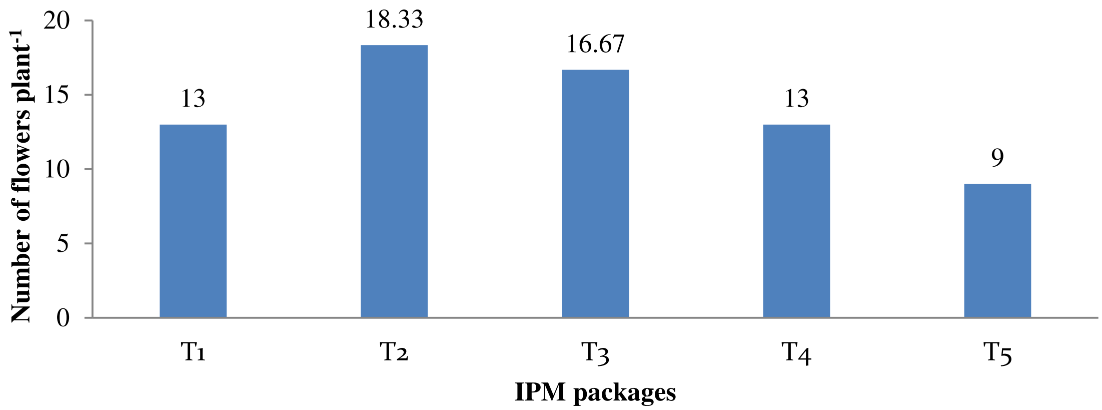


Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

Fig. 2. Effect of different IPM packages on number of branches plant^{-1} of soybean at harvest

4.6.3 Number of flowers plant^{-1}

A significant variation was observed due to the effect of different IPM packages for management of pest on soybean plant in respect of number of flowers plant^{-1} (Fig. 3). The highest number of flowers plant^{-1} (18.33) was observed in T_2 treatment while the lowest number of flowers plant^{-1} (9.00) was observed in untreated control (T_5) treatment. The results also show that the maximum pest attack reduces plant growth, but different IPM packages used reduce pests while increasing plant height, number of branches, number of flowers, and so on.

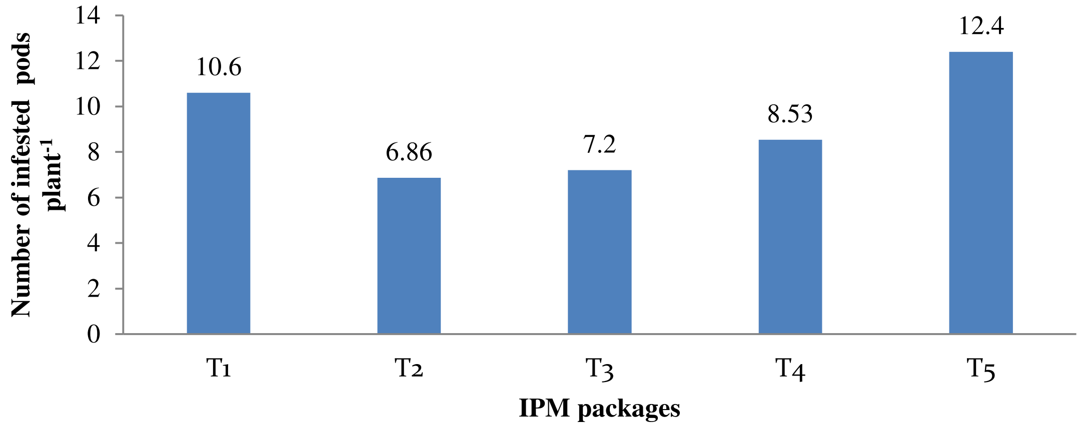


Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

Fig. 3. Effect of different IPM packages on number of flowers plant^{-1}of soybean

4.6.4 Number of infested pods plant-1

In terms of the number of infested pods plant^{-1}, a significant variation was observed due to the effect of different IPM packages for pest management on soybean plants (Fig. 4). Experimental result showed that the highest number of infested pods plant^{-1} (12.40) was observed in untreated control where maximum insect-pest infestation was occurred at different days after sowing. While application of T_2 treatment reduces insect-pest infestation at different days after sowing and recorded the lowest number of infested pods plant^{-1} (6.86) of soybean.

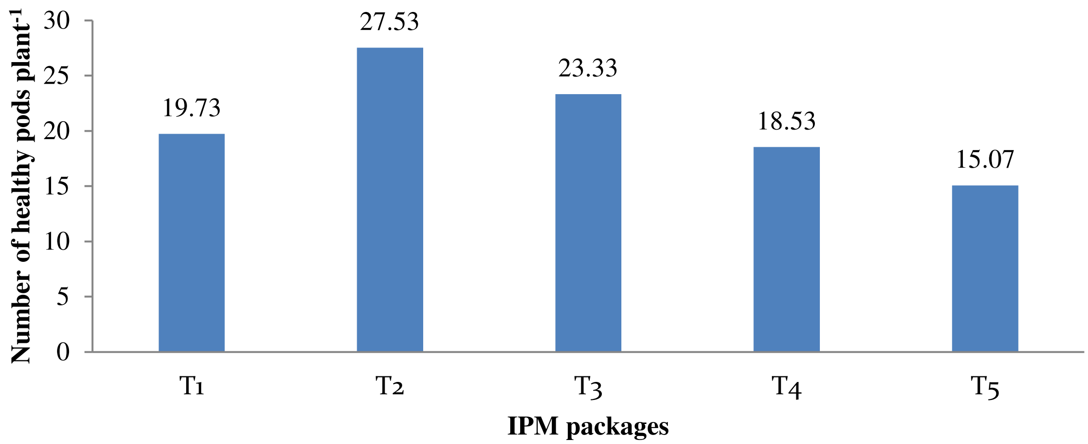


Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

Fig. 4. Effect of different IPM packages on number of infested pods plant^{-1} of soybean

4.6.5 Number of healthy pods plant^{-1}

Due to the impact of various IPM packages against insect pests on soybean in regards to the number of healthy pod plant^{-1}, a significant variation was discovered (Fig. 5). According to the experimental findings the highest number of healthy pods plant^{-1} (27.53) was observed in T_2 treatment where minimum insect-pest infestation was occurred at different days after sowing. While the lowest number of healthy pods plant^{-1} (15.07) of soybean was observed in untreated control (T_5).

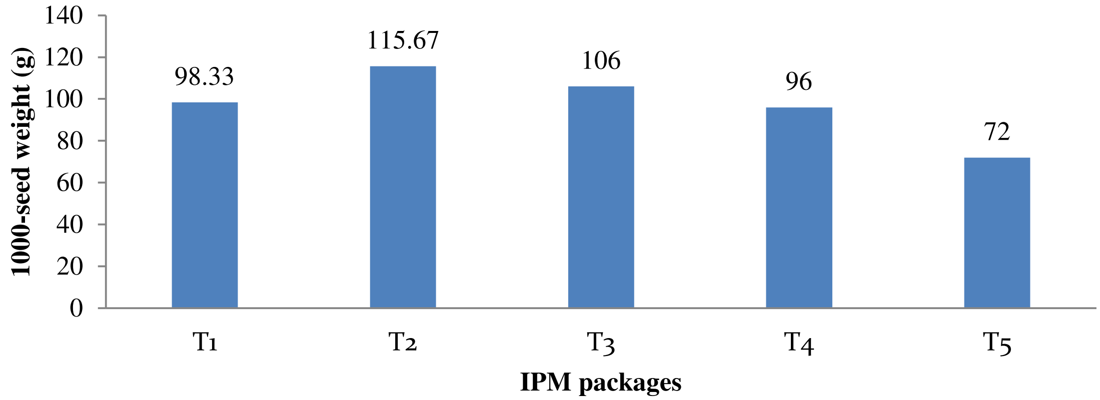


Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

Fig. 5. Effect of different IPM packages on number of healthy pods plant^{-1} of soybean

4.6.6 1000-seed weight (g)

A significant variation was found due to the effects of different IPM packages against insect pests on soybean in relation to the weight of 1000 seeds (Fig. 6). Experimental result showed that the highest 1000-seed weight of soybean (115.67 g) was observed in T_2 treatment while the lowest 1000-seed weight of soybean (115.67 g) was observed in untreated control (T_5).



Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

Fig. 6. Effect of different IPM packages on 1000-seed weight of soybean

4.6.7 Seed yield (t ha^{-1})

The effectiveness of different IPM packages against insect pests on soybean was also determined based on seed yield obtained from different treatments (Table 7). Significantly higher seed yield (2.25 t ha^{-1}) was obtained from T_2 treatment which gave (60.44 %) more yield comparable to untreated control (T_5), while the lowest seed yield (0.89 t ha^{-1}) was obtained from untreated control (T_5). From the above results investigate, it was found that the among all applied different treatments in this study, T_2 treatment showed the superior performance on control the pests as to ensure the optimum vegetative growth and highest number of flowers and healthy fruits per plot as well as maximum yield. Similar result also observed by Ingle *et al*. (2016) who evaluated different modules against insect pest of soybean and reported that chemical module gave maximum yield (1383.70 kg ha^{-1}) as compared to other modules.

Table 7. Effect of different IPM packages to manage the pest and its impact on its impact on yield of soybean

Treatments	Yield (t ha^{-1})	% increased over control
T_1	1.46 c	39.04
T_2	2.25 a	60.44
T_3	1.83 b	51.37
T_4	1.29 d	31.01
T_5	0.89 e	
$LSD_{(0.05)}$	0.11	
CV(%)	4.18	

In a column, means having similar letter(s) are statistically identical at 5% level of significance. Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

4.7 Benefit-cost ratio analysis

The T_2 (IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water) treated plot had the highest (4.72) benefit-cost ratio (Table 8). The T_3 (IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water) treated plot had the second highest benefit cost ratio (4.63). More or less similar benefit cost ratio was observed in T_1 (3.50) and T_4 (3.30) treatment. While the lowest benefit cost ratio (2.84) was observed in control treatment. Similarly the net return was also the highest in T_2 treated plot i.e. Tk. 266030 ha^{-1} followed by T_3 treated plot which is Tk. 215254 ha^{-1}. On the other hand, the lowest net return found in T_5 (Control) treatment which includes Tk. 86542 followed by T_4 (134797 Tk.) treatment (Table 8). The result was similar with the findings of Motaphale *et al.* (2017b) who evaluated IPM modules for effective management of stem fly and girdle beetle on soybean crop and reported that the MAU (Marathwada Agricultural University) IPM module (cultural control, mechanical control, biological control and chemical control) was found to be effective in reducing the girdle beetle and stem fly infestation and recorded the highest BCR comparable to other treatments. Jagadish *et al.* (2006) carried out an IPM module experiment consisting of seed treatment with imidacloprid 70WS (5 g kg^{-1}) + two NSKE spray (5 per cent) and Ha

NPV spray at 250 LE ha^{-1} at 40 and 55 DAS. Results at 55 and 65 DAS revealed a substantial reduction in the population of all sucking pests and defoliators, in addition to a greater incidence of predators, also reported the highest grain yield and Cost: benefit ratio (1:2.32) and superior to chemical control in sunflower.

Table 8. Economic analysis of different IPM packages for managing soybean pest

Treatments	Cost of pest management (TK)			Total cost of production	Yield (t/ha)	Gross return (Tk.)	Net return (Tk.)	Benefit cost ratio (BCR)
	Insecticides (Tk.)	Labour	Total					
T_1	8125	6300	14425	62644	1.46	219000	156356	3.50
T_2	16240	6300	22540	71470	2.25	337500	266030	4.72
T_3	5000	6300	11300	59246	1.83	274500	215254	4.63
T_4	4500	6300	10800	58703	1.29	193500	134797	3.30
T_5	0	0	0	46958	0.89	133500	86542	2.84

In a column, means having similar letter(s) are statistically identical at 5% level of significance. Here, T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers' practice: application of chlorantraniliprole + thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated control

Overhead cost: Land value ha^{-1} was 200000 taka. Land cost at 12.5 % interest for 6 month was 12500 taka. Miscellaneous cost (common cost): It was 5% of total input cost, Price of soybean seed = TK 150.00/kg

Cost of insecticide

T_1: Success 2.5 SC = TK 1625.00 L^{-1}

T_2: Rav-zoom 14.5 SC = Tk 3248.00 L^{-1}

T_3: Convoy 25 EC = TK 800 L^{-1}

T_4: Virtako 40 WG = Tk 12.00 g^{-1}

Cost of labour = TK 450.00 day^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the management of major insect pests of soybean through some IPM packages during the period from November 2021 to February 2022 in the *Rabi* season. The experiment was laid out in Randomized block design with five different IPM packages *viz:* T_1 : IPM package-1: Hand picking of larvae + bird perching + application of spinosad (Success 2.5 SC)@ 1.2 ml L^{-1} of water, T_2 : IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water, T_3 : IPM package-3: Hand picking of larvae + bird perching + application of quinalphos (Convoy 25 EC) @ 1.5 ml L^{-1} of water, T_4 : Farmers practice: Application of Chlorantraniliprole + Thiamethoxam (Virtako 40 WG) @ 2 g L^{-1} of water and T_5 : Untreated (Control) for the management of major insect pests of soybean with three replications for each treatment.

Experimental result showed that in the experimental field, nineteen insect pests from sixteen families and six orders attacked soybean. The majority of them belonged to the Orders Lepidoptera, Hemiptera, and Coleoptera. Among the major pests of soybean, whitefly, jassid, pod borer and leaf roller were effective than other pests on soybean research field. The occurrence of these pests varied significantly due to the use of various IPM packages. Among the treatments, T_2 (IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml/L of water) treatment on soybean plant as an integrated pest management recorded the lowest incidence of whitefly and reduction (62.07 %), incidence of jassid and reduction (70.14%), incidence of pod borer and reduction (85.17%), incidence leaf roller and reduction (63.39%), were recorded at all growth and reproductive stage, respectively on the basis of control treatment.

The use of different integrated pest management packages for pest management on soybean plant significantly influenced growth, yield contributing characters and yield. The highest plant height (47.06 cm),number branches plant^{-1} of soybean (3.46),number of flowers plant^{-1} (18.33),number of healthy pods plant^{-1} (27.53),1000-seed weight (115.67 g),and seed yield (2.25 t ha^{-1}) were recorded in T_2 treatment.

On the other hand, the lowest seed yield (0.89 t ha^{-1}) was found in control treatment (T_5). It is also revealed that T_2 treatment performed as the best treatment in terms of benefit cost ratio (4.72) followed by T_3 (4.63). While the lowest benefit cost ratio (2.84) was observed in control treatment.

Based on the investigation of the above results, it is possible to conclude that among all integrated pest management packages for pest management on soybean plants in this study, the T_2 (IPM package-2: Hand picking of larvae + bird perching + application of indoxacarb (Rav-zoom 14.5 SC) @ 0.7 ml L^{-1} of water) treatment showed the best performance to manage the major pest of soybean as well as on growth and yield characteristics.

Recommendation

The following recommendation may be suggested below-

i. Further research may be required to ensure the major pest incidence on soybean, as well as the growth and yield performance.
ii. Other modules of the IPM package may be required for future research to manage the major pest incidence on soybean.

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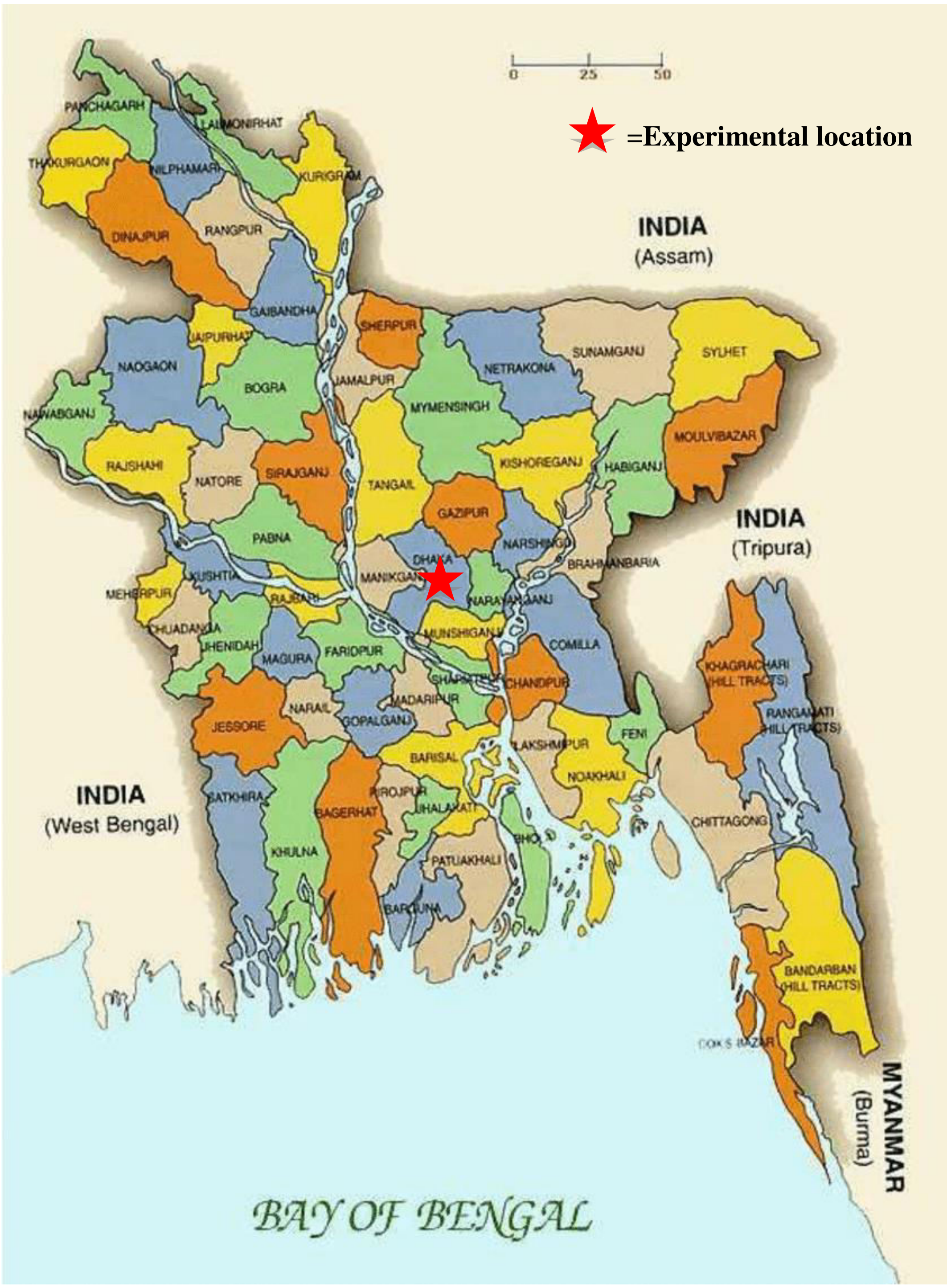
APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0- 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. Monthly meteorological information during the period from October 2021 to February, 2022

Year	Month	Air temperature (^0C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2021	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2022	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m

Source: Meteorological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data on incidence of whitefly on soybean at different days after sowing

Source	Df	Incidence of whitefly at different days after sowing			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.00200	0.00338	0.0980	0.09800
Treatment	4	2.70135**	6.28476**	13.5974**	7.07370**
Error	8	0.00200	0.00188	0.0480	0.03800

** : Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on incidence of jassid on soybean at different days after sowing

Source	Df	Incidence of jassid at different days after sowing			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.01058	0.00338	0.05000	0.00200
Treatment	4	1.96641**	1.55709**	4.31736**	2.86476**
Error	8	0.00758	0.00188	0.02000	0.00200

** : Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on incidence of pod borer on soybean at different days after sowing

Source	Df	Incidence of pod borer at different days after sowing	
		60 DAS	75 DAS
Replication	2	0.01800	0.00038
Treatment	4	4.40676**	2.04909**
Error	8	0.00800	0.00045

** : Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on incidence of leaf roller on soybean at different days after sowing

Source	Df	Incidence of leaf roller at different days after sowing	
		60 DAS	75 DAS
Replication	2	0.00050	0.01152
Treatment	4	0.82149**	0.44994**
Error	8	0.00020	0.00752

** : Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on growth and yield characteristics of soybean

Source	Df	Plant height	No. of branches $plant^{-1}$	No. of flowers $plant^{-1}$	No. of infested pods	No. of healthy pods	1000-seed weight
Replication	2	0.6000	0.00600	0.6000	0.2122	0.6000	21.800
Treatment	4	41.7584**	1.52811**	39.6584**	16.5682**	68.1130**	791.653**
Error	8	1.1000	0.01100	0.3500	0.1972	1.1000	13.050

** : Significant at 0.01 level of probability

Appendix IX. Analysis of variance of the data on yield of soybean

Source	Df	Yield of soybean
Replication	2	0.01400
Treatment	4	0.66429**
Error	8	0.00400

** : Significant at 0.01 level of probability