ASSESSMENT OF THE EFFECTIVENESS OF BIO-PESTICIDES AGAINST THE FRUIT BORER OF CAPSICUM (*Capsicum annum*)

KHAN TAUHIDUR RAHMAN

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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KHAN TAUHIDUR RAHMAN

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APPROVED BY:

Prof. Dr. Md. Mizanur Rahman
Research Supervisor
Department of Entomology
SAU, Dhaka

Prof. Dr. S. M. Mizanur Rahman
Research Co-Supervisor
Department of Entomology
SAU, Dhaka

Prof. Dr. Md. Mizanur Rahman
Chairman
Department of Entomology
SAU, Dhaka

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled, ***ASSESSMENT OF THE EFFECTIVENESS OF BIO-PESTICIDES AGAINST THE FRUIT BORER OF CAPSICUM (Capsicum annum)*** *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 Entomology,*** *embodies the result of a piece of bona fide research work carried out by* ***Khan Tauhidur Rahman,*** *Registration number:* ***14-06159*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June 2021
Dhaka, Bangladesh

Dr. Md. Mizanur Rahman
Research Supervisor
&
Professor
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka-1207

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The Author

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Dedicated

To

My beloved parents

ASSESSMENT OF THE EFFECTIVENESS OF BIO-PESTICIDES AGAINST THE FRUIT BORER OF CAPSICUM (*Capsicum annum*)

BY
KHAN TAUHIDUR RAHMAN

ABSTRACT

The study was carried out in the Central Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2019 to April,2020 to assessment the effectiveness of bio-pesticides against the fruit borer of capsicum. *BARI Misti Morich-1* was used in this study. The experiment comprised with five treatments. and the vizs. were: T_1=Azadirachtin (Bioneem plus 1 EC), T_2=Spinosad (Success 2.5 SC), T_3=*Bacillus thuringiensis* (Bt spray), T_4=Abamectin (Border plus 1.8 EC) and T_5=Untreated control. During cropping season, the highest weight of healthy fruits/plant (876.84 g) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)]. On the other hand, the lowest weight of healthy fruits/plant (320.26 g) was recorded from untreated control (T_5). The lowest weight of infested fruit/plant (268.00 g) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)]. On the other hand, the highest weight of infested fruit (284.92 g) was recorded from untreated control (T_5). The lowest percentage of fruit infestation in weight (23.41%) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)] and the highest fruit infestation (47.08%) was recorded from untreated control (T_5). Fruit infestation reduction over control in weight was estimated and the highest value (58.28%) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)], while the lowest (19.74%) reduction of fruit infestation over control was in T_1 [Azadirachtin (Bioneem plus 1 EC)] treatment. The highest weight of fruit yield (27.26 t ha^{-1}) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)]. The lowest yield (14.41 t ha^{-1}) of fruit was recorded from untreated control (T_5) and was closely (16.71 t ha^{-1}) followed by T_1 [Azadirachtin (Bioneem plus 1 EC)]. Treatment T_3 (*Bacillus thuringiensis* (BT spray)) had higher weight of fruit yield (24.37 t ha^{-1}) but significantly different from T_2 treatment. Yield increase over control in weight was estimated the highest value (89.17%) from the treatment T_2 [Spinosad (Success 2.5 SC)], while the lowest value was (15.97 %) from the treatment T_1 [Azadirachtin (Bioneem plus 1 EC)]. Among the different treatments as awhole, Spinosad was the most effective against controlling fruit borer of *Capsicum* under the study.

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LIST OF ABBREVIATIONS

Agro Ecological Zone	=	AEZ
and others (Co-workers)	=	*et al.*
Bacillus thuringiensis	=	Bt
Centimeter	=	cm
Coefficient of Variation	=	CV
Degree centigrade	=	^{o}C
Degree of freedom	=	df
Namely	=	*viz.*
Fiscal Year	=	FY
Least significant difference	=	LSD
Metric tons	=	mt
Nitrogen	=	N
Non-significant	=	NS
Per Hectare	=	ha^{-1}
Percentage	=	%
Phosphorus	=	P
Potassium	=	K
Randomized Complete Block Design	=	RCBD
Relative humidity	=	% RH
Standard Week	=	SW
Sher-e-Bangla Agricultural University	=	SAU
Soil Resources Development Institute	=	SRDI
Standard Error	=	SE
that is	=	i.e.
Tons	=	t

CHAPTER I
INTRODUCTION

CHAPTER I

INTRODUCTION

Capsicum (*Capsicum annum* L.), also known as 'Bell pepper' or 'Sweet pepper', belongs to the family Solanaceae. It is a highly remunerative vegetable crop grown in most parts of the world including India (Pathipati, 2015). It may be eaten as cooked or raw as well as in salad. Capsicum are chosen because of their high nutritive value and are rich source of vitamin C, bioflavonoid and 6-carotene. Capsicum are rich in capsaicin that may works against inflammation, they have powerful antioxidant properties.

Sweet pepper is considered a minor vegetable crop in Bangladesh and its production statistics is not available (Hasanuzzaman, 1999). Small scale cultivation is found in peri-urban areas primarily for the supply to some city markets in Bangladesh (Saha and Hossain, 2001). In Bangladesh, capsicum is cultivated in an area of 13400 acre with production of 38890 metric tons in 2019–2020 season (BBS, 2020). Dhaka is the major capsicum cultivating district with an area of 2900 acre and production of 17400 metric tons followed by Sylhet, Rangamati and Sirajganj (BBS, 2020). Being the low temperature loving crop, in the plains of Bangladesh it is grown during *rabi* season only. China is the world's major producer of Capsicum with an area of 0.61 million ha and a production of 120 million tons (Sunitha, 2007). In India, capsicum is cultivated in an area of 30,000 ha with production of 1.71 lakh tons (NHB, 2016). On the one hand, the hot pepper variety which is considered as a traditional spice is cultivated near the dwellings, and is sold in all the markets in tropical Africa. On the other hand, the sweet pepper variety is an exotic vegetable which was recently introduced into the area (Grubben and Denton, 2004).

About 35 species of insect and mite pests have been reported to infest capsicum, of which thrips (*Scirtothrips dorsalis* Hood and *Thrips palmi* Karny), aphids (*Aphis gossypii* Glover and *Myzus persicae* Sulzer), whitefly (*Bemisia tabaci* Gennadius), capsule borers (*Helicoverpa armigera* Hubner and *Spodoptera litura* Fabr.) and yellow mite (*Polyphagotarsonemus latus* Banks) cause serious damage to the crop in different regions of Bangladesh (Sunitha, 2007; Kaur *et al.*, 2010 and Kaur and Singh, 2013). About 40% reduction in the worlds crop yield due to pests has been estimated (Navrot *et al.*, 1994). These insects and pests cause both qualitative and quantitative losses in chili in the field. (Shahjahan and Ahmed, 1993). European corn borer (ECB), *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae), was the most important pest of bell peppers in New Jersey and weekly applications of insecticide sprays were needed to control this pest (Ghidiu *et al.*, 2009).

There are some prevailing management practices in Bangladesh to control the major pests of capsicum. These are chemical and non-chemical tactics. The non-chemical tactics are cultural, mechanical, physical, biological, use of light traps, sex pheromone traps, resistant varieties and host plant resistance. These methods are taken by the researcher throughout the world to reduce the economic loss. Over the past half of the decade, crop protection against pests depend solemnly on chemical pesticides and new legislations on chemical usage and the evolution of resistance in pest populations has resulted in their declining usage.

Generally, the farmers are habituated to control these pests by using chemicals because they think pesticides are boom. It was found that 99.76% aphids, 87.22% white flies, 73.89% borers are controlled by using imidacloprid, acephate and cypermethrin @ 70 g ha^{-1}, 1500 g ha^{-1} and 300 g ha^{-1} respectively (Kumar *et al.,* 2001). In sub-continent, it was also reported that dicofol 18.5%, sulphur 80%, endosulfan 35% gave the better result in reducing 85.19% of yellow mite (Srinivasulu *et al.,* 2002). But there are some limitations which hinders the chemical control. Yield losses in case of application of different chemicals were estimated at 40-100% and 15–50%, respectively in different areas of Bangladesh (Agranovsky, 1993). Application of precise dose of the chemical to the field is a difficult job for them. Moreover, indiscriminate as well as long time uses of chemicals affect the soil and human health. Harmful chemical substances enter into the food chain that ultimately causes serious health hazards. Though chemicals are effective in controlling insects and other pests but they are not cost effective.

Fruit borer, *Helicoverpa armigera* is a polyphagous pest and the peak activity is noticed during October to June month in capsicum ecosystem. These caterpillars entered into the fruits and feed inside. Due to the damage, fruits are unfit for selling or consumption. This pest is so severe in capsicum.

In Bangladesh, very few research works have been done on controlled with chemical the management of insects and pest of capsicum. These are mainly on chemical control, cultural control, mechanical control, development of resistant varieties and use of botanical pesticides etc. Bio-pesticides are derivatives of plants, microorganisms and insects. However, synthetic pesticides have become a health hazards for humans and environment due to their toxicity and pollution. Bio-pesticides are potential alternatives to synthetic pesticides. Sources of bio-pesticides are readily available, easily biodegradable, exhibit various modes of action, are less expensive and have low toxicity to humans and non-target organisms. Use of bio-pesticides in capsicum in though low in Bangladesh but is increasing as the organic foods demand is increasing and healthy food is a great concern now.

At present, bio-pesticides are used against many insects and pests. Use of botanical extract against pest is a recent approach to insect management and it has drawn special attention of the entomologist all over the world. In Bangladesh, very few attempts have been made to evaluate bio pesticides against insects pest of capsicum. Therefore, the present study was undertaken to fulfill the following objectives:

- To know the comparative effectiveness of different bio-pesticides on infestation of fruit borer of capsicum;
- To evaluate the efficacy of different bio-pesticides use against fruit borer of capsicum and
- To know the cost-benefit ratio (BCR) against effectiveness of Bio-control agents.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Crops plants are usually grown in a community. Growth and development of sweet pepper or bell pepper (*Capsicum annuum*) plants are greatly influenced by the environmental factors (i.e. light, temperature, insects and pests etc.), variety used and various practices (i.e. fertilizer application, irrigation, weeding, pest management etc.). These factors have a great impact and effect on the growth, yield and yield component of sweet pepper. Sweet pepper is one of the important spices crop in many countries of the world. There are many pests of sweet pepper and among them fruit borers are considered as one of the most damaging one and has profound effect on sweet pepper production in Bangladesh. The concept of management of different insect pests including fruit borer employing eco-friendly materials gained momentum as mankind became more conscious about environment. Use of botanicals and chemicals are the recent approaches for fruit borer control that was commonly practiced. The research work so far done in Bangladesh and elsewhere on effectiveness of bio-pesticides against the fruit borer of *Capsicum* is not adequate and conclusive. A brief but exhaustive review of the related works done around the world in the recent past has been presented below under the following headings and sub-headings:

2.1 Fruit borer biology

2.1.1 Egg

Site and pattern of egg laying

In laboratory, it was observed that, the female moth of *H. armigera* laid eggs singly or in batches of 2 to 3 eggs. The eggs were glued on tender leaf lower surface and shoots of the chilli plant. Occasionally the eggs were also found on pot, piece of black colour muslin cloth and bottom of the cage. The egg laying was slow and low in number in the initial stage, but it increased gradually and slower down at the later part of the oviposition period (Patil *et al*., 2018).

Colour, shape and size

The freshly laid eggs were yellowish white in colour, which changed to deep yellow after a day and become dark brown prior to hatching. Eggs were hemispherical with flat base and prominently sculptured with numerous ridges running from one polar end to another. The result revealed that, length and breadth of freshly laid eggs measured from 0.42 to 0.56 mm and 0.44 to 0.57 mm with an average 0.49 ± 0.04 mm and 0.51 ± 0.04 mm, respectively (Patil *et al*., 2018).

Incubation period

It was clear from the data that the incubation period for eggs of *H. armigera* varied from 2 to 5 days with an average of 3.9 ± 0.74 days (Patil *et al*., 2018).

Hatching percentage

Out of 10484 eggs observed under laboratory conditions, 5577 eggs hatched with hatchability of 53.20% when reared on chilli (Patil *et al*., 2018).

2.1.2. Larva

In order to study the various larval instar of *H. armigera* in laboratory condition, newly hatched larvae were reared individually in plastic culture tube. The larvae passed through six distinct instars, when reared initially on chilli leaves and thereafter on fresh green fruits, till they pupated .

2.1.2.1 First instar

At the time of hatching, larva came out from the egg by making hole on chorion with the help of mouthparts. The body of freshly emerged larva was semi-translucent and dirty white in colour with whitish longitudinal lines on the dorsal surface of the body. Thoracic and anal shield were brown in colour. Whereas, thoracic legs were segmented with first two segments of light brown and tarsi were dark brown to black in colour. Zig-zag spotted line was present on dorsal side and black coloured spiny structure comes out from that spot. The newly emerged larva remained sluggish and became active after 2 to 3 hours on leaves. The neonate larva initially remained in egg shell and found to feed on chorion of the egg. Thereafter, in search of food, larva was found hanging on petridish with the help of thread like substance secreted from mouth. In the beginning, larva found to feed on tender leaves with its chewing and biting type of mouth parts. The change in instar was confirmed by presence of only head capsule on leaf surface. The exuviae of whole body did not observe in this instar during the study. It can be seen from the data that the length of first instar larva measured from 1.30 to 1.98 mm with an average 1.60 ± 0.22 mm and the breadth varied from 0.18 to 0.35 mm with an average 0.26 ± 0.05 mm. The head capsule was large in size which was dark brown to black in colour. The length and breadth of head capsule measured from 0.19 to 0.38 mm and 0.23 to 0.40 mm with an average 0.28 ± 0.32 mm and 0.07 ± 0.06 mm, respectively. The results summarized in indicated that the duration of first instar larva ranged from 2 to 4 days on chilli (2.88 ± 0.73 days) (Patil *et al.*, 2018).

2.1.2.2 Second instar

Second instar larva was morphologically resembled to the first instar larva. The larva was yellowish to light brown in colour. Thoracic legs were dark in colour as compared to abdominal legs. The larva was more active than previous instar. It was also observed that, larva of this instar preferred fresh and tender chilli fruit to feed. The larva measured from 3.36 to 5.54 mm with an average 4.57 ± 0.59 mm in length and 0.50 to 0.90 mm with an average 0.68 ± 0.13 mm in breadth. The head capsule was transparent having brown spot having. The measurement of head capsule is ranged from 0.42 to 0.55 mm (0.49 ± 0.05 mm) in length and 0.44 to 0.59 mm (0.52 ± 0.04 mm) in breadth during the investigation. The duration of second instar larva was ranged from 3 to 4 days (3.46 ± 0.51 days) .

2.1.2.3 Third instar

The third instar larva was similar to second instar in general appearance but differed in size. The colour of the body was yellowish to light brown, but it was darker than previous instar. A dorsal longitudinal line on either side was prominent in third instar. Moreover, a white coloured band was present on lateral side of the body. Prior to moulting, cuticle turn black in colour. The length of third instar larva measured from 7.30 to 11.28 mm (9.55 ± 1.32 mm), while that of the breadth from 0.78 to 1.78 mm (1.16 ± 0.26 mm). The head capsule was more compact and transparent with light brown spots. The data revealed that the length of head capsule of third instar larva measured from 0.61 to 0.75 mm (0.68 ± 0.05 mm), while that of the breadth from 0.62 to 0.83 mm (0.71 ± 0.07 mm). The duration required to complete third instar ranged between 3 to 5 days (3.91 ± 0.79 days) (Patil *et al*., 2018).

2.1.2.4 Fourth instar

Variation in colour was observed in fourth instar larva. It was of green, reddish brown, brown and greenish brown. Setae were also observed all over the body of fourth instar larva. Generally, the lateral strip on all the larvae were yellowish white, but dorsal strip was of variable in colours. The strips were either continues or broken. The length of fourth instar larva was ranged from 8.55 to 15.90 mm (11.98 ± 2.33 mm), while that of breadth ranged from 1.33 to 2.38 mm (1.83 ± 0.29 mm). The head capsule of fourth instar larva measured from 1.17 to 1.53 mm and 1.22 to 1.62 mm with an average of 1.36 ± 0.11 and 1.44 ± 0.12 mm, respectively. The duration of fifth instar larva ranged from 4 to 5 days (4.55 ± 0.51 days).

2.1.2.5 Fifth instar

The fifth instar larva was showed pinkish brown and pale green colour pattern with broken dorsal strips and continues lateral strips. The black spots were reduced in number. Dorsal strip of pinkish brown larvae was thick and black in colour, while in pale green colour larvae strip was thick and white in colour. The abdomen was turn in yellowish green and thoracic region remained dark green coloured, when larvae start moulting. The fifth instar larva was more active and aggressive as compare to previous stage but at the time of moulting larva was less active. The length and breadth of fifth instar larva was ranged from 15.92 to 19.87 mm (17.71 ± 1.27 mm) and 2.12 to 3.16 mm (2.70 ± 0.31 mm), respectively. Head capsule was transparent light orange in colour. The length and breadth of head capsule ranged from 1.77 to 2.14 mm with an average of 1.97 ± 0.13 mm and 1.84 to 2.38 mm with an average of 2.11 ± 0.16 mm, respectively. The duration of fifth instar larva ranged from 4 to 5 days with an average of 4.55 ± 0.51 mm (Patil *et al*., 2018).

2.1.2.6 Sixth instar

The sixth instar larva was flattened ventrally but convex dorsally. The body was pinkish brown and pale green in colour with two black longitudinal strips on dorsal side and scattered short hairy setae present all over the body. The characteristics of larva during moulting were similar to the previous instar. Legs were pinkish to light green in colour. The body length and breadth of sixth instar larva ranged from 20.11 to 30.60 mm (25.93 ± 3.70) and 3.19 to 4.32 mm (3.72 ± 0.37 mm) respectively. Head capsule of sixth instar larvae was similar in appearance as of fifth instar larvae, but differed in size. After moulting, mostly a head capsule was found in excreta. The length of head capsule varied from 1.86 to 3.44 mm (2.69 ± 0.51 mm), while breadth varied from 2.13 to 3.73 mm (2.96 ± 0.49 mm). The data of duration of sixth instar larva ranged from 4 to 6 days (4.71 ± 0.72 days) (Patil *et al*., 2018).

2.1.2.7 Total larval instar

The perusal of data revealed that, the total larval development period of *H. armigera* varied from 21 to 25 days (21.4 ± 1.71 days) on chilli plant (Patil *et al*., 2018).

2.1.3.1 Pre-pupa

After completion of larval development, final instar larva stopped feeding and change its colour from pinkish brown to light pinkish brown and pale green to light green yellowish with less prominent strips. These was the indication of larva undergoing pre-pupal stage. The full-grown larva wondering on the soil for pupation and pupated within the soil by making an cocoon. After preparing a cocoon, the larva contracted its body while the legs remained straight. During this period the larva did not exhibit any movement unless it was disturbed. Finally, larva shedding off cuticle and head capsule was attached with that inside the cocoon and goes into pupal stage. The length and breadth of pre-pupa was varied from 13.02 to 17.29 mm (15.44 ± 1.38 mm) (Patil *et al*., 2018).

The pre-pupal period found ranging from 1 to 2 days (1.48 ± 0.51 days) on chilli plant during the study (Patil *et al*., 2018).

2.1.3.2 Pupa

The newly formed pupa was transparent green to light green in colour and further, it become hard and changed into reddish brown colour with prominent black eye spot after few hours. The pupa was obtect type. It was smooth, cylindrical, long and tapering towards the posterior end with two parallel spines at the posterior tip. Abdomen was distinctly marked into ten segments and well defined dark brown spiracles were visible on fourth to ninth abdominal segments. Male and female pupae were differentiated at pupal stage based on morphometric characters. Male pupa carries genital aperture on ninth abdominal segment, whereas, in case of female, it was present on eight abdominal segments.

Movement of abdomen was observed when pupa was disturbed. The length of pupa measured from 10.98 to 13.42 mm (11.41 ± 1.03 mm), while that of breadth measured from 2.59 to 3.57 mm (3.21 ± 0.36 mm). The morphometric measurements of pupa were also taken to identify the sex of pupa. Accordingly, the distance between anal and genital pores of male pupa was recorded as 0.45 to 0.67 mm (0.56 ± 0.45 mm), while in female, it was 1.39 to 1.72 mm (1.55 ± 0.11 mm). Thus, it was observed that the distance between anal and genital pore was more in female than male. The data revealed that the pupal period varied from 11 to 15 days with an average of 12.67 ± 1.28 days (Patil *et al.,* 2018).

2.1.4 Adult

Immediately after emerging from the pupa, adult took a rest for some time to stretch and harden its wings and other body parts. Once the body acquired normal structure and hardened the wings, adult looking for the food. The compound eyes were dark brown in color and were located laterally on the head. It possessed a pair of antennae of setaceous type on the dorsal side of the head between the compound eyes. Siphoning type of mouthpart was coiled and rested beneath the head. The adults were of medium size with broad thorax possessing yellowish brown forewings and legs were long with dirty white scaly appearance. There was a distinguished colour pattern between male and female moths. Males were of greenish-grey in colour, whereas, females with orange brown and were also identified by the presence of tuft of hairs on the tip of abdomen. There was series of the dots on margin and black kidney shaped marked on underside of each forewing. The transparent membranous part of the forewings was covered with creamy coloured scale. Hind wings were lighter in colour and each possessed a dark coloured patch at the apical end. The length of adult male varied from 15.94 to 18.21 mm (16.94 ± 0.83 mm) and the breadth varied from 32.18 to 34.79 mm (33.12 ± 0.82 mm). Whereas, in case of female, the length varied from 17.90 to 22.83 mm (20.31 ± 1.62 mm) and the breadth varied from 30.16 to 36.68 mm (34.23 ± 1.83 mm) (Patil *et al*., 2018).

2.1.5 Pre-oviposition, oviposition and post-oviposition period

Pre-oviposition period of fruit borer varied from 2 to 4 days (2.86 ± 0.85 days). The oviposition period ranged from 7 to 9 days (8.14 ± 0.85 days). The post-oviposition period during the studies ranged from 1 to 2 days with an average of 1.52 ± 0.51 days (Patil *et al.*, 2018).

2.1.6 Fecundity

In laboratory, the egg laying capacity recorded during this study was varied from 742 to 1235 eggs (1048.40 ± 193.58 eggs) per female on chilli (Patil *et al.*, 2018).

2.1.7 Longevity of adult

The longevity of male ranged from 7 to 10 days (8.67 ± 1.06 days) while mated female lived for 9 to 13 days (10.90 ± 1.22 days) (Patil *et al.*, 2018).

2.1.8 Sex ratio

Based on morphological characters mentioned earlier, the adult was differentiated into their sexes. Out of 100 adults emerged from laboratory mass culture during period of study, 34 were males and 66 were females, which indicated the preponderance of female. The sex ratio of male to female was 1: 2.08 (Patil *et al.*, 2018).

2.1.9 Total life cycle

The total life span from eggs to the death of adult occupied by male was 40 to 59 days (48.43 ± 2.44 days) while, female occupied 47 to 57 days (51.72 ± 2.72 days). Thus, a total life period of male was shorter than female recorded during present investigation. (Patil *et al.*, 2018).

2.2 Fruit borer insect incidence and severity on bell pepper

Ghose *et al.* (2018) conducted field experiments during rabi season of 2015–16 and 2016–17 at Barasat II block, North 24 Parganas, West Bengal to study the seasonal occurrence of pest complex of bell pepper vis-à-vis the effect of weather parameters on their incidence. During the study, whitefly (*Bemisia tabaci* Genn), aphid (*Aphis gossypii* Glover), chilli mite (*Polyphagotarsonemus latus* Banks), thrips (*Scirthothrips dorsalis* Hood) and fruit borer (*Helicoverpa armigera* Hubner) appeared as principal pests of bell pepper. Fruit borers were active from first week of February to first week of April, showing peak population during first fortnight of March. Among the weather parameters, maximum and minimum temperature, wind speed, rainfall and sunshine hour had positive correlation with fruit borer population. Morning and evening humidity showed negative correlation with fruit borer population.

Kaur and Singh (2013), Kaur *et al.* (2010) and Sunitha (2007) from their individual research works reported that about 35 species of insect and mite pests infested *Capsicum*, of which thrips (*Scirtothrips dorsalis* Hood and *Thrips palmi* Karny), aphids (*Aphis gossypii* Glover and *Myzus persicae* Sulzer), whitefly (*Bemisia tabaci* Gennadius), capsule borers (*Helicoverpa armigera* Hubner and *Spodoptera litura* Fabr.) and yellow mite (*Polyphagotarsonemus latus* Banks) cause serious damage to C*apsicum annuum* (sweet pepper) in different regions of India.

Sarker *et al.* (2005) reported that thrips, *Scirtothrips dorsalis* Hood, yellow mite, *Polyphagotarsonemus latus* Banks and fruit borer, *Helicoverpa armigera* Hubner caused economic loss of chilli production every year especially in the southern districts of West Bengal, India and has become a threat to chilli growers.

Berke and Sheih (2000) recorded fruit borer (*Helicoverpa armigera* Hubner) as one of the major insect pests and cause for losses of chilli (*Capsicum annuum* L.) production in Asia.

2.3 Effect of different management practice on fruit borer

Shankar *et al.* (2018) conducted an experiment was to record the incidence and management of major insect pests of bell pepper (*Capsicum annuum*) at Chatha Farm, SKUAST- Jammu during 2016 wherein, var. Indira Hybrid was raised at a spacing of 60 cm × 30 cm in 5 m × 3 m plot size. The population of major insect pests were recorded at weekly intervals during morning hours and mean population were calculated and correlated with the weather factors accordingly. For monitoring the adults of borer insect pests viz., *Helicoverpa armigera* and *Spodoptera litura*, pheromone traps were installed. In order to evaluate the bio-efficacy of certain insecticides/acaricides, the crop (bell pepper) was raised categorized with 10 different treatments (including control) in RBD with three replications on bell pepper. The peak population of fruit borer (*Helicoverpa armigera*) population were recorded in 21st standard week (14.56 mean number of larvae per m² area). Maximum trap catches were recorded for *Helicoverpa* adult moths (125.33 moths per trap/week) and *Spodoptera* adults (40.76 moths per trap/week) during 20th standard week, respectively.

Sujay *et al.* (2015) conducted field experiments during 2011–12, at Agricultural Research Station, UAS, Dharwad, Karnataka, South India to know the efficacy of new molecules and botanicals against chilli pests. viz., green peach aphid (*Myzys persicae* Sulzer, *Aphis gossypi* Glover), thrips (*Scirtothrips dorsalis* Hood), yellow mite (*Polyphagotarsonemus latus* Banks) and fruit borer (*Helicoverpa armigera* Hubner). The results revealed that against *Helicoverpa armigera*, novaluron 10 EC @ 0.75 $ml \cdot l^{-1}$, emamectin benzoate 5 SG @ 0.4 $g \cdot L^{-1}$ and Spinosad 45 SC @ 0.3 $ml \cdot l^{-1}$ were found quite promising. Pooled data of 60, 90 and 120 DAT showed that significantly minimum number of fruit borer larvae per plant (0.29) was noticed in novuluron 10 EC sprayed plots, which was statistically on par with emamectin benzoate 5 SG (0.30) and spinosad 45 SC (0.32) sprays. But, during 2011–12, novuluron 10 EC spray recorded significantly lesser number of fruit borer larvae (0.27/plant). However, this was found to be on par with emamectin benzoate 5 SG and spinosad 45 SC. Pooled mean of four pickings indicated that novaluron 10 EC had recorded significantly less fruit damage (6.52%) and was found to be on par with emamectin benzoate 5 SG, spinosad 45 SC and profenophos 50 EC. The pesticides from biological origin and neem-based formulations might be relatively less harmful to the natural enemies than insecticide like imidacloprid and cypermethrin. The effect of botanicals on fruit damage was found to be superior to untreated check, but was inferior to new molecules. Significantly increased yield (4.65 $q \cdot ha^{-1}$) was recorded in diafenthiuron 50 WP @ 0.75 $g \cdot L^{-1}$ with higher net returns (Rs 22,661$\cdot ha^{-1}$).

Ghidiu *et al.* (2009) recorded that the European corn borer (ECB), *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae), is the most important pest of bell peppers in New Jersey and weekly applications of insecticide sprays are needed to control this pest. Most pepper production (up to 80%) utilizes black plastic mulch with drip irrigation and high wooden stakes, limiting pesticide application equipment. A new chemistry insecticide, chlorantraniliprole, which was highly soil systemic, very soluble, and effective against ECB at very low rates. Because of these properties, a 3-year study was undertaken beginning in 2004 and continuing in 2005 and 2007 applying chlorantraniliprole through a drip irrigation system in bell peppers for control of the ECB. Each year, on every harvest date examined, chlorantraniliprole injected through a drip irrigation system at either 0.05 or 0.07 $kg \cdot ha^{-1}$ was as effective, or more effective, in reducing percentage of ECB-infested peppers than a standard grower pesticide program of two applications of acephate followed by several applications of indoxycarb. All treatments resulted in significantly fewer ECB-infested peppers at harvest compared with untreated on all dates recorded each year.

Mallik (2008) carried out the study to determine the efficacy of botanicals and some selected synthetic pesticides on pest complex of chili (*Capsicum frutescens*). The experiment comprises of eight treatments and among them first five (T_1, T_2, T_3, T_4 & T_5) were the application of botanicals and two others (T_6 & T_7) were synthetic pesticides. The treatments were, T_1: Neem leaf extract @

20 g·L^{-1} at 3 days interval, T_2: Neem seed extract @ 20 g·L^{-1} at 3 days interval, T_3: Neem oil @ 15 ml·L^{-1} at 3 days interval, T_4: Biskatali leaf extract @ 20 g·L^{-1} at 3 days interval, T_5: Garlic clove extract @ 15 ml·L^{-1} at 3 days interval, T_6: Arozim @ 3 g·L^{-1} at 7 days interval, T_7: Thiolux @ 3 g·L^{-1} at 7 days interval, T_8: Untreated control. In total cropping season, the highest incidence (percentage) of fruit borer on fruits was 9.21% with the treatment T_8. On the other hand, the lowest incidence (percentage) of fruit borer on fruits was 3.88% in T_3. In the whole season, the highest infestation (percentage) on leaves was 3.78% with the treatment T_8 and the lowest infestation (percentage) on leaves was 0.88% with the treatment T_3. In case of fruits, the highest infestation (percentage) was 27.20% with the treatment T_8 and the lowest infestation (percentage) was 7.76% with the treatment T_3. Fruit infestation reduction over control in weight was the highest (59.06%) with treatment T_3, while the lowest (30.59%) reduction was in T_1. The highest weight of fruit yield was 30.22 ton·ha^{-1} with treatment T_3 and the lowest yield was 16.87 ton·ha^{-1} with treatment T_8. As a whole, among the different treatments, botanicals were more effective than the chemical pesticides.

Welty and Vitanza (2005) carried out a research trial to evaluate the efficacy of 10 insecticides for European corn borer (ECB), *Ostrinia nubilalis* (Hübner) control in bell peppers (*Capsicum annuum* L. ‘Socrates’). The ECB is the key insect pest of Ohio bell peppers. Chemical management of this pest is the most commonly used tactic by farmers. Orthene is the preferred insecticide against ECB, but its use is limited to a maximum of two applications per season. It is thus necessary to investigate materials that might offer an efficacy comparable to that of Orthene. This study was conducted in 2004, at the North Central Research Station of the Ohio State University, Fremont, Ohio. Insecticide performance against ECB was tested in an RCB design containing 11 treatments and four replications. Peppers were seeded in 200-cell trays in a greenhouse on 5 April and transplanted in the field on 4 June. Each plot was a single row of pepper plants 30 ft long with a guard row on each side. A tractor–drawn hydraulic boom sprayer pressurized by CO_2 with 2.50-gallon stainless steel canisters tanks was used to apply the insecticides at approximately 7-day intervals, starting when the second generation of ECB moths was detected by a blacklight trap, and ending when moth flight ceased. In some weeks, weather conditions delayed chemical applications. Actual dates of insecticide applications were: 12 Jul, 6, 13, 23, and 31 Aug, and 7 and 14 Sep. Dimilin was not included in the 23 Aug application because of logistics problems; instead, it was applied on 27 Aug. The applications were made at a speed of 3 mph, 55 psi, nozzle TJ-60 11003 VS, and a spray volume of 29.5 gpa. For disease management, Champ (24 fl oz product/acre) and Manex (51.2 fl oz product/acre) were applied uniformly on all treatments; including the untreated check on 18 and 30 Jun, 12 Jul, 13 Aug and Sep 10. Quadris (7 fl oz product/acre) was applied on 2 Sep. Wet, cold, and cloudy climatic conditions, especially during the first month of the growing season, delayed and reduced the growth of pepper crops throughout Ohio. All fully red fruit were harvested from a row length of 6.01 m (20 feet), from the centre of each plot, on 16 Sep and 1 Oct. Total fruit number and weight were recorded. Fruit too rotten to pick were not harvested. Each harvested fruit was inspected for damage on the outside, then cut open and examined for larval damage or presence. Data were subjected to ANOVA and means were separated using LSD ($P \leq 0.05$). Pest pressure was heavy as evident in low yield and high amount of damage in the untreated check. Orthene provided the best protection of red bell pepper fruits from ECB injury due to higher harvestable yield and lower percentage of fruit damaged, in both individual harvests and in cumulative harvest data. Orthene was not significantly different than Mustang Max in either variable for any harvest. Avaunt and Intrepid were not significantly different than Orthene for some but not all variables and harvests. Assail, Calypso, Dimilin, SpinTor, Rimon, and Proclaim at the rates tested did not offer a significantly better protection from ECB fruit damage than the untreated checks based on both yield and infestation variables in the cumulative harvest. The untreated check, Assail, and Calypso treatments obtained the lowest cumulative yields.

Kuhar and Speese (2002) conducted an experiment to evaluate foliar insecticides for controlling of European corn borer in peppers (*Capsicum annuum* L. 'Paladin'). Peppers were transplanted on 11 Jun at the Eastern Shore Agricultural Research and Extension Centre near Painter, VA. Each plot consisted of two 20 ft rows that were spaced 3 ft apart. Plots were flanked on either side by an untreated guard row. The experiment had 10 treatments plus an untreated control arranged in an RCB design replicated five times. Treatments were applied using a propane-pressurized sprayer that delivered 30 gpa at 40 psi through a boom with one hollow-cone nozzle oriented over the centre of the row and two hollow-cone drop nozzles oriented to the sides of the row. The first application was made on 16 Jul, when small (0.5–1.0 inch in diameter) fruit were present, and subsequent applications were made on 23 and 30 Jul; 6, 15, and 27 Aug; 4,10, and 17 Sep. To evaluate efficacy, all market-sized fruit (> 2 inch) were harvested from the right-side row of each plot on 21 Aug and 24 Sep. Each fruit was inspected and numbers of ECB damaged and marketable fruit, and the mass of marketable fruit were recorded for each plot. ECB pressure was moderate to heavy throughout the season, with peak moth flights occurring in mid-August. At first harvest (21 Aug), all insecticide treatments had significantly less worm-damaged fruit and produced more marketable fruit than the untreated control. SpinTor 2 SC full season produced significantly more marketable fruit than the other treatments, with the exception of Avaunt, Orthene 97 full season, and Orthene for the first two sprays followed by SpinTor. All treatments except the V1010 2.25 EC and Confirm 2 F produced significantly greater yields of marketable fruit than the untreated control. At second harvest (24 Sep), all treatments again had significantly higher yields and less percent damage than the untreated control. The highest yields and lowest percent damage were found in the Orthene full-season treatment, Treatments 2 (SpinTor full season), 3 (Orthene + Spintor), 5 (V1010), 6 (Avaunt) and 9 (Intrepid) had high yields that did not differ significantly from each other. The low rate of Intrepid and the Confirm treatment had a significantly higher percentage of damaged fruit than most of the other treatments. All treatments had significantly higher season total yields than the untreated control, with the highest yields in treatments 1, 2, 3, 6, and 9.

Kumar *et al*. (2001) conducted a field experiment to evaluate the bio-efficacy of triazophos (350 or 700 $g \cdot ha^{-1}$), acephate (1000 or 1500 $g \cdot ha^{-1}$), cypermethrin (150 and 300 $g \cdot ha^{-1}$) and imidacloprid (50 $g \cdot ha^{-1}$ or 70 $g \cdot ha^{-1}$) against the major pest complex (aphids, *Myzus persicae*, thrips, *Scirtothrips dorsalis*, gram pod borer, *Helicoverpa armigera*, tobacco caterpillar, *Spodoptera litura*, and sun hemp hairy caterpillar, *Utetheisa pulchella*) of chili (*Capsicum* spp.). Cypermethrin (300 $g \cdot ha^{-1}$) was generally the most effective insecticides against pod borers.

Mallapur *et al*. (2001) conducted an experiment to evaluate the efficacy of the premix, Match (difenzoquat) + profenofos (at 1 and 1.5 $litre \cdot ha^{-1}$), against chili (*Capsicum annuum*) cv. Dyavanur Deluxe fruit borer, *Helicoverpa armigera*. The treatment efficacy was compared with profenofos at 1.5 $litre \cdot ha^{-1}$, the standard control (cypermethrin at 0.5 $ml \cdot litre^{-1}$) and the recommended package (carbaryl at 3.0 $g \cdot litre^{-1}$). Two sprays were supplied at an interval of 20 days after appearance of pod borers. The highest larval mortality was observed in plots treated with cypermethrin, followed by Match + profenofos. Fruits whitening was also low in cypermethrin treated plots followed by the premix. The highest yield was obtained by cypermethrin followed by the premix at 1.5 $litre \cdot ha^{-1}$.

Nelson and Natarajan (1994) carried out an experiment to evaluate the efficacy of moult inhibitors and NVP on chilli fruit borer. During a field trial, the moult inhibitor diflubenzuron and a nuclear polyhedrosis virus reduced damage by fruit borers on chilies. In plots treated with diflubenzuron, Larval/pupal intermediaries were observed. A regression equation was obtained to relate damage score to yield loss. Yield losses of up to 50% were observed due to fruit borer damage. Even at the lowest population density observed (2 larva/plant), spraying with dimethoate is recommended to reduce yield losses.

Frank *et al*. (1992) carried out an experiment to determine effects of weed-interference periods and insects on *Capsicum annuum* cv. Yolo Wonder. Weed interference for approx. 40 and 60 days reduced both fruit number and weight by 10% and 50%, respectively. *C. annuum* foliage weight was reduced by 10% and 50% with approx. 20-days and 50-days weed-interference periods, respectively. In 1985 and 1986, insect populations were low, with an average of 10% and 3% of the fruit infested, respectively. Most infested fruit was damaged by European corn borer (*Ostrinia nubilalis*). No differences in insect infestation of fruit as related to time of weed interference periods were noted.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis. The details of experimental materials and methods are described below:

3.1 Experimental period

The experiment was conducted at the central farm, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from October, 2019 to February, 2020.

3.2 Geographical location

The experimental area was situated at 23°77′N latitude and 90˚33′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.3 Agro-Ecological Region

The experimental site belongs to the agro-ecological zone of "Modhupur Tract", AEZ-28 (Anon, 1988a). 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 (Anon, 1988b). The experimental site is shown in the map of AEZ of Bangladesh in Appendix I.

3.4 Climate of the experimental site

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al*., 1979). During the experimental period the maximum temperature (36.8^0C), highest relative humidity (87%) and highest rainfall (273 mm) was recorded for the month of October, 2019 whereas, the minimum temperature (14.60°C), minimum relative humidity (64%) and no rainfall was recorded for the month of January, 2020. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during study period has been presented in Appendix II.

3.5 Soil

Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood levels. The soli data during the study period at the experimental site are shown in Appendix III.

3.6 Experimental treatments

The experiment consisted of single factor. The treatments were as follows:

Table1: Treatments with doses:

Sl. No.	Treatments with doses (applied 10 5 times at 10 days of interval)
T_1	Azadirachtin (Bioneem plus 1 EC) @3 ml/L.
T_2	Spinosad (Success 2.5 SC) @.2ml/L
T_3	*Bacillus thuringiensis* (Bt spray)@1ml/L
T_4	Abamectin (Border plus 1.8 EC)@1ml/L
T_5	Untreated Control (No pesticide use).

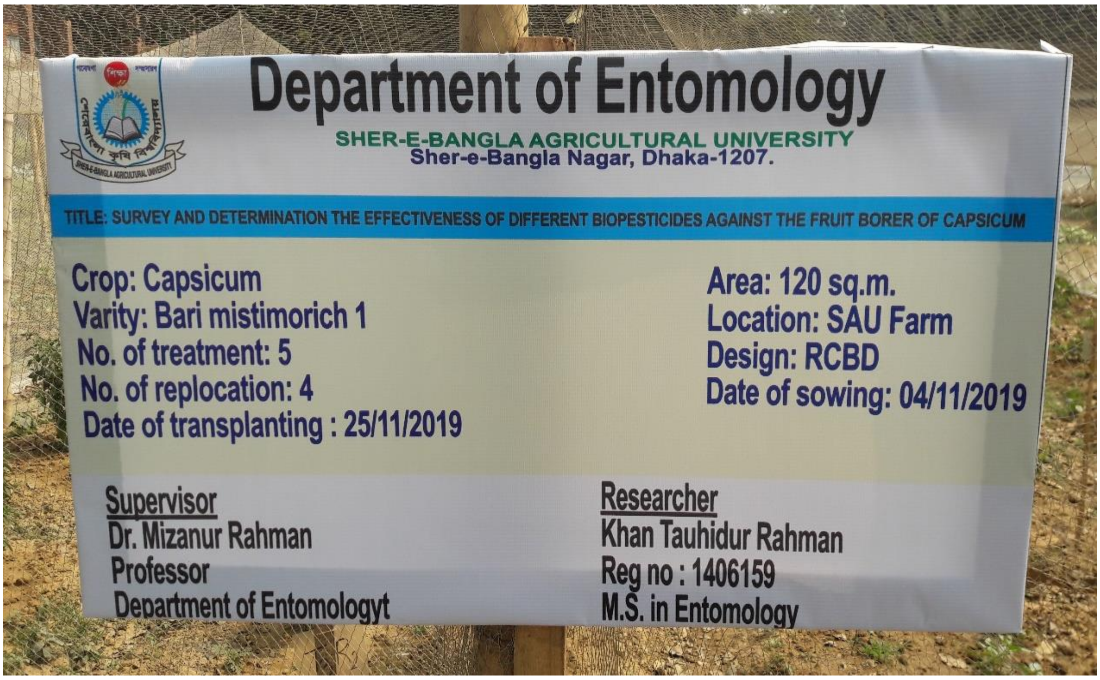

Plate 1. Experimental site

3.7 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four (4) replications. Total 5 unit-pots was made for the experiment with 20 treatments. The size of each unit plot was 4.0 m × 1.5m.

3.8 Planting material

BARI Misti Morich-1 was used in this study.

3.9 Source of Seed

Seeds of the afore-mentioned capsicum variety were collected from Bangladesh Agricultural Research Institute (BARI).

3.10 Collection of bio-pesticides

These were collected from Bangladesh Jute Research Institute, Sher-e-Bangla Nagar, Dhaka. All bio-pesticides were dissolved by 3 ml in 1 liter of water and applied in the main field at 7 days interval.

3.11 Raising of seedlings in seedbed.

The 30 days old capsicum seedlings were raised at the seedbed of Sher-e-Bangla Agricultural University field , Dhaka and transplanted in the main field.

Plate 2. Raising of seedling in seedbed.

3.12 Land preparation

The selected experimental plot was first opened by a power tiller in the month of October, 2019, one month before planting. Several ploughing and cross ploughing with power tiller followed by laddering were done until the desired tilth was achieved for planting the seedlings. The corners of the plots were trimmed by spade. The clods were broken into friable soil and the surface of the soil was leveled. During land preparation, weeds and stubbles of the previous crops were collected and removed from the field. Irrigation and drainage channels were prepared around the plots.

3.13 Manure and fertilizer application

Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum, Boric acid and Zinc sulphate were used as the fertilizer source of the nutrient elements N, P, K, S, B and Zn respectively. The following doses of manure and fertilizer were used for the present study:

Fertilizer	Doses ha^{-1}	Sources
Vermicompost	5.00 t	Nature
Urea	250 kg	$CO(NH_2)_2$
TSP	350 kg	$Ca(H_2PO_4)_2$
MoP	250 kg	KCl
Gypsum	110 kg	$CaSO_4.H_2O$
Boric acid	15 kg	H_3BO_3
Zinc sulphate	5 kg	$ZnSO_4.H_2O$

The total amount of TSP, MoP, Gypsum, Boric acid and Zinc sulphate were applied at the final land preparation as per treatment. Total urea was applied in three installments. The 1st instalments were applied at final land preparation, 2nd installments were applied 25 days after transplanting as top dressing and 3rd installments were applied 45 days after transplanting as top dressing. The fertilizer was thoroughly mixed with the soil.

3.14 Intercultural operations

3.14.1 Weeding

Weeding was necessary to keep the plant free from weeds. The newly emerged weeds were uprooted carefully from the field after complete emergence of sprouts and afterwards when necessary.

3.14.2 Irrigation

Just after full emergence the crop was irrigated by flooding at 15 days after transplanting (DAT) so that uniform growth and development of the crop was occurred and also moisture status of soil retain as per requirement of plants. The second, third and fourth irrigation were done at 25, 45 and 65 DAT, respectively.

3.14.3 Earthing up

Earthing up process was done at two times, during crop growing period. First was done at 35 DAT and second was at 50 DAT.

3.14.4 Harvesting of *Capsicum*

Harvesting of capsicum was done on February to March, 2020. The capsicum of each plot was separately harvested, bagged and tagged and brought to the laboratory. Harvesting was done manually by hand.

Plate 3. Harvesting of capsicum

3.15 Recording of data

The following data were recorded during experimentation period:

1. No. of pest species plant^{-1};
2. No. of health plant plot^{-1};
3. No. of infested plant plot^{-1};
4. Percent (%) of fruit borer plant^{-1};
5. No. of total fruits plant^{-1};
6. No. of healthy fruits plant^{-1};
7. No. of infested fruits plant^{-1};

8. Percent (%) infestation (by number);
9. Reduction over control (%);
10. Weight of total fruits plant^{-1};
11. Weight of health fruits plant^{-1};
12. Weight of infested fruits plant^{-1};
13. Percent (%) infestation (by weight);
14. Reduction over control (%);
15. Yield (kg plot^{-1});
16. Yield (t ha^{-1}) and
17. Increase over control (%).

Plate 4. Fruit borer infestation

3.16 Experimental data measurements

A brief outline of the data recording procedure followed during the study is given below:

3.16.1 Infestation with pest complex

Total number of healthy and infested leaves and fruits from 10 selected plants from each plot were recorded at different stages. Infestation was recorded at each observation were pooled and finally expressed in percentage.

The percentage of damages was calculated using the following formula:

$$\% \text{ fruit infestation (by number)} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

$$\% \text{ fruit infestation (by weight)} = \frac{\text{Weight of infested fruits}}{\text{Total weight of fruits}} \times 100$$

Increase or reduction over control was calculated using the following formula:

$$\% \text{ increase over control} = \frac{\text{Value in treated plot - Value in control plot}}{\text{value in control plot}} \times 100$$

$$\% \text{ reduction over control} = \frac{\text{Value in control plot - Value in treated plot}}{\text{value in control plot}} \times 100$$

3.16.2 Yield plot^{-1}

The data on the weight of healthy and infested fruits for each treatment from whole plot along with their number and weight were recorded.

3.16.3 Yield hectare^{-1}

The weight of fruits for each treatment from whole plot weight was recorded at each harvest. The plot yield was transformed into fruit yields in ton per hectare.

3.17 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package programme. The significant differences among the treatment means were compared by Least Significant Different (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULT AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to asses the effectiveness of bio-pesticides against the fruit borer of capsicum that caused damage of fruits. The results of infestation of capsicum fruits by the pest complex (by number and by weight) and yield under the study have been presented, discussed and possible interpretations also given below with the following headings:

4.1 Number of healthy plant plot^{-1}

Application of bio-pesticides for the management of different insects on plants of capsicum under the present trial showed a statistically significant difference in number of healthy plants plot^{-1} (Table 2). The highest number of healthy plants plot^{-1} (6.00) was recorded from the treatment T_2 (Spinosad (Success 2.5 SC)). On the other hand, the lowest number (2.30) of healthy plants was recorded from T_5 (untreated control). Similarly, from treatment T_1, T_3 and T_4, healthy plants were recorded in intermediate level for these as compare with untreated control (3.33, 5.20 and 4.67, respectively)

Table 2. Effect of bio-pesticides on the incidence of number of healthy plant plot^{-1} and number of infested plant plot^{-1} in capsicum

Treatments	Number of healthy plants plot^{-1}	Number of infested plants plot^{-1}
T_1	3.33 c	6.67 b
T_2	6.00 a	4.00 d
T_3	5.20 b	4.80 c
T_4	4.67 b	5.33 c
T_5	2.30 d	7.70 a
LSD $_{(0.05)}$	0.63	1.30
CV (%)	4.31	3.91

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment. In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

[**Treatments**T_1 = Azadirachtin (Bioneem plus 1 EC), T_2 = Spinosad (Success 2.5 SC), T_3 = *Bacillus thuringiensis* (BT spray), T_4 = Abamectin (Border plus 1.8 EC) and T_5 = Untreated Control (No pesticide use).]

4.2 Number of infested plant plot^{-1}

Statistically significant variation by number of infested plants plot^{-1} presented in Table 2 and Appendix V. The lowest number of infested plants (4.00) were recorded from the treatment T_2 (Spinosad (Success 2.5 SC)) which was statistically similar with the treatment T_3 (*Bacillus thuringiensis* (BT spray)) and T_4 (Abamectin (Border plus 1.8 EC)). On the other hand, the highest number (7.70) of infested plants were recorded from T_5 (untreated control).

4.3 Percent (%) fruit borer plant^{-1}

Presence of fruit borer in percentage on fruits was found Significant with the application of bio-pesticides against pest complex of capsicum among the treatments during the experiment (Figure 1). It was observed that presence of the highest percentage of fruit borer (7.55 %) on fruits was in the treatment of T_5 (untreated control). Presence of higher percentage of fruit borer was also shown in T_1 (Azadirachtin (Bioneem plus 1 EC)) and T_4 (Abamectin (Border plus 1.8 EC)) ranged from 5.36 % - 5.69 % but significantly different from T_5 treatment. On the other hand, the lowest percent of fruit borer (3.88 %) was in treatment T_2 (Spinosad (Success 2.5 SC)) and T_3 (*Bacillus thuringiensis* (BT spray)) showed lower percentage of fruit borer 4.14 % but significantly different from T_2 treatment.

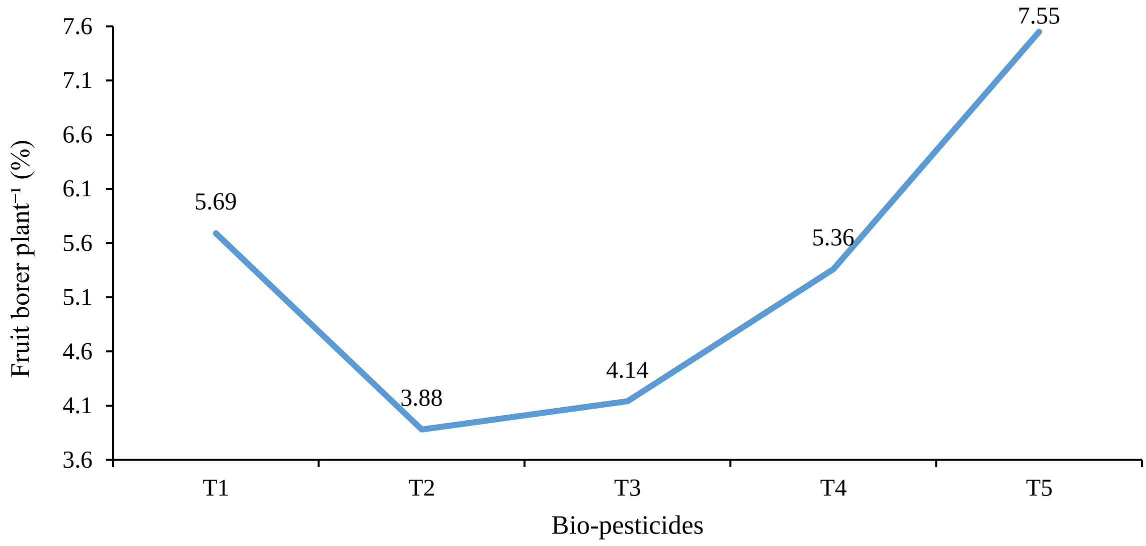

Figure 1. Effect of bio-pesticides on the incidence of fruit borer plant^{-1} (%) in capsicum (LSD $_{0.05}$ = 0.78)

[Treatments: T_1 = Azadirachtin (Bioneem plus 1 EC), T_2 = Spinosad (Success 2.5 SC), T_3 = *Bacillus thuringiensis* (BT spray), T_4 = Abamectin (Border plus 1.8 EC) and T_5 = Untreated Control (No pesticide use).]

Simkin *et. al.* (2003) evaluated the variation of yield effectiveness at different growth stages and fruiting stages on the attack of insect and pests respectively. They observed that attack of pest on growth stages was more harmful for effective yield. They also observed that population number was decreased remarkably where the pest attack of growth stage was more than the attack of fruiting stage of plant.

4.4Effect of treatments on fruits against fruit borer of capsicum

4.4.1 Number of fruits plant^{-1}

The application of different bio-pesticides against fruit borer on fruits of capsicum showed statistically significant variation in number of total fruits plant^{-1} (Table 3). The highest number of fruits (13.20) was recorded from T_2

(Spinosad (Success 2.5 SC)) whereas, the lowest (8.60) was recorded from the treatment T_5 (untreated control). T_1 (Azadirachtin (Bioneem plus 1 EC)) and T_4 (Abamectin (Border plus 1.8 EC)) also gave lower result but not similar with T_5 treatment. From treatment T_3 (*Bacillus thuringiensis* (BT spray)), number of total fruits was recorded in intermediate level for these as compare with untreated control treatment.

Table 3. Effect of bio-pesticides against capsicum fruit borer by number per plant in total cropping season

Treatments	Number of total fruits	Number of healthy fruits	Number of infested fruits	Percent infestation (%)	Reduction over control (%)
T_1	9.60 d	6.03 d	3.57 b	37.19 b	19.44 c
T_2	13.20 a	10.11 a	3.09 d	23.41 d	49.29 a
T_3	12.60 b	8.97 b	3.63 b	28.81 c	37.59 b
T_4	10.80 c	7.43 c	3.27 c	30.28 c	34.41 b
T_5	8.60 e	4.63 e	3.97 a	46.16 a	0
$LSD_{(0.05)}$	**0.34**	**0.51**	**0.17**	**5.3**	**7.89**
CV (%)	**6.36**	**5.33**	**7.99**	**8.56**	**6.78**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment. In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

[**Treatments :** T_1 = Azadirachtin (Bioneem plus 1 EC), T_2 = Spinosad (Success 2.5 SC), T_3 = *Bacillus thuringiensis* (BT spray), T_4 = Abamectin (Border plus 1.8 EC) and T_5 = Untreated Control (No pesticide use).]

4.4.2 Number of healthy fruits plant^{-1}

Significant variation was observed for number of healthy fruits plant^{-1} with the application of different bio-insecticides against pest complex of capsicum (Table 3). The highest number of healthy fruits (10.11) was observed in the treatment T_2 (Spinosad (Success 2.5 SC)). On the other hand, the lowest number of healthy fruits (3.13) was observed in T_5 (untreated control).

4.4.3 Number of infested fruit plant^{-1}

Significant variation was observed for number of infested fruits plant^{-1} with the application of different bio-pesticides against pest complex of capsicum (Table 3). The highest number of infested fruits (5.47) was observed from the treatment T_5 (untreated control) and the lowest number of infested fruits (3.09) was observed from the treatment T_2 (Spinosad (Success 2.5 SC)). It was also observed that T_4 treatment showed lower infestation but significantly different from T_2 treatment. T_1 and T_3 treatment gave higher infestation but significantly different from T_5 treatment.

4.4.4 Percent (%) of fruit infestation

The application of bio-pesticides against pest complex of capsicum showed statistically significant variation for the percent (%) infestation of fruits with fruit borer (Table 3). It was observed that the highest percentage of fruit infestation (46.16 %) was observed in the treatment T_5 (untreated control) and the lowest percentage of infestation (23.41 %) was observed in the treatment T_2 (Spinosad (Success 2.5 SC)). It was also observed that T_3 *Bacillus thuringiensis* (BT spray) and T_4 Abamectin (Border plus 1.8 EC) showed lower percent infestation but significantly different from T_2 treatment. The results from the treatments T_1, T_2 and T_4 treatment were ranged from 32.78 % to 47.60 %. Among the different treatments, application of Spinosad (Success 2.5 SC) was considered as best against percent infestation of fruit with fruit borer.

4.4.5 Infestation Reduction over control

Reduction over control was significantly different among the treatments with the application of different bio-pesticides against pest complex of capsicum (Table 3). It was observed that the highest percentage of reduction over control (49.29%) was observed in the treatment T_2 (Spinosad (Success 2.5 SC)) and the lowest percentage of reduction over control (19.44 %) was observed in the treatment T_1 Azadirachtin (Bioneem plus 1 EC). It was also observed that T_3

Bacillus thuringiensis (BT spray) and T_4 Abamectin (Border plus 1.8 EC) showed higher percentage of reduction over control but significantly different from T_2 treatment. From the findings it is revealed that treatment T_2 performed maximum healthy fruit and minimum infested fruit as well as lowest % of fruit infestation in number whereas in control treatment the situation was reversed. Kulat *et al.* (2001) and Prabal *et al.* (2000) reported from their experiment on extracts of some indigenous plant materials, which are claimed important as pest control like seed kernels of neem. Weekly spray application of the extract of neem seed kernel has been found to be effective against borer (Karim, 1994).

4.5 Effect of treatments on yield against fruit borer of capsicum

4.5.1 Weight of total fruits plant^{-1} (g)

Significant variation was observed in case of total fruit weight plant^{-1} (g) with the application of different bio-pesticides against fruit borer of capsicum during the experiment (Table 4). The highest total fruit weight plant^{-1} (1144.84 g) was obtained from T_2 (Spinosad (Success 2.5 SC)). On the other hand, the lowest value total fruit weight plant^{-1} (605.18 g) was obtained from T_5 (untreated control) treatment. Treatment T_3 (*Bacillus thuringiensis* (BT spray)) and T_4 (Abamectin (Border plus 1.8 EC)) showed higher value of total fruit weight plant^{-1} and ranged from 1023.75 g – 836.57 g but significantly different from T_2 treatment. Treatment T_1 Azadirachtin (Bioneem plus 1 EC) showed lower value (751.86 g) of total fruit weight plant^{-1} compared to the highest value of total fruit weight.

Table 4. Effect of bio-pesticides against capsicum fruit borer by weight per plant in total cropping season

Treatments	Weight of total fruits (g)	Weight of healthy fruits (g)	Weight of infested fruits (g)	Percent infestation (%)	Reduction over control (%)
T_1	751.86 d	467.75 c	284.11 b	37.79 b	19.74 c
T_2	1144.84 a	876.84 a	268.00 c	23.41 d	50.28 a
T_3	1023.75 b	688.19 b	335.56 a	32.78 c	30.38 b
T_4	836.57 c	552.29 c	284.28 b	33.98 b	27.82 b
T_5	605.18 e	320.26 d	284.92 b	47.08 a	0
LSD $_{(0.05)}$	**75.72**	**101.77**	**17.37**	**4.37**	**7.91**
CV (%)	**7.73**	**8.11**	**5.21**	**9.85**	**7.57**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment. In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

[Treatments: T_1 = Azadirachtin (Bioneem plus 1 EC), T_2 = Spinosad (Success 2.5 SC), T_3 = *Bacillus thuringiensis* (BT spray), T_4 = Abamectin (Border plus 1.8 EC) and T_5 = Untreated Control (No pesticide use).]

4.5.2 Weight of healthy fruits plant^{-1} (g)

Weight of healthy fruits plant^{-1} (g) obtained from the different treatment with the application of different bio-pesticides against fruit borer of capsicum during the experiment (Table 4 and Appendix VII) were significantly different. The highest value of healthy fruit weight plant^{-1} (876.84 g) was obtained from T_2 (Spinosad (Success 2.5 SC)). On the other hand, the lowest value of healthy fruit weight plant^{-1} (320.26 g) was obtained from T_5 (untreated control) treatment. Treatments T_3 (*Bacillus thuringiensis* (BT spray)) and T_4 (Abamectin (Border plus 1.8 EC)) showed higher value of healthy fruits weight and ranged from 688.19 g–552.29 g but significantly different from T_2 treatment. Treatment T_1

Azadirachtin (Bioneem plus 1 EC) showed lower value (467.75 g) of healthy fruit weight plant^{-1} compared to highest value of healthy fruit weight.

4.5.3 Weight of infested fruit plant^{-1} (g)

Weight of infested fruit plant^{-1} (g) obtained from the different treatments with the application of different bio-pesticides against fruit borer of capsicum during the experiment (Table 4) were significantly different. The highest value of infested fruits weight plant^{-1} (284.92 g) was obtained from T_5 (untreated control) treatment and the treatments, T_1 (Azadirachtin (Bioneem plus 1 EC)) and T_3 (*Bacillus thuringiensis* (BT spray)) showed higher value of infested fruit weight plant^{-1} but significantly different from T_5 treatment. On the other hand, the lowest value of infested fruits weight plant^{-1} (268.00 g) was obtained from T_2 (Spinosad (Success 2.5 SC)) which was significantly identical (284.28 g) with T_4 (Abamectin (Border plus 1.8 EC)) showed lower infested fruit weight compared to the lowest infested fruit weight.

4.5.4 Percent infestation of fruits (%)

Percent infestation in fruits of capsicum obtained from the different treatment with the application of bio-pesticides against fruit borer of capsicum during the experiment (Table 4) was significantly different. The highest value of percent infestation (47.08 %) was observed from T_5 (untreated control) treatment and the treatments, T1 (Azadirachtin (Bioneem plus 1 EC)) showed higher percent (37.79 %) of infested fruit weight but significantly different from T_5 treatment. On the other hand, the lowest percent of infested fruits weight (23.41 %) was obtained from T_2 (Spinosad (Success 2.5 SC)) and T_3 (*Bacillus thuringiensis* (BT spray)) and T_4 (Abamectin (Border plus 1.8 EC)) showed lower percent of infested fruit weight (32.78 % and 33.98 %, respectively) compared to the lowest percent of infested fruit weight.

4.5.5 Percent Reduction over control (%)

The results obtained from the different treatments, the significant variation was observed in terms of reduction over control (Table 4). The highest percent (50.28%) and lowest (19.74%) reduction over control was shown in treatment T_2 (Spinosad (Success 2.5 SC)) and T_1 (Azadirachtin (Bioneem plus 1 EC)), respectively. T_3 (*Bacillus thuringiensis* (BT spray)) and T_4 (Abamectin (Border plus 1.8 EC)) showed intermediate result of reduction over control compared to the highest and lowest value.

4.6 Single fruit weight (g)

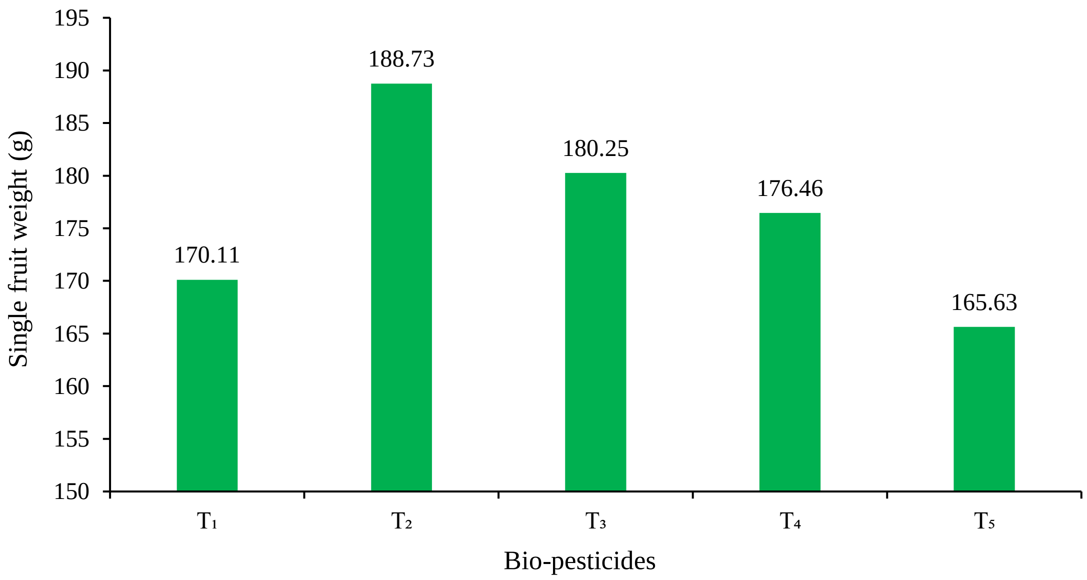

Figure 2. Effect of bio-pesticides on the incidence of single fruit weight (g) in capsicum ($LSD_{0.05}$ = 2.47)

[**Treatments:** T_1 = Azadirachtin (Bioneem plus 1 EC), T_2 = Spinosad (Success 2.5 SC), T_3 = *Bacillus thuringiensis* (BT spray), T_4 = Abamectin (Border plus 1.8 EC) and T_5 = Untreated Control (No pesticide use).]

Significant variation was observed in case of single fruit weight (g) with the application of different bio-pesticides against fruit borer of capsicum during the experiment (Figure 2). The maximum single fruit weight (188.73 g) was obtained from T_2 (Spinosad (Success 2.5 SC)). On the other hand, the minimum single fruit weight (165.63 g) was obtained from T_5 (untreated control) treatment which was statistically identical (170.11 g) with T_1 Azadirachtin (Bioneem plus 1 EC).

Treatment T_3 (*Bacillus thuringiensis* (BT spray)) and T_4 (Abamectin (Border plus 1.8 EC)) showed intermediate results of single fruit weight and ranged from 180.25 g–176.46 g.

4.7 Yield performance

4.7.1 Yield (kg plot^{-1})

Significant variation was recorded for plot yield of capsicum for the application of different bio-pesticides on yield of capsicum during total cropping season against fruit borer of capsicum (Figure 3 and Appendix VIII). The highest yield (30.72 kg) of fruit was obtained from T_2 (Spinosad (Success 2.5 SC)) which was closely (27.71 kg) followed by T_3 (*Bacillus thuringiensis* (BT spray)). On the other hand, the lowest yield of fruit (18.16 kg) was recorded from T_5 (untreated control) which was closely 16.56 kg) followed by T_1 Azadirachtin (Bioneem plus 1 EC). Among the different treatments, application of Spinosad (Success 2.5 SC) was considered as best fruit yield (kg plot^{-1}) against fruit borer of capsicum.

4.7.2 Yield (t ha^{-1})

Yield per hectare varied statistically for the application of different bio-pesticides on yield of capsicum during total cropping season against fruit borer of capsicum (Figure 3). The maximum fruit yield (27.26 t ha^{-1}) was recorded from the treatment T_2 (Spinosad (Success 2.5 SC)). On the other hand, the minimum yield (14.41 t ha^{-1}) of fruit was recorded from T_5 (untreated control) treatment and was closely (16.71 t ha^{-1}) followed by T_1 Azadirachtin (Bioneem plus 1 EC). Treatment T_3 (*Bacillus thuringiensis* (BT spray)) showed higher weight of fruit yield (24.37 t ha^{-1}) but significantly different from T_2 treatment. Among different treatments, application of Spinosad (Success 2.5 SC) was considered as best fruit yield (t ha^{-1}) against fruit borer of capsicum.

4.7.3 Percent (%) Increase over control

Increase over control with the application of different bio-pesticides (Figure 3) varied statistically and the highest value (89.17%) was estimated from the treatment T_2 (Spinosad (Success 2.5 SC)), while the lowest value was (15.97 %) from the treatment T_1 Azadirachtin (Bioneem plus 1 EC) on yield of capsicum during total cropping season against fruit borer of capsicum. T_3 (*Bacillus thuringiensis* (BT spray)) and T_4 (Abamectin (Border plus 1.8 EC)) showed intermediate (69.16 % and 38.23 %, respectively) result of increase over control compared to the highest and lowest value.

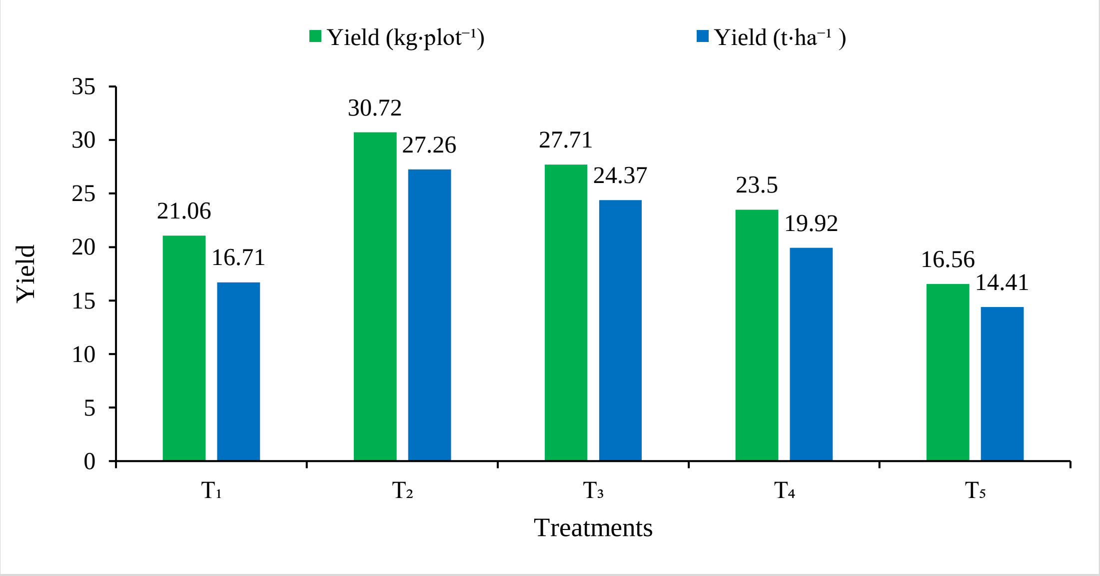

Figure 3. Effect of bio-pesticides on yield of capsicum during total cropping season ($LSD_{0.05}$ = 2.09 and 1.91, respectively)

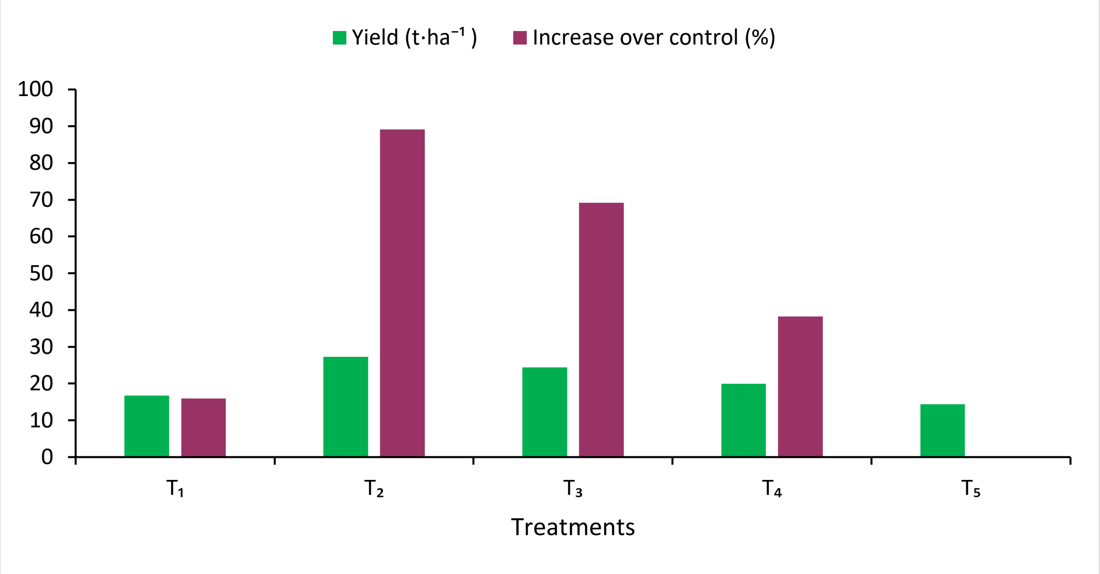

Figure 4. Effect of bio-pesticides on yield of capsicum and increase over control during total cropping season (LSD0.05 = 1.91 and 17.52, respectively)

[**Treatments:** T_1 = Azadirachtin (Bioneem plus 1 EC), T_2 = Spinosad (Success 2.5 SC), T_3 = *Bacillus thuringiensis* (BT spray), T_4 = Abamectin (Border plus 1.8 EC) and T_5 = Untreated Control (No pesticide use).]

Similar finding was obtained by Materska *et. al.* (2006) and they stated that among the different chemicals (imidacloprid, chlorfenapyr, abamectin, cyfluthrin and methiocarb) and plant extract; neem oil (Azadirachtin), karanja oil (*Pongamia glubra*), Mahua oil (*Madhuca lalifolia*) for pipper yield, neem oil was the best protector compared to other botanicals and chemicals in respect of biological yield.

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summery

The study was carried out in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2019 to February, 2020 to assessment the effectiveness of bio-pesticides against the fruit borer of *capsicum*. BARI Misti Morich-1 was used in this study. The experiment comprised with five treatments and the treatments were: T_1=Azadirachtin (Bioneem plus 1 EC), T_2=Spinosad (Success 2.5 SC), T_3=*Bacillus thuringiensis* (BT spray), T_4=Abamectin (Border plus 1.8 EC) and T_5=Control (No pesticide use). The experiment was laid out at Randomized Complete Block Design (RCBD) with three replications. Data were recorded on healthy and infested leaves and fruits at different stage and yield of *Capsicum annum* (sweet pepper).

During the experiment, plants, fruits, yield and yield contributing characters of sweet pepper were significantly influenced by the application of different bio-pesticides on fruit borer of *capsicum*. It was observed that the highest number of healthy plants plot^{-1} (6.00), the lowest number of infested plants plot^{-1} (4.00) and the lowest percent infestation (23.41%) were observed from T_2 treatment [Spinosad (Success 2.5 SC)]. On the other hand, the lowest number of healthy plants plot^{-1} (2.30), the highest number of infested plants plot^{-1} (7.70) and the highest percent infestation (47.08%) were recorded from the treatment T_5 (Control).

It was also observed that the presence (by number) of aphids/plant (56.49) and white fly/plant (5.67) on leaves were the least with the treatment T_2 [Spinosad (Success 2.5 SC)] and the highest (156.78 and 18.73, respectively) at T_5 (Control). The highest reduction over control (50.28%) among the different treatments was observed from T_2 [Spinosad (Success 2.5 SC)] and the lowest (19.74%) from T_1 [Azadirachtin (Bioneem plus 1 EC)].

Effect of the different treatments on fruit borer of *capsicum* on fruits was significantly different. It was observed that the highest number of healthy fruit/plant (10.11) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)]. On the other hand, the lowest number of healthy fruits/plant (4.63) was recorded from untreated control treatment (T_5). Significant variation was observed with the application of different bio-pesticides against fruit borer of *capsicum*. The lowest number of infested fruits/plant (3.09) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)]. On the other hand, the highest number of infested fruits (4.37) was recorded from untreated control (T_5). The lowest percentage of fruit infestation in number (23.41%) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)] and the highest (47.08%) was recorded from untreated control (T_5). Fruit infestation reduction over control by number was estimated where the highest value (50.28%) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)], while the lowest (19.74%) was recorded from T_1 [Azadirachtin (Bioneem plus 1 EC)].

In total cropping season, the highest weight of healthy fruits/plant (876.84 g) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)]. On the other hand, the lowest weight of healthy fruits/plant (320.26 g) was recorded from untreated control (T_5). The lowest weight of infested fruit/plant (268.00 g) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)] which was statistically identical (284.28 g) from the treatment T_4 [Abamectin (Border plus 1.8 EC)]. On the other hand, the highest weight of infested fruit (284.92 g) was recorded from untreated control (T_5). The lowest percentage of fruit infestation in weight (23.41%) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)]. On the other hand, the highest fruit infestation (47.08%) was recorded from untreated control (T_5). Fruit infestation reduction over control in weight was estimated and the highest value (50.28%) was recorded from the treatment T_2

[Spinosad (Success 2.5 SC)], while the lowest (19.74%) reduction of fruit infestation over control was in T_1 [Azadirachtin (Bioneem plus 1 EC)] treatment.

The highest weight of fruit yield (27.26 t ha^{-1}) was recorded from the treatment T_2 [Spinosad (Success 2.5 SC)]. On the other hand, the lowest yield (14.41 t ha^{-1}) of fruit was recorded from untreated control (T_5) and was closely (16.71 t ha^{-1}) followed by T_1 [Azadirachtin (Bioneem plus 1 EC)]. Treatment T_3 (*Bacillus thuringiensis* (BT spray)) showed higher weight of fruit yield (24.37 t ha^{-1}) but significantly different from T_2 treatment. Yield increase over control in weight was estimated the highest value (89.17%) from the treatment T_2 [Spinosad (Success 2.5 SC)], while the lowest value was (15.97 %) from the treatment T_1 [Azadirachtin (Bioneem plus 1 EC)].

5.2 CONCLUSION

From the discussion above it can be concluded that T_2 treatment [Spinosad (Success 2.5 SC)] was successful in controlling insect pest and reducing insect infestation while providing higher yield of capsicum fruit compare to other treatments under study. Among the different biopesticides as a whole, Spinosad was found to be the most effective against controlling fruit borer of *Capsicum*. Bt *(Bacillus thuringiensis*) also shows a good value in controlling fruit borer of capsicum.

5.2 RECOMMENDATION

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Further study may be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.
2. Botanical extract with different concentration may be included in the future study.
3. New chemical pesticide may be included in the future study for comparison.
4. Sole Chemical pesticides and botanicals may be used.

CHAPTER VI
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REFERENCES

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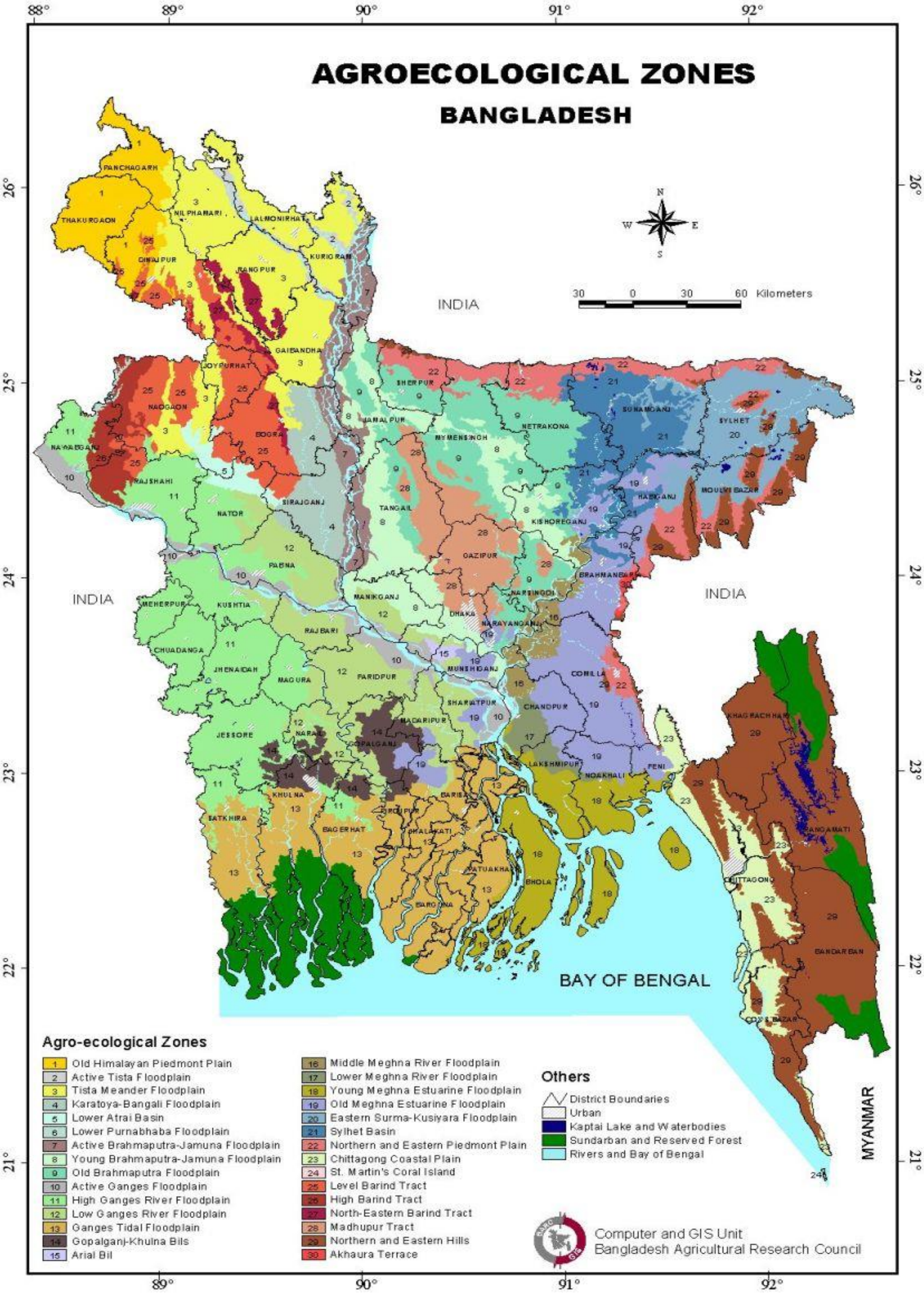
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh



Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from November, 2019 to February, 2020

Month	Air temperature (°C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
October, 2019	31.82	14.04	81	24
November, 2019	26.76	12.30	84	16
December, 2019	23.40	10.50	87	5
January, 2020	20.18	7.04	88	0
February, 2020	18.20	9.70	82	15

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka.

Appendix III. Characteristics of experimental fields soil was analysed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Boro rice-Fallow-Aman rice

B. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30

C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (meq/100 g soil)	0.10
Available S (ppm)	45

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