MANAGEMENT OF INSECT PESTS OF GROUNDNUT BY BIORATIONAL PESTICIDES

SUVRA SARKAR

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

JUNE, 2021

MANAGEMENT OF INSECT PESTS OF GROUNDNUT BY BIORATIONAL PESTICIDES

BY

SUVRA SARKAR

REGISTRATION NO.: 14-06072

A Thesis
Submitted to the Department of Entomology, Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2021

Approved by:

Prof. Dr. Mohammed Ali **Supervisor**	**Prof. Dr. Tahmina Akter** **Co-Supervisor**

Prof. Dr. Mizanur Rahman
Chairman
Examination Committee

DEPARTMENT OF ENTOMOLOGY

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

***Memo No**.: SAU/ENTOM/………* *__Date__:…………………….*

CERTIFICATE

*This is to certify that the thesis entitled **"MANAGEMENT OF INSECT PESTS OF GROUNDNUT BY BIORATIONAL PESTICIDES"** submitted to the Department of ENTOMOLOGY, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **SUVRA SARKAR**, **Registration No. 14-06072**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 been duly acknowledged.

Dated: June, 2021

Place : Dhaka, Bangladesh

Prof. Dr. Mohammed Ali

Supervisor

Professor
Department of Entomology
Sher-e-Bangla Agricultural University,
Dhaka-1207

Dedicated to,

My Brother, INDRANIL DEV SHARMA who taught me about dreams and how to catch them.

ACKNOWLEDGEMENTS

This thesis becomes a reality with the kind support and help of many individuals. Author would like to extend her sincere thanks to all of them.

*Foremost, Author would like to offer this endeavor to **the Almighty** for the wisdom He bestowed upon her, the strength, peace of mind and good health to finish this research.*

*Author would like to express her sincere gratitude to her supervisor **Prof. Dr. Mohammed Ali,** Professor,Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for the continuous support, for his valuable suggestions and immense knowledge. His guidance helped the author in all the time of research and writing of this thesis.*

*Authors' grateful appreciation is conveyed to her co-supervisor **Prof Dr. Tahmina Akter,** Professor,Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his valuable suggestions, inspiration and insightful comments.*

*Author wishes to express her gratitude and best regards towards the Chairman **Prof. Dr. Mizanur Rahman,** Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his valuable suggestions and cooperation during the study period.*

Author also expresses heartfelt thanks to all the teachers and staffs of the Department of Entomology, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study. Author is thankful to her friend Most. Farjana Akter for the stimulating discussions and for the sleepless nights they were working together before the deadline. Author expresses her heartfelt thanks to Rokaia Jamila Roshni, Jannatul Siddiqua, Sabiqunnaher Peya, Shahnaj Parvin, Tahura Begum, Hafsa binte Harun and Mahmuda Binte Qadar for their inspiration during research work.

Last but not the least, author would like to express gratitude towards her beloved parents, brother and the other family members for their constant inspiration and moral support throughtout the life.

The Author

MANAGEMENT OF INSECT PESTS OF GROUNDNUT BY BIORATIONAL PESTICIDES

SUVRA SARKAR

ABSTRACT

A field experiment was conducted to study the management of insect pests of groundnut by biorational pesticides. BARI Chinabadam-8 was used as the test crop for the experiment to evaluate the treatments' effect on insect pests. Eight treatments were applied at 10 days interval viz. T_1: Neem seed kernel @5 g/L of water, T_2: Spinosad @0.5 mL/L of water, T_3: Buprofezin @0.2 g/L of water, T_4: Lufenuron @0.2 g/L of water, T_5: Emamectin Benzoate @1.0 mL/L of water, T_6: Lamda cyhalothrin @1 mL/L of water + Biotrin @1 mL/L of water, T_7: Actara @ 0.5 g/L of water + Ecomec 1.8 EC @1 mL/L of water and T_8: Untreated control. Available insect pests namely aphid, whitefly, hairy caterpillar, thrips and jassid were found in the study field. Spinosad @0.5 mL/L of water at 10 days interval (T_2) showed best performance in reducing aphid and hairy caterpillar population, also their infestation. Treatment T_6 effectively reduced the whitefly population. For reducing thrips population, treatment T_7 showed best performance. Similarly T_2 with T_7 worked best against jassid population. Highest number of all available insect pest population was found in the untreated control plot. Treatment T_2 also showed the best results on yield and yield contributing characteristics viz. maximum pod/plant (22.17) and yield (2.69 t/ha) . The minimum pod/plant (11.20) and lowest yield (1.31 t/ha) was obtained from the untreated control plot, T_8. From the study, a strong negative relationship between available insect population and yield of groundnut was found.

CONTENTS

CONTENTS (CONT'D)

CONTENTS (CONT'D)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	=	Agro Ecological Zone
a.i	=	Active ingredient
BBS	=	Bangladesh Bureau of Statistics
cm	=	Centimeter
CV (%)	=	Percent Co-efficient of Variation
DAE	=	Department of Agricultural Extension
DAS	=	Day after sowing
EC	=	Emulsifiable concentrate
et al.	=	And others
FAO	=	Food and Agricultural Organization
g(gm)	=	Gram(s)
g/L	=	Gram per Litre
Kcal	=	Kilo calorie
kg	=	Kilogram
LSD	=	Least significance Difference
m	=	Meter
mg	=	Miligram
mL/L	=	Mililitre per Litre
mm	=	Millimeter
no.	=	Number
OD	=	Oil dispersion
SC	=	Suspension concentrate
SP	=	Soluble powder
SRDI	=	Soil Resource Development Institute
t/ha	=	Ton per hectare
UNDP	=	United Nation Development Programme
USDA	=	United States Department of Agriculture
Viz.	=	Latin- videre licet (it is permitted to see)
WDG	=	Water dispersible granules
WS	=	Water dispersible powders for slurry treatment
/plant	=	Per plant
@	=	At the rate
%	=	Percentage
>	=	Greater than

CHAPTER I

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), also known as peanut or monkey nut is a legume crop grown mainly for its edible seeds. It is widely grown in the tropics and subtropics. Among the oilseed crops, it occupies third position in respect to area of production and this crop is grown in 47 districts of Bangladesh during 2015 (BBS, 2016). Groundnut is consumed mainly as roasted nut but the best way to eat it on a daily basis is in the form of salad. Groundnut Nutrition Per 100 grams is Calories 567 kcal, Total Carbohydrate 16 g, Dietary fiber 9 g, Sugar 4 g, Protein 26 g, Total Fat 49 g, Saturated fat 7 g, Polyunsaturated fat 16 g, Monounsaturated fat 24 g, Cholesterol 0 mg, Sodium 18 mg, Potassium 705 mg, Vitamin B_1 0.9 mg, Vitamin B_2 0.2 mg, Niacin 17.6 mg, Vitamin B_6 0.5 mg, Folate 350 mcg, Calcium 134 mg, Iron 6.7 mg and Magnesium 245 mg (USDA, 2019). Several studies have shown that women who had a daily consumption of 400 micrograms of folic acid before and during early pregnancy reduced the risk of having a baby born with a serious neural tube defect by up to 70 percent and groundnut contains a good amount of folate. Dietary protein of groundnut is capable of meeting up to 46% of the recommended daily diet. Actually groundnuts are an invaluable source for human nutrition of protein, calories, essential fatty acids, vitamins and minerals (Willett *et al*., 2019).

In Bangladesh, groundnut cultivation covered about 87131 acres and production was about 62832 metric tons during the 2018-2019 cropping season and at 2019-2020, it covered 80828 acres with 60914 metric tons (BBS, 2020). The yield in Bangladesh is very low and fluctuates every year compared to the yield in other countries. This lower yield is mostly attributed from both biotic stresses and abiotic stresses and unavailability of high yielding cultivars and lack of proper management practices. Among numerous biotic stress causing agents, the incidence of insect pests is more crucial. Damage caused by insect and mite pests is one of the major constraints to the successful groundnut production in Bangladesh. Studies show that 15-20% of the overall production of oilseeds is lost directly or indirectly by insect and mite attacks every year (Biswas and Das, 2011). Thirty six species of insect pests were found to infest the different growth stages of groundnut crop at Gazipur, Bangladesh during the rabi seasons of 2008-09 and 2009-2010. Among the recorded pest species, the hairy caterpillar, *Spilarctia obliqua* (Walker); common cutworm, *Spodoptera litura* F.; jassid, *Empoasca terminalis* Distant ; leaf miner, *Stomopteryx nerteria* M. and leaf roller, *Anersia ephippias* (Meyr.) were considered as the major pests, while the rests were of minor importance on the basis of their population densities/plant, nature and extent of damage and yield reductions and most of the major and minor pests infested during the vegetative to pre-maturity stages (45-95 DAS) and the maximum infestation occurred during pod formation and pod filling stages (50-80 DAS) of the crop in both the years (Biswas, 2014). Twelve species of insect pests attacking groundnut crop in Bangladesh were recorded and among these hairy caterpillars; leaf roller, *Anarsia ephippias* and leaf miner, *Stomopteryx nerteria* were recorded as major pests (Kaul and Das 1986). From the survey report of Islam *et al*. (1983) in the northern Bangladesh revealed that 25 species of insect pests have been recorded in different stages of groundnut crop in that area. Of these, 8 species were considered as serious pests. Biswas *et al.* (2009) recorded 25 species of insect pests attacking groundnut at Gazipur, Bangladesh.

The management practices of groundnut insect pests in Bangladesh are mostly limited to use of insecticides of different chemical groups such as organophosphates, synthetic pyrethroids and nicotinoids (Deng *et al*., 2002; Sreekanth *et al*., 2000; Kumar and Krishnaynya, 1999; Ramaprasad *et al*., 1993). Plant derived insecticides have a wide range of mode of action such as feeding deterrents, insecticides, ovicidal and oviposition (Abdullah *et al*., 2011). The plant kingdom is recognized as the most efficient producer of chemical compounds, synthesizing many products that are used in defense against different pests (Islam and Akhter, 2007). Such plants have been in nature without any adverse effects on the ecosystem. Biorational pest management under protected cultivation is an important tool for pest suppression in an economically and ecologically sound way (Reddy 2016). Farmers usually use chemical pesticides to protect the crop from the severe infestation of insect pests. Use of chemicals has also been restricted because of their carcinogenicity, teratogenicity, high and acute residual toxicity, ability to make hormonal imbalance, spermatotoxicity, long degradation period and food residue (Dubey *et al*., 2011; Feng and Zheng, 2007; Khater, 2011).

In this direction, biorational management is essential to combat insect pests in an economically and ecologically sound way which are noxious to groundnut.

Keeping the above scheme in mind, the present study was undertaken to fulfill the following objectives:

- To observe the incidence of insect pests of groundnut at different growth stages
- To evaluate the efficacy of biorational pesticides against insect pests of groundnut
- To identify the most effective biorational pesticide in terms of lowering insect pests population

CHAPTER II

REVIEW OF LITERATURE

Groundnuts are an invaluable source for human nutrition of protein, calories, essential fatty acids, vitamins and minerals. It is the second major oilseed crop in Bangladesh containing 44-56% oil. But the production is hampered due to several factors and the substantial losses occur due to the insect pest infestation. There are many insect pests of groundnut. Among them whitefly, aphid, thrips, hairy caterpillar, jassid, leaf miner, leaf folder, leaf roller, common cutworm are most considerable. There is no defined indication of appropriate methods in controlling these insect pests. The research work in these aspects has been done in Bangladesh or elsewhere is not sufficient. Nevertheless, some of the informative research findings done at home and abroad have been reviewed in this chapter.

2.1 Citable insect pests of groundnut

2.1.1 Whitefly

Whiteflies are tiny, soft-bodied, sap sucking and winged insects from the Aleyrodidae family in the suborder Sternorrhyncha.

Whiteflies cause damage to plants in two ways firstly by sucking the sap and secondly by excreting honey dew on which sooty mould grows. Direct damage is caused through adults and nymphs feeding by inserting their mouthparts especially in young plants phloem sap from sieve tubes with their sucking mouthparts. It has been found that nymphs can inject enzymes that cause changes in plant physiology, leading to irregular ripening of fruit and retarded internal coloration. The honeydew excreted by *Bemisia tabaci* provides a medium for the growth of sooty mold on the leaves and fruits, thus reducing photosynthetic activities, which could negatively affect the quality of farm produce (Solanki and Jha, 2018).

Eggs are pear shaped and usually laid in circular groups, the underside of the young leaves with the broad end touching the surface and the long axis perpendicular to the leaf. Nymphs are pale, translucent white, oval, with convex dorsum and flat elongated ventral side. The adult whitefly is soft and pale yellow, changing to white within a few hours due to deposition of wax on the body and wings (Johnson *et al*., 2005). The pest remains active during the dry season and its activity decreases with the onset of rains. As a result of their feeding the affected plants become yellowish, leaves become wrinkled and curl downwards and eventually fall off. This occurs mainly due to viral infection whereas whitefly functions as a mechanical vector of many diseases.

Table 1. List of insect pests in groundnut

English Name	Scientific Name	Order	Family
Cutworm	*Agrotis ipsilon* (Hufnagel)	Lepidoptera	Noctuidae
Leaf roller	*Anarsia ephippias* Meyrick	Lepidoptera	Noctuidae
Aphid	*Aphis craccivora* Koch	Homoptera	Aphididae
Leaf /Shoot miner	*Aproaerema nerteria* Meyrick	Lepidoptera	Gelechiidae
Leaf/Shoot miner	*Aproaerema modicella* Deventer	Lepidoptera	Gelechiidae
Green grasshopper	*Atractomorpha crenulata* Fabricius	Orthoptera	Acrididae
Ant	*Camponotus* spp.	Hymenoptera	Formicidae
Dried fruit beetle	*Carpophilus hemipterus* (Linneaus)	Coleoptera	Nitidulidae
White leaf hopper	*Cofana spectra* (Distant)	Homoptera	Cicadellidae
Rice moth	*Corcyra cephalonica* (Stainton)	Lepidoptera	Crambidae
Flat grain beetle	*Cryptolestes pusillus* (Schoenherr)	Coleoptera	Laemophloeidae
Black weevil	*Cyrtozemia cognate* Marshall	Coleoptera	Curculionidae
Jassid	*Empoasca kerri Purthi*	Homoptera	Cicadellidae

Table 1 (cont'd)

English Name	Scientific Name	Order	Family
Pod sucking Bug	*Elasmolemus sordidus* (Fabricius)	Hemiptera	Lygaeidae
Jassid	*Empoasca terminalis* Distant	Homoptera	Cicadellidae
Almond moth	*Ephestia cautella* (Walker)	Lepidoptera	Crambidae
Ear wig	*Euborellia stali* (Dohrn)	Dermaptera	Forficulidae
Cotton thrips	*Frankliniella schultzei* (Trybom)	Thysanoptera	Thripidae
Pod borer	*Helicoverpa armigera* (Hübner)	Lepidoptera	Noctuidae
Common cutworm	*Spodoptera litura* Fabricius	Lepidoptera	Noctuidae
Hairy caterpillar	*Spilosoma nydia* Butler	Lepidoptera	Arctiidae
Defoliator	*Spodoptera exigua* (Hubner)	Lepidoptera	Noctuidae
White grub	*Holotrichia serrata* (Fabricius)	Coleoptera	Scarabaeidae
Cigarette beetle	*Lasioderma serricorne* (Fabricius)	Coleoptera	Anobiidae
Longheaded flour beetle	*Latheticus oryzae* Waterhouse	Coleoptera	Tenebrionidae
Flower thrips	*Megalurothrips distalis* (Karny)	Thysanoptera	Thripidae
Termite	*Microtermes obesi* Holmgren	Isoptera	Termitidae
Leaf beetle	*Monolepta signata* Olivier	Coleoptera	Chrysomelidae
Green stink bug	*Nezara viridula* Linnaeus	Hemiptera	Pentatomidae
Termite	*Odontotermes obesus* (Rambur)	Isoptera	Termitidae
Saw-toothed grain beetle	*Oryzaephilus surinamensis* (Linnaeus)	Coleoptera	Silvanidae
Hairy caterpillar	*Pericallia ricini* Fabricius	Lepidoptera	Lymantriidae

Table 1 (cont'd)

English Name	Scientific Name	Order	Family
Chili thrips	*Scirtothrips dorsalis* Hood	Thysanoptera	Thripidae
Groundnut moth	*Scopula emissaria* (Walker)	Lepidoptera	Geometridae
Rice weevil	*Sitophilus oryzae* (Linnaeus)	Coleoptera	Curculionidae
Stem borer	*Sphenoptera perotetti*	Coleoptera	Buprestidae
Common hairy caterpillar	*Spilarctia obliqua* (Walker)	Lepidoptera	Arctiidae
Defoliator	*Spodoptera exigua* (Hubner)	Lepidoptera	Noctuidae
Drugstore Beetle	*Stegobium paniceum* (Linnaeus)	Coleoptera	Anobiidae
Two spotted spider mite	*Tetranychus urticae* Koch	Acarina	Tetranychidae
Semilooper	*Thysanoplusia (Plusia) orichalcea* (Fabricius)	Lepidoptera	Noctuidae
Red flour beetle	*Tribolium castaneum* (Herbst)	Coleoptera	Tenebrionidae
Confused flour Beetle	*Tribolium confusum* Jacquelin du Val	Coleoptera	Tenebrionidae
Khapra beetle	*Trogoderma granarium* Everts	Coleoptera	Dermestidae

Source : DAE, 2019

2.1.2 Aphid

Aphids are small sap-sucking insects and members of the superfamily Aphidoidea.

Aphids are found on groundnut plants and other leguminous crops. Individual adults are capable of producing about 100 nymphs in their 5-30 day life span. These nymphs are dark brown and turn into shiny-black adults in about 10 days. Nymphs and adults suck sap from the tender growing shoots, leaves, flowers and pegs causing stunting and distortion of plants. They secrete a sticky fluid (honeydew) on the plant, which turns black by fungal infection. Heavily infested plants may typically look prostrated and stunted with yellow or whitish streaks on leaves. These streaks, basically, are formed due to the saliva injected by the Russian Wheat Aphid (Kazemi *et al*., 2001).

Climatic condition and temperature in particular, plays a significant role in population dynamics of the aphids. Serious aphid infestation may stunt plant growth, produce plant galls, transmit plant virus diseases and cause the deformation of leaves, buds, and flowers. They have a high biological potential with some of aphid's species (Aphididae) having more than ten generations in one year (Iversen and Harding, 2007).

2.1.3 Thrips

Thrips are minute (mostly 1 mm long or less), slender insects with fringed wings belonging to order Thysanoptera.

Thrips are important pests in groundnut worldwide, and they serve as vectors of devastating orthotospoviruses such as Tomato spotted wilt virus (TSWV) and Groundnut bud necrosis virus (GBNV). Different thrips species feed mostly on plants with rasping-sucking mouthparts that puncture plant cells and suck out their contents. Severe attacks of *Megalurothrips usitatus* cause yield losses of mung bean from 13% to 64% (Farajallah, 2013). Thrips can survive the winter as adults or through egg or pupal diapause. Flower feeding thrips are routinely attracted to bright floral colors including white, blue, and especially yellow. Thrips feed on flowers petioles and stigmas; causing deformity of the inflorescence and premature flower shedding (Kobro, 2011).

2.1.4 Hairy Caterpillar

Hairy Caterpillar is polyphagous and feeds on at least 126 species of plant including oilseeds, fibres, pulses, cereals, vegetables, mulberry and turmeric crops. The name of the insect denotes that there are plenty of hairs on the body surface.

Each female lays up to 1000 eggs on the undersides of leaves in several batches. When these hatch, the larvae at first scrape the under surface of the leaf, but as they grow they feed on the edges of the leaves, giving them a net-like appearance. When sufficiently numerous, they may defoliate the plant (Selvaraj *et al*., 2015).

2.1.5 Jassid

The commonest jassid that attacks groundnuts in Asia is *Emposca kerri.*

Jassid eggs are embedded in the leaf tissue close to the midrib, or in the petiole. About 40 nymphs can be expected from a single female. Both adults and nymphs suck sap from young leaves, mostly from the lower surface. The first symptom of attack is a whitening of the veins. Chlorotic (yellow) patches then appear especially at the tips of leaflets, probably caused by a reaction between the jassids' salivary secretion and plant sap. Infested plants are unthrifty and lack vigor and young plants may be stunted (Islam, 1999). Under severe infestation, the leaf tips become necrotic in a typical V shape, giving the crop a scorched appearance known as 'hopper burn'.

2.2 Accessible insect pests of groundnut and their management

Biswas (2014) reported that Thirty six species of insect pests were found to infest the different growth stages of groundnut crop at Gazipur, Bangladesh during the rabi seasons of 2008-09 and 2009-2010. Among the recorded pest species, the hairy caterpillar, *Spilarctia obliqua* (Walker); common cutworm, *Spodoptera litura* F.; jassid, *Empoasca terminalis* Distant ; leaf miner, *Stomopteryx nerteria* M. and leaf roller, *Anersia ephippias* (Meyr.) were considered as the major pests, while the rests were of minor importance on the basis of their population densities/plant, nature and extent of damage and yield reductions and most of the major and minor pests infested during the vegetative to pre-maturity stages (45-95 DAS) and the maximum infestation occurred during pod formation and pod filling stages (50-80 DAS) of the crop in both the years . The major insect pests of groundnut in ecological conditions of Asian region including Pakistan are termites, aphids (*Aphis craccivora* K.) and red hairy caterpillar (*Amsacta albistriga* Wlk) (Sheirdil *et al*., 2012). Among them, aphid, *Aphis craccivora* Koch (Aphididae: Homoptera) is one of the most destructive brownish gray polyphagous sucking insect pests but showed distinct preference to legumes and oil seed crops including groundnut (David and Ramamurthy, 2011).

Biopesticide, Spinosad showed better performance in reducing aphid population and a result from the observation of Gosh (2020) that Spinosad efficacy against aphid was 76.73 and 73.41 at the year of 2018 and 2019 respectively. Imidacloprid 30.5 SC @

160ml/ha and Spinosad 45 SC @100ml/ha gave significant population reduction of aphid over control, providing 88.73% and 63.04% control respectively (Thakoor *et al*., 2019).

Spinosad 45 EC @ 0.20 ml/l also found effective in reducing thrips population (Gadad and Hegde, 2014).

Chemical management options for thrips in peanuts, like many other row crops, are limited to a few insecticide active ingredients. A study was conducted to evaluate the effect of bio-pesticides and chemical insecticides namely Novastar 56EC, Stargate 48SC, Confidor 70WG, Actara 25 WG, Tracer 45SC, Ecomec 1.8EC, Bioneem plus 1EC to control thrips infesting mung bean in the experimental field of Sher-e-Bangla Agricultural University during November 2017 to February 2018. Significant variations in efficacy of different bio-pesticides and chemical insecticides were observed at vegetative stage of the mung bean in comparison to control. Stargate 48SC treatment (clothianidin) was found very effective to control thrips and there were no thrips on top trifoliate leaves in this treatment. The lowest number of *Megalurothrips usitatus* and *Thrips palmi* (0.99 and 0.02, respectively) on 10 terminal shoot per plant was found in Stargate 48SC treated plot. On the other hand, the highest incidence of *M. usitatus* and *T. palmi* (5.76 and 2.25, respectively) on10 top trifoliate leaves per plant and that of *M. usitatus* and *T. palmi* (6.77 and 2.78, respectively) on 10 terminal shoots per plant was recorded in untreated control plot. Stargate 48SC reduced maximum thrips population 100.00% on top trifoliate leaves and 89.40% on terminal shoots followed by Confidor 70WG (81.25% on top trifoliate leaves and 82.61% on terminal shoots). Among the Bio-pesticides, Ecomec 1.8 EC performed better in reducing thrips population (43.60% and 46.65%) on top trifoliate leaves and terminal shoots respectively (Yasmin *et al*. 2020).

Rahman (2017) conducted a study on against Jute Hairy Caterpillar, Spilosoma Obliqua (Walker) in the laboratory and in the field of Central station, Bangladesh Jute Research Institute (BJRI), Dhaka and JAES, Manikganj during March to September, 2017. Eight treatment, T_1= Emacto 5WDG (Emamectin Benzoate), T_2= Fusion 20SL (Imidacloprid), T_3= Rescue 6WDG (Abamectin 2% + Emamectin Benzoate 4% WDG), T_4= Hayron 5EC (Lufenuron), T_5= Base 45SP (Spinosad), T_6= Perfect 30WDG (Lufenuron 10% + Thiamethoxam 20%), T_7= Mekalux 25EC (Quinalphos) and T_8=control were used. The study revealed that the incubation period was 5.5 ± 0.29 day, total larval period of jute hairy caterpillar was 19.91 ± 0.47 days, pupal period 9.83 ± 0.42 days, egg-adult (female) 42.67 ± 0.69 days and egg-adult (male) 38.67 ± 0.75 days. The pre-oviposition and oviposition periods were 1.42 ± 0.15 days and 3.5 ± 0.29 days respectively. The longevity of female and male moths was 7.41 ± 0.34 days and 3.42 ± 0.26 days. Treatment with Quinalphos: Mekalux 25EC gave the best performance with more than 95% mortality followed by Spinosad: Base 45SP. Emacto 5WDG @ 1.5 kg/ha, Fusion @ 500ml/ha, Rescue 6WDG @ 250/ha, Hayron 5EC @ 500ml/ha, Base 45SP @ 250 ml/ha, Perfect 30 WDG @ 100gm/ha and Mekalux 25EC @ 1.5/ha performed more than 85% mortality of jute hairy caterpillar. All selected doses of insecticides showed more than 80% reduction of plant infestation over control in both two locations Central station, BJRI, Dhaka and JAES, Manikganj. The result of trial in two locations clearly indicated that all the insecticides were effective against jute hairy caterpillars.

Vanisree *et al.* (2017) conducted an experiment during Kharif 2008-09 and 2009-10 on the evaluation of certain new insecticides. Results indicated that spinosad 0.015% was found most effective in reducing the population of *Scirtothrips dorsalis* as well as in increasing yields. It attains the highest cost benefit ratio followed by Diafenthiuron 0.045%, Pymetrozine 0.02% and Fipronil 0.01%. Indoxacarb 0.015% and Flubendiamide 0.012%.

Field studies were carried out to evaluate the efficacy of four new generation insecticides along with a botanical against mustard aphid (*Lipaphis erysimi* Kalt.) and their toxicity to coccinellid beetles and foraging honeybees during 2014-15 at Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Buprofezin 40 SC was found to be the most effective against aphid offering the lowest aphid population (1.56/ top10cm central twig) at 7 days after spraying (DAS) which was statistically identical to Diafenthiuron 500SC (1.85/top 10 cm central twig). Among the treatments, Azadirachtin 1EC appeared to be safest to coccinellid beetles and foraging honeybees because it recorded the highest number of beetle (7.50 /5 plants) and honeybee (9.64 /plot/5 min) population at 7 DAS, although honeybee population did not vary statistically with that of Buprofezin 40 SC and Lufenuron 5EC treated plots. Indoxacarb 145SC was found to be the most toxic against honeybees. However, the highest yield was obtained from Buprofezin 40 SC (1.57 t ha-1) treated plot although this was statistically identical to that Diafenthiuron 500SC (1.52 t ha-1) and Azadirachtin 1EC (1.48 t ha-1) treated plots (Dutta *et al.* 2016).

A study was conducted on the incidence, damage severity and management of jassid on groundnut in the field of the Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during Rabi season of two consecutive years 2011-12 and 2012-13. There were five treatments, namely application of detergent (Jet powder) 3g/litre, Crude Neem seed mixture (NSM) @ 50 g/l, Spraying of Dimethoid (Tafgor 40 EC @ 2ml/l), Spraying of Imidacloprid (Admire 200Sl) @ 0.5 ml/l of water and untreated control with only water were used uniformly. All the treatments reduced jassid population with significant variation among them. Of these Imidacloprid (Admire 200SL @ 0.50ml/l) reduced significantly the highest jassid population (80.25%) over the untreated. Reduction of jassid occurred by 65-68% in Tafgor (Dimethoid) 40 EC @2ml/l and neem seed mixture+Jet powder treated plots and these two treatments caused similar controlling effects on jassid next to Imidacloprid (admire, 82.72%) while Jet powder @ 3g/l reduced the lowest jassid population (49.86%) over the untreated control. The leaf infestation by jassid had the same trend as the number in all the treatments with the highest efficacy of Imidacloprid resulted in 80.72% reduction over untreated control. The lowest efficacy was recorded in jet powder treatment (Biswas, 2015).

Ranganathan (2012) reported that Bihar hairy caterpillar *Spilosoma obliqua* is a sporadic pest of groundnut in India. It causes severe damage to the groundnut productivity. Chemical pesticides of various classes are used for controlling caterpillars in the field. The present study is focused on understanding the baseline susceptibility of five classes of chemical insecticides namely Imidacloprid, Cypermethrin, Emamectin benzoate, Neem and Flubendiamide on third instar larvae of S.obliqua. Based on the LC_{50}, LC_{90} and LC_{99} values results shows Emamectin benzoate as the most potent insecticide (LC_{50}: 2.459g a.i/ha), followed by Cypermethrin (LC_{50}: 41.72g a.i/ha). This information can be used for designing IPM programs in groundnut.

Results revealed that foliar spray of Thiamethoxam 25 WS @ 0.005% followed by spirotetramat 150 OD @ 90 g a.i./ha and Acetamiprid 20% SP @ 0.002% were found to be the most effective treatments and recorded low population of whiteflies (2.66, 3.44 & 4.88/5 plants, respectively) and low mungbean yellow mosaic virus (MYMV) incidence ranging from 10.7% to 14.2%.(Panduranga *et al*., 2011).

Khalid and Prasad (2009) documented the efficacy of Emamectin benzoate in managing thrips incidence in chillies.

Shelton *et al*. (2008) reported that Acetamiprid, Spinosad, Imidacloprid and Dimethoate performed better and found that Acetamiprid reduced damage by 51 percent by reducing the thrips incidence in cabbage.

Ulaganathan and Gupta (2004) reported that Acetamiprid, Imidacloprid, Beta cyfluthrin, Spinosad, Indoxacarb were effective in reducing thrips and jassid populations.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the central field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from October, 2019 to March, 2020. The details materials and methods that were used to conduct this experiment are represented below under the following headings and subheadings:

3.1 Description of the experiment

3.1.1`Experimental period

The experiment was carried out during the period from 21 October, 2019 to 23 March, 2020.

3.1.2 Location

The experiment was carried out in the central research field (Plot no. 5) of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The experimental plots were situated in 23º74´´N latitude and 90º35´´E longitude and an elevation of 8.2 m from sea level (Anon., 1989) and have been presented in Appendix I.

3.1.3 Climate of the experimental field

The climate of the experimental site was subtropical, characterized by three distinct seasons, 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). The maximum and minimum temperature was 29.45ºC and 13.86º C, respectively during the experiment. In our country Rabi season is characterized by plenty of sunshine. Meteorological data which are related to the temperature, relative humidity and rainfall during the experimental period was collected from Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar and has been presented in Appendix II.

3.1.4 Soil of the experimental field

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and is shallow red brown terrace soil. The land of the selected experimental plot is medium high under the Tejgaon series (FAO, 1988). Thesoil is composed of 27% sand, 43% silt and 30% clay. The characteristics of the soil under the experiment plot were analyzed in the soil testing laboratory, SRDI, Khamarbari, Dhaka and has been represented in Appendix III.

3.2 Crop cultivation

3.2.1 Test crop and its characteristics

BARI Chinabadam-8 was used as a test crop for the experiment. The crop was approved by the National Seed Board in 2006. The plant height is 35-45 cm bearing 20-25 number of pods/plant and life cycle is 140-150 days for Rabi season.

3.2.2 Collection of seed

The seeds were collected on 20 October 2019 from the Oilseed Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701.

3.2.3 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experiment consists of a total 24 plots of size 2.5 m × 2 m. The layout of the experiment is shown in Figure 1.

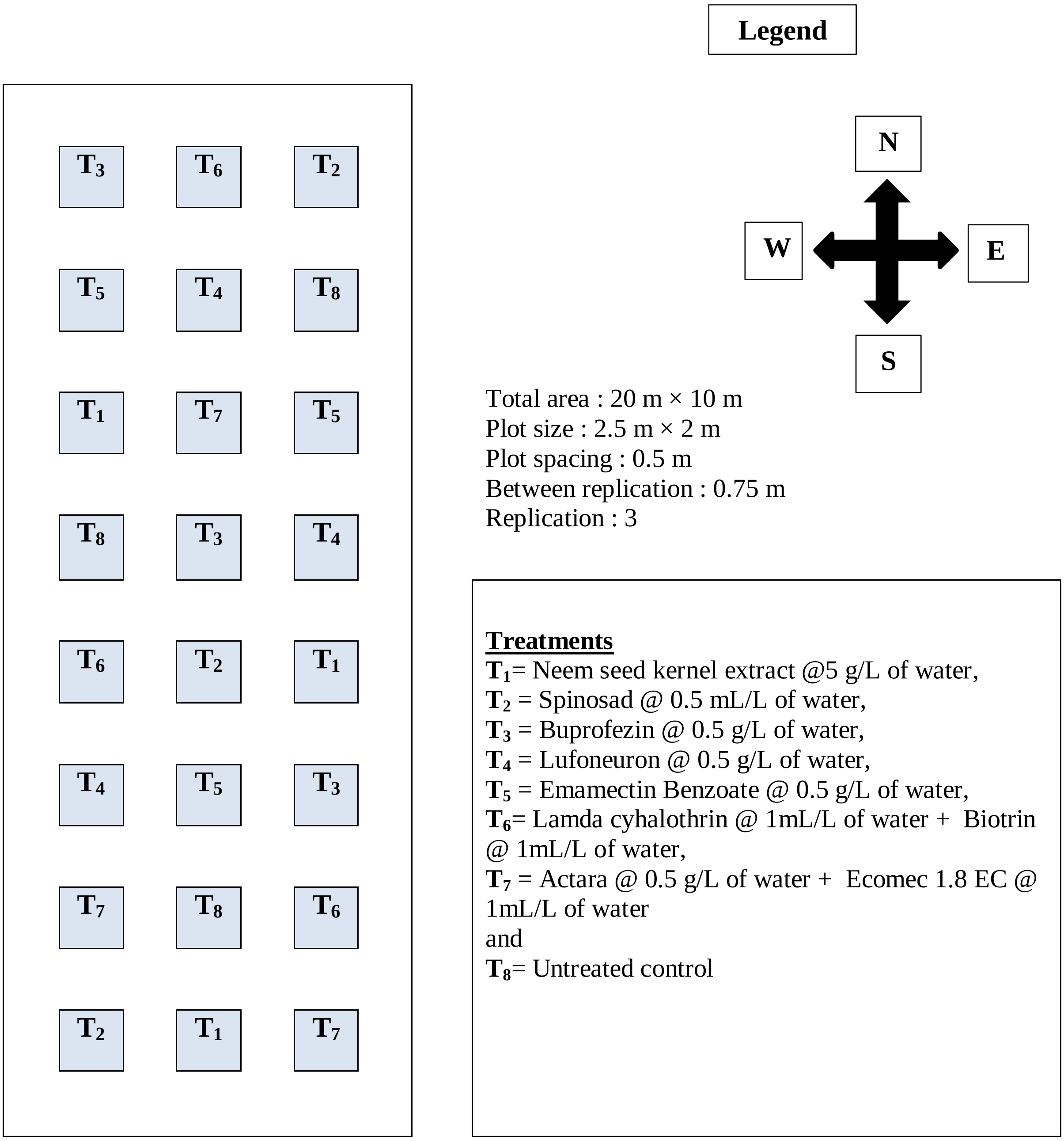


Figure 1. Layout of the experimental plot

3.2.4 Land preparation

The experiment plot was opened in the last week of October 2019 with a power tiller drawn disc plough and was exposed to the sun for a week. Several times cross ploughings were done followed by harrowing and laddering to obtain desirable tilth. All weeds, stubbles and residues were eliminated from the experimental field.

3.2.5 Fertilizers

Fertilizers were applied according to the recommended fertilizer doses for groundnut production per hectare as per fertilizers recommendation guideline of Bangladesh Agricultural Research Institute, 2019. The dose and method of fertilizers application is listed below at Table 2.

Table 2. Dose and method of application of fertilizers in groundnut field

Fertilizers	Dose(Kg/ha)	Application (%)	
		Basal	Rest (after 40-50 days of germination)
Urea	25	50	50
TSP	160	100	--
MP	85	100	--
Gypsum	300	100	--
Boric acid	10	100	--

3.3 Growing of crops

3.3.1 Removal of shell

Groundnut shells were removed carefully to get the seeds.

3.3.2 Sowing of seeds

Peeled seeds were sown (Plate 1) in furrows having a depth like 2.5-3 cm on 29 October 2019 in the experimental plots. And then furrows were covered with soil soon. Row to row distance (30 cm) was maintained as per instruction of Bangladesh Agricultural Research Institute.

3.3.3 Germination and flowering

Seed germination commenced on 3 November 2019 and all the seedlings emerged within the next two days (Plate 3). Flowering (Plate 4) occurred from the next 35 days of germination.

3.3.4 Intercultural operations

3.3.4.1 Gap filling

Almost all the seedlings emerged out in the experimental plots. Some seeds failed to germinate for that seeds were sown quickly for filling the gap.

3.3.4.2 Irrigation and drainage

Irrigation was maintained by understanding the condition of the experimental plots and weather. The whole experimental plot was arranged in well drained facilities as a prevention process of removing rain water if any. First irrigation was done on 13 November 2019.

3.3.4.3 Weeding

Weeds (like nutsedges, bermuda grass, helencha, garden spurge, purslane etc.) were found in the study period. Weeding was done carefully by uprooting and using with mechanical weed control method.

3.3.4.4 Earthing up

Earthing up (Plate 7) was done after 35 to 40 days (after flowering) by taking the soil from the space between the rows.

3.3.5 Treatments used for management

The experiment consisted of eight treatments including an untreated control. Dose of those treatments with application at 10 days interval were listed below:

T_1 = Neem seed kernel extract @5 g/L of water;

T_2 = Spinosad @ 0.5 mL/L of water;

T_3 = Buprofezin @ 0.5 g/L of water;

T_4 = Lufenuron @ 0.5 g/L of water;

T_5 = Emamectin Benzoate @ 0.5 g/L of water;

T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water;

T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and

T_8= Untreated control

3.3.5.1 Preparation of neem seed kernel extract

Dried neem seed kernels were placed in a mortar then grinding these with the help of pestle. For obtaining fine dust (Plate 5), the grinded dust was sieved.

3.3.5.2 Procedure of spray application

The desire amount of each treatment was taken in knapsack sprayer and thoroughly mixed with water and sprayed in the respective plot (Plate 6). Each treatment was repeated at 10 days interval applied in the field. Precaution was taken to avoid any drift to the adjacent plots at the time of the spray application.

3.4 Crop sampling and data collection

Five plants were randomly selected for each treatment of the experimental plot (Plate 2) with the help of sampling method.

3.4.1 Monitoring and data collection

The groundnut plants under different biorational treatments were closely examined, counted and recorded at regular interval commencing from germination to harvest. The following parameters were taken as consideration during data collection –

- Number of aphid population per plant
- Number of whitefly population per plant

- Number of hairy caterpillar population per plant
- Number of thrips population per plant
- Number of jassid population per plant
- Shoot infestation
- Leaf infestation
- Plant height at harvest
- Branches per plant during harvest
- Pod number
- Abnormal pod
- Yield

3.4.2 Determination of incidence of insect pests

Incidence of insect pests was counted from five randomly selected plants. The number of aphid, whitefly, hairy caterpillar, thrips and jassid was counted very early in the morning (Plate 8, Plate 9 and Plate 10).

Plate 1. Seed sown in the experimental plot

Plate 2. The whole experimental plot

Plate 3. Healthy germinated groundnut plants

Plate 4. Flowering in groundnut plant

Plate 5. Neem seed kernel extract

Plate 6. Spraying in the experimental plot

Plate 7. Experimental plot during intercultural operation

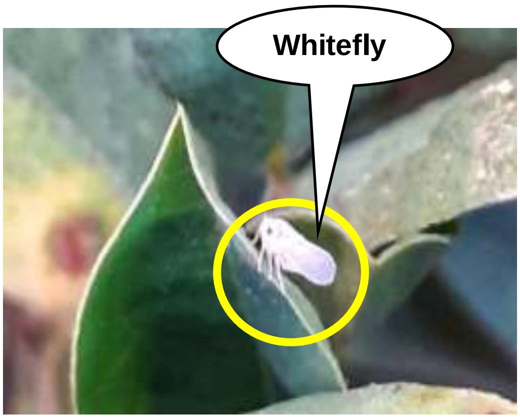


Plate 8. Whitefly infested groundnut leaf

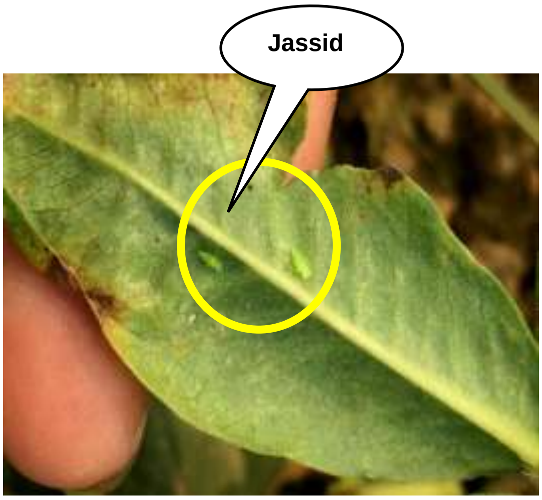


Plate 9. Jassid infested groundnut leaf

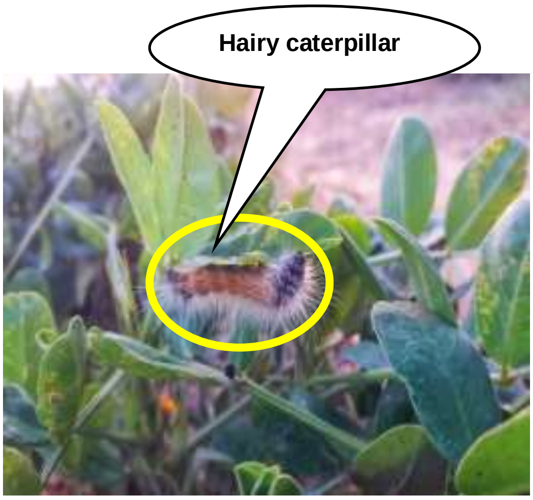


Plate 10. Hairy caterpillar infested groundnut leaf

Plate 11. Severe leaf infestation by Hairy caterpillar in the experimental field

Plate 12. Harvested groundnut pod from the experimental plot

3.4.3 Determination of shoot infestation

Mainly the shoot infestation was caused by the aphids. Healthy and infested shoots were counted from five randomly selected plant of each plot and examined. The healthy and infested shoots were counted and the percent shoot infestation was calculated using the following formula (Awal *et al*., 2017):

$$\%\ \text{Shoot infestation} = \frac{\text{Number of infested shoot}}{\text{Total number of shoot}} \times 100$$

Percentage reduction was calculated by following formula (Abbott, 1925):

$$\%\ \text{Shoot infestation reduction} = \frac{(\%\ \text{infestation in control} - \%\ \text{infestation in concerned treatment})}{\%\ \text{infestation in control}} \times 100$$

3.4.4 Determination of leaf infestation

Leaf infestation was caused by hairy caterpillar (Plate 11). Healthy and infested leaves were counted from five randomly selected plant of each plot and examined. The healthy and infested leaves were counted and the percent leaf infestation was calculated using the following formula (Javad *et al*., 2014):

$$\%\ \text{Leaf infestation} = \frac{\text{Number of infested leaf}}{\text{Total number of leaf}} \times 100$$

Percentage reduction was calculated by following formula (Abbott, 1925):

$$\%\ \text{Leaf infestation reduction} = \frac{(\%\ \text{infestation in control} - \%\ \text{infestation in concerned treatment})}{\%\ \text{infestation in control}} \times 100$$

3.5 Harvest and post-harvest operation

The groundnut was harvested at the maturity of plant (Plate 12) and harvesting was done manually from each plot within two days. After harvesting pods were cleaned and dried under the sun.

3.6 Data collection on yield contributing characters and yield

3.6.1 Plant height at harvest

Plant height was measured with a meter scale from the ground level to the top of five randomly selected plants and then the mean height of these plants was expressed in centimeter (cm).

3.6.2 Branches per plant

Number of branches arisen from the stem was counted from five randomly selected plants.

3.6.3 Number of pod and abnormal pod

Number of pod of selected plants from each plot was counted and the mean number was expressed on basis of per plant. Data were recorded as the average of five randomly selected plants. In term of abnormal pod same procedure was followed.

3.6.4 100 seed weight

One hundred seeds was counted from randomly selected plants and then weighted in grams.

3.6.5 Yield per hectare

Seed weight per plot (kg/plot) was measured form the harvested seeds of groundnut and then per plot yield was converted into hectare and expressed in ton.

3.7 Statistical analysis

The data on the incidence of insect pests and different yield contributing characters were statistically analyzed and treatment mean values were separated by Duncan’s Multiple Range Test (DMRT) (Gomez and Gomez, 1984) by using STATISTIX 10 software in accordance with Completely Randomized Block Design (RCBD).

CHEAPTER IV

RESULT AND DISCUSSION

The experiment was conducted to study the incidence of major insect pests of groundnut and their management by biorational pesticides. The analysis of variance (ANOVA) of the data on the incidence of available insect pests on groundnut plants, shoots and leaves infestation, different yield attributes and yield is given in Appendix IV-XIV. The results have been presented by using different tables, figures like bar graph, pie chart and discussed with possible interpretations under the following headings and sub-headings:

4.1 Abundance of insect pests in groundnut field

Insect pests population was recorded from the early growing stage to mature stage of groundnut. The population of aphid, whitefly, hairy caterpillar, thrips and jassid was observed and population of each species was counted.

4.1.1 Incidence of Aphid

Number of aphid incidence per plant was recorded at early, mid and late stage of groundnut. The average population of aphid in groundnut under different biorational treatments has been shown in Table 3. The mean performance of the treatment having the common letter is identical and those having the different letter are statistically different from each other.

The data table expresses that at early stage the lowest number of aphid (1.16/plant) was observed in T_2 treated plot having significant difference with other treatments and other treatments have intermediate number of aphid. T_4 showed mal performance (5.46/plant) in reducing aphid population. However, the highest number of aphid (6.76/plant) was found in control plot which was significantly higher than all other treated plots. The order of pesticidal effectiveness is $T_2>T_6>T_7>T_5>T_3>T_1>T_4$ at early stage.

At mid stage, the highest amount of aphid population (11.24/plant) was observed in control plot (T_8) whereas the lowest population (3.80/plant) was found in T_2 treated plot having significant difference with other treatments. And the followed treatment in case of lowering aphid population (5.28/plant) at mid stage was T_6. Among the other treatments, T_4 and T_1 showed the poor performance in reducing aphid population (10.40 and 10.15/plant, respectively). The order of tested pesticidal effectiveness is $T_2>T_6>T_7>T_5>T_3>T_1>T_4$ at mid stage.

At late stage, Treatment T_2 showed the minimum incidence of aphid per plant (6.30/plant) and T_6 (6.81/plant) which is statistically identical whereas the maximum incidence of aphid per plant (12.32/plant) was recorded from T_8 (control) treatment. Treatment T_4 followed by T_1 treated plot also showed poor performance at late stage in reducing aphid population. The order of pesticidal effectiveness is $T_2>T_6>T_7>T_5>T_3>T_1>T_4$ at late stage.

It is revealed that the maximum amount of aphid population was 6.76, 11.24 and 12.32/plant at early, mid and late stage, respectively in control plot (T_8) and the lowest amount of aphid was found in T_2 treated plot. Among the other treatments, T_4 showed the poor performance. So as a treatment T_2, Spinosad was most effective against aphid.

Table 3. Effect of different biorational pesticides on Aphid population at different growth stages of groundnut

Treatments	Number of Aphid at different growth stages		
	Early	Mid	Late
T_1	4.60 c	10.15 b	11.14 bc
T_2	1.16 **h**	3.80 **g**	6.30 **f**
T_3	4.10 d	9.10 c	10.17 c
T_4	5.46 b	10.40 b	11.23 b
T_5	3.79 e	8.00 d	9.11 d
T_6	2.17 g	5.28 f	6.81 **f**
T_7	3.28 f	6.72 e	8.07 e
T_8	6.76 **a**	11.24 **a**	12.32 **a**
LSD(0.05)	0.1402	0.4353	1.0190
CV (%)	2.05	3.07	6.19

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.
[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.1.2 Incidence of Whitefly

The number of whitefly was observed in the treated groundnut field is presented in Table 4.

It is revealed that at early stage the highest number of whitefly population (6.56/plant) was in control plot. And the lowest number of whitefly (1.21/plant) was at T_6 treated plot, followed by T_2 (2.36/plant). T_4 (5.55 plant) showed the poor performance in reducing whitefly population. The order of pesticidal effectiveness is T_6>T_2>T_7>T_5>T_3>T_1>T_4 at early stage.

At mid stage, the lowest incidence of whitefly (3.21) per plant was recorded from T_6, followed by T_2 and T_7 (3.76 and 4.21 respectively) whereas the highest incidence per plant (9.33) was recorded from T_8 treated plot. Among the treatments, T_4 showed the poor performance in reducing population. The order of pesticidal effectiveness is $T_6>T_2>T_7>T_5>T_3>T_1>T_4$ at mid stage.

At late stage , the highest incidence of whitefly is 12.19 per plot which was recorded from T_8 treated (control) plot and T_4 showed the poor performance in reducing population among the other .The lowest amount of population (4.10/plant) was recorded from T_6 treated plot. The order of pesticidal effectiveness is $T_6>T_2>T_7>T_5>T_3>T_1>T_4$ at late stage.

Finally it is revealed that the maximum amount of whitefly population (6.56, 9.33 and 12.19/plant respectively at early, mid and late stage) was found in control plot and the lowest amount of whitefly was found in T_6 treated plot. Among the other treatments, T_4 showed the poor performance in reducing whitefly population at different stages.

Table 4. Effect of different biorational pesticides on Whitefly population at different growth stages of groundnut

Treatments	**Number of Whitefly at different growth stages**		
	Early	**Mid**	**Late**
T_1	5.16 c	6.65 c	9.12 c
T_2	2.36 g	3.76 f	5.69 f
T_3	4.62 d	5.96 d	8.07 d
T_4	5.55 b	7.15 b	10.81 b
T_5	3.69 e	5.12 e	7.55 de
T_6	1.21 **h**	3.21 **g**	4.10 **g**
T_7	3.20 f	4.21 f	6.78 e
T_8	6.56 **a**	9.33 **a**	12.19 **a**
LSD(0.05)	0.3341	0.4927	0.9197
CV (%)	4.72	4.96	6.53

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.
[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.1.3 Incidence of Hairy Caterpillar

Incidence of hairy caterpillar showed statistically significant variations due to different biorational treatments in groundnut at early, mid and late stages.

The data Table 5 expresses that at early stage, no hairy caterpillar was recorded from T_2 and T_7 whereas the highest number of hairy caterpillar population (1.64/plant) was in T_8 treated plot which was the control plot. T_1 and T_3 occuring 0.88 and 0.80 population per plant respectively showed the poor performance in reducing hairy caterpillar incidence. The order of pesticidal effectiveness is T_2=T_7>T_5>T_6>T_4>T_3=T_1 at early stage. At mid stage, no hairy caterpillar per plant was recorded from T_2 and T_7 whereas the highest incidence per plant (1.90) was recorded from T_8 treated plot.

Among the treatments, T_1 and T_3 showed the poor performance in reducing the population. The order of pesticidal effectiveness is $T_2=T_7>T_5>T_6>T_4>T_3=T_1$ at mid stage.

At late stage , the highest incidence of hairy caterpillar is 2.17 per plot which was recorded from T_8 treated (control) plot and T_1 and T_3 showed the poor performance in reducing population among the other treatments .The lowest amount of population (0.07/plant) was recorded from T_2 treated plot. The order of pesticidal effectiveness is $T_2>T_7=T_5>T_6>T_4>T_3=T_1$ at late stage.

It is revealed that T_2 treatment is most effective in reducing the hairy caterpillar population and the maximum number of population resulted from treatment T_8. Among the other treatments, T_1 showed the poor performance. Rahaman (2017) showed that Spinosad was effective against hairy caterpillar and more than 95% population reduction occurred from it which justifies the present investigation.

Table 5. Effect of different biorational pesticides on Hairy Caterpillar population at different growth stages of groundnut

Treatments	Number of Hairy Caterpillar at different growth stages		
	Early	Mid	Late
T_1	0.88 b	1.02 b	1.23 b
T_2	0.00 **f**	0.00 **f**	0.07 **f**
T_3	0.80 b	1.00 b	1.20 b
T_4	0.60 c	0.80 c	1.01 c
T_5	0.21 e	0.39 e	0.39 e
T_6	0.43 d	0.62 d	0.81 d
T_7	0.00 **f**	0.00 **f**	0.29 e
T_8	1.64 **a**	1.90 **a**	2.17 **a**
LSD(0.05)	0.1000	0.1401	0.1849
CV (%)	10.02	11.17	11.78

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.
[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.1.4 Incidence of Thrips

Incidence of thrips showed statistically significant variations due to different biorational treatments in groundnut at early, mid and late stages.

The data Table 6 expresses that at early stage the lowest number of thrips (0.07/plant) was observed in T_7 treated plot followed by T_6 treated plot (0.91/plant) having significant difference between them. Other treatments have intermediate number of thrips. T_1 showed poor results (2.26/plant) in reducing thrips population. However, the highest population (3.31/plant) was found in control plot (T_8) which was significantly higher than all other treated plots. The order of effectiveness is $T_7>T_6>T_2>T_5>T_4>T_3>T_1$ at early stage.

At mid stage, the lowest incidence of thrips per plant (1.03) was recorded from T_7 whereas the highest incidence per plant (6.35) was recorded from T_8 treated plot. Among the treatments, T_1 showed the poor performance in reducing population. The order of pesticidal effectiveness is $T_7>T_6>T_2>T_5>T_4>T_3>T_1$ at mid stage.

At late stage, the highest incidence of thrips was 9.97 per plot which was recorded from T_8 treated (control) plot and T_1 showed the poor performance in reducing population among the other treatments. The lowest amount of population (2.31/plant) was recorded from T_7 treated plot. The order of pesticidal effectiveness is $T_7>T_6>T_2>T_5>T_4>T_3>T_1$ at late stage.

The statistical analysis revealed that T_7 treatment is the most effective in reducing the thrips population and among the other treatments, T_1 showed the poor performance. Ecomec 1.8 EC performed better in reducing thrips population (Yasmin *et al*. 2020) and the effective treatment in the experiment against thrips was Actara + Ecomec 1.8 EC (T_7).

Table 6. Effect of different biorational pesticides on Thrips population at different growth stages of groundnut

Treatments	Number of Thrips at different growth stages		
	Early	Mid	Late
T_1	2.26 b	5.59 b	7.26 b
T_2	1.29 e	2.997 e	4.22 e
T_3	1.88 c	4.52 c	6.50 c
T_4	1.71 cd	4.33 c	5.86 cd
T_5	1.55 de	3.82 d	5.56 d
T_6	0.91 f	2.04 f	3.89 e
T_7	0.07 **g**	1.03 **g**	2.31 **f**
T_8	3.31 **a**	6.35 **a**	9.97 **a**
LSD(0.05)	0.2848	0.3398	0.6634
CV (%)	10.02	5.06	6.65

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.
[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.1.5 Incidence of Jassid

Incidence of jassid showed statistically significant variations due to different biorational treatments in groundnut at early, mid and late stages.

The data Table 7 expresses that no jassid was recorded from treatment T_2 and treatment T_7 at early stage. However, the highest population (1.90/plant) was found in control plot (T_8) which was significantly higher than the other treated plots. Treatment T_4 showed poor result (1.20/plant) in reducing jassid population. At mid stage, the highest incidence of jassid is 2.997 per plot which was recorded from T_8 treated (control) plot whereas there was no jassid population at treatment T_2 and in treatment

T_7, incidence of jassid was 0.19 per plant which was statistically identical. In case of reducing population, T_4 showed the poor performance than other treatments. The order of effectiveness is $T_2=T_7>T_6>T_5>T_3>T_1>T_4$ at mid stage.

At late stage, the lowest population of jassid 0.20 and 0.33 per plant was recorded from treatment T_2 and T_7 respectively which is statistically identical. In case of reducing population, T_4 showed the poor performance than other treatments and treatment T_8 treated plot showed the highest incidence (3.10/plant) of jassid. The order of effectiveness is $T_2=T_7>T_6>T_5>T_3>T_1>T_4$ at late stage.

It is revealed that T_2 and T_7 treatment were most effective in reducing the jassid population whereas T_1 showed the poor performance among the treatments. And again treatment T_8, the control plot had the highest incidence of jassid population.

Table 7. Effect of different biorational pesticides on Jassid population at different growth stages of groundnut

Treatments	Number of Jassid at different growth stages		
	Early	Mid	Late
T_1	0.997 c	2.09 c	2.19 c
T_2	0.00 **g**	0.00 **g**	0.20 **g**
T_3	0.80 d	1.46 d	1.56 d
T_4	1.20 b	2.56 b	2.66 b
T_5	0.62 e	1.00 e	1.10 e
T_6	0.39 f	0.62 f	0.72 f
T_7	0.00 **g**	0.19 **g**	0.33 **g**
T_8	1.90 **a**	2.997 **a**	3.10 **a**
LSD(0.05)	0.1610	0.2145	0.1969
CV (%)	12.45	8.97	7.59

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.
[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.2 Overall insect population under different treatments during study period

During the whole study period, groundnut field was infested with various types of insect pests which has been showed in Figure 2. At a glance the figure expresses that, a number of insect pests was recorded in the groundnut field. Their occurrence level varied with higher and lesser extent during the period. Among different treatments, T_2 treatment comprising spinosad showed the best performance in terms of lowest population comparable to other treatments whereas the maximum number of insect pests was recorded in T_8 treated (control) plot.

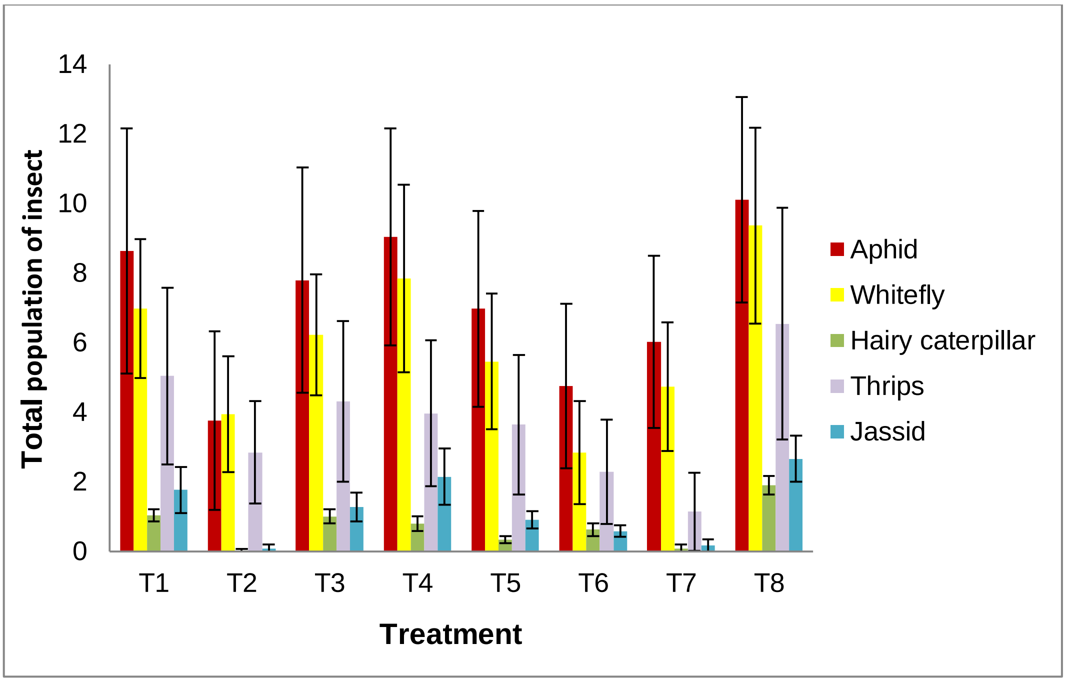


Figure 2. Incidence of insect pests in groundnut field after spraying during the study period

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.3 Incidence of shoot infestation of groundnut

Shoot infestation occurred in different stage of groundnut plant. The infestation caused by aphid at different stages (early, mid and late) is presented below:

4.3.1 Shoot infestation at early stage

Number of healthy shoots, infested shoots and percent shoot infestation of groundnut caused by aphid showed statistically significant differences at early stage for different biorational pesticides (Table 8). The mean performance of the treatment having the common letter is identical and those having the different letter are statistically different from each other. In Table 8, the highest number of healthy shoot (22.50/plant) was observed in T_2 (Spinosad) treated plot having significant difference with other treatments and other treatments have intermediate number of healthy shoot. Treatment T_4 (15.82/plant) and T_1 (16.64/plant) showed poor results in increasing healthy shoot number. However, the lowest number of healthy shoot (14.19/plant) was found in control plot which was significantly lower than all other treated plots.

The lowest number of infested shoot (0.39/plant) was observed in T_2 (Spinosad) treated plot which is statistically different with T_6 treated plot (0.85/plant), T_7 treated plot (0.95/plant). Other treatments have intermediate number of infested shoot. T_4 (1.21/plant) showed poor results in reducing infested shoot number. However, the highest number of infested shoot (2.04/plant) was found in control plot which was significantly higher than all other treated plots.

The lowest percentage of infested shoot (1.78%) was observed in T_2 (Spinosad) treated plot which is statistically different with treatment T_6 treated plot (4.03%) and treatment T_7 treated plot (4.66%). Other treatments have intermediate percentage of infested shoot. Lufenuron treated plot, T_4 (7.63%) showed poor result in reducing infested shoot percentage. However, the highest percentage of infested shoot (14.42%) was found in control plot which was significantly higher than all other treated plots.

Similarly, T_2 (Spinosad) showed the best performance (87.68%) in reduction of infestation over control. Only treatment T_2 (Spinosad) gave the standard level of reduction (80%) of infestation over control. The results of the study revealed that all the treatments significantly reduced percentage of shoot infestation. However, Spinosad (T_2) was the most effective insecticide against shoot infestation at early stage and T_4 (Lufenuron) was poorly effective against shoot infestation by aphid.

The order of pesticidal effectiveness is $T_2>T_6>T_7>T_5>T_3>T_1>T_4$.

Table 8. Effect of different biorational pesticides on shoot infestation of groundnut caused by Aphid at early growth stage

Treatments	at Early stage			
	Healthy shoots	**Infested shoots**	**% Shoot infestation**	**% Reduction over control**
T_1	16.64 e	1.12 bc	6.71 bc	53.44
T_2	22.50 **a**	0.39 **e**	1.78 **g**	87.68
T_3	17.91 d	1.05 bcd	5.88 cd	59.26
T_4	15.82 e	1.21 b	7.63 b	47.12
T_5	19.45 c	1.04 bcd	5.37 df	62.75
T_6	21.01 b	0.85 d	4.03 f	72.06
T_7	20.41 bc	0.95 cd	4.66 ef	67.70
T_8	14.19 **f**	2.04 **a**	14.42 **a**	-
LSD(0.05)	1.0318	0.2045	1.1995	
CV (%)	3.19	10.80	10.86	

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.
[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.3.2 Shoot Infestation at mid stage

Number of healthy shoots, infested shoots and percent shoot infestation of groundnut caused by aphid showed statistically significant differences at mid stage for different biorational pesticides (Table 9). The mean performance of the treatment having the common letter is identical and those having the different letter are statistically different from each other. The highest number of healthy shoot (27.12/plant) was observed in T_2 (Spinosad) treated plot. Other treatments have intermediate number of healthy shoot. However, the lowest number of healthy shoot (19.19/plant) was found in control plot which was significantly lower than all other treated plots.

The lowest number of infested shoot (0.93/plant) was observed in T_2 (Spinosad) treated plot which is statistically different from all other treatments. Other pesticides have intermediate number of infested shoot. However, the highest number of infested shoot (3.34/plant) was found in control plot which was significantly higher than all other treated plots.

The lowest percentage of infested shoot (3.45%) was observed in T_2 (Spinosad) treated plot which is followed by treatment T_6 treated plot (4.40%). Other treatments have intermediate percentage of infested shoot. However, the highest percentage of infested shoot (17.40%) was found in control plot which was significantly higher than all other treated plots.

Similarly, T_2 (Spinosad) showed the best performance (80.20%) in reduction of infestation over control. Treatment T_4 showed poor results (46.03%) in reduction of infestation over control. Only treatment T_2 (Spinosad) gave the standard level of reduction (80%) of infestation over control. The results of the study revealed that all the insecticides significantly reduced percentage of shoot infestation.

However, Spinosad (T_2) was the most effective and T_4 (Lufenuron) was poorly effective against shoot infestation by aphid at mid stage.

The order of pesticidal effectiveness is $T_2>T_6>T_7>T_5>T_3>T_1>T_4$.

Table 9. Effect of different biorational pesticides on shoot infestation of groundnut caused by Aphid at mid growth stage

Treatments	at Mid stage			
	Healthy shoots	Infested shoots	% Shoot infestation	% Reduction over control
T_1	21.64 d	1.88 b	8.70 b	49.99
T_2	27.12 **a**	0.93 **f**	3.45 **f**	80.20
T_3	22.91 c	1.51 c	6.62 c	61.98
T_4	21.79 cd	2.05 b	9.39 b	46.03
T_5	24.46 b	1.33 d	5.44 d	68.74
T_6	25.34 b	1.11 e	4.40 ef	74.73
T_7	25.11 b	1.21 de	4.81 de	72.37
T_8	19.19 **e**	3.34 **a**	17.40 **a**	-
LSD(0.05)	1.1150	0.1731	0.9963	
CV (%)	2.72	5.92	7.56	

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.4.3 Shoot Infestation at late stage

Number of healthy shoots, infested shoots and percent shoot infestation of groundnut caused by aphid showed statistically significant differences at late stage for different biorational pesticides (Table 10). The highest number of healthy shoot (28.04/plant) was observed in T_2 (Spinosad) and T_6 (Lamda cyhalothrin + biotrin) treated plot (27.84/plant) which is followed by T_7 treated plot (25.61/plant) having significant differences among the treatments. Other insecticides have intermediate number of healthy shoot. Treatment T_4 (22.91/plant) showed poor results in increasing healthy shoot number. However, the lowest number of healthy shoot (21.82/plant) was found in control plot which was significantly lower than all other treated plots.

The lowest number of infested shoot (0.94/plant) was observed in T_2 (Spinosad) treated plot which is statistically different from T_6 treated plot (1.16/plant) and T_7 treated plot (1.44/plant). Other treatments have intermediate number of infested shoot. T_4 (3.04/plant) showed poor results in reducing infested shoot number. However, the highest number of infested shoot (4.44/plant) was found in control plot which was significantly higher than all other treated plots.

The lowest percentage of infested shoot (3.36%) was observed in T_2 (Spinosad) treated plot which is statistically identical with T_6 treated plot (4.18%), followed by treatment T_7 (5.62%). Other treatments have intermediate percentage of infested shoot. Lufenuron treated plot, T_4 (13.28%) showed poor results in reducing infested shoot percentage. However, the highest percentage of infested shoot (20.34%) was found in control plot which was significantly higher than all other treated plots.

Similarly, T_2 (Spinosad) showed the best performance (83.48%) in reduction of infestation over control. Treatment T_4 showed poor result (34.71%) in reduction of infestation over control. Only treatment T_2 (Spinosad) gave the standard level of reduction (80%) of infestation over control. The results of the study revealed that all the treatments significantly reduced percentage of shoot infestation.

However, Spinosad (T_2) was the most effective and T_4 (Lufenuron) was poorly effective against shoot infestation by aphid at late flowering stage.

The order of pesticidal effectiveness is $T_2 > T_6 > T_7 > T_5 > T_3 > T_1 > T_4$.

Table 10. Effect of different biorational pesticides on shoot infestation of groundnut caused by Aphid at Late growth stage

Treatments	at Late stage			
	Healthy shoots	Infested shoots	% Shoot infestation	% Reduction over control
T_1	23.56 cd	2.35 c	9.96 c	51.03
T_2	28.04 **a**	0.94 **g**	3.36 **g**	83.48
T_3	24.16 cd	2.16 c	8.93 d	56.09
T_4	22.91 de	3.04 b	13.28 b	34.71
T_5	24.89 bc	1.86 d	7.48 e	64.22
T_6	27.84 **a**	1.16 f	4.18 **g**	79.45
T_7	25.61 b	1.44 e	5.62 f	72.36
T_8	21.82 **e**	4.44 **a**	20.34 **a**	-
LSD(0.05)	1.4532	0.2184	.9872	
CV (%)	3.34	5.74	6.16	

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.
[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.4 Incidence of leaf infestation by Hairy Caterpillar at late stage

Incidence of hairy caterpillar occurred in early, mid and late stages of groundnut during the study period but symptom like the leaf infestation became visible only in late stage. Number of healthy leaves, infested leaves and percent leaves infestation of groundnut caused by hairy caterpillar showed statistically significant differences at late stage for different biorational pesticides (Table 11). The mean performance of the treatmenthaving the common letter is identical and those having the different letter are statisticallydifferent from each other. In Table 11, the highest number of healthy leaves (55.45/plant) was observed in T_2 (Spinosad), followed by T_7 treated plot (53.24/plant) having significant difference between them. Other treatments have intermediate number of healthy leaves. Treatment T_1 (49.39/plant) showed poor results in increasing healthy leaves number. However, the lowest number of healthy leaves (46.86/plant) was found in control plot which was significantly lower than all other treated plots.

The lowest number of infested leaves (0.81/plant) was observed in T_2 (Spinosad) treated plot which is statistically different from other treatments. T_1 (5.93/plant) showed poor results in reducing infested leaves number. However, the highest number of infested leaves (8.90/plant) was found in control plot which was significantly higher than all other treated plots.

The lowest percentage of infested leaves (1.45%) was observed in T_2 (Spinosad) treated plot which is statistically different from T_5 treated plot (3.68%). Other treatments have intermediate percentage of infested shoot. Neem seed kernel extract treated plot, T_1 (12.02%) showed poor result in reducing infested leaves percentage. However, the highest percentage of infested leaves (18.997%) was found in control plot which was significantly higher than all other treated plots.

Similarly, T_2 (Spinosad) showed the best performance (92.35%) in reduction of infestation over control. Treatment T_1 showed poor result (36.73%) in reduction of infestation over control. Treatment T_2 (Spinosad), T_7 (Actara + Ecomec 1.8 EC) and T_5 (Emamectin Benzoate) gave the standard level of reduction (80%) of infestation over control. The results of the study revealed that all the insecticides significantly reduced percentage of leaves infestation.

However, Spinosad (T_2) was the most effective insecticide against leaves infestation at late stage. Treatment T_1 (Neem seed kernel extract) was poorly effective against leaves infestation by hairy caterpillar at late stage.

The order of pesticidal effectiveness is $T_2>T_7>T_5>T_6>T_4>T_3>T_1$.

Table 11. Effect of different biorational pesticides on leaf infestation of groundnut caused by hairy caterpillar at Late growth stage

Treatments	Healthy leaf	Infested leaf	% leaf infestation	% Reduction over control
T_1	49.39 d	5.93 b	12.02 b	36.73
T_2	55.45 **a**	0.81 **g**	1.45 **g**	92.35
T_3	49.92 d	3.39 c	6.79 c	64.27
T_4	50.75 cd	3.04 d	5.98 d	68.50
T_5	52.69 b	1.94 e	3.68 e	80.61
T_6	51.76 bc	2.12 e	4.10 f	78.40
T_7	53.24 b	1.51 f	2.84 f	85.04
T_8	46.86 **e**	8.90 **a**	18.997 **a**	-
LSD(0.05)	1.7713	0.2834	0.6859	
CV (%)	1.97	4.68	5.61	

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.5 Effect of biorational pesticides on yield contributing parameters and yield of groundnut

4.5.1 Plant height (cm)

Incidence of insect pests on groundnut may stunt the growth and plant height. Plant height was significantly affected by the application of biorational pesticides (Table 12). Among the treatments, the tallest plant (44.39 cm) was observed in T_2 (Spinosad) treated plot which is statistically different from T_7 (Actara + Ecomec 1.8 EC) treated plot (42.83 cm). On the other hand, the shortest plant (24.53 cm) was recorded from the untreated control plot (T_8). Among the other biorational treatments, T_1 (Neem seed kernel extract) treated plot showed poor result in increasing plant height.

4.5.2 Branches per plant

Available insect pests on the study field infest the branches of groundnut plant. Application of different biorational pesticides showed statistically significant differences in terms of number of branches per plant of groundnut (Table 12). Among the treatments, the maximum branches (9.48/plant) was observed in T_2 (Spinosad) treated plot which is statistically different from T_7 (Actara + Ecomec 1.8 EC) treated plot (9.00/plant). On the other hand, the minimum branchces (4.58/plant) was recorded from the untreated control plot (T_8). Among the other biorational treatments, T_1 (Neem seed kernel extract) treated plot showed poor result (6.47/plant) in increasing plant height.

Table 12. Effect of different biorational pesticides on yield contributing parameters and yield of groundnut

Treatments	Plant height (cm)	Branches /plant	Weight of 100 Seeds (g)	Yield/plot (kg)	Yield (t/ha)
T_1	31.73 f	6.47 f	38.83 d	1.013 c	2.03 c
T_2	44.39 **a**	9.48 **a**	49.06 **a**	1.35 **a**	2.69 **a**
T_3	37.95 d	7.49 d	42.37 cd	1.15 bc	2.31 bc
T_4	35.67 e	7.00 e	40.03 d	1.12 bc	2.23 bc
T_5	39.15 d	7.53 d	45.03 bc	1.21 ab	2.43 ab
T_6	41.00 c	8.40 c	47.50 ab	1.27 ab	2.55 ab
T_7	42.83 b	9.00 b	48.13 ab	1.29 ab	2.58 ab
T_8	24.53 **g**	4.58 **g**	32.93 **e**	0.6567 **d**	1.31 **d**
LSD(0.05)	1.3951	0.3651	3.7435	0.1889	.3779
CV (%)	2.14	2.78	4.97	9.52	9.52

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05% level of probability.
[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.5.3 Number of total pod and abnormal pod

Treatments with biorational pesticides showed statistically significant differences in terms of pod number plant per plant of groundnut and number of abnormal pod per plant also varied in different treatments (Figure 3).

Among the treatments, maximum number of pod (22.17/plant) resulted from T_2 (Spinosad), followed by T_7 which is statistically identical with treatment T_2. Other treatments have intermediate result and treatment T_1 showed poor result in producing pod number. The minimum number of pod (11.20/plant) resulted from the untreated control plot (T_8).

In terms of abnormal pod, maximum abnormal pod (2.60/plant) resulted from the control plot. No abnormal pod was found at T_2 (Spinosad) treated plot. Other treatments have intermediate number of abnormal pod. Among the other treatments T_1 showed much abnormal pod.

This result is revealed that there was no abnormal pod on T_2 treated (Spinosad) plot and maximum number of pod per plant also resulted from it. Similar result was also observed by Gadad and Hegde (2014) who found highest pod yield recorded from spinosad treatment.

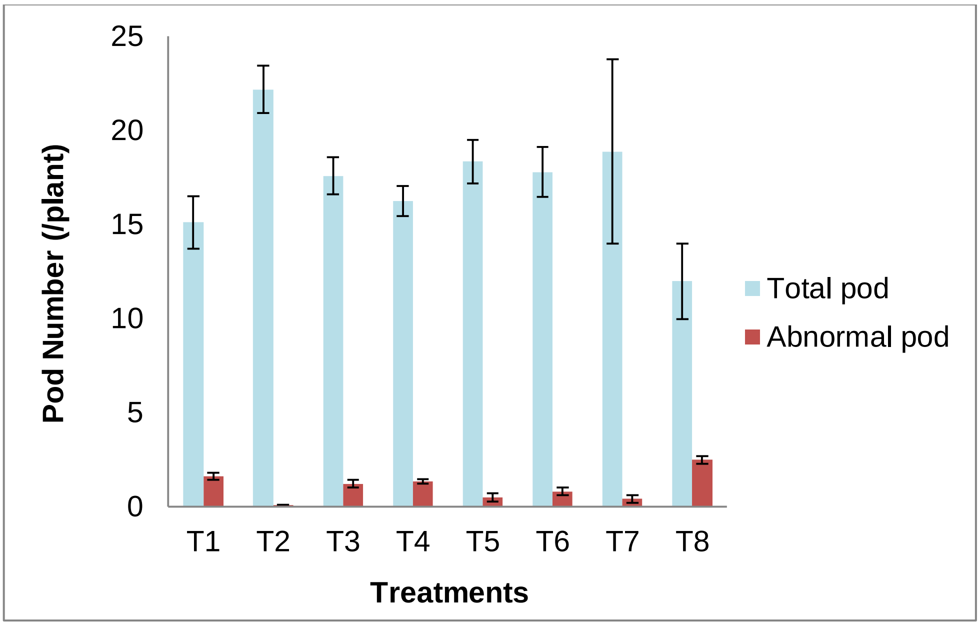


Figure 3. Effect of biorational pesticides on number of total pod and abnormal pod per plant of groundnut

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.5.4 100 seed weight (gm)

Table 12 showed 100 seed weight was significantly affected by the application of biorational pesticides on groundnut plant. Among the treatments, T_2 (Spinosad) produced the highest weight (49.06 gm) of seed which was statistically identical with T_7 (48.13 gm) and T_6 (47.50 gm) treated plot. On the other hand, the lowest (32.93 gm) was recorded in control or untreated treatment which was statistically different than all other treated plot. Rest of the treatments showed the statistically more or less similar results.

Treatment T_1 (Neem seed kernel extract) showed poor results (38.83 gm) which was statistically identical with T_4 (Lufenuron) treated plot(40.03 gm) in case of seed weight.

4.5.5 Yield per hactare (ton)

Yield was significantly affected by application of biorational pesticides against the incidence of insect pests on groundnut (Table 12). Among the treatments, treatment T_2 (Spinosad) produced the highest yield (2.69 t/ha) which was statistically identical with T_6 (2.55 t/ha), T_7 (2.58 t/ha) and T_5 (2.43 t/ha) treated plot. On the other hand, the lowest yield (1.31 t/ha) was recorded in untreated control treatment which was statistically different from all other treated plot. Rest of the treatments showed more or less similar results statistically.

4.6 Relationship between available insect population and yield

4.6.1Aphid population and yield

Regression analysis was done to establish the relationship between the available insect population of aphid at early, mid and late stages and yield of groundnut. Aphid population was considered as independent variable and yield of groundnut as a dependent variable.

Figure 4 showed that the regression equation $y = -0.085x + 1.742$ gave a good fit to the data and the co-efficient of regression ($R^2 = 0.720$) showed that, fitted regression line had a significant regression co-efficient. A strong negative relationship was found between the population number of aphid and yield of groundnut. 0.72% variation in yield can be explained by the presence of aphid population.

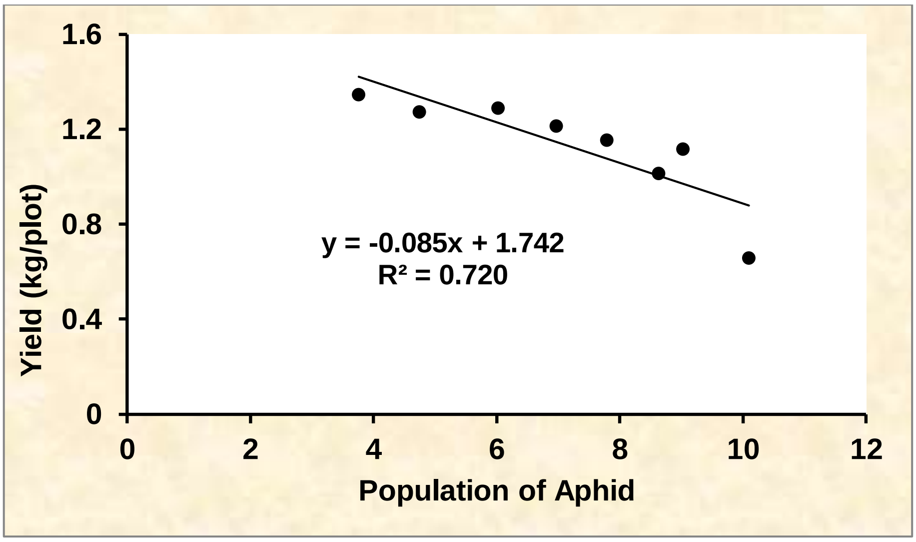


Figure 4. Relationship between aphid population and groundnut yield

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.6.2 Whitefly population and yield

Regression analysis was done to establish the relationship between the available insect population of whitefly at early, mid and late stages and yield of groundnut. Whitefly population was considered as independent variable and yield of groundnut as a dependent variable.

Figure 5 showed that the regression equation y = -0.090x + 1.667 gave a good fit to the data and the co-efficient of regression (R^2 = 0.766) showed that, fitted regression line had a significant regression co-efficient. A strong negative relationship was found between the population number of whitefly and yield of groundnut. 76.6% variation in yield can be explained by the presence of whitefly population.

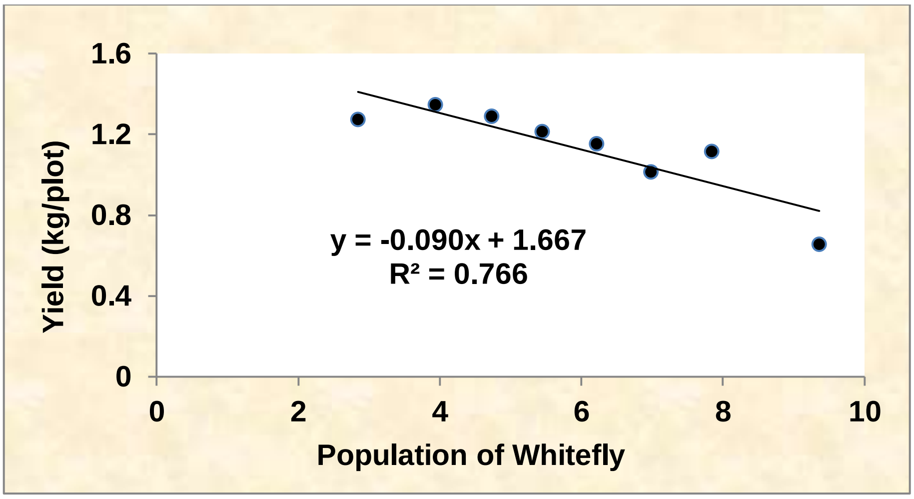


Figure 5. Relationship between whitefly population and groundnut yield

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.6.3 Hairy Caterpillar population and yield

Regression analysis was done to establish the relationship between the available insect population of hairy caterpillar at early, mid and late stages and yield of groundnut. Hairy caterpillar population was considered as independent variable and yield of groundnut as a dependent variable.

Figure 6 showed that the regression equation y = -0.095x + 1.425 gave a good fit to the data and the co-efficient of regression (R^2 = 0.873) showed that fitted regression line had a significant regression co-efficient. A strong negative relationship was found between the population number of hairy caterpillar and yield of groundnut. 87.3% variation in yield can be explained by the presence of hairy caterpillar population.

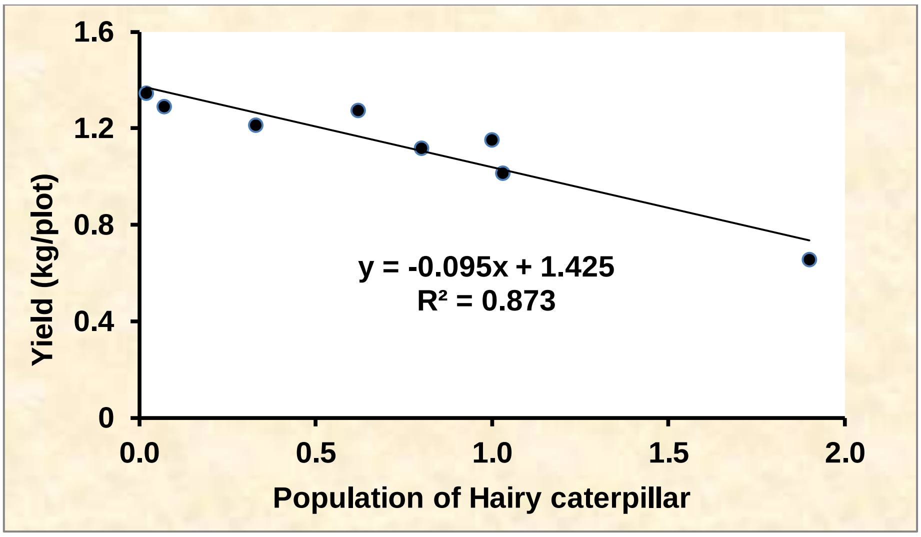


Figure 6. Relationship between hairy caterpillar population and groundnut yield

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.6.4 Thrips population and yield

Regression analysis was done to establish the relationship between the available insect population of thrips at early, mid and late stages and yield of groundnut. Thrips population was considered as independent variable and yield of groundnut as a dependent variable.

Figure 7 showed that the regression equation y = -0.117x + 1.568 gave a good fit to the data and the co-efficient of regression (R^2 = 0.794) showed that fitted regression line had a significant regression co-efficient. A strong negative relationship was found between the population number of thrips and yield of groundnut. 79.4% variation in yield can be explained by the presence of thrips population.

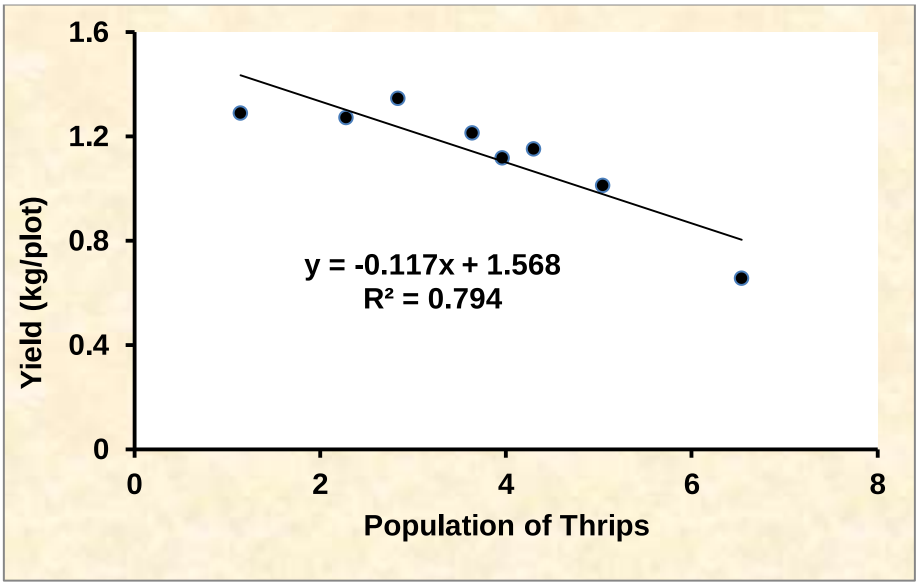


Figure 7. Relationship between thrips population and groundnut yield

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

4.6.5 Jassid population and yield

Regression analysis was done to establish the relationship between the available insect population of jassid at early, mid and late stages and yield of groundnut. Jassid population was considered as independent variable and yield of groundnut as a dependent variable.

Figure 8 showed that the regression equation y = -0.210 x + 1.383 gave a good fit to the data and the co-efficient of regression (R^2 = 0.800) showed that fitted regression line had a significant regression co-efficient. A strong negative relationship was found between the population number of jassid and yield of groundnut. 80% variation in yield can be explained by the presence of jassid population.

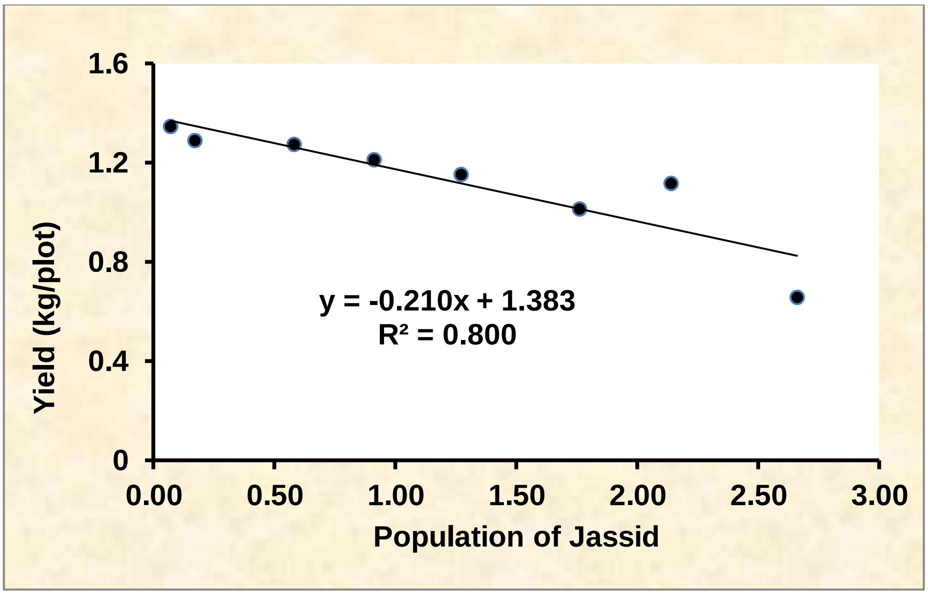


Figure 8. Relationship between jassid population and groundnut yield

[T_1 = Neem seed kernel extract @5 g/L of water; T_2 = Spinosad @ 0.5 mL/L of water; T_3 = Buprofezin @ 0.5 g/L of water; T_4 = Lufenuron @ 0.5 g/L of water; T_5 = Emamectin Benzoate @ 0.5 g/L of water; T_6= Lamda cyhalothrin @ 1mL/L of water + Biotrin @ 1mL/L of water; T_7 = Actara @ 0.5 g/L of water + Ecomec 1.8 EC @ 1mL/L of water and T_8= Untreated control]

CHAPTER V
SUMMARY AND CONCLUSION

SUMMARY

The experiment was conducted in the central field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from October, 2019 to March, 2020.

BARI Chinabadam-8 was used as the test crop for the experiment to evaluate the treatment on insect pests. The experiment comprised of eight treatments viz. T_1: Neem seed kernel @5 g/l of water, T_2: Spinosad @0.5ml/l of water, T_3: Buprofezin @0.2 g/l of water, T_4: Lufenuron @0.2g/l of water, T_5: Emamectin Benzoate @1.0 ml/l of water, T_6: Lamda cyhalothrin @1ml/l of water + biotrin @1ml/l, T_7: Actara @ 0.5g/l of water + Ecomec 1.8 EC @1 ml/l and T_8: Untreated control. Accessible population and infestation were caused by aphid, whitefly, hairy caterpillar, thrips and jassid. In untreated control plot, the order of observed available insect was Aphid> Whitefly > Thrips> Jassid> Hairy caterpillar.

All the treatments had significant effect against insect pests of groundnut. Spinosad showed best performance in term of reducing available aphid population and among the other treatments, Lufenuron showed poor performance. Similar effectiveness of Spinosad was identified in term of lowering hairy caterpillar population. In case of reducing aphid and hairy caterpillar population, Buprofezin and Neem seed kernel extract showed poor result. Lamda cyhalothrin with Biotrin was effective against the whitefly population and treatment Lufenuron showed poor performance to reducing the population.

Actara with Ecomec 1.8 EC showed best result in reducing thrips population and Neem seed kernel extract treated plot showed poor result.

The effectiveness of Spinosad and Actara with Ecomec statistically identical was best in term of reducing population of jassid.

Groundnut shoot infestation caused by aphid at early, mid and late stages was estimated. At early, mid and late flowering stage, Spinosad was the most effective and Lufenuron was poorly effective against shoot infestation by aphid and highest number of healthy shoot resulted from Spinosad treated plot.

Leaf infestation by hairy caterpillar noticed at late stage of groundnut and Spinosad showed best result in reduction of leaf infestation. Highest number of healthy leaf

resulted from Spinosad treated plot and in terms of reducing leaf infestation, treatment Neem seed kernel extract showed poor result among the treatments.

Spraying of biorational pesticides significantly influenced on growth characteristics of groundnut. The tallest plant (44.39 cm) was found from Spinosad treated plot and shortest plant height 24.53 cm resulted from the control plot. The maximum number of branch (9.48/plant) resulted from Spinosad treated plot whereas the mimimum number of branch (4.58/plant) resulted from control plot. Yield and yield contributing characters also showed significant difference due to the application of biorational treatments. However, Spinosad performed the greater results on whole yield and yield contributing characteristics viz. number of pod per plant (22.17), 100 seed weight (49.06 gm) and yield (2.69 t/ha). The minimum number of pod per plant (11.20), lowest 100 seed weight (32.93 gm) and lowest yield (1.31 t/ha) were obtained in control treatment.

Regression analysis between the available insect pests (Aphid, Whitefly, Hairy caterpillar, thrips and jassid) population and yield always established a strong negative relationship.

CONCLUSION

Aphid, White fly, Hairy caterpillar, Thrips and Jassid were the insect pests attacked the groundnut during the study period. It could be concluded that among the all biorational treatments, Spinosad showed the superior performance and in terms of whitefly and thrips population Lamda cyhalothrin + Biotrin and Actara + Ecomec 1.8 EC showed effective performance, respectively. Neem seed kernel extract and Lufenuron showed poor performance compared to other biorationals.

RECOMMENDATION

Before recommendation of usage of biorational pesticides for managing the insect pests of groundnut further study is needed in different agro-ecological zones of Bangladesh for regional adaptability.

REFERENCES

Abbott, W. S. (1925). A method of computing the effectiveness of an insecticide. *J. Econ. Entomol*. **18**(2): 265-267.

Abdullah, N., Majeed, I. and Oyeyi, T.I. (2011). Studies on efficacy of Vitellara paradoxa seed oil on the oviposition, hatchability of eggs and emergence of *Callasobruchus maculates* (F) (Coleoptera: Bruchidae) on treated cowpea. *Seed J. Entomol*. **8**: 391-397.

Anonymous. (1989). Textile Outlook International.The Economist Intelligence Unit, 40, Duke Street, London, U.K. pp. 3-4.

Awal, A., Rahman, M. M., Alam, M. Z. and Khan, M. M. H. (2017). Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Lepidoptera: crambidae) using some selected insecticides in field condition, Bangladesh. *Jahangirnagar University J. Biol. Sci.* **6**(1): 35-43.

BARI. (2019). Description of agricultural technology invented by BARI.**In:** Krishi Projukti Hatboi (Handbook on Agro-Technology), 8th edition Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. pp. 105-106.

BBS. (2020). Yearbook of Agricultural Statistics, 2019. 31st series. Statistics and Informatics Division(SID). Ministry of Planning, Government of the Peoples Republic of Bangladesh.

BBS. (2016). Yearbook of Agricultural Statistics, 2015. 27th series. Statistics and Informatics Division(SID). Ministry of Planning, Government of the Peoples Republic of Bangladesh.

Biswas, DR. G.C. (2015). Incidence, damage potential and management of jassids in groundnut field. *Bangladesh J. Agril. Rcs*. **40**(3): 507-512.

Biswas, G.C. (2014). Insect pest of groundnut (Arachis hypogaea L.), nature of damage and succession with the crop stages. *Bangladesh J. Agril. Rcs*. **39**(2): 273-282.

Biswas, G. C. and G. P. Das. (2011). Insect and mite pests diversity in the oilseed crops ecosystems in Bangladesh. *Bangladesh J. Zool*. **39**(2): 232-235.

Biswas, G.C., K.H. Kabir and R. Islam. (2009). Insect pest management of oilseed crops in Bangladesh: Problems and Prospects. pp.109-122. **In:** Advances in oilseed research in Bangladesh edited by M.A. Bakr and H. U. Ahmed. Proceedings of the National Workshop on Prospects and Development of Oilseed crops in Bangladesh and Future Challenges 29-30 April 2009.

DAE (Department of Agricultural Extension). (2019). Pest list of Bangladesh. Department of agriculture. Khamarbari,Dhaka.

Deng, Y., Wang, Y., Li, J. and Yang, L. (2002).A study on the insecticidal Activity of acotaniprid on insects.Department of Biology, Buangxi Normal University, Guilin, China. Southwest China. *J. Agril. Sci*. **15**(1): 50-53.

David, V.B. and Ramamurthy, V.V. (2011). Elements of economic entomology. Namrutha publications, Chennai, Tamin Nadu, pp. 385.

Dubey, N. K., R.Shukla, A. Kumar , P. Singh and B, Prakash. (2011). Global Scenario on the application of Natural Products in integrated pest management.**In:** Natural products in Plant Pest Management, Dubey, N. K., CABI, Oxfordshire, UK., ISBN : 9781845936716. pp. 1-20.

Dutta, N. K., Alam, S. N., Mahmudunnabi, M., Khatun, M. F. and Kwon, Y. J.(2016). Efficacy of some new generation insecticides and a botanical against mustard aphid and their toxicity to coccinellid predators and foraging honeybees. *Bangladesh J. Agril. Rcs*. **41**(4): 725-734.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People‘s Republic of Bangladesh. p. 118.

FAO. (1988). Production Year Book.Food and Agricultural Organization of the United Nations, Rome, Italy. **42**: 190-193.

Farajallah, A. (2013). Effect of chemical and botanical insecticides on thrips and yield of mungbean.*Indonesian J. Agric*. **6**(2): 87-92.

Feng, W. and Zheng, X. (2007). Essential oil to control *Alternaria alternaria* in vitro and in vivo . *Food Control*. **18**: 1126- 1130.

Gadad, Hanamant and Hegde, Mahabaleshwar. (2014). Evaluation of biopesticides and biorationals against thrips and leafminer in rabi/summer groundnut.*Rcs. Reviews*: *J. Agric. Allied Sci*. **3**: 25-31.

Gomez, K.A. and Gomez, A.A. (1984).Statistical procedures for Agricultural Research.Second Edition.A Wiley Interscience Publications Jhon Wiley and Sons, New York, Chichester, Torento, Singapore.p. 680.

Gosh, SK. (2020). Aphid (Aphis craccivora Koch.)Management on groundnut crop (*Arachis hypogaea*) by using bio-pesticides.*Int. J. Curr. Microbiol. App. Sci.* **9**(10): 24-34.

Islam, M. (1999).Integrated pests (insects) management of vegetables.Consultancy Report.AVRDC-USAID Bangladesh Project.HRC. BARI, Joydebpur, Gazipur.

Isman, M. B. and Y. Akhtar. (2007). Plant Natural Products as a Source for Developing Environmentally Acceptable Insecticides. **In:** Insecticides Design Using Advanced Technologoes. Shaaya , I., Nauen, R. and Horowitz, A.R. (eds.). Springer, Berlin, Heidelberg.pp. 235- 248.

Iversen, Trine and Harding, Susanne. (2007). Life table parameters affecting the population development of the woolly beech aphid, *Phyllaphis fagi.Entomologia Experimentalis et Applicata.***123**: 109 - 117.

Javed, H., Iqbal, J., and Mateen, Z. (2014). Response of different cultivars of groundnut, Aarachis hypogaea L.(Fabaceae: Fabales) to aphids, *Aphis craccivora* K.(Aphididae: Homoptera) in interaction with local weather factors. *Pakistan J. Zool.* **46**(1): 75-81.

Johnson, F. A., Short, D. E. and Castner, J. L. (2005). Entomology and Nematology Department special publication 90 (revised ed.). Gainesville, Florida: Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Kaul, A. K. and Das, M. L. (1986).Oilseeds in Bangladesh.Bangladesh Canada Agriculture Sector Team.Ministry of Agriculture, Govt. of the People‟s Republic of Bangladesh, Dhaka.324 P.

Kazemi, M.H., Talebi-Chaichi, P., Shakiba, M.R. and Mashhadi-Jafarlou, M. (2001). Evaluation of susceptibility to Russian wheat aphid, *Diuraphisnoxia* (Homoptera: Aphididae) in several wheat cultivars at stem elongation growth stage. *Iranian J. Agril. Sci*. **11**(2): 103-111.

Khalid, Ahmed and Prasad, NVVSD.(2009). Efficacy of emamectin benzoate 5% SG against thrips, *Scritothrips dorsalis* Hood and pod borer, *Spodoptera litura* Fab.on chillies. *Pestology*. **33**: 22-25.

Khater, H. F. (2011). Ecosmart Biorational Insecticides: Alternative Insect Control Strategies .**In:** Insecticides. F. Perveen, (ed.). In Tech, Rijeka, Croatia, ISBN 979-953-307-667-5.

Kobro, Sverre (2011). *Norwegian J. Entomol*.**58**: 21–26. Retrieved October 25, 2014.

Kumar, D.A. and Krishnaynya, P.V. (1999). Effect of diflubenzuron in combination with selected insecticides on major lepidopteran pests of groundnut, *Arachis hypogaea* L. *J. Appl. Zool. Rcs.***10**(1): 1-5.

Marcic, D., Prijovic, M., Drobnjakovic, T., Medo, I., Peric, P. and Milenkovic, S. (2012). Greenhouse and field evaluation of two biopesticides against *Tetranychus urticae* and *Panonychus ulmi* (Acari: Tetranychidae). *Pesticide Phytomed*.**27**(2): 313–320.

Panduranga, G. S., Vijayalakshmi, K. and Reddy, K. L. (2011). Evaluation of insecticides for management of Bemisia tabaci and MYMV disease in mungbean [*Vigna radiata* (L.) Wilczek]. *Annal. Plant Protec. Sci.* **19**(2): 295-298.

Rahman, Md. Mezbah Ur. (2017). Study on biology and effectiveness of some chemical insecticides against jute hairy caterpillar, *Spilosoma Obliqua* (Walker). M.S.thesis. Dept. of Entomology. Sher-e-Bangla Agricultural University, Dhaka-1207.

Ramaprasad, G., Rao, S.N. and Joshi, B.G. (1993).Relative efficacy of synthetic pyrethroids and some other insecticides against *Spodoptera litura* on Tobacco.*Indian J. Plant Protect.* **21**(2): 201-204.

Ranganathan, Muthusamy. (2012). Baseline susceptibility of five classes of insecticides on bihar hairy caterpillar *Spilosoma oblique* (Walk.) (Lepidoptera: Arctiidae). *Resistant Pest Management Newsletter.* **21**: 8-11.

Reddy, P. Parvatha.(2016). Sustainable Crop Protection under Protected Cultivation.Indian Institute of Horticultural Research Bangalore, India. pp. 99-108.

Saleem, M.S., Batool, T.S., Akbar, M.F., Raza, S. and Shahzad, S. (2019). Efficiency of botanical pesticides against some pests infesting hydroponic cucumber, cultivated under greenhouse conditions. *Egypt J. Biol. Pest Control.* **29**: 37.

Selvaraj, K., Gotyal, B.S., Satpathy, S. and Ramasubramanian, T. (2015). "First Record of *Protapanteles obliquae* (Wilkinson) (Braconidae: Hymenoptera) on *Spilosoma oblique* Walker on jute crop". *J. Biol. Control*. **29**(3): 169–170.

Sheirdil, R. A., Mahmood, A., Khan, R. U., Khalid, R. and Amara, U. (2012). Groundnut; a crop for subsistence in edible oil production in Pakistan. **In**: Agrihunt. Retrieved October, 30, 2013.

Shelton, AM., Plate, J. and Chen , M. (2008). Advances in Control of Onion Thrips Thysanoptera: Thripidae) in Cabbage. *J. Econ. Entomol*. **101**(2): 438-443.

Solanki, R.D. and Jha, S. (2018). Population dynamics and biology of whitefly (*Bemisia tabaci* Gennadius) on sunflower (*Helianthus annuus* L.). *J. Pharmacogn. Phytochem*. **7**(1): 3055–3058.

Sreekanth, M., Babu, T.R., Sultan, M.A. and Rao, B.N (2000).Evaluation of certain new insecticides against lepidopteran pests of cabbage.Department of Entomology, College of Agriculture, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, *India.Intl. Pest Contrl*. **42**(4): 134-137.

Thakoor, P., Ghosh, S. K., Nihal, R. and Ramya Sri, N. (2019).Effect of abiotic factors on seasonal incidence and bioefficacy of some newer insecticides against aphid (Aphis gossypii) in tomato.*J. Entomol. Zool. studies*. **7**(3): 513-516.

Ulaganathan, P. and Gupta, GP. (2004). Effect of insecticidal spray on sucking pests of American cotton *Gossypium hirsutum*. *Annals. Plant. Protect. Sci*. **12**(2): 283-287.

UNDP. (1988). Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome. pp. 212, 577.

USDA. (U.S. Department of Agriculture, Agricultural Research Service). (2019). Food Data Central, 2019. fdc.nal.usda.gov.

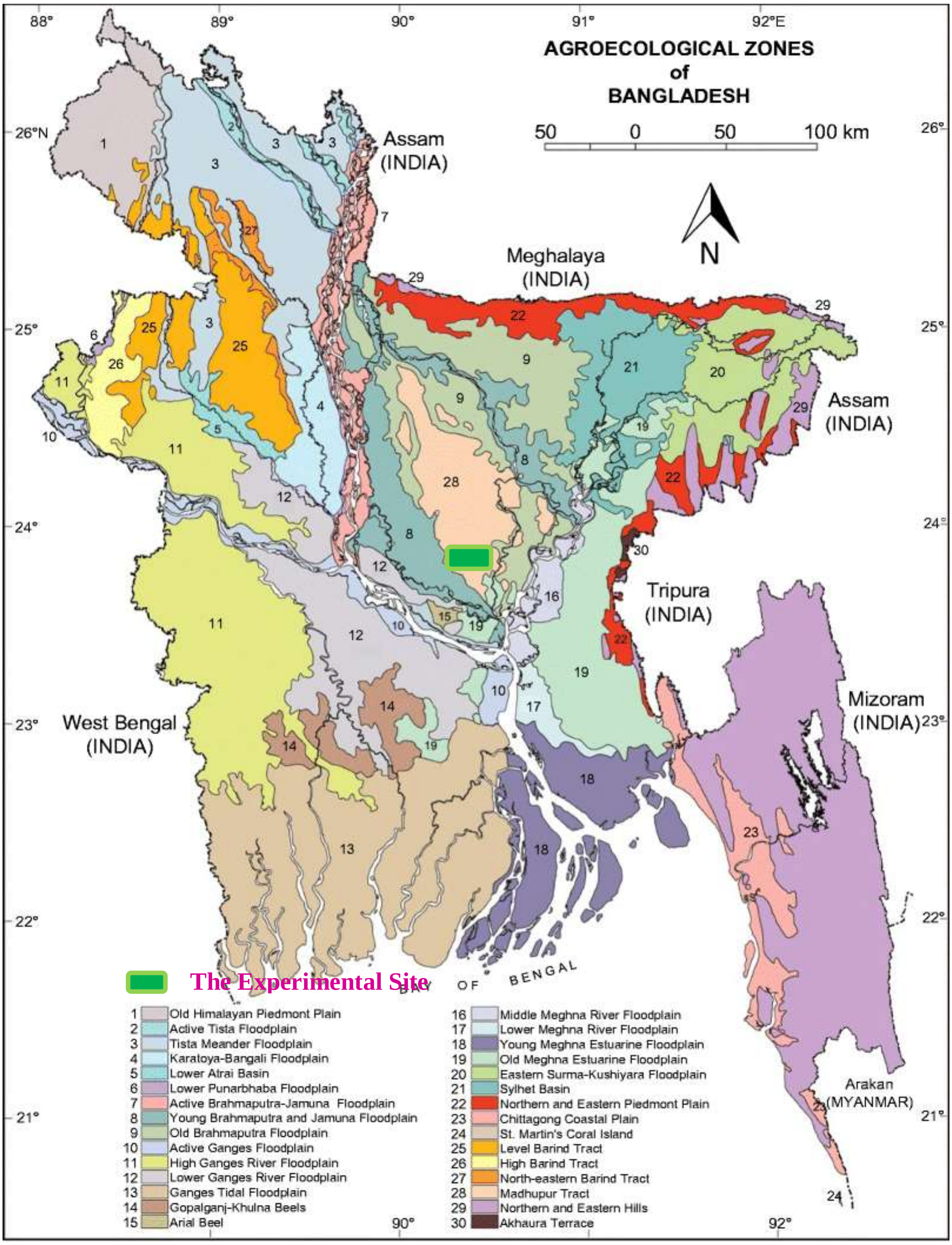
Vanisree, K., Upendhar, S., Rajasekhar, P. and Rao, G Ramachandra . (2017). Effect of newer insecticides against chilli thrips, *Scirtothrips dorsalis* (Hood).*J. Entomol. Zool. Stud.* **5**(2): 277-284.

Willett, W., Rockstrom, J., Loken, B., Springmann, M., Lang, T., and Vermeulen, S. (2019). Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet*. **393**(10170): 447–492.

Yasmin, S., Latif, M. A., Ali, M. and Rahman, M. M. (2020).Management of thrips infesting mungbean using pesticides. *SAARC J. Agri.* **17**(2): 45-52.

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly average air temperature, relative humidity and rainfall during the period from October 2019 to April 2020 at Sher-e-Bangla Agricultural University campus

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	**October**	30.42	16.24	23.33	68.48	52.60
2019	**November**	28.60	8.52	18.56	56.75	14.40
2019	**December**	25.50	6.70	16.10	54.80	0.0
2020	**January**	23.80	11.70	17.75	46.20	0.0
2020	**February**	22.75	14.26	18.51	37.90	0.0
2020	**March**	35.20	21.00	28.10	52.44	20.4
2020	**April**	34.70	24.60	29.65	65.40	165.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agro-ecological Zone	Madhupur Tract
PH	5.47 – 5.63
Organic matter	0.82
Total N (%)	0.43
Available phosphorous	22 ppm
Exchangeable K	0.42 meq / 100 g soil

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Analysis of variance on Aphid population at different growth stages of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean Square		
		Aphid		
		Early	Mid	Late
Replication	2	0.00258	0.1356	0.1712
Treatment	7	9.44013**	20.8616**	14.4278**
Error	14	0.00641	0.0618	0.3386

**Significant at 1% level of probability

Appendix V. Analysis of variance on whitefly population at different growth stages of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean Square		
		Whitefly		
		Early	Mid	Late
Replication	2	0.02618	0.1343	0.0882
Treatment	7	9.39083**	12.3365**	20.9628**
Error	14	0.03640	0.0791	0.2758

**Significant at 1% level of probability

Appendix VI. Analysis of variance on Hairy caterpillar population at different growth stages of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean Square		
		Hairy caterpillar		
		Early	Mid	Late
Replication	2	0.01065	0.03401	0.02446
Treatment	7	0.89850**	1.16153**	1.35064**
Error	14	0.00326	0.00640	0.01115

**Significant at 1% level of probability

Appendix VII. Analysis of variance on Thrips population at different growth stages of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean Square		
		Thrips		
		Early	Mid	Late
Replication	2	0.03770	0.03363	0.8396
Treatment	7	2.73479**	9.39476**	16.4211**
Error	14	0.02645	0.03764	0.1435

**Significant at 1% level of probability

Appendix VIII. Analysis of variance on Jassid population at different growth stages of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean Square		
		Jassid		
		Early	Mid	Late
Replication	2	0.03293	0.00138	0.00184
Treatment	7	1.21923**	3.66167**	3.51505**
Error	14	0.00845	0.01500	0.01265

**Significant at 1% level of probability

Appendix IX. Analysis of variance on shoot infestation by Aphid at early growth stage of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean square		
		Early		
		Healthy shoot	Infested shoot	% Shoot infestation
Replication	2	0.4179	0.01715	0.4313
Treatments	7	24.1831**	0.63878**	41.6594**
Error	14	0.3471	0.01364	0.4692

**Significant at 1% level of probability

Appendix X. Analysis of variance on shoot infestation by Aphid at mid growth stage of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean square		
		Mid		
		Healthy shoot	Infested shoot	% Shoot infestation
Replication	2	0.9823	0.00762	0.3209
treatments	7	19.3865**	1.78823**	60.6071**
error	14	0.4054	0.00977	0.3237

**Significant at 1% level of probability

Appendix XI. Analysis of variance on shoot infestation by Aphid at late growth stage of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean square		
		Late		
		Healthy shoot	Infested shoot	% Shoot infestation
Replication	2	0.3088	0.00528	0.1122
treatments	7	14.9064**	3.89184**	92.7361**
error	14	0.6886	0.01555	0.3178

**Significant at 1% level of probability

Appendix XII. Analysis of variance on leaf infestation by Hairy caterpillar at late growth stage of groundnut influenced by different biorational pesticides

Source of variation	Degrees of freedom	Mean square		
		Hairy caterpillar		
		Healthy leaf	Infested leaf	% Leaf infestation
Replication	2	0.9011	0.0136	0.045
treatment	7	20.8662**	21.7576**	101.832**
Error	14	1.0231	0.0262	0.153

**Significant at 1% level of probability

Appendix XIII. Analysis of variance on yield contributing parameters and yield of groundnut under different biorational pesticides

Source of variation	Degrees of freedom	Mean square			
		Plant height	Branches/plant	Weight of 100 seed	Yield/plot (Kg)
Replication	2	1.796	0.04133	1.0022	0.10875
Treatment	7	126.388**	7.19400**	92.2793**	0.14500**
Error	14	0.635	0.04347	4.5696	0.01164

**Significant at 1% level of probability

Appendix XIV. Analysis of variance on number of pod and abnormal pod per plant of groundnut under different biorational pesticides

Source of variation	Degrees of freedom	Mean square	
		Pod per plant	**Abnormal pod per plant**
Replication	2	4.8029	0.06167
Treatment	**7**	30.2199	1.90762
Error	14	4.5082	0.02548

**Significant at 1% level of probability