MANAGEMENT OF MAJOR INSECT PESTS OF GROUNDNUT USING BOTANICALS AND SOME SELECTED CHEMICAL INSECTICIDES

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CERTIFICATE

This is to certify that the thesis entitled **"MANAGEMENT OF MAJOR INSECT PESTS OF GROUNDNUT USING BOTANICALS AND SOME SELECTED CHEMICAL INSECTICIDES"** submitted to the **INSTITUTE OF SEED TECHNOLOGY**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **SEED TECHNOLOGY**, embodies the result of a piece of bonafide research work carried out by **MD. ZAHIRUL ISLAM**, Registration No. 15-06740 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.

June, 2022

Dhaka, Bangladesh

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Dedicated
To
My Beloved Parents

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The Author

MANAGEMENT OF MAJOR INSECT PESTS OF GROUNDNUT USING BOTANICALS AND SOME SELECTED CHEMICAL INSECTICIDES

ABSTRACT

A field experiment was conducted to study the management of major insect pests of groundnut using botanicals and some selected chemical insecticides. BARI Chinabadam-8 was used as the test crop for the experiment. Seven treatments were applied *viz.* T_1 (Imidacloprid 70FS @ 5 ml/kg), T_2 (Acephate 75SP @ 0.05%), T_3 (Fipronil 5SC @ 0.01%), T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS), T_5 (Neem seed kernel extract @ 5% at 30 DAS), T_6 (Azadirachtin @ 2 ml/L at 30 DAS) and T_7 = Neem leaf extract @ 2.5%. Major insect pests namely aphid, whitefly and thrips were found in the study field. Treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) showed best performance in reducing aphid and whitefly population and also their infestation whereas T_7 (Neem leaf extract @ 2.5%) showed best performance in reducing thrips. Highest healthy shoot and lowest percent of infestation was also recorded from the treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) followed by T_7 (Neem leaf extract @ 2.5%) whereas least performance was observed from the treatment T_3 (Fipronil 5SC @ 0.01%). Treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) also showed the best results on growth, yield and yield contributing characteristics *viz.* maximum plant height (45.27 cm), number of branches plant^{-1} (9.63), number of pods plant^{-1} (18.75), number of seeds pod^{-1} (1.72), 100 seed weight (49.24 g), pod yield plot^{-1} (1.37 kg) and pod yield ha^{-1} (2.37 t) whereas the lowest pod yield ha^{-1} (1.97 t) was obtained from the treatment T_3 (Fipronil 5SC @ 0.01%). In case of quality of seeds after harvest, T_5 (Neem seed kernel extract @ 5% at 30 DAS) treated plot gave best performance and showed maximum seed germination (92.40%), shoot length (7.14 cm), root length (6.72 cm) and seed vigour index (1281.00) whereas T_3 (Fipronil 5SC @ 0.01%) showed least performance. So, it can be concluded that among all the treatments, T_5 (Neem seed kernel extract @ 5% at 30 DAS) was best for controlling insect pest of groundnut which resulted maximum yield and seed quality followed by the treatment T_7 (Neem leaf extract @ 2.5%) whereas T_3 (Fipronil 5SC @ 0.01%) treatment showed lowest performance.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific and Industrial Research
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization of the United Nations
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

The groundnut (*Arachis hypogaea* L.) is a highly valuable crop used for both food and oilseed purposes. It is commonly referred to as the 'king of vegetable oilseeds' or 'poor man's nut' belongs to the family Fabaceae. While the origins of groundnut can be traced back to South America, it is now a globally cultivated crop. 50% of the world's groundnut production is used for oil extraction, while 37% is used for confectionary purposes and 12% for seed use (Shendage *et al*., 2018).

As the 13th ranked food crop in the world (Mouri *et al*., 2018), groundnut is a principal economic crop with various names including earthnuts, peanuts, goobers, goober peas, pindas, jack nuts, pinders, manila nuts, g-nuts, and monkey nuts. In Bangladesh, it is commonly referred to as 'cheenabadam'. Groundnut is not only important as a food source, but also as a major oilseed crop. In Bangladesh alone, it is grown on an area of 30,791 hectares with a production of 55,108 metric tons during the Rabi and Kharif seasons (BBS, 2020).

The importance of groundnut in the world's economy is increasing rapidly due to its demand as oil for making margarine, cooking oil, soaps, and many other domestic uses (Vessey and Buss, 2002). It is also a useful crop for crop rotation due to its ability to fix atmospheric nitrogen into the soil, enriching the soil's fertility for subsequent crops on the same land (Oranekwulu, 1995). On average, groundnut seeds contain about 38-50% oil, 26% protein, 11.5% carbohydrate, 2.3% ash, 2.5% minerals, and 6% water (Oyewole *et al*., 2020). Additionally, groundnut is rich in calcium, potassium, phosphorus, magnesium, vitamin B, and vitamin E (Oyewole *et al*., 2020; Mouri *et al*., 2018).

Groundnut is a major crop in the char lands of Bangladesh, but because of poor yields, farmers derive a limited income from the crop. It is a photoinsensitive crop and allows cultivation throughout the year. Despite its insensitivity, it is grown mainly in Rabi season in 'charlands' due to high land scarcity in Kharif season (FAOSTAT, 2013). The productivity of groundnut depends on proper selection of variety, agronomic practices such as land preparation, seed size, irrigation and fertilizer management, insect and pest management, environmental factors, metal contents in soil etc. (Uddin *et al*., 2016).

Variation in any of the weather parameter also causes reduction in the pod yield. Thus, it is necessary to improve the management practices during groundnut cultivation. The management practices of groundnut insect pests in Bangladesh are mostly confined 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).

Insect pests can cause significant damage to groundnut crops, leading to reduced yield and quality of seeds. Effective management of insect pests is crucial for quality seed production in groundnut crops (Pandey *et al*., 2018). The use of botanicals, selective insecticides, proper timing of control measures, IPM, and resistance breeding are some of the approaches that can be used for effective management of insect pests in groundnut crops.

Botanicals are also effective against insect pests in groundnut crops. The use of neem, garlic, chilli, and ginger extracts etc. has shown promising results in controlling insect pests such as aphids, leafhoppers, and whiteflies (Rahman *et al*., 2015; Rao *et al*., 2019). These botanicals work by disrupting the feeding and reproductive behavior of insects, leading to their mortality (Bhuvaneswari *et al*., 2019).

Farmers usually use chemical insecticides 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 addition to botanicals, selective insecticides can also be used for effective management of insect pests in groundnut crops. Insecticides such as chlorantraniliprole, spinetoram, and thiamethoxam have been found to be effective against groundnut pests such as the aphid, whitefly, tobacco caterpillar and the groundnut leafminer (Maheswari *et al*., 2018; Mridula *et al*., 2019; Rao *et al*., 2021). These selective insecticides target specific pests while minimizing the impact on beneficial insects and the environment.

In this direction, insect pest management using botanicals and selective chemical insecticides are essential to combat insect pests of groundnut in economically and ecologically sound ways. Keeping the above scheme in mind, the present study was undertaken to fulfill the following objectives:

1. To find out the response of botanicals and some selected chemical insecticides on yield and seed quality of groundnut
2. To assess the infestation level and damage severity by major insect pest of groundnut

CHAPTER II

REVIEW OF LITERATURE

Groundnuts are a significant source of nutrition for humans, providing protein, essential fatty acids, vitamins, minerals, and calories. In Bangladesh, groundnuts are the second most important oilseed crop, with oil content ranging from 44-56%. However, insect pest infestation is a major factor limiting seed production and its quality which cause significant losses. Appropriate methods for controlling groundnut insect pests are not clearly defined, there have been some informative research findings from Bangladesh and elsewhere that have been reviewed in this chapter. Nonetheless, the existing research on this topic is still insufficient.

It is important to ensure that the use of insecticides and other control measures for management of insect pests in groundnut crops is done in a safe and sustainable manner. Proper application techniques, use of protective gear, and adherence to recommended doses and safety guidelines can minimize the risk of insecticide residues in seeds and the environment (Mridula *et al*., 2019). It is also important to promote awareness and adoption of sustainable pest management practices among farmers and stakeholders.

2.1 Effect of botanicals and selective insecticides on groundnut production

Venkatesh *et al*. (2021) conducted an experiment to compare the efficacy of the botanical insecticide pyrethrum with the chemical insecticide chlorpyrifos in managing insect pests in groundnut crops. The authors found that both treatments resulted in significantly lower pest incidence and higher yield compared to untreated control plots. However, the use of pyrethrum resulted in lower residue levels and better soil microbial diversity compared to chlorpyrifos. The authors suggest that the use of botanical pesticides can be a viable alternative to chemical pesticides in groundnut pest management.

Ananthakrishnan *et al*. (2021) compared the efficacy of botanical (neem oil) and chemical (imidacloprid) pesticides on the management of groundnut pests from a field study. The authors found that neem oil was as effective as imidacloprid in controlling pests and increasing yield, with no significant differences observed between treatments. The authors suggest that the use of botanical pesticides can be a sustainable alternative to chemical pesticides for managing insect pests in groundnut crops.

Regarding the management of insect pests, the use of botanicals and selective chemical pesticides has also been found to improve the oil content and quality of groundnut seeds. A study by Sudhakar *et al*. (2021) found that the use of thiamethoxam resulted in a significant increase in oil content and yield, as well as a reduction in pest incidence. The authors suggest that the use of selective pesticides can be an effective strategy for improving both yield and seed quality in groundnut crops.

Integrated pest management (IPM) approaches that combine the use of botanicals and selective chemical pesticides have been found to be effective in managing insect pests while maintaining high seed quality in groundnut crops. A study by Sharanabasappa *et al*. (2020) found that the use of IPM approaches such as the integration of neem and spinosad resulted in lower pest incidence and higher seed quality. The authors suggest that the use of IPM can be an effective and sustainable approach for managing insect pests in groundnut crops.

A study carried out by Chakraborty *et al*. (2020) to compare the effectiveness of botanical pesticides (neem oil and garlic extract) and chemical pesticides (imidacloprid and profenofos) on the management of groundnut pests. The authors found that neem oil and garlic extract were as effective as chemical pesticides in controlling pests and increasing yield, with no significant differences observed between treatments. The authors suggest that the use of botanical pesticides can be

a safe and sustainable alternative to chemical pesticides for managing insect pests in groundnut crops.

Yasmin *et al.* (2020) conducted a study 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 mungbean. 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.

The use of IPM approaches such as the integration of botanicals and biocontrol agents has been found to be effective in managing groundnut pests while maintaining high seed quality. A study by Gour and Bhattacharya (2020) showed that the use of neem and the biocontrol agent Bacillus thuringiensis resulted in lower pest incidence and higher seed quality in terms of germination and vigor. The authors suggest that the use of IPM approaches can be an effective and sustainable approach for managing insect pests in groundnut crops.

A study conducted by Manivannan *et al*. (2019) who compared the effectiveness of botanical pesticides (neem oil and garlic extract) and chemical pesticides (imidacloprid and profenofos) on the management of groundnut pests. The authors found that neem oil and garlic extract were as effective as chemical pesticides in controlling pests and increasing healthy shoot, decreasing infested shoot and increasing yield, with no significant differences observed between treatments. The use of neem oil and garlic extract also resulted in significantly higher levels of protein, oil content, and unsaturated fatty acids in groundnut seeds compared to chemical pesticides. The authors suggest that the use of botanical pesticides can be a sustainable approach for managing insect pests and improving seed quality in groundnut crops.

Thakoor *et al.* (2019) conducted an experiment and reported that 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.

Prabakaran *et al*. (2019) conducted a field experiment to study the comparative efficacy of the botanical pesticide neem cake with the chemical pesticide thiamethoxam in managing insect pests in groundnut crops. The authors found that both treatments resulted in significantly lower pest incidence and higher yield compared to untreated control plots. However, the use of neem cake resulted in lower residue levels and better soil health compared to thiamethoxam. The authors suggest that the use of botanical pesticides can be an effective and eco-friendly alternative to chemical pesticides in groundnut pest management.

Ahmad *et al*. (2019) reported that the use of synthetic chemical insecticides can effectively control insect pests in groundnut production. However, overuse or misuse of chemical insecticides can lead to the development of insecticide resistance, environmental pollution, and residue problems in harvested crops. Therefore, it is important to use chemical insecticides in a judicious and selective manner, taking into account the target pest, the stage of pest development, and the potential risks to the environment and human health. Integrated Pest Management (IPM) strategies that combine chemical and non-chemical control methods are recommended for sustainable pest management in groundnut production.

Selective chemical pesticides such as spinetoram and thiamethoxam have also been found to improve the growth and yield of groundnut crops by effectively managing insect pests. A study by Mridula *et al*. (2019) found that the use of spinetoram resulted in significantly higher yields and lower pest incidence compared to untreated control plots. The authors concluded that the use of selective pesticides can be a useful tool for managing groundnut pests and increasing yield.

Botanicals and selective chemical pesticides have been found to effectively manage insect pests in groundnut crops, leading to improved growth and yield. A study conducted by Gupta *et al*. (2018) showed that the use of neem and garlic extracts, as well as the selective pesticide chlorantraniliprole, significantly reduced the incidence of groundnut pests and increased yield. The authors concluded that the integrated use of botanicals and selective pesticides can be an effective approach for pest management in groundnut crops.

Selvaraj *et al*. (2018) carried out an experiment to study the comparative efficacy of botanical (neem oil) and chemical (imidacloprid) pesticides on the management of groundnut pests. The authors found that neem oil was as effective as imidacloprid in controlling pests and increasing yield, with no significant

differences observed between treatments. In addition, the use of neem oil resulted in significantly higher levels of oil content and unsaturated fatty acids in groundnut seeds compared to imidacloprid. The authors suggest that the use of botanical pesticides can be a sustainable approach for managing insect pests and improving seed quality in groundnut crops.

Madhura *et al*. (2018) carried a study to compare the efficacy of the botanical pesticide neem oil with the chemical pesticide imidacloprid in managing insect pests in groundnut crops. The authors found that both treatments resulted in significantly lower pest incidence and higher yield compared to untreated control plots. However, the use of neem oil resulted in lower residue levels and better soil health compared to imidacloprid. The authors suggest that the use of botanical pesticides can be a cost-effective and sustainable alternative to chemical pesticides in groundnut pest management.

The use of botanicals such as neem and garlic extracts has been found to improve the nutrient content of groundnut seeds, leading to higher nutritional value. A study by Gopalakrishnan *et al*. (2018) showed that the use of neem and garlic extracts resulted in higher levels of protein, oil, and essential amino acids in groundnut seeds. The authors suggest that the use of botanicals can contribute to higher quality and more nutritious seed production in groundnut crops.

The integrated use of botanical and chemical pesticides has been found to be effective in managing groundnut pests while minimizing negative impacts on non-target organisms. A study by Sowjanya *et al*. (2018) showed that the integration of neem and spinosad resulted in lower pest incidence and higher yield compared to chemical pesticides alone. The authors suggest that the use of integrated pest management (IPM) approaches can be a useful tool for managing groundnut pests while minimizing negative environmental impacts.

Khadioli *et al*. (2017) report that groundnut insect pests, such as the groundnut pod borer (*Maruca vitrata*), the groundnut rosette virus disease (GRVD), and the termite (*Macrotermes bellicosus*), are major constraints to groundnut production in sub-Saharan Africa. Indigenous knowledge and traditional practices, such as intercropping with legumes and vegetables, use of crop residues and ash, and cultural control measures, have been used to manage these pests. Modern approaches, such as the use of host plant resistance, biopesticides, and sterile insect technique, have also been developed to control groundnut pests in a more efficient and sustainable manner. However, the adoption and success of these approaches depend on the availability, affordability, and accessibility of the technologies and the capacity of farmers to use them effectively.

Vanisree *et al.* (2017) conducted an experiment for 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%.

The use of botanical pesticides such as pyrethrum and azadirachtin has been found to effectively manage groundnut pests while maintaining soil health. A study by Ojuederie and Babalola (2017) showed that the use of pyrethrum and azadirachtin resulted in lower pest incidence and higher soil microbial diversity compared to chemical pesticides. The authors suggest that the use of botanical pesticides can be a sustainable approach for managing insect pests in groundnut crops.

A study conducted by Arivudainambi *et al*. (2017) and compared the effectiveness of botanical pesticides (neem and pongamia oil) and chemical pesticides (imidacloprid and profenofos) on the management of groundnut pests. The authors found that both neem and pongamia oil were as effective as chemical pesticides in

controlling pests and increasing yield, with no significant differences observed between treatments. The authors suggest that the use of botanical pesticides can be a viable alternative to chemical pesticides for managing insect pests in groundnut crops.

Devi *et al*. (2017) conducted a study and compared the efficacy of the botanical pesticide azadirachtin with the chemical pesticide profenofos in managing insect pests in groundnut crops. The authors found that both treatments resulted in significantly lower pest incidence and higher yield compared to untreated control plots. However, the use of azadirachtin resulted in lower residue levels and better soil health compared to profenofos. The authors suggest that the use of botanical pesticides can be an effective and environmentally sustainable alternative to chemical pesticides in groundnut pest management.

The use of selective chemical pesticides such as imidacloprid and fipronil has been found to effectively manage groundnut pests while reducing pesticide residues in the soil and plant tissues. A study by Singh *et al*. (2016) showed that the use of imidacloprid and fipronil resulted in lower pest incidence and lower pesticide residues compared to untreated control plots. The authors suggest that the use of selective pesticides can be a useful tool for managing groundnut pests while minimizing negative impacts on human health and the environment.

Dutta *et al.* (2016) carried out field studies 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. 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.

The use of botanicals such as neem, garlic, and ginger extracts has been found to positively impact the quality of groundnut seeds. A study conducted by Rahman *et al*. (2015) who showed that the use of neem and garlic extracts resulted in a significant reduction in insect pests and increased seed quality in terms of germination and vigor. The authors suggest that the use of botanicals can contribute to higher quality seed production in groundnut crops.

Rahman *et al*. (2015) conducted and experiment to compare the efficacy of the botanical pesticides neem and garlic extracts with the chemical pesticide endosulfan in managing insect pests in groundnut crops. The authors found that all treatments resulted in lower pest incidence and higher yield compared to untreated control plots. However, the use of neem and garlic extracts resulted in higher seed quality in terms of germination and vigor compared to endosulfan. The authors suggest that the use of botanical pesticides can contribute to higher quality seed production in groundnut crops.

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.

Panduranga *et al.* (2011) reported 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%.

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.

Gowda *et al*. (2008) reported that different botanicals, such as neem (Azadira*chta indica*), tobacco (*Nicotiana tabacum*), and chilli (*Capsicum annuum*), have been found to have insecticidal properties and can be effective in controlling groundnut pests. The active compounds in these botanicals can affect the feeding, development, and reproduction of pests, as well as repel or deter them from feeding on the plants. The use of botanicals in pest management can be a viable and eco-friendly alternative to chemical insecticides, especially for small-scale and organic farming systems. However, the efficacy of botanicals can vary depending on the pest species, the plant stage, and the environmental conditions. Therefore, it is important to conduct research on the optimal use and formulation of botanicals in groundnut pest management.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out during the period from October 2021 to April 2022 to study the management of major insect pests of groundnut using botanicals and some selected chemical insecticides. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental location

The present piece of research work was conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site was 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter 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). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4 Test crop

BARI Chinabadam-8 was used as a test crop for the experiment.

3.5 Experimental details

3.5.1 Treatments

1. T_1 = Imidacloprid 70FS @ 5ml/kg at 30 DAS continued as 10 days interval
2. T_2 = Acephate 75SP @ 0.05% at 30 DAS continued as 10 days interval
3. T_3 = Fipronil 5SC @ 0.01% at 30 DAS continued as 10 days interval
4. T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS continued as 10 days interval
5. T_5 = Neem seed kernel extract @ 5% at 30 DAS continued as 10 days interval
6. T_6 = Azadirachtin @ 2 ml/L at 30 DAS continued as 10 days interval
7. T_7 = Neem leaf extract @ 2.5% at 30 DAS continued as 10 days interval

3.5.2 Preparation of botanicals

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, the grinded dust was sieved. Neem seed kernel extract was applied in the field at 10 days interval started from 30 DAS.

Neem leaf extract: Fresh green leaves were collected from Sher-e-Bangla Agricultural University campus. Then the fresh leaves were grinded by a blender. The extract was made up @ 2.5%. Neem leaf extract was applied in the field at 10 days interval started from 30 DAS.

3.5.3 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experiment consists of a total 21 plots of size 2.5 m × 2 m. The layout of the experimental field is presented in Figure 1.

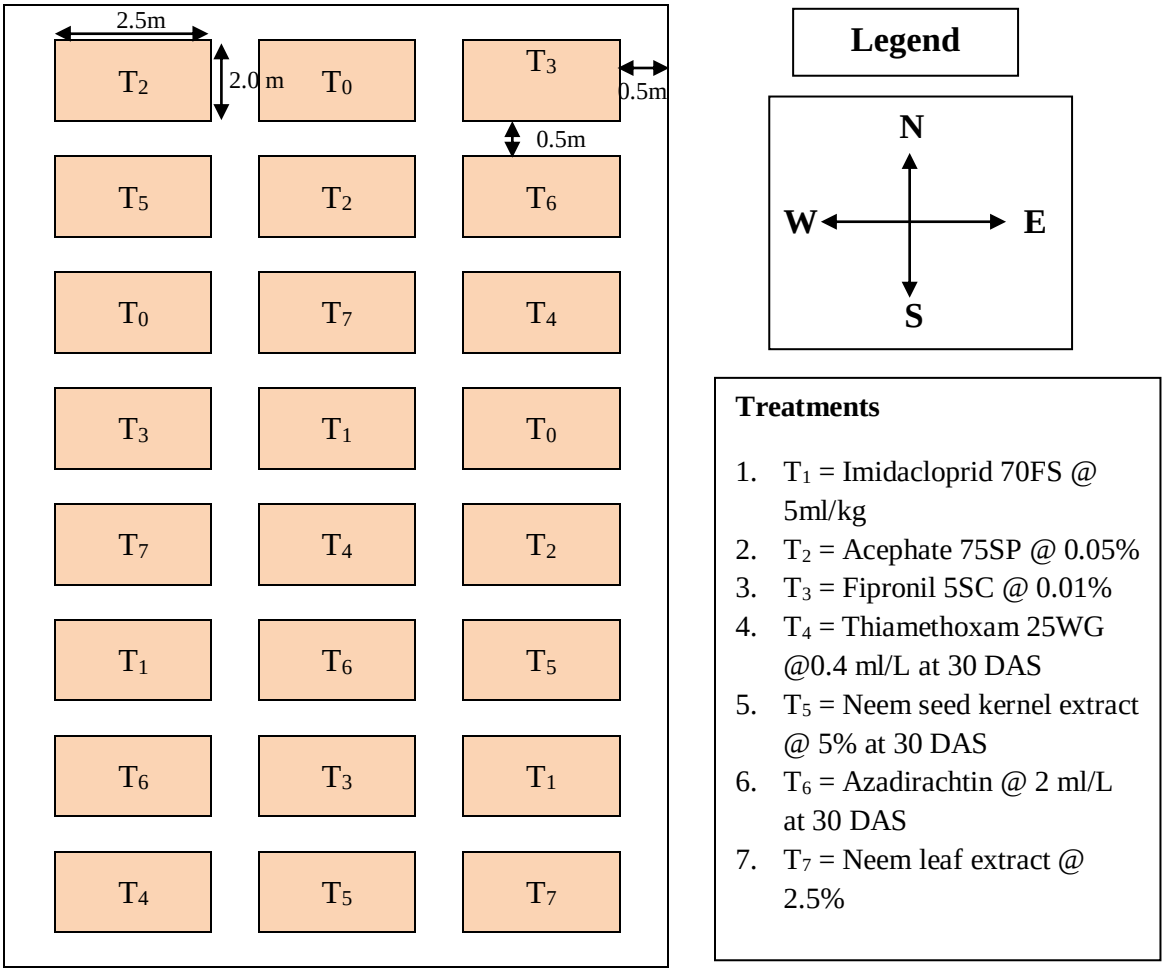

Fig. 1. Layout of the experimental plot

3.6 Seed collection

The seeds were collected on 18 October 2021 from the Oilseed Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701.

3.7 Description of the variety: BARI chinabadam-8

BARI cheenabadam-8 is a high yielding variety of groundnut that developed by the Oil Seed Research Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. The pedigree line (ICGV-94322) of the variety was suitable with Bangladesh climatic condition and crossed with some released varieties in deferent steps for experimentation, after that the variety was released in 2006 by the authorization of National Seed Board. It takes about 140-150 days to mature in rabi season and 125-140 days during kharif season. It attains a plant height of 35-42 cm at maturity. Leaf color deep green, it contains 20-25 nuts per plant with cluster, the shells are smooth and whitish in color and soft in nature, seeds are reddish brown in color. Medium 100 seeds weight of about 55-60 g with a shelling percentage is about 65-70%. The cultivar gives a pod yield of 2.3-2.5 t ha^{-1} of unshelled nuts. This is a Spanish class variety. This is one of the best variety so far released by BARI.

3.8 Land preparation

The plot selected for the experiment was opened in the last week of October, 2021 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for seed sowing. The land preparation was completed on 1st November 2021. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.9 Fertilizers and manure application

Application of fertilization (basal dose) was completed on 2nd November, 2021. Fertilizers were applied to the experimental plot considering the recommended doses of BARI (2019).

Manures/fertilizers	Doses ha^{-1}
Urea	25 kg
TSP	160 kg
MoP	85 kg
Gypsum	170 kg
$ZnSO_4$	4 kg
Boric acid	10 kg

Half of urea along with other fertilizers were applied during final land preparation as basal dose and thoroughly mixed with soil. The rest half urea was applied at 45 days after sowing (DAS) when flowers were initiated by side dressing.

3.10 Seed sowing

Seeds of the variety of groundnut (BARI cheenabadam-8) was sown at the rate of 100 kg ha^{-1} (unshelled groundnut) on 3rd November, 2021. Before sowing seeds, germination percentage was recorded. The groundnuts were first unshelled and treated with Bavistin 250 WP @ 2 g kg^{-1} seed, then sown in lines maintaining a line to line distance of 30 cm and seed to seed distance of 15 cm having 2 seeds $hole^{-1}$ in the well prepared plot.

3.11 Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the groundnut.

3.11.1 Irrigation and drainage

Pre-sowing irrigation was given to ensure the maximum germination percentage. Generally for upland soil 2 irrigations are required but considering the experiment

field soil condition several time irrigations was given. Irrigations were given depending on the soil moisture content after soil moisture testing by hand. Before harvesting a last irrigation was given for convenience harvesting.

3.11.2 Gap filling, thinning, weeding and mulching

Thinning and gap filling were done at 18 and 21 DAS, respectively to maintain the uniformity of plant population. The crop was infested with some weeds during the early stage of crop establishment. Two hand weedings were done. After irrigation the soil surface became crusty, so there needed several operations done manually to break down the hard soil crust.

3.11.3 Earthing up

Earthing up was done lightly on 40 days after sowing. It was done to encourage pegging and potential pod development.

3.12 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. 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.

3.13 Harvesting and post harvest operation

There is a thumb rule that the crop should be harvested when about 75% of the pods became mature at 115 DAS. After observing some maturity indices such as leaf became yellow, spots on the leaf, pod became hard and tough and dark tannin discoloration inside the shell crops were harvested. The samples were collected from the area of 1 m^2 of each plot avoiding the border plants. During harvest the pod contained 35% moisture. The harvested crops were tied into bundles and carried to the threshing floor. Then the pods were separated from the plants. The separated pod and the stover were sun dried by spreading those on the threshing

floor. The seeds were separated from the pod and dried in the sun for 3 to 5 consecutive days for achieving safe moisture (8%) of seed.

3.14 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.

3.14.1 Monitoring and data collection

The groundnut plants under different 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 –

1. Number of aphid population per plant
2. Number of whitefly population per plant
3. Number of thrips population per plant
4. Shoot infestation at early, mid and late stage
5. Plant height at harvest
6. Number of branches plant^{-1} at harvest
7. No. of pods plant^{-1}
8. No. of seeds pod^{-1}
9. Weight of 100 seeds (g)
10. Pod yield plot^{-1} (kg)
11. Pod yield ha^{-1} (t)
12. Seed quality of groundnut after harvest
    - Seedling emergence/germination percentage
    - Shoot length (cm)
    - Root length (cm)
    - Seed vigour index

3.15 Procedure of recording data

3.15.1 Determination of incidence of insect pests

Incidence of insect pests was counted from five randomly selected plants. The number of aphid, whitefly, and thrips were counted very early in the morning.

3.15.2 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):

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

3.15.3 Data collection on growth, yield contributing characters and yield

3.15.3.1 Plant height

Five plants were selected randomly from the inner rows of each plot. The height of the plants was measured from the ground level to the tip of the plant at harvest. The mean value of plant height was recorded in cm.

3.15.3.2 Number of branches plant^{-1}

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

3.15.3.3 Number of pods plant^{-1}

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

3.15.3.4 Weight of 100-seeds

From the seed stock of each plot 100 seeds were counted randomly and the weight was measured by an electrical balance. It was recorded in gram (g).

3.15.3.5 Yield plot^{-1}

Pod yield plot^{-1} was calculated from unshelled, cleaned and well dried grains collected from each plot and expressed as t ha^{-1} on 8 % moisture basis.

3.15.3.6 Yield ha^{-1}

Pod yield was calculated from unshelled, cleaned and well dried grains collected from the central 1 m^2 area of inner rows of each plot (leaving boarder rows) and expressed as t ha^{-1} on 8 % moisture basis.

3.15.4 Seed quality test

3.15.4.1 Percent (%) seed germination

Seed germination test was done from which seeds that were obtained from field experiment of the present study. Germination test was done using 20 seeds placed in the petridish and replicate thrice. The number of sprouted and germinated seeds (Seedling emergence) was counted daily commencing. Germination was recorded at 24 hrs interval and continued up to 12th. More than 2 mm long plumule and radicle was considered as germinated seed. The germination rate (seedling emergence) was calculated using the following formula:

$$\text{Rate of germination (\%)} = \frac{\text{Total number of germinated seeds}}{\text{Total seed placed for germination}} \times 100$$

3.15.4.2 Root length (cm)

The Root length of five seedlings from each sample was recorded finally at 12 DAS. Measurement was done using a meter scale and unit was expressed in centimeter (cm).

3.15.4.3 Shoot length (cm)

The shoot length of five seedlings from each sample was measured finally at 12 DAS. Measurement was done using the unit centimeter (cm) by a meter scale.

3.15.4.4 Seed vigor index

The vigor index (VI) of the seedlings can be estimated as suggested by Abdul-Baki and Anderson (1973):

$$VI = (RL+SL) \times GP,$$

Where,

RL = root length (cm),

SL = shoot length (cm) and

GP = germination percentage.

3.16 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatments by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the management of major insect pests of groundnut using botanicals and some selected chemical insecticides. The results have been presented by using different table and discussed with possible interpretations under following headings and sub-headings -

4.1 Insect pests incidence

Incidence of insect pests was recorded for aphid, white fly and thrips. Per plant data for the incidence of insect pests were counted and presented as follows-

4.1.1 Aphid

Number of Aphids showed statistically significant variations due to different management practices in groundnut at early, mid and late flowering stages (Table 1 and Appendix IV).

At early growth stage, the lowest number of Aphids (1.20) was recorded from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was significantly different to other treatments but close to the treatment T_7 (Neem leaf extract @ 2.5%) (2.25). The highest number of Aphids (5.52) at early growth stage was observed from the treatment T_3 (Fipronil 5SC @ 0.01%) which was statistically identical to the treatment T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) (5.44).

At mid growth stage, the lowest number of aphids (2.10) was recorded from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was significantly different to other treatments but adjacently lower than the treatment T_7 (Neem leaf extract @ 2.5%) (3.20). The highest number of aphids at mid growth stage (8.80) was observed from T_3 (Fipronil 5SC @ 0.01%) treatment which was followed by

T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments (7.20 and 7.12, respectively).

At late growth stage, the lowest number of aphids (4.24) was recorded from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was significantly different to other treatments while the second lowest aphid incidence was recorded from T_7 (Neem leaf extract @ 2.5%) treatment (5.33) whereas the highest number of aphids (10.90) was observed from T_3 (Fipronil 5SC @ 0.01%) treatment which was which was statistically identical to the treatment T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) (10.72).

Table 1. Effect of different botanicals and selective insecticides on aphid population at different growth stages of groundnut

Treatments	Number of aphid at different growth stages		
	Early	Mid	Late
T_1	3.12 c	4.62 d	6.40 d
T_2	4.00 b	6.00 c	7.12 c
T_3	5.52 a	8.80 a	10.90 a
T_4	5.44 a	7.20 b	10.72 a
T_5	1.20 e	2.10 f	4.24 f
T_6	4.20 b	7.12 b	8.36 b
T_7	2.25 d	3.20 e	5.33 e
$LSD_{0.05}$	0.328	0.464	0.493
CV(%)	5.36	8.91	6.42
SE	0.012	0.024	0.027

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

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

This result revealed that the treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) was more effective among the management practices for controlling aphids at early, mid and late growth stages which was followed by T_7 (Neem leaf extract @ 2.5%) treatment. The result obtained from the present study was similar to the findings of Yasmin *et al.* (2020).

4.1.2 White fly

Number of white fly showed statistically significant variations due to different management practices in groundnut at early, mid and late growth stages (Table 2 and Appendix V).

At early growth stage, the lowest number of whitefly (1.20) was recorded from the treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) which was statistically identical to T_7 (Neem leaf extract @ 2.5%) (1.27) treatment. Incidence of whitefly at early growth stage from T_1 (Imidacloprid 70FS @ 5ml/kg) and T_2 (Acephate 75SP @ 0.05%) treatment also comparatively lower (3.20 and 3.26, respectively) but significantly differed to other treatments. The highest number of whitefly at early growth stage (5.24) was observed from T_3 (Fipronil 5SC @ 0.01%) treatment that was statistically identical to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) treatment (5.10).

At mid growth stage, the lowest number of whitefly (3.00) was recorded from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically identical to T_7 (Neem leaf extract @ 2.5%) treatment (3.12) followed by T_1 (Imidacloprid 70FS @ 5ml/kg) and T_2 (Acephate 75SP @ 0.05%) treatments (4.00 and 4.12, respectively) whereas the highest number of whitefly (6.93) was observed from T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) treatment (6.72).

At late flowering stage, the lowest number of whitefly (4.04) was also recorded from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was

statistically identical to T_7 (Neem leaf extract @ 2.5%) treatment (4.18). The highest number of whitefly (9.76) was observed from T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) treatment (9.52).

This result indicated that the treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) was more effective among the management practices for the controlling whitefly at different growth stage (early, mid and late) of groundnut which was followed by the treatment T_7 (Neem leaf extract @ 2.5%). Sudhakar *et al*. (2021) also found similar result with the present study.

Table 2. Effect of different botanicals and selective insecticides on whitefly population at different growth stages of groundnut

Treatments	Number of whitefly at different growth stages		
	Early	Mid	Late
T_1	3.20 c	4.00 c	6.48 d
T_2	3.36 c	4.12 c	7.63 c
T_3	5.24 a	6.93 a	9.76 a
T_4	5.10 a	6.72 a	9.52 a
T_5	1.20 d	3.00 d	4.04 e
T_6	4.42 b	5.30 b	8.27 b
T_7	1.27 d	3.12 d	4.18 e
$LSD_{0.05}$	0.355	0.445	0.551
CV(%)	4.78	6.39	7.21
SE	0.014	0.022	0.032

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

4.1.3 Thrips

Incidence of thrips showed statistically significant variations due to application of different botanicals and selective insecticides treatments in groundnut at early, mid and late growth stages (Table 3 and Appendix VI).

At early growth stage, results revealed that the no incidence of thrips (0) was observed in T_5 (Neem seed kernel extract @ 5% at 30 DAS) and T_7 (Neem leaf extract @ 2.5%) treatment whereas the highest number of thrips (0.80) was recorded in T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) treatment that was statistically identical to T_3 (Fipronil 5SC @ 0.01%) treatment.

At mid growth stage, treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) and T_7 (Neem leaf extract @ 2.5%) showed no incidence of thrips (0) whereas the highest incidence of thrips (1.00) was recorded from T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) treatment which was statistically similar to T_3 (Fipronil 5SC @ 0.01%) treatment.

At late growth stage, the lowest number of thrips (0.10) was recorded from T_7 (Neem leaf extract @ 2.5%) treatment which was statistically identical to T_5 (Neem seed kernel extract @ 5% at 30 DAS). The highest incidence of thrips (1.24) was recorded from T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) treatment which was statistically identical to T_3 (Fipronil 5SC @ 0.01%) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments.

The statistical analysis revealed that T_7 (Neem leaf extract @ 2.5%) and T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatments is the most effective in reducing the thrips population. Among the other treatments, T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) and T_3 (Fipronil 5SC @ 0.01%) showed poor performance for controlling thrips. Yasmin *et al.* (2020) also found similar result with the present study.

Table 3. Effect of different botanicals and selective insecticides on thrips population at different growth stages of groundnut

Treatments	Number of thrips at different growth stages		
	Early	Mid	Late
T_1	0.24 c	0.40 c	0.52 b
T_2	0.27 c	0.48 c	0.63 b
T_3	0.75 a	0.92 ab	1.20 a
T_4	0.80 a	1.00 a	1.24 a
T_5	0.00 d	0.00 d	0.12 c
T_6	0.60 b	0.80 b	1.16 a
T_7	0.00 d	0.00 d	0.10 c
$LSD_{0.05}$	0.097	0.169	0.258
CV(%)	3.17	5.24	5.76
SE	0.001	0.003	0.007

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

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_5 (Neem seed kernel extract @ 5% at 30 DAS) showed the best performance in terms of lowest population of aphid, whitefly and thrips (7.54, 8.24 and 0.12, respectively) comparable to other treatments whereas the maximum number of insect pests (25.22, 21.34 and 3.04, respectively) was recorded in T_3 (Fipronil 5SC @ 0.01%) treatment.

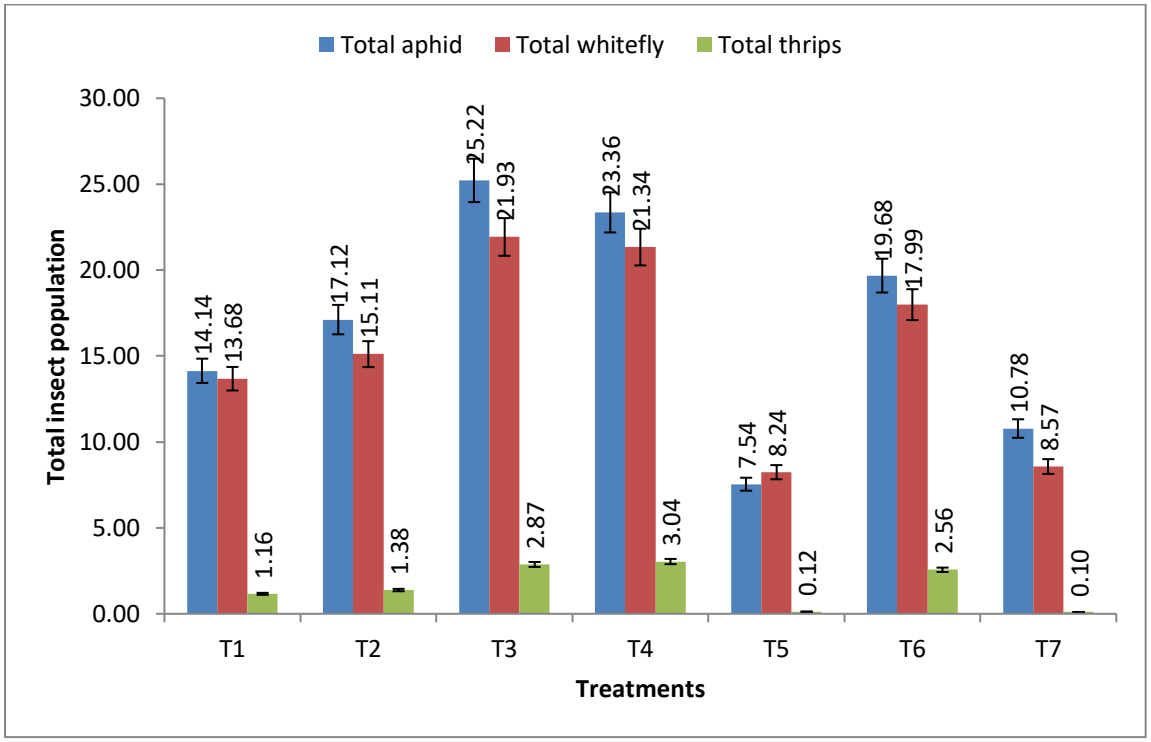

Figure 2. Incidence of insect pests in groundnut field after spraying during the study period

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

4.3 Shoot infestation of groundnut plant

Shoot infestation occurred in different stage of groundnut plant. The infestation caused by different insect pests at different growth stages is presented below:

4.3.1 Shoot infestation at early growth stage

Number of healthy shoots, infested shoots and percent infestation of shoots showed significant differences at early growth stage for different management practices of groundnut (Table 4 and Appendix VII).

The highest number of healthy shoots/plant (21.80) was recorded in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically similar to the treatment T_7 (Neem leaf extract @ 2.5%) (20.67/plant). On the other hand, the lowest number of healthy shoots/plant (15.24) was found in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments (15.52 and 16.48, respectively).

The highest number of infested shoots/plant (1.33) was recorded in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically similar to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS), T_6 (Azadirachtin @ 2 ml/L at 30 DAS) and T_2 (Acephate 75SP @ 0.05%) (1.27, 1.20 and 1.12, respectively) whereas the lowest number (0.42) was observed in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which differed significantly to other treatments but close to the treatment T_7 (Neem leaf extract @ 2.5%) (0.78).

The highest percentages of infested shoots/plant (8.73%) was obtained in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically similar to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) treatment (8.18%) while the lowest percentage of infested shoots/plant (1.93%) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was significantly different to other treatments but close to treatment T_7 (Neem leaf extract @ 2.5%).

From the finding it is revealed that spraying of T_5 (Neem seed kernel extract @ 5% at 30 DAS) was more effective among the management practices for reduction of shoots infestation of groundnut at the early growth stage which was followed by T_7 (Neem leaf extract @ 2.5%) under the present trial.

Table 4. Effect of different botanicals and selective insecticides on shoot infestation of groundnut at early growth stage

Treatments	At early stage		
	No. of healthy shoots	No. of infested shoots	% shoot infestation
T_1	18.88 bc	0.85 bc	4.50 d
T_2	18.60 c	1.12 ab	6.02 c
T_3	15.24 d	1.33 a	8.73 a
T_4	15.52 d	1.27 a	8.18 ab
T_5	21.80 a	0.42 d	1.93 e
T_6	16.48 d	1.20 a	7.28 b
T_7	20.67 ab	0.78 c	3.77 d
$LSD_{0.05}$	1.815	0.337	0.994
CV(%)	7.24	3.97	5.89
SE	0.347	0.012	0.104

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

4.3.2 At mid growth stage

Number of healthy shoots, infested shoots and percent infestation of shoots were differed significantly among different management practices of groundnut at mid growth stage (Table 5 and Appendix IX).

The highest number of healthy shoots/plant (28.20) was recorded in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically identical to the treatment T_7 (Neem leaf extract @ 2.5%) (20.67/plant). Reversely, the lowest number of healthy shoots/plant (20.20) was found in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments (21.12 and 22.50, respectively).

The highest number of infested shoots/plant (2.12) was recorded in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically similar to T_4 (Thiamethoxam 25WG @ 0.4 ml/L at 30 DAS) (1.92) whereas the lowest number of infested shoots/plant (1.10) was observed in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically identical to the treatment T_7 (Neem leaf extract @ 2.5%) (1.16).

The highest percentages of infested shoots/plant (10.19%) was recorded in T_3 (Fipronil 5SC @ 0.01%) treatment which was followed by T_4 (Thiamethoxam 25WG @ 0.4 ml/L at 30 DAS) treatment (9.09%) while the lowest percentage of infested shoots/plant (3.90%) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically similar to T_7 (Neem leaf extract @ 2.5%) treatment.

Table 5. Effect of different botanicals and selective insecticides on shoot infestation of groundnut at mid growth stage

Treatments	At mid stage		
	Healthy shoots	Infested shoots	% shoot infestation
T_1	25.42 b	1.27 cd	5.00 cd
T_2	24.87 b	1.42 c	5.71 c
T_3	20.80 c	2.12 a	10.19 a
T_4	21.12 c	1.92 ab	9.09 b
T_5	28.20 a	1.10 d	3.90 e
T_6	22.50 c	1.83 b	8.13 b
T_7	27.75 a	1.16 d	4.18 de
$LSD_{0.05}$	1.987	0.239	1.054
CV(%)	8.94	4.57	6.39
SE	0.416	0.006	0.117

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

From the finding it is revealed that spraying of T_5 (Neem seed kernel extract @ 5% at 30 DAS) was more effective among the management practices for reduction of shoots infestation of groundnut at the mid growth stage which was followed by T_7 (Neem leaf extract @ 2.5%) under the present trial.

4.3.3 At late growth stage

Number of healthy shoots, infested shoots and percent infestation of shoots showed significant differences at late growth stage for different management practices of groundnut (Table 6 and Appendix X).

The highest number of healthy shoots/plant (28.20) was recorded in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically identical to the treatment T_7 (Neem leaf extract @ 2.5%) (20.67/plant). On the other hand, the lowest number of healthy shoots/plant (20.80) was found in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to T_4 (Thiamethoxam 25WG @ 0.4 ml/L at 30 DAS) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments (21.12 and 22.50, respectively).

The highest number of infested shoots/plant (2.12) was recorded in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically similar to T_4 (Thiamethoxam 25WG @ 0.4 ml/L at 30 DAS) (1.92) whereas the lowest number (1.10) was observed in T_5 (Neem seed kernel extract @ 5% at 30 DAS) which was statistically identical to the treatment T_7 (Neem leaf extract @ 2.5%) (1.16).

The highest percentages of infested shoots/plant (10.19%) was found in T_3 (Fipronil 5SC @ 0.01%) treatment followed by T_4 (Thiamethoxam 25WG @ 0.4 ml/L at 30 DAS) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments (9.09% and 8.13%) while the lowest percentage of infested shoots/plant (3.90%) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically similar to the treatment T_7 (Neem leaf extract @ 2.5%) (4.18%).

Table 6. Effect of different botanicals and selective insecticides on shoot infestation of groundnut at late growth stage

Treatments	At late stage		
	Healthy shoots	Infested shoots	% shoot infestation
T_1	26.10 b	1.62 c	6.21 c
T_2	25.64 b	1.75 c	6.83 c
T_3	21.27 c	2.42 a	11.38 a
T_4	21.36 c	2.25 ab	10.53 a
T_5	28.90 a	1.20 d	4.15 d
T_6	23.20 c	2.04 b	8.79 b
T_7	28.44 a	1.25 d	4.40 d
$LSD_{0.05}$	2.262	0.278	1.119
CV(%)	9.63	4.27	5.14
SE	0.539	0.008	0.132

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

From the finding it is revealed that spraying of T_5 (Neem seed kernel extract @ 5% at 30 DAS) was more effective among the management practices for reduction of shoots infestation of groundnut at the late growth stage which was followed by T_7 (Neem leaf extract @ 2.5%) under the present study. Similar result was also achieved by the findings of Manivannan *et al*. (2019).

4.4 Effect of biorational insecticides on yield contributing parameters and yield of groundnut

4.4.1 Plant height (cm)

Plant height of groundnut at harvest showed statistically significant differences in different management practices of different botanicals and selective insecticides

(Table 7 and Appendix XI). The highest plant height (45.27 cm) was recorded in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically similar with T_7 (Neem leaf extract @ 2.5%) (44.83 cm) and T_1 (Imidacloprid 70FS @ 5ml/kg) (42.92 cm) whereas the lowest plant height (37.42 cm) was found in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically similar to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) (39.50 cm).

4.4.2 Number of branches per plant

Different management practices of botanicals and selective insecticides showed statistically significant differences in terms of number of branches plant^{-1} of groundnut (Table 7 and Appendix XI). Data revealed that the maximum number of branches plant^{-1} (9.63) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which differed significantly to other treatments followed by T_7 (Neem leaf extract @ 2.5%), while the minimum number of branches plant^{-1} (6.72) was observed in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to T_4 (Thiamethoxam 25WG @ 0.4 ml/L at 30 DAS) (6.88).

4.4.3 Normal pods per plant

Different management practices showed statistically significant differences in terms of pods plant^{-1} of groundnut as influenced by different management practices against insect pest using botanicals and selective insecticides (Table 7 and Appendix XI). Results showed that the maximum number of normal pods plant^{-1} (18.75) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically similar to T_7 (Neem leaf extract @ 2.5%) (18.25) and T_1 (Imidacloprid 70FS @ 5ml/kg) (17.50) while the minimum pods plant^{-1} (14.50) was observed in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments.

Table 7. Effect of different botanicals and selective insecticides on growth, yield contributing parameters and yield of groundnut

Treatments	Growth, yield contributing parameters and yield						
	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}	Weight of 100 seeds (g)	Pod yield plot^{-1} (kg)	Pod yield ha^{-1} (t)
T_1	42.92 ab	8.78 bc	17.50 ab	1.60 bc	48.12 b	1.21 b	2.42 b
T_2	41.46 bc	8.60 c	16.20 bc	1.52 cd	47.80 b	1.17 b	2.33 b
T_3	37.42 d	6.72 e	14.50 c	1.36 e	45.30 d	0.99 c	1.97 d
T_4	39.50 cd	6.88 e	14.75 c	1.42 e	45.52 d	1.01 c	2.01 cd
T_5	45.27 a	9.63 a	18.75 a	1.72 a	49.24 a	1.37 a	2.73 a
T_6	40.27 c	7.72 d	15.30 c	1.45 de	46.63 c	1.07 c	2.14 c
T_7	44.83 a	9.12 b	18.25 a	1.65 ab	48.72 ab	1.32 a	2.64 a
$LSD_{0.05}$	2.459	0.467	1.707	0.097	0.989	0.097	0.169
CV(%)	8.94	5.23	7.87	4.28	8.64	6.73	6.75
SE	0.637	0.023	0.307	0.001	0.103	0.001	0.003

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

4.4.4 Number of seeds pod^{-1}

Different treatments of botanicals and selective insecticides against insect pest of groundnut showed significant variation on number of seeds pods^{-1} (Table 7 and Appendix XI). Results revealed that the maximum number of seeds pods^{-1} (1.72) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically similar to T_7 (Neem leaf extract @ 2.5%) (1.65) whereas the minimum number of seeds pods^{-1} (1.36) was observed in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically similar to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments.

4.4.5 Weight of 100 seeds (g)

Different management practices of botanicals and selective insecticides against insect pest showed statistically significant differences in terms of weight of 100 seeds of groundnut (Table 7 and Appendix XI). Results showed that the highest weight of 100 seeds (49.24 g) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically similar with T_7 (Neem leaf extract @ 2.5%) treatment whereas the lowest weight of 1000 seeds (45.30 g) was observed in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to the treatment T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS).

4.4.6 Pod yield plot^{-1} (kg)

Different treatments of botanicals and selective insecticides against insect pest of groundnut showed significant variation on pod yield plot^{-1} (Table 7 and Appendix XI). Results indicated that the maximum pod yield plot^{-1} (1.37 kg) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically identical to T_7 (Neem leaf extract @ 2.5%) (1.32 kg) whereas the minimum pod yield plot^{-1} (0.99 kg) was recorded in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically identical to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) and T_6 (Azadirachtin @ 2 ml/L at 30 DAS) treatments.

4.4.6 Pod yield ha^{-1} (t)

Different treatments of botanicals and selective insecticides against insect pest of groundnut showed significant variation on pod yield ha^{-1} (Table 7 and Appendix XI). Results indicated that the maximum pod yield ha^{-1} (2.73 t) was found in T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment which was statistically identical to T_7 (Neem leaf extract @ 2.5%) (2.64 kg) whereas the minimum pod yield ha^{-1} (1.97 kg) was recorded in T_3 (Fipronil 5SC @ 0.01%) treatment which was statistically similar to the treatment T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) (2.01 t ha^{-1}). The result obtained from the present study was similar with

the findings of Venkatesh *et al*. (2021), Ananthakrishnan *et al*. (2021), Chakraborty *et al*. (2020) and Yasmin *et al.* (2020).

4.5 Seed quality parameters

4.5.1 Seed germination

Seed obtained from the present study after applying different treatments of botanicals and selective insecticides, germination test was done as seed quality parameter to observe which treatment produced best quality seeds. Significant variation was recorded for seed germination among the treatments (Table 8 and Appendix XII). Results showed that the maximum seed germination (92.40%) was recorded from the treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) that was statistically identical to T_7 (Neem leaf extract @ 2.5%) (91.25%) whereas T_3 (Fipronil 5SC @ 0.01%) treatment showed the minimum seed germination (85.25%) which was statistically similar to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS).

4.5.2 Shoot length

Shoot length was registered at 12 days of seedlings after germination of groundnut seeds. Different treatments of botanicals and selective insecticides showed significant variation on shoot length (Table 8 and Appendix XII). It was observed that the treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) gave the highest shoot length (7.14 cm) which was statistically similar to T_7 (Neem leaf extract @ 2.5%) (6.96 cm) whereas the lowest shoot length (4.75 cm) was given by the treatment T_3 (Fipronil 5SC @ 0.01%) which was statistically similar to T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) treatment.

4.5.3 Root length

Root length was observed at 12 days of seedlings after germination. Significant variation was recorded for root length due to different treatments of botanicals and

selective insecticides against insect pest of groundnut (Table 8 and Appendix XII). Results exhibited that the highest root length (6.72 cm) was recorded from the treatment T_3 (Fipronil 5SC @ 0.01%) that was statistically identical to T_7 (Neem leaf extract @ 2.5%) (6.50 cm) whereas the treatment T_3 (Fipronil 5SC @ 0.01%) showed the lowest root length (4.07 cm) which was statistically identical to T_4 (Thiamethoxam 25WG @ 0.4 ml/L at 30 DAS) treatment.

Table 8. Effect of different botanicals and selective insecticides on seed quality of groundnut after harvest

Treatments	Seed quality of groundnut after harvest			
	Seedling emergence/ germination percentage	Shoot length at 12 DSG* (cm)	Root length at 12 DSG* (cm)	Seed vigour index
T_1	89.40 b	6.63 bc	6.04 b	1133. 00 c
T_2	88.75 bc	6.48 c	5.88 b	1097.00 d
T_3	85.25 e	4.75 e	4.07 d	751.90 g
T_4	86.30 de	4.88 de	4.20 d	783.60 f
T_5	92.40 a	7.14 a	6.72 a	1281.00 a
T_6	87.50 cd	5.12 d	4.80 c	868.00 e
T_7	91.25 a	6.96 ab	6.50 a	1228.00 b
$LSD_{0.05}$	1.388	0.351	0.323	31.31
CV(%)	8.94	6.18	5.29	11.12
SE	0.203	0.013	0.011	103.20

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

* DSG = Days of seed germination

T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS, T_7 = Neem leaf extract @ 2.5%

4.5.4 Seed vigor index

Seed vigor index of groundnut seeds as quality parameter, significant variation was found due to different treatments of botanicals and selective insecticides (Table 8 and Appendix XII). Results indicated that the highest seed vigor index (1281.00) was recorded from the treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) followed by T_7 (Neem leaf extract @ 2.5%) (1228.00) whereas the lowest seed vigor index (751.90) was recorded from the treatment T_3 (Fipronil 5SC @ 0.01%) which was significantly different to other treatments followed by T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) (783.60).

CHAPTER V

SUMMARY AND CONCLUSION

5.1 SUMMARY

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from October 2021 to April 2022 to study the management of major insect pests of groundnut using botanicals and some selected chemical insecticides. The experiment comprised of the seven treatments *viz*., T_1 = Imidacloprid 70FS @ 5ml/kg, T_2 = Acephate 75SP @ 0.05%, T_3 = Fipronil 5SC @ 0.01%, T_4 = Thiamethoxam 25WG @0.4 ml/L at 30 DAS, T_5 = Neem seed kernel extract @ 5% at 30 DAS, T_6 = Azadirachtin @ 2 ml/L at 30 DAS and T_7 = Neem leaf extract @ 2.5%. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

There were many insect pests of groundnut among them aphids, white fly and thrips were majorly observed in the experimental plot. T_5 (Neem seed kernel extract @ 5% at 30 DAS) was more effective among the management practices for controlling the observed pests in early, mid and late flowering stage which was followed by T_7 = Neem leaf extract @ 2.5%.

All the treatments had significant effect against insect pests of groundnut. T_5 (Neem seed kernel extract @ 5% at 30 DAS) showed best performance in term of reducing available aphid and whitefly population and among the other treatments followed by T_7 (Neem leaf extract @ 2.5%) whereas T_3 (Fipronil 5SC @ 0.01%) showed poor performance. Similarly, T_7 (Neem leaf extract @ 2.5%) was identified as the most effective in term of lowering thrips population whereas T_6 (Azadirachtin @ 2 ml/L at 30 DAS) gave least performance against thrips of groundnut.

In terms of the incidence of aphid and whitefly, at early, mid and late growth stages the minimum incidence was recorded from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatments followed by T_7 (Neem leaf extract @ 2.5%) whereas the maximum incidence of aphid and whitefly was recorded from T_3 (Fipronil 5SC @ 0.01%). The treatment T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) also gave poor performance for controlling aphid and whitefly. Similarly, for controlling thrips at early, mid and late growth stages, the treatment T_7 (Neem leaf extract @ 2.5%) showed minimum incidence of thrips which was very close to T_5 (Neem seed kernel extract @ 5% at 30 DAS) whereas T_4 (Thiamethoxam 25WG @0.4 ml/L at 30 DAS) showed maximum incidence of thrips followed by T_3 (Fipronil 5SC @ 0.01%).

Groundnut shoot infestation at early, mid and late stages was estimated. At early, mid and late growth stages, T_5 (Neem seed kernel extract @ 5% at 30 DAS) was the most effective and T_3 (Fipronil 5SC @ 0.01%) was poorly effective against shoot infestation and highest number of healthy shoot resulted from T_5 (Neem seed kernel extract @ 5% at 30 DAS) (21.80, 28.20 and 28.90, respectively) treated plot whereas T_3 (Fipronil 5SC @ 0.01%) gave the minimum number of healthy shoot (15.24, 20.80 and 21.27, respectively). Accordingly, the minimum shoot infestation at early, mid and late growth stages, treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) showed best performance (1.93, 3.90 and 4.15%, respectively) whereas T_3 (Fipronil 5SC @ 0.01%) gave least performance and gave maximum shoot infestation (8.73, 10.19 and 11.38% respectively).

Spraying of botanicals and selective insecticides significantly influenced on growth, yield contributing characters and yield of groundnut. The highest plant height (45.27 cm) and number of branches plant^{-1} (9.63) was found from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treated plot and the lowest plant height (37.42 cm) and number of branches plant^{-1} (6.72) resulted from the treatment T_3 (Fipronil 5SC @ 0.01%).

Regarding yield contributing parameters and yield of groundnut, the highest number of pods plant^{-1} (18.75), number of seeds pod^{-1} (1.72), 100 seed weight (49.24 g), pod yield plot^{-1} (1.37 kg) and pod yield ha^{-1} (2.37 t) were recorded from the treatment T_5 (Neem seed kernel extract @ 5% at 30 DAS) whereas the lowest number of pods plant^{-1} (14.50), number of seeds pod^{-1} (1.36), 100 seed weight (45.50 g), pod yield plot^{-1} (0.99 kg) and pod yield ha^{-1} (1.97 t) were recorded from the treatment T_3 (Fipronil 5SC @ 0.01%).

Considering seed quality parameters after harvest of groundnut, the maximum seed germination (92.40%), shoot length (7.14 cm), root length (6.72 cm) and seed vigour index (1281.00) was recorded from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treated plot followed by T_7 (Neem leaf extract @ 2.5%) whereas the minimum seed germination (85.25%), shoot length (4.75 cm), root length (4.07 cm) and seed vigour index (751.90) was recorded from T_3 (Fipronil 5SC @ 0.01%) treatment.

5.2 CONCLUSION

Aphid, whitefly and thrips were the major insect pests attacked the groundnut during the study period. It could be concluded that among the all botanicals and selective insecticide treatments, T_5 (Neem seed kernel extract @ 5% at 30 DAS) showed the superior performance for controlling insect pest of groundnut and also maximum growth and yield of groundnut was found from T_5 (Neem seed kernel extract @ 5% at 30 DAS) treatment and next to the treatment T_7 (Neem leaf extract @ 2.5%) whereas the treatment T_3 (Fipronil 5SC @ 0.01%) gave the least performance compared to other treatments.

RECOMMENDATION

Before recommendation of usage of botanicals and other selective insecticides for managing the insect pests of groundnut further study is needed in different agro-ecological zones of Bangladesh for regional adaptability.

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APPENDICES

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

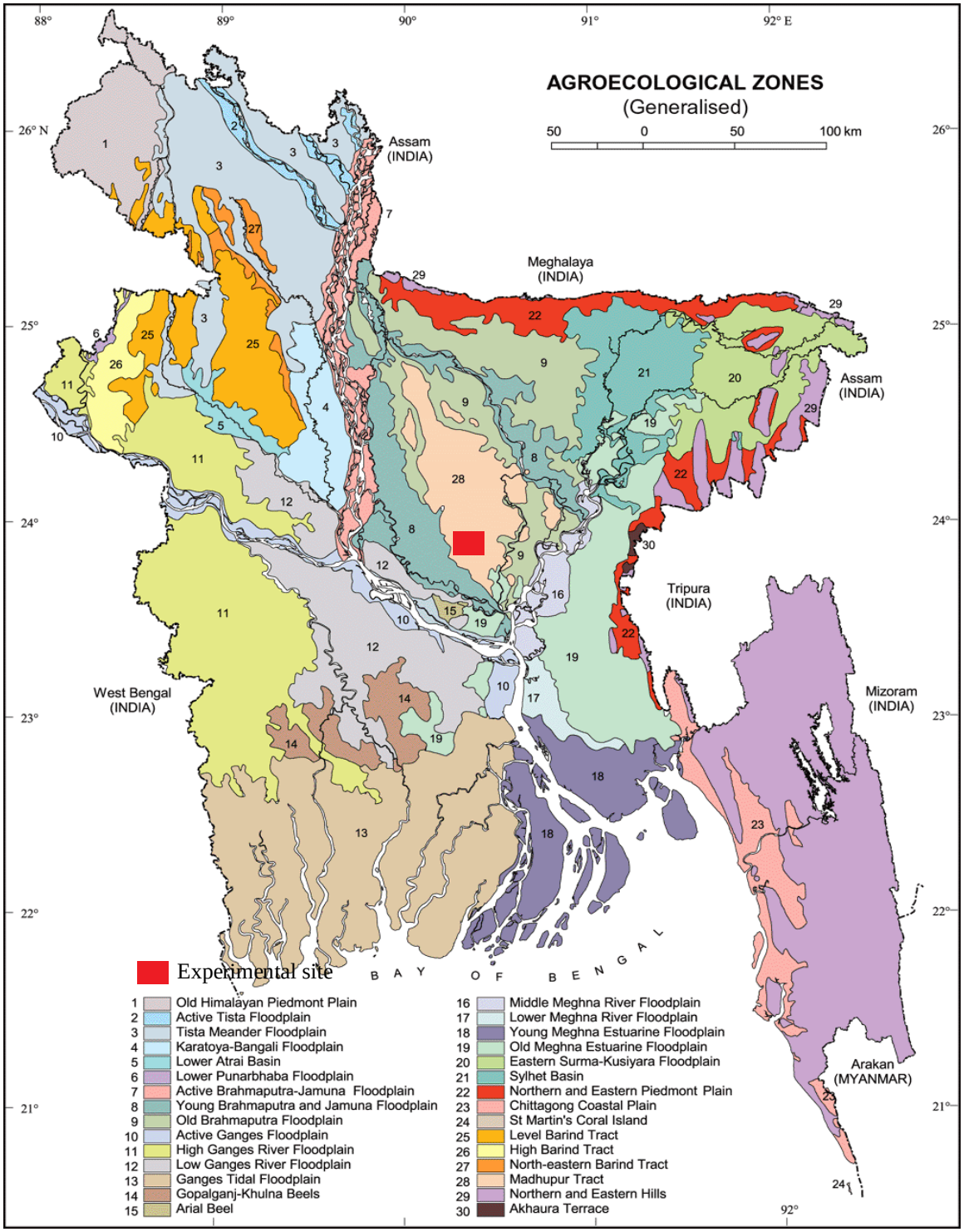

Figure 3. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from December 2020 to May 2021.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2020	December	25.50	6.70	16.10	54.80	0.0
2021	January	23.80	11.70	17.75	46.20	0.0
2021	February	22.75	14.26	18.51	37.90	0.0
2021	March	35.20	21.00	28.10	52.44	20.4
2021	April	34.70	24.60	29.65	65.40	165.0
2021	May	32.64	23.85	28.25	68.30	182.2

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

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Appendix IV. Effect of different botanicals and selective insecticides on aphid population at different growth stages of groundnut

Sources of variation	Degrees of freedom	Number of aphid at different growth stages		
		Early	Mid	Late
Replication	2	0.311	0.437	0.289
Treatment	6	11.36*	9.571*	21.74*
Error	12	0.012	0.024	0.027

* = Significant at 5% level

Appendix V. Effect of different botanicals and selective insecticides on whitefly population at different growth stages of groundnut

Sources of variation	Degrees of freedom	Number of whitefly at different growth stages		
		Early	Mid	Late
Replication	2	0.117	0.214	0.366
Treatment	6	8.942*	13.27*	16.92*
Error	12	0.014	0.022	0.032

* = Significant at 5% level

Appendix VI. Effect of different botanicals and selective insecticides on thrips population at different growth stages of groundnut

Sources of variation	Degrees of freedom	Number of thrips at different growth stages		
		Early	Mid	Late
Replication	2	0.011	0.016	0.047
Treatment	6	1.314**	1.364**	1.073**
Error	12	0.001	0.003	0.007

** = Significant at 1% level

Appendix VII. Effect of different botanicals and selective insecticides on shoot infestation of groundnut at early growth stage

Sources of variation	Degrees of freedom	At early stage		
		Healthy shoots	Infested shoots	% shoot infestation
Replication	2	0.718	0.062	0.116
Treatment	6	103.42*	6.38**	12.73*
Error	12	0.347	0.012	0.104

* = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Effect of different botanicals and selective insecticides on shoot infestation of groundnut at mid growth stage

Sources of variation	Degrees of freedom	At mid stage		
		Healthy shoots	Infested shoots	% shoot infestation
Replication	2	0.714	0.036	0.087
Treatment	6	63.44*	2.733**	8.507*
Error	12	0.416	0.006	0.117

* = Significant at 5% level ** = Significant at 1% level

Appendix IX. Effect of different botanicals and selective insecticides on shoot infestation of groundnut at late growth stage

Sources of variation	Degrees of freedom	At late stage		
		Healthy shoots	Infested shoots	% shoot infestation
Replication	2	3.624	0.073	0.207
Treatment	6	78.26*	2.103**	14.371*
Error	12	0.539	0.008	0.132

* = Significant at 5% level ** = Significant at 1% level

Appendix X. Effect of different botanicals and selective insecticides on growth, yield contributing parameters and yield of groundnut

Sources of variation	Degrees of freedom	Growth, yield contributing parameters and yield						
		Plant height	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}	Weight of 100 seeds	Pod yield plot^{-1}	Pod yield ha^{-1}
Replication	2	2.714	0.617	1.038	0.104	1.387	0.012	0.118
Treatment	6	204.75*	13.26*	26.378*	1.311**	306.83*	3.712**	7.944*
Error	12	0.637	0.023	0.307	0.001	0.103	0.001	0.003

* = Significant at 5% level ** = Significant at 1% level

Appendix XI. Effect of different botanicals and selective insecticides on seed quality of groundnut after harvest

Sources of variation	Degrees of freedom	Seed quality of groundnut after harvest			
		Seedling emergence/ germination percentage	Shoot length	Root length	Seed vigour index
Replication	2	1.835	0.238	0.107	23.241
Treatment	6	103.439*	5.071**	3.114**	20361.24*
Error	12	0.203	0.013	0.011	103.20

* = Significant at 5% level ** = Significant at 1% level

Plate 1. Overall field view at vegetative stage

Plate 2. Overall field view at premature stage

Plate 3. Field visit at flowering stage

Plate 4. Insecticide spray at infested condition

Plate 5. Overall field view at maturity stage