BIORATIONAL MANAGEMENT OF SUCKING INSECT PESTS OF OKRA

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CERTIFICATE

*This is to certify that the thesis entitled "**BIORATIONAL MANAGEMENT OF SUCKING INSECT PESTS OF OKRA**" submitted to the Department of Entomology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka in partial fulfillment of the requirements for the degree of Master of Science (M.S.) in Entomology, embodies the result of a piece of bona fide research work carried out by **PRIYANKUR CHAKMA, Registration No. 19-10129** 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, as has been availed of during the course of this investigation has been duly acknowledged by the Author.

Dated: June, 2021

Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

The study was conducted to investigate biorational management of sucking insect pests of okra in the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2020 to February 2021. The experiment consisted of the management practices (T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @ 1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4= Neem oil @ 5.0 ml/L of water with detergent; T_5= Abamectin @ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7= Untreated control) are applied at 7 days interval. The experiment was designed with Randomized Complete Block Design (RCBD) with three replications. Data on different pest incidence level of infestation, yield attributes and yield were collected and recorded. At total fruiting stage, in number basis, considering the % fruit infestation, the lowest infested fruits per plant were recorded from Buprofezin @ 0.2 g/L of water (33.62%), while the highest infested fruits were recorded in control (44.21%). The lowest plant infestation was found from Buprofezin (34.25%), whereas the highest infested plants were recorded in untreated control (46.33%). The tallest plant was recorded from neem oil (244.9 cm), while the shortest plant was found from Spinosad (195.2 cm). The highest yield of fruits was observed from Buprofezin @ 0.2 g/L of water at 7 days interval (15.59 ton/ha), while the lowest yield per hectare was found from control (11.36 ton/ha). Among the treatments, Buprofezin @ 0.2 g/L of water at 7 days interval was more effective for the controlling of insect pests as well as highest yield contributing characters and yield of Okra.

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CHAPTER-I

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is an essential alimentary vegetable belonging to the family Malvaceae. It is familiar by different names such as "Bhendi or dheros" in the subcontinent, "Bamia" in Middle East, "Ladyfinger" in England, "Krejaib Kheaw" in Thailand and "Okura" in Japan (Ndunguru and Rajabu, 2004). Okra is commercially grown as vegetable and garden crop throughout the world in tropical as well as in subtropical states (Rubatzky and Yamaguchi, 1997; Saifullah and Rabbani, 2009). The main okra growing countries are India, Turkey, Japan, Iran, Bangladesh, Malaysia, Thailand, Ethiopia and Pakistan (Benjawan *et al*. 2007; Qhureshi, 2007). Okra is highly nutritive in nature and considered as the important component of human diet. It comprises of carbohydrates, proteins, fat, vitamin A, vitamin C, vitamin B_6, folic acid, calcium, iron, Zn, magnesium, potassium, P, β carotene, fibre and riboflavin (Glew *et al*, 1997; Cook *et al.* 2000; Gopalan *et al.* 2007 and Varmudy, 2011). A 100 gram palatable portion of okra fruit comprises of moisture (89.6 g), protein (1.9 g), fat (0.2 g), fibre (1.2 g), phosphorus (56.0 mg), sodium (6.9 mg), sulphur (30 mg), riboflavin (0.1 mg), oxalic acid (8 mg), minerals (0.7 g), carbohydrates (6.4 g), calcium 66 mg, iron (0.35 mg), potassium (103 mg), thiamine (0.07 mg), nictonic acid (0.6 mg), vitamin C (13 mg), magnesium (53 mg) and copper (0.19 mg) (Gopalan *et al.* 2007).

Though okra is grown mainly in the Kharif season it is cultivated even in dry areas and almost available throughout the year (Rashid, 1999 and Norman, 1992) for favourable climatic conditions (Memon *et al.*, 2004). Entire production of okra was about 44000 metric tons from 26000 acres of land in Bangladesh with an average yield of nearly 4.6 t/ha in the year 2019-2020 (BBS, 2020), which is much lower in compare with the yield ranges from 7-12 t/ha in the developed countries (Yamaguchi, 1998).

It is mostly cultivated in summer season at optimum temperature range of 30-35º C, 6-7 pH in sandy loam soil (Akinyele and Temikotan, 2007; Adilakshmi *et al.,* 2008 and Akanbi *et al.,* 2010). The plants generally grow up to the height of 5 feet and bears broad spirally settled leaves. The reaped/immature fruits are usually used as vegetables in many parts of the world. Fruits comprise number of seeds which are 3-6 mm in diameter and are gray to black in color (Dada and Fayinminnu, 2010). Okra seed oil is eatable having a pleasant taste with odor and rich in unsaturated fats (oleic acid and linoleic acid) (Arapitsas, 2008). The whole production of green pods per capita is low due to many aspects such as lack of good quality seed, insect pest and disease infestation, weed competition, low plant density, improper application of fertilizers, space availability and many more (Rahman *et al.,* 2012).

Among them, insect pests are one of the significant factors in reducing the production of okra. Since okra allocates the cropping season of cotton, it is a main substitute host of cotton insect pests as well. Nearby 72 species of insects have been detected on the okra crop (Rahman *et al.,* 2013). It is vulnerable to the attack of several insects from vegetative to reproductive stage that causes significant damage. Jassid is the main polyphagous pest of numerous crops and is known as "the devastator" because of its plain damaging nature. It reasons the undersized plant growth by sucking cell sap from the plant (Asi *et al.,* 2008). It also release poison material into the plant which causes damage by decreasing the photosynthetic area (Bhatangar and Sharma, 1991).

The jassids suck the cell sap from lower exterior of the leaves and inject toxic substance subsequent in curling of leaves, as a result of which the plant development is retarded. The plain infestation of the pest causes burning of leaves which fall finally and results in 40-60 percent decrease in yield. Thrips is apolyphagous insect that can reduce crop yield straight by piercing plant tissues with their needle-shaped mouth and circuitously by vectoring plant diseases. The affected leaves become yellowish and start twisting (Ananthakrishnan, 1993). The whitefly transmits viral diseases from diseased to healthy plants as a vector (Narke and Suryawanshi, 1987). Whitefly is an insignificant polyphagous insect pest of numerous agronomic and horticultural crops with piercing and sucking mouthparts alike to plant hoppers. Nymphs and adults feed on the sap usually from the beneath surface of the leaves and disturb the photosynthesis development. The affected plant show undersized growth and compact vigor. It also conceals honeydew which endorses the sooty mold fungal development. It also assists as a vector of "Yellow Vein Mosaic Disease (YVMD)" causing destruction to okra crop (Salim, 1999). It is also a carrier of Cotton Leaf Curl Virus (CLCV) that causes rising curling of leaves (cup shaped), setting of veins and stunted plant growth that leads to reduced crop yield (Harrison *et al.*, 1997; Ahmad *et al.*, 2002). Shoot and fruit borer injure the generative parts of the plant including buds, tender flora, flowers and make rounded holes in the fruits. The small brown caterpillars of shoot borer bore into the top shoot and feed internally the shoots, usually before fruit formation. A larva attacks a number of stems and pods one after another. This caused in the wilting of shoots and plant develops damaged branches. Fruit borer enter into the fruit and feed inner part of the fruits that resulted in smaller and deformed pods of okra (Rahman *et al.*, 2013).

As high as 72 species of insects have been verified on okra (Srinivasa and Rajendran, 2003), of which, the sucking pests including of aphids, leafhopper, whiteflies and mite causes significant damage to the crop. Leafhopper causes about 40 to 56 percent losses in okra. Aphids and leafhoppers are vital pests in the early stage of the crop which desap the plants, make them weak and reduce the yield. Disappointment to control them in the initial phases was reported to cause a yield loss to the tune of 54.04 per cent (Chaudhary and Dadeech, 1989). Chemical control is most usually used and current method, and farmers are still trusting on the chemicals to control these insect pests (Naranjo, 2001). However, the unnecessary use of insecticides may lead to serious problems such as pesticidal contamination, mortality of beneficial insects or natural enemies and pollinators, reduction in nitrogen fixation and biodiversity (Miller, 2004). The permanent use of pesticides for a long period may also result in different neurological, psychological and behavioral disfunctions (Uversky *et al.,* 2002). Unfortunately, these chemicals are not simply degradable and get accumulated in the environment. Moreover, management of sucking pests by chemical application is a routine and never ending process because some pests are controlled measured by the use of selective new particles but repeated application of the same might lead to resistance development coupled with accumulation of residue in the fruits. Therefore, the usage of safer and environment friendly pesticides is the need of the time. Botanicals can be the promising substitute of chemicals for the control of insect pest due to their potential insecticidal properties. The benefit of these plants is that these are eagerly available and cheaper unlike other pesticides. These are comparatively easily degradable, least toxic to natural enemies, pollinators and mammals and safer for the environment and finally capable to reduce insect rests in the crop field.

Therefore, the present study has been undertaken with the following objectives:

- To know the infestation level of major sucking insect pests in okra;
- To evaluate the efficacy of some biorational pesticides against insect pests of okra;
- To identify the effective insecticides for the management of sucking insectpests.

CHAPTER II

REVIEW OF LITERATURE

Okra (*Abelmoschus esculentus* L.) is an important vegetable crop in Bangladesh is infested by a large number of insect pests that cause considerable yield loss. Among them okra aphid, *Aphis gossypii*; okra whitefly, *Bemisia tabacib* and okra jassid, *Amrasca biguttula*; is notorious pest, occurring sporadically or in epidemic form every year throughout Bangladesh. But published literature on this pest especially on its infestation status and management are scanty in Bangladesh. Literatures cited below under the following headings and sub-headings reveal some information about the present study.

2.1 Aphid

2.1.1 Biology of aphids

No sexual forms of Aphids species are known in the tropics so reproduction is most probably and exclusively parthenogenetic. Many generations occur during the year; only three to five days at 28-30°C and 10-12 days at 25-28°C are required to complete the development from the first nymphal instar to the adult. The number of nymphs, which are produced by one female under favorable conditions may reach upto 150 (Schmutterer, 1969).

2.1.2 Incidence of aphids

Singh *et al*. (2013) reported that the incidence of aphid commenced from fourth week after sowing that is, second week of September. The aphid population gradually increased and reached the peak level during the second week of October. Thereafter declined trend observed and population of aphid reached its lowest level in third week of November.

Boopathi *et al.* (2011) reported that the incidence of *A. gossypii* commenced from first week of June i.e. seventh week after sowing on all the cultivars. *A.*

gossypii population reached the peak infestation level at third week of June i.e., ninth week after sowing.

2.1.3 Management of aphids

2.1.3.1 Management by botanical

Naik *et al.* (2012) revealed that Neemazol @ 3.5%, Neem oil @ 2%, NSKE @ 5% was found superior against aphids than other botanicals like Vitex negundo leaf extract @ 5%, chilly garlic leaf extract @ 5% and Neemazol + chilly garlic leaf extracts.

According to Dhanalakshami (2006) among the indigenous materials tested, NSKE + GCK + CU (5.11 aphids/2 leaves) was found to be most effective with 81.25 per cent reduction in okra aphid (*A. gossypii*) which was followed by GCK + CU + CD (8.94 aphid/2 leaves) and GCK + CU (8.99 aphids/2 leaves).

2.1.3.2 Management by chemical

Wadnekar *et al.* (2004) reported that, mean number of aphid (0.4, 0.83 and 1.17 aphids/leaf after 2, 7 and 14 DAS, respectively) was found to be significantly low in thiamethoxam 25 WG @ 150 g a.i/ha. Thiamethoxam 25 WG @ 100 g and thiamethoxam 25 WG @ 75 g a.i/ha recorded 4.95 and 5.9 aphids per leaf, respectively.

Mishra (2002) evaluated some newer insecticides like thiamethoxam (Actra 25 WG), imidacloprid (confider 200 SL) and profenophos + cypermethrin (Rocket 44 EC) along with conventional insecticides like dimethoate (Rogar 30 EC), cypermethrin (super killer 10 EC), profenophos (Curacron 50 EC) against okra aphid, *A. gossypii* and leafhopper, *A. biguttula biguttula*. The results revealed that imidacloprid and thiamethoxam, both belonging to nitroguanidine group used @ 25g a.i/ha proved significantly superior in controlling aphids and leafhoppers on okra compared to other conventional insecticides.

2.2 Whitefly

2.2.1 Biology of whitefly

According to Schmutterer (1969), whiteflies are known to reproduce bisexually or parthenogenetically, and hence numerous generations can occur during the year. Both adults and nymphs suck the plant sap. Eggs are tiny (about 0.2 mm long) and pear-shaped. They stand upright on the leaves, being anchored at the broad end by a short stalk inserted into the leaf. They are laid usually in arcs or circles, on the undersides of young leaves. Hatching occurs after 5-10 days at 30°C depending on species, temperature and humidity (Martin, 1999). On hatching, the first instar nymph is the only mobile nymphal stage. It moves to a suitable feeding location on the lower leaf surface where it settles.

2.2.2 Incidence of whitefly

Pal *et al.* (2013) studied the incidence of insect pests infesting okra (cv.Indam-9) in Sriniketan, West Bengal, India, during summer (March to June) of 2009. The incidence of whitefly occurred at the early crop periods. The maximum and minimum temperatures, relative humidity, rainfall and sunshine were positively correlated with the incidence of the insect pest.

Hasan *et al.* (2008) conducted a field experiment in Uttar Pradesh, India, in 2005 and 2006, to determine the spatial distribution of *B. tabaci* on different okra cultivars. The results showed significant differences on the pest density at different stages of crop growth i.e. 30, 45 and 60 days after planting. The peak population was recorded on 60 days old crop, while the lowest was on 30 days old crop in 2005 & 2006. Population density was higher (3.2 to 6.7 adult/ leaf) during kharif season 2006 than that in 2005 (2.1 to 4.2 adult/ leaf). *B. tabaci* followed a regular distribution, while aggregated distribution pattern was also recorded when the population was low in 2005.

It causes three types of damage namely direct damage, indirect damage and virus transmission (Berlinger, 1986). Direct damage is caused by piercing and sucking of sap from the foliage of plants. Heavy infestation of adult and their progeny can cause the death of seedling, reduce the plant growth rate and yield due to sap removal. When adult and immature whiteflies feed, they excrete honeydew, a sticky excretory waste that is largely composed of plant sugars. It may also cause leaf chlorosis, leaf whitening and premature dropping of leaves that eventually results in plant death. Indirect damage results in the accumulation of honeydew produced by the whiteflies. This honeydew serves as a substrate for growth of black sooty mould on leaves and fruiting bodies. The mould reduces photosynthesis and lessens the value of the plant or yields rendering them unmarketable (Berlinger, 1986). The third type of damage is caused by vectoring of plant viruses by the whitefly. It is considered as the most common and important vector of plant viruses worldwide. *B.tabaci* transmits plant viruses of seven distinct virus groups including: geminiviruses, oviruses, carlaviruses, potyviruses, nepoviruses, loteoviruses and DNA-containing rod-shaped viruses (Duffus, 1996).

2.2.3 Management of whitefly

2.2.3.1 Management by botanicals

Naik *et al.* (2012) revealed that Neemazol @ 3.5%, neem oil @ 2% and NSKE @ 5% were found superior against whiteflies than other botanicals like Vitex negundo leaf extract @ 5%, chilly garlic leaf extract @ 5% and Neemazol + chilly garlic leaf extracts.

2.2.3.2 Management by chemical

Raghuraman and Gupta (2005) reported that acetamiprid 40 g a.i/ha and imidaclopird 100 g a.i./ha were the most effective treatments against *B. tabaci* and 48 and 45% increase in seed cotton yield over control, respectively. They suggested acetamiprid and imidacloprid are good substitute for conventional insecticides in vogue, which could use in formulating a successful management strategy for *B. tabaci.* According to Kale *et al.* (2005), treatment with thiamethoxam @ 5 g a.i./ha followed by alphamethrin 0.05% spray was the most effective in reducing whitefly populations in okra with higher yield and cost benefit ratio.

2.3 Jassid

2.3.1 Biology of jassid

Curved, greenish-yellow eggs (0.7-0.9 × 0.15-0.2 mm) are laid deeply embedded in the midrib or a large vein on the either surface of the leaf or in a petiole or young stem but never in the leaf lamina. Depending on species, 29-60 eggs can be laid singly and they hatch in 4-11 days (Sharma, 1997). Nymphs are pale green, wedge-shaped, 0.5-2.0 mm long, having carb like sideways movement characteristics when disturbed (Kochar, 1986). They are confined to the under surface of leaves during the daytime,but can be found anywhere on the leaves at night (Evans, 1965). The nypmphal period can vary from 2 to 21 days depending on food supplies and temperature (Hussain *et al.*, 1979). A generation takes 3-4 weeks in the summer *Amrasca devastans* is estimated to have 11 generations in a year in India (Iqbal, 2008). Adults are small, elongate and wedge-shaped, about 2.5 mm long, semitransparent plae green body, shimmering wings, very active, having a sideways walk like the nymphs, but quick to hop and fly when disturbed. (Singh *et al.*, 2003; Kakar and Dobra, 1988). They have a life span of up to 2 months.

2.3.2 Incidence of jassid

Singh *et al.* (2013) recorded that the incidence of leafhopper commenced from 2nd week after sowing i.e. the fourth week of August. Thereafter the peak pest population was recorded during the fourth week of September. Boopathi *et al.* (2011) observed that the incidence of *A. biguttula biguttula* was active from last week of May to till the final harvest i.e. first week of August. The peak level of incidence was noticed during first week of July.

Anitha and Nandihalli (2008) revealed that population of leafhopper on Kharif crop started appearing from first week of August, 2006. Peak incidence of leafhopper was noticed during last week of October, 2006.

2.3.3 Management of jassid

2.3.3.1 Management by botanicals

Shabozoi *et al.* (2011) reported the minimum mean population of jassid (1.65/leaf) was recorded in Biosal or neem oil, whereas the maximum pest population (2.39/leaf) was found in control.

Harischandra Naik *et al.* (2012) revealed that Neemazol @ 3.5%, neem oil @ 2% and NSKE @ 5% were found superior against leafhopper than other botanicals like Vitex negundo leaf extract @ 5%, chilly garlic leaf extract @ 5% and Neemazol + chilly garlic leaf extracts.

2.3.3.2 Management by chemicals

Among the imidacloprid formulations, imidacloprid 17.8 SL at 25 g a.i./ha was found superior against leafhoppers and this was with acephate 75 SP, thiamethoxam 25 WG, acetamiprid 20 SP, imidacloprid 17.8 SL at 20 g a.i./ha and imidacloprid 70 WG at 25 g a.i./ha (Honnappagouda *et al.,* 2011).

Sujay Anand *et al.* (2013) reported that the thiamethoxam and acetamiprid resulted in the effective management of leafhopper in okra followed by buprofezin and pymetrozine. Hence these biorationals offers as a good alternative to neonicotinoids. The spiromesifen was very effective in managing the whitefly in okra.

Results showed that imidacloprid @ 2 ml, thiamethoxam and carbosulfan @ 2 g/kg seed were found effective in controlling okra leafhopper (*A. devastans*). Seed yield was higher in thiamethoxam, imidacloprid and carbosulfan treatments. (Rana *et al.*, 2006).

2.4 Insect pests in okra and their control measures

Dandale *et al.* (1984) reported the superiority of cypermethrin, fenvalerate and endosalfan in reducing pod borer infestation in red gram. Four sprays of 0.08% cypermethrin (at flowering, at 50 and 100% flowering and at 100% pod setting) afforded complete protection against *Maruca testulalis* on pigeon pea in Bangladesh in winter season of 1987-88. Dimethoate was not as effective as cypermethrin. But no such trial has so far been conducted on bean in Bangladesh. Several commonly used insecticides such as endosulfan, carbaryl, methomyl, monocrotophos have been found effective against *Maruca testulalis* G. on cowpea (Lalasangi, 1988).

The biology of *Aphis gossypii* was studied by Kandoria and Jamwal (1988) on okra, aubergine and chilli (*Capsicum annuum*) in screenhouse cages in the Punjab, India, during August-October 1986. Nymphal development lasted for 8.38, 8.30 and 8.25 days, on okra, aubergines and *C. annuum*, resp. Nymphal survival was highest on okra (96%), followed by aubergine (95%) and *C. annuum* (92%). Adult longevity was 11.66, 11.48 and 10.95 days on aubergines, *C. annuum* and okra, respectively, and the generation time was 19.35, 19.94 and 19.22 days on these crops.

Kumar and Urs (1988) were evaluate the seasonal incidence of *Earias vittella* on okra in Karnataka, India, in 1983-85 showed that infestation of shoots and fruits started in the 2nd and 6th weeks after germination, respectively. Crops sown in any month had infested shoots from the 3rd to 5th weeks in both years of the study. The infestation level on fruits varied from 8.4 to 53.8 and 9.2 to 73.2% in different weeks during 1983-84 and 1984-85, respectively. The pooled data revealed an infestation level varying from 12.6 to 32.6 and 13.6 to 46.7% in crops sown in different months in 1983-84 and 1984-85, respectively. The crop suffered heavily in the 10th week after sowing in 1983-84 and in the 11th week after sowing in 1984-85. Infestation was more severe in crops sown in warmer months than in those sown in rainy or cooler months.

The optimum time and spray interval for application of 0.05% monocrotophos (Nuvacron 40 EC) for the control of the cicadellid *Amrasca biguttula biguttula* on okra were determined by Srinivasan and Krishnakumar (1988) in Karnataka, India. Two applications of monocrotophos, 21 and 35 days after germination, gave the most effective and economical control. Application of carbofuran (Furadan 3G) at 1 kg a.i./ha at sowing did not control cicadellids in later stages of crop growth and yield was reduced by 37.9% in comparison with the most effective treatment.

Hibiscus yellow vein mosaic virus was controlled by 3 sprays of phosphamidon (0.02%) or methyl demeton [demeton-S-methyl] (0.025%), a single soil application of Foratox [phorate] (15 kg/ha) or by early sowing (1 Mar.) or intercropping okra with cowpea [*Vigna unguiculata*] or mungbean [*V. radiata*] by Singh *et al*. (1989). The insecticides reduced numbers of *Bemisia tabaci*/plant and increased yields more effectively than the other treatments.

Verma (1989) tested Lindane, endosulfan, fenitrothion, methyl-O-demeton [demeton-O-methyl], phosalone, monocrotophos, dimethoate, Sevimol [carbaryl], Sevisulf [carbaryl plus sulfur], permethrin and deltamethrin were tested by against control of the cicadellid *Amrasca biguttula biguttula* on okra in the field in India. Deltamethrin at 0.01 and 0.02% resulted in a 100% reduction of the cicadellid population, 15 days after spraying. Lindane was the least effective treatment, resulting in 44-46% mortality, 15 days after the 1st spray. In the laboratory, the time for 50% mortality (LT50) for permethrin, monocrotophos, endosulfan, fenitrothion, phosalone, malathion and lindane at the recommended concentration was 9.8, 8.0, 5.1, 4.0, 3.3, 3.2 and 0.6 days, respectively.

Kumar *et al*. (1989) evaluated the critical time of insecticidal application for control of *Aphis gossypii* and *Amrasca biguttula biguttula* on okra was investigated in Karnataka, India. Application of insecticide (monocrotophos 36 EC at 500 g a.i./ha) 21-42 days after germination resulted in the lowest infestation of both pests and the highest cost : benefit ratio. Application of carbofuran 3G at 1 kg a.i./ha at the time of sowing did not give effective control at the later crop stages.

A schedule of insecticide sprays using decis (Deltamethrin) and systoate (Dimethoate) on 35, 45, 55 and 65 days after planting was investigated in Benin to determine the most effective treatment against the pyralid *M. testulalis* on cow pea (Atachi and Sourokou, 1989). Application of deltamethrin, cypermethrin or fenvalerate @ 0.008% or dimethoate, fenitrothrin, malathion, quinalphos or monocrotophos @ 0.008% or endosulfan 0.10% one at flowering and then at pod setting stage would be highly effective. However, at lower infestation, insecticide application would not be economically advisable.

Cypermethrin was sprayed at 0.2 kg a.i./ha to control different densities of pyralid *M. testulalis* larvae when infestation in flowers reached 10, 20, 30, 40 and 50% in 1985 and 10; 20 and 30% in 1986 (Ogunwolu, 1990). The effect of rainfall on the numbers of *Amrasca biguttula* biguttula infesting 13 varieties of okras sown on 21 July 1986 was studied in Ludhiana, Punjab, India. The cicadellid first appeared on crops 2 weeks after sowing. Thereafter, the population increased with the age of the crop, except during the 2nd half of the 4th and 5th weeks. Continuous heavy rainfall for 4 days (61.1 mm) during the 2nd half of the 4th week, a low mean temperature (<29^0C), a high RH (>78%) and less sunshine (6.4 h) drastically reduced the pest population on the different varieties of okras, irrespective of their level of susceptibility to attack. Under these weather conditions, the pest population was reduced by 72.6%.

Spraying of synthetic pyrethroid insecticides at the rate of 1 ml per liter of water has been recommended for the control of the pest of okra (Karim, 1993). The life cycle of *Tetranychus macfarlanei*, a pest of okras in South Gujarat, India, was studied by Sejalia *et al*. (1993) in the laboratory during March-April and July- August. Low temperatures and humidity during March-April prolonged the developmental period, whereas higher temperatures and humidity during July- August resulted in a decrease in developmental period. At 29.67^{0}C and 87.3% RH (during July-August), the net reproductive rate, mean generation time, innate capacity for increase and the finite rate of increase were 30.37, 12.04 days, 0.28 and 1.33 per day, respectively.

The effect of simulated exposure to natural infestation of *Amrasca biquttula biguttula* at different crop ages on seed yield of okra with respect to 3 sowing dates and 2 varieties was investigated by Mahal *et al*. (1994) in the Punjab, India. The crop at the time of sowing was covered with muslin cages and the plants were periodically exposed to natural jassid infestation at 5, 15, 25 and 35 days after germination (DAG). The unexposed plants were kept as controls. After 45 DAG blanket sprays of monocrotophos (Nuvacron 36 SL) were given regularly at 10- day intervals to control further infestation. The crop kept free from natural infestation of *A. biguttula* throughout the vegetative phase of growth (up to 45 DAG) and that exposed after 35 DAG (10 days feeding exposure) exhibited longer plants and fruits, and more fruits per plant, seeds per fruit and seed yield in contrast to early exposure for up to 15 DAG. This trend was evident in both cvs, *Pusa Sawani* and Punjab-7, at all the sowing dates. In the late sown crop, exposures beyond 25 DAG and jassid-free plants were on a par with respect to all the parameters. Early exposure to jassid infestation up to 15 DAG, especially in the early and normal sown crops, resulted in greater losses in seed yield (37.55 and 42.18%, respectively) than in late-sown crop (20.39%). The losses were marginal (3.56 and 2.95%, respectively) when the crop was exposed to jassid infestation late in season at 35 DAG.

A number of reports revealed that a hundred of insecticides are used against pod borer. Most of the cases the farmers reduced their spray interval. A report showed that the vegetable growers of Jossore Region of Bangladesh spayed insecticides almost every day or every alternate day in their bean field (Anon., 1994). Some of the farmers spray insecticides in their vegetable field even 84 times in one season. Majority of the farmers were found to sell their produce harvested residues with bean that causes health hazards to the consumers.

Singh and Brar (1994) carried out an experiment on Okras sown on May 15 in Ludhiana, Punjab, India, harboured the highest mean population of *Amrasca biguttula biguttula* and *Earias* spp., followed by the crop sown on May 30. Maximum damage by *Earias* spp. was observed on okras sown on June 15 and lowest on okras sown on July 30. The highest fruit yield was obtained by sowing the crop on May 15. Crops protected from the insect pests gave a greater fruit yield than the control and the losses in yield varied from 32.06 to 40.84%.

Application of deltamethrin, cypermethrin or fenvalerate or cyfluthrin (Bethroid 0.50 EC) at the rate of 1.0 ml / 1 of water may be helpful for the control of the pod borer (Karim, 1995). The red spider mite, *Tetranychus macfarlanei*, so far recorded as a minor pest in South and Central Gujarat, India, is rapidly becoming a pest causing considerable damage to okra, aubergines and cotton by Rai *et al*. (1995). The rate or multiplication of *T. macfarlanei* was studied when reared on okra leaves under laboratory conditions at 29.67°C average temperature and 87.30% average relative humidity. The maximum female birth (mx = 6.18) was on day 11 of the pivotal age. Under a given set of conditions and food supply, the mite was able to multiply on okra leaves. In the stable age-distribution, a 93% contribution was made by immature stages including egg, larva, protonymph and deutonymph.

An overview is given of insect pests found in India on okras during 2 cropping seasons (spring-summer and rainy season) by Arora *et al*. (1996). Various management practices including the appropriate timing of sowing, judicious use of fertilizers, use of resistant cultivars, physical control, botanical insecticides (neem seed extracts), microbial control (*Bacillus thuringiensis*) were more effective than the control and the use of economic thresholds to take spraying decisions.

Dubey *et al*. (1998) conducted a field experiment in Madhya Pradesh with okra cv. Parbhani Kranti, 9 treatments were compared for the control of *E. vittella*. The application of 1 kg phorate a.i./ha basally + single spray of monocrotophos (0.05%) 30 DAS (days after sowing) followed by 4 sprays of cypermethrin (0.006%) (45, 55, 65 and 75 DAS) produced the lowest infestation level on fruits (12.68%) and the highest marketable fruit yield (10.42 t/ha).

Satpathy *et al*. (1998) reported that both sowing time and crop growth stage influenced the insect population significantly in okra crop sown from 15 May to 15 July during the 1996 and 1997 cropping season in Varanasi, Uttar Pradesh, India. The crop was found to be most susceptible to the jassids (*Amrasca biguttula*) at 50 DAS, where as peak population of jassids were observed in the first sown crop. With the advancement of sowing time jassid infestation decreased and borer (*Earias vittella*) damage increased. However, maximum yield was obtained from the crop sown in the first week of June. Although a considerable number of jassids were present during this period, suitable growing conditions resulted in maximum yield.

In a field experiment was conducted by Faqir in 1995 in Pakistan with okra cv. T-13, Richgreen, Perkingdwarf, Pussagreen, Climsonspinless [*Clemson Spineless*] and Swat local. Dimethoate 40 EC, dichlorvos 100 EC, imidacloprid 200 SL, methylparathion [parathion-methyl] 50 EC and monocrotophos + alpha-cypermethrin 42 EC were tested against cicadellids (*Amrasca devastans* [*A. biguttula biguttula*]). Imidacloprid 200 SL was effective in controlling the pest over a longer time period than the other insecticides. Yield was highest in plots treated with monocrotophos + alpha-cypermethrin (11.85 t/ha), which was not significantly different from 10.31 t obtained in imidacloprid treated plots. All the cultivars were susceptible to the pest.

A field experiment was conducted by Adiroubane and Letchoumanane (1998) during 1994 to evaluate efficacy of 3 plant extracts, sacred basil (*Ocimum sanctum*), Malabar nut (*Adhatoda vesica*), Chinese chaste tree (*Vitex negundo*) and synthetic insecticides (endosulfan and carbaryl) and their combination products in controlling okra jassids, *Amrasca biguttula biguttula* and fruit-borers during the rainy season in 1994 by spraying them at 10, 25 and 40 days after sowing. All the treatments suppressed both the jassid population and fruit borer incidence.

Rai and Satpathy (1999) carried out an experiment to find out the effect of sowing date and insecticides in controlling the insect pests of okra, studied in a field experiment conducted in Varanasi, Uttar Pradesh, India during 1996 and 1997, showed that there is gradual increase in jassid population with advancement of sowing date up to mid-June. Thereafter it declined substantially. However, late- sown crops suffer more from borers. Crops sown in the second week of July (S_6) recorded maximum fruit damage which was lowest on 25 May (S_2)-sown crops. Monocrotophos at 500 g a.i./ha controlled the jassids more effectively than cypermethrin at 50 g a.i./ha. Beta-cyfluthrin @ 12.5, 18.75, 25, 37.5 and 75 g a.i. ha^{-1}, lambda-cyhalothrin @ 37.5 g a.i. ha^{-1} and imidacloprid @ 40 g a.i. ha^{-1} were sprayed at the fruiting stage of the okra crop by Dikshit *et al*. (2000). In a separate experiment, okra seeds were treated with imidacloprid (Gaucho 600 FS) @ 3, 5.4, 10.8 and 21.6 g kg^{-1} seeds and were sown. Residues of the insecticides from okra declined progressively with time and became non detectable on 7th d from beta-cyfluthrin and on 10th and 15th d from imidacloprid and lambda-cyhalothrin spray treatment, respectively.

Field trials were conducted in by Chakraborty *et al*. (2002) West Bengal, India to determine the effect of methomyl (Lannate 40 SP; at 150, 300 and 450 g a.i./ha) and/or 60 g cypermethrin/ha or 250 g quinalphos/ha to control jassid (*Amrasca biguttula*) and fruit borer (*Earias vitella*) on the first season of spray (March-July 1996), and leaf rollers (*Sylepta derogata* [*Haritalodes derogata*]) and fruit borers on the second spray. Methomyl at 300 g a.i./ha provided sufficient reduction (75%) in pest population and its performance was similar to that of quinalphos. Methomyl at 150 g a.i./ha was chemically compatible with cypermethrin; the performance of this combination was superior to all other treatments in terms of pest control and yield. Residues declined progressively with time. All pesticidal treatments were superior to the untreated control plots in terms of pest control and yield.

2.5 Non-chemical control

Farmers believe that insecticides are the only method to control insect pest. This mental makeup has been created from their practice of using insecticides to control the insect pests attacking their crops over many years (Islam, 1999). Moreover, the Government’s policy of giving 100% subsidy on pesticides i.e., giving the pesticides free of cost to the farmers had helped encourage and develop the habit of indiscriminate use of pesticides among the farmers. This is serious problem in achieving success in IPM programs.

2.6 Use of botanical extracts

Botanical pesticides are becoming popular day by day and now a day these are using against many insect pests. It was found that Lepidopteron insect is possible to control by botanical substances.

Khan and Khan (1984) stated that the toxicity of the vegetable oils 1% taramira (seed oil of *Eruca sativa*) and 1% Aartemisia (oil from the distilation of leaves and shoots alone and in combination with 0.5% DDT and 0.5% lindane against *Dacus dorsalis, D. zonatus* were assessed in the laboratory. Direct and indirect spray techniques were used. The vegetables oils alone and in combination with the DDT and lindane were effective against the tephritids.

Ranganath *et al*. (1997) tested a number of botanical against *Bactrocera cucurbitae* on cucumber (*Cucumis sativus*) and ribbed gourd (*Luffa acutangula*) and found that neem oil at 1.2% was the most effective treatment in reducing damage to cucumber (mean percentage damage 6.2%, as compared with 39.0% in the control), while neem cake at 4.0% and DDVP (dichlorovs) at 0.2% were the most effective against the pest on ribbed gourd, reducing damage to 9.1 to 9.5% as compared with 32.9% in control.

Lopez *et al.* (1999) assayed short-term choice and no-choice feeding used to assess the antifeedant activity of *T. havanensis* fruit extracts (at 5000 ppm) against 5th-instar *Heliothis armigera* larvae. The acetonic extract gave the highest activity and was further fractionated by silica gel column chromatography. Of the 7 fractions isolated, 5 were identified as the limonoids azadirone, trichilinone acetate, 14,15-deoxyhavanensin-1,7-diacetate, 14,15-deoxyhavanensine-3,7- diacetate and a mixture of havanensin-1,7-diacetate and havanensin-3,7-diacetate. Choice and no-choice feeding assays of each fraction at 1000 ppm, showed that the mixture of havanensin-1,7-diacetate and havanensin-3,7-diacetate had the highest antifeedant activity against *H. armigera* larvae. Azadirone and trichilinone acetate were also antifeedants. No antifeedant activity was found in the remaining fractions. It is suggested that all of the limonoids with antifeedant activity have a similar mode of action, which is probably toxic.

Ju *et al*. (2000) tested six desert plants chosen to study their toxicity and effects on the growth and metamorphosis of the insect pest, *Heliothis armigera* [*Helicoverpa armigera*]. An artificial diet containing 5% aqueous extracts of *Cynanchum auriculatum* or *Peganum harmala* var. *multisecta* showed strong toxicity to the larvae and caused mortality of 100% and 55%, respectively. These two extracts at the same dosage also significantly affected metamorphosis of the insect. An artificial diet containing 1% aqueous extracts of *C. auriculatum* or 5% aqueous extracts of *P. harmala* resulted in mortality of 85% and 55%, respectively, and a zero emergence rate. Tests of extracts of *C. auriculatum* made at different pH showed that the pH 3 and pH 10 portions of the extracts affected the larvae growth significantly. The other plant species tested were *Euphorbia helioscopia, Sophora alopecuroides, Peganum nigellastrum and Thermopsis lanceolata*; extracts of these species caused either much lower mortality of *H. armigera* or zero mortality (*E. helioscopia*).

Sundarajan & Kumuthakalavalli (2000) tested Petroleum ether extracts of the leaves of *Gnidia glauca* Gilg., *Leucas aspera* Link., and *Toddalia asiatica* Lam. against sixth instar larvae of *Helicoverpa armigera* (Hubner.) at 0.2, 0.4, 0.6, 0.8 and 1.0% by applying to bhendi (okra) slices. After 24 hr, percentage mortality, EC50 and EC90 were calculated. Total mortality was recorded in the treatment with 0.8% of the extract of *G. glauca.* Of the three leaf extracts used, *G. glauca* showed an EC50 of 0.31%.

Kulat *et al.* (2001) conducted an experiment on extracts of some indigenous plant materials, which are claimed important as pest control like seed kernels of neem, *Azadiracta indica*, *Pongamia glabra* [*P. pinnata*], leaves of tobacco, *Nicotiana tabacum* and indiara, a neem based herbal product, against *H. armigera* on chickpea cv. I.C.C.V.5 for its management in Rabi seasons of 1993-96 at College of Agriculture, Nagpur, Maharashtra, India. The results revealed that the crop treated with the leaf extract of *N. tabacum* and seed extract of *P. glabra* (5%) and indiara (1%) and neem seed kernel extract (5%)

Exhibited low level of population built up compared to control.

Sundarajan (2002) screened methanol extracts of selected plants namely *Anisomeles malabarica, Ocimum canum [O. americana], O. basilicum, Euphorbia hirta, E. heterophylla, Vitex negundo, Tagetes indica and Parthenium hysterophorus* for their insecticidal activity against the fourth instar larvae of *Heliothis armigera* by applying dipping method of the leaf extracts at various concentrations (0.25, 0.5, 1.0, 1.5 and 20) on young tomato leaves. The larval mortality of more than 50% has been recorded for all the plant extracts in 2 per cent test concentration (48 h) except *Euphorbia heterophylla* which recorded 47.3 per cent mortality in 2 per cent concentration. Among the plant extracts tested *V. negundo* is found to show higher rate of mortality (82.5%) at 2 per cent concentration.

2.7 Use of Neem oil

Experiment with botanical pesticides has also been conducted in Bangladesh on a limited scale. Islam (1983) reported that extract of leaf, seed and oil of neem, showed potential as antifeedants or feeding and oviposition deterrents for the control of brown plant hopper, green leaf hopper, rice hispa and lesser rice weevil. He also conducted experiments to asscertain the optimal doses of the extract against rice hispa, and pulse beetle. Addition of sesame or linseed oil to extract of neem resulted in higher mortality of the grubs and in greater deterrence in feeding and oviposition compared to those obtained with extract alone (Islam, 1986).

Fagoonee (1986) used neem in vegetable crop protection in Mauritius and showed neem seed kernel extract was found to be effective as deltamethrin (Decis) against the *Plutella xylostella* and *Crocidolomia binotalis.* He also found neem extract alternate with insecticides gave best protection against *Helicovarpa armigera.* Neem product have been used to control vegetable pests under field condition and good control of *Plutella xylostella* and Pyralid, *Hellula undalis* on cabbage was achieved with weekly application of 25 or 50 gm neem kernel powder/liter of water (Dreyer, 1987).

Field trail with neem products have shown, not only a decrease in damage by pest but also an increase in crop yield compared to those obtained with recommended synthetic insecticides. A methanol suspension of 2-4% of the neem leaves have been used against the caterpillar of diamondback moth, *Plutella xylostella* and it was as effective as either synthetic insecticides mevinphous (0.05%) or deltamethrin in (0.02%) in Togo (Dreyer, 1987). In Thailand, a field trail showed that piperanyl butoxide increased the efficacy of neem and the combination was as active as cypermethrin (0.025%) against *Plutella xylostella* and *Spodoptera litura,* which revealed that neem oil with synthetic insecticides may have some synergetic effect in controlling insect pests (Sombatsiri and Tigvattanont, 1987).

Saxena (1988) summarized the effectiveness of neem oil against 87 arthropods and 5 nematodes, 100 insects and mites and 198 different species of insects, respectively. Neem *(Azadicachat Indica A. Juss*) seed oil, a botanical pesticide have also been used to control different insect pests of important agricultural crops in different countries of the world. More than 2000 species of plants have been reported to posses' insecticidal properties (Grainge and Ahmed, 1988). The neem tree *(Azadirachta indica*) is one of them. The development and use of botanical pesticides become an integral part of the integrated pest management (IPM) strategies.

Entomologist of many countries including India, the Philippines, Pakistan and Bangladesh has conducted various studies of neem against different insect pests. Most of the cases the investigators have been used a particular concentration of the neem extract. Neem seed kernel extracts (3-5%) were effective against *Nilaparbata lugens, Nephotettix* spp., *Marasmia patnalis, Oxya nitidula* and Asian gall midge. Neem leaf extract, however, is less effective than neem seed kernel extract. But the same extract of 5-10% was highly effective, inclusive of *Scirpophaga incertulus* and thrips. Damage by leaf folders was reduced by 3% neem oil. Neem seed kernel extracts reduced egg deposition on rice seedling by *Nephotettix* spp. and *Nilaparvata lugens* (Jayaraj, 1991). Neem seed kernel extract was an effective antifeedent to pigeon pea pod borer. He also found that there has been no adverse effect, even though neem was systemic. According to him neem oil can be used @ 1-3% without any problem. But 5% neem oil will cause phytotoxicity in many plants. The effect of neem oil is systemic, though not persistent. It should be noted that application of neem oil beyond 5% will cause serious phytotoxicity in rice. At 3%, the initial phytotoxicity effects are minimum and the plant can recovered completely. Thus, neem oil should be applied at concentrations not beyond 3% (Jayaraj, 1991).

Most of the cases, the user of neem oil use it at different doses ranged from 0.5-50% (Krishnaiah and Kalode, 1991). They use different emulsifier to mix neem oil with the water. Detergent in water helps neem oil to emulsify in the water. In a field observation of neem oil, Krishanaiah and Kalode (1991) used soap as emulsifier with water. Another study with neem oil in rice field, Palanginan and Saxena (1991) added 1.66% Teepol (liquid detergent) to the extract solutions as an emulsifier. In a study of Bangladesh Rice Research Institute (BRRI), Gazipur, Alam (1991) added 1 ml (0.1%) of teepol detergent per liter of water and spray at 7 days interval against stem borer of rice.

Stoll (1992) summarized the potential benefits of botanical pesticides which diminish the risk of resistant development, natural enemy elimination, secondary pest out break and ensure overall safety to the environment. The seed and leaves of the neem tree contain terpenoids with potent anti-insect activity. One of the most active terpenoids in neem seeds is “azadirachtain” which acts as an antifeedant and growth disrupter against a wide range of insect pest at microgram levels. The active terpenoids in neem leaves include nimbin, deactylnimbin and thionemone (Simmonds *et al.*, 1992).

The leaf extract of neem tested against the leaf caterpillar, *Selepa docilis* at 5% concentration had a high anti-feedant activity with a feeding ratio of 28.29 followed by 3% having only medium anti-feedant properties with 23.89 as the feeding ratio (Jacob and Sheila, 1994).

CHAPTER III
MATERIALS AND METHODS

The experiment was carried out during the period from October 2020 to February 2021. The materials and methods that were used for conducting the experiment have been presented in this chapter.

3.1 Location of the experimental site

The experiment was carried out at the central farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in 240 09/ N latitude and 900 26/ E longitudes. The altitude of the location was 8 m from the sea level.

3.2 Climatic condition of the experimental site

Experimental location is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of April to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment were collected from the Bangladesh Meteorological Department, Agargoan, Dhaka (Appendix I).

3.3 Soil characteristics of the experimental site

Selected land of the experimental field was medium high land in nature with adequate irrigation facilities and remained utilized for crop production during the previous season. The soil is belongs to the Modhupur Tract under AEZ No. 28. The soil texture of the experimental soil was sandy loam. The nutrient status of the farm soil under the experimental plot with in a depth 0-20 cm were collected and analyzed in the Soil Resources Development Institute (SRDI) Dhaka, and result have been presented in Appendix II.

3.4 Design and layout of the experiment

The study was conducted with seven treatments. The experiment was laid out ina Randomized Complete Block Design (RCBD). The field was divided into

3 equal sub-plots maintaining 3mX2m plot size, 1 meter block to block distance. 0.75 meter plot to plot distance, where each block was used for each replication and each treatment was randomly assigned in each plot. Plant to plant distance was 20cm and row to row distance was 30cm. Each treatment was allocated randomly within the block and replicated three times.

3.5 Land preparation

The plot selected for conducting the experiment was opened in the second week of October, 2020 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilt. Weeds and stubbles were removed and finally obtained a desirable tilt of soil was obtained for sowing okra seeds.

All weeds, stubbles and residues were eliminated from the field. Finally, a good tilt was achieved. The soil was treated with insecticides (cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.6 Application of manure and fertilizers

Urea, Triple super phosphate (TSP) and Muriate of Potash (MP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers that were applied to the experimental plot. The total amount of cowdung, TSP and MP was applied as basal dose at the time of final land preparation dated at 13 October, 2020. Urea was applied at 15, 30 and 45 days after sowing (DAS).

3.7 Collection and sowing of seeds

Seeds of green finger (Okra F_1) were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Dhaka. Seeds were sown in the experimental plots on 15 October, 2020 at the rate of 63 seeds/plot (three seeds per pit and 21 pits per plot). The row to row and plant to plant spacing was maintained at 20 cm x 30 cm respectively. The field was irrigated lightly immediately after sowing.

3.8 Intercultural operations

The seedlings were always kept under close observation. Necessary intercultural operations were done throughout the cropping season to obtain proper growth and development of the plants.

3.9 Cultural practices

3.9.1 Gap filling

Dead, injured and weak seedlings were replaced by new vigor seedling from the stock on the border line of the experiment.

3.9.2 Thinning

When the seedlings got established, one healthy seedling in each location was kept and other seedlings were removed.

3.9.3 Irrigation

Light overhead irrigation was provided with a watering can to the plots once immediately after sowing of seed and then it was continued at 3 days interval after seedling emergence for proper growth and development of the seedlings. When the soil moisture level was very low the plants of a plot had shown the symptoms of wilting the plots were irrigated on the same day with a hosepipe until the entire plot was properly wet.

3.9.4 Drainage

Stagnant water effectively drained out at the time of heavy rains.

3.10 Harvesting

As the seeds were sown in the field at times, the crops were harvested at different times. Green pods were harvested at four days interval when they attained edible stage. Green pod harvesting was started from 20 December 2020 and was continued up to 28 February, 2021.

3.11 Treatments

The comparative effectiveness of the following six treatments for okra shoot & fruit borer and whitefly were evaluated on the basis of reduction of these pests.

T_1-Spinosad @0.5 ml/L water at 7 days interval.

T_2-Matrine @1.0 ml/L water at 7 days interval.

T_3-Thiamethoxam @0.2 ml/L water at 7 days interval.

T_4- Neem oil @5.0ml/L of water with detergent at 7 days interval.

T_5-Abamectin@1.0ml/L of water at 7 days interval.

T_6-Buprofezin 0.2g/L of water at 7 days interval.

T_7- Untreated Control.

3.12 Application of the treatments

Spraying was done at 12.00 pm to avoid moisture on leaves. The selected insecticides with their assigned doses were started to apply in their respective plots after 55 days of germination. Treatments were applied at 7 days interval. Spraying was done by knapsack sprayer having a pressure of 4.5 kg/cm^2. To get complete coverage of plant, spraying was done uniformly on the entire plant with special care. In case of untreated control, only fresh water was sprayed for respective plots.

3.13 Data collection

Data on infestation by okra shoot and fruit borer under different treatments were recorded during both vegetative and reproductive stages. Infested shoots from 5 randomly selected plants were counted and recorded at two days interval by the presence of bores and excreta on flower bud, shoot and fruit at stages respectively.

3.14 Collection of data on yield and yield contributing character

Infestation of okra by okra shoot and fruit borer was monitored during both vegetative and reproductive stages. Infested shoots and fruits were counted and recorded at 7 days intervals after observing the bores and excreta in both vegetative and reproductive stage.

3.15 Data recorded

The data on the following parameters were recorded at different time intervals as given below:

- Number of white fly after applying different treatments per plot
- Number of aphid after applying different treatments per plot
- Number of jassid after applying different treatments per plot
- Yield contributing characters/yield attributes
- The number of fruits per plants
- Single fruit length(cm)
- Single fruit weight(gm)
- Yield of Okra (ton/ha)

3.15.1 Percent of OkYVCMV infected plant in number

Number of infected plant was counted from total plants per plot and percent plant infection by OkYVCMV was calculated by using the following formula:

$$\% \text{ OkYVCMV infected plant} = \frac{\text{No. of OkYVCMV infected plant}}{\text{Total no. of plants per plot}}$$

3.15.2 Percent of OkYVCMV infected leaf in number

Number of infected leaves was counted from total leaves per five tagged plants per plot and percent leaf infection by OkYVCMV was calculated by using the following formula:

$$\% \text{ OkYVCMV infected leaf} = \frac{\text{No. of OkYVCMV infested leaf}}{\text{Total no. of leaves}}$$

3.15.3 Fruit infestation

The data on the number of healthy and infested fruits were recorded from 5 tagged plants in each treatment. The percent infestation of fruit was calculated with the following formula

$$\textbf{\% infestation of fruit} = \frac{\text{Number of OSFB infested fruits}}{\text{Total number of fruits}}$$

3.15.4 Height of plant

Height of plant from randomly selected 5 plants were taken and then averaged for each treatment separately..

3.15.5 Single pod weight

Single pod weight was counted from the ten randomly selected plants and was weighed by a digital electronic balance. The weight was expressed plant^{-1} basis in gram (g).

3.15.6 Fruits yield plot^{-1}

The fruits were collected from 6.0 m^2 of each plot in each harvest and weighted. The weight of fruits per plot was expressed in kilogram (kg).

3.15.7 Yield per hectare

Total yield of okra per hectare for each treatment was calculated in tons from cumulative fruit production in a plot. Effect of different treatments on the increase and decrease of okra yield over control was also calculated by the following formula:

$$\% \text{ increase of yield over control} = \frac{\text{Yield of treated plot- Yield of control plot}}{\text{Yield of control plot}} \text{ X } 100$$

3.16 Statistical analysis of data

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package MSTAT program (Gomez and Gomez, 1976). The treatment means were separated by Duncan's Multiple Range Test (DMRT).

CHAPTER-IV
RESULTS AND DISCUSSION

The present research work was conducted to investigate the biorational management of sucking insect pests of okra crop. The bio-rational management of sucking insect pests of okra in the fields was evaluated at vegetative, flowering and fruiting stages to investigate the sucking insect's incidence, number of nymphs and adults per plot, plant height, number of total fruit and total yield varied significantly with different treatments.

4.1 Incidence of major insect pests of okra

Incidence of major sucking pests of okra was recorded for the entire cropping season when aphid, white fly and jassid were observed. Data were taken from each plant at vegetative, flowering and fruiting stages to investigate the sucking insect's incidence.

4.1.1 Incidence of aphid, white fly and jassid of okra at vegetative stage

Number of aphid per plant was recorded at vegetative stage and statistically significant variation was observed among the treatments applied for controlling major insect pests of okra (Table 1). At the vegetative stage of aphid, significant variations were observed in different treatments in case of number of nymph per plant. Results showed that, the lowest number nymph of aphid was recorded in T_6(0.78) treated plot which was statistically identical with T_5(0.92) treatments and closely followed (1.15, 1.17 and 1.31) by T_4, T_3 and T_2, whereasthe highest number of nymph (1.64) was recorded in T_7 treatment which wasstatistically identical with T_1(1.56) treatments..

At the vegetative stage, for aphid, significant variations were observed in differenttreatments in case of number of adult per plant. Results showed that, the lowest number of adult aphid was recorded in T_6(1.19) treated plot which was statistically identical with T_5(1.42) treatments. On the other hand, the highest number of adult was recorded in T_7(2.19) treatment which was significantly identical (2.04) with T_1 and closely followed (1.78, 1.189 and 1.72) by T_4, T_2 and T_3 treatments.

In case of whitefly, significant variations were observed among the treatments in terms of okra per plant. From the results it was revealed that, the lowest number of nymph of whitefly (0.56) was recorded in T_6 treated plot which was statistically identical (0.67) with T_5 treatment and closely followed (0.99 and 1.02) by T_4 and T_3 treatments. The highest number of nymph in okra (1.27) was recorded in T_7 which was significantly identical (1.21) with T_1 treatment closely followed (1.29) by T_2 and T_3 treatments.

In case of number of whitefly in okra, number of adult per plant was also varied significantly due to different types of treatments. Results showed that, the lowest number of adult in whitefly (0.98) was recorded in T_6 treatment, which was significantly close with T_5 (1.08) treatments. On the other hand, the highest number of adult in okra was recorded in T_7 (1.56) which was statistically identical with T_1(1.46) and T_2 (1.35) and closely followed by T_3(1.29) treatments.

In the number of jassid in okra, significant variations were observed among the treatments in terms of okra per plant. From the results it was revealed that, the lowest number of nymph in okra was recorded in T_6 (0.61) treated plot which was statistically identical with T_5 (0.88) and T_4 (1.03) treatment and closely followed (1.09) by T_3. The highest number of nymph in okra (1.47) was recorded in T_7 which was significantly identical with T_1 (1.41) treatments and statistically similar with in T_2 (1.23) treatment.

In the number of jassid in okra, number of adult per plant was also varied significantly due to different types of treatments. Results showed that, the lowest number of adult was recorded in T_6 (1.04) treatment which was significantly identical with T_5 (1.11) treatments and closely followed (1.43 and 1.43) by T_3 and T_4 treatments. On the other hand, the highest number of adult in okra (1.89) was recorded in (T_7) which was statistically identical (1.87) with T_1 treatments.

Table 1: Number of nymph and adult per five tag plant of major sucking insect pests at vegetativestage

Treatment	Number of aphid		Number of whitefly		Number of jassid	
	Nymph	Adult	Nymph	Adult	Nymph	Adult
T_1	1.56 a	2.04 a	1.21 a	1.46 a	1.41 a	1.87 a
T_2	1.31 b	1.89 ab	1.13 ab	1.35 a	1.23 ab	1.63 b
T_3	1.17 b	1.72 b	1.02 b	1.29 ab	1.09 b	1.43 b
T_4	1.15 b	1.78 ab	0.99 b	1.30 a	1.03 c	143 b
T_5	0.92 c	1.42 c	0.67 c	1.08 bc	0.88 c	1.11 c
T_6	0.78 c	1.19 c	0.56 c	0.98 c	0.61 d	1.04 c
T_7	1.64 a	2.19 a	1.27 a	1.56 a	1.47 a	1.89 a
CV (%)	0.18	8.14	9.96	9.97	9.77	9.67
LSD (0.05)	0.13	0.32	0.17	0.28	0.23	0.36

[In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications].

T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @ 1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4= Neem oil @ 5.0 ml/L of water with detergent; T_5= Abamectin@ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7=Untreated control.

4.1.2 Incidence of aphid, white fly and jassid of okra at flowering stage

At flowering stage number of jassid, aphid and white fly showed statistically significant variation due to different treatment or management practices (Table 2).

In context to aphid, the lowest number nymph in each plant was found from T_1 (0.63) which was statistically identical with T_3 (0.77) and closely followed by T_3 (1.07), whereas the highest number was obtained from control (1.77) which was statistically identical with T1 (1.69) and closely followed by T_2 (1.23). In case of adult in okra, the lowest number in each plant was found from T_6 (0.96) which was statistically different from T_5 (1.23) and T_4 (1.52) treatments, whereas the highest number was obtained from T_7 (2.19) which was statistically identical with T_1 (2.13) and closely followed by T_2 (1.82).

Considering white fly, the lowest number of nymph per plant (0.42) was observed from T_6 which was statistically similar with (0.56) in T_5 and closely followed by T_4 (0.75) and T_3 (0.88), consequently the highest number from T_7 (1.42) which was statistically identical (1.36) with T_1 and closely followed by T_2 (1.06) treatment (Table 2).

In case adult in whitefly, the lowest number of adult in each plant was found from T_6 (0.41) which was statistically very close with T_5 (0.72) treatments, whereas the highest number was obtained from T_7 (1.73) which was statistically identical with (1.67) in T_1 and closely followed by T_2 (1.23), T_3 (1.16) and T_4 (1.06) treatments.

For jassid, the lowest number of nymph per plant was recorded from T_6 (0.53) which was statistically very close with T_5 (0.73). On the other hand, the highest number of nymph was found from T_7 (1.69) which was statistically identical with T_1 (1.63) and closely followed by T_2 (1.13), T_3 (1.02) and T_4 (0.98) treatments. In case of adult in okra, the lowest number of adult in each plantwas found from T_6 (0.89) which was statistically identical with T_5 (1.02) treatments, whereas the highest number was obtained from T_7 (2.13) which was statistically identical with (2.04) in T_1 and closely followed by T_2 (1.55), T_3 (1.36) and T_4 (1.31) treatments.

Table 2: Number of nymph and adult per five tag plant of major sucking insect pests at floweringstage

Treatment	Number of aphid		Number of whitefly		Number of jassid	
	Nymph	Adult	Nymph	Adult	Nymph	Adult
T_1	1.69 a	2.13 a	1.36 a	1.67 a	1.63 a	2.04 a
T_2	1.23 b	1.82 b	1.06 b	1.23 b	1.13 b	1.55 b
T_3	1.07 bc	1.57 c	0.88 c	1.16 b	1.02 b	1.36 bc
T_4	1.03 c	1.52 c	0.75 d	1.06 b	0.98 b	1.31 c
T_5	0.77 d	1.23 d	0.56 e	0.72 c	0.73 c	1.02 d
T_6	0.63 d	0.96 e	0.42 f	0.41 d	0.53 d	0.89 d
T_7	1.77 a	2.21 a	1.42 a	1.73 a	1.69 a	2.13 a
CV (%)	8.69	8.92	8.17	9.66	8.69	8.43
LSD (0.05)	0.19	0.26	0.19	0.18	0.18	0.23

[In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications].

T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @ 1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4= Neem oil @ 5.0 ml/L of water with detergent; T_5=Abamectin@ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7=Untreated control.

4.1.3 Incidence of aphid, white fly and jassid of okra at fruiting stage

At fruiting stage number of aphid, white fly and jassid, showed statistically significant variation due to different treatment or management practices (Table 3).

In context to aphid, the lowest number nymph in each plant was found from T_6 (0.52) which was statistically close with T_5 (0.69) and closely followed by T_4 (0.93), and T_2 (0.97) whereas the highest number of nymph was obtained from T_7 (1.97) which was statistically identical with T_1 (1.89), and closely followed by T_2 (1.15). In case of adult in okra, the lowest number of adult in each plant was found from T_6 (0.77) which was statistically very close with T_5 (1.05) treatments, whereas the highest number was obtained from T_7 (2.43) which was statistically identical with (2.39) in T_1 and closely followed by T_2 (1.66).

Considering white fly, the lowest number of nymph per plant (0.39) was observed from T_6 which was statistically identical with T_5(0.43) and closely followed by T_4 (0.59) and T_3 (0.69), consequently the highest number of nymph from T_7 (1.63) which was statistically identical with T_1 (1.55) and closely followed by T_2 (.86) treatment (Table 3).

In case of adult in whitefly, the lowest number of adult in each plant was found from T_6 (0.33) which was statistically very close with T_5 (0.63) treatments, whereas the highest number was obtained from T7 (2.03) which was statistically identical with (1.92) in T_1 and closely followed by T_2 (1.11), T_3 (1.03) and T_4 (0.98) treatments.

For jassid, the lowest number of nymph per plant was recorded from T_6 (0.37) which was statistically close with T_5 (0.51). On the other hand, the highest number of nymph was found from T_7 (2.11) which was statistically identical with T_1 (1.98) and closely followed by T_2 (1.06) treatments. In case of adult in okra, the lowest number of adult in each plant was found from T_6 (0.63) which was statistically identical with T_5 (0.78) treatments, whereas the highest number was obtained from T_7 (2.49) which was statistically identical with (2.44) in T_1 and closely followed by T_2 (1.39), T_3 (1.21) and T_4 (1.22) treatments.

Table 3: Number of nymph and adult per five tag plant of major sucking insect pests at fruiting stage

Treatment	Number of aphid		Number of whitefly		Number of jassid	
	Nymph	Adult	Nymph	Adult	Nymph	Adult
T_1	1.89 a	2.39 a	1.55 a	1.92 a	1.98 a	2.44 a
T_2	1.15 b	1.66 b	0.86 b	1.11 b	1.06 b	1.39 b
T_3	0.97 c	1.43 c	0.69 c	1.03 b	0.89 c	1.21 b
T_4	0.93 c	1.33 c	0.59 d	0.98 b	0.71 d	1.22 b
T_5	0.69 d	1.05 d	0.43 e	0.63 c	0.51 e	0.78 c
T_6	0.52 e	0.77 e	0.39 e	0.33 d	0.37 f	0.63 c
T_7	1.97 a	2.43 a	1.63 a	2.03 a	2.11 a	2.49 a
CV (%)	7.92	8.21	6.66	8.33	6.64	8.42
LSD (0.05)	0.17	0.25	0.12	0.16	0.14	0.23

[In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications].
T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @ 1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4= Neem oil @ 5.0 ml/L of water with detergent; T_5= Abamectin@ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7=Untreated control.

4.2 Leaf infestation of okra

The significant variations were observed among the different treatments used for the management practices in terms of percent leaf infestation by number due to attack of pests during the study period, which is shown in Table 4.

The highest number of leaf per plant (14.15) was recorded in T_4 treatment, which was statistically identical with T_6 (14.07) treatments and closely followed (13.42) by T_5 treatment. Accordingly, the lowest number of leaves was recorded in T_1 (8.67) treatment, which was statistically similar to T_3 (10.33) treatment.

The significant variations were observed among different treatments used for the management practices in terms of curled by number due to attack of pests during the study period, which is shown in Table 4. The highest number of curled leaf per plant (5.39) was recorded in T_7 treatment, which was statistically identical (5.37) with T_1 treatments and closely followed (4.78 and 4.29) by T_2 and T_3 treatment. Accordingly, the lowest number of curled leaves (1.85) was recorded in T_6 treatment, which was statistically identical with T_5 (2.30) treatment.

Again, considering the number of infested leaves per plant, the lowest number of leave infestation (13.18%) caused by pests was recorded in T_6 treatment, which was statistically different from all other treatments. Accordingly, the highest number of infested leaves per plant (62.97) was recorded in T_1 which was statistically identical (61.92) with T_1 treatments.

Table 4: Plant infestation per twelve tag plant

Treatments	Total leaves	Curled leaves	% leaf infestation
T_1	8.67 d	5.37 a	61.92 a
T_2	10.33 cd	4.78 ab	46.30 b
T_3	11.33 bc	4.29 b	37.86 c
T_4	14.15 a	4.33 b	30.62 d
T_5	13.42 ab	2.30 c	17.24 e
T_6	14.07 a	1.85 c	13.18 f
T_7	8.56 d	5.39 a	62.97 a
CV (%)	12.61	11.11	1.27
LSD (0.05)	2.45	0.78	0.83

[In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications].

T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @ 1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4= Neem oil @ 5.0 ml/L of water with detergent; T_5= Abamectin@ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7=Untreated control.

4.3 Plant infestation

The significant variations were observed among the different treatments used for the management practices in terms of percent plant infestation by number due to attack of pests during the study period, which is shown in Table 5. The data revealed that the highest infested plant was obtained in T_7 (5.56) followed by 5.44 and 5.13 in T_4 and T_6 respectively. The lowest plant infestation was obtained from the T_1 (4.11), which was statistically similar with T_2 (4.27) treatment.

Again, considering the number of infested plant, the lowest number of infested plant (34.25%) caused by pests was recorded in T_6 treatment, which was statistically close (35.60) with T_2. Accordingly, the highest number of infested plant (46.33) was recorded in T_7 which was statistically identical

(45.32) with T_4 treatments and closely followed (42.75, 41.41 and 39.87) by T_6, T_5 and T_3 treatments.

Table 5: Plant infestation per twelve tag plant

Treatment	Total plants	Infested plants	% plant infestation
T_1	12	5.13 ab	42.75 ab
T_2	12	4.27 bc	35.60 bc
T_3	12	4.78 abc	39.87 abc
T_4	12	5.44 ab	45.32 a
T_5	12	4.97 abc	41.42 abc
T_6	12	5.56 a	34.25 c
T_7	12	4.11 c	46.33 a
CV (%)	-	11.86	11.64
LSD (0.05)	-	0.98	8.11

[In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications].

T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @ 1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4= Neem oil @ 5.0 ml/L of water with detergent; T_5= Abamectin@ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7=Untreated control.

4.4 Fruit infestation

At the fruiting stage of okra, no fruit infestation was occurred. At this fruiting stage of okra, no significant variations were observed in different treatments in case of percent of curled fruits infestation per plant. Results showed that, the lowest percent of fruit infestation (33.62) was recorded in T_6 treated plot which was statistically close to T_5 (36.13) and T_4 (38.11) treatments respectively. On the other hand, the highest percent of fruit infestation (44.21) was recorded in okra (T_7) treatment, which was significantly identical (43.41) treatments and closely followed (41.57) by T_2 treatment.

Table 6: Fruit infestation

Treatments	Total fruits	Curled fruits	% fruit infestation
T_1	28.17 a	12.23 a	43.41 a
T_2	29.13 a	12.11 a	41.57 ab
T_3	29.72 a	11.89 a	40.00 c
T_4	34.09 a	12.99 a	38.11 d
T_5	31.47 a	11.37 a	36.13 de
T_6	32.23 a	10.87 a	33.62 f
T_7	27.96 a	12.36 a	44.21 a
CV (%)	11.40	10.78	1.61
LSD (0.05)	6.05	2.21	1.63

[In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications].

T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @ 1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4= Neem oil @ 5.0 ml/L of water with detergent; T_5= Abamectin@ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7=Untreated control.

4.5 Yield contributing characters of okra

Significant variation was found in different treatments in case of height of plant as well as number, length, girth, weight of fruit which were measured as the yield contributing character of okra shown in Table 7.

4.5.1 Height of plant

The height of okra plant showed significant variation among the treatments. The maximum height of plant (244.9 cm) was recorded in T_4 treatment, which was statistically close to T_5 (223.1 cm) and T_6 (220.6 cm) treatment. On the other hand, the minimum height of plant (195.2 cm) was recorded in T_1 treatment which was statistically very close with (203.2) T_2 treatments.

4.5.2 Single pod weight (g)

In case of the single pod weight (g) of okra significant variation was obserbed among the treatments. The maximum single pod weight (g) of okra (16.00 g) was recorded in T_4 treatment, which is statistically similar with all other treatments except (12.60) T_1 and (12.56) T_7 treatment. On the other hand, the minimum single pod weight (g) of okra (12.60 g) was recorded in T_1 treatment, which were statistically similar to all others treatments except T_4.

4.5.3 Yield/plot (kg)

Yield of okra showed significant variation among the treatments (Table-7). The maximum yield plot^{-1} of okra (8.89 g) was recorded in T_4 treatment, which were statistically similar with (7.21) T_7 and (7.27) T_1 treatment. On the other hand, the minimum yield plot^{-1} of okra (7.21 g) was observed in T_7 treatment, which was significantly similar to T_1 (7.27), T_2 (7.66), T_5 (7.78), T_5 (8.12), and T_6 (8.33) treatments respectively.

4.5.4 Yield/ha (ton)

Effect of different treatments on the yield of okra significant differences were observed among the treatments in terms of yield in ton ha^{-1} and percent increase over control during the entire cropping season, presented in Table 7.

In case of the yield t ha^{-1} of okra showed significant variation among the treatments. The maximum yield of okra (15.59 t ha^{-1}) was recorded in T_6 treatment which was statistically similar with (14.59) T_5 treatment. On the other hand, the minimum yield of okra (11.36) was observed in T_7 treatment, which was significantly identical to T_1 (11.63), treatments.

Table 7: Yield attributing characteristics and yield

Treatment	Plant height (cm)	Single pod weight (g)	Yield/plot (kg)	Yield/ha (ton)
T_1	195.2 e	12.60 b	7.27 b	11.63 e
T_2	203.2 d	13.40 ab	7.66 ab	12.72 d
T_3	211.7 c	13.67 ab	7.78 ab	13.45 c
T_4	244.9 a	16.00 a	8.89 a	13.58 c
T_5	220.6 b	14.46 ab	8.12 ab	14.59 b
T_6	223.1 b	14.87 ab	8.33 ab	15.59 a
T_7	194.8 e	12.56 b	7.21 b	11.36 e
CV (%)	11.47	11.12	10.33	1.83
LSD (0.05)	3.47	2.54	1.43	0.47

[In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications].

T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @ 1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4=Neem oil @ 5.0 ml/L of water with detergent; T_5=Abamectin@ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7=Untreated control.

CHAPTER 5
SUMMARY AND CONCLUSION

The experiment was conducted to study effectiveness of some biorational insecticides against the sucking insect pests of okra. The experiment consists of the management practices (T_1= Spinosad @ 0.5 ml/L of water; T_2= Matrine @1.0 ml/L of water; T_3= Thiamethoxam @ 0.2 g/L of water; T_4= Neem oil @ 5.0 ml/L of water with detergent; T_5= Abamectin@ 1.0 ml/L of water; T_6= Buprofezin @ 0.2 g/L of water and T_7=Untreated control.). The experiment was designed in Randomized Complete Block Design (RCBD) with three replications. Data on different pest incidence their level of infestation, yield attributes and yield were collected and recorded.

The lowest number of nymph of aphid (0.78) was recorded in T_6 treated plot, whereas the highest number of nymph (1.64) was recorded in T_7 treatment. The lowest number of adult (1.19) was recorded in T_6 treatments. On the other hand, the highest number of adult (2.19) was recorded in okra (T_7) treatment. The lowest number of nymph in whitefly (0.56) was recorded in T_6 treated plot. The highest number of nymph in okra (1.27) was recorded in T_7 treatments.

The lowest number of adult in whitefly (0.98) was recorded in T_6 treatment, which was significantly similar (1.08) with T_5 treatments. On the other hand, the highest number of adult in okra (1.56) was recorded in (T_7) which was statistically identical (1.46 and 1.35) with T_1 and T_2 and closely followed (1.29) by T_3 treatments.

The lowest number of nymph in jassid (0.61) was recorded in T_6 treatment and closely followed (1.09) by T_3. The highest number of nymph in okra (1.47) was recorded in T_7 which was significantly identical (1.41) with T_1 treatments and statistically similar with (1.23) in T_2 treatment.

The lowest number of adult in jassid (1.04) was recorded in T_6 treatment which was significantly identical (1.11) with T_5 treatments and closely followed (1.43 and 1.43) by T_3 and T_4 treatments. On the other hand, the highest number of adult in okra (1.89) was recorded in (T_7) which was statistically identical (1.87) with T_1treatments.

In context of aphid, the lowest number nymph in each plant was found from T_1 (0.63) which was statistically identical with T_3 (0.77) and closely followed by T_3 (1.07), whereas the highest number was obtained from T_7 (1.77) which was statistically identical with (1.69) in T_1, and closely followed by T_2 (1.23). In case of adult in okra, the lowest number of adult in each plant was found from T_6 (0.96) which was statistically similar with T_5 (1.23) and T_4 (1.52) treatments, whereas the highest number was obtained from T_7 (2.21) which was statistically identical with (2.13) in T_1 and closely followed by T_2 (1.82).

Considering white fly, the lowest number of nymph per plant (0.42) was observed from T_6 which was statistically similar with (0.56) in T_5 and closely followed by T_4 (0.75) and T_3 (0.88), consequently the highest number from T_7 (1.42) which was statistically identical (1.36) with T_1 and closely followed by T_2 (1.06) treatment (Table 2).

In case of adult in whitefly, the lowest number of adult in each plant was found from T_6 (0.41) which was statistically similar with T_5 (0.72) treatments, whereas the highest number was obtained from T_7 (1.73) which was statistically identical with (1.67) in T_1 and closely followed by T_2 (1.23), T_3 (1.16) and T_4 (1.06) treatments.

For jassid, the lowest number of nymph per plant was recorded from T_6 (0.53) which was statistically similar with T_5 (0.73). On the other hand, the highest number of nymph was found from T_7 (1.69) which was statistically identical with T_1 (1.63) and closely followed by T_2 (1.13), T_3 (1.02) and T_4 (0.98) treatments. In case of adult in okra, the lowest number of adult in each plant was found from T_6 (0.89) which was statistically identical with T_5 (1.02) treatments, whereas the highest number was obtained from T_7 (2.13) which was statistically identical with (2.04) in T_1 and closely followed by T_2 (1.55), T_3 (1.36) and T_4 (1.31) treatments.

In context of aphid, the lowest number nymph in each plant was found from T_1 (0.52) which was statistically similar with T_5 (0.69) and closely followed by T_4 (.93), and T_2 (0.97) whereas the highest number of nymph was obtained from T_7 (1.97) which was statistically identical with (1.89) in T_1, and closely followed by T_2 (1.15). In case of adult in okra, the lowest number of adult in each plant was found from T_6 (0.77) which was statistically similar with T_5 (1.05) treatments, whereas the highest number was obtained from T_7 (2.43) which was statistically identical with (2.39) in T_1 and closely followed by T_2 (1.66).

Considering white fly, the lowest number of nymph per plant (0.39) was observed from T_6 which was statistically identical (0.43) with T_5 and closely followed by T_4 (0.59) and T_3 (0.69), consequently the highest number of nymph from T_7 (1.63) which was statistically identical (1.55) with T_1 and closely followed by T_2 (.86) treatment (Table 3).

In case of adult in whitefly, the lowest number of adult in each plant was found from T_6 (0.33) which was statistically similar with T_5 (0.63) treatments, whereas the highest number was obtained from T7 (2.03) which was statistically identical with (1.92) in T_1 and closely followed by T_2 (1.11), T_3 (1.03) and T_4 (0.98) treatments.

For jassid, the lowest number of nymph per plant was recorded from T_6 (0.37) which was statistically similar with T_5 (0.51). On the other hand, the highest number of nymph was found from T_7 (2.11) which was statistically identical with T_1 (1.98) and closely followed by T_2 (1.06) treatments. In case of adult in okra, the lowest number of adult in each plant was found from T_6 (0.63) which was statistically identical with T_5 (0.78) treatments, whereas the highest number was obtained from T_7 (2.49) which was statistically identical with (2.44) in T_1 and closely followed by T_2 (1.39), T_3 (1.21) and T_4 (1.22) treatments.

The highest number of leaf per plant (14.15) was recorded in T_4 treatment, which was statistically identical (14.07) with T_6 treatments and closely followed (13.42) by T_5 treatment. Accordingly, the lowest number of leaves (8.67) was recorded in T_1 treatment, which was statistically similar to T_3 (10.33) treatment.

The highest number of curled leaf per plant (5.39) was recorded in T_7 treatment, which was statistically identical (5.37) with T_1 treatments and closely followed (4.78 and 4.29) by T_2 and T_3 treatment. Accordingly, the lowest number of curled leaves (1.85) was recorded in T_6 treatment, which was statistically identical with T_5 (2.30) treatment.

Again, considering the number of infested leaves per plant, the lowest number of infested leaves (13.18%) caused by pests was recorded in T_6 treatment, which was statistically different from all other treatments. Accordingly, the highest number of infested leaves per plant (62.97) was recorded in T_1 which was statistically identical (61.92) with T_1 treatments.

The data revealed that the highest infested plant was obtained in T_7 (5.56) followed by 5.44 and 5.13 in T_4 and T_6 respectively. The lowest plant infestation was obtained from the T_1 (4.11), which was statistically similar with T_2 (4.27) treatment.

Again, considering the number of infested plant, the lowest number of infested plant (34.25%) caused by pests was recorded in T_6 treatment, which was statistically similar (35.60) with T_2. Accordingly, the highest number of infested plant (46.33) was recorded in T_7 which was statistically identical (45.32) with T_4 treatments and closely followed (42.75, 41.41 and 39.87) by T_6, T_5 and T_3 treatments.

The lowest percent of fruit infestation (33.62) was recorded in T_6 treated plot which was statistically similar to T_5 (36.13) and T_4 (38.11) treatments respectively. On the other hand, the highest percent of fruit infestation (44.21) was recorded in okra (T_7) treatment, which was significantly identical (43.41) treatments and closely followed (41.57) by T_2 treatment.

The maximum height of plant (244.9 cm) was recorded in T_4 treatment, which was statistically similar to T_5 (223.1 cm) and T_6 (220.6 cm) treatment. On the other hand, the minimum height of plant (195.2 cm) was recorded in T_1 treatment which was statistically similar with (203.2) T_2 treatments.

The maximum single pod weight of okra (16.00 g) was recorded in T_4 treatment; on the other hand, the minimum single pod weight (g) of okra (12.60 g) was recorded in T_1 treatment. The maximum yield of okra (8.89 g) was recorded in T_4 treatment, on the other hand, the minimum yield plot of okra (7.21 g) was observed in T_7 treatment. The maximum yield of okra (15.59 t ha^{-1}) was recorded in T_6 treatment, on the other hand, the minimum yield of okra (11.36) was observed in T_7 treatment.

CONCLUSION

From the study the following conclusions may be drawn:

- Among the treatment Buprofezin @ 0.2 g/L of water at 7 days interval was more effective for the controlling of insect pests as well as highest yield contributing characters and yield of Okra.

- These findings illustrated that, the T_6 treatment was more effective for the reduction of incidence of major insect pests of okra.

RECOMMENDATION

Considering the findings of the study the following recommendations can be suggested:

- Application of Buprofezin @ 0.2 g/L of water at 7 days interval may be recommended as an effective control measure applied against major insect pests infested okra.
- Further intensive studies based on different doses of Buprofezin may be conducted.
- More chemicals and botanicals with their derivatives should be included in further elaborative research for controlling major insect pests of okra.

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APPENDIX

Appendix I. Monthly record of air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from October 2020 to February 2021

Year	Month	Air temperature (°c)			Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum	Average		
2020	October	30.97	23.31	27.14	75.25	208
	November	29.45	18.63	24.04	69.52	00
	December	26.85	16.23	21.54	70.61	00
2021	January	24.52	13.86	19.19	68.46	04
	February	28.88	17.98	23.43	61.04	06

Source: Bangladesh Meteorological Department (climate division) Agargoan, Dhaka-1212.

Appendix II. Characteristics of Horticulture Farm soil as analyzed by Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis	
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (mc/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix III: Analysis of variance of the data on the effect of different treatments number of nymph and adult of aphid, whitefly and jassid of okra at early flowering stage

Source of variance	Degrees of freedom	Mean square					
		Number of aphid		Number of whitefly		Number of jassid	
		Nymph	Adult	Nymph	Adult	Nymph	Adult
Replication	2	0.17**	0.374**	0.108**	0.213**	0.14**	0.253**
Factor A	5	0.23*	0.295**	0.201*	0.096**	0.233*	0.292*
Error	10	0.011	0.029	0.009	0.015	0.011	0.017

*** Significant at 10% level; **Significant at 5% level; *Significant at 1% level, NS Non-significant

Appendix IV: Analysis of variance of the data on the effect of different treatments number of nymph and adult of aphid, whitefly and jassid of okra at mid flowering stage

Source of variance	Degrees of freedom	Mean square					
		Number of aphid		Number of whitefly		Number of jassid	
		Nymph	Adult	Nymph	Adult	Nymph	Adult
Replication	2	0.13**	0.289**	0.073**	0.119**	0.118**	0.221**
Factor A	5	0.417*	0.524*	0.35*	0.568*	0.425*	0.503*
Error	10	0.009	0.019	0.005	0.01	0.008	0.014

*** Significant at 10% level; ** Significant at 5% level; * Significant at 1% level, NS Non-significant

Appendix V: Analysis of variance of the data on the effect of different treatments number of nymph and adult of aphid, whitefly and jassid of okra at late flowering stage

Source of variance	Degrees of freedom	Mean square					
		Number of aphid		Number of whitefly		Number of jassid	
		Nymph	Adult	Nymph	Adult	Nymph	Adult
Replication	2	0.111**	0.227**	0.054*	0.107**	0.072*	0.174**
Factor A	5	0.686*	0.938*	0.547*	0.867*	0.996*	1.223*
Error	10	0.007	0.014	0.002	0.008	0.004	0.012

*** Significant at 10% level; ** Significant at 5% level; * Significant at 1% level, NS Non-significant

Appendix VI: Analysis of variance of the data on the effect of different treatments on infested plants and percent plant infestation of okra

Source of variance	Degrees of freedom	Mean square	
		Infested plants	% plant infestation
Replication	2	3.793 **	262.942**
Factor A	5	0.782***	270.909***
Error	10	0.322	22.291

*** Significant at 10% level; ** Significant at 5% level; * Significant at 1%level, NS Non-significant

Appendix VII: Analysis of variance of the data on the effect of different treatments on total fruits, curled fruits and percent fruit infestation of okra

Source of variance	Degrees of freedom	Mean square		
		Total fruits	Curled fruits	% fruit infestation
Replication	2	151.537***	21.213**	8.331**
Factor A	5	14.527***	8.047*	3.234*
Error	10	12.334	1.647	0.001

*** Significant at 10% level; ** Significant at 5% level; * Significant at 1%level, NS Non-significant

Appendix VIII: Analysis of variance of the data on the effect of different treatments on plant height, single pod weight, yield per plot and yield per hectare of okra

Source of variance	Degrees of freedom	Mean square			
		Plant height	Single pod weight	Yield/plot	Yield/ha
Replication	2	7.559**	32.413**	10.209**	0.141***
Factor A	3	2.612***	4.346***	0.967***	5.771*
Error	22	3.155	2.725	0.836	0.061

*** Significant at 10% level; ** Significant at 5% level; * Significant at 1%level, NS Non-significant