Abundance of pest, predator and pollinator in cotton field and their impact on yield and seed quality

A Thesis
By

H. M. Syfullah Azad

Student No.: 0805012

Master of Science (MS) in Entomology

Department of Entomology
Hajee Mohammad Danesh Science and Technology University
Dinajpur

August 2009

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Sumbitted to the Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur in partial fulfillment of the requirements for the Degree of

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Approved as to style and content by

Dr Md. Ruhul Amin Supervisor	S. M. Abul Hossain Co-Supervisor

Prof. Md. Abdul Ahad
Chairman
Examination Committee

Department of Entomology
Hajee Mohammad Danesh Science and Technology University
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Dedicated to

My beloved parents

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Abundance of pest, predator and pollinator in cotton field and their impact on yield and seed quality

Student No. 0805012

Department of Entomology

Hajee Mohammad Danesh Science and Technology University, Dinajpur

Abstract

This study was undertaken with three cotton varieties viz. CB9, CB10 and SR05 to explore the abundance of pest, predator and pollinators in the field and their impact on yield and seed quality. Results showed that 16 species of insect and one species of mite were abundant in threshold based insecticide sprayed field. The incidence of sucking pests such as jassid, aphid, white fly and thrips on different varieties were statistically different in insecticide free condition, however in threshold sprayed condition only the white fly showed significant difference. The chewing pests (american bollworm, spotted bollworm, pink bollworm) incidence were statistically similar on different cotton varieties both in threshold sprayed and no-sprayed condition. But armyworm incidence was found significantly different in no-sprayed condition. Data of the predator visitors associated with cotton plants indicated that 29 species of insects in 9 orders and 19 families were abundant during the season. One predatory mite species and one spider species were also abundant. The incidence of predators such as lady beetle, syrphids, lace wing and spider on different varieties were statistically different in insecticide free condition and in threshold sprayed condition only the lady beetle showed statistically similar incidence. The pollinator visitors on different cotton varieties constituted of 12 species of which 5 species in two families of Hymenoptera, 5 species in two families of Lepidoptera and 2 species in two families of Diptera. The major pollinator honeybee and bumblebee incidence were statistically similar on the studied cotton varieties both in threshold sprayed and non-sprayed condition. The findings of the present study demonstrated that abundance of pest, predator and pollinators significantly influenced on the production of boll / plant, yield / ha, number of seeds / boll and seed index. Boll production of different varieties under enclosed, threshold sprayed and non-sprayed condition varied from 39.4 ± 11.3 to 44.2 ± 8.3, 32.2 ± 7.6 to 40.1 ±8.8 and 8.2 ± 3.5 to 12.6 ± 3.1 / plant, respectively. The production of yield (seed cotton) under these conditions ranged from 2350.0 ± 17.3 to 2751.7 ± 23.6, 2173.3 ± 15.3 to 2498.3 ± 18.9 and 618.3 ± 12.6 to 792.3 ± 8.7 kg / ha, respectively. Among the cotton varieties CB9 produced the highest number (36.2 ± 6.9) of seeds / boll and the variety CB10 produced the lowest (30.2 ± 5.1) number in non-sprayed condition. The variety CB9 and CB10 resulted the highest (83.5 g) and lowest (75.0 g) seed index when these varieties were cultivated under enclosed and threshold sprayed condition, respectively. The study showed that the abundance of pest, predator and pollinators did not affect significantly the ginning out tern (GOT%) and germination rates of cotton seeds.

Dissertation Submitted to the Department of Entomology for Partial Fulfillment for the Degree Master of Science in Entomology

Chapter I
Introduction

Cotton fibre has exercised a profound influence on human from time immemorial. With a history going back to antiquity, the fibre has maintained its pristine purity and importance to this day. From emergence until harvest, various pests attack the roots, leaves, stems or fruit (squares, blooms and bolls) of cotton. The number of insect species attack the crop may about 162 but significant damage is caused by 15 species (Sundramurthy and Chitra 1992, Luttrell *et al.*1994, Anonymous 1999, Dhawan 2000). The most destructive pests of cotton in Bangladesh are jassid (*Amrasca biguttulla*), aphid (*Aphis gossypii*), white fly (*Bemisia tabaci*), thrips (*Thrips tabaci*), spotted bollworm (*Earias insulana*), american bollworm (*Heliothis armigera*), pink bollworm (*Pectinophora gossypiella*) and armyworm (*Spodoptera litura*).

Jassid, aphid and white fly, are important sucking pests and cause heavy losses (Kulkarni *et al.* 2003). Jassid is commonly known as leaf hopper; suck sap from the leaves and cause phytotoxic symptoms known as "hopper burn" which results in complete desiccation of plants (Narayan and Singh 1994). Cotton aphids are commonly found at lower surfaces of the leaf on the terminal leaf and other soft and tender parts of cotton plants. They feed by sucking sap from phloem tissue. The accumulation of honey dew causing the appearance of sticky and shiny leaf surfaces often indicates the presence of this pest. Severe infestations cause stunting of plants and reduced yields. Honey dew secretions on open bolls may result in lint staining or sticky cotton (Bohmfalk *et al.* 1996).

White fly sucks sap usually from the under surface of the leaves and excrete honey dew. Infested leaves reduce vigor, wilt and turn yellow (Bohmfalk *et al.*

1996). Thrips are early season pests of cotton seedlings. Thrips suck sap from cotton leaves and terminal buds. The rupture cells, which caused stunted growth. During severe infestation terminal buds may be destroyed and cause excessive branching of plants. Sometimes cotyledon of seedlings become silvery appearance and termed 'bronzing' (Bohmfalk *et al.* 1996).

Spotted bollworm and american bollworm are the most destructive chewing pests of cotton in Bangladesh. They damage 30 to 40% of seed cotton (Haque 1991). Spotted bollworm larvae usually attack the growing shoots, buds, squares and developing bolls (Alam 1969). They destroy a large number of squares, flowers, green bolls, tender shoots, and consequently declined yield (Anonymous 2003, Aslam *et al.* 2004).

Pink bollworm is a key pest of cotton and larvae feed on bolls reducing both yield and lint quality. They cut through the lint fibre and move from seed to seed. Pink bollworm makes holes in the boll and later on infected by diseases. During severe infestation, many bolls are rendered unpickable (Bohmfalk *et al.* 1996). The armyworm laid in clutches of several hundred eggs at under surface of the leaves and covered with brown, hair like scales from the body of the female. Newly hatched larvae of armyworm feed only on the superficial tissues of the lower leaf surfaces, but older individuals eat entire leaves and may severely damage buds, flowers and bolls (Bohmfalk *et al.* 1996).

More than 600 insect and spider predator species have been recorded in cotton fields (Hoffmann and Frodsham 1993). The predators associated with cotton pests include beetles, true bugs, lacewings, flies, midges, spiders, wasps, and predatory mites. Insect predators can be found throughout plants. Some predators are specialized in their choice of prey, others are generalists. Some are extremely useful natural enemies of insect pests. Unfortunately, some prey on other beneficial insects as well as pests.

Native predators are of great economic benefit to the cotton farmer. They voluntarily enter the cotton field, are self-multiplying and are completely free of cost. Most predators in cotton fields are general feeders that do not depend on a single pest species for food. Thus, if one prey species becomes scarce, predators switch to another prey or may even resort to plant juices or nectar for survive. A complex of predator species can coexist and bring stability to the eco-system. As any one pest species increases, bringing it out of balance with the system, predators switch to this new food source and again bring the pests into equilibrium. In general, small predators feed on small preys such as eggs and small larvae, and larger predators kill large ones. Thus, identification of small, immature insects, spiders, predators, as well as adults is of important in the pest management strategies.

Fye (1971) increased interest in using cropping diversification for cotton pest suppression by suggesting that alternating large strips of cotton and grain sorghum would result in earlier and more abundant predator populations in cotton. Predation is often a key factor maintaining populations of lepidopteran pests at a level that prevents injury to annual crops. Studies in cotton (Nuessly and Sterling 1994, Pfannenstiel 2004, Sansone and Smith 2001) and soybean (Anderson and Yeargan 1998) and soybean and corn (Pfannenstiel and Yeargan 2002) have demonstrated that predation on lepidopteran eggs can be consistently high. Studies have attempted to identify predators of Lepidoptera using a variety of techniques, including visual observation (Whitcomb and Bell 1964), autoradiography (McCarty *et al.* 1980) and molecular techniques (Ruberson and Greenstone 1998, Sisgaard *et al.* 2002). These studies have produced widely varying results and it is unclear whether the variation is due to regional / yearly variation in predator abundance or variation in methodology.

Pollination is an ecological process fundamental for the maintenance of the viability and diversity of flowering plants and provides important ecosystems services to human (Allen-Wardell *et al.* 1998, Daily *et al.* 1997, Kevan 1999, Klein *et al.* 2007). At a global scale, about one-third of the human food is obtained from plant species that depends on pollinators to produce fruits and seeds (McGregor 1976), and these pollination services have been valued in 112 billons of American dollars (Costanza *et al.* 1997).

Introduction of exotic pollinators, mainly *Apis mellifera* L., has been useful for increasing crop production around the world (Allen-Wardell *et al.* 1998). However, wild pollinators may provide pollination services, even with higher efficiency than *A. mellifera*, without incurring in economic costs (Kearns *et al.* 1998, Kremen *et al.* 2002, Olschewski *et al.* 2006). Nevertheless, fruit and seed production in agroecosystems may also depend, among other factors, on the population dynamics (e.g., temporal variability in abundance) of the pollinator species, pollination efficiency of different pollinator species, competition between cultivated and wild plants for pollinators, distance between crops and native vegetation patches, availability of resources (other than crops) for pollinators and land management systems used by farmers (Kevan 1999).

Recently, there has been a great reduction of wild insect pollinators due to the environmental disruption caused by abuse of pesticides as well as habitat destruction derived from industrialization in the pursuit of economic development throughout the world. Eventually, the drastic important to conserve and survey the substantial utilization of wild species for crop pollination. Heavy use of pesticides are also a major threat to protect the diversity of insect pollinators, although precautions such as better regulation, avoidance of over spray, and changes in the type and timing of pesticide use can reduce the threat. Currently, the world is facing an "impending pollination crisis" in which both wild and managed pollinators are disappearing at alarming rates owing to habitat loss, poisoning, mainly on pollinators. Insect pollination is a necessary step in the production of many forage crops utilized by livestock. Growers of fruits, vegetables, as well as hay and many other crops depend on insect pollinators both managed and wild to produce fertile seeds and full-bodied fruit. Only 15% of these crops are serviced by domestic honeybees, while at least 80% are pollinated by wild bees and other wildlife (Buchmann and Nabhan 1996).

The management of insect pests is an integral part of an economic production system. It increases producers' profits and reduces the amount of environmental contamination from pesticides. Integrated pest management (IPM) is the integration of all practical pest control methods in a compatible manner as possible to maintain pest populations below the economic threshold (ETL). In a cotton production system, IPM includes combining cultural practices--appropriate variety selection, land preparation, planting dates and early stalk destruction -- frequent field scouting; biological control through conservation of natural predators, parasites and pathogens; and selective use of insecticides to keep the insect and mite populations below economically threshold levels (ETL).

This cotton pest management system is designed to keep inputs at a minimum while maintaining or increasing production for maximum profit. This study covers the abundance of insect pests, predators and pollinators associated with cotton. Regular crop monitoring (scouting) was adopted as a method of determining the abundance of pest, predator and pollinator species.

Chapter II

Materials and methods

The experiment was conducted in the Regional Cotton Research Station, Dinajpur, Bangladesh during the period from 7 August 2008 to 1 March 2009.

2.1. Location, soil and climatic condition

From the farm record, the site is situated approximately between $25^0 13'$ latitude north and between $88^0 23'$ longitudes east and about 37.5 m above the sea level. The soil was sandy loam with p^H 4.5 to 5.5. Previous crop of the plot was sun hemp as a green manure. Irrigation and drainage facilities were readily available in the farm. During the experimental period meteorological data were collected August 2008 to March 2009 from Wheat Research Centre, Dinajpur (Appendix-1). The sites belong to the Tista Meander Flood Plain under AEZ 03, besides the river Garveshori.

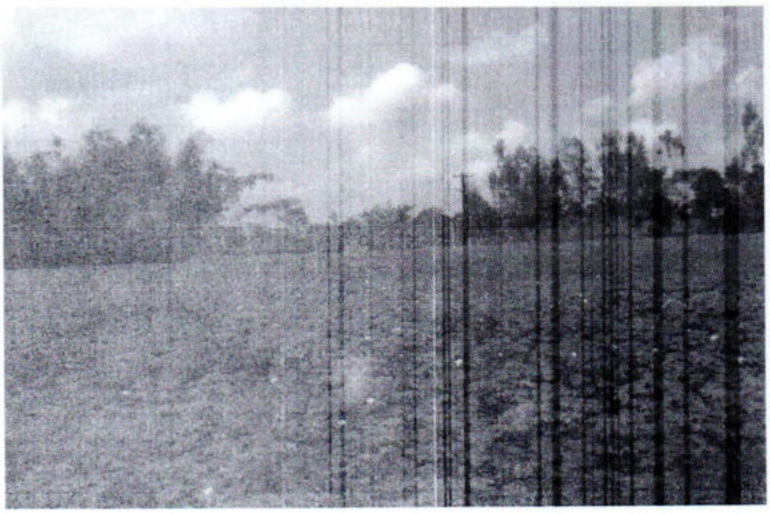

Plate 1. Cotton field

2.2. Systematic position of cotton plant

Kingdom: Plantae

Division: Embryophyta siphonogama

Subdivision: Angiospermae

Class: Dicotyledoneae

Subclass: Archichlamydeae

Order: Malvales

Family: Malvaceae

Subfamily: Malvoideae

Tribe: Gossypieae

Genus: *Gossypium*

Species: *Gossypium hirsutum* L.

2.3. Morphological characteristics of cotton plant

The cotton plant is considered an annual, although it is a perennial in some parts of the world where it is grown commercially. When cotton emerges, the first leaf structures are called cotyledonary or seed leaves. They appear on the lowest node and are borne on opposite sides of the main stem. The nodes above the seed leaves bear a single true leaf. These leaves have a spiral arrangement around the stem. The true leaves have five or more clearly defined lobes. At the base of each main stem leaf, in the angle between the leaf and the stem, there are two and sometimes three buds. They are called axillary buds and give rise to the vegetative and fruiting branches. The vegetative branches normally are restricted to the lower nodes on the stem. In most American upland cottons the first fruiting branch begins developing at the fifth or sixth node above the seedling leaves.

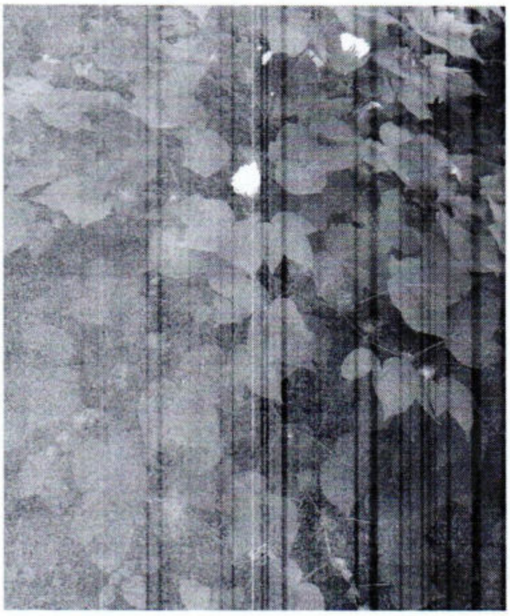

Plate 2. A typical cotton plant

The fruiting branches produce floral buds, called cotton squares that develop into bolls. Flowers (blooms) are creamy white when first open. Fertilization occurs on day that flowers open; it turns pink the day after anthesis. Then boll development begins. The interval between corresponding nodes on successive fruiting branches (vertical flowering interval) is 2 to 3 days, and the interval between successive flowers on the same fruiting branch (horizontal fruiting interval) is 5 to 6 days. Fruit of the cotton plant is the enlarged 3-to 5-loculed ovary commonly referred to as a cotton boll. Mature bolls vary in size and shape depending on the variety and environmental conditions but usually are 1 ½ to 2 inches in diameter.

2.4. Cultivation of crop

Land preparation: The land was prepared at field condition (Joe) by deep ploughing and harrowing followed by laddering. It was leveled properly. The field layout was done after final land preparation.

Seed sowing: Seeds of cotton varieties viz. CB9, CB10 and SR05 were sown in rows on the 3rd of the August 2008 @ 15 kg/ha. A distance of 45 cm from plant to plant and row to row distance was 90 cm, depth 1 cm to 1.5cm of the soil and these were covered with loose soil.

Fertilizer application: The experimental plots were fertilized with following fertilizers (CDB, 1993):

Name of the fertilizers	Rate (kg/ha)
Urea	250
Triple Super Phosphate (TSP)	175
Murate of Potash (MOP)	175
Gypsum	100
$ZnSO_4$	10
$MgSO_4$	10
Borax	10

One fourth of urea and two third of the other fertilizers were applied in furrow during sowing. The rest of the fertilizers were applied in 2 split doses started from 25 Day after sowing (DAS). But urea was applied in 3 split doses. The last split was applied in 75 DAS.

Intercultural operation: Intercultural operations such as mulching, weeding and irrigation etc were done when necessary. Weeding was done 3 times manually. 1st weeding was done at 15 DAS and final thinning was done at 25-27 DAS; keeping one plant at each hill. 1st top dressing was done after final thinning and other two weedings were at 45 DAS and 70 DAS. Three flood irrigations were given in the month of November and December at the stress condition of the crop.

2.5. Experimental design and layout

The experiment was conducted in randomized complete block design (RCBD). The plot size was 5.4 m × 5 m. The spacing between block to block and plot to plot was 1.5 m and 1m respectively. Footpath was 2 m.

2.6. Treatments

The experiment was conducted with three cotton varieties viz. CB9, CB10 and SR05. For observation of the abundance and impacts of pests, predators and pollinators each variety was cultivated under enclosed with mosquito net, ETL based insecticide sprayed and non-sprayed conditions following three replications.

Plate 3. Cotton variety CB9

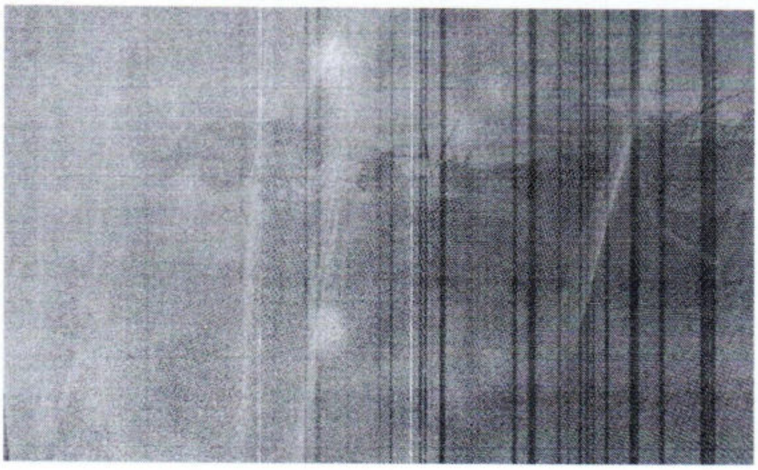

Plate 6. Plants grown under encloser

2.7. Scouting

Counts of different pest and predator populations were started after 2 weeks of DAS and counting of pollinator populations were started after blooming of flower. In each replication 5 plants were selected randomly for the examination. Scouting was done once in a week and on the same day in each week. The scouted plants were selected along in a zigzag method throughout the field, so that a representative sample was obtained showing in the diagram.

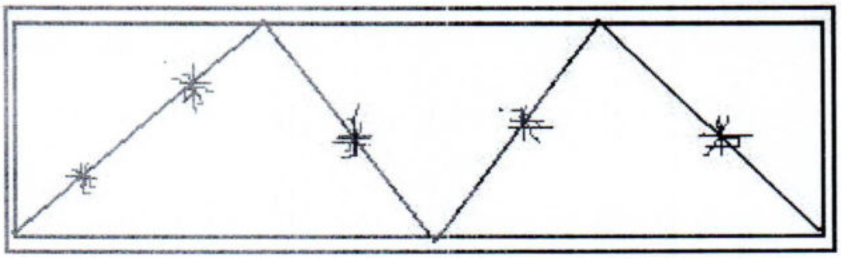

Plate 7. Selection of scouted plant in a single plot

The plants were examined with the sun behind as light goes to the plant. This avoided glare from the leaf surfaces that provided ample light to see the presence of insect in the plant during scouting. Newly growing parts with two fully expanded leaves were examined for sucking pests and predators, middle parts for armyworm and twigs flowers, squares and bolls for bollworm, and blooming flowers for pollinators.

Plate 8. Collection of pest and predators

2.8. Threshold levels

Insect	Threshold
Jassid	2.0 nymphs / plant
Aphid	A grade of 1.50 / plant
White fly	5 - 6 adults / plant
Thrips	3 - 4 adults / plant
American bollworm	0.25 larva or 0.50 eggs / plant
Spotted bollworm	0.25 larva or 0.50 eggs / plant

Jassid: The number of jassid nymphs and adults found in each replication were recorded taking 5 plants randomly from every plot.

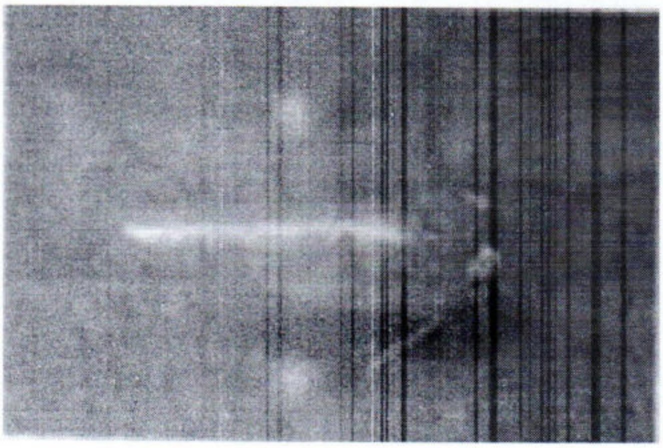

Plate 9. Jassid

Aphids: Infestations were graded as follows

0- No symptoms.

1- Edge of the leaves starting to curl down. No discolouration.

2- Edge of leaves curling and yellowed.

3- More than one leaf or the one leaf or the growing point infested.

4 - Entire plant is infested

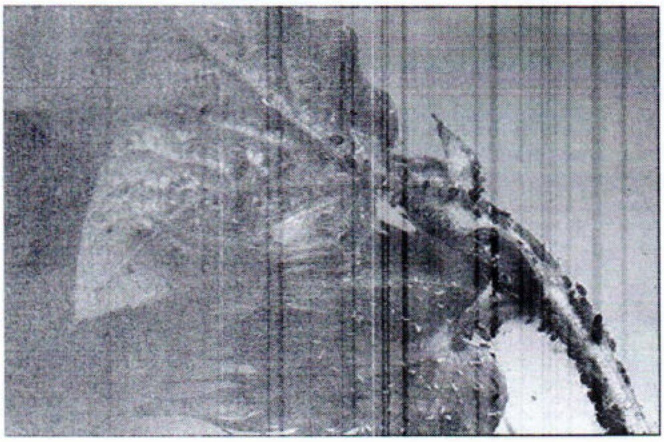

Plate 10. Aphid

White fly: The number of nymphs and adults of whitefly were recorded taking 5 plants randomly from each replication.

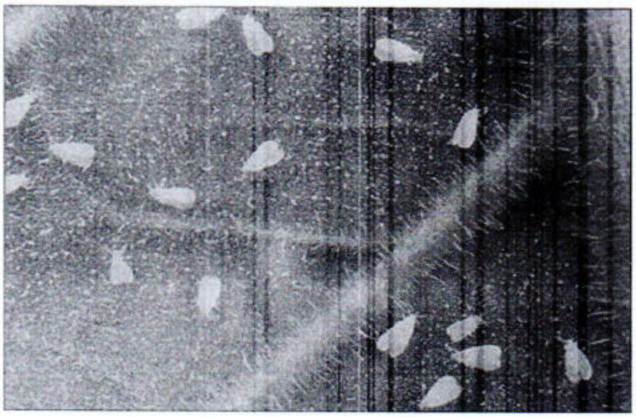

Plate 11. White fly

Thrips: The numbers of thrips found in each replication were recorded taking 5 plants randomly from every plot.

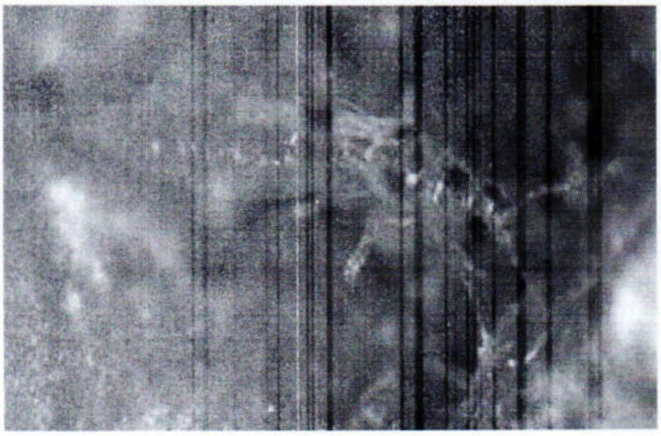

Plate 12. Thrips

Bollworm and armyworm: Started at the bottom of the plant and examined every branch in turn. It was examined upper and lower surfaces of the leaves joints of stems, leaf stalks, branches, buds, flowers and bolls. If a bud or boll contains a larva it was cut open for accurate identification of the larva. For the estimation of armyworm, the middle portion of the plant (4-7 leaves from the top) was checked accurately.

Plate 13. American bollworm moth

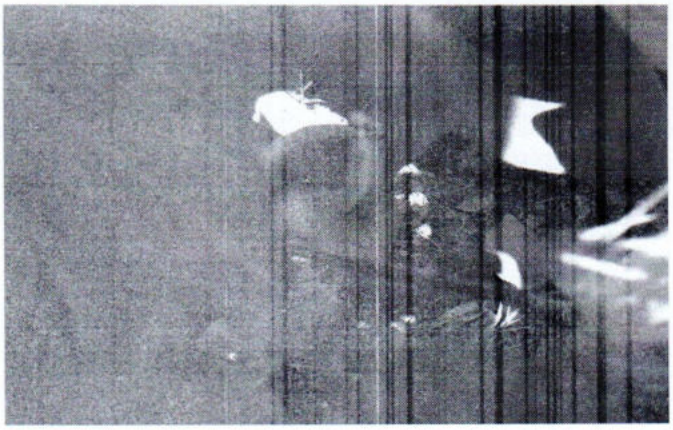

Plate 14. American bollworm larva

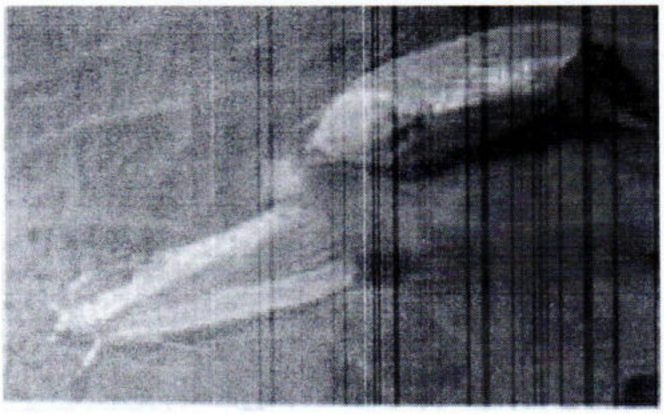

Plate 15. Spotted bollworm moth

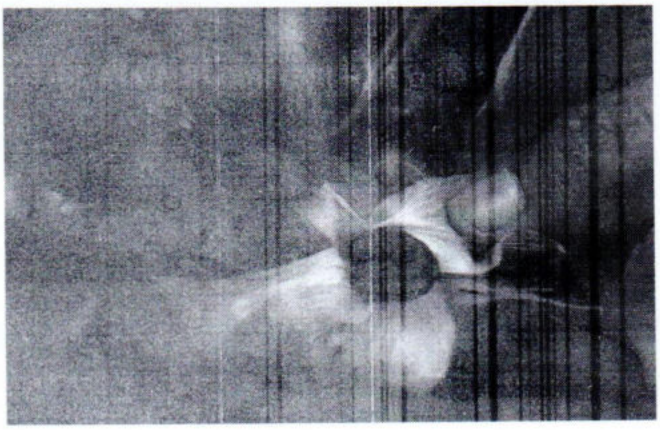

Plate 16. Spotted bollworm larva

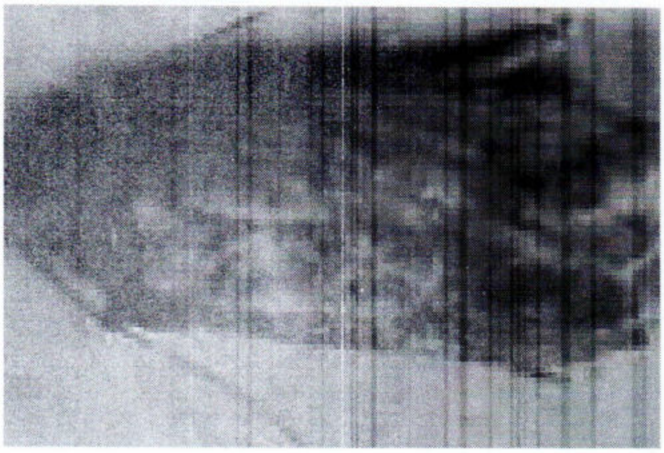

Plate 17. Pink bollworm moth

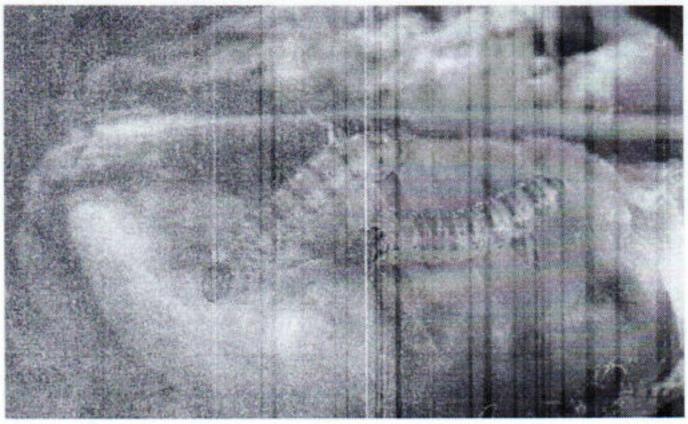

Plate 18. Pink bollworm larvae

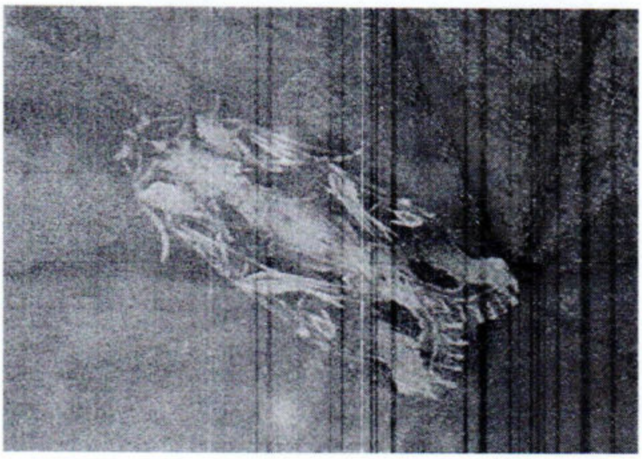

Plate 19. Armyworm moth

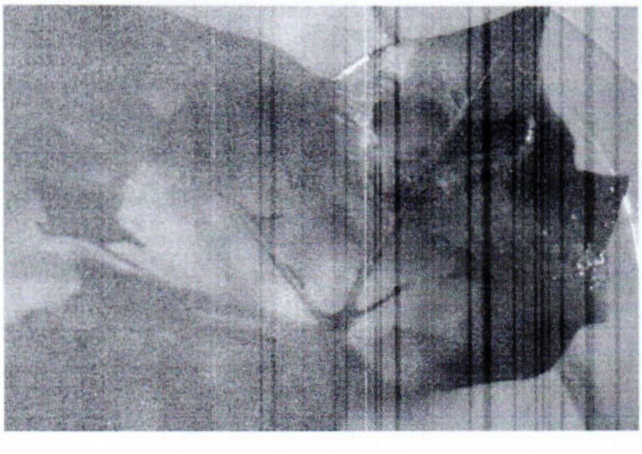

Plate 20. Armyworm larvae

Predators: During examination of the plant the number of different predators were counted and recorded in a zigzag method.

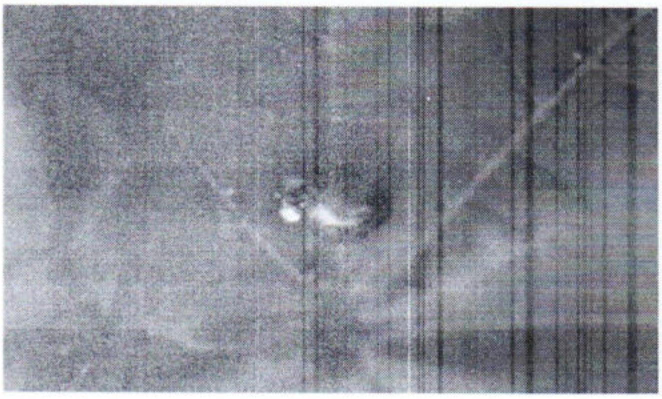

Plate 21. Lady beetle

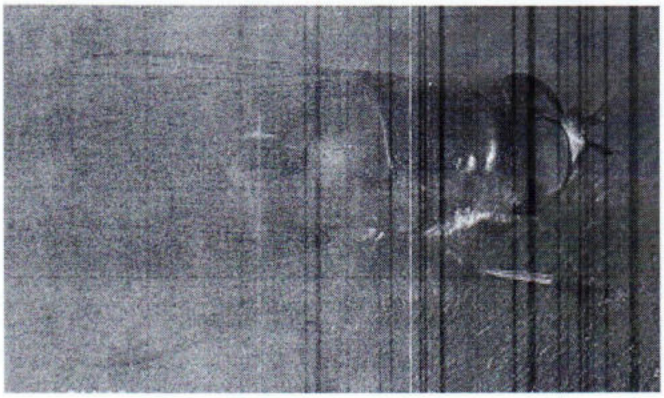

Plate 22. Syrphid fly

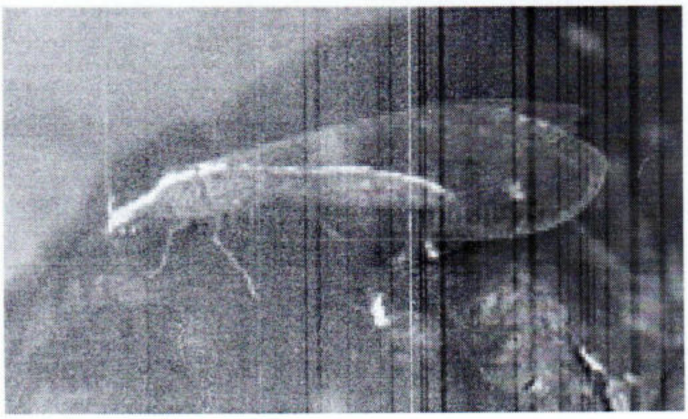

Plate 23. Lace wings

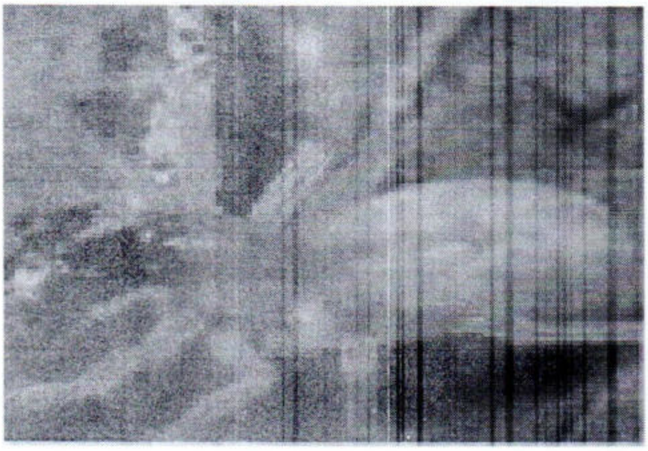

Plate 24. Spider

Pollinators: The pollinators were counted during the flowering periods of the test crops. Insects were observed once a week at 2 hour intervals starting from 6 am to 6 pm and the number of visiting pollinators per plant was taken.

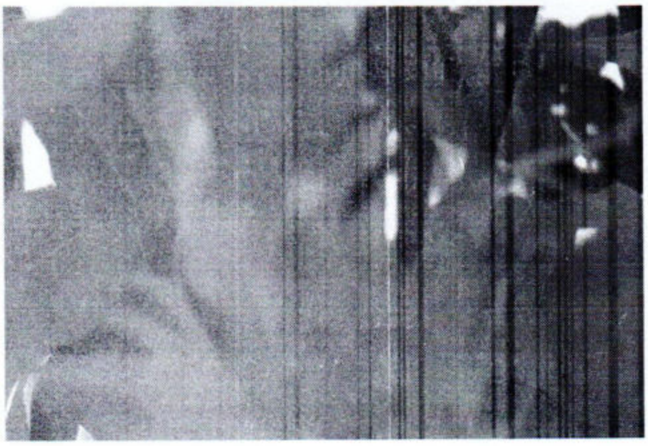

Plate 25. Honeybee

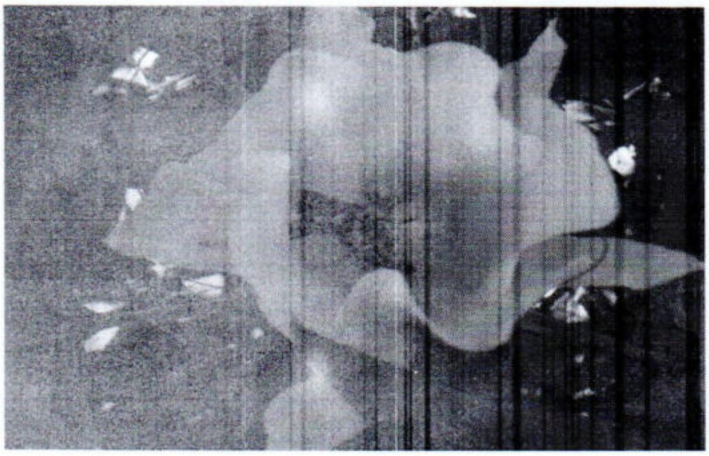

Plate 26. Bumblebee

2.9. Scouting records

A scouting form was used during estimation of the pests. For each plant the number of pests or infested grades or damage grade was entered into the relevant rows, during scouting. The number in each column was added together to give the total number of pests or grade for the field. These figures are then converted to numbers per plant by dividing the total by the number of plants taken each treatment. Thus, a pest summary of the mean insect levels for each week was maintained for observing and predicting infestation trends and spray decision.

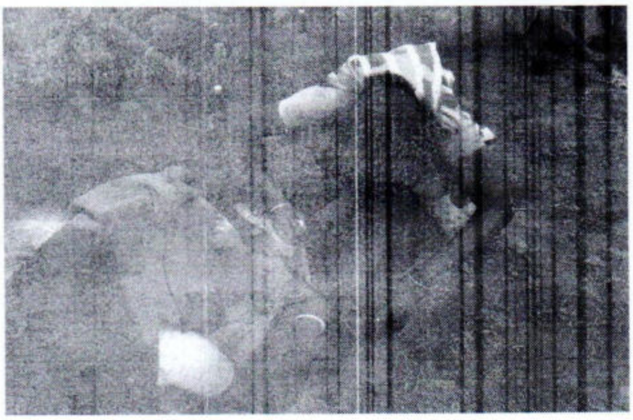

Plate 27. Counting of pest

2.10. Spray decision

Sprays were applied when the pest levels exceeded the relevant threshold at regular weekly counts. Actara, Asataf and Decis were used to suppress the pest below ETL level. Spraying was done by the knapsack spray using the volume 100-200 liter/ha, with swath 2 rows at early and 1 row swath at the later stage; walking speed 1 meter / second and keeping the pressure 2 bars within the machine. The tip of the nozzle kept 30 cm apart from the canopy head of the crop using in favor of the wind. Scorching sunlight was avoided during spray.

Pests	Recommended insecticide
Chewing insects	Decis 2.5 EC
	Ripcord 10 EC
	Relothrin 25 EC
Sucking insects	Asataf 75 SP
	Imitaf 20 SL
	Actara 25 WG

2.11. Spray volume

Water was mixed with insecticide to act as carrier of the insecticide to the plant and to ensure good coverage. The effectiveness of the insecticide was influenced by the amount and density to cover of the plant surface, which was sufficiently dense and even for the pest to easily come in contact with the deposit. The spray volume was increased from 100 to 200 litres per hectare as the plants grow taller. 200 liters per hectare were used when the plants were more than 60 cm tall or more than 10 weeks old. The nozzle of the spray breaks the spray liquid into droplets. The small droplet had given dense cover per unit area than large droplets. Cone nozzles were used during the spray.

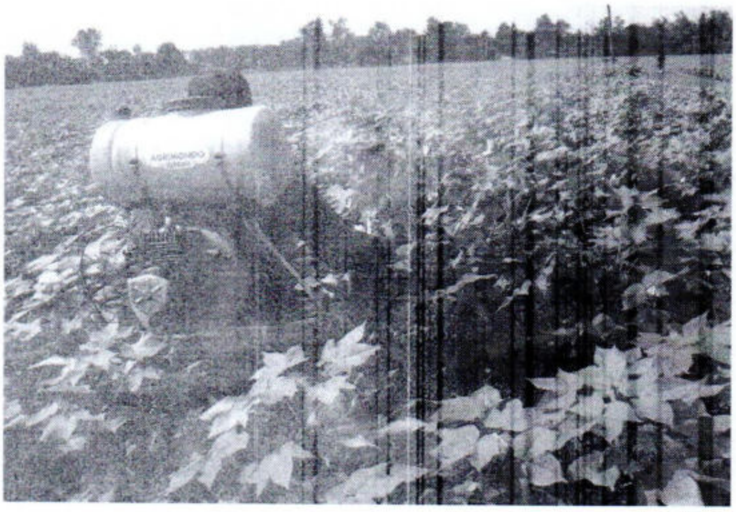

Plate 28. Spraying of insecticides

2.12. Mixing

Only clean water was used in spraying, as dirty water could cause filter and nozzle blockages and affect the performances of insecticides. The spray tank cap should not be placed on the ground where it could collect dirt. When mixing, the sprayer was half filled with water and the required amount of insecticide was added. Wettable powder were first mixed with little amount of water to form a thin cream and then added to the main spray tank. The filter cap was replaced and sprayer was shaken to mix with water and insecticide. The remaining water was then added and the sprayer was shaken for perfect mixing.

2.13. Knapsac spraying

Spraying was not done in strong wind and usually started at the down wind edge of the field; so, that the spray operator could move upwind through unsprayed cotton. The volume used 100 - 200 L / ha with the walking speed 1.4 meter/second. Sufficient pressure was maintained to produce small spray droplets at all times. The nozzle was held 30 cm apart from the plants to allow the spray cloud to expand and to cover a great area one side of the row with the nozzle pointing upwards for better under leaf coverage and penetration of the spray into the plant canopy.

2.14. Picking and weighing of seed cotton

Cotton was harvested from the inner rows of the plots excluding the border rows to give the yield / ha. The cotton from the bulk areas was bulked up. Weighing was done at the same time to avoid the hygroscopic effects.

Plate 29. Picking of seed cotton

2.15. Measurement of yield

The amount of seed cotton obtained from each experimental plot (5.4 m × 5 m) was converted to kg / ha.

2.16. Germination test and calculation of germination percentage

Germination test was conducted using sand as substratum. The sand was sieved to discard particles bigger than 0.8 mm and smaller than 0.05 mm in diameter.

Rectangular plastic boxes were used to put the sand. For every test new sand was used. Seed was placed on a uniform layer of moist sand and then covered to a depth of 10 mm with sand, which was left loose. 200 seeds were planted in each plastic tray and replicated three times. The plastic trays with seeds were incubated at room temperature and irrigated at every odd day. After 5 days germination percentage was recorded. The normal seedlings and abnormal seedlings and ungerminated seeds were classified according to the prescribed rules given by ISTA.

$$\text{Germination (\%)} = \frac{\text{Number of normal seeds germinated}}{\text{Number of seeds tested}} \times 100$$

2.17. Data collection

The following data were collected during the crop period.

(i) Record of weekly scouting for determination of pest's status in the field.

(ii) Record of sucking pest to know their presence in the field.

(iii) Record of chewing pest to know their field incidence.

(iv) Records of predator insects were done to know their presence in the field.

(v) Records of pollinator insects were done to know their presence in the field.

(vi) Spray log was maintained for spray records.

(vii) Yield (kg/ha) were recorded to find out the better performance of the treatment.

(viii) Germination percentage was recorded to know the quality of the seed.

2.18. Data analysis

Data were analyzed by Analysis of Variance (ANOVA) and the mean values were separated by Duncan's Multiple Range Test (DMRT).

Chapter III

Results

Part 1. Abundance of pest visitors associated with cotton plant

3.1. Pest visitors in ETL based insecticide sprayed cotton field

Table 1 showed the list of pest visitors abundant in ETL based insecticide sprayed cotton field during the season 2008. The data in the table showed that insects of Hemiptera, Thysanoptera, Lepidoptera, Coleoptera and spider mites of Acarina were abundant in the field.

Table 1. Pest visitors in ETL based insecticide sprayed cotton field during the season

Pests	Order	Family	Genus	Species
Jassid	Hemiptera	Cicadellidae	*Amrasca*	*Amrasca biguttula* *A. devastans*
Aphid	Hemiptera	Aphididae	*Aphis*	*Aphis gossypii*
White fly	Hemiptera	Aleyrodidae	*Bemisia*	*Bemisia tabaci*
Lygus bug	Hemiptera	Miridae	*Lygus*	*Lygus hesperus*
Red cotton bug	Hemiptera	Pyrrhocoridae	*Dysdercus*	*Dysdercus koenigii* *Dysdercus suterellus* *Dysdercus cingulatus*
Thrips	Thysanoptera	Thripidae	*Thrips*	*Thrips tabaci*
Spotted bollworm	Lepidoptera	Noctuidae	*Earias*	*Earias insulana*
American bollworm	Lepidoptera	Noctuidae	*Helicoverpa*	*Helicoverpa armigera*
Pink bollworm	Lepidoptera	Noctuidae	*Pectinophora*	*Pectinophora gossypiella*
Armyworm	Lepidoptera	Noctuidae	*Spodoptera*	*Spodoptera litura*
Semilooper	Lepidoptera	Noctuidae	*Tarache*	*Tarache notabilis*
Leaf roller	Lepidoptera	Pyralidae	*Sylepta*	*Sylepta derogata*
Boll weevil	Coleoptera	Curculionidae	*Anthonomous*	*Anthonomous grandis*
Flea beetle	Coleoptera	Chrysomelidae	*Longitarsus*	*Longitarsus belegaumensis*
Red spider mite	Acarina	Tetranychidae	*Tetranychus*	*Tetranychus telarius*

The Hemipteran pests constituted jassid (*Amrasca biguttula, A. devastans*), aphid (*Aphis gossypii*), white fly (*Bemisia tabaci*), lygus bug (*Lygus hesperus*) and red cotton bug (*Dysdercus koenigii, Dysdercus suterellus, Dysdercus cingulatus*) and they belonged to the family Cicadellidae, Aphididae, Aleyrodidae, Miridae and Pyrrhocoridae, respectively. Only one species of Thysanopteran insect, thrips (*Thrips tabaci*) was found to the cotton crops. The

Lepidopteran pests found in the cotton field were spotted bollworm (*Earias insulana*), american bollworm (*Helicoverpa armigera*), pink bollworm (*Pectinophora gossypiella*), armyworm (*Spodoptera litura*) and semilooper (*Tarache notabilis*) belonged to the family Noctuidae and leaf roller (*Sylepta derogata*) of Pyralidae. The Coleopteran pests constituted with boll weevil (*Anthonomous grandis*) and flea beetle (*Longitarsus belegaumensis*) and these are under the families of Curculionidae and Chrysomelidae, respectively. The spider mite species *Tetranychus telarius* belonged to the family Tetranychidae were abundant in the cotton field.

3.2. Incidence of major sucking pests on different cotton varieties in insecticides free field

Table 2 showed the incidence of sucking pests frequented in the insecticide free cotton field during the season. Results showed that the incidence of jassid varied from 6.5 to 8.1 and the cotton variety CB10 showed significantly the highest incidence. The abundance of aphid grade ranged from 3.1 to 4.0 and the cotton varieties showed significant variation. The highest abundance was found on the variety CB10 followed by SR05 and CB9. The incidence of white fly significantly varied among the cotton varieties. The highest incidence of white fly was observed on the variety CB9 followed by CB10 and SR05. The incidence of thrips on the cotton varieties CB9, CB10 and SR05 were 8.9, 11.9 and 9.8, respectively and the results were statistically different.

Table 2. Incidence of major sucking pests on different varieties in insecticide free cotton field during the season

Cotton variety	Number of insects / plant			
	Jassid	Aphid grade	White fly	Thrips
CB9	6.50 c	3.10 c	10.00 a	8.90 ab
CB10	8.10 a	4.00 a	8.30 b	11.90 a
SR05	7.50 b	3.60 b	6.50 c	9.80 b

Means within a column followed by same letter(s) are not significantly different (DMRT, $p \leq 0.05$)

3.3. Incidence of major sucking pests on different cotton varieties in ETL based insecticide sprayed field

The incidence of major sucking pests frequented in the ETL based insecticide sprayed cotton field presented in table 3. Results showed that the incidence of jassid varied from 1.65 to 1.95 and there is no significant difference among the cotton varieties. The abundance of aphid grade ranged from 1.00 to 1.30 and the cotton varieties showed statistically similar results. The incidence of white fly significantly varied among the cotton varieties. The highest incidence of white fly was observed on the variety CB9 (4.50) followed by CB10 (3.00) and SR05 (2.75). The incidence of thrips on the cotton varieties ranged from 4.25 to 5.00 and the results were statistically indifferent.

Table 3. Incidence of major sucking pests on different cotton varieties in ETL based insecticide sprayed field

Cotton variety	Number of insects / plant			
	Jassid	Aphid grade	White fly	Thrips
CB9	1.65 a	1.00 a	4.50 a	4.25 a
CB10	1.95 a	1.30 a	3.00 b	5.00 a
SR05	1.75 a	1.15 a	2.75 ab	4.50 a

Means within a column followed by same letter(s) are not significantly different (DMRT, $p \leq 0.05$)

3.4. Incidence of major chewing pests on different cotton varieties in insecticide free field

Table 4 showed the incidence of major chewing pests frequented in the insecticide free cotton field during the season. Results showed that the incidence of american bollworm, spotted bollworm and pink bollworm varied from 0.75 to 1.00, 1.10 to 1.24 and 0.56 to 0.75, respectively and the incidence on different varieties were statistically similar. The incidence of armyworm significantly varied among the cotton varieties. The highest incidence (2.52) of armyworm was found on the variety CB9 followed by CB10 (1.75) and SR05 (1.53).

Table 4. Incidence of major chewing pests on different cotton varieties in insecticide free field during the season

Cotton variety	Number of insects / plant			
	American bollworm	Spotted bollworm	Pink bollworm	Armyworm
CB9	1.00 a	1.24 a	0.75 a	2.52 a
CB10	0.82 a	1.12 a	0.61 a	1.75 ab
SR05	0.75 a	1.10 a	0.56 a	1.53 b

Means within a column followed by same letter(s) are not significantly different (DMRT, $p \leq 0.05$)

3.5. Incidence of major chewing pests on different cotton varieties in ETL based insecticide sprayed field

The incidence of major chewing pests on different cotton varieties in ETL based insecticide sprayed field did not show significant difference (Table 5). However, the incidence of american bollworm, spotted bollworm, pink bollworm and armyworm varied from 0.18 to 0.22, 0.150 to 0.20, 0.10 to 0.15 and 0.95 to 1.25, respectively.

Table 5. Incidence of major chewing pests on different varieties in ETL based insecticide sprayed cotton field during the season

Cotton variety	Number of insects / plant			
	American bollworm	Spotted bollworm	Pink bollworm	Armyworm
CB9	0.22 a	0.20 a	0.15 a	1.25 a
CB10	0.20 a	0.15 a	0.10 a	1.00 a
SR05	0.18 a	0.15 a	0.10 a	0.95 a

Means within a column followed by same letter(s) are not significantly different (DMRT, $p \leq 0.05$)

Part 2. Abundance of predator visitors associated with cotton plant

3.6. Predator visitors in ETL based insecticide sprayed cotton field

Table 6 showed the list of predator visitors abundant in ETL based insecticide sprayed cotton field during the season 2008. The data revealed that insects of Odonata, Orthoptera, Dermaptera, Dictyoptera, Hemiptera, Thysanoptera, Neuroptera, Diptera, Hymenoptera and Coleoptera were abundant in the field.

Table 6. Predator visitors in ETL based insecticide sprayed cotton field during the season

Predator	Order	Family	Genus	Species
Dragon fly	Odonata	Aeshnidae	*Aeshna*	*Aeshna verticalis*
Damsel fly	Odonata	Coenagrionidae	*Coenagrion*	*Coenagrion puella*
				Nabis capsiformes
Cricket	Orthoptera	Gryllidae	*Gryllus*	*Gryllus campestris*
Long horned grasshopper	Orthoptera	Tettigoniidae	*Conocephalus*	*Conocephalus longipennis*
Ear wig	Dermaptera	Forficulidae	*Forficula*	*Forficula auricularia*
Preying mantid	Dictyoptera	Mantidae	*Mantis*	*Mantis religiosa*
Green stink bug	Hemiptera	Pentatomidae	*Nezara*	*Nezara virridula*
Damsel bug	Hemiptera	Nabidae	*Nabis*	*Nabis capsiformis*
Assassin bug	Hemiptera	Reduvidae	*Zelus*	*Zelus renardii*
			Sinea	*Sinea diadema*
Bigeyed bug	Hemiptera	Geocoridae	*Geocoris*	*Geocoris punctipes*
				G. uliginosus
Anthocorid bug	Hemiptera	Anthocoridae	*Orius*	*Orius niger*
Thrips	Thysanoptera	Thripidae	*Scolothrips*	*Scolothrips sexmavulatus*
Lace wings	Neuroptera	Chrysopidae	*Chrysopa*	*Chrysopa carnea*
				Chrysopa rufilabris
Syrphid fly	Diptera	Syrphidae	*Syrphus*	*Syrphus opinator*
Robber fly	Diptera	Asilidae	*Holcocephala*	*Holcocephala fusca*
Wasps	Hymenoptera	Vespidae	*Vespula*	*Vespula vulgaris*
Ants	Hymenoptera	Formicidae		*Solenopsis invicata*
				S. geminata
Ground beetle	Coleoptera	Carabidae	*Carabus*	*Carabus nemoralis*
Lady beetle	Coleoptera	Coccinellidae	*Coccinella*	*Coccinella septempunctata*
				C. transversalis
			Micraspis	*Micraspis discolor*
			Menochilus	*Menochilus sexmaculatus*
			Hipodamia	*Hipodamia convergens*
Predatory mite	Acarina	Phytoseiidae	Galendromus	*Galendromus occidentalis*
Winter spider	Araneae	Miturgidae	*Chiracanthium*	*Chiracanthium inclusum*

The abundant predators of the order Odonata were dragon fly (*Aeshna verticalis*) and damsel fly (*Coenagrion puella, Nabis capsiformes*) belonged to the family Aeshnidae and Coenagrionidae, respectively. Two Orthopteran predators viz. cricket (*Gryllus campestris*) and long horned grasshopper (*Conocephalus longipennis*) belonged to the families Gryllidae and Tettigoniidae, respectively were also abundant. The predators ear wig, *Forficula auricularia* (Dermaptera: Forficulidae), preying mantid, *Mantis religiosa* (Dictyoptera: Mantidae), thrips, *Scolothrips sexmavulatus* (Thysanopterra: Thripidae) were found during the cropping season. The species of lace wings, *Chrysopa carnea* and *C. rufilabris* (Neuroptera: Chrysopidae) appeared as predator of cotton pests. The Hemipteran predators constituted with green stink bug (*Nezara virridula*), damsel bug (*Nabis capsiformis*), assassin bug (*Zelus renardii, Sinea diadema*), bigeyed bug (*Geocoris punctipes, G. uliginosus*) and anthocorid bug (*Orius niger*). These predators are insects under the family Pentatomidae, Nabidae, Reduvidae, Geocoridae and Anthocoridae, respectively. The popular predator lady beetle (Coleoptera: Coccinellidae) were most abundant and the observed species were *Coccinella septempunctata, C. transversalis, Micraspis discolor* and *Menochilus sexmaculatus*. The ground beetle, *Carabus nemoralis* (Coleoptera: Carabidae) was also observed as predator. The Dipteran insects syrphid fly, *Syrphus opinator* (Syrphidae), robber fly, *Holcocephala fusca* (Asilidae), and Hymenopteran insect wasp, *Vespula vulgaris* (Vespidae) and ants, *Solenopsis invicata, S. geminata* (Formicidae) were appeared as predator during the season. The predatory mite, *Galendromus occidentalis* (Acarina: Phytoseiidae) and winter spider, *Chiracanthium inclusum* (Araneae: Miturgidae) were found as predator in the cotton field.

3.7. Incidence of major predators on different cotton varieties in insecticide free field

Table 7 showed the incidence of major predators frequented in the insecticide free cotton field during the season. Results showed that the incidence of lady beetle varied from 6.45 to 7.52 and the cotton variety CB10 showed significantly the highest incidence. The abundance of syrphids ranged from 5.10 to 6.24 and the cotton varieties showed significant variation. The highest abundance was found on the variety CB10 followed by SR05 and CB9. The incidence of lace wings significantly varied among the cotton varieties. The highest incidence was observed on the variety CB10 followed by SR05 and CB9. The incidence of spiders on the cotton varieties CB9, CB10 and SR05 were 3.08, 4.10 and 3.76, respectively and the results were statistically different; a significant variation is found between CB9 and CB10.

Table 7. Incidence of major predators on different cotton varieties in insecticide free field during the season

Cotton variety	Number of predators / plant			
	Lady beetle	Syrphids	Lace wing	Spider
CB9	6.45 ab	5.10 ab	4.51 b	3.08 b
CB10	7.52 a	6.24 a	5.76 a	4.10 a
SR05	7.13 b	6.04 a	5.06 ab	3.76 ab

Means within a column followed by same letter(s) are not significantly different (DMRT, $p \leq 0.05$)

3.8. Incidence of major predators on different cotton varieties in ETL based insecticide sprayed field

The incidence of major predators frequented in the ETL based insecticide sprayed cotton field presented in table 8. Results showed that the incidence of lady beetle varied from 3.52 to 4.10 and the cotton variety CB10 showed significantly the highest incidence. The incidence of syrphids ranged from 3.10 to 4.54 and the cotton varieties showed statistically different results. The incidence of lace wings significantly varied among the cotton varieties. The highest incidence of lace wing was observed on the variety CB10 (3.55) followed by SR05 (3.03) and CB9 (2.50). The incidence of spider on the cotton varieties ranged from 2.05 to 3.25. SR05 and CB10 are significantly varied from CB9.

Table 8. Incidence of major predators on different cotton varieties in ETL based insecticide sprayed field during the season

Cotton variety	Number of predator / plant			
	Lady beetle	Syrphids	Lace wing	Spider
CB9	3.52 a	3.10 b	2.50 b	2.05 b
CB10	4.10 a	4.54 a	3.55 a	3.25 a
SR05	3.75 a	4.02 ab	3.03 ab	3.10 a

Means within a column followed by same letter(s) are not significantly different (DMRT, $p \leq 0.05$)

Part 3. Abundance of pollinator visitors associated with cotton plant

3.9. Pollinator visitors in ETL based insecticide sprayed cotton field

A list of insect visitors abundant in the cotton field during the growing season 2008 presented in table 9. The data in the table clearly showed that insects of three orders viz. Hymenoptera, Lepidoptera and Diptera are attracted to the crops during the blooming seasons. The Hymenoptera constituted five species of pollinators belonged to two families and four genus. The cotton plants attracted five species of Lepidopteran pollinators those are under four different genus and families. The Dipteran cotton pollinators constituted with two species belonged to two different genus and families.

Table 9. Pollinator visitors in ETL based insecticide sprayed cotton field during the season

Pollinator	Order	Family	Genus	Species
Honeybee	Hymenoptera	Apidae	*Apis*	*Apis florea* *Apis cerana indica*
Bumblebee	Hymenoptera	Apidae	*Bombus*	*Bombus ignitus*
	Hymenoptera	Halticidae	*Halticus*	*Halticus sp*
Alkalibee	Hymenoptera	Halticidae	*Nomia*	*Nomia melanderi*
Lemon butterfly	Lepidoptera	Papilionidae	*Papilio*	*Papilio demoleus*
Sulphur butterfly	Lepidoptera	Pieridae	*Pieris*	*Pieris spp*
Lady's finger shoot and fruit borer	Lepidoptera	Noctuidae	*Earias*	*Earias vitella*
Hover fly	Diptera	Syrphidae	*Eristalis*	*Earistalis spp*
House fly	Diptera	Muscidae	*Musca*	*Musca spp*

3.10. Incidence of major pollinator visitors on different cotton varieties in insecticide free field

The incidence of major pollinators frequented on different cotton varieties in insecticide free field did not show significant difference (Figure 1). However, the incidence of honeybee and bumblebee varied from 5.10 to 5.60 and 4.91 to 5.80 per plant, respectively.

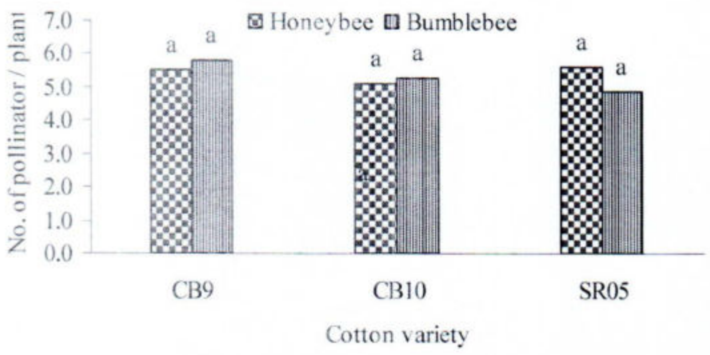

Figure 1. Incidence of major pollinator visitors on different varieties in insecticide free cotton field during the season. Bars with common letter (s) are not significantly different (DMRT, $p \leq 0.05$)

3.11. Incidence of major pollinator visitors on different cotton varieties in ETL based insecticide sprayed field

Figure 2 showed the incidence of major pollinators frequented on different cotton varieties in ETL based insecticide sprayed field. Results showed that the incidence of honeybee varied from 2.75 to 3.1 and the results were statistically similar. The incidance of bumblebee ranged from 2.60 to 3.10 and results did not show significant difference.

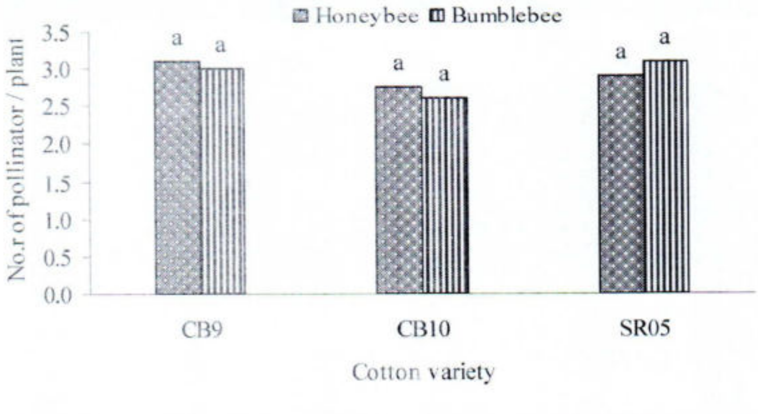

Figure 2. Incidence of major pollinator visitors on different varieties in ETL based insecticide sprayed cotton field during the season. Bars with common letter (s) are not significantly different (DMRT, $p \leq 0.05$)

Part 4. Impact on yield and seed quality

3.12. Effects of pest, predator and pollinator on the boll production

Figure 3 demonstrated the effect of pest, predator and pollinator on the bolls production of three cotton varieties. Results indicated that number of bolls varied with different varieties cultivated in enclosed condition and ranged from 39.4 ± 11.3 to 44.2 ± 8.3, and the variety SR05 produced significantly the highest number of bolls $plant^{-1}$. The cotton varieties produced significantly different number of bolls in ETL based insecticide sprayed condition. The cotton variety SR05 produced significantly the highest number of bolls (40.1 ± 8.8 $plant^{-1}$) followed by CB9 (34.1 ± 8.9 $plant^{-1}$) and CB10 (32.2 ± 7.6 $plant^{-1}$). In the non-sprayed field, the variety SR05 and CB10 produced significantly the highest (12.6 ± 3.1 $plant^{-1}$) and lowest (8.2 ± 3.5 $plant^{-1}$) number of bolls, respectively.

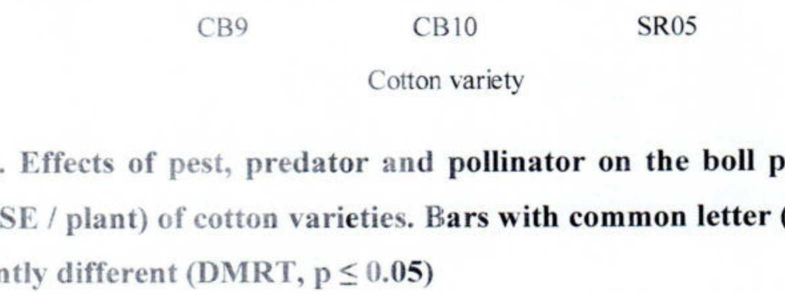

Figure 3. Effects of pest, predator and pollinator on the boll production (mean ± SE / plant) of cotton varieties. Bars with common letter (s) are not significantly different (DMRT, $p \leq 0.05$)

3.13. Effects of pest, predator and pollinator on the yield

Figure 4 presented the effects of pest, predator and pollinator on the yield of different cotton varieties. Results showed that yield obtained from different varieties cultivated in enclosed condition ranged from 2496.7 ± 20.8 to 2751.7 ± 23.6 kg / ha and variety SR05 produced significantly the highest yield. The yields obtained from different varieties cultivated in ETL based insecticide sprayed condition showed significant differences. The cotton variety SR05 produced significantly the highest yield (2498.3 ± 18.9 kg / ha) followed by CB9 (2248.3 ± 18.9 kg / ha) and CB10 (2173.3 ± 15.3 kg / ha). In the non-sprayed field, the variety SR05 and CB10 produced significantly the highest (792.3 ± 8.7 kg / ha) and lowest (618.3 kg / ha) yield, respectively.

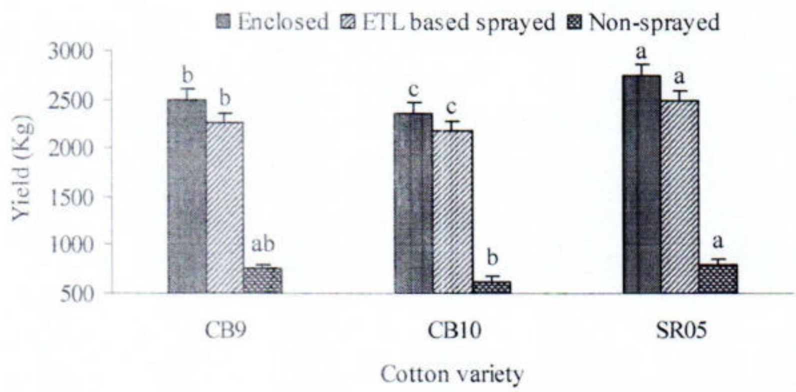

Figure 4. Effects of pest, predator and pollinator on the yield (mean ± SE kg / ha) of cotton varieties. Bars with common letter (s) are not significantly different (DMRT, p ≤ 0.05)

3.14. Effects of pest, predator and pollinator on the seed production

Pest, predator and pollinators had significant effect on the seed production of different cotton varieties (Figure 5). In enclosed condition, the cotton varieties CB9 and CB10, respectively produced significantly the highest (36.2 ± 6.9) and lowest (34.1 ± 8.1) number of seeds / boll. In ETL based insecticide sprayed condition these two varieties also produced the highest (35.9 ± 6.5) and lowest (33.1 ± 7.0) number of seeds / boll. The variety CB9 and SR05 produced significantly the lowest (30.2 ± 5.1) and highest (32.2 ± 4.7) number of seeds / bolls when they were cultivated under non-sprayed condition.

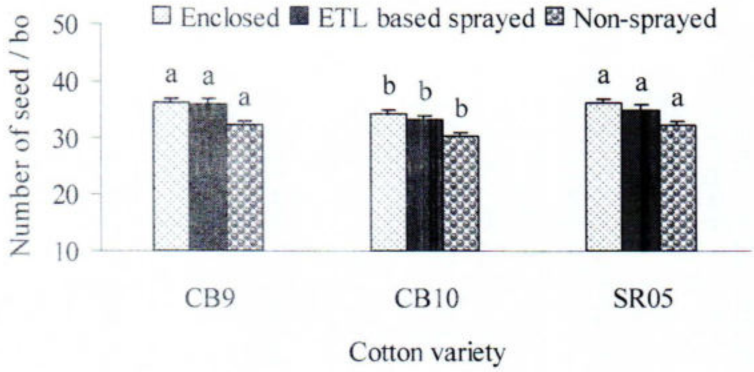

Figure 5. Effects of pest, predator and pollinator on the seed production of cotton varieties. Bars with common letter (s) are not significantly different (DMRT, $p \leq 0.05$)

3.15. Effects of pest, predator and pollinator on the ginning out tern

The ginning out tern (GOT%) of the cotton varieties CB9, CB10 and SR05 did not show significant variation when the varieties were cultivated under enclosed, ETL based insecticide sprayed and non-sprayed condition (Figure 6). The counted GOT of the varieties ranged from 36.3 to 37.9 %.

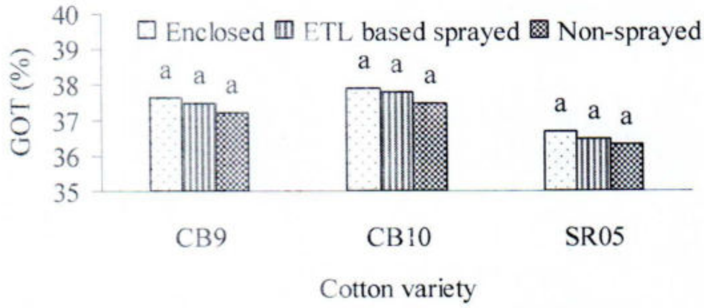

Figure 6. Effects of pest, predator and pollinator on the ginning out tern (GOT%) of cotton varieties. Bars with common letter (s) are not significantly different (DMRT, $p \leq 0.05$)

3.16. Effects of pest, predator and pollinator on the seed index

Figure 7 showed that the cotton variety CB9 cultivated under enclosed condition showed significantly the highest seed index (83.5 g) followed by SR05 (78.3 g) and CB10 (75.2 g). This variety also showed significantly the highest seed index both in ETL based insecticide sprayed and non-sprayed condition (83.0 and 83.1g, respectively). On the other hand, the variety CB10 showed the lowest seed index in these conditions (75.0 and 75.1g, respectively).

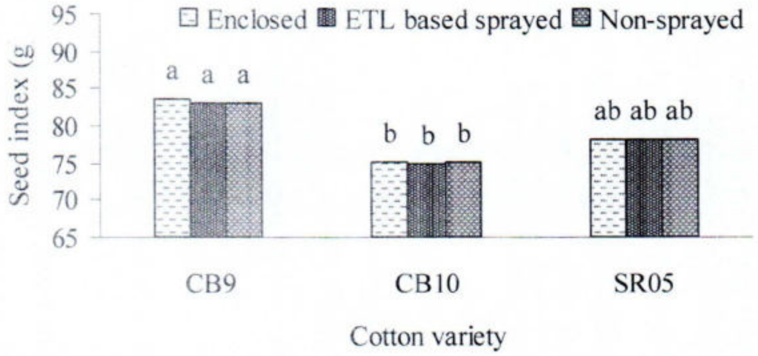

Figure 7. Effect of pest, predator and pollinator on the seed index of cotton varieties. Bars with common letter (s) are not significantly different (DMRT, $p \leq 0.05$)

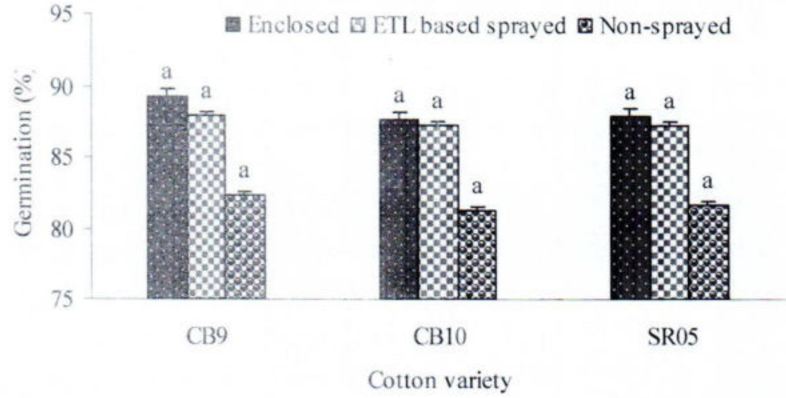

Figure 8. Effects of pest, predator and pollinator on the germination of cotton seed. Bars with common letter (s) are not significantly different (DMRT, $p \leq 0.05$)

3.17. Effects of pest, predator and pollinator on the germination rates

The germination percentage of different cotton varieties presented in figure 8 showed no significant difference. However, the germination percentage of different cotton varieties cultivated in enclosed, ETL based insecticide sprayed and non sprayed condition varied from 87.7 ± 3.5 to 89.3 ± 5.5, 87.3 ± 4.6 to 88.0 ± 4.6 and 81.3 ± 6.1 to 82.3 ± 6.0, respectively.

Chapter IV

Discussion

4.1. Abundance of pest visitors associated with cotton plants

The moderate temperature, high humidity and cloudiness conditions of the environment during the cotton growing season encourage the growth of the pest populations (Ram and Pathak 1987). Kabir and Khan (1980) stated that the sucking pests prefer the soft and tender parts of the crop. In the month of October and November, the cotton plants are in juvenile stage which offers maximum food and good habitat for all types of sucking and chewing pests. There are about 162 species of insects caused damage to cotton plants of which 15 are considered as major pest (Bohmfalk *et al.* 1996). The results of this study showed that 16 species of insect and one species of mite were abundant in ETL based insecticide sprayed cotton field. But 8 species of insect such as jassid, aphid, white fly, thrips, spotted bollworm, american bollworm, pink bollworm and armyworm were most abundant. In the present experiment, chemical insecticides were applied at the threshold level for controlling the major pests which suppressed the incidence of the minor pests. Amin *et al.* (2009a) reported that ETL based application of systemic insecticides were confident and prudent enough to suppress the pest populations of cotton.

The studied cotton varieties CB9, CB10 and SR05 possessed different morphological characteristics and played significant role on the incidence of major sucking pests. But cultivation of these varieties with ETL based insecticide sprayed condition did not show significant effect on the incidence of jassid, aphid and thrips however, the incidence of white fly were significantly different. This study showed agreement with Amin *et al.* (2008a) who reported that cultivation of cotton varieties CB3, CB5, CB8, CB9, CB10, SR05 and SR01 had significant effect on the incidence of sucking pests. The findings of the study indicated that application of synthetic pyrethroids reduced the incidence of chewing pest populations. The bollworms abundance were not dependent on cotton varieties but armyworm abundance showed significant variation in insecticide free condition. These results are in accordance with Amin *et al.* (2009b) who observed that synthetic pyrethroids significantly reduce the incidence of bollworm on CB9 variety.

4.2. Abundance of predator visitors associated with cotton plants

Predation is often a key factor maintaining insect populations below pest status in annual crops. The evaluations reported here focused on the predator complexes feeding on cotton pests. There are numerous arthropods in cotton fields. The arthropod predators of insect and mites include beetles, true bugs, lace wings, flies, midges, spiders, wasps and predatory mites (Weeden *et al.* 2009). The present study showed the predator species that were abundant in the ETL based insecticide sprayed cotton field. Results revealed that 29 species of insects in 9 orders and 19 families were abundant during the season. One predatory mite species and one spider species were also abundant. Hoffman and Frodsham (1993) recorded 600 species of predators in 45 families of insects and 23 families of spiders and mites in Arkansas cotton. This study showed considerable reduction in the number of predator species that might me the reason of indiscriminate insecticide applications in Bangladesh that regulates the population abundance of natural enemies.

Plant morphological traits such as leaf pubescence affect hervivores and their natural enemies at the individual, population and community levels (Seelman *et al.* 2007). This study showed that the abundance of predators varied significantly among the cotton varieties. The variety CB10 revealed higher number of predator abundance both in ETL based insecticide sprayed and non-sprayed condition. The lowest number of predator abundance was found to the variety CB9. The abundance of predator was found higher in smooth variety rather than hairyness. The presence of more pests in smooth varieties invited more predators than hairy varieties like SR05. Amin *et al.* (2008a) stated positive relationship of predator and preys in cotton varieties. They reported that the cotton varieties possessed dense hairs and trichomes are more tolerant to sucking pests and showed lower incidence of predator abundance. In the variety SR05, both the predators and prey feel uncomfortable for its less canopy volume and high degree of ventilation.

4.3. Abundance of pollinator visitors associated with cotton plants

Pollination is the transfer of pollen grains from one another to stigma and is a fundamental ecological service provided by bees, butterflies, beetles and many other wild life species (Stern 1994). Cotton flowers contain valuable resources for insects (Mailhot *et al.* 2007). The flower blooms from bottom to top with a cream-coloured opening in the morning shortly after dawn, turning pink in the afternoon and closing at night, never to reopen (van Deynze 2005). The flower is preferred by Hymenopteran, Lepidopteran and Dipterans with short and long mouthparts. The pollinators abundant in the cotton field of this study composed of 12 species of which 5 species in two families of Hymenoptera, 5 species in two families of Lepidoptera and 2 species in two families of Diptera. The present study showed that two species of honeybees were found in the cotton field. Whereas, in various parts of India, honeybee species *A. dorsata*, *A. cerana*, *A florea* and *A mellifera* are the most effective pollinators (Chandel *et al.* 2004). There are over 100 species of bumblebees are distributed in Asia (Kwon *et al.* 2003). But this study stated that only one species of bumblebee was found in the cotton field.

Herrera (2005) observed a total of 60 pollinator species of which 26 Lepidopterans, 23 Hymenopterans and 11 Dipterans on *Lavandula latifolia*. In the present study 5 Lepidopteran species were observed on cotton plants. Variation in pollinator composition among populations of the same plant seems to be the rule in nature (Herrera 1988, Gomez and Zamora 1999, Thompson 2001, Eckert 2002). Kumer *et al.* (1989) stated that pollinator attraction towards crops varied with the type and variety of crops. Dipterans are among the most common insects that visit flowers. At least 71 Dipteran families contain pollinators (Larson *et al.* 2001). This study stated that only hover fly and house fly were the most common Diptarans in the cotton field. Hoverflies (Diptera: Syrphidae) play an important role in pollination (Bohart *et al.* 1970) which were observed in this study. Results of this study showed that both in ETL based insecticide sprayed and non-sprayed condition the cotton varieties were cultivated did not show significant variation on the incidence of major pollinator abundance. However, the incidence of abundance was lower in ETL based insecticide sprayed field compared to non-sprayed field.

4.4. Impact on yield and seed quality

Cotton is highly susceptible to insect pests and attacked by different species from germination to final picking. Because of the incidence of many pest species a lot of predators exist in the field. Although cotton is a self-pollinated crop many pollinators visit during the season and played role for production of more yield and higher level of seed germination (El-Sarrag *et al.* 1993). The findings of the present study revealed that abundance of pest, predator and pollinators greatly influenced on the production of boll / plant, yield / ha, number of seeds / boll and seed index. The varieties CB9, CB10 and SR05 in enclosed, ETL based insecticide sprayed and non-sprayed conditions produced 8.2 ± 3.5 to 44.2 ± 8.3 bolls / plant which showed harmony with the findings of Amin *et al.* (2008a) who cultivated different varieties under ETL based insecticide sprayed conditions and found 17.67 to 29.0 bolls / plant. They found 34.83 to 41.33% GOT which were very close to the results (36.3 to 37.69) of this study. This study referred that cultivation of cotton varieties under enclosed condition produced significantly higher yield (2350 ± 17.3 to 2751.7 ± 23.6 kg / ha) which showed accordance with the results of Amin *et al.*

(2009a) who cultivated CB10 variety following ETL based insecticide application and attained 2650 kg / ha yield. Cotton varieties were cultivated under enclosed condition were completely free from pests attack. As a result, in this condition the yield as well as number of bolls / plant and number of seeds / boll attained significantly higher. However, cotton varieties were cultivated under ETL based insecticide sprayed condition gave better performance of yield and seed quality.

Threshold spray usually justifies the use of control measures and resulted more profit (Ali and Karim 1990). In the present study systemic insecticides and pyrethroids were applied in the threshold level to avoid unnecessary burden of the environment. Dahiya and Singh (1982) reported that the systemic insecticides were successful in killing the sucking pests of cotton. Hossain *et al*. (2003) stated that mixed application of synthetic pyrethroids greatly affect the bioassay of cotton sucking pests. Considering the different parameters, the response of synthetic pyrethroids and systemic insecticides showed better performances. However, to protect predators and pollinators insecticides should be applied at the proper doses and should be applied only when necessary, as determined by frequent field inspections, to prevent economic losses from pests.

Chapter V

Conclusion

Conservation of natural enemies and pollinators in the cotton field is of urgent need. But insecticides affect the behavior and biology such as fecundity, their life span, growth and development of the predators and pollinators. There is a positive correlation between predators and pest populations. Toxicity of chemical highly influences this relationship by killing preys and predators. Recently, there has been a great reduction of wild insect pollinators such as native honeybees, bumblebees, solitary bees, flower flies and butterflies etc. Reduced pollinator services will result in reduced out crossing and seed set that can potentially lead to declines in the abundance of plant species. Negative effect upon plant populations may have further implications for plant community dynamics, associated herbivores and other animals depend on plant resources.

Pest tolerant and competent variety is profitable for cultivation and quality product. Findings of this study indicated that the variety CB9 showed more tolerant to sucking pests because of its dense hairs and trichome contents. SR05 is a well ventilated and serrated leaf variety which showed potential and prudent enough to protect from insect attack. On the other hand, american bollworm and white fly prefers pubescent or hairy variety compared to glabrous one. The smooth variety (CB10) is more preferable for predator and pollinators.

Insects and mites of different orders and families were found in the cotton fields of which few are considered as major pests. Fortunately, many are beneficial while a small number have no demonstrable effect on the plants or insects / mites present in the field. In this study, insecticides were applied at the threshold level to avoid unnecessary burden of the environment. As a result predators and pollinators were found abundant in the field.

Chapter VI

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Chapter VII

Appendix

Appendix 1. Daily average temperature (°C), Relative humidity (%) and Rainfall (mm) of Wheat Research Centre, Dinajpur from August 2008 to February 2009

August 2008

Date	Average temperature (°C)	Rainfall (mm)	Humidity (%)
1	29.7	26.6	79
2	27.4	3.4	91
3	28.4	0.0	80
4	28.6	3.2	79
5	29.6	0.0	75
6	29.4	0.0	72
7	30.5	0.0	75
8	31.4	76.0	74
9	28.6	4.0	78
10	30.0	33.0	75
11	27.4	6.0	91
12	28.1	1.6	81
13	29.2	29.4	86
14	28.3	14.0	82
15	28.5	22.2	82
16	28.3	12.6	80
17	29.2	9.4	78
18	28.3	6.4	78
19	28.6	35.0	80
20	29.1	1.6	86
21	29.8	0.0	80
22	28.4	8.0	73
23	28.9	103.0	83
24	28.3	4.0	86
25	29.1	0.0	82
26	31.1	0.0	76
27	29.2	0.0	70
28	29.5	53.0	74
29	28.9	0.0	75
30	30.0	0.0	70
31	29.9	0.0	68

September 2008

Date	Average temperature (^oC)	Rainfall(mm)	Humidity(%)
1	30.0	0.0	68
2	29.9	0.0	73
3	30.3	0.0	70
4	29.0	0.0	72
5	25.9	29.6	69
6	28.3	0.0	82
7	29.5	0.0	68
8	30.9	1.0	69
9	29.2	0.0	70
10	29.7	4.6	68
11	27.9	0.0	74
12	29.9	0.0	73
13	30.1	0.0	70
14	29.9	0.0	68
15	30.3	0.0	68
16	29.4	0.0	78
17	29.3	0.0	69
18	30.4	0.0	66
19	30.7	0.0	63
20	31.4	0.0	66
21	30.3	0.0	69
22	29.3	21.0	66
23	28.4	4.0	73
24	27.6	12.6	74
25	27.9	18.0	80
26	29.3	4.2	68
27	28.1	2.6	82
28	29.4	3.2	70
29	29.7	0.0	78
30	29.5	24.6	84

October 2008

Date	Average temperature (°C)	Rainfall(mm)	Humidity(%)
1	29.0	0.0	72
2	30.4	0.0	73
3	30.8	0.0	72
4	29.5	0.0	71
5	30.1	0.0	69
6	30.6	0.0	66
7	30.4	0.0	65
8	29.6	19.2	70
9	27.9	0.0	66
10	28.6	0.0	68
11	28.7	0.0	63
12	28.5	0.0	67
13	28.4	13.2	74
14	25.2	0.4	79
15	26.3	0.0	76
16	26.9	0.0	71
17	27.5	0.0	69
18	26.0	13.8	85
19	26.2	4.8	93
20	27.2	0.0	74
21	27.7	0.0	71
22	27.2	0.0	66
23	26.8	0.0	62
24	26.4	0.0	62
25	27.1	0.0	64
26	27.7	0.0	63
27	27.3	0.0	60
28	25.9	0.0	55
29	25.0	0.0	54
30	25.1	0.0	56
31	24.7	0.0	58

November 2008

Date	Average temperature (^{o}C)	Rainfall(mm)	Humidity(%)
1	25.1	0.0	63
2	25.9	0.0	70
3	26.3	0.0	67
4	26.8	0.0	65
5	26.0	0.0	68
6	26.5	0.0	71
7	26.3	0.0	65
8	27.2	0.0	66
9	26.1	0.0	64
10	25.8	0.0	70
11	25.5	45.0	79
12	21.6	156.2	95
13	21.9	0.0	88
14	23.3	0.0	73
15	23.7	0.0	69
16	23.3	0.0	64
17	22.7	0.0	65
18	23.1	0.0	64
19	23.2	0.0	63
20	23.1	0.0	70
21	22.9	0.0	69
22	22.2	0.0	63
23	22.4	0.0	65
24	22.9	0.0	65
25	23.2	0.0	64
26	23.8	0.0	62
27	23.9	0.0	64
28	23.8	0.0	61
29	24.1	0.0	63
30	23.9	0.0	62

December 2008

Date	Average temperature (°C)	Rainfall(mm)	Humidity(%)
1	23.9	0.0	63
2	23.0	0.0	63
3	22.6	0.0	63
4	21.9	0.0	65
5	21.5	0.0	63
6	21.8	0.0	63
7	21.1	0.0	65
8	21.4	0.0	62
9	21.7	0.0	63
10	21.3	0.0	60
11	21.0	0.0	61
12	20.2	0.0	64
13	20.5	0.0	60
14	21.5	0.0	67
15	22.4	0.0	67
16	21.3	0.0	62
17	21.3	0.0	63
18	21.3	0.0	63
19	21.6	0.0	65
20	22.1	0.0	68
21	20.5	0.0	78
22	20.5	0.0	83
23	18.9	0.0	82
24	18.3	0.0	83
25	17.8	0.0	77
26	19.1	0.0	73
27	18.2	0.0	71
28	17.5	0.0	71
29	17.1	0.0	64
30	15.7	0.0	74
31	17.0	0.0	76

January 2009

Date	Average temperature (^oC)	Rainfall(mm)	Humidity(%)
1	16.9	0.0	69
2	18.2	0.0	74
3	19.6	0.0	60
4	19.3	0.0	62
5	17.3	0.0	59
6	16.5	0.0	75
7	15.9	0.0	73
8	13.4	0.0	91
9	12.3	0.0	90
10	13.4	0.0	88
11	13.0	0.0	85
12	14.1	0.0	85
13	12.5	0.0	91
14	14.3	0.0	85
15	14.5	0.0	88
16	15.9	0.0	83
17	17.3	0.0	78
18	18.7	0.0	62
19	19.3	0.0	59
20	17.9	0.0	55
21	15.5	0.0	60
22	12.9	0.0	75
23	15.0	0.0	68
24	15.2	0.0	56
25	17.0	0.0	61
26	17.5	0.0	60
27	17.0	0.0	58
28	18.4	0.0	60
29	18.8	0.0	64
30	20.2	0.0	64
31	19.8	0.0	59

February 2009

Date	Average temperature (°C)	Rainfall(mm)	Humidity(%)
1	20.3	0.0	60
2	20.6	0.0	59
3	21.5	0.0	61
4	22.0	0.0	59
5	20.1	0.0	68
6	19.9	0.0	60
7	20.6	0.0	58
8	21.6	0.0	64
9	22.0	0.0	65
10	23.1	0.0	66
11	22.6	4.2	57
12	22.0	1.2	70
13	22.8	0.0	60
14	21.4	0.0	62
15	21.0	0.0	61
16	20.5	0.0	57
17	21.3	0.0	57
18	22.2	0.0	55
19	23.4	1.0	54
20	23.2	0.0	55
21	22.0	0.0	57
22	20.8	0.0	54
23	20.6	0.0	55
24	21.6	0.0	56
25	22.8	0.0	54
26	24.7	0.0	59
27	24.9	0.0	64
28	25.4	0.0	57