EFFECT OF POLLINATORS ON YIELD CHARACTERISTICS OF DIFFERENT VARIETIES OF SESAME

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CERTIFICATE

This to certify that thesis entitled, "**EFFECT OF POLLINATORS ON YIELD CHARACTERISTICS OF DIFFERENT VARIETIES OF SESAME**" submitted to the Faculty of Agriculture Sher-e- Bangla Agricultural University Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **S. Kaushik Kumar Mohanta,** Registration No.**05-01639** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2011
Place: Dhaka, Bangladesh

(Prof. Dr. Shahnaz Sarkar)
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DEDICATED TO

MY

BELOVED PARENTS

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EFFECT OF POLLINATORS ON YIELD CHARACTERISTICS OF DIFFERENT VARIETIES OF SESAME

ABSTRACT

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during May 2011 to September 2011 in kharif season with a view to find out the effect of pollinators on yield contributing characteristics of different varieties of sesame. The experimental treatments included four sesame varieties *viz.* BARI Til-2 (V_1), BARI Til-3 (V_2), BARI Til-4 (V_3) and Krisno (V_4). The experiment was laid out in randomized complete block design with three replications. The variables measured at the 30, 45 and 60 DAS were plant height, plant girth, branches per plant, leaf per plant, leaf length, leaf breadth, days to first anthesis, days to edible maturity, pod length, pod diameter, pods per plant and pod yield. Significant differences were observed for pods per plant and pod yield due to the variety BARI Til-4 (V_3) produced highest pods per plant (95.67) and yield per hectare (1.65 t). Invertebrate pollinators were observed to find out the effective pollinations for sesame. Insects of different order such as, Lepidoptera, Coleoptera and Diptera were found during the flowering period. Insects of Hymenoptera order were the major pollinators, visiting sesame flowers and peak of foraging activity was found during 9-11 am. Pollination increased the highest number of pod setting (86.67), number of seeds per pod (69) and germination percentage (80.93%) in BARI Til-4 (V_3) was found in flowers without net (T_4).

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LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
%	Per cent
^{0}C	Degree Centigrade
AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
cm	centimeter
CV %	Percentage of Coefficient of Variance
cv.	Cultivar
DAS	Days after sowing
DF	Degree of freedom
EC	Emulsifiable Concentrate
et al.	and others
etc.	Etcetera
g	Gram
hr	hour
K	Potassium
Kg	kilogram
LSD	Least significant difference
m	Meter
m^2	meter squares
mm	Millimeter
N	Nitrogen
ns	Non significant
P	Phosphorus
ppm	Parts per million
S	Sulphur
SAU	Sher-e- Bangla Agricultural University
viz.	namely
Zn	Zinc

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Sesame (*Sesamum indicum)* is a flowering plant in the family of Pedaliaceae. It is widely naturalized in tropical regions around the world. Numerous wild relatives occur in Africa and a smaller number in India. It is introduced to human over 5000 years ago. Drought tolerant capacity of sesame is very high. It has been called a survivor crop, with an ability to grow where most crops fail (Raghav *et al.*, 1990). Oil content of sesame seed is very high. With a rich nutty flavor, it is a common ingredient in cuisines across the world (Hansen, 2011). It's pod bear numerous seed and it grow for the purpose of these seeds. From all over the world 3.84 million metric tonnes sesame was harvested in 2010 and the largest producer of Sesame seeds in 2010 was Myanmar (FAO, 2012). The world's largest exporter of sesame seeds was India, while Japan the largest importer. In Bangladesh 70,215 acre of land is cultivated for sesame production and 23,610 metric tons is produced with an average yield of 336 kg per acre (BBS, 2008). The main growing regions are greater Faridpur, Barishal, Rangamati, Dinajpur, Pabna, Khulna, Dhaka, Mymensingh, and Comilla.

Sesame is commonly known as "Till". It is one of the earliest domesticated plants. It is a short duration crop grown throughout the year. It can be cultivated both in kharif and rabi seasons. The seeds of the plant yield edible oil. Due to the presence of potent antioxidant, sesame seeds are known as "the seed of immortality". Two distinct types of seed are recognized, the white and the black. There are also intermediate colored varieties varying from red to rose or from brown or grey. Sesame contains 47% oil, 20% protein and 16-18% carbohydrate (Rahman, 1976).

Co-evolution of flowering plants and their pollinators started about 225 million years ago (Price, 1975). Insufficient number of suitable pollinators causes a decline in fruit and seed production (Partap, 2000). Of the total pollination activities, over 80% is performed by insects and bees therefore, they are considered the best pollinators (Robinson and Morse, 1989). Sesame is self-pollinating, although differing rates of cross pollination (Yermanos, 1980, Ashri, 2007 and Sarker, 2004). Sesame flower structure facilitates cross-pollination, even though the crop is usually considered as self-pollinating. The rate of cross-pollination is between 0.5% and 65% depending on insect activity, environmental conditions and availability of other vegetation (Rakesh and Lenin, 2000). Ashri (2007) achieved pollination rates between 2.7 and 51.7% in Nigeria. Both opened and bee pollination treatments were effective in increasing the seed yield of sesame from 22 to 33% compared to "pollination without insects" (Panda *et al.*, 1988). In addition to increasing the yield, crosspollination also helps raising the quality through a more unified ripening period and an earlier harvesting time.

Kai-shu (2011) stated that the number of honeybee accounts for 92%, and is the main pollinating agent in the sesame field. However, little investigation has done on the performance of sesame varieties and very few studies were done about pollinators effect on yield in Bangladesh condition. Hence, with the mentioned facts in mind, the present investigation is undertaken with the following objectives:

- to compare the performance and suitability of different sesame varieties,
- to study the different pollinators on sesame varieties,
- to observe the pollination performance on sesame varieties.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Sesame is an important oil seed crop grown round the year in Bangladesh. Though it is a most common crop, limited attempt has been made for varietal improvement. Pollination is an important stage in the reproduction of flowering plants. It is the transfer of pollen from male to female part of the flower that helps fruit setting. Different types of insects are involved in pollination process. A good number of works related to varietal aspects and pollinators have been done in different parts of the world. Some of the available research works in relevant to the present study have been reviewed in this chapter under the following subheadings:

2.1 Effect on growth and yield contributing characters of sesame

Dorothea (1986) found significant differences of growth and yield contributing charecters among sesame varieties collected from 20 countries.

In Australia, Bennett (1998) strives for 30–35 plants/m^2 and Sapin *et al.*, (2000) recommend 20–40 plants/m2. In Venezuela, Avila (1999) found little difference between 30–35 plants/m^2.

In numerous yield analyses, Langham (2007) has found little difference in the yields of populations between 10–26 plants/m^2 with lines that adjust to the population, i.e., produce more branches in low populations. When the stands are uniform, even lower populations plants can provide equal yields, and when there is adequate moisture and fertility, much higher populations can still yield well.

In sesame removal of leaves subtending capsules had relatively little effect and the greatest reduction in seed yield occurred when the growth terminal removed after heavy fruiting (Tewolde *et al.*, 1994).

In Texas, Kinman and Martin (1954) found little difference in yield between 2.5–49 plants/m2 because of high stand tolerance.

Khalaque and Begum, (1991), the main reason behind lower yield of sesame is lack of high yielding variety and poor management practices.

Khan *et al.* (2009) conducted an experiment at Agricultural Research Station, Comilla during summer (Kharif) season, 2009 to estimate the proportionate yield and economic loss of sesame due to different management factors and to identify major factors of yield loss reduction of sesame. From the results of the experiment, it was found that the yield reduction of sesame variety BARI Til-3 were reduced over the recommended package of practices by 24.6%, 15.10%, 15.05% and 7.40% from the treatments with delay sowing, no seed treatment, no insect control and no disease control, respectively. The highest net return (Tk.18320ha^{-1}) was obtained from the treatment with recommended package. The highest economic loss Tk. 11840/- was recorded from the treatment with delay sowing and the second highest economic loss Tk. 6980/- was found from no seed treated plot. The highest yield (1595.67 kg ha^{-1}) was found from full package treatment followed by no fungicide treatment (1477.33 kg ha^{-1}) and the lowest yield (1201.3 kg ha^{-1}) was found from delay sowing treatment.

Mondal *et al.* (2001) the performance of sesame variety in the research station is very good but in the farmer's field performance is not so satisfactory. The yield of sesame variety may be improved.

Nath *et al.* (2003) indicated that sesame growth rate was negatively affected by low temperature and low effective photosynthesis rate.

Reddy and Narayanan (1987) reported that around 80% of the dry weight is produced during the fruit and seed formation in plants.

Sesame flowers have five petals with lower petal being linger, forming what is known as the lip. The lip is folded over the top of the flower keeping it closed to around sunrise, when it opens it forms a running strip for bees (Langham, 2007).

Temperature and variety affected seed yield variation by 69 and 39%, respectively. Seed yield of sesame significantly differed from season to season during 1998-2000 as found by Sharma (2005).

The results are partially supported by Tewolde *et al.* (1994) who obtained 77-93, 72-89 and 16-34% yield of control with defoliation at the vegetative, flowering and capsule filling stages, respectively and observed that the greatest reduction in seed yield occurred when all leaves were defoliated and the growth terminal removed after heavy fruiting.

Yield is the manifestation of various physiological processes occurring in plants and they are usually modified by management practices. Improvement of sesame yield can be achieved by clipping at 35 DAS (Kokilavani *et al.*, 2007)

2.2 Effect of pollinators on sesame yield

A survey of insects associated with sesame, *Sesamun indicum* L. (Pedaliaceae) was conducted at the Agriculture Research Farm of The Faculty of Agriculture, University of Suez Canal during the growing seasons 2010 and 2011 (Mahmoud, 2012). All different insect species found on the experimental site were collected for identification. Sampling was done once a week and three times a day. Three methods were used to collect insects from the sesame plants (a sweep net, pitfall traps, digital camera and eye observation). A total of 31 insect species were collected and properly identified during the survey. Insects recorded on the plants were divided into four groups, true pollinators (Hymenoptera), other pollinators (Diptera, Coleoptera and Lepidoptera), pests (Orthoptera, Odonata, Hemiptera and Homoptera) and natural enemies (Coleoptera, Hymenoptera, Neuroptera and Dictyoptera) (Mahmoud, 2012). For studying the impact of insect pollination on sesame production, the experiment was divided in two: opened and non-opened pollination of sesame. 50 plants from nonopened pollination were covered with a perforated paper bag to allow the air to pass through and to prevent insects from approaching the plants. Quantitative and qualitative parameters were measured as follows: pod weight, number of seeds in each pod, weight of 1000 seeds, germination (%), seedlings vigour and oil content (%). Results clearly demonstrate that the opened pollination improved the crop production (Mahmoud, 2012)

According to Rakesh and Lenin (2000) Apoidea were the predominant flower visitors (96%) of sesame.

Both open pollination and bee pollination treatments were effective to increase the seed yield of sesame up to 22 to 33 percent more than that in "pollination without insects" (Panda *et al.*, 1988).

Kamel (1997) reported nine species of Hymenopterans as predominant visitors of sesame flowers.

Langham (2007) found considerable cross pollination in the Arizona nurseries where many farmers maintained bees for pollinating other seed crops, but little cross pollination in the Texas nurseries.

Mellifera was the most abundant (44.9%) followed by *A. dorsata* (31.4%) and *A. florea* (19.7%). *A. mellifera* comprised 30 and 32% of the foraging population on sesame crops in Egypt where species of *Megachile, Polistes* and *Eristalis* were also important (Rashad *et al.*, 1979).

Partap *et al.* (2000) in the field study in Kathmandu valley reported that worker bees of *A. mellifera* carried significantly heavier pollen loads from both peach and plum flowers than those of *A. cerana* worker bees.

Recent research has indicated an increase in yield with high populations of bees (Mazzani, 1999; Sarker, 2004).

Self-pollinated crops also benefit from insect pollination, that increase yield up to 30% from pollinator visits and also collection of nectar or pollen and benefit farmers from pollinator's service. Lack of pollinators causes decline in fruit and seed production (Partap, 2001a).

Sesame is self-pollinating, although differing rates of cross pollination have been reported by Yermanos (1980), Ashri (2007) and Sarker (2004).

The pollination process occurs at the time the flowers open (Kafiriti and Deckers, 2001; Langham, 2007).

The relative abundance of pollinator fauna of sesame during two successive seasons is large. Hymenopterans insects were higher, followed Dipterans and Lepidopterans. (Viraktmath *et al.*, 2001).

The self-pollinated crop species occupy less than 15% and the remaining are cross-pollinated crops that need help of pollinating agents, wind, water or insects for fertilization. Some crops also exhibit often cross-pollinated nature. The genetic architecture of such crops is intermediate between self- and cross-pollinated species (Partap, 2001b). The self-pollinated crop species also benefit from cross pollination and hybrids grown these days require pollination in order to bear satisfactory marketable crops. Some plants may carry thousands of flowers, but unless there is adequate pollination, little if any fruit will be produced. Pollination is one of the most important factors in fruit production (Partap, 2001b).

Very few studies were conducted to assess yield increment and impact of insect pollination in Nepal. But it is clear that insect pollinators play vital role in producing high yield due to their service in crop pollination. Importance of insects visiting flowers and pollination has been recognized in various crops in many countries (Atwal, 2000).

Yermanos (1980) found less than 1% pollination? when the sesame was surrounded by cotton and other crops. In Moreno, California, he found 68% pollination in a field where the sesame was the only blooming plant in a semi-arid area.

2.3 Foraging behaviour of honey bees in different genotypes of sesame

According to Panda *et al.* (1988) honey bees were the main pollinators of sesame with more bee visits/m^2/minute in bee pollination than in open pollination.

According to Rakesh and Lenin, (2000) Apoidea were the predominant flower visitors (96%) of sesame. Among these, *A. mellifera* was the most abundant (44.9%) followed by *A. dorsata* (31.4%) and *A. florea* (19.7%). During foraging on sesame flowers, *A. mellifera, A. dorsata*, and *A. florea* spent 8.9, 8.6 and 11.2 seconds per flower and visited 8, 5 and 4 flowers per minute. Sesame bloom attracted *A. dorsata, A. mellifera, A. cerana, and A. florea* at Dharwad, Karnataka. Honey bees collectively formed 96.70 percent of total pollinators. *A. dorsata, A. mellifera, A. cerana, A. florea* formed 63.07, 21.28, 6.67, and 5.68 percent respectively. The same species of honey bees were also recorded on niger at Dharwad with honey bees collectively forming 88.21 percent of total pollinators. However *A. dorsata, A. mellifera, A. cerana*, and *A. florea* constituted 45.88, 10.81, 4.71 and 27.35 percent respectively (Viraktamath *et al.*, 2001).

Honey bees constituted 91.3 percent of insect visitors observed on plots of flowering niger at Pune. *A. dorsata, A. cerana* and *A. florea* made up 29.5 percent, 10.3 percent and 51.5 percent of the total visitors, respectively (Mohana and Suryanarayana, 1990).

Mohana Rao *et al.* (1981) conducted a study on foraging behaviour of honey bees in sesame (*Sesamum indicum* L) at Pune, and found that *Apis cerana* bees were the most frequent visitors followed by *Apis dorsata* and *Api florea* on four cultivars.

Panda *et al.* (1993b) studied the foraging behaviour of *A. cerana, A. dorsata* and *A. florea* on niger cultivar IGP 72, Alasi 1, GA 10, Raichur 70 and IGP 76. *A. cerana* was the main forager. *A. dorsata and A. cerana* were relatively more active in the morning while *A. florea* was active in the afternoon. The bees behaved differently on the different cultivars.

Panda *et al.* (1995) studied the relative abundance and foraging behaviour of common bee species on niger in Phulbani District, Orissa India. Among *Apis* species, *A. florea* was the most common, followed by *A. cerana*, and *A. dorsata. A. florea* was the most efficient pollinator among the *Apis* species. The largest amount of loose pollen was found on the bodies of *A. cerana* pollen collectors and *A. dorsata* nectar foragers.

Patnaik *et al.* (2004) found that *A. cerana* predominated among the foragers in sesame crop. Peak foraging activity (5-8 bees/m^2/5 min.) by *A. cerana* was observed at 50 percent flowering of the crop (41 days after sowing). The population of *A. mellifera* was the lowest (3.8 bees/m^2/5min).

The abundance and foraging behaviour of pollinators of sesame cultivar, HT-1 grown at Haryana Agricultural University, Hisar, India was studied. *A. dorsata* was more abundant (7.53 bees/m/5 minutes) than *A. mellifera* and *A. florea*. The time spent by *A. florae* on each flower (18.33 seconds) was longer compared to *A. dorsata* (6.66 seconds) and *A. mellifera* (11.33 seconds) (Sachdeva *et al.*, 2003).

The experiment conducted on foraging behaviour and pollination efficiency of Indian honey bee *A. cerana* on sesame at Marathwada Agricultural university revealed that honey bees were the primary pollinating agents with *A. dorsata* as predominant and constituted 74.34 percent, while *A. cerana* and *A. florea* formed 6.7 percent (Kulkarni, 2007).

2.4 Influence of bee attractants on bee visitation in sesame and other oil seed crops

Bee-Q at 12.5 g/l and 4 ml Bee-here/l had significant influence in attracting more number of pollinators (*A. dorsata, A. mellifera, A. cerana, A. florea* and others) up to the fifth day after first spray (10% flowering) and up to 3rd day after the second spray (50% flowering) in sesame (Viraktamath and Patil, 1999). However Bee-Q when tested at Coimbatore as an attractant for honey bees (*Apis* spp.) in hybrid sunflowers KBSH-1, there were no significant effects on bee visits in hybrid seed production (Srimathi *et al.,* 1999).

Fruit-Boost along with *Swertia densifolia* and Citral Z enhanced more bees to visit sunflower in rabi season (Srikanta Nath, 2008).

Guruprasad (2001) found that spraying of Fruit -Boost @ 0.5 ml/l and tube rose floral scented water had significant influence in attracting more number of pollinators in niger.

Manjunatha (2003) reported that spraying of Fruit-Boost and Bee-Q significantly enhanced visitation by *A. dorsata, A. mellifera, A. cerana* and other pollinators in sunflower. However, the effect of the attractants lasted for three to five days. *A. mellifera* foraged for longer time (0.43-0.51 min) in treated plot.

Sanjivan *et al.* (2000) observed that maximum bees (20.74 bees/5 flower/minute) were attracted to the sugar syrup sprayed sunflower crop followed by Bee-Q (18.10 bees/5 flower/minute).

Singh and Sinha (1996) studied the effects of Bee-Q on honey bee visits. There was no increase in number of honey bee visits in Bee-Q treated hybrid sunflower plots during experiment conducting years.

Spraying sesame plants with the bee attractants Bee-Q and Bee was effective in attracting higher numbers of pollinators (*Apis* spp.) (Patil *et al.*, 2000).

Various solutions of Bee-line were sprayed on plots of safflower. These solutions made the safflower more attractive to insects than untreated controls (Pinzauti, 1985).

2.5 Influence of bee attractants on yield parameters of sesame and oil seed crops

According to Bhosle *et al.* (1992) sunflower when sprayed with 2.5 percent sucrose solution resulted in greater seed yield than control. Significant increases in yield by bee (*A. cerana*) pollination (2.4 - 44.4%) and open pollination (33.6-81.3%), compared to without insect pollination were observed in niger at different sowing dates (Panda *et al.* 1993a).

Guruprasad (2001) found that spraying of Fruit -Boost @ 0.5 ml/l and tube rose floral scented water @ 10 percent significantly enhanced yield parameters of niger. Similarly higher dosage of Bee-Q (10.00, 12.50 and 15.00g/l) spray significantly enhanced both qualititative and quantitative parameters in mustard crop (Viraktamath and Murasing, 2002).

Highest yield of 18.38 q/ha, higher filled seed rows (26.02) and filled seed weight (42.61 g) was obtained from the sunflower crop sprayed with Fruit - Boost twice (Manjunatha, 2003).

Maximum yield of 220.76 kg/ha was obtained in Bee-Q sprayed niger crop at 12.5 percent which was on par with crop caged with bees, crop sprayed with jaggery 10 percent and 10 percent sugar solution (Sattigi *et al.*, 2004).

Nagaraj and Bhat (2006) studied the extent of dependability of niger on honey bees for cross pollination. It was found that maximum attainable seed set was 57/capitula when the capitula were kept open throughout the bloom period and minimum was one seed when the capitula was bagged throughout the bloom period.

On plots caged with *A. cerana* the yield of niger was 3 times higher than on plots without insects (Mohana and Suryanarayana, 1990).

Panda *et al.* (1989) observed that seed yields on plots of sesame caged with *A. cerana* was nearly two times higher than on plots caged to exclude insects. On niger plots the presence of bees made little difference on yield, although bees increased seed set.

Singh and Sinha, (1996) reported that there was no difference in number of filled seeds/head, percentage seed setting and test weight of 1000 seeds in Bee-Q treated hybrid sunflower plots. In sesame two applications of Bee-Q and Bee increased the number of capsules per plant, seeds per capsule, heavier seeds, yield and oil content (Viraktamath and Patil, 1999). Similar results have been obtained by Patil (1999) and Patil *et al.* (2000).

Srikanta Nath (2008) reported that spray of *Fagara budrunga* and *S. densifolia* produced heavier heads in morden variety of sunflower. Number of seeds per head was highest in *S. densifolia*, *F. budrunga* and Citral Z treated crop. *S. densifolia* sprayed crop produced highest yield of 19.53 qha^{-1}. Application of bee attractants had no effect on 100 seed weight, germination percentage, and root length, shoot length and vigour index.

Sunflower sprayed with trionic acid gave maximum seed set (82.31 seed/head), 1000 seed weight (76.78 g.), and oil content (39.87%) (Sanjivan Kumar *et al.*, 2000).

The seed yield was recorded highest on sesame plants visited by *A. dorsata* (Mohana Rao *et al.*, 1981). Both open and bee pollination treatments were effective to increase the seed yield in sesame and niger by 50-59 percent and 22-23 percent, respectively, over that in pollination without insects (Panda *et al.*, 1988).

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, intercultural operations, data collection and statistical analysis.

3.1 Experimental period

The experiment was conducted during the period from May, 2011 to September, 2011 in kharif season.

3.2 Site description

The experiment was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. For better understanding the experimental site is shown in the Map of AEZ of Bangladesh in Appendix III.

3.3 Climate

The experimental area under the sub-tropical climate is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The weather data during the study period at the experimental site are shown in Appendix II.

3.4 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. The soil data at the experimental site are shown in Appendix I.

3.5 Planting materials

Four sesame varieties BARI Til-2, BARI Til-3, BARI Til-4 and Krisno (local variety) were used as the test crop.

3.6 Seed collection and sowing of seeds

The seeds of sesame cv. BARI Til-2, BARI Til-3, BARI Til-4 and Krisno were collected from Kushtia Seed Store, Dhaka. The seeds were soaked in water for 24 hours and then wrapped with a piece of thin cloth. The soaked seeds were then spreaded over polythene sheet for 2 hours to dry out the surface water. This treatment was given to help quick germination of seeds. The seeds were sown in the rows of the raised bed on 15 April, 2011. Two to three seeds were sown in each pit. Then the seeds were covered with fine soil by hand.

3.7 Preparation of experimental land

The experimental field was first opened on 15 April, 2011 with the help of a power tiller and then it was kept open to sun for seven days prior to further ploughing. Afterwards it was prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good tilth. All kinds of weeds and residues of previous crop were removed from the field. Simultaneously the clods were broken and the soil was made into good tilth. The basal dose of fertilizer and well decomposed cowdung 10 t ha^{-1} were mixed into the soil during final land preparation. The field layout was made on 15 April, 2011 according to design immediately after final land preparation. The plots were raised 10 cm from the soil surface to keeping the drain around the plot. Individual plots were cleaned and finally leveled.

3.8 Fertilizer management

The experimental plots were fertilized with 125, 150, 50, 110, 5, 10 kg ha^{-1} urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, zinc sulphate and boron, respectively. TSP, gypsum, zinc sulphate and boron were given as basal during final land preparation (BARI, 2011). Split application of urea and MP were done at 20, 40 and 60 days after sowing.

3.9 Experimental treatments

Treatment was considered as following

- V_1 = BARI Til-2
- V_2 = BARI Til-3
- V_3 = BARI Til-4
- V_4 = Krisno

3.10 Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with three replications. There were 12 treatments combinations. The total numbers of unit plots were 12. The size of unit plot was 3 m x 3 m = 9 m^2. The distances between plots to plot, plant to plant were 50 and 40 x 55 cm, respectively.

3.11 Observation of pollinators

Weekly observation on pollinators starting from initial flowering to the final session during four time intervals of the day 9-11 am, 11-1 pm, 1-3 pm and 3-5 pm. Observation time was ten minutes at each interval. Fifty sweeps per plot were taken to collect the pollinators. The collected insects were killed in a killing bottle and transferred to the laboratory. The large insects were pinned, labeled and preserved in the collection box. The smaller insects were mounted, labeled and preserved too. Insects were identified to species where possible through the use of published systematic keys and direct comparisons with museum specimens at the Department of Entomology, Sher-e-Bangla Agricutural University. Data were recorded for pollinators belonging to different insect orders.

3.12 Pollinators effect

T_1 = Flowers bagged with net with medium mesh

T_2 = Flowers bagged with net with very small mesh

T_3= Flowers bagged with net and Vaseline rubbed at the bottom of peduncle

T_4 = Flower without net (control)

Four different treatments to find out the effect of pollinators on sesame yield. Medium meshed netted flowers can stop the entry of medium sized pollinating insects but not small sized insects. Small meshed netted flowers are used to stop all sized insect pollinators except minute insect like ants. Vaseline with netted flowers are used to stop the entry of all kinds of insects including the minute crawling insects which have the ability to enter inside the net and to visit flowers. Flowers without net in controlled condition are face for open pollination by all kinds of insect pollinators.

3.13 Intercultural operations

3.13.1 Gap filling

After one week of sowing, a minor gap filling was done where it was necessary using the seed from the same source.

3.13.2 Weeding

During plant growth stage two hand weeding were done, first weeding was done at 20 DAS (Days after sowing) followed by second weeding at 40 DAS.

3.13.3 Application of irrigation water

Irrigation water was applied to each plot at critical stage. The experimental plots were irrigated through watering cans.

3.13.4 Drainage

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

3.13.5 Plant protection measures

Diazinone 60 EC @ 3.5 ml/l of water was sprayed thrice at an interval of 10 day after the appearance of infestation. This was done forcontrolling shoot and pod borer before pod setting. After fruit setting Nogos @ 0.02% was sprayed 4 times at an interval of 7 days for controlling Jassid.

3.14 General observation of the experimental field

The field was investigated time to time to detect visual difference among the treatment. Any kind of infestation by weeds, insects and diseases was addressed properly to minimize the considerable losses by pest. Incidence of shoot borer, pod borer, jassid was observed time to time for their management viral affected plant in the field was removed.

3.15 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting was done on 11 Aug., 2011. An area of 3 m^2 was harvested from the centre of each plot avoiding the border effect. The crop of each plot was collected and harvested separately, bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to maintain moisture content at 12%. Straw was also sun dried properly. Finally grain and straw yields $plot^{-1}$ were calculated and converted to t ha^{-1}.

3.16 Recording of data

A. Growth characters

1. Plant height (cm) was measured at 15 days interval started from 30 DAS to harvest
2. Branches per plant (No.) were counted at 15 days interval started from 30 DAS to harvest
3. Leaves per plant (No.) were counted at 15 days interval started from 30 DAT to harvest
4. Leaf length (cm) was measured at 15 days interval started from 30 DAS to harvest

B. The following yield contributing characters were considered:

1. Pod length (cm)
2. Pod diameter (cm)
3. Numbers of pods per plant
4. Number of seeds per pod
5. Weight of 1000 seed

C. Yield

Yield of seed (t ha^{-1}) was calculated.

D. Pollinators

Number of visited pollinators per flower was recorded in three different times.

E. Pollinators effect

- Number of setting fruit
- Number of seeds $fruit^{-1}$

3.17 Experimental measurements

The necessary data were collected from sample plants during the course of study. Randomly ten plants from each plot were selected for recording data. The plants in the outer rows and at the extreme end of the middle rows were excluded from the random selection to avoid the border effect. The data were collected at 30, 45 and 60 DAS. The following growth, yield contributing characters and yield were considered in this study.

3.17.1 Plant height (cm)

The height of the plant was determined at 30, 45 and 60 DAS by measuring length of the plant from the soil surface to the tip of the leaf. Average heights of 10 plants were calculated from the randomly selected plants.

3.17.2 Number of branches per plant

Numbers of leaves per plant were counter from the randomly selected plants. All the branches of each plant were counted separately at 30, 45 and 60 DAS. The smallest young branches at the growing point of the plant were excluded from counting. Mean number of branches per plant was recorded.

3.17.3 Numbers of leaves per plant

Numbers of leaves per plant of 10 randomly selected plants were counted. All the leaves of each plant were counted separately. But the smallest young leaves at the growing point of the plant were excluded from counting. The mean numbers of leaves per plant was calculated.

3.17.4 Leaf length

Length of leaves was measured in cm with the help of a meter scale from the base of leaf which attached with petiole up to tip point of leaves and mean leaf length of 10 leaves per plant were recorded from randomly selected sample plants.

3.17.5 Days to first flowering

Dates of first flowering of different varieties were recorded. The observation was considered when the first flower opens.

3.17.6 Pod length (cm)

Five green pods from randomly selected plants of each accession were taken and length was measured at harvest from the selected pod with the help of a measuring tape in centimeter (cm).

3.17.7 Number of pods per plant

The number of pods was recorded from 5 randomly selected plants and their mean number was calculated

3.17.8 Number of seeds per pod

The number of seeds per pod was recorded from 5 randomly selected plants and their mean was considered.

3.17.9 Weight of 1000 seed

Weight of 1000 seeds was recorded in gram (g) from 5 randomly selected plants and their mean was taken.

3.17.10 Yield of seed (t ha^{-1})

The pod yield per plant and per hectare as calculated in ton by converting the total yield of pod per plot.

3.18 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT software to find out the significance of variation resulting from the experimental treatments. The mean values for all the treatments were calculated and the analysis of variance for most of the characters was accomplished by "F" variance test. The significance of difference among the means was tested at 5% and 1% level of probability (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to compare the performance of different cultivable modern sesame varieties.

4.1 Plant height

Plant height of the sesame varieties was measured at 30, 45 and 60 DAS. It is evident from Figure 1 that plant height was significantly influenced by the varieties at all the sampling stages. Regardless of varietal differences, plant height increased progressively up to harvesting (Fig. 1 and appendix IV).

At 30 DAS, maximum plant height (94.89 cm) was observed in BARI Til-3 (V_2). The second highest plant height (92.07 cm) was found in Krisno (V_4) which was statistically similar with BARI Til-4 (V_3) (87.93 cm). The lowest plant height (79.95 cm) was measured from BARI Til-2 (V_1).

At 45 DAS, maximum plant height (131.5 cm) was obtained from BARI Til-3 (V_2). The minimum plant height (111.5 cm) was measured from BARI Til-2 (V_1) which was statistically similar (115.1 cm) with BARI Til-4 (V_3).

At 60 DAS, the highest plant height (143.0 cm) was measured from BARI Til-3 (V_2). The second highest plant height (129.3 cm) was measured from Krisno (V_4) which was statistically similar (123.0) with BARI Til-4 (V_3) and BARI Til-2 (114.3) (V_1). The lowest plant height (114.3 cm) was measured from BARI Til-2 (V_1).

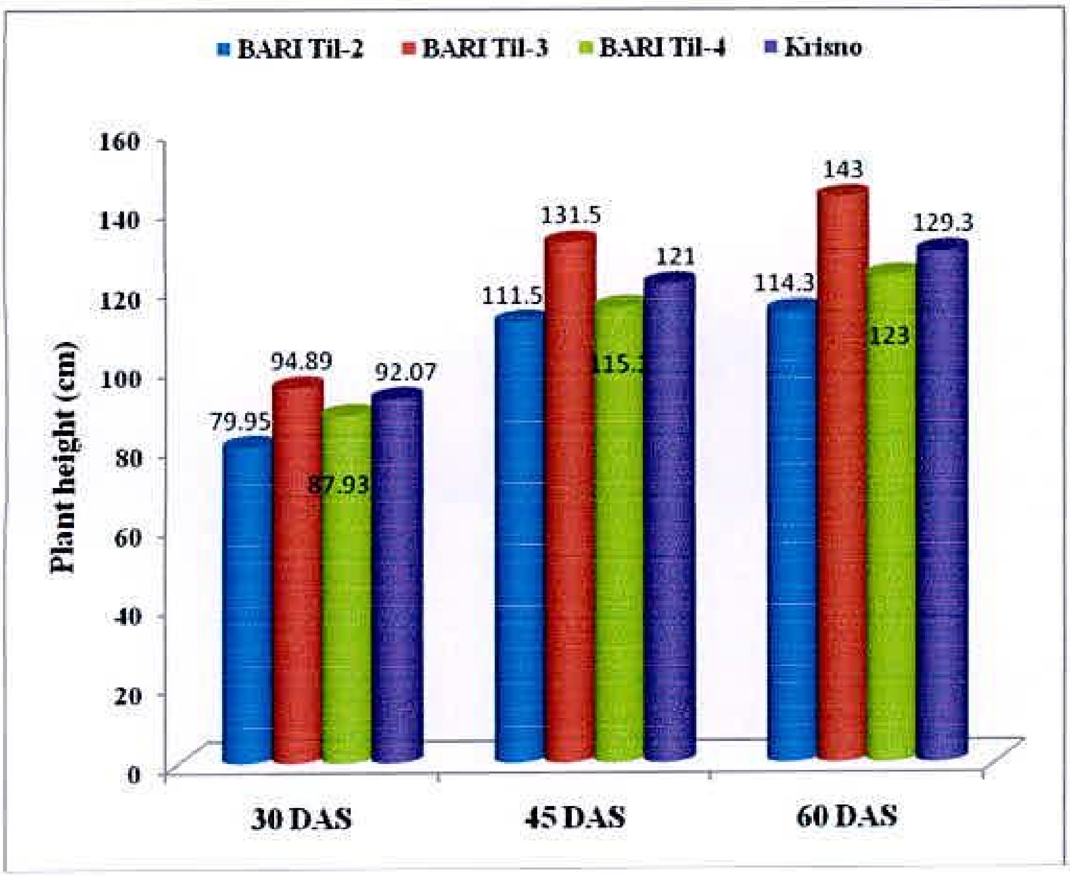

Fig. 1. Effect of varieties on plant height at different days after sowing (DAS) (LSD=13.85, 4.656, 9.903 and CV % =7.82, 1.95 and 4.05 at 30, 45 and 60 DAS, respectively)

4.2 Number of branches per plant

Significant variation was observed among the cultivars in respect of number of branches per plant at 45 DAS but insignificant at 30 and 60 DAS (Table 1 and appendix V).

At 30 DAS, numerically higher number of branches per plant (9.00) was obtained from Krisno (V_4) and BARI Til-3 (V_2) while the lowest number of branches per plant (7.67) from BARI Til-2 (V_1) which was followed by (8.33) in BARI Til-4 (V_3). However, all of them were statistically similar.

At 45 DAS, higher number of branches per plant (12.00) was obtained from Krisno (V_4) and lower number of branches per plant (9.33) from BARI Til-2 (V_1). The branches per plant of V_2, V_3 and V_4 were not significantly different.

At 60 DAS, numerically maximum number of branches per plant (13.00) was obtained from Krisno (V_4) which was statistically similar with BARI Til-3 (12.67) (V_2) and BARI Til-4(12.33) (V_3) .The minimum number of branches per plant was found from (10.67) from BARI Til-2 (V_1) which was not significantly different from that of V_2 and V_3.

Table 1. Effect of varieties on number of branches per plant at different days after sowing

Treatments	Number of branches per plant		
	30 DAS	**45 DAS**	**60 DAS**
V_1	7.67 a	9.33 b	10.67 b
V_2	9.00 a	11.00 a	12.67 ab
V_3	8.33 a	10.67 ab	12.33 ab
V_4	9.00 a	12.00 a	13.00 a
LSD $_{(0.05)}$	1.490	1.490	2.209
F-test	ns	*	ns
CV (%)	8.77	6.93	9.09

ns =Nonsignificant, *= Significant at 5% level of probability

- V_1 = BARI Til-2
- V_2 = BARI Til-3
- V_3 = BARI Til-4
- V_4 = Krisno

4.3 Number of leaves per plant

Significant variation was observed among the cultivars in respect of number of leaves per plant at 30 DAS but insignificant at 45 and 60 DAS (Fig. 2 and appendix VI).

At 30 DAS, higher number of leaves per plant (85.00) was obtained from BARI Til-3 (V_2) and lower number of leaves per plant (52.67) from BARI Til-4 (V_3) but it was statistically similar to BARI Til-2 (V_1) and Krisno (V_4).

At 45 DAS, numerically higher number of leaves per plant (145.7) was obtained from BARI Til-3 (V_2) and lower number of leaves per plant (119.3) from BARI Til-4 (V_3).

At 60 DAS, numerically maximum number of leaves per plant (182.0) was obtained from BARI Til-3 (V_2). The minimum number of leaves per plant was found from (146.7) from BARI Til-4 (V_3).

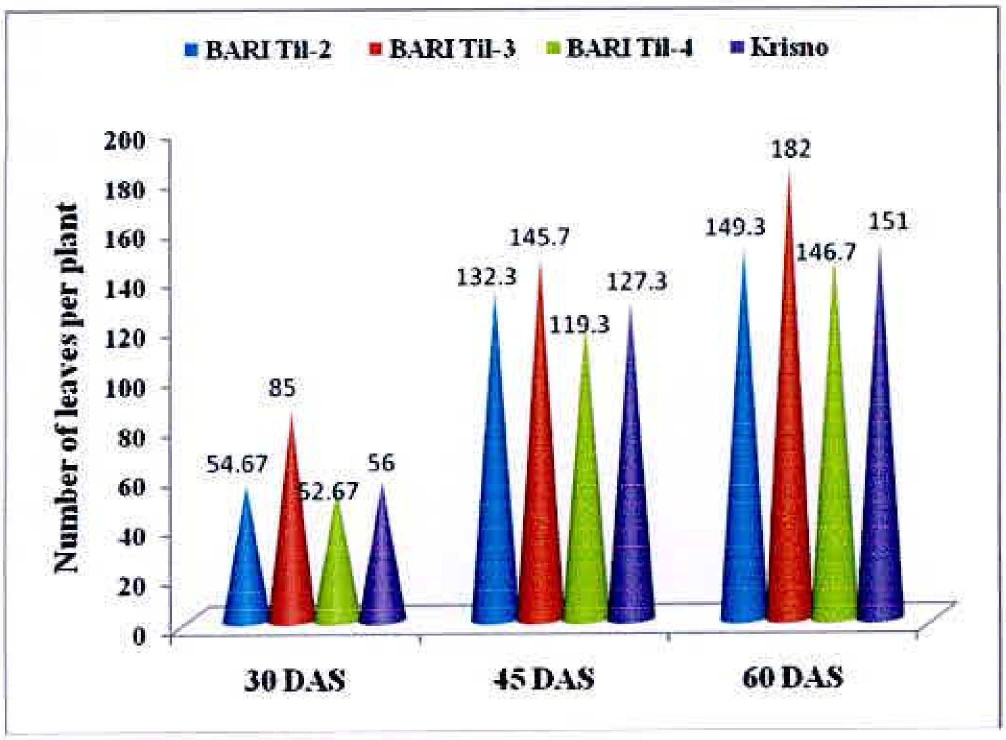

Fig. 2. Effect of varieties on number of leaves per plant at different days after sowing (DAS) (LSD=18.76, 42.89, 41.60 and CV % =15.13, 16.37 and 13.24 at 30, 45 and 60 DAS, respectively).

4.4 Leaf length

Significant variation was observed among the cultivars in respect of leaf length at 30 DAS but insignificant at 45 and 60 DAS (Fig. 3 and appendix VII).

At 30 DAS, the highest leaf length (17.39 cm) was found from BARI Til-3 (V_2) and lowest leaf length (12.91 cm) was found from Krisno (V_4).

At 45 DAS, numerically higher leaf length (17.98 cm) was measured from BARI Til-3 (V_2) and lowest leaf length (15.45 cm) was found from BARI Til-4 (V_3).

At 60 DAS, numerically higher leaf length (18.59 cm) was measured from BARI Til-3 (V_2) and lowest leaf length (16.09 cm) was found from BARI Til-2 (V_1).

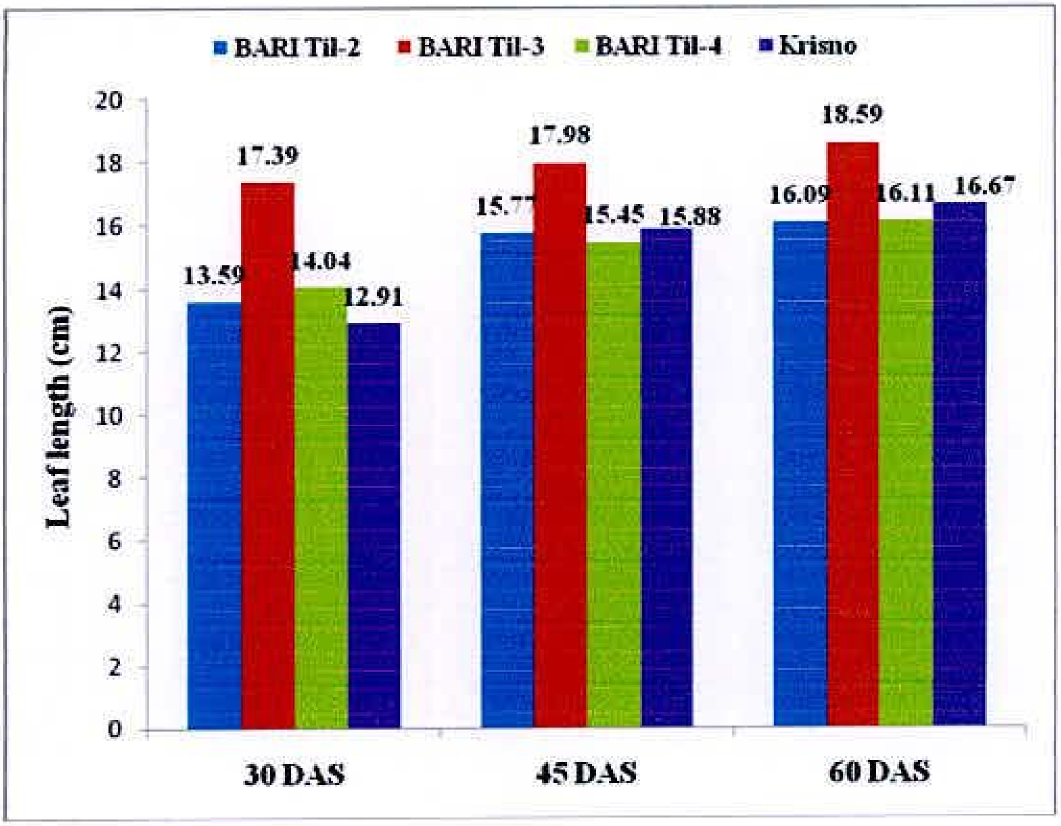

Fig. 3. Effect of varieties on leaf length at different days after sowing (DAS) (LSD=1.794, 2.412, 2.807 and CV % =6.20, 7.42 and 8.33 at 30, 45 and 60 DAS, respectively)

4.5 Days to first flowering

No significant variation was observed among the cultivars in respect of days to flowering (Table 2). The variety BARI Til-3 (V_2) required 34 days to first flowering. But other varieties required near about 32 days to first flowering.

Table 2. Effect of varieties of sesame on days to first flowering and edible maturity

Treatments	Days to first flowering
V_1	31.76
V_2	34
V_3	32
V_4	31.60
Lsd $_{0.05\%}$	ns
CV (%)	2.05

- V_1 = BARI Til-2
- V_2 = BARI Til-3
- V_3 = BARI Til-4
- V_4 = Krisno

4.6 Pod length

No significant variation was observed among the cultivars in respect of pod length (Table 3 and appendix VIII). Numerically highest pod length (2.45 cm) was found from Krisno (V_4) and lowest pod length (2.35 cm) was found from BARI Til-2 (V_1) and BARI Til-3 (V_2).

4.7 Number of pods per plant

Number of pods per plant differed significantly among the tested varieties (Table 3 and appendix VIII). Significantly the highest number of pods per plant (95.67) was obtained from BARI Til-4 (V_3). The minimum number of pods per plant (34.67) was found from and Krisno (V_4) which was significantly different from that of V_1 (57.67) and V2 (63.33). But the water two were statistically identical.

4.8 Number of seeds per pod

Number of seeds per pod differed significantly among the tested varieties (Table 3 and appendix VIII). The maximum number of seeds per pod (68.33) was obtained from BARI Til-4 (V_3) which was statistically similar to Krisno (V_4). The minimum number of seeds per pod (57.67) was found from and BARI Til-3 (V_2) which was statistically identical to that of BARI Til-2 (V_1).

4.9 Weight of 1000 seed

Weight of 1000 seed differed significantly among the tested varieties (Table 3 and appendix VIII). Significantly the highest weight of 1000 seeds (3.24 g) was obtained from BARI Til-4 (V_3). The minimum weight of 1000 seeds (2.82 g) was found from Krisno (V_4) which was statistically similar to BARI Til-2 (V_1).

4.10 Yield per hectare

Yield of seed differed significantly among the tested varieties (Table 3 and appendix VIII). Significantly the highest pod yield (1.65 t/ha) was obtained from BARI Til-4 (V_3). On the other hand significantly the lowest yield ha^{-1} (0.73 tha^{-1}) was found from Krisno (V_4). The yield obtained from V_1(1.00 tha^{-1}) and V2 (1.48tha^{-1}) were significantly different.

Table 3. Effect of varieties on pod length, number of pods per plant, number of seeds per pod, weight of 1000 seed and yield per hectare at different days after sowing

Treatments	Pod Length	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 1000 seed (g)	Yield (tha^{-1})
V_1	2.35 a	57.67 b	58.67 b	2.91 c	1.00 c
V_2	2.35 a	63.33 b	57.67 b	3.06 b	1.48 b
V_3	2.42 a	95.67 a	68.33 a	3.24 a	1.65 a
V_4	2.45 a	34.67 c	67.33 a	2.82 c	0.73 d
LSD $_{(0.05)}$	0.1094	21.95	7.658	0.1094	0.1094
F-test	ns	**	*	**	**
CV (%)	2.44	17.49	6.08	1.81	4.68

ns =Nonsignificant, **= Significant at 1% level of probability, *= Significant at 5% level of probability

- V_1 = BARI Til-2
- V_2 = BARI Til-3
- V_3 = BARI Til-4
- V_4 = Krisno

4.11 Pollinators

4.11.1 Types of pollinators

Investigations carried out on the major insect orders visiting sesame during flowering period. A great majority of the sesame flowered between third and fifth week of flowering. The flowering lasted 42-50 days and this period was remarkably constant from year to year. Most bees were recorded when the number of flowers per plant was maximum (at the fourth week of flowering). Bee population decreased with diminishing of flowers per plant due to advancing age of the crops. Fig. 4 revealed that four groups of pollinators visited the sesame belonging to order Hymenoptera, Diptera, Lepidoptera and coleopteran of class insect during the flowering period. The number of Hymenoptera was higher (79%), followed by Lepidoptera (12%) and then Coleoptera (6%) and Diptera (3%). The results indicate that Hymenopterans (79%) and Lepidopterans (12%) are the major pollinators visiting sesame flowers. These findings are in close agreement with that of Viraktmath *et al.*, (2001) who studied the relative abundance of pollinator fauna of sesame during two successive seasons and stated that Hymenopterans insects were higher, followed Dipterans and Lepidopterans. Kamel (1997) also reported nine species of Hymenopterans as predominant visitors of sesame flowers.

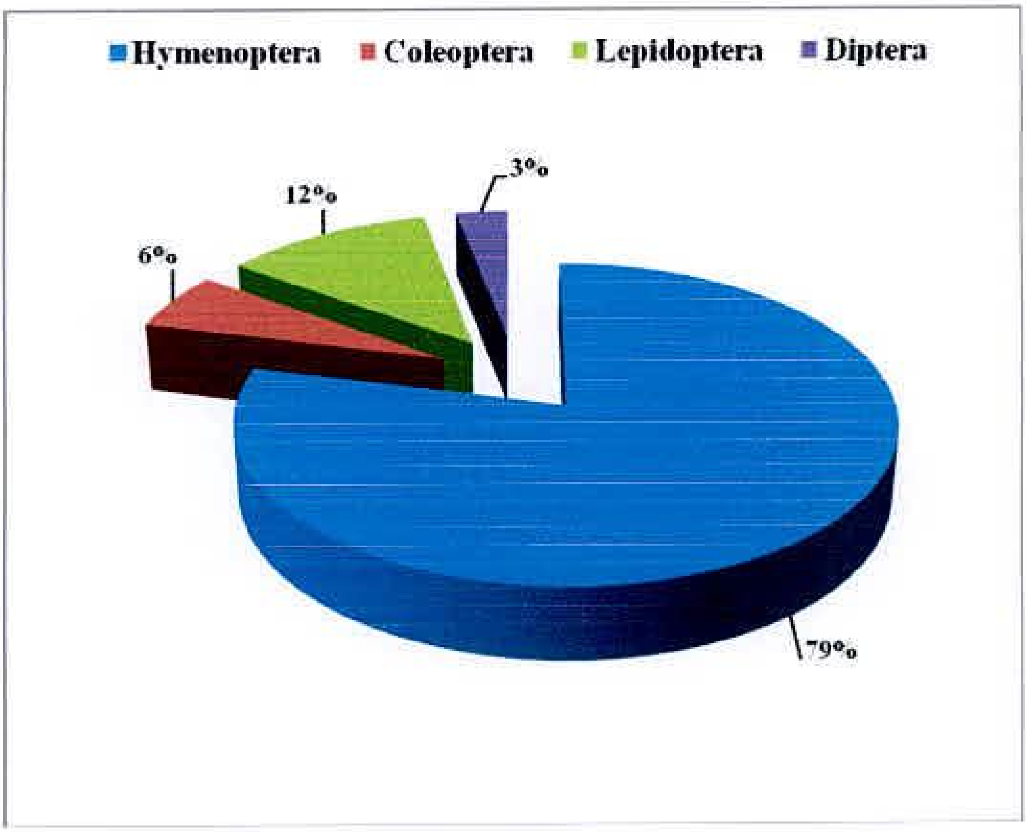

Fig. 4. Proportion (%) of the major insect orders visiting sesame field during flowering period

4.11.2 Time span of visiting pollinators

The types as well as the number of insect visitors chanced with time during the flowering span of the sesame. Results revealed that insects belonging Hymenoptera order increased with increase (%) of flowering in all the varieties of sesame. Most insects were recorded when the number of flowers per plant was maximum at the fourth week of flowering. Insect population decreased with diminishing of flowers per plant due to advancing age of the crops (Fig. 5 and appendix IX).

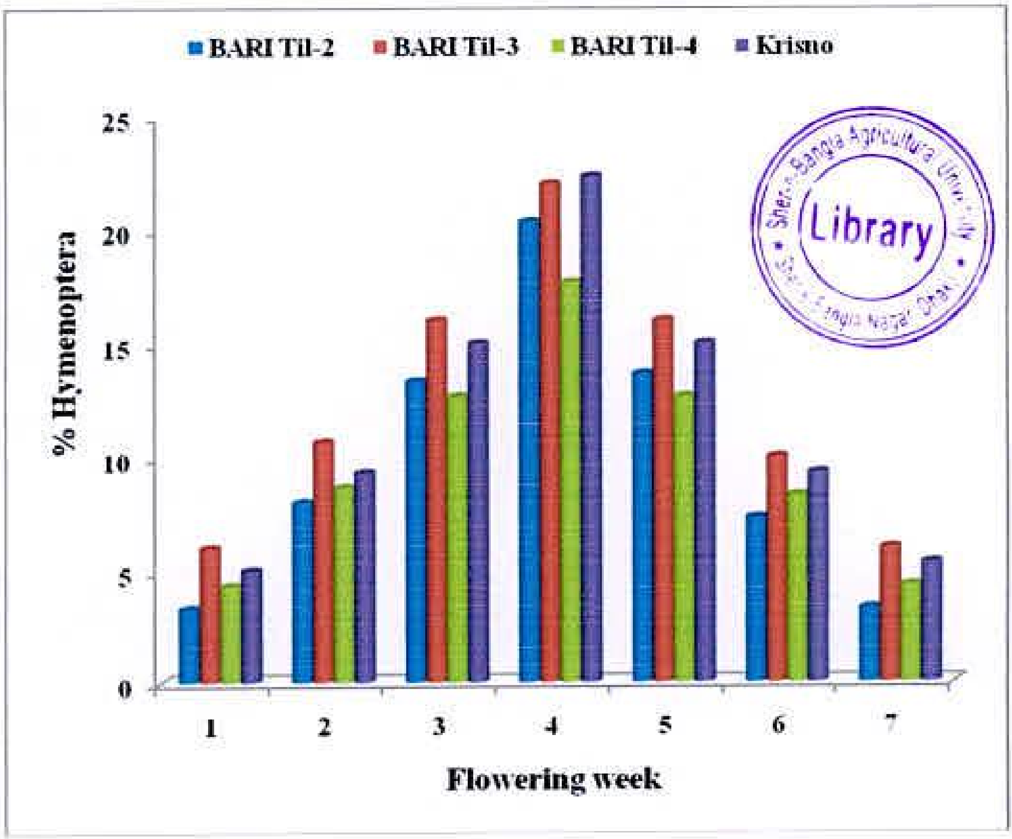

Fig. 5. Fluctuation percent of Hymenopterous population during flowering period (LSD = 0.66, 0.74, 1.37, 7.103, 0.665, 0.576, 1.153 and CV % =7.14, 4.07, 4.82, 17.27, 2.33, 3.30 and 12.15 at 30, 45 and 60 DAS, respectively) of different weeks of flowering.

4.11.3 Time of foraging activity

4.11.3.1 Foraging activity of Hymenopterans insects

Figure 6 and Appendix X showed the foraging activity of the major insect of Hymenoptera orders visiting sesame varieties during flowering period. Peak of foraging activity was observed in Hymenoptera order during 9-11 am whereas the peak foraging activity was noticed at 8-9 am by Munir and Aslam (2002) and lowest during 3-5 pm in this study. These findings can help to save the pollinators by applying insecticides late in the afternoon. By protecting the pollinators high yields may be ensured. Insect pollination not only ensures the increase in yields but also improve its quality. It ensures uniform maturity and early harvest of crop. Mazzani (1999) and Sarker (2004) indicated an increase in yield with high populations of bees.

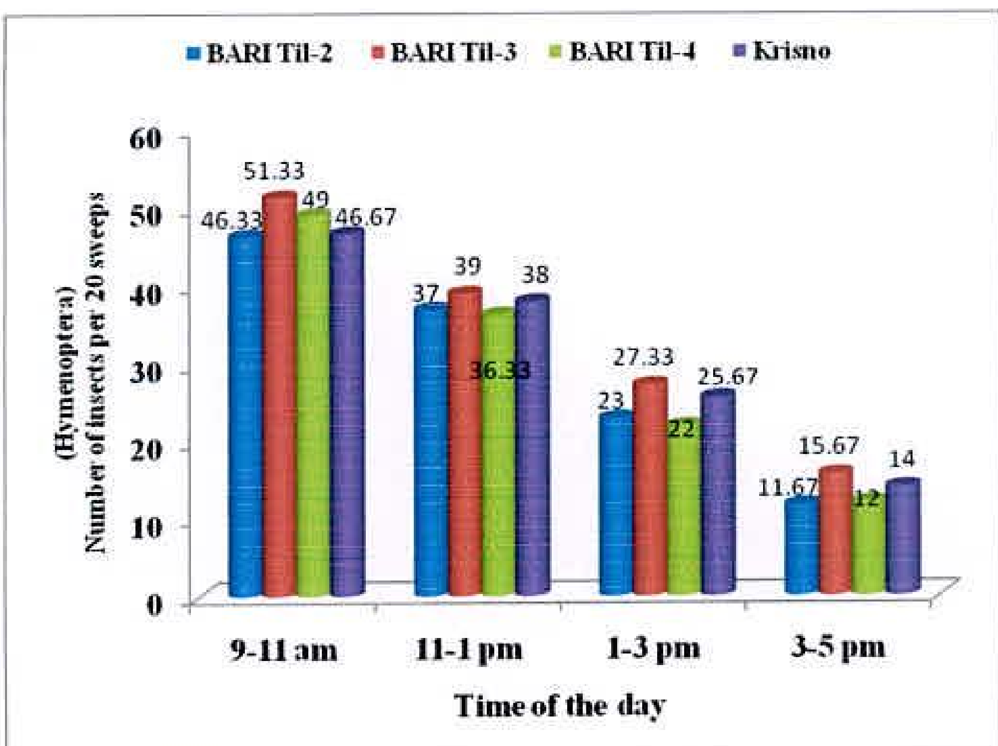

Fig. 6. Foraging activity of insect of Hymenoptera order visiting sesame during flowering period (LSD=4.22, 1.91, 0.74, 1.45 and CV % =4.38, 2.55, 1.52 and 5.45 at 30, 45 and 60 DAS, respectively) at different time of the day.

4.11.3.2 Foraging activity of *Apis dorsata*

Peak of foraging activity of *Apis dorsata* was observed in Dorsata during 9-11 am and the lowest during 3-5 pm in this study (Table 4 and Appendix XIV). This finding is agreement with that of Sachdeva *et al.* (2003) and Rashad *et al.*, (1979) who stated that abundance and foraging behaviour of *A. dorsata* in sesame cultivar, HT-1 was higher in the morning hours.

Table 4. Foraging activity of *Apis dorsata* visiting sesame during flowering period at different time of the day.

Treatments	9-11 am	11-1 pm	1-3 pm	3-5 pm
V_1	28.33 c	21.67 c	12.67 c	5.333 b
V_2	33.00 a	25.33 a	16.67 a	8.000 a
V_3	29.00 c	20.67 d	13.00 c	5.667 b
V_4	31.00 b	23.33 b	14.33 b	7.333 a
$LSD_{0.05}$	1.913	0.8800	1.105	1.105
F-test	**	**	**	**
CV (%)	3.16	1.94	3.90	8.40

**= Significant at 1% level of probability

- V_1 = BARI Til-2
- V_2 = BARI Til-3
- V_3 = BARI Til-4
- V_4 = Krisno

4.11.3.3 Foraging activity of *Thyreus*

Data in figure 7 showed the foraging activity of *Thyreus* visiting sesame varieties during flowering period. Peak of foraging activity of *Thyreus* was observed in *Thyreus* during 9-11 am and lowest during 3-5 pm in this study (Appendix XV).

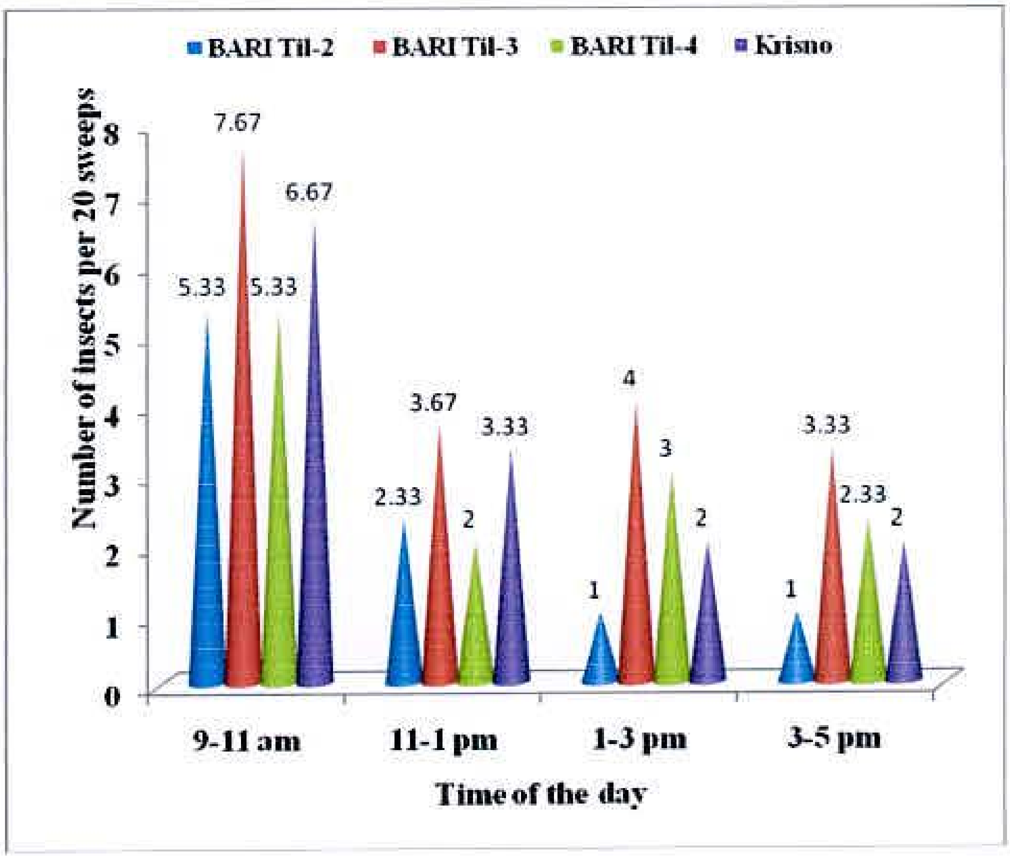

Fig. 7. Foraging activity of Thyreus visiting sesame during flowering period (lsd=2.02, 0.74, 0.06, 0.88 and CV % =16.22, 13.15, 1.10 and 20.35 at 30, 45 and 60 DAS, respectively) at the time of the day.

4.11.3.4 Foraging activity of Black bee and *Megachille*

Data in Table 5 showed the foraging activity of the Black bee and *Megachille* visiting sesame varieties during flowering period. Peak of foraging activity was observed in Black bee and *Megachille* during 9-11 am and lowest during 3-5 pm in this study (Appendix XVI).

Table 5. Foraging activity of Black bee and *Megachille* on sesame during flowering period at different time of the day.

Treatments	Black bee				*Megachille*			
	9-11 am	11-1 pm	1-3 pm	3-5 pm	9-11 am	11-1 pm	1-3 pm	3-5 pm
V_1	3.67 b	2.33 b	1.00 b	0.33 a	4.33 c	2.33 c	1.00 b	0.67 b
V_2	5.67 a	3.33 a	2.00 a	0.67 a	7.00 a	3.67 a	2.67 a	2.00 a
V_3	3.67 b	2.00 b	1.33 b	0.67 a	4.67 bc	2.67 bc	2.00 a	0.67 b
V_4	5.00 ab	3.33 a	2.00 a	1.00 a	6.00 ab	3.33 ab	2.67 a	1.67 ab
$LSD_{0.05}$	1.525	0.5756	0.5756	1.105	1.597	0.8800	0.8800	1.290
F-test	*	**	*	ns	*	*	*	ns
CV (%)	16.97	10.50	18.23	82.92	14.53	14.70	21.17	51.64

ns= Nonsignificant, **= Significant at 1% level of probability, *= Significant at 5% level of probability

- V_1 = BARI Til-2
- V_2 = BARI Til-3
- V_3 = BARI Til-4
- V_4 = Krisno

4.11.3.5 Foraging activity of Coleopterous insect

Fig. 8 and Appendix XI showed the foraging activity of the major insect of Coleoptera orders on sesame varieties during flowering period. Peak of foraging activity was observed in Coleopterous order during 9-11 am and lowest during 3-5 pm in this study. Panda *et al.* (1993b) stated that foraging behavior of insects relatively more active in the morning. This is because nectar flow is copious in the sesame crop especially in the morning period; there after the nectar quantity gradually diminishes.

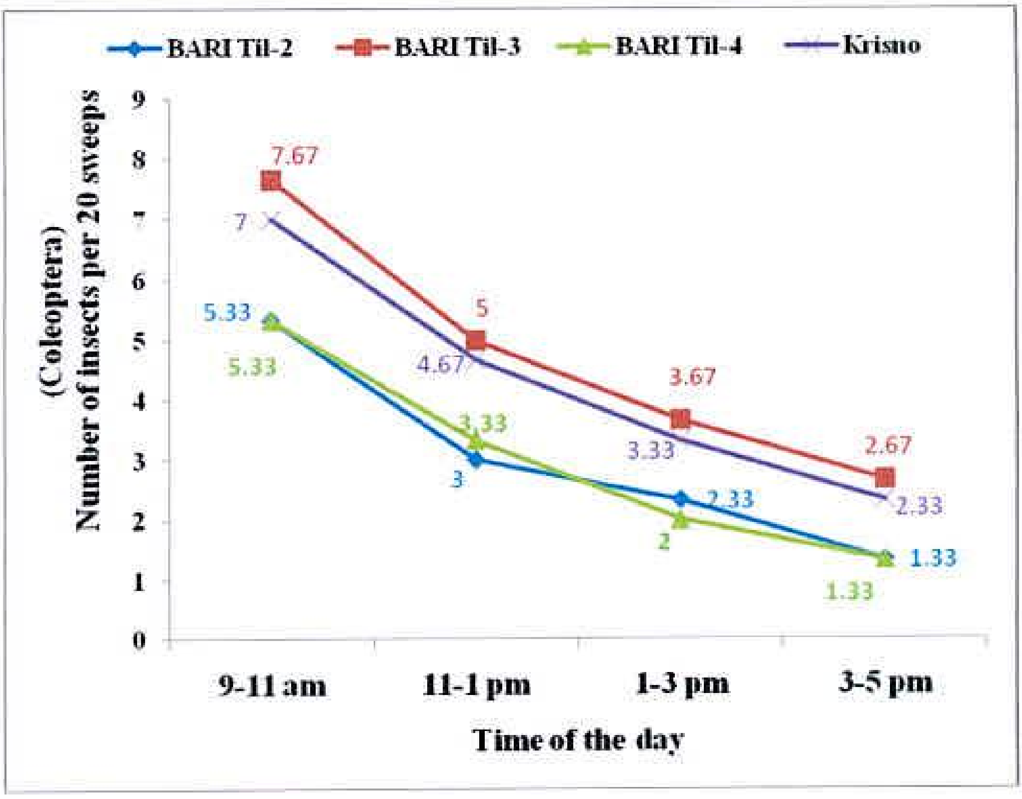

Fig. 8. Foraging activity of insect of Coleoptera order visiting sesame during flowering period (lsd=1.59, 1.88, 0.74, 0.99 and CV % =12.62, 23.57, 13.15 and 26. at 30, 45 and 60 DAS, respectively) at different time of the day.

4.11.3.6 Foraging activity of Lepidopterous insect

Result showed the foraging activity of the major insect of Lepidoptera orders visiting sesame varieties during flowering period. The peak of foraging activity of insect of Lepidoptera order was observed during 9-11 am and lowest during 3-5 pm in this study (Table 6 and Appendix XII).

Table 6. Foraging activity of insect of Lepidoptera order on sesame during flowering period at the different time of the day.

Treatments	9-11 am	11-1 pm	1-3 pm	3-5 pm
V_1	17.00 b	11.33 b	6.667 c	3.000 b
V_2	19.67 a	14.67 a	9.000 a	5.333 a
V_3	17.00 b	11.33 b	7.333 bc	3.333 b
V_4	19.33 a	13.00 ab	8.333 ab	4.333 ab
$LSD_{0.05}$	1.970	1.794	1.105	1.632
F-test	*	*	**	*
CV (%)	5.40	7.13	7.06	20.41

*= Significant at 5% level of probability

- V_1 = BARI Til-2
- V_2 = BARI Til-3
- V_3 = BARI Til-4
- V_4 = Krisno

4.11.3.7 Foraging activity of Dipterous insect

Fig. 9 and Appendix XIII showed the foraging activity of the major insect under Diptera orders on sesame varieties during flowering period. Peak of foraging activity of insect under Diptera order was observed during 9-11 am and lowest during 3-5 pm in this study.

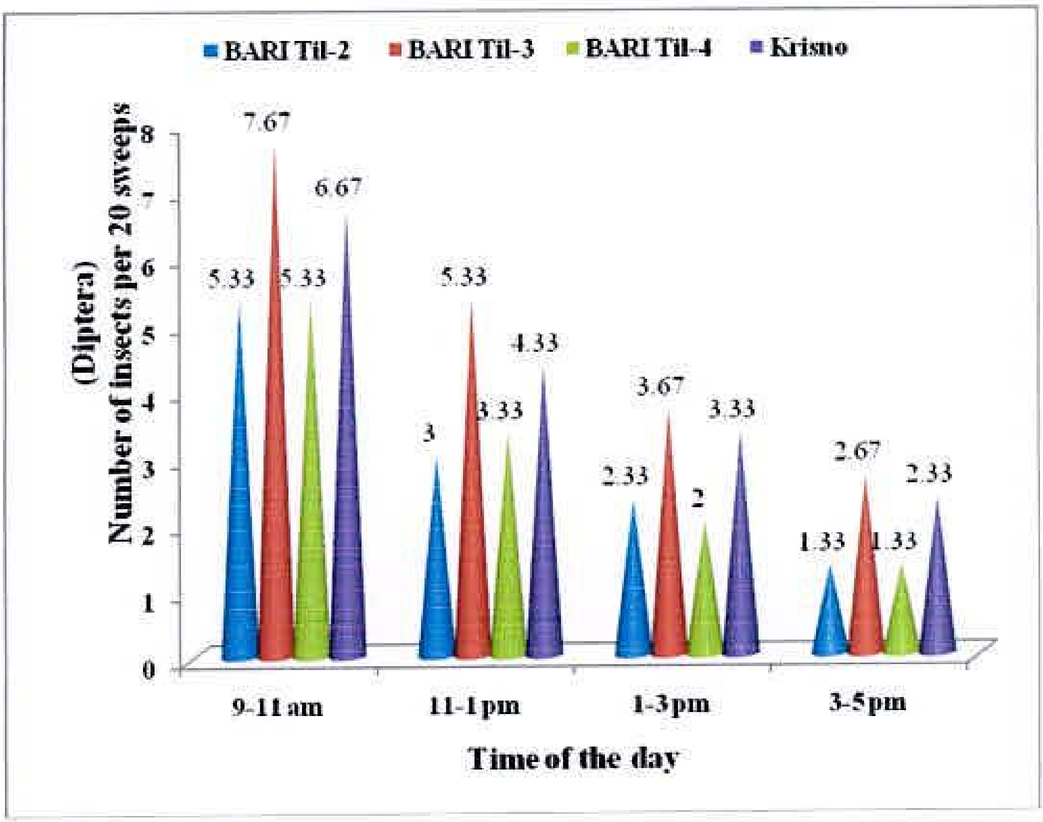

Fig. 9. Foraging activity of insect of Diptera order visiting sesame during flowering period (lsd=2.02, 1.63, 0.74, 0.99 and CV % =16.22, 20.41, 13.15 and 26.09 at 30, 45 and 60 DAS, respectively) at different time of the day.

4.12 Effect of pollinators

4.12.1 Number of pod set

Significant variation was observed among the four treatment i.e. flowers bagged with net with medium mesh (T_1), flowers bagged with net with very small mesh (T_2), flower bagged with net and Vaseline rubbed at the bottom of peduncle (T_3) and flower without net (T_4) in respect of number of pod setting (Fig. 10 and Appendix XVII). The highest number of pod (86.67) in BARI Til-4 (V_3) was found with flower without net (T_4) due to the foraging activity of insects of different orders without any kind of obstacle during the flowering period of sesame. This helps to pollination which ultimately increases the number of pod setting. The lowest number of pod set (1.00) in Krisno (V_4) was obtained from the flowers bagged with net and Vaseline rubbed at the bottom of peduncle (T_3) due to the obstacle against foraging activity of major insects during the flowering period of sesame which probably reduces the pollination and ultimately decreases the number of pod setting.

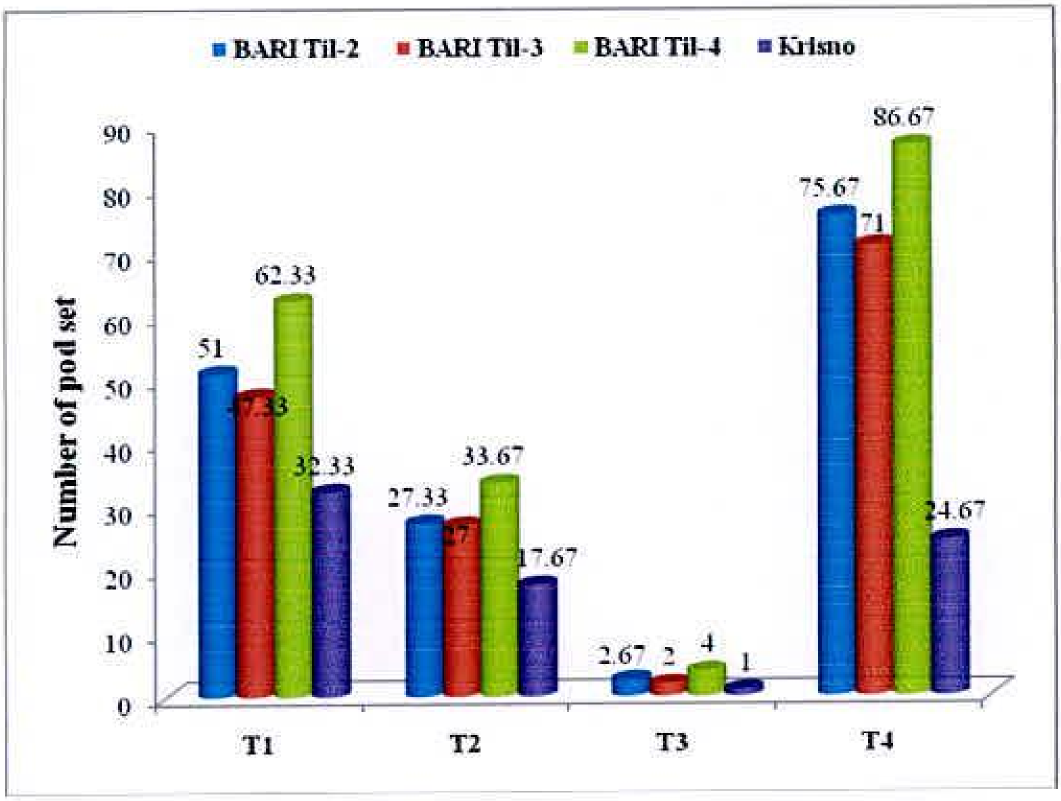

Fig. 10. Effect of pollinators on pod setting of sesame (LSD=5.123 and CV%= 8.68) in different treatments.

T_1=Flower bagged with net with medium mesh, T_2= Flower bagged with net with very small mesh, T_3= flower bagged with net and Vaseline rubbed at the bottom of peduncle and T_4= Flower without net (control)

4.12.2 Number of seeds per pod

Significant variation was observed among the treatments i.e. flowers bagged with net with medium mesh (T_1), flowers bagged with net with very small mesh (T_2), flower bagged with net and Vaseline rubbed at the bottom of peduncle (T_3) and flower without net (T_4) in respect of number of seeds per pod (Fig. 11 and Appendix XVII). The highest number of seeds per pod (69) in BARI Til-4 (V_3) was found with flower without net (T_4) due to the proper pollination effect which ultimately increases the number of seeds per pod. The lowest number of seeds per pod (14) in BARI Til-2 (V_1) was obtained from the flowers bagged with net plas Vaseline rubbed at the bottom of peduncle (T_3) due to hindering foraging activity of major insects during the flowering period of sesame which reduces the pollination and ultimately decreases the number of seeds per pod.

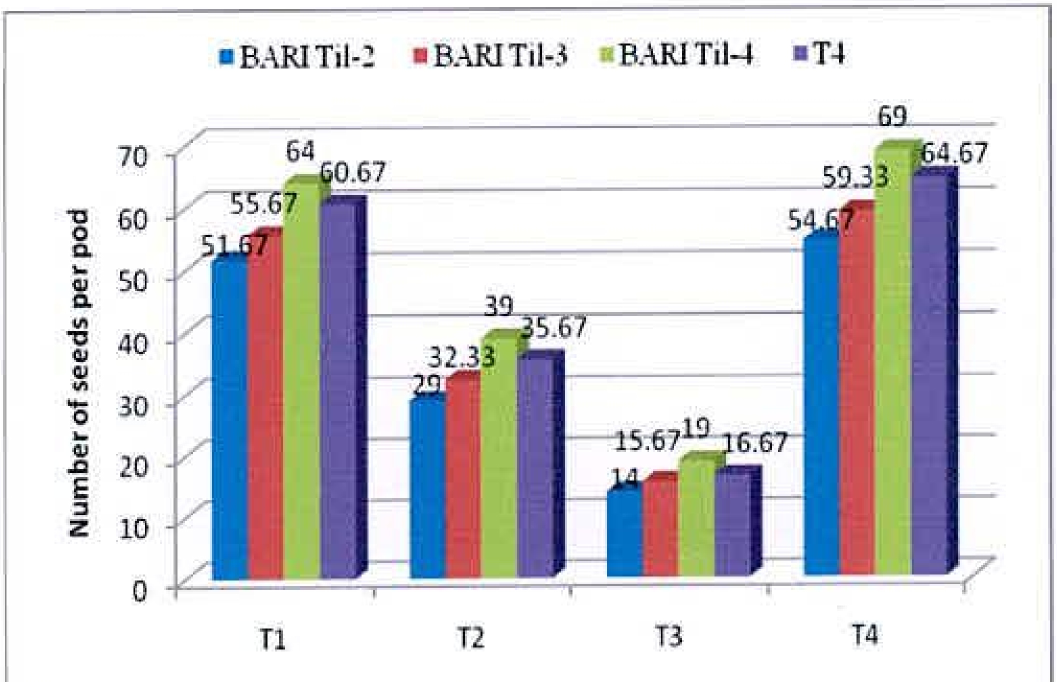

Fig. 11. Effect of pollinators on number of seeds per pod (Lsd =1.668 and CV%= 2.35) in different treatment.

T_1=Flower bagged with net with medium mesh, T_2= Flower bagged with net with very small mesh, T_3= flower bagged with net and Vaseline rubbed at the bottom of peduncle and T_4=Flower without net (control)

4.12.3 Germination test

No significant variation was observed among the treatment i.e. flowers bagged with net with medium mesh (T_1), flowers bagged with net with very small mesh (T_2), flower bagged with net and Vaseline rubbed at the bottom of peduncle (T_3) and flower without net (T_4) in respect of percent of germination of seeds (Fig. 12 and Appendix XVII). Numerically the highest number of germination of seed (80.93%) was found in BARI Til-4 (V_3) was found with flower without net (T_4) due to the proper pollination effect. The lowest number of germination of seed (69.37%) in Krisno (V_4) was obtained from the flowers bagged with net plus Vaseline rubbed at the bottom of peduncle (T_3) due to the obstacle of foraging activity of major insects during the flowering period of sesame which reduces the pollination and ultimately decreases the germination percentage.

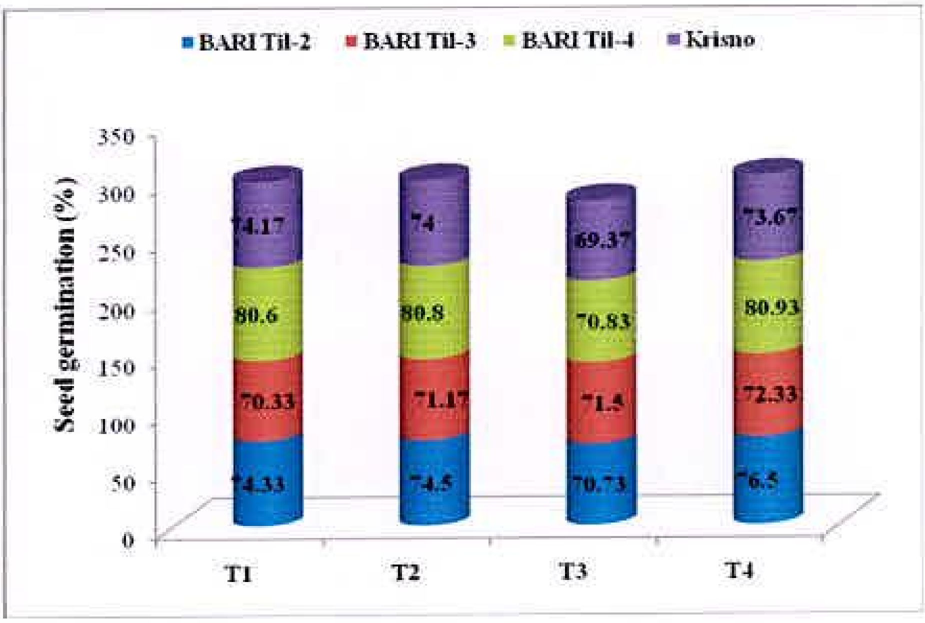

Fig. 12. Effect of pollinators on seed germination percentage (LSD=3.629 and CV%= 2.89) in different treatments using four varieties.

T_1=Flower bagged with net with medium mesh, T_2= Flower bagged with net with very small mesh, T_3= flower bagged with net and Vaseline rubbed at the bottom of peduncle and T_4= Flower without net (control).

Chapter 5
Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted at the research farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from May, 2011 to September, 2011 to study the effect of pollination and yield performance of different varieties of sesame. There were four sesame varieties such as BARI Til-2 (V_1), BARI Til-3 (V_2), BARI Til-4 (V_3) and Krisno (V_4) were used as the test crop. The experiment was laid out in RCBD design with three replications.

Experimental result revealed that all growth and yield parameters studied were significantly influenced by variety of sesame where sesame variety BARI Til-4 (V_3) gave almost highest value. The lowest values were obtained from Krisno (V_4).

Pollinators played a vital role on the pollination of sesame. Four groups of pollinators visited the sesame belonging to order Hymenoptera, Diptera, Lepidoptera and coleopteran of class insecta during the flowering period. The results indicated that Hymenopterans were the major pollinators visiting sesame flowers while the insects of Diptera were minor.

Foraging of Insects belonging to Hymenoptera order increased with the increasing the percent of flowers in all varieties of sesame. Fourth week of flowering period were the peak period for visiting of Hymenopterans insects while the insect population decreased with diminishing of flowers per plant due to advancing age of the crops.

Findings of the study indicated that the foraging activity of all insect onsesame varieties continued during flowering period. Peak of foraging activity was observed in Hymenoptera, Diptera, Lepidoptera and coleopteran of class insecta during 9-11 am of the day while it was minimum during 3-5 pm.

The highest number of pod, seeds per pod and germination of seed was found in flower without net (T_4) (Open flower) due to the foraging activity of different insect orders without any obstacle during the flowering period of sesame. This helped successful pollination which ultimately increases the number of pod setting. It was lower in the flowers bagged with net plas Vaseline rubbed at the bottom of peduncle (T_3) due to the obstacle against foraging activity of major insects during the flowering period which reduces the pollination and ultimately decreased the number of pod setting.

Considering the present study, it may be suggested that by protecting pollinators through applying insecticides late in the afternoon might increase the seed yields and also improve its quality. But further investigation is needed in different agro-ecological zones of Bangladesh under variable field condition to confirm the result of the present study.

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Appendices

APPENDICES

Appendix I. The morphological, physical and chemical characteristics of the soil of the experimental site:

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	Medium high land
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix II. Monthly record of air temperature, rainfall, relative humidity, soil temperature and sunshine of the experimental site during the period from May, 2011 to September, 2011

Year	Month	Air temperature (°C)		Relative Humidity (%)	Rainfall (mm)
		Max.	Min.		
2011	May	31.33	27.42	76.15	250.10
2011	June	32.00	29.15	64.10	377.50
2011	July	31.20	25.95	85.00	361.50
2011	August	30.86	25.75	86.40	590.00
2011	September	31.50	27.00	86.50	208.45

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka, Bangladesh

Appendix III. Map showing the experimental site

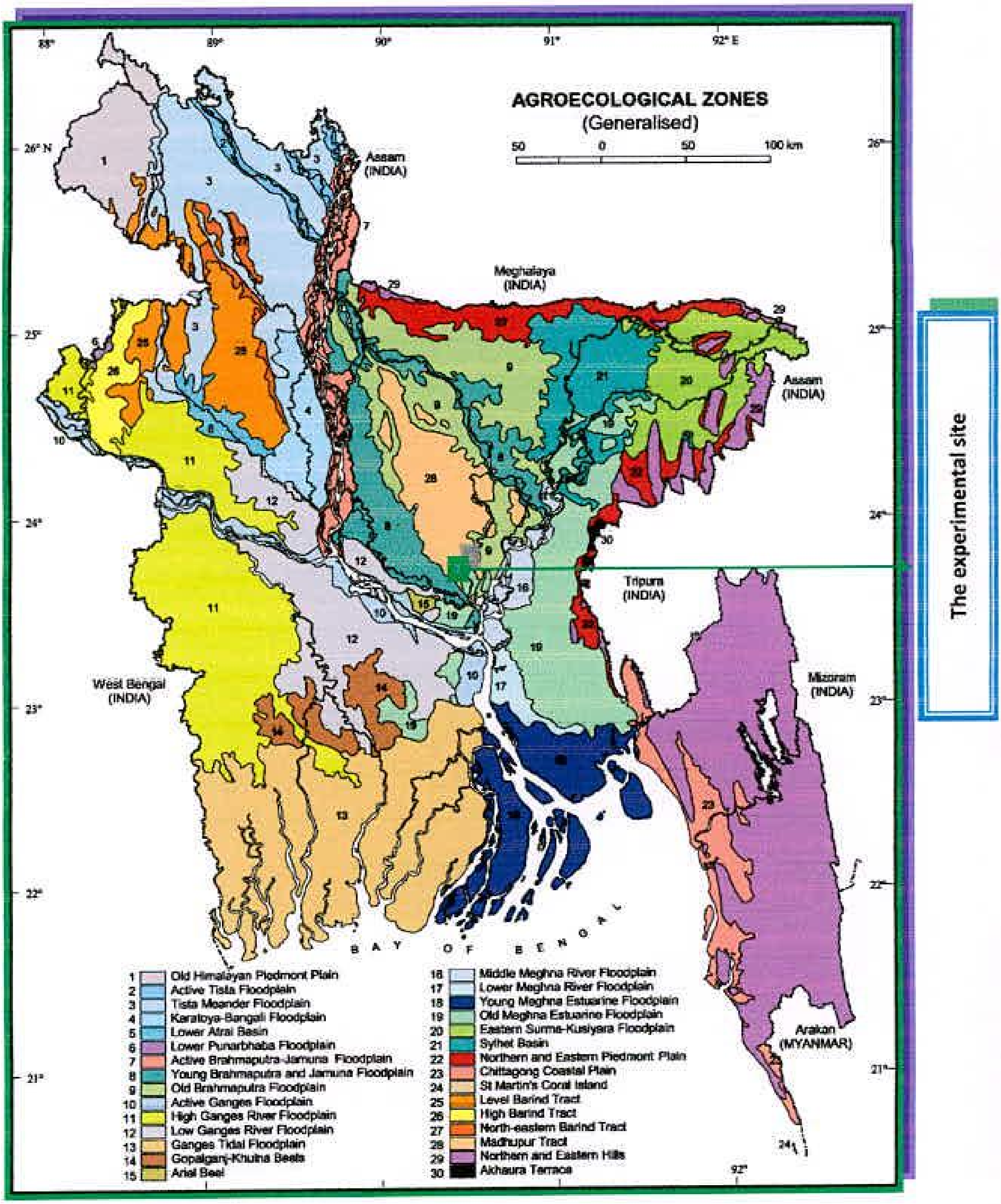

Figure. Map showing the experimental site under study

Appendix IV. Analysis of variance of the data on plant height at different days after sowing

Source of variation	Degrees of freedom	Mean square		
		Plant height (cm) at		
		30 DAS	45 sDAS	60 DAS
Replication	2	64.523	137.343	4.480
Variety	3	126.818 ns	228.289**	587.609**
Error	6	48.061	5.432	24.596

**: Significant at 0.01 level of probability; ns: Nonsignificant

Appendix V. Analysis of variance of the data on number of branches per plant at different days after sowing

Source of variation	Degrees of freedom	Mean square		
		Number of branches per plant at		
		30 DAS	45 DAS	60 DAS
Replication	2	3.000	1.000	0.333
Variety	3	1.222 ns	3.639*	3.222 ns
Error	6	0.556	0.556	1.222

Appendix VI. Analysis of variance of the data on number of leaves per plant at different days after sowing

Source of variation	Degrees of freedom	Mean square		
		Number of leaves per plant at		
		30 DAS	45 DAS	60 DAS
Replication	2	216.083	212.583	137.250
Variety	3	705.861*	366.333 ns	826.306 ns
Error	6	88.194	460.917	433.472

Appendix VII. Analysis of variance of the data on leaf length at different days after sowing

Source of variation	Degrees of freedom	Mean square		
		Leaf length (cm) at		
		30 DAS	45 DAS	60 DAS
Replication	2	0.554	0.342	0.977
Variety	3	11.914**	3.992 ns	4.185 ns
Error	6	0.806	1.457	1.974

Appendix VIII. Analysis of variance of the data on pod length, Number of pods per plant, Number of seeds per pod, Weight of 1000 seed and Yield per hectare at different days after sowing

Source of variation	Degrees of freedom	Mean square				
		Pod Length	No. of pod	Seeds per Pod	1000 seed weight	yield t/ha
Replication	2	0.035	440.083	12.250	0.015	0.006
Variety	3	0.008 ns	1898.333**	94.444*	0.102**	0.536
Error	6	0.003	120.750	14.694	0.003	0.003

Appendix IX. Analysis of variance of the data on Fluctuation percent of insect population during flowering period

Source of variation	Degrees of freedom	Mean square			
		Fluctuation percent of			
		Hymenoptera	Coleoptera	Diptera	Lepidoptera
Replication	2	2.333	2.583	9.250	11.083
Variety	3	3.778**	3.889**	6.972**	13.639 ns
Error	6	0.111	0.139	0.472	12.639

Appendix X. Analysis of variance of the data on Foraging activity of the major insect Hymenoptera visiting okra during flowering period

Source of variation	Degrees of freedom	Mean square			
		Foraging activity of Hymenoptera order			
		9-11am	11-1 pm	1-3 pm	3-5 pm
Replication	2	17.583	16.583	5.250	5.083
Variety	3	16.222 ns	4.083*	17.889**	10.444**
Error	6	4.472	0.917	0.139	0.528

Appendix XI. Analysis of variance of the data on Foraging activity of Coleopterans insect visiting sesame during flowering period

Source of variation	Degrees of freedom	Mean square			
		Foraging activity of Coleopterans insect			
		9-11am	11-1 pm	1-3 pm	3-5 pm
Replication	2	1.083	1.000	0.583	0.583
Variety	3	4.222*	2.889 ns	1.889**	1.417*
Error	6	0.639	0.889	0.139	0.250

Appendix XII. Analysis of variance of the data on Foraging activity of Lepidopterans insect visiting sesame during flowering period

Source of variation	Degrees of freedom	Mean square			
		Foraging activity of Lepidopterans insect			
		9-11am	11-1 pm	1-3 pm	3-5 pm
Replication	2	1.750	1.583	2.083	1.000
Variety	3	6.306*	7.639*	3.222**	3.333*
Error	6	0.972	0.806	0.306	0.667

Appendix XIII. Analysis of variance of the data on Foraging activity of Dipterans insect visiting sesame during flowering period

Source of variation	Degrees of freedom	Mean square			
		Foraging activity of Dipterans insect			
		9-11am	11-1 pm	1-3 pm	3-5 pm
Replication	2	2.250	1.000	0.583	0.583
Variety	3	3.861 ns	3.333*	1.889**	1.417*
Error	6	1.028	0.667	0.139	0.250

Appendix XIV. Analysis of variance of the data on Foraging activity of Dorsata insect visiting sesame during flowering period

Source of variation	Degrees of freedom	Mean square			
		Foraging activity of Dorsata insect			
		9-11am	11-1 pm	1-3 pm	3-5 pm
Replication	2	1.583	0.750	6.083	5.083
Variety	3	13.333**	12.528**	9.889**	4.972**
Error	6	0.917	0.194	0.306	0.306

Appendix XV. Analysis of variance of the data on Foraging activity of Thyreux insect visiting sesame during flowering period

Source of variation	Degrees of freedom	Mean square			
		Foraging activity of Thyreux insect			
		9-11am	11-1 pm	1-3 pm	3-5 pm
Replication	2	2.250	0.583	0.000	0.083
Variety	3	3.861 ns	1.889**	5.000**	2.778**
Error	6	1.028	0.139	0.001	0.194

Appendix XVI. Analysis of variance of the data on Foraging activity of Black bee and Megachille insect visiting sesame during flowering period

Source of variation	Degrees of freedom	Mean square							
		Foraging activity of Black bee insect				Foraging activity of Megachille insect			
		9-11am	11-1 pm	1-3 pm	3-5 pm	9-11am	11-1 pm	1-3 pm	3-5 pm
Replication	2	3.250	1.750	0.083	0.083	1.750	1.750	1.083	0.750
Variety	3	3.000*	1.417**	0.750*	0.222 ns	4.556*	1.111*	1.861*	1.417 ns
Error	6	0.583	0.083	0.083	0.306	0.639	0.194	0.194	0.417

Appendix XVII. Analysis of variance of the data on pollinators on pod setting of sesame

Source of variation	Degrees of freedom	Mean square		
		Pod setting	No. of seeds/pod	Germination test
Replication	2	100.771	47.313	9.906
Factor A	3	1659.521**	243.910**	190.142**
Factor B	3	8722.132**	5496.743**	2.175 ns
A B	9	393.539**	10.132**	1.072 ns
Error	30	9.438	1.001	4.737

Appendix XVIII . Some plate of research field

Plate 1. Net treated plant to make barrier for insects

Plate 2. Control plant for insects pollination

Plate 3. Newly germinated plant in a plot

Appendix XIX .Major flower visiting insects in sesame varieties

Plate 1. Foraging activity of Hymenopterous insects on sesame flower

Plate 2. Foraging activity of Hymenopterous insects on sesame flower

Plate 3. Foraging activity of Hymenopterous insects on sesame flower

Plate 4. Foraging activity of Hymenopterous insects on sesame flower

Plate 5. Bee Pollinator on sesame flower