EFFECT OF BEE POLLINATION ON THE YIELD OF SESAME, *SESAMUM INDICUM* L.

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EFFECT OF BEE POLLINATION ON THE YIELD OF SESAME, *SESAMUM INDICUM* L.

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CERTIFICATE

This is to certify that thesis entitled ***"THE EFFECT OF POLLINATIONBY HONEYBEE (APISMELLIFERA) ON YIELD PERFORMANCEOF SESAME(SESAMUM INDICUM L.)"*** *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 (MS) IN ENTOMOLOGY,*** *embodies the result of a piece of bona fide research work carried out by* ***MD.ZILLUR RAHMAN, Registration No. 12-05242*** *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, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: JUNE, 2014
Place: Dhaka, Bangladesh

……
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DEDICATED
TO
MY BELOVED
PARENTS

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Dated: JUNE, 2014 **The Author**

SAU, Dhaka

EFFECT OF BEE POLLINATION ON THE YIELD OF SESAME , *SESAMUM INDICUM* L.

MD. ZILLUR RAHMAN[1]

ABSTRACT

The experiment was conducted in the Central Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from April to July, 2013 to observe the foraging behavior of *Apis mellifera* in sesame field. The treatments were T_1 (Caged with honey bee); T_2 (Caged without honey bee) and T_3 (Open plot).The result revealed that pollinator *Apis mellifera* visitation was highest (101.75) in T_1 treatment followed by T_3(51.25) and T_2 (24.25) which were significantly different from each other. The highest number of pollinators visitation time was recorded from 6.00 A.M to 9.00 A.M in all three treatment where as lowest number of visitation was recorded in mid-day (2.00 P.M to 3.00 P.M). T_1 treatment that caged with honey bee was the most effective in increasing no. of capsule per plant (86.50) and no. of seeds per capsule (56.75) followed by T_3 treatment which was significantly different.In case of thousand seed weight (g), the highest result was recorded in T_1 (3.48) treatment followed by T_3 (3.20) treatment was significantly different. Yield of sesame after harvest was highest in T_1 (1.16 t/ha) followed by T_3 (1.03 t/ha) with no significant difference.

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ABBREVIATIONS AND ACRONYMS

AEZ	:	Agro-Ecological Zone
et al.	:	And others
BBS	:	Bangladesh Bureau of Statistics
cm	:	Centimeter
CV	:	Coefficient of variation
DAT	:	Days After Transplanting
^{o}C	:	Degree Celsius
d.f	:	Degrees of freedom
etc.	:	Et cetera
EC	:	Emulsifiable Concentrate
FAO	:	Food and Agriculture Organization
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
p^{H}	:	Hydrogen ion concentration
J.	:	Journal
Kg	:	Kilogram
LSD	:	Least Significant Difference
L	:	Liter
m	:	Meter
MS	:	Mean sum of square
mm	:	Millimeter
MP	:	Muriate of Potash
no.	:	Number
%	:	Percent
RCBD	:	Randomized Complete Block Design
SAU	:	Sher-e-Bangla Agricultural University
m^2	:	Square meter
t	:	Ton
TSP	:	Triple Super Phosphate

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CHAPTER I

INTRODUCTION

Sesame *(Sesamum indicum* L.) is an important oil seed crop belonging to the family Pedaliaceae. It is reported that sesame is native to Asian and some African countries (Bedigian, 2003; Desai, 2004). It is also believed that sesame is one of the oldest crops in the world, cultivated for over 4,300 years in Babylon and Assyria (Hwang, 2005). Its cultivation has great economic potential, because of great demand, both nationally and internationally. Presently, sesame is explored in 65 countries across Asia, Africa, Europe and Central and South America. Asia and Africa hold about 90% of the planted area (Vieira, 2004; Beltrão, 2001). The main producing countries are Egypt, Central Africa, Israel, Peru, Saudi Arabia and Macedonia. The current world production is estimated at 7,725,706 tons, with yield of 390 kg ha^{-1}, Sesame was introduced in Brazil by the Portuguese in the XVI century from their Indian colonies (Elleuch *et al.*, 2007; Koca *et al.*, 2007; Wiess, 1983). The seeds, which contain about 50% oil, are the main reason for its cultivation, and may be used in the food, pharmaceutical and chemical industries (Blal, 2013; Elleuch *et al.*, 2007; Alves, 1986; Namiki, 2007). It is also third most important field oil seed crop in Bangladesh. Among the oil producing crops cultivated area in Bangladesh, about 73% is occupied by mustard and rape seed, 18% by groundnut and 9% by sesame (BBS, 2004a). It covers the area of 45,840 hectare of land having a production of 35,007 metric tons (BBS, 2000b). Sesame is grown in both summer and winter season in Bangladesh. The summer sesame covers about two thirds of the total area (BARI, 2004 and Bilu,1994).

Sesame has zygomorphic flowers with pendulous tubular corolla of 3-4 mm in length and coloring of various shades of purple white. They occur singly or in groups of two to three in the leaf axils and are hermaphrodite. The androecium consists of four stamens, two long (1.5-2.0 mm) and two short (1.0-1.5 mm) and the gynoecium has superior ovary, multi carpel and a long style (1.5 - 2.0 mm) with bifid stigma. The flower produces nectar in a nectary disk surrounding the ovary and in a couple of extra floral nectaries on both sides of the pedicel. Anthesis occurs early in the morning when the stigma becomes receptive and senescence can occur 6 to 12 hours later, depending on the variety and environmental conditions (Free, 1993). These characteristics of floral biology refer to varieties cultivated especially in warm

weather environments, but there is an evidence that varieties adapted to tropical conditions behave differently.

Sesame is self-pollinating, although differing rates of cross pollination have been reported by both open pollination and bee pollination treatments were effective to increase the seed yield of sesame upto 22 to 33 percent more than that in "pollination without insects" (Panda *et al.,* 1988). In addition to increasing the yield, cross-pollination also helps to raise quality through a more unified ripening period and an earlier harvesting time. According to Wiess (1983), this species is predominantly autogamous. Nevertheless, crossing rates reported in some studies ranged from only 1 to 68% (Abdel *et al.,* 1976; Ashiri, 2007; Free, 1993; Sarker, 2004; Yermanos, 1980), evidencing the need for further clarifications in this regard. Honey bees are good pollinators for many reasons. Their hairy bodies trap pollen and carry it between flowers.

Sesame's blossom structure facilitates cross pollination, even though the crop is usually viewed as self-pollinating. With regard to the pollination requirements of sesame, there is no consensus on the predominant type of pollination.

OBJECTIVES:

In Bangladesh sesame is grown without managed pollination. Nearly all the sesame growers get their pollination services free from nature. Pollinators are declining worldwide day by day due to anthropogenic activities against nature. However, very few research has been done to observe the pollination effects on sesame yield, and therefore, the present investigation was taken

- To observe different flower visiting insects in sesame.
- To find out the effects of managed bee pollination on sesame yield.

CHAPTER II

REVIEW OF LITERATURE

Sesame (*Sesamum indicum* L.) is a flowering plant in the genus *Sesamum*. Sesame has higher oil contents in comparison to other oilseed crops. With a rich nutty flavor, it is a common ingredient in cuisines across the world. Like other nuts and foods, it can trigger allergic reactions in some people. Recently sesame has drawn the attention of many researchers and some works on sesame have been done in different regions of Bangladesh. The findings of some relevant works in connection with the present works are presented in this chapter.

2.1 SESAME NOMENCLATURE AND LINEAGE

Carl Linnaeus presented *Sesamum indicum* in his Species Plantarum (1753), to which he added a second species, *Sesamum orientate* L. As regards *S. orientate*. he referred to a considerable number of previous publications, but he based *S. indicum* on a Van Royen specimen only, and included Plukenet's plant with trifid basal leaves (Wijnands, 1983).

2.2 SYNONYM

- *Dysosmon amoenum* Raf.
- *Sesamum africanum* Tod.
- *Sesamum occidentalis* Heer & Regel
- *Sesamum oleiferum* Sm.
- *Sesamum orientale* L.
- *Volkameria orientalis* (L.) Kuntze

2.3 Systematic position

Phylum : Plantae

Class : Angoisperms

Sub-class : Eudicots

Division : Asteriods

Order : Lamiales

Family : Pedaliaceae

Genus : *Sesamum*

Species : *Sesamum Indicum*

2.4 Origin and Distribution

Sesame seed is considered to be the oldest oilseed crop known to humanity (Romero and Cowley, 1990) Sesame has many species, and most are wild. Most wild species of the genus *Sesamum* are native to sub-Saharan Africa. *Sesame Indicum*, the cultivated type was originated in India (Zohary and Hopf, 2012)

Charred remains of sesame recovered from archeological excavations have been dated to 3500-3050 BC (Bedigian and Harlan, 2012). Fuller claims trading of sesame between Mesopotamia and the Indian sub-continent occurred by 2000 BC (Fuller, 2003). Some reports claim that sesame was cultivated in Egypt during the Ptolemiac period (Shaw, 2012), while others suggest the New Kingdom (Freeman *et. al.*, 2004).

Records from Babylon and Assyria, dating about 4000 years ago mention sesame. Egyptians called it sesame, and it is included in the list of medicinal drugs in the scrolls of the Ebers Papyrus dated to be over 3600 years old. Archeological reports from Turkey indicate that sesame was grown and pressed to extract oil at least 2750 years ago in the empire of Urartu (Rosengarten *et, al.,* 2004).

The historic origin of sesame was favored by its ability to grow in areas that do not support the growth of other crops. It is also a robust crop that needs little farming support—it grows in drought conditions, in high heat, with residual moisture in soil after monsoons are gone or even when rains fail or when rains are excessive. It was a crop that could be grown by subsistence farmers at the edge of deserts, where no other crops grow. Sesame has been called a survivor crop (Langham, 2011).

2.5 Floral biology of sesame

The flowering period was from November to December, starting the ripening of fruit after 60 days of flowering. At the end of December, the flowering decreased, ceasing completely in January (Hwang, 2005).

Unlike other varieties of sesame which have one or two flowers per leaf axil, the CNPA G2 variety has three flowers. The flowers are complete, gamopetalous, zygomorphic and with a short stalk. The calyx has five fused sepals. One of the petals serves as a landing platform for the visiting insects. The tubular corolla is white, with a lobe upwards and the other downwards. (Ali and Taha, 2012).

The androceium is didynamous with four stamens, in pairs, one lower than the other, epipetalous, fused at the base of the upper lip of the corolla tube, and anthers with rimosa or longitudinal dehiscence. Anthers are yellowish and 1 mm in length. The pollen grain is yellowish; gynoecium is bicarpelar, with bilocular ovary and axile placentation. The observations showed that the ovary is superior and green, and the style is filiform, ending in a bifid stigma. The fruit is dehiscent, and the dehiscence starts at the apex toward the base. These features are apparently common to many varieties of sesame, considering the similarity with that observed in other varieties by several authors (Quer, 1970; Prata, 1969; Yermanos, 1980).

2.6 Pollination Biology

The floral development, floral buds had a green corolla slightly rigid, which with the passing of time was growing and changing from green to white. At this stage, while the flower was developing, the anthers of the longer stamens were located below the height of the stigma, but still closed, while those of the shorter stamens, in turn, were located well below the anthers of the longer stamens. Two hours before anthesis, the four filaments of stamens elongated rapidly, so that at the time of anthesis (6:30 to 7h), anthers of longer stamens reached the stigma height, while those of shorter stamens were positioned just below the stigma. At that point, all four anthers opened up longitudinally and released pollen grains and the two lobes of the stigma opened in Y, coming into contact with the anthers and receiving a large amount of pollen on the inner surface. In this way, flowers of sesame autopollinate around the time of anthesis. (Vaissiére *et al.,* 2011).

A higher number of seeds per fruit is a desirable feature for sesame both from the commercial and ecological point of view, being an important indicator of plant reproductive success, since

a greater number of seeds produced will increase the chances of perpetuation of species (Roubik, 1989). In this experiment, the number of seeds produced per fruit in sesame indicated that the pollination requirements of sesame flower were met. In nature, self-pollination is less advantageous because it does not favor new genetic combinations and thus the production of more vigorous seeds and plants, so that some plant species have mechanisms to prevent the occurrence of self-pollination (Consolaro, 2005; Raven *et al.*, 2007). On the other hand, self-pollination ensures the perpetuation of the species when one partner is not nearby or promoters of cross-pollination agents are absent or scarce. In this sense, although many plant species get more benefits by cross-pollination also accept a certain percentage of self-pollination. This becomes especially clear in species from harsh habitats with few biotic pollinators (Free, 1993; Freitas; Paxton, 1998; Holanda-neto *et al.*, 2002). Nevertheless, sesame seems to have evolved to favor self-pollination, but also developed mechanisms to attract biotic pollinators, such as differently flower, showy color, odor and nectar secretion, in order to promote some percentage of cross-pollination (Faegri; Van Der Pijl, 1979).

Currently, stocks of honey-bees are experiencing many diseases, and populations of wild pollinator species are declining in several regions (Kluser and Peduzzi, 2007), raising concern that a potential global 'pollination crisis' threatens our food supply (Withgott, 1999; Kremen and Ricketts, 2000; Richards, 2001; Wester and Gottsberger, 2002; Steffan-Dewenter *et al.*, 2005). In North America, the number of managed honey-bee hives has declined almost 60 % since the mid 1940s, due to the increasing incidence of parasitic mites and other unidentified factors (National Research Council, 2007; Oldroyd, 2007; Stokstad, 2007). Correspondingly, the diversity of wild bees has decreased greatly over much of Western Europe, mostly owing to habitat destruction (Biesmeijer *et al.*, 2006; Fitzpatrick *et al.*, 2007). Despite evidence that pollination shortages affect fruit and seed quality and quantity of many crops in many places (Klein *et al.*, 2007), data that we compiled previously did not provide strong evidence of pollinator limitation affecting global agricultural production (Aizen *et al.*, 2008). However, we did determine that cultivation of pollinator-dependent crops has, on average, been expanding faster than that of non-dependent crops in both developed and developing countries over the period 1961–2006, so the demand for pollination service is rising at the same time that pollinator abundance and diversity are declining. In the near future, such opposing trends threaten crop yields, which could be averted either by further increases in inputs to compensate for a decline in productivity or by implementation of technical

alternatives to traditional pollination practices. This bleak scenario calls for better information on the dependence of agriculture on pollinators. Estimates that should be more precise than the enlightening, but raw values reported so far (Klein *et al.,* 2007).

Many studies have attempted to estimate the value of crop pollination and pollinator dependency in financial terms, generating net dollar values for this ecosystem service (Southwick and Southwick, 1992; Costanza *et al.,* 1997; Losey and Vaughan, 2006; Gallai *et al.,* 2009).

Ashri (2007) reported that the cross pollination rates were between 2.7and 51.7% in Nigeria.

Yermanos (1980), Ashri (2007) and Sarker (2004). The pollination process occurs at the time the flowers open (Kafiriti and Deckers, 2001; Langham, 2007). Yermanos (1980) found less than 1% when the sesame was surrounded by cotton and other crops. In Moreno, California, he found 68% in a field where the sesame was the only blooming plant in a semi-arid area. 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.

The current dependency of global agriculture on pollinator services can be estimated in terms of either losses related to a pollination shortage or the cost of mitigation. The first, deficit, approach requires quantification of the decrease in relevant measures of productivity, such as total production, yield and diversity, in the absence of animal pollination. The second, compensation, approach requires prediction of the increased agricultural inputs needed to offset the pollination deficiency, such as increases in cultivated area, number of managed bees, labour required for hand pollination, breeding for autonomous pollination and adoption of pheromones to increase the foraging activity of bees. Both approaches are implicit in calculations of the value of insect or, more specifically, honey-bee pollination to particular crops or the agriculture of specific countries (Robinson et al., 1989; Morse and Calderone, 2000; Ricketts *et al.,* 2004; Morandin and Winston, 2006). Regardless of the approach adopted, estimation of the agricultural dependence on animal pollination must recognize that most crops provide some yield in the absence of pollinators and so depend only partially on pollinators. Therefore, any global estimate of pollinator dependency must account for variation among crops in the contribution of animal pollination to production to guard against overstating the agricultural importance of pollinators (Ghazoul, 2005).

2.7.1 Foraging Range

Bees are known to fly as far as 12 km (8 miles), but usually foraging is limited to food sources within 3 km. Westerkamp and Gottsberger (2002) studied that approximately 75% of the bees from a colony forage within one kilometre while young field bees only fly within the first few hundred metres.

2.7.2 Foraging Fidelity

Foraging bees tend to limit their visits to a single species of plant during each trip. This behavioural adaptation is critically important for plants since it assures the transfer of pollen from one plant to another plant of the same species. In commercial crops, foraging constancy is essential for optimizing seed set and fruit development. (Free, 1993).

Individual foragers will acquire a sample through scouting in the morning and tend to fly to the same source as long as it remains profitable. Bees will shift to another plant species if the nectar or pollen fails. Even then, memory will cause these foragers to return several times and re-check. In areas with great floral diversity and small plantings, a higher percentage of foraging bees will visit different kinds of plants during the same trip. This would account for the mixed pollen loads of returning bees (Winters, 2007).

2.8 Effect of temperature and relative humidity on honeybee foraging behavior

There were differences in mean temperature and relative humidity during the observation times. The time period of 12:30-13:30 PM had the highest temperature, and 8:30-9:30AM had the lowest relative humidity and temperature (Rahman, 2000).

In the hive, pollen is removed from the rear legs by a spike on the mid legs and is placed in cells. Often the head is used to pack the pollen in cells. Honey is added to maintain pollen quality. This final product is called bee bread. There was no correlation of air temperature and relative humidity with the frequency of foragers' exiting, foraging rate and time honeybees spent per flower. Abundance of insects tended to be positively correlated with mean air temperature ($r= +0.42$), while there was a negative tendency with relative humidity ($r = -0.22$). Semida (2006) indicated that abundance of honeybees had positive relationship with relative humidity ($r = + 0.20$), while there was negative trend with air temperature ($r= -0.30$). Omoloye and Akinsola (2006) also indicated negative correlation between the intensity of visitation

by honeybees and temperature. Foraging rate of bees tended to be positively associated with air temperature (r= +0.21), while there was a negative tendency with relative humidity (r= -0.19). Similarly, Peat and Goulson (2005) revealed that temperature did not significantly influence foraging rate of bees.

Temperature and relative humidity had significant effect on the pollen and nectar preference of honeybees. The number of bees that collected nectar had a positive association with air temperature (r=0.67; P=0.01) and negative relationship with relative humidity (r=-0.59; P=0.001). However, the number of bees that collected pollen had a positive correlation with relative humidity (r=0.62; P=0.001) and negative association with air temperature (r =-0.72; P=0.001). This might be the reason why honeybees were collecting more nectar starting from 12:30 to 13:30PM in which high temperature was recorded. Peat and Goulson (2005) also revealed that weather had a great influence on whether bees collected pollen or nectar. In stingless bees the number of pollen loads increased as relative humidity rose (r = 0.40), while high temperatures had negative influence on the number of pollen loads collected (r = -0.23); and the number of nectar loads was also positively correlated with air temperature (r = 0.24) (Fidalgo and Kleinert, 2010).

2.9 Foraging Behavior of honey bee

Under normal colony conditions, the forager bees are workers with an age of over 21 days, at which time they shift to perform out-colony tasks including water, nectar, pollen or resin collection. The division of labour and the change of the nurse bees to perform foraging tasks were suggested to be impacted by colony factors (Huang and Robinson, 1996), elevated levels of the foraging gene (Amfor) (Ben-Shahar *et al.*, 2003) and/or the variations in the abundance of mRNA (Whitfield *et al.*, 2003) in the worker's brain. Also, many other factors were suggested to have a key role in the shifting of worker bees from In-colony tasks to Out-colony tasks. The anticipation of the commencement of foraging is associated with an increased titre of juvenile hormone (JH) in foragers which is not affected by foraging experience but by diurnal variations (Elekonich *et al.*, 2001). Further, Schulz *et al.*, (2002) found higher octopamine concentrations in the antennal lobes of the bee brain in foragers compared to nurses regardless of the age. They also found that changes in octopamine are modulated by juvenile hormone. The earlier age of foraging activity commencement (shifting to Out-colony tasks) was found to be affected by bovine insulin treatments

(Mott and Breed, 2012). In another study, and under reduced brood rearing activity a delay in foraging commencement and death was found to be associated with increased vitellogenin levels (Amdam *et al.*, 2009). Generally, the foraging skills and the number of forager workers are increased with age (Dukas and Visscher, 1994). Additionally, the forager bees have different n-alkane profiles than the nurse bees with a higher quantity of n-alkane which may help the forager bees to tolerate the ambient conditions (Kather *et al.* 2011)

2.9.1 Foraging time

It is known that the foraging activity of honey bees is initiated in early morning and finishes in the evening. In some studies, honey bee workers started foraging activity at 6.17 AM (Joshi and Joshi, 2010) but this commencement time can be greatly impacted by the region. Under desert conditions, Alqarni (2006) found that a higher number of foragers left the colonies at 8 am than at 10 am. In general, the foraging activity fluctuates during the day from the morning until the evening. Reyes-Carrillo et al. (2007) found high pollen collection in the early morning while low amounts of pollen were collected in the afternoon. Pernal and Currie (2010) reported a higher foraging rate mean during the afternoon period (36.02 foragers/min) than during the morning period (17.66 foragers/min). Yucel and Duman (2005) found that honey bee workers visited onion flowers from 8.15 to 16.30 h and the peak foraging was between 11.00 to 12.00 h. Foragers have the ability to remember the time of the day at which the higher food resources are available as found with *Sysirinchium palmifolium* plants (Silva *et al.*, 2013) and such ability may correlate with foraging activity peaks. In general, the normal foraging interval at the same feeding site is less than 5 min (Yang *et al.*, 2008) and bees spend different times per flower depending on the plant species. The time spent per flower was 6.92, 6.50 and 5.54 s for Chinese cabbage, broccoli and kohlrabi, respectively (Sushil *et al.*, 2013).

2.9.2 Foraging distance

The energy hypothesis which suggests that foragers estimate the feeder distance (food resource) based on the spent energy during foraging flight is now considered to be incorrect and another hypothesis based on optical flow was suggested (Esch and Burns, 1996). Both hypotheses can be considered as integrated explanations inasmuch as the energy spent during flight as well as the speed motion of the ground image

received by the retina are both essential for estimating distance as well for distance calculation. The mean foraging distance for *A. Carnica* was 1526.1 m while foraging distances of pollen-collecting bees had a mean of 1743 m in simple landscapes and 1543.4 m in complex landscapes (Steffan-Dewenter and Kuhn, 2003). The mean of foraging distances for small colonies of *Apis mellifera* was 670 m and for large colonies it was 620 m in July, while the values were 1430 m for small colonies and 2850 m for large colonies in August (Beekman *et al.* 2004). Hagler *et al.,* (2011) found that the foraging range of honey bees ranged from 45 m to 5983 m. Under desert conditions, water foragers can fly up to 2 km from their colonies to collect water (Visscher *et al.,* 1996). It seems that the foraging distance for colonies in the same region is impacted by race, colony strength, food resource, month and the time of the day.

2.9.3 Foraging preference

Forager bees prefer the collection of water, nectar, pollen or resin from some resources over others. There are many examples of foraging preference; only a few examples are presented here. Water foragers were noticed to prefer continuous water sources than stable ones as well as large water containers than small ones (Abou-Shaara, 2012). Also, forager bees have a preference to collect water from some unusual sources (e.g. cow dung) over clean water (Butler, 1940). Nectar foragers sometimes prefer one food source over another as well as the specific position of one flower over another. Sushil *et al.,* (2013) found that more honey bee foragers visited broccoli followed by kohlrabi and finally Chinese cabbage with 6.05, 5.35 and 5.05 bees/plant, respectively. Mayer and Lunden (1988) found more nectar foragers on the top of the flowers of Manchurian crabapple than red delicious apple. Fohouo *et al.,* (2008) found the highest number of forager workers was on *Syzygium guineense* var. *guineense* and the lowest number on *Psorospermum febrifugum*. Weaver (1965) Also detected differences in honey bee foraging behaviour on hairy vetch (*Vicia vitlosa* Roth) flowers; some bees used the flower base while others use the flower mouth. Honey bees have a preference for apple tree branches located in the middle of trees rather than for those branches located higher up or lower (Mattu *et al.,* 2012). Similarly, pollen and resin foragers prefer some resources over others. More studies are required to fully uncover the preference behaviour of forager bees.

2.9.4 Foraging behaviour of honey bee subspecies

Differences between foraging activity as the number of bees leaving the hives were found between three honey bee subspecies; Yemeni, Italian and Carniolan honey bees, with a higher foraging activity of Yemeni then Italian and finally Carniolan honey bees under desert conditions (Alqarni 2006). Also, Ali (2011) found a higher foraging rate for Yemeni honey bees than Carniolan honey bees during June and August and at different monitoring times; 6–7 am, 11–12 AM and 4–5 PM. The same trend was found by Abou-Shaara *et al.,* (2013), where Yemeni honey bees had higher foraging activity than Carniolan honey bees under desert conditions. In contrast, no clear impact of bee race was found for ARS Russian or Italian honey bees with respect to the percentages of pollen foragers or flight activity (Danka *et al.,* 2006). The differences between the foraging activity of honey bee subspecies can be explained partly by the variations in their morphological characteristics. Bees with large wings were reported to have higher flying ability than small ones (Mostajeran *et al.* 2006). Higginson *et al.* (2011) found that bees with damaged wings had less foraging trips and flew closer to the hive than healthy ones. Positive correlations were found between foraging activity and sealed brood area as well as bee number (Abou-Shaara *et al.* 2013). Also, the adaptation of honey bee subspecies to certain environmental conditions may influence the foraging activity (Alqarni 2006). Forager workers of Yemeni and Carniolan honey bee subspecies, under laboratory conditions, showed different abilities to tolerate different temperatures and relative humidity gradients (Abou-Shaara *et al.*, 2012).

2.9.5 Factors impacting foraging activity

There are many factors that can impact foraging activity. These factors can be divided into two major groups: in-colony factors and out-colony factors. The first group (in-colony factors) include: queen presence and case (virgin or mated). Higher foraging activity with less pollen collection was found in colonies headed by virgin queens than colonies headed by mated queens while lower foraging activity and pollen collection were found in queenless colonies than in colonies with a mated or virgin queen (Free *et al.*, 1985b). Also, foraging activity is impacted by colony strength and brood rearing activity (Amdam *et al.,* 2009; Abou-Shaara *et al.,* 2013), and the degree of pollen need (Weidenmuller and Tautz 2002). Beehive type also has an impact on the foraging activity of honey bees (Abou-Shaara *et al.,* 2013). The infection of honey

bee foragers with diseases and parasites such as *Nosema* sp. or *Varrao destructor* may result in the inability of foragers to return to their colonies or increased time to return (Kralj and Fuchs, 2006; Kralj and Fuchs, 2010). The genotype of honey bee strains (e.g. high and low pollen-hoarding bees) strongly affected foraging behaviour for nectar or for pollen (Pankiw *et al.*, 2002). The inheritance of high pollen-hoarding behaviour is a recessive trait unlike honey storing behaviour, which shows a more dominant pattern (Page *et al.*, 1995). Beside these factors, ovariole number can influence nectar collection by honey bee workers (Siegel *et al.*, 2012).

With regard to out-colony factors, the availability of suitable plant resources has a great impact on foraging activity, and forager bees have a preference for some resources over others (see, preference of honey bees paragraph). Moreover, Fulop and Menzel (2000) found that the reward volume (e.g. sucrose solution or nectar) has an impact on foraging activity and that bees can perceive the amount of reward from the feeding source.

With respect to environmental factors which influence foraging activity, *A. mellifera* bees were observed to commence their foraging activity at ambient temperatures with a mean of 6.57 °C (Tan *et al.*, 2012) while in another study this value was found to be 16 °C (Joshi and Joshi 2010). At ambient temperatures of about 20 °C, the highest activity was recorded (Tan *et al.* 2012) while at 43 °C the lowest foraging activity was found (Blazyte-Cereskiene *et al.*, 2010) as well as at or below 10 °C (Joshi and Joshi 2010). Further, a significant negative correlation ($r = -0.09$) was found between foraging activity and temperature (Abou-Shaara *et al.*, 2013). Thus, it is expected that foraging activity is influenced passively by elevated temperature as found by Cooper and Schaffer (1985) with pollen foragers. In contrast, relative humidity had less of an effect on flight activity (Joshi and Joshi 2010). Further investigations are required in order to elucidate these phenomena.

It was also found that other environmental factors can have an impact on foraging activity. Collins *et al*., (1997) found no impact of solar ultraviolet-B (UV-B) on the foraging activity of honey bees on two species of mustard, *Brassica nigra* and *B. rapa* grown under controlled conditions. However, Mattu *et al.*, (2012) reported that altitude influenced foraging commencement and cessation time, duration of foraging activity and trips as well as the number of flowers visited per minute. Further, Sharma and Kumar (2010) found a negative effect of an electromotive field on foraging

behaviour. Surprisingly, diesel exhaust can diminish the foraging efficiency of honey bee workers by reducing the ability of worker bees to recognize floral odours (Girling *et al.,* 2013).

Foraging behaviour can also be influenced by natural enemies of honey bees. In the United kingdom Kirk *et al.,* (1995) found that the pollen beetle *Meligethes aeneus* (Nitidulidae) influenced the foraging behaviour of honey bees on oilseed rape flowers: forager bees preferred fully open flowers without beetles on them. Foraging activity can also be affected by the presence of predators (e.g. hornets) and a reduction in the foraging visits by 55–79% and residence times by 17–33% was previously reported (Tan *et al.,* 2013). Also, the presence of bee-eaters impacted passively on foraging activity (Ali and Taha, 2012).

Insecticides may also influence foraging behaviour. Yang *et al.,* (2008) reported effects of sublethal doses of imidacloprid on the foraging behaviour of honey bees which manifested as a delay in their visit to the feeding site. The delay depended on the imidacloprid concentration. Schneider *et al.,* (2012) found a significant reduction in foraging activity as well as longer foraging flights at doses of two neonicotinoid insecticides;0.5 ng/bee or more for clothianidin and 1.5 ng/bee or more for imidacloprid during the first 3 h after treatment. In contrast, the presence of residues in the nectar and pollen of oilseed rape and maize due to seed treatment with thiamethoxam was reported to represent a low risk to honey bees (Pilling *et al.* 2013). More investigations on these factors are urgently required especially since neon-ictinoids are so widely used.

Other factors may also have an impact on foraging behavior. For example, foraging distance was found to be affected by the time of year (Steffan- Dewenter and Kuhn 2003; Beekman *et al.,* 2004). Pearce *et al.,* (2013) found no considerable effects of moving beehives from their location to another location as far as 26 km from their original site on honey bee foraging activity. Sushil *et al.,* (2013), meanwhile, found that foragers spent less time in a flower under open conditions than in net house conditions. Brittain *et al.,* (2013) observed alterations in honey bee foraging behaviour in California almond orchards due to the presence of other bee species communities. Picard-Nizou *et al.,* (1995) found no effects of oilseed rape (*Brassica napus* L.) genetically modified by the introduction of a chitinase gene to enhance disease resistance on the foraging behavior of honey bees (*Apis mellifera* L.).

2.9.5 Monitoring of foraging activity

Foraging activity is measured by employing different parameters including, the foraging commencement or/and cessation time (Joshi and Joshi 2010; *Mattu et al.,* 2012; Tan *et al.,* 2012); the number of bees returning to the beehive (Beekman *et al.* 2004; Pernal and Currie 2010; Ali 2011) or leaving beehives (Alqarni 2006) or both (Abou-Shaara *et al.,* 2013); the peak and fluctuations of foraging over time (Malerbo-Souza 2011); foraging speed and foraging distance (Steffan-Dewenter and Kuhn 2003); or estimation of foraging distance by decoding of the waggle dance (Pearce *et al.,* 2013).

Other parameters related to foraging activity and the visiting of plants include, the number of foragers per flower (Sushil *et al.,* 2013); the number of visited flowers per forager (Mattu *et al.,* 2012); and time spent per flower (Sushil *et al.* 2013); nectar and pollen collection method from the blooms (Mackenzie 1994); the position of the forager bees on or at the side of the flower (Mayer and Lunden 1988; Mattu *et al.,* 2012); the position of visited branches and flowers (Mattu *et al.,* 2012); the proportion of pollen or nectar foragers relative to total foragers; foraging type; the load of pollen and pollen type; concentration of crop nectar sucrose (Pearce *et al.,* 2013); and competition with other pollinators (Mackenzie, 1994; Brittain *et al.,* 2013).

Also, some studies monitor foraging activity under net conditions (Sushil *et al.,* 2013). Marking and recapturing forager workers has been used in certain studies (Akinwande and Badejo 2009). Hagler *et al.,* (2011) used self-marking devices for studying the foraging range of honey bees on an alfalfa seed production field. Colin *et al.,* (2004) developed a method to quantify the foraging activity of small colonies of honey bees confined in insect-proof tunnels using video recording. Pollen foraging activity can be monitored with pollen traps (Reyes-Carrillo *et al.* 2007). In some studies, syrup foraging rate was investigated (e.g. Paleolog 2009). Harmonic radar can also be used in recording the flight paths of foraging honey bee workers (Riley and Smith 2002; Riley *et al.,* 2007). A standard protocol for monitoring foraging behaviour was presented by Scheiner *et al.,* (2013) and other protocols for studying plant pollination by honey bees were reported by Delaplane *et al.,* (2013). During the monitoring of foraging activity there are some important factors that should be taken into consideration including, the equal strength of the studied bee colonies especially the number of brood and pollen frames; the presence of any diseases in the studied

colonies; the time of day and year; temperature and relative humidity as well as the presence of bee competitors or predators. Forager bees can be collected from the hive entrance by using forceps in front of the colonies as well as using an aspirator (Yucel and Duman, 2005). Also, specific devices (e.g. Bee scan) can be used for counting forager bees (Scheiner *et al.*, 2013).

2.10 Importance of foraging activity

Beside of the basic importance of foraging activity for honey bee colonies in collecting pollen, nectar, water and resin there are numerous reports of its importance for plant pollination (e.g., Young *et al.*, 2007) especially for plants where honey bees are the primer pollinator. A vast number of species were found to be honey bee-pollinated plants including, highbush blueberry; apple and pears; almonds; Cantaloupe; rape varieties; and others (e.g. Boylan-Pett *et al.*, 1991; Mayer and Lunden 1988; Reyes-Carrillo *et al.*, 2007; Blazyte-Cereskiene *et al.*, 2010). In a study by Sushil *et al.*, (2013) honey bees were found to have a key role in increasing the seed production of three crops: broccoli, kohlrabi and Chinese cabbage. Also, an increase in the seed quality and quantity of onion, *Allium cepa,* cultivar Valencia was found (Yucel and Duman 2005). Mishra *et al.*, (2013) found other benefits besides pollination to be mediated by foragers; namely the deposition of nitrogen (in faeces) on plants during visits. They found about 2.27 to 2.69 g nitrogen per month as the mean production rate of bee frass by a 5000-bee colony. Forager bees also have the ability to distribute certain biocontrol agents including *Erwinia herbicola* Eh252 of fire blight onto apple flowers as well as onto nashi flowers (Cornish *et al.*, 1998). To maximize the benefit of forager bees in spreading biocontrol agents, a new high-performance 'Triwaks' dispenser was developed (Bilu *et al.*, 2004).

The foraging activity of honey bees is very important as a bioindicator for indirect studies of environmental contamination with pesticides (e.g.Balayiannis and Balayiannis, 2008). Foraging bees can even be trained using proboscis extension reflex conditioning for the detection of TNT. The foraging activity of honey bees has also been used to help monitor flowering plant species in an area. Foraging bees can also be used in the identification of pest infestation (e.g. fruit flies; Chamberlain *et al.*, 2012). Beekeepers can benefit from the foraging behavior of their colonies by fixing pollen traps or venom collection boards in front of hives to collect pollen or bee venom, respectively.

Foraging behavior also has importance in computer science. It is known that forager bees can select their food sources in an optimal way although many food resources may be available (Thuijsman *et al.*, 1995). Thus, honey bee foraging behavior and related skills in food scouting and collection (Swarm intelligence) was used in computer science to solve many optimisation problems. Swarm intelligence is currently an important field in Artificial Intelligence (Kumar and Govindaraj, 2013). Baig and Rashid (2007) presented an algorithm based on the swarming of honey bees called Honey Bee Foraging (HBF), which they proposed as useful for multimodal and dynamic nature optimisation problems.

2.11 Disadvantages of foraging activity

Despite the great importance of foraging behavior there are also some disadvantages associated with this activity. Honey bee foragers are able to transmit the bacteria *Erwinia amylovora*, the cause of fire blight of apple and pears (Keitt 1941). Also, as found by Boylan-Pett *et al.* (1991) forager bees play a key role in the transmission and spread of pollen-borne blueberry leaf mottle virus (BBLMV). This virus has the ability to remain infectious within honey bee colonies for at least 10 days. Honey bees are not effective pollinators of some plants; for example, Mackenzie (1994) found that bumble bees were better than honey bees in cranberry pollination (*Vaccinium macrocarpon* Ait). Bee-to-bee contact can also result in the transmission of bee parasites from one forager to another. Moreover, honey bees can transmit different mite species from plant to plant or even to their colonies. Foragers can also collect the poisonous pollen of some plant species and subsequently store these pollens in their colonies with harmful consequences for the colony's health.

2.12 Controlling foraging activity

It has been found that treatment with certain chemicals can enhance foraging activity. Pankiw (2004) found, using a suspended glass plate containing synthetic brood pheromone in isopropanol that colonies treated with this brood pheromone had higher ratios of pollen to non-pollen foragers entering colonies 1 h after the treatment. Mott and Breed (2012) found that bovine insulin treatments increased the threshold of the bees' sucrose response and significantly decreased the age at which foraging activity commenced for winter worker bees and summer nurse bees, respectively. Also, Schulz *et al.*, (2002) found an earlier commencement of foraging in young bees

in colonies treated with octopamine. Additionally, the pollination mediated by honey bees, *A. mellifera*, can be improved by the presence of other bee species in the orchards as found by Brittain *et al.,* (2013) in California almond orchards. In addition, the use of modified beehives as demonstrated by AShaara *et al.,* (2013), can improve foraging activity.

In contrast, Free *et al.,* (1985a) found that treatment of oil-seed rape, field beans and sunflower heads with 2-heptanone and isopentyl acetate (honey bee alarm pheromones) were repellent to honey bee foragers. Kirk *et al.,* (1995) found that the simulation of adult beetles using black spots on flower petals deterred nectar-foraging honey bees from landing on the flowers. Also, certain pesticides are repellent to honey bees.

CHAPTER III

METERIELS AND METHODS

This chapter deals with the materials and methods that were used in conducting the experiment. It consists of a short description of location of' the experimental plot, characteristics of soil, climate, material used, treatments, layout and design of experiment, land preparation and gap filling, after cares, harvesting, and collection of data. These are described below:

3.1 Experimental Site

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from April 2013 to July 2013. The experimental field was located at 90º 33 E longitude and 23º71 N latitude at a height of 9m above the sea level. The land was medium high.

3.2 Soil

The soil was silty clay in texture having 26% sand, 45% silt and 29% clay and the pH was 5.6. The physio-chemical properties of the soil are presented in Appendix I. The experimental site belongs to the Madhupur Tract Agro Ecological Zone (AEZ-28) as shown in Appendix III. The experimental site was a medium high land. The morphological characters of soil of the experimental plots as indicated by UNDP (1998).

3.3 Climate

The climate of experimental site was under the sub-tropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). There is more or less rainfall during growing season (April-July) of sesame. This weather is the favorable for crop production. The average maximum temperature during the period of experiment was 33.9°C and the average minimum temperature was 23.6°C. Details of the meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix II.

3.4 Planting materials used for experiment

Sesame is a broad-leveled annual oilseed crop. It is herbaceous growing to a height of 0.5 to 1.5 meters with tap root system. The stem is erect, normally square in section. Stem color ranges from light green to almost purple, but the most common is darkish green, covered with short hairs, leaves are green, broad, opposite, alternate or mixed. The inflorescence is raceme, flowers are two lipped with white white color tabular corolla. Fruits are capsule, dehiscent. Seeds are oval shaped, black amd sometimes creamy white. The variety BARI Til-4 used in the experiment as test crop.

3.5 Experimental Design and layout

The experiment was conducted considering three treatments and laid out in a Randomized Complete Block Design (RCBD). Each treatment was allocated randomly in four replications. The unit plot size was 5 m ×4.5 m having 0.75 m space between the blocks and 1m between the plots. Each plot contains two rows having 30cm distance between the row and that between plants was 5 cm. The following table shows the design of the experimental plot.

3.6 Collection of seeds:

The seeds of cultivar BARI Til-4 were collected from Bangladesh Agricultural Research Institute(BARI), Joydebpur, Gazipur.

3.7 Land preparation and fertilization

The plot selected for the experiment was opened in the first week of April 2013 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilt. Each ploughing was followed by laddering to have a desirable fine tilt. Weeds and stubble were removed, and finally obtained a desirable tilt of soil for sowing. During land preparation 10 t/ha decomposed cow dung were mixed with soil and following fertilizers were applied. Urea, TSP, MP and Boric acid as the source of Nitrogen (N), Phosphorus (P_2O_5), Potassium (K_2O) and Boron (B). Fertilized with (TSP)and(MP) at the rate of 120 and kg ha^{-1}, respectively (BARI, 2006). Urea was applied as the sources of nitrogen, as per experimental treatment.

3.8 Methods of fertilizer application

All the fertilizers except urea were applied during final land preparation. Urea was applied in two splits: first half was applied as basal dose and second half was applied after 30 days of sowing following nitrogen levels. Fertilized with (TSP) and(MP) at the rate of 120 and kg ha^{-1} respectively (BARI, 2006). Urea was applied as the sources of nitrogen

3.9 Sowing of seeds

Seeds are sown continuously on April 8, 2013 in 2-2.5 cm deep furrows made by hand iron tine maintaining row spacing following variables. After placement of seeds were covered with soil by hand. Four days after sowing the germination was satisfactory.

3.10 Treatments of the Experiment:

There are three treatment combinations will be tested in this experiment.

T_1= Caged with honey bees: Three framed one number bee box was used to observe honeybee pollination. The full plot was covered by net with managing bee foraging species. Artificial bee food also supplied in one week interval until the end of blooming period.

T_2=Caged without honey bees: All plots of this treatment were only netted and therefore no bees could not visit those plot.

T_3=Open plot: Netting was not done and no managed bee boxes established in the open plot.

3.11 Seed processing and treatment

The seeds of BARI TIL-4 of were collected from Bangladesh Agricultural Research Institute, Gazipur. Germination test was done before sowing. The rate of germination was found more than 95%. The seeds were treated with Vitavax 200 at the rate of 2 g per kg seed to protect seedlings against foot and root rot diseases.

3.12 Intercultural operations

Intercultural operations like thinning, weeding and mulching were done as and when necessary for proper growth and development of the crop. Thinning was done during first weeding keeping a distance of 5 cm.

3.13 Pest Management

The management was not taken as the crops were not infested.

3.14 Irrigation

Three irrigations were given throughout the growing period. The first irrigation was given at 7 days after planting followed by irrigation 15 days after the first irrigation and the other was done in the same way. Mulching was also done by breaking the soil crust after irrigation properly. Stagnant water was effectively drained out at the time of heavy rains.

3.15 Harvesting

The crop was harvested at maturity. The maturity dates were different among the varieties. Harvesting was done when 75-80% of leaf becomes yellow in colour (June 4, 2013). The harvested plants were brought to the threshing floor and dried in the sun. The seed and stover were than separated, cleaned and dried in the sun for to 4 consecutive days for achieving safe moisture content of seed. The yield obtained from each plot was converted into yield per hectare.

3.16 Sample collection and data recording:

Ten plot were selected randomly from each plot at 30, 45 and 60 (at harvest) DAS to record data of the following-

- Plant height/plant
- No. of flower/plant
- No. of branches/plant
- No. leaves/plant
- No. of capsule/plant
- Blooming period
- No. of seed/capsule
- 1000 seed weight
- Yield/plot

3.17 Outline of the data recording

A brief of the data recording has been given below –

Number of capsules plant^{-1}

All the capsules borne on all the ten sample plants of each unit plot were counted to determine the average number of capsule plant

Number of seeds capsule^{-1}

From each treatment 20 capsules were randomly selected and all the seeds of them were counted. The number of seeds capsule^{-1} was determined by averaging the data.

1000-seed weight (g)

One thousand sun-dried seed were counted and then weight was recorded by means of an electrical balance.

Seed yield (kg ha^{-1})

The crop was harvested at full maturity from pre determined area from which seeds were separated out from the capsule, cleaned and dried in the sun to bring them at safety moisture content of seed and there after the weight of the seed was taken and converted to yield per hectare (kg ha^{-1}).

3.18 Calculation of the recorded data

The data recorded on different parameters were calculated using the following formula:

% increase or decrease over control

$$= \frac{\text{Mean value of treated plot–Mean value of untreated plot}}{\text{Mean value of untreated plot}} \text{ x } 100$$

3.19 Statistical Analysis:

The collected data on different parameters were statistically analyzed to obtain the level of significance using the MSTAT-C computer package program developed by Russell (1986). The mean differences among the treatments were adjusted by using Least Significant Difference (LSD) test for significance.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the explanation and presentation of the results obtained from the experiment on effect of bee pollination on the yield of sesame (*Sesamum indicum* L.). The data have been presented and discussed and possible interpretations are made under the following sub headings:

4.1 Insect pollination visitation in sesame field

The comparative effectiveness of three treatments on Different pollinators visitation in sesame field has been evaluated and presented in Table 1. In T_1 treatment a honeybee hive was set into the cage. So the number of *Apis Mellifera* was highest (101.75) in T_1 treatment which was significantly different from T_2 (24.25) and T_3 (51.25) treatments. In terms of *Apis dorsata/ Apis florae* species, there is no number of bees was found in T_1 treatment. But in T_2 and T_3 treatments that is caged without bees and open plot respectively was shown 12.25 and 18.00 number of *Apis dorsata/ Apis florae* which were non-significant. T_1 treatment is significantly different from T_2 and T_3 treatments.

Table-1: Different pollinators visitation in sesame field

Treatment	List of pollinators			
	Apis Mellifera	*Apis dorsata/ Apis florae*	*Apis cerena*	Ant
T_1	101.75 a	0.00 b	0.00 b	60.53 a
T_2	24.25 c	12.25 a	8.00 a	52.31 a
T_3	51.25 b	18.00 a	12.75 a	61.93 a
$LSD_{(0.05)}$	16.77	6.28	5.85	17.82
CV (%)	16.40	36.02	48.85	17.70

In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Least Significant Difference(LSD).

[T_1= Caged with honeybees, T_2= Caged without honeybees and T_3= open plot]

Another pollinators *Apis cerena* was nil in T_1 treatment that is caged with bees. But in other treatments *Apis cerena* number is 8.00 and 12.75, respectively which were non-

significant. Only significant different was found in T_1 treatment with T_2 and T_3 treatments. Another insect ant was count in all three treatment. But there is no significant different. Highest (61.93) ant observed in T_3 treatment.

4.2 Time of visitation

There are three visitation time was recorded and presented in Table 2. The first visitation time was 6.00 A. M. to 9.00 A. M. The number of pollinators was highest (101.00) in T_1 treatment followed by T_3 (91.25) treatment which was non significant between them. But in T_2 treatment that is caged without bees was shown lowest (5.25) number of pollinators which was significantly different from T_1 and T_3 treatment. During mid day (2.00 P.M. to 3.00 P.M) comparatively all treatment shows a lowest number of pollinators. Among them T_1 shows the best (10.75) result which was significantly different from T_2 (1.00) treatment. At noon (4.00 P.M. - 6.00 P.M.), the highest number of pollinators was found in T_1 (75.25) treatment followed by T_3 (7.25) treatment with no significant different.

Table-2: Visitation time of different pollinators

Treatment	Visitation time		
	6.00 AM - 9.00 AM	2.00 PM - 3.00 PM	4.00 PM - 6.00 PM
T_1	101.00 a	10.75 a	75.25 a
T_2	5.25 b	1.00 b	2.75 b
T_3	91.25 a	4.75 ab	73.25 a
$LSD_{(0.05)}$	29.30	9.26	22.33
CV (%)	25.73	16.87	25.60

In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Least Significant Difference(LSD).

[T_1= Caged with honeybees, T_2= Caged without honeybees and T_3= open plot]

4.3 Flower initiation of sesame plant

Pollinators are pre-requisite for flower initiation. First flower initiation was observed in T_1 treatment. First flower initiation was started from May 15. After four weeks about 80% of flower was initiated. Table 3 shows the number of flower per plant among three treatments. The highest (101.25/plant) number of flower per plant was recorded in T_1 treatment followed by T_3 (89.50/plant) and T_2 (75.50/plant), respectively has significant difference.

Table-3 : Number of flower per plant

Treatment	Number of flower per plant
T_1	101.25 a
T_2	75.50 b
T_3	89.50 ab
$LSD_{(0.05)}$	18.55
CV (%)	12.08

In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Least Significant Difference(LSD).

[T_1= Caged with honeybees, T_2= Caged without honeybees and T_3= open plot]

4.4 Effect of capsule per plant

The comparative effectiveness of three treatments on Number of capsule per plant has been evaluated and presented in Table 4. The capsule number was increased with the increase of flower initiation. The highest (86.50/plant) number of capsule per plant was recorded in T_1 treatment followed by T_3 (83.50/plant) was not significantly significant different. But T_2 treatment was significantly different among two treatment. As the pollinators number was highest in T_1 treatment, capsule production was increased in T_1 treatment i.e. caged with honeybees.

Table-4: Number of capsule per plant

Treatment	Number of capsule per plant
T_1	86.50 a
T_2	58.75 b
T_3	83.50 a
$LSD_{(0.05)}$	10.13
CV (%)	7.68

In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Least Significant Difference(LSD).

[T_1= Caged with honeybees, T_2= Caged without honeybees and T_3= open plot]

4.5 Effect of Seed production per Capsule

Number of seeds per Capsule was recorded among three treatments has been evaluated and presented in Table 5. The highest (56.75/capsule) number of seeds per capsule was recorded in caged with honeybees plot i.e. T_1 treatment followed by caged without honeybees and open plot that is (45.75/capsule) and T_3 (51.50/capsule) and T_2 which were significant different from each other.

Table-5: Number of seeds per capsule

Treatment	Number of seeds per capsule
T_1	56.75 a
T_2	45.75 b
T_3	51.50 c
$LSD_{(0.05)}$	3.72
CV (%)	4.20

In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Least Significant Difference(LSD).

[T_1= Caged with honeybees, T_2= Caged without honeybees and T_3= open plot]

4.6 Effects on thousand seed weight of sesame plant

The comparative effectiveness of three treatments on 1000 seed weight (gm) has been evaluated and presented in Table 6. The best (3.48 gm) result was found in T_1 treatment (caged with honeybees) followed by T_3 treatment (3.20) i.e. open plot which was significantly different. The lowest weight was found in T_2 treatment (2.85) followed by T_3 treatment which significant difference.

Table 6: Thousand seed weight of sesame under three treatment after harvest

Treatment	1000 seed weight (g)
T_1	3.48 a
T_2	2.85 c
T_3	3.20 b
$LSD_{(0.05)}$	0.23
CV (%)	4.19

In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Least Significant Difference(LSD).

[T_1= Caged with honeybees, T_2= Caged without honeybees and T_3= open plot]

4.7 Effectiveness on yield of Sesame under three treatments

The comparative effectiveness of two treatments on yield (t/ha) has been evaluated and presented in Table 7. The highest (1.12 t/ha) yield (t/ha) was found in T_1 treatment that is caged with bees followed by T_3 treatment (1.03 t/ha) i.e. open plot has no significant difference. But there is a significance different between T_2 (0.78 t/ha) treatment and other treatments (T_1 and T_3).

From the above findings it was revealed that in case of yield (t/ha) the plot that was caged with honeybees performed better than other plot.

Table 7: Yield of sesame under different treatments after harvest

Treatment	Total yield (t/ha)
T_1	1.16 a
T_2	0.78 b
T_3	1.03 a
$LSD_{(0.05)}$	0.16
CV (%)	9.63

In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Least Significant Difference(LSD).

[T_1= Caged with honeybees, T_2= Caged without honeybees and T_3= open plot]

4.8 Relationship between No. of capsule/ plant and No. of Flower/plant

Correlation study was done to established a relationship between No. of capsule/ plant and No. of Flower/plant. From the study it was revealed that significant correlation existed between the characters (Figure-1). The regression equation y= -0.943x -8.98 gave a good fit to the data and value of the co-efficient of determination (R^2 = 0.999). From this it can be concluded that the capsule number per plant was increase with the increase of flower number per plant.

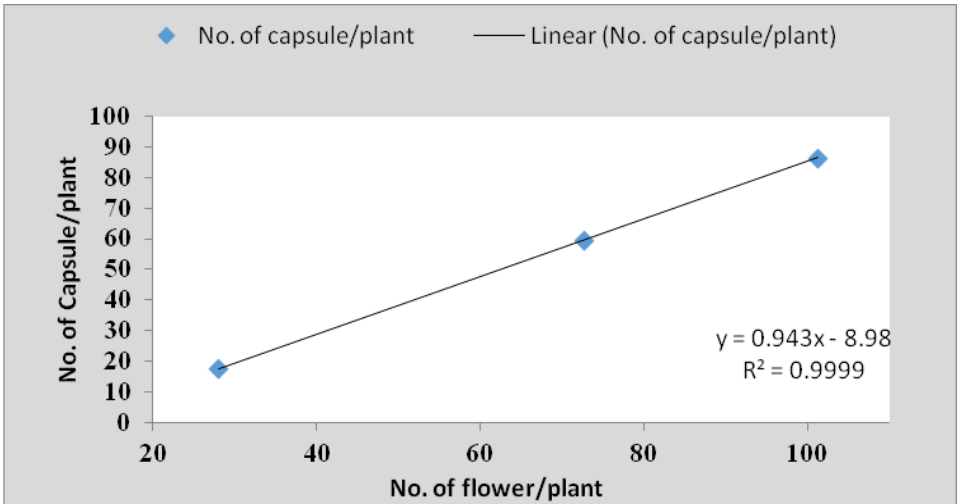

Figure-1: Relationship between No. of capsule/plant and No. of Flower/plant

4.9 Relationship between No. of Capsule/plant and yield of sesame

Correlation study was done to established a relationship between no. of Capsule/plant and yield. From the study it was revealed that significant correlation existed between the characters (Figure-2). The regression equation y= 0.004x +0.74 gave a good fit to the data and value of the co-efficient of determination (R^2 = 0.972). From this relations it can be concluded that the yield was increased with the increase of number of capsule per plant.

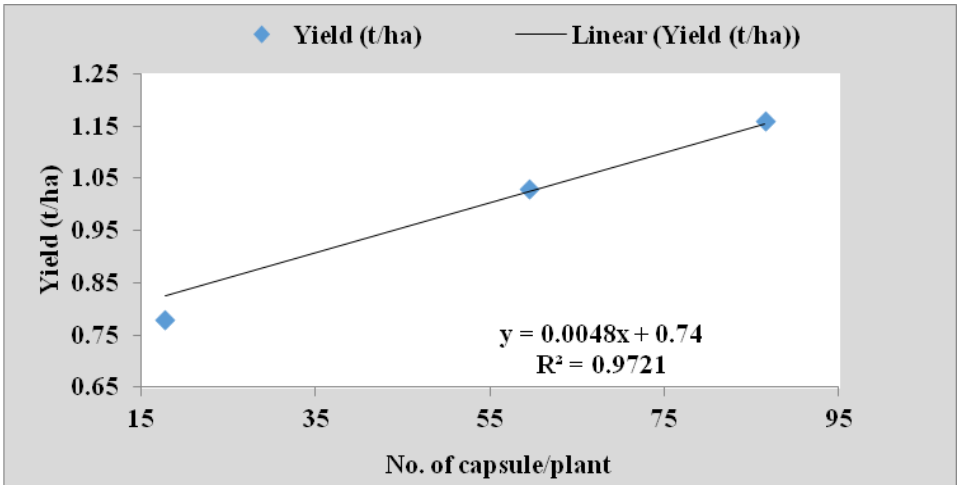

Figure-2: Relationship between No. of capsule/ plant and Yield (t/ha)

4.10 Major insect orders visiting sesame plant during flowering period

Data were carried out on the major insect orders visiting sesame during flowering period from May 2013 to June 2013. Figure 6 revealed that four groups of pollinators visited the sesame belonging to order Hymenoptera, Diptera, Lepidoptera and Coleoptera of class insecta during the flowering period. The number of Hymenoptera was higher, followed by Lepidoptera, and then both of Coleoptera and Diptera. The results indicate that hymenopterans and Lepidopterans are the major pollinators visiting sesame flowers.

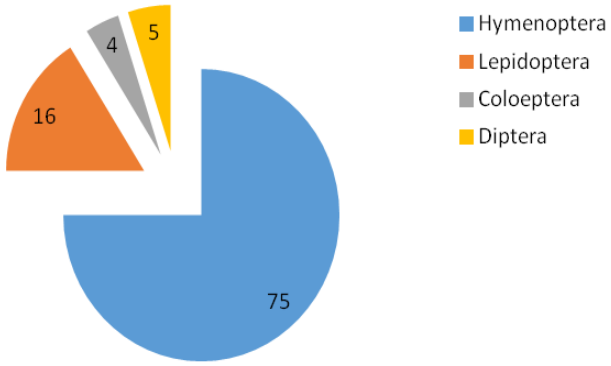

Fig-3: Percentage proportion of the major insect orders visiting sesame during flowering period of sesame

4.11 Hymenopterous population during flowering period

Interestingly, the types as well as the number of insect visitors changed with time during the flowering span of the sesame crop. Results in Figure 7 revealed that insects belonging Hymenopterous order increased by increasing the percentage of flowers. A great majority of the sesame flowered between third and fourth week. 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.

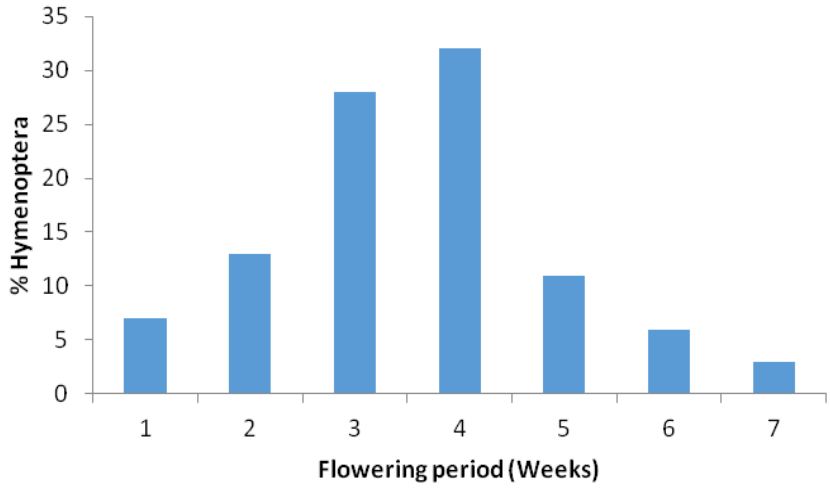

Fig-4: Fluctuation percent of Hymenopterous population during flowering period from May 15 to June 30, 2013

4.12 Foraging activity of the major insect orders visiting sesame during flowering period

Data in Figure 5 showed the foraging activity of the major insect orders visiting sesame during flowering period. Peak of foraging activity was observed in Hymenoptera order during 9-11 am in our study. The comparison among number of different bee species clearly showed that the number and foraging activity of *Apis mellifera* was higher than *Anthidium sp.* and *Xylocopa sp.* at all four time period i.e., 9.00-11.00 AM, 11.00-1.00 PM, 1.00-3.00 PM and 3-5 PM (Figure 5). The maximum number of *A. mellifera* was observed during 9.00-11.00 AM and decreased with time during the day. This is because nectar flow is copious in the sesame crop especially in the morning period; there after the nectar concentration gradually diminishes.

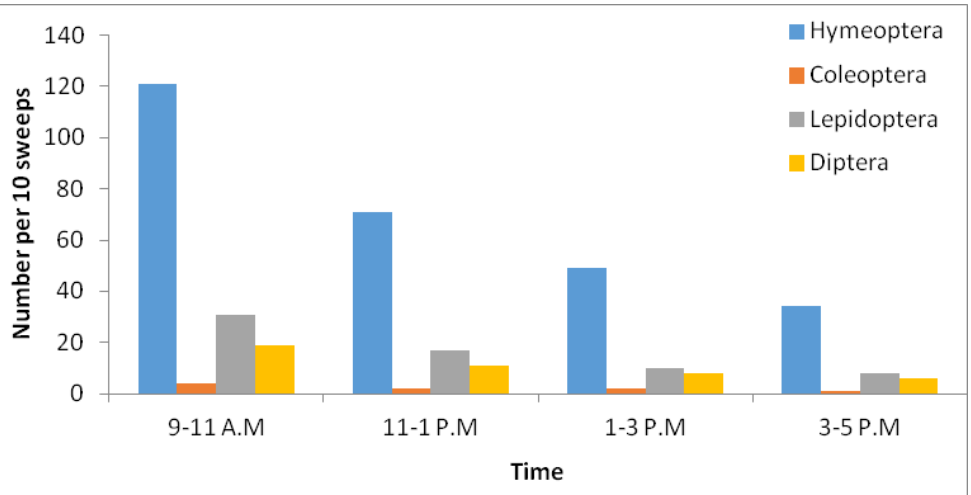

Fig-5: Foraging activity of the major insect orders visiting sesame during flowering period from May 15 to July 30, 2013

CHAPTER V
SUMMARY AND CONCLUSION

Effect of bee pollination on the yield of sesame (*sesamum indicum* L.) were investigated at the farm of the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from April 2013 to July 2013. The three treatments are T_1= Caged with honeybees, T_2= Caged without honeybees and T_3= open plot. The experiment was laid out in single factor Randomized Complete Block Design (RCBD) with four replications.

Different insect pollinators visited in sesame plot. Highest pollinators number was observed in caged with honeybee managed plot. In T_1 treatment a honeybee hive was set into the cage. So the number of *Apis mellifera* was highest (101.75) in T_1 treatment which was significantly different from T_2 (24.25) treatment , Due to the design of T_1 treatment , *Apis dorsata/ Apis florae* species, there is no number of bees was found in T_1 treatment. But in T_2 and T_3 treatments that is caged without bees and open plot respectively was shown 18.00 and 12.75 Number of *Apis dorsata/ Apis florae* and *Apis cerana* which were non-significant. T_1 treatment is significantly different between T_2 and T_3 treatments. The highest (61.93) ant was found in T_3 treatment that is open plot. But no significant difference was observed.

Commonly pollinators visited mostly in the morning and evening. Three visitation time was recorded. They are 6.00 -9.00 AM, 2.00-3.00 PM and 4.00-6.00 PM. The number of pollinators was highest (101.00) in T_1 treatment followed by T_3 (91.25) treatment which was non-significant between them. But T_2 treatment was shown lowest (5.25) number of pollinators which was significantly different from T_1 and T_3 treatment. During mid-day (2.00-3.00 PM) comparatively all treatment shows a lowest number of pollinators. Among them T_1 shows the best (10.75) result which was significantly different with T_2 (1.00) treatment. At noon (4.00- 6.00 PM), the highest number of pollinators was found in T_1 (75.25) treatment followed by T_3 (7.25) treatment which has no significant difference.

First flower initiation was started from May 15. Flower number is important for sesame seed production. The highest (83.50/plant) number of flower per plant was recorded in T_1 treatment followed by T_3 (81.25/plant) and T_2 (78.50/plant), respectively which has no significant difference.

The capsule number was increased with the increase of flower initiation. The highest (86.50/plant) number of capsule per plant was recorded in T_1 treatment followed by T_3 (83.50/plant) which was not significantly different. But a significant difference was found in T_2 (58.75/plant) treatment among other treatment. As the pollinators number was highest in T_1 treatment, capsule production was increased in T_1 treatment i.e. caged with honeybees.

In terms of seed production per capsule, the highest (56.75/capsule) number of seeds per capsule was recorded in caged with honeybees plot that is T_1 treatment followed by caged without honeybees and open plot that is T_2 (45.75/capsule) and T_3 (51.50/capsule) treatments which has significant difference. Again considering the thousand seed weight of sesame, The best (3.48 g) value was found in T_1 treatment (caged with honey bee) followed by T_3 treatment (3.20) i.e. open plot treatment which was significantly difference and lowest weight of 1000 seeds was found in (2.85g) T_2 treatment followed by T_3 treatment with significant difference. The highest yield (1.12 t/ha) was found in T_1 treatment that is caged with honey bees followed by T_3 treatment (1.03t/ha) that is open plot without significant difference while significantly lowest yield was recorded in T_2 (0.78 t/ha) treatment.

Conclusion

- Peak of foraging activity of *Apis mellifera* in sesame field was observed during 6.00-9.00 AM in our study.
- The best yield performance was recorded in caged with honeybee plot
- Flower Number, Capsule number, Number of Seeds per Capsule, and 1000 seed weight was increased in caged with honeybee plot.

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

1. A bee hive may be attached beside a sesame field to enhance pollination and production.
2. Further intensive studies based on foraging should be done.

CHAPTER VI

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APPENDICES

Appendix I. The physical and chemical characteristics of soil of the experimental site as (0-15 cm depth).

Mechanical composition:

Soil parameters	**Observed values**
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 mcq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil

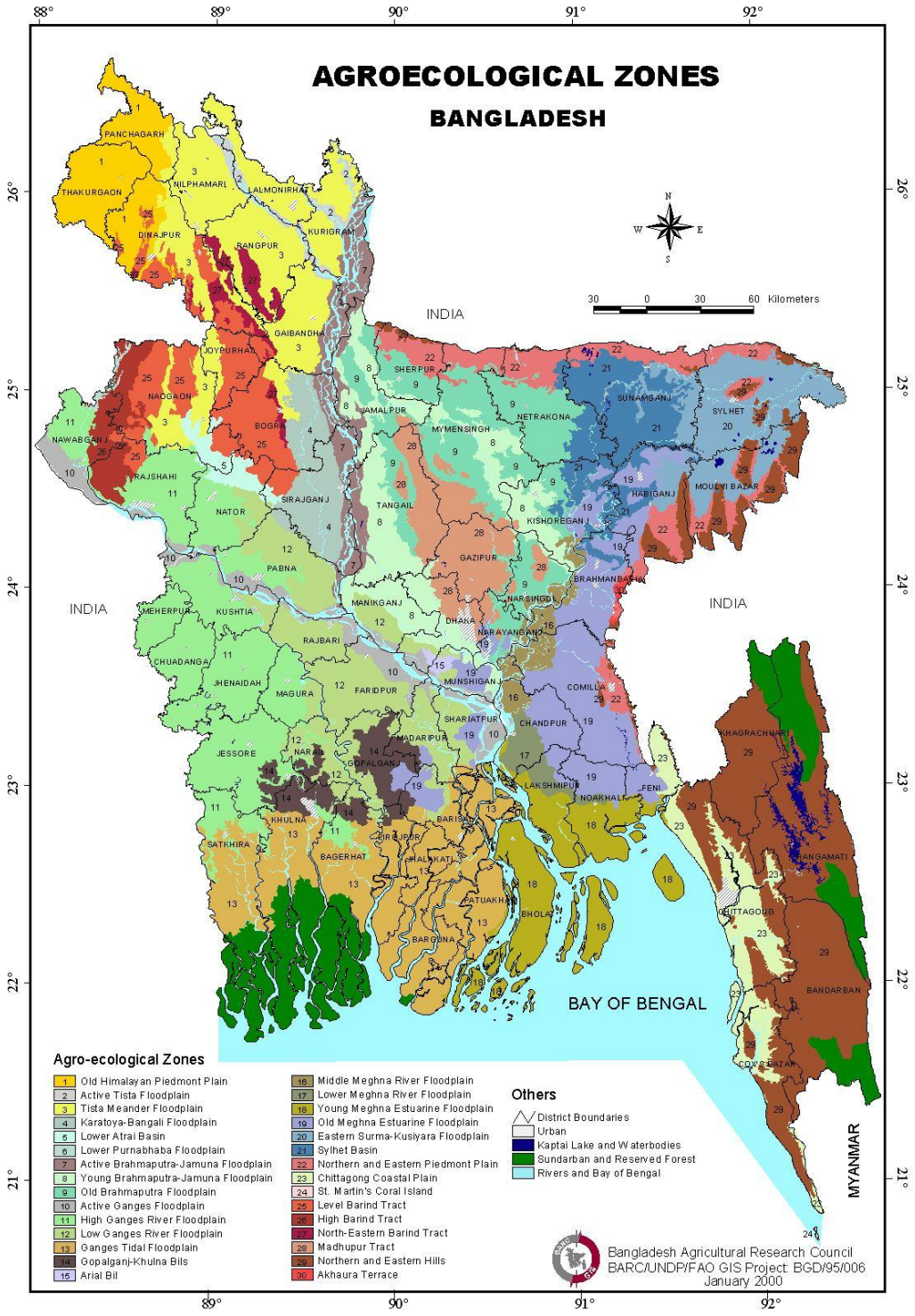
Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka.

Appendix II: Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from April 2013 to July 2013

Month	**Temperature**		**Relative Humidity (%)**	**Total Rainfall (mm)**
	Max	**Min**		
April	33.9	23.6	71	156.3
May	32.9	24.5	76	339.4
June	32.1	26.1	82	340.4
July	31.4	26.2	83	373.1

Source: Climate and Weather Division, Bangladesh Meteorological Department, Agargoan, Dhaka- 1207.

Appendix III. Experimental location on the map of Agro-ecological Zones of Bangladesh.



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.