STUDY ON POLLINATOR DIVERSITY IN LITCHI ORCHARD

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CERTIFICATE

There is to certify that the thesis entitled **STUDY ON POLLINATORS DIVERSITY IN LITCHI ORCHARD,** Submitted to Department of Entomology, the faculty of Agriculture, Sher-e-Bangla Agriculture University, Dhaka. In partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN ENTOMOLOGY, embodies the result of a piece of Bonafede research work carried out by **Ruaida Armin, Registration No. 14-06013,** Under my supervision and guidance.

No part of their thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information has been availed of during the course of their investigation has duly been acknowledge.

Date: June, 2021

Place: Dhaka, Bangladesh

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DEDICATED TO MY

BELOVED PARENTS

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The Author

Study On Pollinators Diversity in Litchi Orchard

By

Ruaida Armin

Abstract

A study was conducted in the village Kachubari of Thakurgaon district in a litchi orchard to keep record of the diversity and relative abundance of litchi flower visiting insect and to see the production difference in the condition of netting (T_2) and without netting (T_1). In without netting (T_1) condition, the maximum number of inflorescences per branch was 8.01(no.) whereas the minimum no was 8.03 (no.) in netting condition. The percentage of Male, Female and Hermaphrodite flower was 28%, 40% and 32% respectively. We have found different kind of insect's species that visit the litchi flower including honeybees, ants, different flies and some other insects. The most visited pollinator were Honeybee (49.72%) then Ant (36.5%) and the lowest visited was Dipteran (22%). The other foraging insects were some Lepidopteran, Coleopteran, Hemipteran etc. The foraging time of the honeybees were high at 6.00am to 8.00am and 4.00 pm to 6.00 pm. The butterflies were present during 10.00 pm to 2.00 pm. Other than honeybees the ant and the flies were noticed almost throughout the day. In the netting condition the flies, honeybees, butterfly, beetles and other foraging insects were not able to enter the net but ants were seen in the net. The yield difference between the netting and without netting condition was very significant. In netting condition, the yield was 8% (0.11 kg/branch) whereas without netting condition it was 92% (1.28 kg/branch) due to the pollinating agent. From this study it is evident that the role of pollinators on litchi orchard is very significant. It also helps to let us know to conserve pollinator in Litchi orchard.

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ABBREVIATIONS AND ACRONYMS

FULL WORD	ABBREVIATION
And others	*et al*
Cultivar	cv.
Degree Celsius	℃
Id est (means That is)	i.e
Figure	Fig
Gram	G
Kilogram	Kg
Namely	Viz
Percentage	%
Species (plural number)	Spp
Variety	var

CHAPTER I

INTRODUCTION

Litchi (*Litchi chinensis)* is one of the main summer fruits in Bangladesh. It is also a very important commercial fruit which is the sole member of the genus Litchi in the Sapindaceae family. Litchi is a tall evergreen tree. It bears small, berry type fruit. The fruit is very delicious and juicy pulp with attractive color and flavor. Litchi is also an important source of vitamin C. Litchi contains 77.83% water, 6.74%-20.64% sugar, 0.8-0.9% protein, 0.3% fat, mineral specially calcium, phosphorus and iron 0.7% and vitamin C 40.2-90mg/100g of fruits. (Bose and Mitra 1990, Scanlan 1995).

Litchi was originated in southern China but it is now cultivated throughout the warm sub-tropics and is believed to have been introduced in the Indian sub-continent, through Myanmar towards the end of the 17^{th} century (Bose and Mitra 1990). The leading Litchi growing countries of the world are China, Myanmar, Taiwan, Thailand, India, Pakistan, Philippines, West Indies, USA (Hawaii and Florida), Brazil, Israel, Madagascar, South Africa and Australia (Menzell and Simpson 1986, Tindall 1994). Litchi is grown through out of Bangladesh in different areas are Rajshai, Dinajpur, Thakurgaon, Jessore, Khulna, Kustia, Dhaka, Chittagong district. Bombay is the oldest high yielding variety in the country, although there are a number of cultivar growing in different areas of Bangladesh. These are Rajshahi, Madrajie, Mongolbari, Kadmi and Kalipuri. Muzaffari, Bedana and China-3, introduced in the 1950's are now successfully in different part of Bangladesh. (Siddiqui, Litchi production in Bangladesh).

The world litchi production is estimated about 3.5 million ton of which 80% (2.8 million ton) of litchi was produced in China in 2018 (S.k. Mitra and J. Pan 2020). The other major producers are India (0.67 million ton), Vietnam (0.38 million ton), Madagascar (0.10 million ton), and Thailand (0.048 million ton).

In Bangladesh, the most litchi produced in Dinajpur District which is the northern part of the country. Due to its suitable geographical location, soil

condition and rainfall large number of litchi are produces in this district. Dinajpur district has an average elevation of 37 meters above sea. The study areas were belong to the old Himalayan piedmont plain of Agro-Ecological Zones (AEZ) (BBS 2013).

Pollinators are very significant for the pollination of the litchi and to expect the high yield. The total pollination activities, over 80% is performed by insects and bees. Therefore, they are considered the best pollinators (Robinson and Morse 1989). Insufficient number of suitable pollinators causes a decline in fruit and seed production (Partap 2000).

A total of 12 insect species belonging to the order Hymenoptera and Diptera visited the flowers during the entire blossom period of Litchi. (Kumar *et al.* 2013) 20 pollinator species under 23 genera of 8 families belonging to orders Diptera, Hymenoptera and Coleoptera visiting Litchi flowers in Muzaffarpur, Bihar. (Srivastava *et al.* 2017). *Apis dorsata* Fab., *Apis melliferae* L. and *Apis cerana indica* Fab. as the most important and efficient pollinators of Litchi (Abrol and Kitroo 1998). Besides Honeybees, Syrphids and non-Apis bees also play a very important role in pollination. Syrphids found to be one of the most beneficial groups of pollinators. There are several reasons for conserving pollinator diversity beyond these key pollinator species in the agricultural landscape. One is to provide insurance over time and space, as species that are rarely observed on crops now may, in future, become important (Hector *et al.* 2010; Kleijin *et al.* 2015). Diversity of pollinators needs to protect to increase the total agricultural production and also helpful for sustainable crop production. The significance of pollinators is to increase the volume and quality of the crop.

Litchi is a cross-pollinated crop. Successful pollination and fertilization are the prerequisites for good harvest.

In our study we also found that the production is increased from the previous year as we placed two boxes of Honeybees. Farmers are greatly benefited when they introduced their crop to different pollinator specially the Bees. Now a day many farmers are placing Honey bee boxes on their crop field. Bees not only

increase the crop production but also provide honey to the farmer which is very beneficial to our health and also very economical thus the farmers can sell the extra honey to get some extra income. Other pollinators are do not required to introduced manually as they are naturally attracting to the crops. So it can say that these pollinators are also very important for the crops and environment. Humans activities have destroyed and fragmented many native pollinators habitats. Humans introduced many types of insecticides, herbicides, pesticides and other chemicals for the improvement of the crop production. It has been analysed that decline of honeybee population is due to application of insecticides like organochlorine, carbamate, organophosphorus and pyrthroid. The damage to honeybee colony by application of pesticides not only depends by toxicity of chemical substances, number and methods of insecticides application, time of application, weather but also by type of nectar, type of food flower collected, season of damage and number of honeybee in colony (Bura, M. *et al.* 2005). It has been shown that pyrethroid insecticides and fungicides exhibit synergism if applied to honey bees and increases the toxicity 10 to 100 folds (Colin and Belzunces, 1992, Pilling and Jepson, 1993) Although it helped in the crop production it greatly hampered the pollinators life cycle and their habitats. As a result, day by day it is gradually decreasing the number of pollinators and other beneficial insects, which may pose threat to our environment and crop production. The use of chemicals is increasing gradually the day is not very far when we have to face severe food epidemic.

Therefore, the objectives of the present study were-

- To study the foraging insects of Litchi plant.
- To find out the effect of managed pollination on Litchi yield.
- To study the influence of pollinators on litchi yield.

CHAPTER II

REVIEW OF LITERATURE

Litchi is highly self-sterile and insect-pollination is necessary for the fruit set (Pandey and Yadava 1970, Phadke and Naim 1974). The litchi flowers are visited by many insects during blossoming period. Litchi (*Litchi chinensis Sonn*.) is a member of Sapindaceae family which includes 150 genera and 2000 species and sub-family Nepheleae. It is one of the main sub-tropical tall evergreen trees. It is usually less then 15 meters (49ft) long but sometimes up to 28 meters (92ft) long. Litchi is cultivated in many countries as an important commercial fruit crop. It is famous for its fleshy edible part with juicy and sugary flavor.

Taxonomy of Litchi

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Dicotyledonae

Order: Sapindaceae

Family: Sapindaceae

Genus: Litchi

Species: *Litchi chinensis*

Origin and History of Litchi

Litchi (*Litchi chinensis Sonn.*) is one of the precious and economically important fruit crops of the world. The species belongs to the family Sapindaceae, which comprises about 2000 species of tropical and subtropical trees, shrubs and vines that have been classified into 140 genera (Chapman 1984).

Litchi cultivation was reported since 1500 BC by the people of Malayan descent and has been growing for thousands of years in southern Guangdong province of China. The first reference to this fruit is available in the literature

of the Han dynasty (140 BC to 86 BC). It is sure that litchi is native of South China but according to Blume, Cochin-China and the Philippine islands are the lands of its origin (Popenoe 1920).

It is reported to have originated in Chinas Kwangtung and Fukein provinces and have been cultivated in China for about forty centuries (Ochse *et al* 1961). A monograph written by Tsai Hsiang in 1059 AD is considered to be the first publication in the world devoted to this fruit (The Litchi Biotechnology).

From China it reached Burma (Myanmar) by the end of the seventeenth century and was introduced in India about 100 years later. Litchi reached Madagascar and Mauritius around 1870 and was introduced in Hawaii in 1873 by a Chinese trader. It arrived in Florida from India, between 1870 and 1880 and was - introduced in California in 1897. Litchi was reported to be brought to Australian by Chinese migrants in 1954 and arrived in Israel sometime between 1930 and 1940 (Koul and Singh 2017).

The litchi which originated in China, was introduced to Israel in the 1930s. Only two cultivars have been planted commercially: 'Mauritius'. Introduced from South Africa, and 'Floridian', introduced from the U.S. The latter is probably a seedling of cv. Brewster (Degani *et al* 1995b).

Distribution

Litchi is undoubtedly an interestingly delicious fruit. It is loved by all because of its variety of colors, smell and variety. The temperate climate of the evergreen tree litchi requires specific climatic adaptation. Due to which litchi cultivation is done commercially in a few countries of the world.

Among the countries where Litchi is widely cultivated are China, India, Australia, Vietnam, Thailand, Taiwan, Israel and South Africa. It is found in relatively high areas of the country. The name of the country in the world that comes easily with the name litchi is China where the lion's share of the world's total Litchi production. It can be said that it is the center of Litchi cultivation.

Litchi is also one of the most important fruit crops in Bangladesh and also plays an important role in our economy. In Bangladesh and India, it is a

summer fruit and here it blooms in February and the fruit usually ripens in May. Litchi is widely grown in Murshidabad, Malda and Dinajpur districts of West Bengal, India and all over Bangladesh, but it grows well in Dinajpur, Rajshahi, Natore, Meherpur, Magura, Moulovibazar and Ishwardi upazila of Pabna in North Bengal.

Production

Litchi plantation requires a warm subtropical to tropical climate (Rivera-Lo'pez *et al* 1999). Besides China and India, Litchi fruit is also grow as a commercial crop in subtropical Asia, Hawaii, Israel, Mexico, Australia and South Africa (Jiang *et al* 2001). India is the second largest producer of litchi after China with an annual production of 428,900 metric tons from 56,200 ha. Litchi is mostly grown in Eastern India, and Bihar state alone contributes to 74% of Indian litchi production. As litchi is an introduced fruit crop, it has great potential of yield in India (Koul and Singh 2017). In Bangladesh Litchi covered 43901 ha area of total crop production of Litchi is 798348 MT (BBS 2020). Litchi production is highest in Rangpur division (20372 MT) and lowest in Barisal division (BBS 2020).

Climate and Soil

Flowering, fruit set, fruit quality, bud initiation, and flavor are depend on the temperature, relative humidity, rainfall and soil quality. For litchi cultivation deep well-drained loamy soil having a pH 6.5-6.8 is suitable, although litchi is not fastidious about its soil requirements and in Bangladesh it grows in all types of soil. However, it performs better in deep sandy loamy soil. The selected land should be flood free, open and under direct sunshine (Siddiqui 2001).

Litchi is adapted to the warm sub-tropics where summer is long and hot (temperature >25 ℃), with moderate precipitation (1200 mm) and high humidity. It can be grown on a wide range of soil types, but well drainage deep fertile loamy soil of high land is best. However, it grows better in deep sandy loamy soil. (Zannat *et al* 2021). Dinajpur is the best for litchi cultivation which is a part of Barind tract which belongs to an old alluvial formation and usually

composed of massive argillaceous beds of pale radish brown color that often turn yellowish on weathering. Kankar (lime nodules) are pisolitic ferruginous concentrations occur throughout the soil. Locally the soils vary from 6.0 to 7.5 (Husain 2020).

Our experimental site was Thakurgaon which is also belongs to an old Himalayan piedmont plain area.

The litchi growers are interested in litchi production for its economic benefit but Deep, well drained loamy soil, rich in organic matter having pH in the range of 5.0 to 7.0 is ideal for litchi cultivation (Chowdhury and Hassan 2013).

Insect pests of Litchi

Insect pests and diseases are one of the main constraints of litchi production. They also responsible for the deterioration of quality product. Litchi fruit borer, leaf curl mite and leaf-miners are the major pest of litchi. They attack the young fruit and leaf and cause damage to the fruit production. In Bangladesh, litchi fruit borer (*Argyroploce illepida*), leaf curl mite (*Aceria litchi*) and leaf-miners (*Acrocercopus spp*.) were serious (major) pest whereas leaf eating caterpillar, bark eating caterpillar (*Indarbela spp.*) snow scale insect *Chionaspis sp.* Shoot borer (*Chuletia transversa*) and lac insect *lacca spp*. were minor pest (Ahad 2010). Litchi trees are attacked by a number of pests-both insects and mite (Alcock 1903, Fletcher 1921, Singh and Singh 1954, Wadhi and Batra 1964 Vevai 1971 and Singh 1975).

Litchi fruit and shoot borer damages the developing and mature fruits and reduce yield and marketability. Litchi mites causes serious damage to the leaf and young fruits. Thus, it causes serious loss in the yield.

Litchi Flower

Three types of flowers are found in litchi, which open in succession on the same panicle and the flowers vary in sexual development, length and functionally of the stamens and development and functionally of the pistil (Mustard *et al* 1953, Stern and Gazit 1998).

Three distinct flowering waves can usually be observed in every florescence. Each wave consists of flowers of the same type: the first wave consists of male

flowers(M1), the second of female flowers(F), and the third of pseudohermaphroditic flowers, which function as males (M2) (Scholefield 1982, Joubert 1986, Costes 1988, Stern *et al* 1993b). There is a similar number of open flowers at each wave (Stern *et al* 1993a). The transition between waves in the same inflorescence is distinct. The anthers in M and M2 flowers dehisce gradually throughout the day and night (McGregor 1976, Menzel 1984). Female flowers remain receptive for 3 days from anthesis (Chaturvedi and Saxena 1965).

Types of litchi flower

Three types of flowers of different distinct sexual forms are found in litchi They all form on the same panicle and mature at different times over a two-to-six-week period on most cultivars. The flower types are Male, Female and Hermaphrodite. A Hermaphrodite flower carrying both male and female part in the same flower. Male flower open and release viable pollen. Hermaphrodite female flowers open which set fruit if pollinated and Male Hermaphrodite flowers open and shed viable pollen. The Male and Male Hermaphrodite flowers produce the pollen that fertilizes the female, although the Male flowers in the third stage are most responsible for fertilization as the anthers of these flowers tend to shed the most viable pollen (Beeaware.org.au).

Male flower

Male flowers usually have 7-9 stamen filaments connecting to the base. The pollen bearing anthers are attached to these long filaments. When the pollen is ripe the anthers turn yellow and break open to release the pollen to fertilize the female flowers. Each anther may produce several thousand grains of pollen. When the pollen comes into contact with the stigmatic surface of the female flower the pollen germinates and forms a tube which penetrates into the stigma and then the ovary (litchisonline.com).

Female flower

A fully developed Hermaphrodite female flower bear 3 parts: ovary, style, and stigma. The female flower also has stamen with pollen sacs that never open to release pollen and degenerate. Female flowers usually open in the earlier

morning from 7-8 am and again in the afternoon between 2-5 pm (Litchisonline.com).

Hermaphrodite flower

Hermaphrodite male flowers have degenerated pistils (the receptive female part that has a stigmatic surface that receives pollen) with undeveloped ovaries and no stigma on their styles. These cannot form fruits.

Fig:1 Hermaphrodite male flower

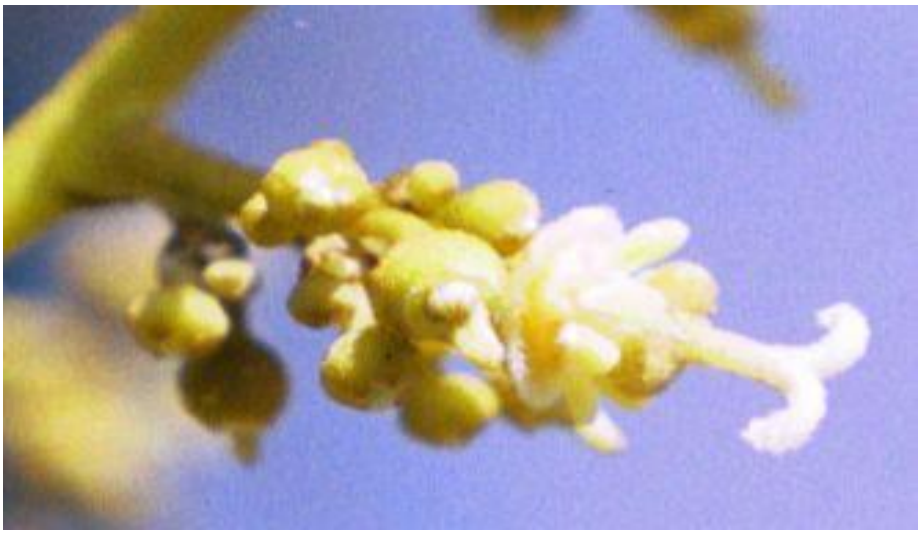

Fig:2 Hermaphrodite female flower.

Fig : 3 Male flower

Pollinators

Insect Pollinators are the great help for the food production and development. They also very significant for the environment sustainability and to keep the environment balanced. Most of the plants especially the flowering plants need pollinator for pollination process. Most flowering plants (75%) require an animal pollinator (Burger 1982, Gullan and Cranston 2010). There are over 200000 species of animal pollinators and the vast majority of these are insects (Berenbaum 2007). Insect pollinators include honey bees, solitary bees, wasp, butterfly, moth, fly, ant, bumble bees, and beetles. Many crops benefit from pollinators because they enhance output and improve quality. By buffering the effects of climate change and changing land use, good pollination can promote agricultural production stability, lowering year-to-year and place-to-place variability in yield. When there aren't enough insects to pollinate crops that demand it, they won't be capable to achieve full potential.

Insect pollinators are very beneficial for entomophilous crops. Adequate amount of nectar in the flower attracts honeybees, flies, ants, butterfly and wasp which leading to successful pollination.

Kings *et al.* (1998) stated that pollination of entomophilous crops by honeybees is regarded as one of the effective and cheapest method for improving the yield and quality of crops.

Pollinator populations and the pollination services they provide are threatened by changing farm land use, illness, intense agricultural management methods, environmental pollution, invasive alien species, climate change and agrochemicals. Both controlled and wild pollinator populations have experienced a decline in numbers and species richness as a result of this. With the rising demand for food and the primary goal of ensuring food security, there is an urgent need to conserve and manage insect pollinators. Pollination is an essential ecosystem service for most of the agricultural system. Three quarters of globally important crops benefit at least in part from animal pollination which can increase the yield, quality and economic value of crops. As the global population continuous to grow and demand for food production increases, the areas of flowering crops needed to meet this demand will continue to expand and so will the reliance on pollination services. Pollinators provide a wide range of production, economic, and health benefits and they will need to be increasingly considered as a legitimate agricultural input contributing to food security.

According to Aastha Gautam in her research on role of insect pollinators on crop production (2020), she provides some information about pollinators. She said that there are about 250000 species of flowering plants globally which are pollinated by 200000 species of animals. Out of 95 percent of the flower which are cross pollinated, more than 85 percent depend on insects for pollination. Insects pollinators include honey bees, bumble bees, pollen wasp, ants, flies including bee flies, hoverflies and mosquitos, butterflies and moths and flower beetles. Fifty percent of the plant species propagated by seed are dependent on insect pollination whereas one third of the food supply is either directly or indirectly depend on these insects pollinated plants. Similarly, more than 65 percent of all flowering plants are insect pollinated. Sustainability of ecosystem, environmental quality and biodiversity conservation is all

maintained through propagation of wild species brought about by insect pollination.

World top pollinators

Bees (73%)

Flies (19%)

Bats (6.5)

Beetles (5%)

Wsaps (5%)

Birds (4%)

Butterfly and Moth (4%)

Globally there are many pollinators that play an essential role in pollination both intrinsically and extrinsically. Some pollinators are significant pollinators that participate in enormous numbers.

Honey bee (*Apis spp.)*

Honey bees are the large group of pollinator. Nearly 17,000 species of bees have been formally described, and as many as 30,000 are estimated worldwide (Michener 2000, Griswold, USDA, Bee Biology and systematics Laboratory, presentation to the committee, 2005). *A.mellifera* is highly suitable as a commercial pollinator because of its biology (Hoopingarner and Waller 1992). Several other bees produce and store some kind of honey, but only members of the genus Apis are true honey bees (Kleinjans *et al.* 2012). The western honey bee (*Apis melliferae* L.) provides highly valued pollination services for a wide variety of agricultural crops (Calderone 2012). And ranks as the most frequent single species of pollinator for crops worldwide (Garibaldi *et al.* 2013).

Syrphid (*syrphus sp)*

Syrphid fly also known as ‘Hoverflies’ are the member of the family Syrphidae, which is a well-known group of fly pollinators. Syrphids are found all throughout the world and there are over 6000 different species. Hoverflies are important pollinators of flowering plants worldwide (Larson *et al.* 2001). Often hoverflies are considered to be the second most important pollinators after wild bees. (Larson *et al.* 2001).

Moreover, the importance of syrphids to pollination has been estimated to be equal to that of bees in a number of global evaluations, at least in some circumstances. Syrphids, unlike bees are more mobile and capable of visits longer distances, allowing them to disperse pollen across wider areas. Additionally, many syrphid species disperse and these dispersion events contribute to extreme pollen distribution, which has been estimated to involve a number of individuals similar to that of British managed honeybees at maximum population size the United Kingdom.

Wasp *(Vespa tropica)*

Wasps are the member of the order Hymenoptera and include in the family of the vespidae. Wasps are mainly a predator insect they do not fed on pollen so they do not participate in pollination much but during prey on the insects they travel from flower to flower as a result some pollen are attached to their body. The wasps are smooth-bodied and they do not belong much hair so a small amount of pollen are attached to the body. Eventually, they do provide some incidental pollination, carrying and dropping some pollen grains as they move among flowers.

Ants *(Camponotus compressus*)

Ants are under the order of Hymenoptera and the Family is Formicidae. Ants are the wingless insects they crawled into each flower to collect sugar. Although ants are collectively involved in thousands of inter actions with plants and are commonly observed on flowers, they pollinate few species (about 20) of angiosperms (Thien and Rico-Grey 2004, Rico-Gray and Oliveira 2006)

Beetles

Beetles are the member of Coleoptera order which are the largest insect order. With about 350,000 described species, beetles constitute the largest insect order (Grimaldi and Engel 2005). Beetle pollination is believed to have contributed to the pollination of different lineages of flowering plants for over 120 million years (Bernhardt 1999).

Butterfly and moth

Butterfly and Moth both belong to the order Lepidoptera. They also take a vital role in the pollination. Butterflies attract to the big petal and colorful flower the most. As the moths are the nocturnal they visit the flower during the night time. They are known to pollinate a diverse suite of plants, ranging from cacti (Clark-Tapia and Molina-Freaner 2004) to orchid (Little *et al.* 2005) to trees (Lin and Bernardello 1999). They are not major pollinator of food crops but various moths are important pollinators of other commercial crops such as tobacco. Pollination by certain moths may be important, however or even crucial for some wildflowers mutually adapted to specialist pollinators. The legs and the butterfly's proboscis are longer and farther away from the flower's pollen so less pollen collects on its body parts than it does on bees, but still, they are very effective pollinators (Cerruti *et al.* 2020)

Fly

The true flies (order Diptera) are among the most diverse of the insects, with more than 150000 species described (Thompson 2006). Flies might have been the first pollinators (Labandeira 1998).

Most higher flies are flower visitors and many have been documented as pollinators. Flies as flower visitors (antophiles) and pollinators have been reviewed by Larson and colleagues (2001).

Research that has been done within the last 15 years showed that fly pollination dominates in plants species that are recognized by small flowers that flourish under shade and in seasonally moist habitats.

Effect of insect pollinator

There are three types of flowers of varying distinct sexual forms occurring in Litchi. They are all form on the same panicle and mature at different times over a two to six-week period on most cultivar. Type-1 flowers are functionally male, lack ovules and having 6-8 stamens which produce much pollen. Type-2 flowers are Hermaphrodite but function as female with well-developed pistil and stigma, having 5-8 stamens which do not dehisce. Type-3 flowers are male, having 6-8 stamens which produce plentiful viable pollen. They also have a rudimentary pistil which lacking of style and stigma (stern and Gazit 1998).

Anthesis of flowers occurs in overlapping cycles, normally of 10 days for type 1, 7-10 days for type 2 and 7-10 days for type 3 (Mustard *et al.* 1953, Stern and Gazit 1996). In spite of presence of functional male and female flowers on a single tree, at the same time, self-pollination does not occur in Litchi, as the Hermaphrodite flowers are generally recognized as self-sterile and therefore, insect pollination is necessary for the proper fruit set (Pandey and Yadava 1970 Phadke and Naim 1974). Existence of rich amount of nectar in the self-sterile flowers, engage insect like honeybees, ants, butterfly wasp leading to entomophilic cross pollination. Among different types of these insect's honeybees are found to be most beneficial. Litchi flowers are functionally unisexual; Fruit set can occur only if pollen from male flowers is transferred to the stigma of female flowers. Litchi flowers are entomophilic and pollination is usually performed by insects one of which is the honey bee (Mcgregor, 1976, King *et al.* 1989, Free 1993). A large number of insects especially bees, visit lichee flowers mainly during the morning hours (Free, 1993, Pivovaro 1974). Adequate pollination is ensured by the facts that the female flowering wave occurs between two pollen releasing waves (M_1 and M_2) and by the abundance of pollinating agents (Groff 1943**,** Butcher 1956,1957 Pandey and Yadava 1970, McGregor 1976, DeGrandi Hoffman 19887), provided that weather condition do not limit bee activity (Menzel 1984). Litchi flowers are visited by variety of insects including Coleoptera, Hemiptera and Lepidoptera; however, honeybees, ants, flies and wasps are important flower visitors (Chaturvedi 1965). Pandey and Yadava (1970) found that *Apis* and *Melipona spp.* represent 98-99% of the all visitors of Litchi, but *Apis melliferae* plays leading role and recognized as the principal pollinator (McGregor 1976, Vithange and Ironside 1986)

Pollination

Pollination is an ecosystem process that has evolved over millions of years to benefit both flowering plants and pollinators. Pollination is the act of transferring pollen grains from the male anther of a flower to the female stigma. The goal of every living organism including plants is to create

offspring for the next generation. One of the ways that plant can produce offspring is by making seeds. Seeds contain the genetic information to produce a new plant. Pollination is usually the unintended consequences of an animal's activity on a flower. Flowers are visited by many pollinators for many reasons including feeding, pollen collection and warmth. When pollinators visit flowers pollen rubs or drops onto their bodies. When pollinators visit another flower for the same reason, pollen can fall off onto the flower's stigma and may result in successful reproduction of the flower. This process is a vital stage in the life cycle of all flowering plants and is necessary to start seed and fruit production in flowers. Pollination contributes a great role in genetic recombination and survival of plant species in heterogenous environment. Many plants can reproduce vegetative or by self-pollination but it is not possible for most plant species and for long distance colonization and genetic combination. Pollinator facillated reproduction is the key factor maintaining population of ephemeral or sparsely distributed plant species. Pollination not only contributes in production of fruit and seed but also support associated food webs. Pollination is not just fascinating natural history. It is an essential ecological survival function. Without pollinators, the human race and all of earth's terrestrial ecosystems would not survive. Of the 1400 crop plants grown around the world, i.e., those that produce all of our food and plant-based industrial products, almost 80% require pollination by animals. Visits from bees and other pollinators also result in larger, more flavorful fruits and higher crop yields. In the United States alone, pollination of agricultural crops is valued at 10 billion dollars annually. Globally, pollination services are likely worth more than 3 trillion dollars. More than half of the world's diet of fats and oils come from animal-pollination plants (oil palm, canola, sunflowers etc.). More than 150 food crops in the U.S. depend on pollinators, including almost all fruit and grain crops. The USDA estimated that crops dependent on pollination are worth more than 10 billion per year.

Environmental Benefits of Pollination

Clean air

Plants produce oxygen which is the main factor for human and other animals and by using the carbon di oxide that exhales by the human and animals they produce food which is also very important for us. Thus the pollinators help to run the pollination system to produce many wild flower, fruit and the plants help to purify the air for all organism.

Water and soil

Flowering plant help to purify water and prevent erosion through roots that holds the soil in place and foliage that buffers the impact of rain as it falls to the earth. The water cycle depends on plants to return moisture to the atmosphere and plants depend on pollinators to help them reproduce (Mainelli 2005).

Biodiversity

Biodiversity stimulates health, resilience and the productivity of ecosystems. Without pollination there would be significantly lower diversity of flowers, crops, grasses and trees. To get a better idea, imagine life without foods the majority of us takes for granted such as apples, onions, cherries or potatoes. This is just a small fraction of goods that would disappear, if there was no pollination. Needless to say, the animals and insects which are dependent on many of these plants as their source of food and shelter would go extinct along with the plants in question.

Nutrition

Research carried out by Elisabeth Eilers and her colleagues in 2011 revealed shocking facts about the decline of pollinators and link to the availability of key nutrient such as vitamins and minerals. According to their data, 98% of vitamin C comes from vegetables and fruits that depend on common pollinator species.

Similarly, essential to our body vitamin A is found in around 70% of pollinated plants and it is not only vitamins that we obtain from plants some minerals such as calcium, or fluoride that our found in nuts and vegetables represent irreplaceable part of our diet as well.

Economic importance of pollination

Pollination is doubtlessly an important factor for reservation of our environment, agriculture and for the human, animal and other organism for their existence. Pollination process can be carried out by air, water, animal and through other sources but most importantly is that 75% of the crop plants grown worldwide for food, fiber, beverages, condiments, spices and medicines is carried out by animals. Thus, we can say that pollinators are important role player in pollination. The beneficial value of pollination has become a crucial step in agricultural production. Among the various pollinating agent's insects are the basic one and generally considered the best to obtain a good and profitable production (Badiyala and Garg 1990, DuToit 1994, Menzel and Waite 2005).

It has been calculated that one out of every three to four mouthfuls of food we eat and beverages we drink is delivered to us by pollinators. As such, agricultural products that are produced with the help of pollinators make a significant contribution to the economy.

Shahnawaz *et al.* (2011) stated that animals and insects provide pollination services for over three-quarters of the staple crop plant and for 80 percent of all flowering plants in the world. The economic value of animal pollination to world agriculture has been estimated to be 200 billion US dollars per year. More than one lakh different animal species play roles in pollinating the 250000 kinds of wild flowering plants on our planet. Many crops of commercial importance (almond, cherry, pear, apple, coffee, sunflower, turnip, rape, water melon, cucumber, melon, avocado, alfalfa etc.) rely on pollination by insects and of these insects, bees, are by far the most important. Pollinators participate in sexual reproduction of many plants by ensuring cross pollination, essential for some species, or major factors in ensuring genetic diversity for others. As plants are the primary food source for animal, the reduction of one of the primary pollination agents, or even their possible disappearance has raised concern and the conservation of pollinators has become part of biodiversity conservation effect USDA Report (2007) reveals some facts that

15 percent of pollination is done by domestic bees, while at least 80 percent are done by wild bees and others. More than 100,000different animal's species and perhaps as many as 200,000 play roles in pollinating the 250,000 kinds of flowering plants on this planet. Honey bee poisoning result in annual losses of $13.3 million. There are no documented cases of bees becoming resistant to insecticides. If pollinators are available in sufficient numbers, the income from harvests could increase by an estimated $400 million per year. Californian almond production (80 percent of world's supply, and a $1.2 billion industry) relies on honeybees. Honey bees pollinate approximately $10 billion worth of crops in the United States each year.

Economic Importance of Pollinators

Animal pollinators are needed for the reproduction of 90 percent of flowering plants (Bunchman and Nabhan 1996). Value of pollination services for global agriculture is $200 billion (Maheshwari 2003). Pollinator services of insects are worth about $19 billion annually in the United States (Borror *et al.* 1992). Pollination services provide by all insects including honey bees is approximately $40 billion per year (Pimental *et al.* 1997). Non apis bee pollination to alfalfa seed growers is estimated to be 35 percent of annual crop production in Canada (Balwat and Fingler 1994). Kevan (1997) calculated roughly that providing about on hive of honey bee per hectare resulted in about one extra seed per apple. These improved apples were estimated to provide $200\ha compared to an orchard without honeybees. Costanza *et al.* (1997) said that economic calculations of the value of pollination services (commercial +wild) widely range from $112-200 billion annually at the global scale. Pandey and Yadava (1970) found that *Apis* and *Melipona* spp. represent 98-99% of the all visitors of Litchi, but *Apis mellifera* plays leading role and recognized as the principal pollinator. Carreek and Williams (1998) stated that value of honey bee and bumble bee as pollinators of major selected UK crops has been estimated to be 172 million euros for outdoor crops (rapa, beans, tree and soft fruits) and 30 million Euros for glasshouse crops (tomatoes and sweet peppers). Pollination is an important step of seeds production in all spermatophytes (seed

plants), resulting in the production of genetically diverse offspring (Dafni *et al.* 2005). Insect pollinators are a great part in the pollination process and it has a large economic importance in the market. Insect Pollinators not only help in pollination but they also give some important by product through the pollination process. As an example we all know that honey bee provides a lot of product and by product. From a honey bee hive we can get honey, Bee wax and royal jelly. Honey has a high medicinal and industrial value. Bee wax uses in the industries for many kind of production such as candles, cosmetics etc.

CHAPTER IV

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the village Kachubari of Thakurgaon district in Bangladesh 26°01’51” latitude 88°28’11” longitude with an elevation of 57m. The experiment was carried out during January 2020- June 2020.

Litchi blooming period, fruiting stage, harvesting period, insect visiting rate and types of foraging insects that was selected for data recording.

Climate

The experiment was conducted during the month January-June. The flower initiate mainly in the month February. The maximum and minimum temperature in February was 30.6℃ and 16.7℃. The fruit set was started at the month of March when the maximum and minimum temperature was 28.3℃ and 17.6℃. The rainfall was about in average of 200mm.

Soil

The experimental site was under the Old Himalayan Piedmont Plain (AEZ-1) which is suitable for Litchi cultivation. Other than it is also suitable for tea and organic cultivation. The soil characteristics of the experimental site is well-drained, sandy-sandy loam soil and the pH is in between 5.24-6.65 which is ideal for the litchi production as it was mentioned in previous.

Preparation of field

As our selected trees were well established before conducting the experiment we cleaned the orchard. The bottom of the selected trees was cleaned and the soil was spaded at the distance of 1meter from the bottom of the trees to water the plant and to provide fertilizer.

Application of fertilizer

For good production proper fertilization is important for the tree. The tree was provided with 20kg of Farm Yard Manure, 1.5 kg urea, 1kg SSP and 0.5

kg MP. Application of organic fertilizer improve the fruit production and quality.

Intercultural operation

The trees were pruned manually before the netting. Training and pruning is a essential for litchi tree. The old, damaged and diseased branches were remove. The healthy branches were kept and was maintained for the good production. The fruit bearing is also dependent in these operations. The weeds were removed by spading.

Diversity and Relative abundance of insect pollinators

Observation of foraging insects were taken from the start of flowering until approximate 90% of the flower faded. The number of insect pollinators visiting the flowers was studied on randomly selected five plants during morning to afternoon (6.30 am to 5.30 pm) at seven days' interval. Observations were made from all directions of the plant and each direction, an inflorescence with blooms was observed for 5 min from which the relative abundance of these insect visitors was calculated by using the formula:

Relative abundance (%)= (Population of a particular species visiting flowers/ Total population of all species visiting flowers) × 100

Methodology

- An orchard of 30 Litchi plant was selected for the study.
- Netting was done for avoidance of pollinators in Litchi flower.
- The experiment was laid out in Paired lot technique.

Plans

1. Visual observation was done for flower visiting insects: In this experiment the foraging insects and the pollinators were observed from 6.30 am to 5.30 pm.
2. For managed pollination paired plot technique was applied.

Treatment

In this experiment, we conduct two treatments one is without netting (T_1) and other one is Netting (T_2). Netting was done in the lower and mid branches of

the tree as the trees were average 4-5.5 meter. So, it was difficult to netting the upper branches. We also cover a whole tree with net as the tree were small in size so it was possible to cover the whole tree.

Treatment, T_1= Without netting

Treatment, T_2= Netting.

Data collection

Data was collected from the morning 6.30 am -6.30 pm. During the flowering period in the month of February the data of inflorescences and flowers were taken. The sex ratio of the flowers was counted per inflorescences. During the harvesting period the single fruit weight, and total fruit were taken in netting and without netting conditions to understanding the differences. The data were collected that are given below-

- Inflorescence/branch.
- Flowers/inflorescence.
- Sex ratio of flowers in the inflorescence
- No. of fruit set/inflorescence.
- No. of fruit harvested/inflorescence.
- Fruit weight.
- Fruit girth.
- Fruit length.
- Weight of fruit/inflorescence.
- Total fruit weight/plant.

Data analysis

The data obtained for different characters were statistically analyzed to find out the significance of effects/impacts. The mean value of all the characters were evaluated, and analysis of variance (ANOVA) was performed by the F (variance ratio) test using the STATISTICS10 program. The significance of the difference among the different combinations for different characters will be estimated by the Duncan's Multiple Range test (DMRT) at 5% level of probability.

Fig : 4 Net covering for managed pollination.

Fig.5 Managed pollination show no fruiting

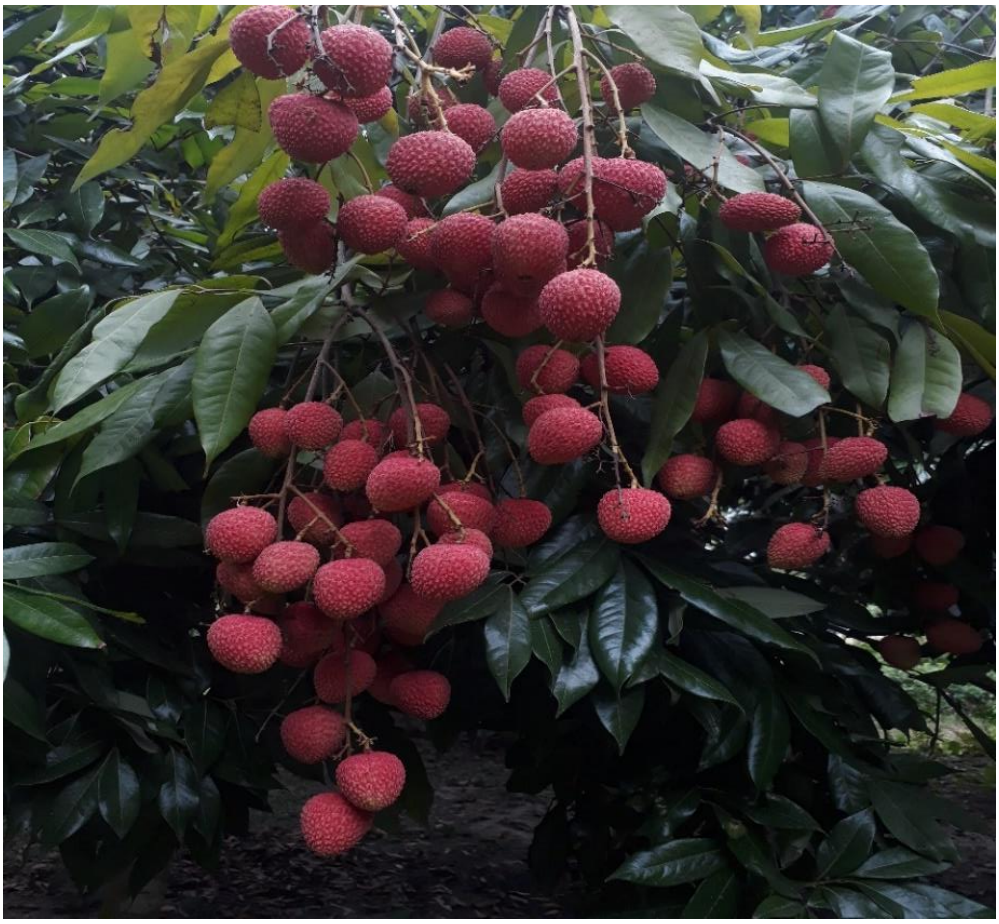

Fig. 6 Fruiting in without netting condition

CHAPTER V

RESULT AND DISCUSSION

Performance of insect pollination on Litchi was investigated and the findings of the present study have been discussed under different characters. The result of the study showed a marked variation in different characters which are presented by following tables and figures. The data pertaining to Litchi as well as yield and its contributing characters were computed and analyzed statistically and the results thus obtained are discussed below under the following headings:

Diversity of insect pollinators visiting litchi flower

The insect pollinators visiting the litchi flowers were collected and identified by using the available literature and listed in Table-1 along with their systemic position. During the observation ten insect species belonging to three orders and seven families of class insect (Table 1) were recorded during the blooming period of litchi plants. Hymenoptera were the most numerous, with seven species from three different families namely Apidae, Vespidae, Formicidae. The family apidae was most numerous consisting of four species of honey bees namely, Rock bee, *Apis dorsata*, Italian bee, *Apis melliferae*, Indian bee, *Apis cerana indica* and little bee, *Apis florea*. On the other hand, the rest two families were represented each by single species of insect visitors namely, Wasp, *Vespa tropica* (Vespidae), and Ant, *Camponotus compressus* (Formicidae). However, Diptera was the second controlling insect visiting order on litchi flowers comprising of five species from three different families Syrphidae, Calliphoridae and Muscidae. Three species were found in the syrphidae family viz. *Episyrphus balteatus*, *Eristalis* sp. And *Syrphus* sp. While, the others two families having single species of insect visitors each. Families Calliphoridae and Muscidae each were represented by Blow fly, *Lucilia sericata* and House fly, *Musca* sp. Coleoptera was smallest diversified order visiting litchi flowers comprising single species viz., lady bird beetle, *Coccinella septumpunctata* from the family Coccinellidae.

In the proximity of present finding, Kumar *et al.* (2013) found a total of 12 insect species belonging to the order Hymenoptera and Diptera visited the flowers during the entire blossom period of litchi. Similarly, in another study, Srivastav *et al.* (2017) reported 20 pollinator species under 23 genera of 8 families belonging to orders Diptera, Hymenoptera and Coleoptera visiting litchi flowers in Muzaffarpur, Bihar.

Sl no.	Name	Scientific name	Family	Order
1	Rock bee	*Apis dorsata*	Apidae	Hymenoptera
2	Italian Bee	*Apis melliferae*		
3	Indian Bee	*Apis cerana indica*		
5	Wasp	*Vespa tropica*	Vespidae	
6	Ant	*Camponotus copressus*	Formicidae	
7	Syrphid	*Syrphus sp.*	Syrphidae	Diptera
8	Blow fly	*Lucilia cericata*	Calliphoridae	
9	House fly	*Musca sp.*	Muscidae	
10	Ladybird beetle	*Coccinella septumpunctata*	Coccinellidae	Coleoptera

Table 1: List of different insect visitors

Relative abundance of pollinator

Relative abundance of pollinator was recorded on litchi flowers at seven days' interval during March, 2020 following the methods mentioned earlier. The number of pollinators recorded per inflorescence of litchi is presented in Table-2. Among the different insect pollinators, *A. dorsata* was the predominant species found to visit the litchi flowers during the entire flowering period. The average population of *A.dorsata* was recorded 2.22 per inflorescence which represented 55.22% of population of total insect pollinators visiting litchi flowers. Syrphids in total were the second dominant insect visitors with an

average of 1 insect per inflorescences constituting 19.9% of total insect. Other than *A dorsata* the other three species of honey bee were also found to visit the flowers throughout the flowering period but comparatively with much lower population load. Abundance of *Apis melliferae* and *Apis cerana indica were* 6.72%, and 13.43% respectively.

It was also observed that the pollinator populations increased at succeeding period of flower opening. A peak population of all the pollinators (6.6 insects per inflorescence) was observed on 24th March, 2020 and after that the populations gradually decreased towards the cessations of the flowers. Average number of insects per inflorescence during the flowering period was recorded and it to be 4.02.

Date / Pollinator	10.3.2020	17.3.2020	24.3.2020	31.3.2020	Total	Mean	Mean population (%)
Apis dorsata	1.5	2.45	3.6	1.32	8.87	2.22	55.22
Apis melliferae	0.2	0.14	0.5	0.25	1.09	0.27	6.72
Apis cerana indica	0.42	0.76	0.75	0.25	2.18	0.54	13.43
Syrphids	0.35	0.25	1.5	1.1	3.2	0.8	19.9
Total	2.72	3.74	6.6	3.06	16.12	4.02	

Table 2: Observations for abundance (Percentage of insect Fauna Per inflorescence per 5 min) of different insect pollinators on Litchi flowers

Foraging behavior of honey bee

Foraging behavior of three different species of honey bees viz. *Apis dorsata; A. melliferae; A. cerana indica* were also observed during the course of study. To study the foraging behavior, observations regarding foraging rate in terms of number of flowers visited per minute per forager and foraging speed in terms of time spent by each species on a flower were taken. All the observations were

taken during the flowering period from the morning 6.30 am to 5.30 pm once a week at following intervals 6.30-7.30 am, 7.30-9.30 am, 9.30-11.30 am, 11.30-1.30 pm, 1.30-3.30 pm, 3.30-5.30 pm.

Foraging speed

Foraging speed of different honeybees in terms of time spent by each species on a flower is presented in Table 3. Foraging start nearly at 7-7:30 am, highest foraging speed was recorded during 9.30-11.30 am which gradually decreased towards the succeeding time of the day. *A. dorsata* start foraging at the speed of 4.55 sec and highest foraging speed was 5.5 sec. at 9.30-11.30 am. After that, the activity gradually declined. The lowest foraging speed was recorded during 3.30-5.30 pm with 3.3 sec. Among the honey bees, the mean foraging speed throughout the day were found to be maximum for *A. dorsata* (4.49) sequentially followed by *A. melliferae* (4.23), *A. cerana indica* (3.27).

Similar results were also documented by Mishra and Kumar (2018), they record the maximum foraging speed in *A. dorsata* (10.28 sec.) followed by *A. melliferae* (9.15 sec.) and minimum in case of *A. florea* being 6.97 sec. Similarly, the species while the minimum foraging rate was observed at 15.00 h in all the species.

Das et al. (2019) found *A.dorsata* started foraging at 7-7.30 am with mean foraging speed of 4.64 sec which was maximum and *A.florea* was found to be minimum at the mean foraging speed of 3.32 sec.

Time / Pollinator	9.30am-11.30am	11.30am-1.30 pm	1.30 pm-3.30pm	3.30pm-5.30pm	Total	Mean
Apis dorsata	5.5	4.5	4.65	3.3	22.45a	4.49a
Apis melliferae	5.34	4.89	3.20	3.53	21.16b	4.23b
Apis cerana indica	3.35	3.75	2.87	2.78	16.35c	3.27c

Table 3: Foraging speed (Time spent in minute per flower per forager) *Apis spp.*

Foraging rate

Foraging rate of different honey bees in terms of number of flowers visited per minute per forager is presented in Table 4. Among the three honey bees, *A. cerana indica* having the highest mean foraging rate (12.03), which sequentially followed by *A. melliferae* (11.10) and *A. dorsata* (10.31).

In earlier study Mishra and Kumar (2018), recorded that among different honey bees, maximum foraging rate (no. of flowers visited per minute was observed in *A.florea* (14.17) followed by *A.melliferae* (11.61) and *A.dorsata* (10.41). Similarly, the maximum and minimum foraging rate was observed at 15.00 hr. and 9.00 hr. in all the three species respectively.

Das *et al.* (2019) found *A florea* having the highest mean foraging rate (12.29) which was sequentially followed by *A.cerana indica* (12.26), *A.melliferae*(11.12) and *A.dorsata* (10.54). A gradual increase in foraging rate was observed in case of *A.cerana indica* and *A.melliferae*, where lowest and maximum numbers of flowers were visited at 7-9 am (11.17 and 11.03) and 3-5 pm (13.39 and 13.43) respectively.

Time / pollinator	6.30am-9.30am	9.30am-11.30am	11.30am-1.30 pm	1.30 pm-3.30 pm	3.30pm-5.30pm	Total	Mean
Apis dorsata	10.5	9.5	8.45	10.86	12.25	51.56c	10.31
Apis melliferae	10.71	10.67	9.67	11.25	13.23	55.53b	11.10
Apis cerana indica	11.19	11.92	11.56	12.52	12.98	60.17a	12.03

Table 4: Foraging rate (Number of flowers visited per min per forager) of *Apis spp.*

Yield contributing factors

The pollinators had a great effect on the fruit setting which ultimately leads to higher yield of litchi crop. The litchi is a cross pollinated crop which requires insect pollinators for getting maximum yield. The maximum no of fruit (70 no.) fruit length (4.2 cm), weight (15.5g) were recorded in open pollinated plants. The minimum no of fruits (12 no) fruit length (3.01cm), weight (12.3 g) were recorded in pollinator excluded plants. According to Stern *et al.* (1996), the pollen effect has significant on nut and kernel weight, with fruit containing from cross-pollination being heavier than that from self-pollination. Similarly, the maximum yield (50.5 kg/plant) was recorded in without netting condition and maximum yield in netting condition was (1kg/plant). Thus, there is significant increase in yield obtained in open pollinated as compared to pollinator excluded.

Butcher (1957) reported that the reduced activity of insect pollinators could be major reason for the low yield in litchi orchards and recommended augmenting pollination with honey bee during flowering period for increasing yield.

Similarly, Badiyala and Awasthi (1991) recorded a maximum yield (38 kg/tree) in Dehradun cultivar of litchi with bee pollination as compared to without bee pollination (9.60 kg/tree) that clearly indicates the importance of insect pollination for enhancing the litchi yield.

Character / Treatment	Number of inflorescence/branches	No. of fruit/branch	Fruit girth (cm)	Fruit weight/ branch (Kg)	Fruit weight/plant (Kg)	Fruit length(cm)
Without netting (T_1)	8.55 a	60.67a	3.85a	1.28a	50.5a	4.2a
Netting(T_2)	8.33 a	0.83b	3.77a	0.11b	1b	3.01b

Table 5: Yield contributing Factor

Number of inflorescences per branch

At without netting and netting condition, the average number of inflorescences per branch was 8.01 (no.) and 8.03 (no.) (Fig 7). There was no significant difference between netting and without netting condition on the number of inflorescences. Pollinating agent does not affect the so no significant difference was seen in the number of inflorescence. The data was recorded after 90% of the inflorescences were fully initiate. The lower branches and the branches that can easily be reached by hand were selected for the data collection.

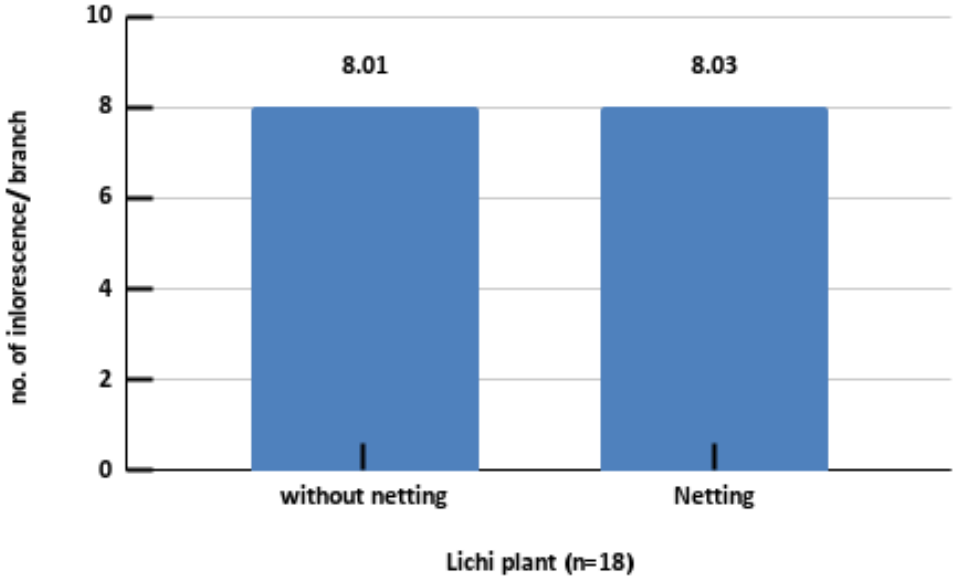

Fig 7: Bar diagram showed the number of inflorescence of Litchi at without netting and netting condition.

Number of flower per inflorescences

At litchi plant three types of flowers are found viz. male, female, hermaphrodite. No. of flower per inflorescence was recorded during the full bloom period of the litchi flower during the month of March. The number of flower per inflorescence was 32% for hermaphrodite, 28% for male, and 40% for female (Fig 8). This is the varietal genetic features. Pollinating agent does not effect the flowering, so, there was no significant difference between netting and without netting condition on number of flowers per inflorescence. Many insects were visiting the litchi flowers but among them some major insects were found to be visiting the litchi flower very rapidly Honey bees with its four species Italian bee (*Apis melliferae*), Rock bee(*Apis dorsata*), Indian bee (*Apis cerana indica*) were predominant in contrast with the other insect. Syrphid fly, Blow fly, House fly, Ant and Lady bird bettle also seen to visited in without netting condition. But in Netting condition no insect was seen except ant.

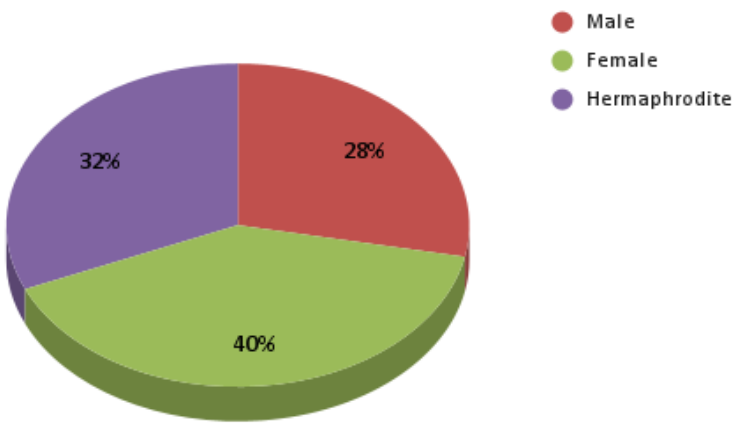

Figure 8: Pie chart showed the number of flower per inflorescence on Litchi plant.

Litchi fruit girth

The maximum litchi girth was 3.85cm at without netting condition. On the other hand, the minimum litchi girth was 3.77cm (Fig 9) at netting condition. There was no significant difference between netting and without netting condition in term of girth of litchi, as a fact, no significant effect of the pollinating agent was observed on fruit girth.

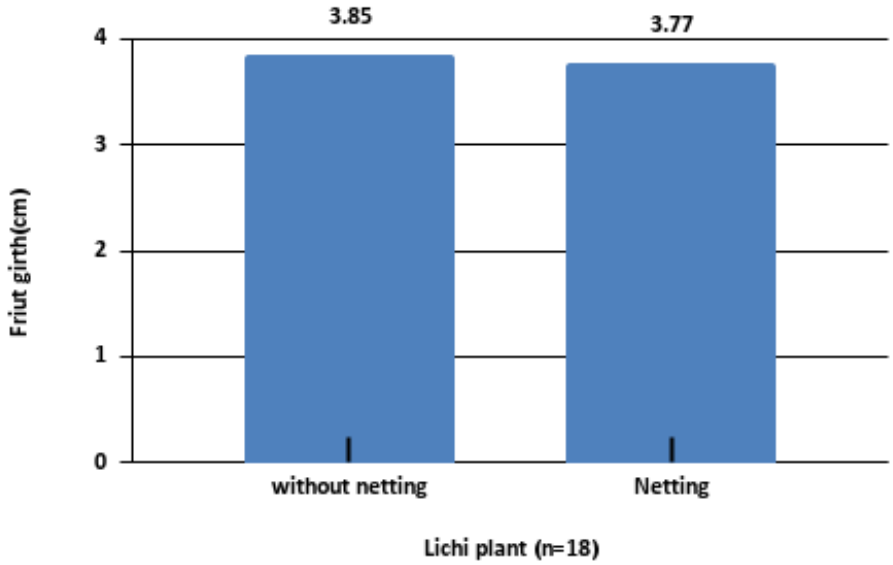

Fig 9: Bar diagram show the fruit girth at netting and without netting condition

CHAPTER V

CONCLUSION

Litchi is one of the main fruit crops of Bangladesh. It is very delicious and healthy also. Pollination is an important part for this fruit crop thus the pollinators are very important as they conduct the pollination. It not only increases the crop production but also provide quality food. Pollinators and beneficial insects visiting hour is seen at very first hour of the morning and in the afternoon. The study revealed that a total number of nine insect species from three different orders viz. Hymenoptera, Diptera and coleoptera were found to visit the litchi flowers. Hymenopteran pollinators (75.37%) and Dipteran pollinators (22%) during the entire flowering period. Among Hymenopterans, *Apis dorsata* (55.22 %) was predominant vsitor followed by *A. cerana indica* (13.43%) and *A. melliferae* (6.72%). The mean foraging speed (time spent in sec. per flower per forager) was found to be maximum in *A.dorsata* (4.49 sec) while *A.cerana* (3.75 sec.) showed lowest. Whereas, maximum and minimum mean foraging rate (number of flowers vsited per minute per forager) was recorded in *A.cerana* (12.03) and *A.dorsata*(10.31) respectively.

Honey bees are found to be most visited pollinator other pollinators are found in the order of Hymenoptera (Wasp, Ant), Diptera (Blow fly, House fly Syrphid fly), Coccinellidae Lady bird beetle). The production of netting and without netting which is 0.11 kg and 1.28 kg per branch on average. Pollinators have a greater effect on the total production of the litchi. Pollinators had no significant effect on the inflorescences, flower and fruit girth of the litchi while the No. of fruit per branches, fruit weight per branch and total fruit weight per plant were greatly affected by the pollinators.

The average no. of fruit per branch (60.67no) and (0.83no), Fruit weight per branch (1.28kg) and (0.11kg) and total fruit weight per plant (50.5kg) and (1 kg) for without netting and netting condition.

From our study we found that insect pollinators had a huge effect on the yield of litchi. So, we may recommend that adding honeybee boxes in the litchi orchard will be very beneficial to the production as we can see that the pollinators directly affect the yield positively and honeybee is an important pollinator for the crop. To attract other pollinator, we can also intercrop litchi other flowering crops like drumsticks, onion, mustard, Chickpea, lentil etc. These crop will not affect the production of litchi but pollinators will be active during the whole year thus it will increase the production for both and the farmers also benefitted with both fruit and vegetable crop. Like litchi there are many other fruit crops like Mango, Papaya, Pomegranate, Guava, Pear, figs etc. will be benefited if this type of study conduct more and more. It will help us to increase the production naturally and also help to conserve the pollinators.

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APPENDIX

Appendix I: Map showing the geographical area of Litchi cultivation and the experimental site

Experimental site

Litchi cultivation area

Appendix II: Maximum and minimum temperature (℃), Average RH (%) and rainfall during the study period (January-June 2020)

Month	Maximum temperature	Minimum temperature	Average RH(%)	Rainfall total (mm)
01-07 January	23.5	17	81	9.87
08-15 January	25.9	10.3	67.67	0
16-22 January	25.7	12.3	77.55	2.4
23-31 January	23.4	13.8	72.73	0
01-07 February	24.1	15	70.63	3
08-15 February	27.2	15.4	55.93	0
16-22 February	27.4	17.8	56.61	0
22-29 February	30.6	16.7	75.86	54.02
01-07 March	29.9	16.2	74.92	47.46
08-15 March	28.3	18.4	75.04	36.99
16-22 March	30.1	19.4	73.9	12.72
23-31 March	30.1	19.2	71.68	61.85
01-07 April	34.4	20.1	59.88	0
08-15 April	34.4	21.9	66.20	15.95
16-22 April	30.3	22.1	82.83	184.18
23-30 April	30.6	21.7	82.53	151.55
01-07 May	32.5	23.5	81.41	181.24
08-15 May	34.2	24	76.02	148.84
16-22 May	33.3	25.9	85.72	347.65
23-31 May	32.3	26.3	84.79	353.65
01-07 June	34	26.2	83.87	297.82

08-15 June	**36.2**	**27.4**	**82.46**	**392.75**
16-22 June	**32.7**	**27.6**	**87.26**	**374.8**
23-30 June	**32.8**	**27.4**	**88.84**	**650.76**