Behavioural strategies of some lycaenid butterflies in relation to nutrition of host and nectar plants

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Submitted by
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DEDICATION

To my family...

always appreciate the value of knowledge, inexorably supporting me in all my endeavours and never let doubt my ability to achieve the goal

DECLARATION

I do hereby declare that the thesis entitled **'Behavioural strategies of some lycaenid butterflies in relation to nutrition of host and nectar plants'** submitted to the University of Dhaka, Bangladesh for the degree of Doctor of Philosophy. The research work is based on my own investigation and carried out in the Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka under the joint supervision of Professor Dr. M. A. Bashar and Professor Humayun Reza Khan of the same Department. This research work as a whole or part of it has not been submitted for any degree or diploma at any university or other institution. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

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CERTIFICATE

This is to certify that the Ph.D. thesis entitled '**Behavioural strategies of some lycaenid butterflies in relation to nutrition of host and nectar plants**' is the record of basic research carried out in the Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka under our direct joint supervision. The author recorded data on her own effort and practical exercise of experimentation was carried out regularly. All the data, figures and parts presented in this thesis are based on her own observations and data collection, and no portion thereof has been used in any other thesis for a degree.

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ABSTRACT

Behaviours are resulted from the functional activities of butterflies in every stages of life cycle. They exhibit different behavioural activities for nutrition, reproduction, and defense. The behavioural activities of butterflies are associated with enormous numbers of plants. An attempt has been undertaken to study on "Behavioural strategies of some lycaenid butterflies in relation to nutrition of host and nectar plants" from January 2015 to December 2017. The field investigation has been carried out in Butterfly Research Park of Bhawal National Park, Gazipur; Madhupur National Park, Tangail; Satchori National Park and Rema-kalenga Wildlife Sanctuary of Habigonj. Several field studies also conducted in Botanical Garden, Bangladesh Agricultural University, Mymansingh; Krishibari Butterfly Park at Savar, Dhaka; and also in Botanical garden and Zoological garden of Curzon Hall, University of Dhaka.

The behavioural activities of 25 lycaenid butterfly species were observed on related plants in experimental sites. 53 plant species was identified as the supporting factors for lycaenid activities. This study provided basic information of lycaenid butterflies and their activity-related plants. A total of 6724 lycaenids have been recorded from four experimental forests to assess their relative abundance and population dynamics. The dominant species was *Arhopala pseudocentaurus* with 21.85% relative frequency and the least abundant species was *Rathinda amor* with 0.75% relative frequency. Butterfly Research Park showed the maximum number of butterfly individuals with a covariance of 40% followed by Madhupur National Park (37%), Rema-Kalenga Wildlife Sanctuary (13%), and Satchori National Park (10%). Lycaenid butterflies displayed highest abundance (13.19%) in December and lowest (5.38%) in October, though this phenomenon is altered in years among habitats. Temperature and relative humidity influences the presence of butterflies. Lycaenid butterflies demonstrated highest abundance (887) in 26.9°C temperature along with 64% relative humidity whereas least abundance (362) has been recorded at 31.7°C temperature with 77% relative humidity.

Adult lycaenid butterflies display a surprising range of behaviours including mating, egg-laying, basking, resting, puddling, and most common foraging behaviour. A total of 473 individuals under 20 lycaenid species were observed in foraging to exploit 20 plant species belong to 11 families. They visit 2,585 times on different examined flowers and engaged 85,052 seconds in foraging. Flowers of *Chromolaena odorata* and *Ziziphus mauritiana* has been foraged by highest (9) number of species whereas *Catharanthus roseus* and Mussaenda frondosa visited by only one species. The flowers of the family Asteraceae have been found most attractive to lycaenid butterflies. A total of 245 individuals belong to 16 lycaenid species spent 31,152 seconds in foraging for 1,373 times visit to flowers of family

Asteraceae. A significant relationship was also found ($F = 74.03$, $R^2 = 0.81$; p-value = 0.23) between the flowering plants and the flower visit frequency of butterflies. Seven lycaenid butterflies (67 individuals) were considered to record nectar feeding activities from five selected plants (viz. *Catharanthus roseus*, *Ixora coccinea*, Pentas lanceolata, Mussaenda frondosa and *Lantana camara*). *Lampides boeticus* spent more time in nectar searching (16.86±11.08 seconds) and nectar feeding (33.71±16.68 seconds) whereas *Tajuria cippus* spent less time in nectar searching (8.50±4.79 seconds) and nectar feeding (17.25±10.64 seconds). The collected nectar volume per flower was measured as 1.85±0.35 µL, 0.92±0.88 µL, 2.24±0.91 µL, 2.92±0.59 µL, and 0.13±0.04 µL from the flowers of *Catharanthus roseus***,** *Pentas lanceolata***,** *Ixora coccinea***,** *Mussaenda frondosa*, and *Lanatana camara*, respectively. Lycaenids usually visited nectaring flowers with corolla tube between 2.5 and 10 mm long because of their short probosces. The pollen grains of lycaenid related plants were collected, and their structural variations were studied. The mobility of the butterflies has been examined assessing the gene-flow activities to the related plants. In an experiment, butterflies visited 55 plants out of 60 plant species. The number of visits made by butterflies was 1-42 times/individuals per hours. They visited 15 to 46 plant species at a time with foraging time ranges 1-62 seconds. Because of the diverse and distance covering mobility butterflies are considered as diverse pollinators.

A total of 172 individuals belonging to 16 lycaenid species have been observed 2748 times for 69,113 seconds in basking with different baking postures. Butterflies spent 20,429 (29.56%) seconds in basking with horizontal wing posture, and the frequencies were 819 (29.8%). The lycaenids used 22,110 (31.99%) seconds for basking in angled wing posture with 943 (34.32%) frequencies. Butterflies engaged 26,574 (38.45%) seconds for basking in closed sun posture with 986 (35.88%) basking frequencies. The basking time has been accelerating from 1-10 seconds time frame, and a prominent peak was made within 31-40 seconds time frame. After that basking time was decreasing along with frequencies. The highest frequencies of basking was recorded from 10-11 am and made a highly evident peak. Lycaenid basking is negatively correlated with temperature ($r = -0.41$) and relative humidity ($r = -0.13$). The basking is increased with decreasing temperature and relative humidity. 12 lycaenid species (107 individuals) were observed to puddle 138 times for the duration of 656 minutes on different substratum. The lycaenid spent maximum time (194 min) on moist ground while minimum (33 min) on mud. The highest number (31) of butterflies puddles on moist ground whereas lowest (7) on dung.

Eight lycaenid species was observed in mating condition. Among them, maximum (26) number of *Chilades lajus* were found in mating while minimum (2 individuals) in *Tarucus*

callinara. The highest (20) number of butterflies was found in mating during the month of March and lowest (4 individuals) in August and December. Maximum (34) lycaenid butterflies were recorded in mating condition from 11.00 am to 12.00 pm whereas minimum (6 individuals) were spotted in between 15.00 and 16.00 pm. The egg laying behaviour of lycaynid butterflies was also examined. 17 females of three lycaenid speices were considered to record data on egg laying activities. The egg laying duration of lycaenid females was noted from 0.5 to 2 seconds time range. The duration of egg laying or egg deposition done by *Chilades lajus* was between the time range of 0.01-0.50 seconds in maximum (13) eggs and that of the 1.01-1.50 seconds in minimum (4) eggs while *Catochrysops strabo* and *Remelana jangala* laid maximum (17 and 14) eggs within 0.51-1.00 seconds and minimum (5 and 4) eggs between 1.51 to 2 seconds, respectively. No *Chilades lajus* was spotted to lay eggs within 1.51-2.00 seconds. In a short duration of 1-2 seconds *Chilades lajus* and *Catochrysops strabo* laid maximum four eggs at one bout while *Remelana jangala* laid maximum five eggs at one bout. Females completed 2-3 egg laying bouts in short period. The butterflies were also spotted to deposit eggs on different part(s) of host plants.

Biology of five lycaenid butterflies has been studied under laboratory condition and their interacting plants' phenology also observed in the study sites. Metamorphosis from egg to adult, or life cycle duration of examined species *Chilades lajus*, *Chilades pandava*, *Catochrysops strabo*, *Remelana jangala* and *Rathinda amor* required 21.43, 19.54, 23.09, 30.05 and 22.45 days, respectively. Larvae of *Remelana jangala* exclusively feed on flowers with unopened petals. *Chilades lajus* feed young tender leaves only while *Chilades pandava* feed on tender leaves and the undersurface of young/mature leaves leaving the upper epidermis intact. The larvae of *Catochrysops strabo* feed on young tender leaves, young buds, flowers, young pods and young seeds inside pods. And larvae of *Rathinda amor* feed on young tender leaves, young buds, and flowers. Larval food consumption, growth, and food utilization efficiencies were also calculated. Larval food materials of host plants have been analyzed. Proximate composition of macronutrients (viz. carbohydrates, protein, fat etc.) was sequestered from feeding parts of host plants (viz. *Citrus aurantifolia*, *Cycas pectinata*, *Cajanus cajan* and *Ixora coccinea*). Fourteen amino acids were also extracted from consumed materials of host plants. The plant nutritional elements played vital role in the development of immature stages. Lycaenid butterflies are strongly adapted to their respective host plants from the adult morphological behaviour to the larval nutrition, and completely depend upon them.

Lycaenid butterfly displays a diverse array of life history strategies. An intricate relationship has been found between lycaenid activities and activity-related plants. This behavioural study offers a vibrant idea to test biotic-biotic interaction in an ecosystem.

ORGANIZATION OF THESIS

The thesis is organized into ten chapters. Each chapter of this thesis has been innovated with an emphasis on lycaenid butterflies, their habitat and eco-ethological activities with the related plants in Bangladesh perspective. By introducing some ideas of the author and informative collections found in the different published and unpublished documents, **Chapter 1** and **2** has been developed in a different style. The two chapters are accommodated as '**General Introduction**' and '**Review of Literature**', respectively. This arrangement is made more or less in the traditional pattern. These chapters are made substantial to drive elevating academic particulars. The **Chapters** from **3** to **7** collectively made a main body of the thesis. The chapters (**3** to **7**) have been accommodated a style of different way than of the traditional thesis writing. Redaction of each of the chapter was structured with 'Introduction, Material and methods, Results, and Discussions' separately. This style made the 'work done' more clear and explanatory. In connection with this, the chapters' result promoted the 'work done' conclusively. **Chapter 3** documented some lycaenid butterflies and the identification of their related plants. This chapter describes some vital evidences of lycaenid butterfly trophic resources and the other resources they utilized within the forest areas. This chapter is significant for getting knowledge on taxonomic traits. Based on field investigation, **Chapter 4** examines the abundance and population dynamics of lycaenid butterflies in different experimental sites. This chapter is dealt with the fluctuation pattern of lycanid butterflies with biotic and abiotic factors in the forest ecosystem. The obtained result is noteworthy in utilizing lycaenid butterflies as 'biotic indicators' for monitoring impacts of forest ecosystem in Bangladesh. **Chapter 5** is a large chapter which deals various behavioural activities of lycaand butterflies in relation to their associated plants. This chapter details the assessment of relationship between lycaenid butterflies and their related plants based on different behavioural aspects (viz. feeding, pudling, basking, resting, mating, egg laying and gene flow activities); and provides information of biotic-biotic interaction in nature. It is important in the question of gene flow activities of lycaenid butterflies and their status as biotic indicators. **Chapter 6** describes the biology of five selected lycaenid butterflies and their host plants phenology. This chapter provides information on immature stages and their larval food plants. This knowledge is valuable for taking necessary steps to increase species richness. **Chapter 7** is designated with some experiments on larval feeding activities and the nutritional agents in their host plants. This chapter supplies vital

evidences of larval nutrient intake from their host plants. Nutrient balance is important factor in butterfly. The result is significant to govern lycaenid population in natural ecosystem. **Chapter 8** is focused on conclusive aspect of the research work as a whole. Chronology (alphabetic arrangements) has been maintained in the **Chapter 9** as '**Literature cited**'. Finally, the tabular addition of the raw data obtained both in field and laboratory experiments are displayed in '**Appendix**'.

CONTENTS

Chapter 4

Chapter 5

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

LIST OF APPENDIXES

ABBREVIATIONS

AD – Approximate Digestibility

ANOVA – Analysis of Variance

AOAC – Association of Official Analytical Chemists

BCSIR – Bangladesh Council of Scientific and Industrial Research

BG, BAU – Botanical Garden, Bangladesh Agriculture University

BNP – Bhawal National Park

BRP – Butterfly Research Park

CH, DU – Curzon Hall, Dhaka University

EBBL – Environmental Biology and Biodiversity Laboratory

ECD – Efficiency of Conversion of Digested Food

ECI – Efficiency of Conversion of Ingested Food

GoB – Government of Bangladesh

IP – Incubation period

KBP – Krishibari Butterfly Park

LSD – Latin Square Design

MNP – Madhupur National Park

RH – Relative Humidity

RKS – Rema-Kalenga Wildlife Sanctuary

ScNP – Satchori National Park

SMH, DU – Salimullah Muslim Hall, Dhaka University

GENERAL INTRODUCTION

1.1 Background

Butterflies are the most beautiful and spectacular forms of life with various sizes, shapes as well as different colours and patterns. They are the most commonly observed among insects and enhance aesthetic value for their attractive colour patterns (Gupta and Majumder 2012). Butterflies are typically day active and very skilled in flight that they have achieved an almost world-wide distribution (Mathew 2001). They inhabit even very high altitude, Arctic, Antarctic, mountains covered with perpetual snow and glaciers (Hassan 1997). According to Fres (1989) the greatest numbers of butterfly species are seen to live in the tropical regions. They are found to show their abundance particularly where tropical rainforests abound; for example in Africa (south of Sahara), in the Oriental region (Far East and India) and the Neotropical region (South America). Among the insects butterflies are the most taxonomically studied groups, and have attained reasonable attention worldwide (Ghazoul 2002).

Butterflies are scaled wing insects belong to the order Lepidoptera of class Insecta (Nimbalkar *et al.* 2011). According to Kristensen *et al.* (2007) Lepidoptera (moths and butterflies) are among the most diverse animal groups with over 1,60,000 described and 5,00,000 estimated species. Butterflies are a large group, with twice as many species as terrestrial birds and about three times the number of mammals, reptiles, dragonflies, mosquitoes, termites, or tiger beetles. It is estimated that there are 17,500 butterfly species in the world and among them 90% have been described (Robbins and Opler 1997). The butterflies comprise a single super family of Lepidoptera, the Papilionoidea. In comparison with many other super families of insects they are uniform morphologically and behaviourally (Ehrlich and Raven 1964). According to Bashar (2014) seven families viz. Papilionidae, Pieridae, Nymphalidae, Danaidae, Satyridae, Lycaenidae and Riodinidae of this super family are found in Bangladesh.

Members of family Lycaenidae are commonly known as “Gossamer-winged butterflies” comprising a huge number of species – an estimated 6,000 species worldwide, with greatest diversity in the tropics (Ackery and Vane-Wright 1984, Fiedler 1996). They are remarkably uniform considering the number of species and genera (Ehrlich and Raven 1964). All of them are rather small in size, brilliantly coloured, and frequently showing marked sexual dimorphism (Roberts 2001). Lycaenidae are found worldwide throughout

most tropical and temperate regions. Some genera of these butterflies are confined to the Oriental Region, although other genera may have circumtropical or particular Old World area distribution (Corbet and Pendlebury 1992).

Lycaenid butterflies are commonly referred to as blues, coppers, hairstreaks, and harvesters. The males are usually smaller and more colourful than the females. The predominant colour of the upper side is often lustrous blue; it may otherwise be purple, green, orange, brown or even white (Pinratana 1981). Sexual dimorphism almost always occurs as a difference in pattern on the upper wing surface (Corbet and Pendlebury 1992). According to Pinratana (1981) females are typically more drably coloured, but shades of dull blue are still commonly found on the upper wing surfaces, whereas the undersides of the sexes are usually similar. Though the sexes differ in the upper wing colour pattern, the under wing pattern is consistent within genera and between the sexes, and is the most important feature in aiding identification (Roberts 2001). In addition, both sexes of many species have filamentous tails; it looks like antenna when lycaenids rub their tails in resting or foraging condition. This tail may be used as a camouflage protection to confuse predators (Fleming 1975). Robbins (1981) has also stated that the ventral wing pattern of lycaenid butterflies creates a 'false head' impression at the posterior end of the butterflies that diverts predator attacks towards the less vulnerable end of the insects. In both sexes the forelegs are functional, not degenerate, though they are always smaller in male (Ek-Amnuay 2006). They are in some respects rather homogeneous, in that the forewing has a reduced number of veins, usually eleven, in some genera only ten, with the forewing cell narrow and close at the end (Roberts 2001).

The butterflies need strong species assemblage of various plants species in an ecosystem as their larval host plants, adult nectar plants and shelter/shade plants for their survival in nature (Bashar 2015). Being herbivorous insects, butterflies are almost entirely plant-feeding group with a few exceptions of species feeding on fungi, lichens, ants and other diets (Ehrlich and Raven 1964), and occur in many habitats (Thomas 1991, Kremen *et al.* 1993, Brown and Hutchings 1997). The combined diversity of herbivorous insects and the plants they feed on make up more than half of the diversity on earth (Strong *et al*. 1984), and the ecosystem services they provide, make it important to understand the source of this diversity (Kim 1993). Insect-plant relationship, host-plant selection strategies are based on the insect's plant-recognition abilities and adaptations in an ecological condition suitable for both of them (Jermy 1988). The contribution to plant-butterfly interaction

emphasize on the chemical and behavioural components of butterfly and plant evolution, chemical ecology which flourished with plant-lepidopteran studies (Brower and Brower 1964, Fenny 1976).

The biotic-biotic interactive mechanism i.e. butterfly-plant interaction, maintains a synchronization of coincidences between the life stages of butterfly and the phenological stages of associated plants in an ecosystem (Bashar 2012b). Biotic interaction is the direct or indirect interaction between species or individuals. The effect of interaction between two components can be positive, neutral or negative (Begon *et al*. 1996). According to Kelager (2015) indirect interactions are any activity where organisms change the environment whereby conditions for other organisms are altered. Direct interaction is when individual of the same or different species interact. As phytophagous insects, lycaenid butterflies stand in second trophic level and make a direct interaction with specific plants (Akand *et al*. 2015b). They appear to be 'ordinary' herbivoures with much phylogenetic conservatism in host plant use (Fiedler 1996). Host plant availability and host plant specialization are closely related among lycaenid species; lycaenids that use a broader variety of host plants on average have more total host plants available to them (Hughes 2000). More than two thirds of the lycaenid species are restricted to one plant family or genus (Fiedler 1996). Most lycaenids avoid plant families characterized by the accumulation of toxic 'qualitative' defense systems (Fiedler 1996). Legumes (Fabales) are the most important host plant taxon of lycaenid butterflies, followed by Santalales and various Rosidae families (Fiedler 1995a). These butterflies are more synchronized with the flowers of ground vegetation, herbs and shrubs than that of canopy trees (Akand *et al*. 2016). Research on interactions of butterfly species with specific host plants, distribution of butterfly species, and priority areas for butterfly conservation will be helpful to better understand the conservation needs of these creatures and the ecosystem as a whole (Bhatt and Nagar 2017).

Butterflies are often good entrants to study population and community ecology (Pollard 1990). They are highly sensitive to changes in microclimate and habitat, and are considered as excellent bio indicators (Kocher and Williams 2000, Parmesan 2003). By using butterflies as indicators, increase of species richness and species assemblage have been augmented to 47% in a wild state. This wild state has been used as the healthy habitat for all kinds of animals (Bashar 2010).

Butterflies are possibly the best group for assessing and monitoring patterns of terrestrial arthropod diversity (Kremen 1992, 1994). The structural complexity of habitat and diversity of vegetation forms have been shown to be correlated with animal and insect species diversity (Gardner *et al*. 1995). Butterflies as a group eat a wide array of Angiosperms and occasionally other plants or animals (Ehrlich and Raven 1964, Singer *et al.* 1971, Singer 1986) and occur in many habitats (Thomas 1991, Kremen *et al.* 1993, Brown 1996, Brown and Hutchings 1997). They play an important role in food chain, because their sheer numbers supply vast food sources for birds, reptiles, spiders and predatory insects (Akand 2012). The distribution, abundance and richness of insect species can be influenced by the climate, vegetation and their interactions (Wolda 1978, Marinoni and Ganho 2003, Kittelson 2004, Torres and Madi-Ravazzi 2006). Among insects, butterflies are ideal subject for ecological studies (Thomas and Malorie 1985).

Changes in abundance of various species are routine phenomena and normally unremarkable (Dunn 2007). The most natural way to define abundance is population density, i.e. the number of individuals per unit of area (Komonen *et al.* 2011). Seasonal pattern can be defined as a phenomenon such as the abundance of active adults, appearance of reproductive activity or of dispersal which may occur only at certain times of the year or year round (Silva *et al.* 2011). Seasonal fluctuation in insect population is a common phenomenon and is reported from all parts of the world, including the tropics (Wolda 1978, 1980, Denlinger 1986). In the tropics there is variation of climate conditions that can affect the seasonal patterns of insects (Wolda and Fisk 1981). The seasonal variation is very common in butterfly population, and the seasonal fluctuations are often unfair due to environmental factors (viz. temperature, light, rainfall, relative humidity), variation in the availability of larval food resources, and vegetation covers such as herb and shrubs (Tiple 2009). Dempster and Pollard (1981) showed that populations of many species appear to be determined primarily by fluctuations in their food resources, even though they may be occurring at low densities. Some studies have also suggested that the distribution of adult butterflies reflects the availability of nectar sources more than the presence of suitable host plants does (Grossmueller and Lederhouse 1987, Loertscher *et al.* 1995). The abundance of adult butterfly species is closely associated with the abundance of flowers, the key nectar source for butterflies (Faber *et al.* 1996, Steffan-Dewenter and Tscharntke 1997, Bergman *et al.* 2008). Hughes **(**2000) stated that factors other than host plant specialization and host plant availability

have a greater influence over interspecific differences in lycaenid abundance. Although host plant availability does not explain differences in the relative abundances of lycaenid species, some lycaenids are affected by their resource availability, but which species are affected is not related to local host plant specialization. The abundance of a lycaenid species is positively correlated with its local distribution (Hughes 2000). Understanding and predicting species abundances are the fundamental goal of ecology (Andrewartha and Birch 1954). Abundance data are widely used to monitor long-term population trends for management and conservation of species of interest (Casner *et al*. 2014). Bashar (2010) claimed that butterflies have got serious sensitiveness to determine the phenological changes in the plants; and in connection with the changes in plants, immediate changes in the life cycle and time-lag in butterflies are occurred. Then the population sustenance of butterflies gives them the "status of indicators" for forecasting impact of climatic changes and for the sustenance of biodiversity in an ecosystem.

Behaviours are portrayed as packaged possessions that are activated, released and steered by elements of the environment (Akand 2012). Butterfly behaviours are ethological activities of great importance (Dennis 2010, Dennis *et al*. 2005). They perform all movements and activities purposefully, rhythmically, timely and in synchronized way with the coincidences of events facing during their life time in nature (Bashar 2015). In appearance and in behaviours, butterflies show some special characters which enable everybody to deal with the butterfly behaviours, association, significance, classification and also its role in nature conservation (Bashar 2011).

The adult emergence is the single most important determinant of individual reproductive success for insects. Indeed, insect life history strategies appear to be shaped around such phenological considerations (Taylor 1981, Kingsolver 1989). The process of a butterfly emerging from its pupa is called eclosion. Eclosion is controlled by hormones which are released to soften the pupal shell and to trigger the central nervous system begin the movements needed to complete the emergence process. Emergence times are determined primarily by weather conditions and temperature dependent development rates (Taylor 1981, Currey and Feldman 1987).

Feeding is a significant activity and food may often be the most decisive factor affecting distribution, abundance and movements of animals (Nimbalkar *et al*. 2011). In butterflies, this has a special relevance because food and mode of feeding are different in the larval and adult stages (Kunte 2000). Since larvae feed on host plants, adult butterflies need

nectar rich plants (Bashar 2014). The adults typically visit whatever flowers are available and suitable for nutrition (Pometto 2014).

Butterflies are frequent diurnal visitors to flowers. Butterflies' flower choice is not random and they often exhibit distinct flowers preferences which can differ between species (Jennersten 1984). The choice of flower from which nectar can be obtained is based on various factors that can interact: length of the proboscis, body mass and wing span of the butterfly (Porter *et al.* 1992, Corbet 2000); vagility and phenology of the adult butterfly (Tudor *et al.* 2004); the number of different habitats visited by the butterfly and the availability of larval host plants (Tudor *et al.* 2004); the quality of the floral nectar (Watt *et al.* 1974, Pivnick and McNeil 1985, Corbet 2000), odour (Ilse 1928, Andersson 2003), colour and design (Ilse 1928, Watt *et al.* 1974, Jennersten 1984), shape and depth of the corolla, size of the flowers (Ilse 1933, Kingsolver and Daniel 1979). Butterflies seek nectar from many types of plants including ground covers, annuals, perennials, shrubs, trees etc. Generally, the best butterfly nectar plants are those that are sun-loving, purple, pink, yellow or white in colour, and single-flowered rather than double flowered (Bashar 2012a). The association of butterflies with pinkish flowers was noted by Muller (1883), and with red flowered tropical and subtropical plants mentioned by Proctor and Yeo (1973). The number of flowers visited per unit time and the time spent at the flowers is an indication of the mobility of the insects, which in turn speaks of the effectiveness to utilize the floral resources (Tiple *et al*. 2009a, Ram and Mathur 1984, Harinat *et al*. 2015a). Each species of butterfly differs from the other in the length of time spent, and the time spent by the same species on different plants also differs (Reddi and Bai 1984).

Adult butterflies feed mainly on fluids, especially flower nectar using a long thin, attractive proboscis (Krenn 2008, Subramanian and Vijayakumari 2011). The proboscis consists of the two extremely elongated galeae enclosing the central food canal. The proboscis uncoils to sip nectar, and then coils up again into a spiral when the butterfly is not feeding (Krenn 1998). The usefulness of butterfly foraging depends on corolla depth and proboscis length, which limits the range of flowers from which nectar can be extracted (Porter *et al*. 1992, Corbet 2000). Adult butterflies as a group are apparently more generalized and opportunistic in their feeding habits than most other nectarivores (Gilbert and Singer 1975, Opler and Krizek 1984). Demand for nectar may vary due to different energy and nutritional needs in different butterfly species (Boggs 1997b).

Nectar is a complex mixture of chemicals including carbohydrates, proteins, lipids, water, antioxidants, alkaloids, vitamins, organic acids, and inorganic materials such as minerals (Baker 1978, Baker and Baker 1973b, 1975, 1983c). Nectar contains a range of carbohydrates, of which sucrose, fructose and glucose are the most common (Romeis and Wackers 2002), and various levels of free amino acids and other non-nutritional substances (Baker and Baker 1982, Kloft *et al*. 1985). A great increase in the number of butterfly visits to flower during a drought, driven there by the need for water (Vogel 1978, Percival 1965). Butterflies use nectar as an immediate energy source, or store it as fat (Opler and Krizek 1984). Several studies have demonstrated that nectar sugar feeding affects longevity and reproduction of butterflies (Murphy *et al.* 1983, Hill and Pierce 1989, Hill 1989). Butterfly-pollinated flowers contain higher levels of amino acids than flowers that are pollinated by bees (Baker and Baker 1986). It has also been shown that nectar amino acids can increase female butterfly reproduction (Mevi-Schutz and Erhardt 2005, Cahenzli and Erhardt 2012a). Male butterflies have a demand for amino acid-rich food sources in their adult diet in order to supplement larval resources for the production of spermatophores (Cahenzli and Erhardt 2013). Females also acquired amino acids from spermatophores via nuptial gifts during mating (Boggs 2009), which can enhance female fitness and reproduction (Boggs and Gilbert 1979, Wedell 1996, Karlsson 1998).

Nectar, a sugary aqueous liquid produced by specialized glandular tissues (nectaries), becomes available to insects and other visitors to plants (Baker *et al*. 1978). Nectar secretion varies between plants, time of day, and is even influenced by age of flowers. In general nectar secretion is influenced by a variety of environmental factors i. e. humidity and temperature (Pacini and Nepi 2007). Plants not only display particular rhythms of nectar secretion, but also nectar reabsorption (Nicolson *et al.* 2007). The chemical constitution, concentration, and amount of floral nectar have adaptive significance in relation to the behaviour and nourishment of animal visitors to flowers (Heinrich and Raven 1972, Baker and Baker 1973a, 1973b, 1975, Heinrich 1975, Baker 1977, 1978). Decisions made by foragers are based upon rewards, and are quite different from nectar volumes that protected from flower visitors (McDade and Weeks 2004a, 2004b). Butterflies are known to learn which flower species have provided them with reward, and can distinguish between differentially rewarding age-class of flowers (Goulson 2000).

In foraging for nectar, animals carry out the vital role of pollination (Gardener and Gillman 2002). Insects are especially important group of flower-visiting animals; the

evolution of flowering plants (angiosperms) and insects, particularly bees (Hymenoptera) and butterflies (Lepidoptera) has often been linked (Burger 1981, Crane *et al*. 1995). Plant flowers benefit from insects' visits by being pollinated and are adapted to their pollinators' size, behaviour and other biological characteristics (Proctor *et al*. 1996). While foraging at the flowers for nectar, the pollen grains adhere to the various butterfly body parts such as proboscis, head, thorax, legs, wings; the exact pollen region depend on the floral architecture, more so whether the essential organs are exerted or concealed within the corolla (Reddi and Bai 1984). The pollen thus adhered is likely to be transferred on the stigmatic surface when the butterfly moves to another conspecific flower, thus performing pollination (Price and Waser 1979, Reddi and Bai 1984).

The effectiveness of pollination is determined by floral structure, nectar volume, concentration, and constituents, as well as the distribution of nectar among flowers, resource partitioning among visitors, and intraspecific competition (Kevan 1978, 1980, Kevan and Baker 1983). The pollinators benefit from the interaction of the same coadaptive phenomena, in addition to the optimal use of time and energy by the visitor in foraging. Concomitantly, floral structures and attractants increasingly heighten the precision of visit and pollination through their coevolution with pollinator anatomy, preferences, behaviour, and learning ability (Kevan and Baker 1983). Butterflies acts as good pollinating agents (Subramanian and Vijayakumari 2011). In doing collection of nectar the butterflies carry out most vital function in nature to do the pollination among plants available in an ecosystem (Bashar 2012a). Although their role in pollination is reportedly of minor importance (Jennersten 1984) or limited to specialized plants (Bloch *et al*. 2006, Lind *et al*. 2008), butterflies may enhance pollination by other pollinators (Carvlaheiro *et al*. 2011). They can be regarded as suitable bioindicators for flower-visiting insects (Pe'er and Settele 2008, Pywell *et al*. 2011). The pollinating activities of butterflies are responsible for variability in gene-flow and then for creation of new species for the plants in an area where the activities of butterflies are free and in ‘randomism’ without having or facing any disturbance from the outside (Bashar 2012a).

The fruit-feeding butterflies are those species that attracted to fruit, but this does not mean that fruits are the main food source for them (DeVries 1988). This opportunistic behaviour could be especially important in periods when their natural food sources are scarce (Sourakov *et al*. 2012). Only a small proportion of butterflies in tropical forests regularly feed on both nectar and fruit (DeVries 1987). Species of fruit-feeding butterflies

can be expected to show preferences for different fruits based on such variables as texture and chemical composition, while nectar-feeding butterflies may specialize in certain flowers (Corbet 2000). Fruit feeding butterflies are usually attracted to the volatiles produced by the fermentation process of their food sources, which differs from nectar-feeding butterflies that are attracted mainly by colour displays (Sourakov *et al.* 2012). Nutrient quality of fruit juice differs from flower nectar (Baker *et al.* 1998). Concentrations of important nutrients such as sugar and amino acids can change during fermentation, with potentially profound effects on the diet quality of fruit-feeding butterflies (Kinzey and Norconk 1993, Genard *et al.* 2003).

Adult Lepidoptera exhibits a behaviour to feed on mud, dung, carrion, or sweat. This behaviour is called 'puddling' behaviour (Norris 1934, Adler 1982). Such behaviour of butterflies is particularly prevalent in the tropics, although it also occurs in the temperate zone (Molleman *et al*. 2005c). Puddling behaviour has probably evolved from the drinking of water (Adler 1982), and in dry habitats the need for water may be a prime reason for visiting puddles (Larsen 1996). This kind of feeding is stimulated by sodium (Arms *et al.* 1974, Adler and Pearson 1982, Beck *et al.* 1999), or in some species, by proteins (Beck *et al.* 1999). In Lepidoptera often exclusively males puddle. Sodium gathered by an adult male butterfly while puddling is transferred to his mate in the spermatophore during mating, which can result in an increase in egg production (Boggs 1986) and sometimes in offspring fitness (Pivnick and McNeil 1987). Therefore, puddling not only benefits the male nutritionally but also the female and in some cases their offspring (Adler and Pearson 1982, Smedley and Eisner 1996). Hence, sodium constitutes a nuptial gift from the male to the female (Vahed 1998). Lepidopteran species specialize on different puddling substrates, likely obtaining different arrays of nutrients. The puddling substrates varied in soluble sodium content, with mud having the lowest concentrations and carnivore dung having the highest (Boggs and Dau 2004). Butterfly families differed consistently in their resource preferences. In particular, Lycaenidae preferred the protein resource. Visual cues play an important role in locating puddling resources for papilionids and pierids, while for lycaenid butterflies searching for nitrogen sources, olfactory cues emitted by decaying organic matter are more likely to be important (Beck *et al.* 1999).

Butterflies are especially dependent on flight for most activities during adult life, including foraging, escaping predation, locating mates, searching for host plants, and

dispersal (Kingsolver 1983a, 1983b, Saastamoinen and Hanski 2008, Niitepold *et al*. 2009, Gibbs 2010). Ectotherms or 'Cold-blooded' animals like butterflies regulate their body in order to meet thermal requirements for flight (Kingsolver 1985b, Subramanian and Vijayakumari 2011). Active flight of butterfly in particular, requires the maintenance of a high muscle temperature (Josephson 1981, Heinrich 1993). Flying ectotherms have to increase their body temperature considerably above air temperature to reach values that allow flight activity (Van Dyck and Matthysen 1998). Since flight muscles are mainly located in the thorax, thoracic temperature is the most relevant body temperature in relation to flight (Casey 1988, Dennis 1993). Butterflies achieve these temperatures by behaviorual thermoregulation (Kingsolver 1985c). Active adult butterflies keep their body temperature within the range of 28-42°C by behavioural thermoregulation (Kingsolver 1985b).

Thermoregulation in butterflies is connected at two different but complementary levels: the physiological and behavioural mechanisms by which butterflies regulate their body temperatures, and thermoregulation provides a vital link relating weather to the population ecology of butterflies (Kingsolver 1985b). The principal way that butterflies regulate heat gain is by behavioural orientation and posture relative to the sun, called basking (Dennis 1993, Kingsolver 1985b). In other way, basking in butterflies is the process of sun-bathing that increases temperature in the wing muscles to bring the insects in a physiological condition which makes the butterflies able for taking off to their flight (Bashar 2015, Akand *et al*. 2015b, Kamrunnahar *et al*. 2018). Butterfly starts fly at their very best when the air temperature range from 24°C to 32°C (Bashar 2015). During basking butterflies exhibit various postures based on wing position (Kingsolver 1987, Kemp and Krockenberger. 2002). Posture is known as the position or bearing of the body at a given time especially with respect to capability in particular circumstances (Henrich 1990, Shreeve *et al*. 2009). Basking posture in terms of a body orientation angle is relative to the sun, and a wing angle (Kingsolver 1985b). Cooling rates are also dependent on posture (Kingsolver and Moffat 1982).

In butterflies, three different basking postures are generally recognized: dorsal basking; ventral basking; and reflectance basking (Clench 1966, Kingsolver 1985d, Shreeve 1990, 1992). Dorsal basking is the most common type of basking is with the wings positioned flat, facing the sun. Butterflies that bask this way often have black bodies and dark coloured areas on their wings (Bashar 2015). Lateral basking occur when butterfly wings are folded and facing the sun. This is because the undersides of their wings are darker

than the topsides, or the bases of the wings are darker than the edges (Bashar 2015, Kamrunnahar *et al*. 2018). In reflectance basking the wings are held open at an angle, with the dorsal surface of the body oriented towards the solar beam (Kingsolver 1988). In this case, the wings are used to reflect the sun light to the butterfly's body rather than absorb it or as solar reflectors (Bashar 2015, Kingsolver 1985c, 1985d). Many lycaenid butterflies absorb maximum heat by basking with closed wings and at an angle to the sun (Akand *et al*. 2015b).

Besides behavioural adaptations and adjustments, variation in morphological traits like basal wing colour and body size has been shown to be relevant for thermoregulation (Shreeve 1990, 1992, Heinrich 1993). Dorsal and ventral wing surfaces play an important role in the process of heat transfer, either by conductance of absorbed heat to the thorax, reflectance of solar radiation onto body tissues or via shielding body tissues from solar radiation (Wasserthal 1975, Rawlins 1980, Kingsolver 1985c, Kingsolver 1987). The wings of Lycaenidae with a greater proportion of melanised scales have been demonstrated to become warmer than wings with a high proportion of reflective cover scales (Biro *et al*. 2003). The dark pigments on the underside of the wings absorb more radiant energy and warm the flight muscles of the thorax efficiently (Akand *et al*. 2015b). Knowledge of the effects of thermoregulation and basking on butterfly's movement is required for a mechanistic understanding of the consequences of climate change and environmental disintegration.

Butterflies seldom select shaded areas and prefer larger nectar source bushes which serve as a resting and roosting area (Michael 2004). Plants under shady areas are preferred for resting. In the summer time the butterflies take complete rest, starting from (off) 1:30 am to 3.30-4.30 pm (Bashar 2015). During resting time they do not move, and feed anything, but resting place need to be with high humidity and comparatively comfortable for them (Bashar 2012a).

Mating is the initial stage of butterfly reproduction. By this process male butterfly passes genetic materials to female for egg maturation. The mating behaviour is an instinctive and species specific behaviour (Bashar 2014). Different butterfly species exhibit considerable diversity in the pattern of their mating systems (Gilbert 1976, Wiklund 1977, Davies 1978). Generally males initiate sexual behaviour in butterfly species and visually locate females (Magnus 1958, Obara 1970, Hidaka and Yamashita 1975). Male butterflies use movement, wing colour, and odour to find receptive female (Ferris and Brown 1981).

Among butterflies, four distinctive male mate location behaviours have been identified, referred to as perching, patrolling, territorial defence and lek assembly (Shields 1967, Baker 1972, 1984, Scott 1974, Davies 1978). In patrolling, males actively seek females, whereas in perching they await the arrival of females soliciting courtship (Baker 1972). In perching butterflies initial approach is mainly based on visual stimuli particularly on female movement and size, which is helpful to discriminate between same and different species (Tinbergen 1941). Territorial activity is a measure of the preparedness of males to defend an area, distinct from fidelity to an area or site; in butterflies territorial encounters often involve physical contact (Wickman and Wiklund 1983, Dennis and Williams 1987, Kemp and Wiklund 2001). In lek assembly, sites are at a premium, aggregations of males occur in close proximity and females choose among several males. These mate location behaviours are by no means mutually exclusive or always clear cut (Tiple *et al*. 2010). Butterflies also recognize each other through pheromones, or scents (Scott 1973). Pheromones play an important communicating role in the butterfly mating (Bashar 2014). Once a male butterfly locates a receptive conspecific female, aerial or ground based courting behaviour will follow depending on species (Pinzari 2009). There is tremendous diversity of wing, antenna and body movements during courtship. Differences of activities of male and female individuals are pre-requisite for understanding the courtship behaviour (Bashar 2015). During mating, the female settles and the male grasps the end of her abdomen with his claspers (Bashar 2014). The female is active partner in the family Lycaenidae (Miller and Clench 1968). Mating butterflies tend to remain nearly motionless. If the pair are disturbed during mating they use to take a flight with one partner (usually the male) being dominant and dragging the other after it (Bashar 2014). Females can mate on the day of emergence, but males do not mate for several days (Scott 1973). A male is capable of mating with several females (Fres 1989). Studies on mating behaviour and copulation mechanisms are helpful to understand the evolution of mating systems (Thornhill and Alcock 1983). In Lepidoptera, it is useful to examine how ecological conditions curtail or promote sexual selection and the evolution of different mating systems (Hughes *et al*. 2000).

Egg-laying is a particularly important ecological interaction between phytophagous insects and their food-plants (Rabasa *et al*. 2005). Butterflies are among the most studied groups of insect in relation to their oviposition behaviour and host-plant selection. In butterflies, egg laying (i.e. oviposition) on host plants is evoked by species-specific

combinations between chemoreceptors and plant compounds (Nishida and Fukami 1989). During oviposition, females must first search for and locate a potential host, evaluate its suitability as a larval host and then decide to accept or reject the plant for oviposition (Bernays and Chapman 1994, Renwick and Chew 1994). Typical volatile compounds emitted by host plants guide herbivores while searching and play an important role in host plant recognition (Visser 1986, Honda 1995, Bruce *et al*. 2005). Visual cues (viz. shape, and colour) also play an important role for butterflies in host finding (Bernays and Chapman 1994, Renwick and Chew 1994). Egg-laying females may exhibit biased preferences toward particular plant species, toward particular plant individuals and even toward certain parts of the food-plant, which will determine the physical and chemical attributes to which insects respond (Thompson and Pellmyr 1991, Bernays and Chapman 1994).

Within a population of a single host plant species, female are able to discriminate among plants due to different size (Forsberg 1987, Sparks *et al*. 1994), physiological condition (Bourn and Thomas 1993), flowering status (Wiklund and Ahrberg 1978, Courtney 1982), spatial position within the patch (Courtney and Courtney 1982, Dennis 1984), microhabitat (Rausher 1979b, Thomas 1983a, McKay 1991, Grundel *et al*. 1998, Roy and Thomas 2003), distance to nectar sources (Murphy 1983, Grossmueller and Lederhouse 1987), presence of conspecific eggs (Dempster 1992), and occurrence of mutualists (Jordano *et al*. 1992, Seufert and Fiedler 1996, Wagner and Kurina 1997, Van Dyck *et al*. 2000). Likewise, within a single plant, females may exhibit preference for particular types of plant modules, such as leaves, stems, flowers or fruits (Thompson and Pellmyr 1991), or even for specific modules within a particular type (Williams 1981, Dennis 1984, Rodriguez *et al*. 1993, Ellis 2003). The importance of female oviposition strategies is addressed for determining patterns of host use among herbivorous insects (Sirot and Bernstein 1996, Janz and Nylin 1997, Nylin *et al*. 2000).

The early stages of about 75% of all lycaenids with a known life history exhibit an exceptional behaviour termed as ‘myrmecophily’. The term ‘myrmecophily’ is used mainly for animals that associate with ants. These associations entail an exchange of goods and services that usually results in net benefits for both partners (Pierce *et al.* 1987, Cushman *et al.* 1994a). The larvae of many lycaenid butterflies interact with ants. Lycaenid larvae in such relationships generally emit semio-chemicals from a pair of tentacular organs and secrete a sugar-rich solution from a dorsal nectary organ to attract and retain their ant guards (Axen *et al.* 1996, Axen 2000, Daniels *et al.* 2005), which then

protect the larvae from predators and parasitoids (Pierce and Mead 1981, Fiedler *et al.* 1996). The majority of lycaenids have associated with ants that can be facultative or obligate, and range from mutualism to parasitism (Trager and Daniels 2009). These associations ranging from loose facultative interactions in which larvae are only occasionally tended by several species of ants (about 45% of associations), to complex obligate associations in which larvae are always tended by ants, often by only a single species (30%). These ant associations and specialized behaviour may have contributed to the high rates of speciation in this family (Fiedler 1991, Pierce *et al.* 2002).

Phytophagous insects have the strong interaction with their natural host plants, and a particular host plant choice is an important step in the life-cycle (Rabasa *et al*. 2005, Janz *et al*. 2005a). A butterfly grows and develops as a feeding caterpillar, inactive pupa and emerges as an adult; the female spends much time and energy in mating, egg production and in finding suitable food plant(s) on which to lay her eggs (Braby 1994). Females may exhibit preference and specificity for plant species, individual plants within populations, and different parts within plants (Thompson and Pellmyr 1991). Because the hatching larvae are often relatively immobile, their growth and survival depend on the choice of food plant by the female (Renwick and Chew 1994, Rausher 1979b). Larval choice plays an important role in food plant relationships. Larvae eat the young, soft leaves of plants but not the old and tough leaves of the same plants (Ehrlich and Raven 1964). Most lycaenid butterflies are phytophagous. Their larvae are external feeders, either eating whole plant tissues or organs (flower buds, flowers and fruits) or skeletonizing foliage (New 1993).

In nature, insect herbivores can attempt to regulate nutrient intake by feeding on different plants or plant parts (Schultz 1983, Raubenheimer and Bernays 1993, Chambers *et al*. 1996). Plants vary considerably in the mixture and concentrations of nutrients (Lee 2007). The nutritional value of host plants has profound effects on the ecology, behaviour and physiology of herbivores and is determined by multiple traits, such as the quantity and quality of various nutrients, leaf toughness, water content and secondary chemistry (Bernays and Chapman 1994, Schoonhoven *et al*. 1998). The quality of the food source, determined by nutrient availability and presence of secondary compounds, affects the time needed by larvae for the completion of development as well as the mass achieved at the end of larval stage (Scriber and Slansky 1981).

The host plant plays an integral role in the life of a butterfly (Jermy 1984). Plant chemistry is tightly linked to the essential components determining butterfly fitness in

relationship with their hosts (Friberg and Wiklund 2016). Most butterflies have very specialized host plant use. Following successful ovipostition the larva must be able to feed, grow and survive on the plant (Davidson 2012). Herbivorous larvae of lycaenid butterflies must extract all nutrients from their host plant (Fiedler 1996). Primary plant metabolites/compounds rather called macronutrients involved in fundamental plant physiological processes such as proteins, carbohydrates and lipids, form essential nutrients for herbivores (Schoonhoven *et al*. 1998, Heimann 2012). Components of host plant quality (such as carbon, nitrogen, and defensive metabolites) directly affect potential and achieved herbivore fecundity (Awmack and Leather 2002).

Protein is a source of nitrogen for growth and maintenance of tissues, production of enzymes, etc., as well as a source of metabolic energy (O'Brien *et al*. 2002). The quantity of protein (or nitrogenous nutrients) has long been recognized as a limiting factor for herbivore survival, growth and fecundity (McNeill and Southwood 1978, Mattson 1980, Scriber and Slanksy 1981, White 1993). Protein quality is primarily the function of amino acid composition (Lehninger *et al*. 1993). An imbalanced amino acid composition is associated with reduced growth (Briegel 1985, Karowe and Martin 1989). Being the major source of metabolic energy, carbohydrate is used for structural purposes (cuticle deposition) as well as being converted into body lipids and some nonessential amino acids (O'Brien *et al*. 2002). Lipids which serve as storage for energy are fatty acids, phospholipids and sterols, whereas sterols are again essential for insects (Heimann 2012).

Butterflies utilize different nutritional resources during the larval and adult stages (Murtazina 2014). The quality and quantity of nutrient resources available from each life stage vary among species (Boggs 1997a). The Lepidoptera, feeding as larvae on protein-rich plant foliage, to primarily rely on larval-derived nutrients for reproduction and somatic maintenance (Leather 1995, Jervis and Boggs 2005, Mevi-Schutz and Erhardt 2005, O'Brien *et al*. 2002, Telang *et al*. 2001). It has been assumed that resources derived from the larval stage are the more nutritionally rich and determines the fitness and longevity of the butterfly (Hill and Pierce 1989, Romeis and Wackers 2002). Most nitrogen in butterflies is incorporated during the larval stage and ability to restore nitrogen in the adult stage is limited (O'Brien *et al*. 2002). Amino acids from the larval diet may also be stored for later allocation into metamorphosis, reproduction, and adult survival (Wheeler *et al.* 2000). Larval storage proteins that are rich in essential amino acids have been identified in female Lepidoptera (Telfer and Kunkel 1991) and appear to

serve as an amino acid reservoir for ovipositing adult females (Pan and Telfer 1996, 2001). Many butterflies and moths store proteins ingested during the larval phase for use in metamorphosis and reproduction (Wheeler *et al.* 2000).

While proteins and carbohydrates have equal energetic value, they are utilized differently. Carbohydrates serving as an energy source, and proteins providing amino acids that are assembled into structural tissues, enzymes and proteins are involved in almost every physiological process (Clark *et al*. 2015). A food's nutrient content is a primary driver of animal feeding behaviour, so the analysis of an animal's macronutrient intake patterns is a critical step in understanding how nutrition influences subsequent aspects of performance (Waldbauer and Friedman 1991, Chambers *et al*. 1995, Simpson *et al*. 2004, Behmer 2009, Simpson and Raubenheimer 2012). Without knowing what is consumed, and how much, it is difficult to elucidate how nutrients are allocated, and the nature of constraints affecting allocation (Clark *et al*. 2015). Therefore, improving on existing or available knowledge, information on the nutritional requirements of butterflies is necessary for a better understanding of the link between phytophagous insects like butterflies and their host plants.

Butterflies can open an access to the researches on different aspects in the field of biodiversity conservation and bio resource management. Giving importance on the subject, the lycaenid butterflies have been selected in the research programme. The programme has been envisaged to investigate with the following objectives.

1.2 Objectives of the research work

Behavioural activities are interdependent between the life stages of butterflies and the phenology of the associated plants. This research work has been undertaken to examine some base-points on the behavioural activities of the lycaenid butterflies with their related plants. The objectives of the research work have been sectioned as follows.

- To select some lycaenid butterflies and their related plants for assessing the behavioural strategies (viz. foraging, resting, basking, egg laying, and gene-flow activities).
- To examine concomitant behavours of the lycaenid butterflies in their life stages and the nutritional contents of the host plants.

REVIEW OF LITERATURE

A great deal of research work has been done on taxonomy, biology, behaviour, ecology, and conservation of lycaenid butterflies from different parts of the world. It is not possible to mention all the publications on this aspect on global basis. In this chapter, some important and quotable research papers, monographs and other outstanding publications and books on aforementioned aspects of butterfly-fauna, from both national and international work are reviewed. It becomes utmost and necessary to mention those pertinent research works and a brief account of some of them is cited below alphabetically-

Abu-Shall *et al.* (2014) carried out morphological studies of the egg, larva and pupa of the cycas blue butterfly, *Chilades pandava* (Lepidoptera: Lycaenidae), a pest of cycas palm trees, using SEM photographes. First instar larvae were light pink in colour while second instar slightly darker. The length of first, second, third and fourth instar larva was also measured. The obtect pupa was quite smooth and fuscous, and the dorsal aspect was darker than ventral one. The adult was measured from 9 to 12 mm in body length.

Adjaloo *et al*. (2015) assessed nectar production of two melliferous plant species in response to climatic factors. The nectar volume and sugar concentration of 100 flowers (50 per plant species) were measured at hourly intervals. Microclimatic parameters in the vicinity of the two plant species, and honeybee visits to their flowers were recorded. The volume of nectar in both melliferous plant species was high in the early hours of the day. Total mean volumes in *Antigonon leptopus* and *Thevetia peruviana* were 14.86 ml and 16.58 ml, respectively. Sugar concentration in *A. leptopus* increased from 11% at 0.6:00 h to 30% in the afternoon; but in *T. peruviana* it increased gently after 07:00 h and peaked at 17:00 h. Significant differences occurred in the concentration of nectar sampled during the day (n =50, $F_{2.35}$ df = 49, P = 0.56). The sugar concentration of nectar produced in both plant species was inversely proportional to the volume of nectar produced. Positive correlation existed between sugar concentration and temperature in *A. leptopus* (r = 0.59, P = 0.05), and *T. peruviana* (r = 0.32, P = 0.05). Temperature had greater influence on nectar production (F = 0.211) and sugar concentration

Aich *et al*. (2016) investigated the life stages of butterfly, *Pachliopta aristolochiae* with its host plant *Aristolochia indica* and their close association.The plant was found to grow synchronously with emergence of the related butterfly's new generation-arrival in the

experimental ecosystem. The butterfly was colonized in the laboratory as well as in the natural condition. The adopted colonizing technique has shown that some developmental stages in the host plant were effective in giving high rate of adult production. The feeding potential of the host plant's phonological stages was found to be significant for some of the developmental stages (particularly 3rd and 4th instars larval stages). Sixteen compounds were isolated from the leaves of the host plant and structures of five compounds were characterized which indicated the role of host plant and the feeding potential in the developmental process. Among those five compounds three were the derivatives of Aristolochic acids, namely Cepharanone-A-N-β-D-gluco-5,13"-O, 4"-icosyl-aristolenone (1), Cepharanone-A-N-β-D-gluco-5,13"-O,4"-ethyl-aristolenone (2), and Cepharanone-A-2-hydroxy-N-β-D-gluco-5,13"-O-4"-icosyl-aristolenone (3). This experiment suggesting the presence of high amount of Aristolochic acids in the leaves of the host plant that made the butterfly toxic and unpalatable both in adult and immature stages to its predators. This toxicity might suggest that the presence of warning colouration results in the adults via the biochemical (metabolic) changes in the larval stages.

Aja *et al*. (2015) examined the quantitive phytochemical analyses of *Cajanus cajans* leaves and seeds in dry samples. Quantitative phytochemical analyses were carried out spectrophotometrically and revealed the presence of the bioactive compounds such as flavonoids (423.75±57.81 and 31.08±8.20 mg/100g), tannins (31.55±2.67 and 17.30±0.47 mg/100g), alkaloids (3118.86±79.35 and 385.54±75.15mg/100g), saponins (51.21±4.66 and 1.82±0.29mg/100g), cyanogenic glycosides (43.91±5.99 and 12.42±1.84mg/100g), glycosides (3.55±1.98 and 3.80±1.01mg/100g) and anthocyanins (8.35±0.172 and 4.75±0.174mg/100g) in the leaf and seed samples respectively. The results also indicated that the leaves contain more of the bioactive compounds than the seeds.

Akand (2000) studied 440 butterfly specimens belonging to the family Papilionidae, Pieridae, Danaidae, Nymphalidae, Satyriadae and Lycaenidae, collected from the selected forest areas (viz. Karerhat, Mirsarai, Chunati in Chittagong district and Fashiakhali, Eidgaon in Cox's Bazar district) during November 1999 to March 2000. The research mainly dealt with the taxonomic study of butterflies. Among collected butterflies, 284 were identified as species level belonging to 30 species under 17 genera of above mentioned families. The morphological and structural characteristics of butterflies, their

distribution over the forest areas, and abundance of butterflies and their relationship with plants were also investigated.

Akand (2012) made an attempt to study on colonization of lycaenid butterflies on related plants and its role in the conservation of biodiversity from January 2010 to December 2011. The research work carried out at the Butterfly Research Park of Bhawal National Park, Gazipur and Zoological Garden, Curzon Hall, University of Dhaka. 45 lycaenids was identified from the preserved butterflies in Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka. Author also studied biology of three lycaenid butterflies under laboratory condition, observed host plant's phenology and butterfly-host plant interaction at the study site. Lycaenid behaviours (viz. flying, mating, egg-laying, foraging, basking, resting, puddling and myrmecophily), their seasonal abundance and diversity were observed and recorded. Different associated plants (host plants, nectar plants and shade/resting plants) planted and cultivated to ensure suitable habitat for making colony of lycaenid butterflies. Plants species was also being used later by various arthropod fauna such as arachnids as well as odonates, coleopteran, dipteran, hemipteran, hymenopteran and lepidopteran (moth) insects, and different species of amphibians, reptiles, birds and mammals. Author concluded that the species assemblage and richness of flora and fauna act as a biological subsystem through colonization process of butterfly. This subsystem might be the greatest weapon against climate change and could play a great role on conservation of biodiversity.

Akand *et al*. (2015a) studied the biology of the gram blue butterfly, *Euchrysops cnejus* (Fabricius) (Lycaenidae: Lepidoptera) and its relationship with the phenology of host plant cowpea, *Vigna unguiculata* L. (Fabaceae). Eggs were reared under the laboratory conditions at 28±2°C and 74±3% RH. The incubation period of the eggs found as 2.33±0.51 days, larval developmental period 14.65±0.51 days, pre-pupal period 0.30±0.04 day and pupal period 5.66±0.51 days. The species took 22.94±0.55 days for the development from egg to adult stage under the laboratory condition. The length of 1st, 2nd, 3rd and 4th instar larvae was 3.66±0.40, 6.16±0.51, 12.16±0.51 and 15.33±0.40 mm, respectively. The pre-pupal length was 9.16±0.61 mm and the pupal length was 9.08±0.37 mm. The host-plant occurred in the field from February to July and the butterfly appeared in March. The coincidence of the gram blue butterfly to its host-plant occurred between April and early July. The oviposition behaviour, incubation and immature stages were found to be profoundly related with host plant-phenological phases.

Akand *et al*. (2015b) conducted a field investigation during January-December 2015 to assess the behavioural activities of lycaenid butterflies with their related plants. The lycaenid behaviours (viz. foraging, resting, basking, egg-laying and gene-flow activity) were found to synchronize with the appearance of flowers and fruits of related plants. A total of 879 individuals under 29 lycaenid species and 44 plant species were recorded. Examined butterflies utilized 34 plants species for resting and nine species for egg-laying support in the experimental site. The same plant could be utilized by the different behavioural activities. Among the observed lycaenids, 396 individuals demonstrated foraging activities, 257 showed resting behaviours, 171 basking and 55 were active in egg-laying behaviour in order. It was found that both biotic factors and physical conditions maintained the significant size of lycaenid populations. The combination of the factors displayed the highest abundance (121 individuals) in November and lowest (38 individuals) in April. The study revealed that the behavioural activities of lycaenid butterflies were highly related with phenological changes of the experimental plants. This interrelationship produced interesting findings to study the identification of bioresources in a certain ecosystem.

Akand *et al*. (2016) conducted a field survey to assess the abundance of lycaenid butterflies in the Butterfly Research Park at the Bhawal National Park, Gazipur from January 2010 to October 2011. The survey was carried out along with four transects (viz. TR-I, TR-II, TR-III and TR-IV) in four seasons (viz. winter, summer, monsoon and post-monsoon) of the year. 22 species of lycaenid butterflies was recorded from a total of 1,321 collected individual specimens. Out of 22 species, 10 species belonged to the subfamily Polyommatinae and 12 species belonged to the subfamily Theclinae. The dominant lycaenid butterfly was represented by two species of *Arhopala* (*A. pseudocentaurus*, 35.73% and *A. amantes*, 23.47%). The lycaenid butterflies showed the highest abundance (34.82%) in winter and lowest (13.24%) in summer. The maximum number (38.30%) of the butterflies was recorded from Transect-IV followed by the Transect-I (25.36%), Transect-II (24.53%) and Transect-III (11.81%). It was found that lycaenid butterfly was more synchronized with the flowers of ground vegetation, herbs and shrubs than that of canopy trees at the experiment site. The lycaenid abundance increased with the decrease of temperature ($r = -0.66$; $p = 0.13$) and with the increase of relative humidity ($r = 0.41$; $p = 0.19$). This study revealed that the availability of lycaenid butterflies was related to plant-phenological changes in the study area.

Akand *et al*. (2017) conducted a laboratory examination on the morphometric variation of lycaenid butterflies. Analysis was undertaken following identifying characteristics, viz. forewing length (FWL), hind wing length (HWL), body length (BdL) and antennal length (AntL). A total of 514 individuals of lycaenid butterflies was identified under two subfamilies Polyommatinae and Theclinae. Among them, 265 individuals were placed under 19 species of Polyommatinae and 249 individuals under 25 species of Theclinae. ANOVA tests were conducted to find differences between the butterfly species of the two subfamilies through identifying characters like FWL ($F=10.37$, $P=0.005$), HWL ($F=3.81$, $P=0.067$), BdL ($F=5.78$, $P=0.027$) and AntL ($F=2.77$, $P=0.114$). A linear regression analysis of FWL, HWL, BdL and AntL of the species under the two subfamilies showed significant differences between Polyommatinae and Theclinae. These differences among the species of both the subfamilies produced good results to identify the species more correctly.

Alam *et al*. (2014) studied the biology of *Pachliopta aristolochiae* on its host plant *Aristolochia indica*. Singly laid eggs on the host plant were collected from the field and reared in the laboratory under optimum conditions of temperature (28±3°C) and relative humidity (70±5% RH). Incubation period of the egg was 5.0±0.6 days, larval developmental period was 11±0.3 days, pre-pupal period was 0.87±0.08 day, and the pupation took 12±0.63 days. The length of 1st, 2nd, 3rd and 4th instar larvae was 4.0±0.63, 9±0.63, 22.6±5.2 and 38.2±4.70 mm, respectively. The feeding potential rate of 1st, 2nd, 3rd and 4th instar larvae was 11.4±5.04, 29.6±5.12, 51.4±6.0 and 72.8±4.9%, respectively. The weight of the faeces of 1st, 2nd, 3rd and 4th instar larvae was 0.012±0.004, 0.047±0.018, 0.0114±0.023 and 0.274±0.045 gm, respectively.

Alam *et al*. (2017) carried out an experiment on colonization for the butterfly *Pachliopta aristolochiae* (Fabricius, 1775) (Lepidoptera: Papilionidae) on host plant species creeper plant *Aristolochia indica* at the Zoological Garden, Curzon Hall, University of Dhaka and Bhawal national park, Gazipur from 2010 to 2011. *A. indica* was cultivated to study butterfly oviposition behaviour and developmental stages. The oviposition behaviour of gravid female, hatching of eggs, feeding and moulting behaviour of the four larval instars, and pupation behaviour were recorded. Both laboratory and field observations revealed that while there was availability of food, 1st and 2nd instar larvae preferred tender leaves, whereas the 3rd and 4th instar larvae fed both on young and mature leaves. However, mature larvae were also observed to feed on the stems, flower and fruits of the host-plant

in absence of suitable succulent leaves. The feeding time was recorded for each larval instar and it was relatively low for 1st and 2nd instar larvae, remarkably higher in 3rd instar larvae and highest in the case of ultimate and penultimate larval instars. The egg, larval and pupal mortalities were counted during the study period. Their survivability rate was 80% or more. This result was found to stand satisfactory for a successful colonization process of the butterfly *P. aristolochiae.*

Awmack and Leather (2002) studied host plant quality and fecundity in herbivorous insects. Components of host plant quality (such as carbon, nitrogen, and defensive metabolites) directly affected potential and achieved herbivore fecundity. The responses of insect herbivores to changes in host plant quality varied within and between feeding guilds. Host plant quality also affected insect reproductive strategies: egg size and quality, the allocation of resources to eggs, and the choice of oviposition sites be influenced by plant quality, as egg or embryo resorption on poor-quality hosts. Many insect herbivores changed the quality of their host plants, affecting both inter- and intraspecific interactions. They concluded that host plant quality affected the fecundity of herbivorous insects at both the individual and the population scale.

Axen (2000) examined behavioural variation of lycaenid larvae attended by ant species. Lycaenid butterfly larvae often interact mutualistically with several ant species of different size to protect the larvae. Attending ants were rewarded with nutritious secretions. Both ant behaviour and a larva's need for protection influenced larval investment in the lycaenid butterfly *Glaucopsyche lygdamus*. The overall levels of secretion, as well as the response to varying number of attending ants, were found to be influenced by ant species.

Badenes-Perez *et al.* (2009) studied larvae of three species *Erora opisena* (Druce), *Parrhasius polibetes* (Cramer) and *Temecla paron* (Godman and Salvin) of hairstreak butterflies belong to the subfamily Theclinae (Lepidoptera: Lycaenidae) in Costa Rica. Host plant used by the three theclines was similar, with eggs being laid on inflorescences and cryptic larvae remaining there throughout development. Feeding damage by *E. opisena* was most abundant in pre-flowering *Miconia calvescens*, when 23% of inflorescences showed feeding damage characteristic of this species. Feeding damage by *T. paron* peaked at flowering, when 30% of inflorescences were affected. At field sites, *E. opisena* and *T. paron* damaged an average of 26% and 18% of each attacked inflorescence, respectively. In cage experiments, individual third and fourth instar larvae

of *E. opisena* damaged an average of 24% and 21% of an inflorescence before pupating, respectively. In this study host plant for *E. opisena* and *T. paron*, the presence of feeding *P. polibetes* on Melastomataceae, and *E. opisena* and *T. paron* were firstly recorded in Costa Rica.

Baker and Baker (1986) sampled approximately 1500 angiosperm species for the assessment of the amino acids in their nectar. They reaffirmed that the findings provided statistically significant data linking differences in the concentration with pollinator type. Flowers that were pollinated by animals having alternative sources of protein-building amino acids showed lower amino acid concentration than those that were not. There was a tendency for woody plant nectar amino acids to be less concentrated than those of herbaceous plants, but there could be "phylogenetic constraints" which reduced the correlations of amino acid concentration with pollinator type and with life form. The individual amino acids form complements which were qualitatively extremely constant within species. Proline was a normal constituent of many type of nectar and does not necessarily indicated contamination of the nectar by pollen. The authors summarized that data for families and genera indicated that high or low amino acid concentration could typify certain families and genera of both relatively "primitive" and relatively "advanced" nature. They also quoted for future research on an ecosystem basis.

Bakowski and Boron (2005) observed flower visit patterns of 4 species of Lycaenidae in meadows near the city of Poznan (western Poland) during 2001-2002. *Polyommatus icarus* (Rott.) and *Plebeius argyrognomon* (Bgstr.) used broad ranges of flowers as nectar sources: 19 and 14 plant species, respectively. These butterflies fed most frequently on flowers of *Lotus corniculatus*. The univoltine species *Polyommatus semiargus* (Rott.) and *P. amandus* (Schn.) generally directed their foraging activities towards a limited number of available plants. *P. semiargus* visited 5 species of plants, most frequently *Lathyrus pratensis* and *Vicia* spp. *P. amandus* visited 4 plant species, most frequently *Vicia cracca*. A relationship between adults of all 4 butterfly species studied and the plants belonging to the family Fabaceae has been confirmed.

Bakowski *et al*. (2010) examined the foraging behaviour of the endangered butterfly *Lycaena dispar* (Haw.) in a wet meadow in Poznan (western Poland) in the summer of 2003. Observations showed that the males spent more time resting 11.3% compared to 5.9% female and less time nectaring 24.8% compared to 35% females. The mean time of one visit on a flower was almost three times shorter in males than in females. In total,

adults visited flowers of nine nectar plant species, the most frequent ones were *Inula britannca*, *Lychnis flos-cuculi* and *Cirsium arvense*, which were some of the most abundant plant species there. They observed differences of nectar plant use between sexes and generations of the butterflies, but did not confirm preference for the plant colour.

Barton *et al*. (2014) conducted field and laboratory measurements to assess how basking posture affects the core-body temperature of an Australian butterfly, the common brown (*Heteronympha merope*). They showed that, with wings held open, heat lost through convection was reduced while heat gained through radiation was simultaneously maximized. These responses had been incorporated into a biophysical model that accurately predicted the core-body temperature of basking specimens in the field, providing a powerful tool to explore how climate constrains the distribution and abundance of basking butterflies. Poikilothermic animals are often reliant on behavioural thermoregulation to elevate body temperature above the temperature of their surroundings. Butterflies are able to do this by changing body posture and location while basking, however the specific mechanisms that achieve such regulation vary from species to species.

Bashar (2010) identified butterflies as the 'biotic-indicators' for the species richness monitoring system in an ecosystem and similarly for forecasting the climatic change impacts on biodiversity. It has already been found from the scientific experiments that, by using butterflies as indicators, increase of species richness and species assemblage have been augmented to 47% in a wild state. Butterflies are very sensitive to the change of phenology of the plants in a forest ecosystem as they require plants of all heights for their life sustenance. Any climatic change affects phenological changes in plants. Any phonological, temporal and seasonal changes on plants affect the life cycle of the butterflies. Any abnormal change in the life cycle of butterflies affects the butterfly populations in any area. So, assessing the population fluctuation visually, 'climatic change' forecasting can be measured. The south eastern forest areas of Bangladesh have been facing the question of climatic changes, especially in the status of conserving biodiversity.

Bashar *et al.* (2006) recorded the abundance of the wild and semi-wild plants, like herbs, shrubs, grasses, vines, climbers, trees in the forests of Chittagong and Cox's Bazar during 1999-2000. It was observed that Papilionidae, Pieridae, Danaidae and Nymphalidae were at the peak of their population in the month March-June. While, Satyridae had its highest

abundance in November, December and January; Hesperiidae and Lycaenidae had similar pattern of population distribution whereas Fashiakhali and Eidgaon had different pattern of population abundance. Not the seasonal variation but plant phenology and species richness could be the factors for the appearance of this kind of abundance. They also described that the forest area of Bangladesh was once a rich tropical rain with high density forest and a natural sanctuary of many wild lives. The theme of nature conservation is the global maximization of the plant and animal diversity where the role and significance of plant-animal association has got great importance in the maintenance of the wild plants and animal populations. The protection of forests depends on their effective identification and evaluation of floral and faunal assemblage (richness) in these ecosystems.

Bashar *et al*. (2013) described the pattern of butterfly abundance and diversity, abiotic (temperature, humidity, rainfall, photoperiod) and biotic (plants) factors in the Butterfly Research Park (BRP) at Bhawal National Park, Gazipur, Bangladesh. Total 2393 individuals per day comprising 44 species under 32 genera belonging to the families Danaidae, Nymphalidae, Pieridae, Papilionidae, Lycaenidae, Hesperiidae and Satyridae were recorded during January-December, 2012. The butterflies were more abundant in May, November and December; while least abundant in August and September respectively. Danaidae showed a highest abundance over the other families. Hesperiidae and Pieridae were very common; Nymphalidae and Papilionidae were common; and Lycaenidae and Satyridae were few in number. Papilionids, Pierids and Nymphalids were found highest in May and June. Danaids, Satyrids and Hesperiids were peak in November and Lycaenids in April. Danaids and Papilionids were at lowest number in August; Hesperiids and Satyrids in March; Nymphalids, Pierids and Lycaenids were in September, October and December, respectively.

Bashar *et al*. (2015b) used the natural butterfly park as a study area to investigate how lively ethological behaviours of butterfly interact. The three-acre area of the park was designed with four area-components as hedge-boundary, canopy-tree area, jangle-bush hedges and multimorphic beds-area. The areas ensured safe pupation and provided both sheltering plants and host-plants for butterflies. The accumulation and well-planned arrangement of these four area-components facilitate the system mechanism of butterfly colonizing process. The colonization process has been made functional by applying some procedural methods and also by accommodating butterfly-activities in the present

investigation. They divided the experiment into two sections to exercise accommodating butterfly-activities in the assessment of the interaction between phenological stages of related plants and the developmental stages of the butterflies. These were to examine the criteria responsible for determining the establishment of butterfly colonization process and to examine the impacts of butterfly colonization on the enhancement of seed production capacity of the target plants in the centre premises. This process of conservation ensures the reasonable optimum use of the biological resources in accordance to the demand and need to protect them for future use.

Bashar *et al*. (2017) practiced indigenous methods for biodiversity assessment techniques on Bangladesh context. Diversification of using assessment methods depends on various factors, both biological and physical. Five distinct methods have been practiced to complete butterfly census programme at the experimental stations (forest areas). These methods are: 1. Random-plain count-method; 2. Biotic-epicentre model; 3. EBBL model for assessment of biodiversity status; 4. Use of Latin square design; and 5. Practice of Butterfly-Plant assessment model. Butterflies of seven major families (viz. Hesperiidae, Papilionidae, Nymphalidae, Pieridae, Danaidae, Lycaenidae and Satyridae) were considered to study the population census in different areas of Bangladesh. This study revealed that the highest number of host-plant families was observed in the case of Lycaenidae. The butterflies of the family Lycaenidae were found to depend on the host-plants belonging to 25 different families. The total species number of the butterfly family was 45. Only the greenness is an ecosystem (even of a forest ecosystem) did not show species richness of butterflies, but the plant-species richness maintains species richness of the butterflies in an ecosystem. It was also found that not only random plant species richness shows the result but the butterfly host species (plants) richness shows the butterfly species richness in an ecosystem principally. The random species richness acts as additional factor for species richness in an ecosystem. The richness of non-host plant species of butterflies provide shelter plants, nectar plants, mating plants, egg-laying plants and sometimes sources of various other behavioural support plants.

Baylis and Pierce (1991) investigated the effect of caterpillar nutrition on the ant-defense. Juveniles of the Australian lycaenid butterfly, *Jalmenus evagorus* (Donovan), secrete to ants a solution of sugars and amino acids, primarily serine. Potted food plants of *Acacia decurrens* were either given water containing nitrogenous fertilizer or were given water alone. Fertilized plants had higher nitrogen content than unfertilized plants. Fifth instar

larvae of *J. evagoras* feeding on fertilized plants attracted a larger ant guard than those feeding on unfertilized plants. In the absence of caterpillars, ants were not differentially attracted to fertilized and unfertilized plants. In the presence of ants, over a 10-day period, larvae on fertilized plants survived better than larvae on unfertilized plants. In the absence of ants larvae survived equally on fertilized and unfertilized plants. They concluded that larvae on fertilized plants attracted a larger ant guard, and thereby survived better, than larvae on unfertilized plants. Adult females of *J. evugoras* preferred to lay egg batches on fertilized, rather than unfertilized plants, but they did not lay larger egg batches.

Beck (2007) investigated the effects of amino acids in the diet of butterflies (13 species) from a Borneo rainforest community (using caged males without mating opportunity). Amino acids derived from adult feeding, these were suspected to be a major contribution to fitness. Four species lived substantially longer when given a mix of amino acids additionally to water, sodium and sugar solutions. No significant phylogenetic pattern was found for effects of amino acid feeding, although none of six pierid species were among the taxa with significant effects. Species that reacted to amino acids, tended to be among the most long-lived taxa in the community, suggesting that amino acids were a key variable to attain long life spans. The findings indicated that adult amino acid intake might not be a rare strategy of few exotic taxa, but it has been at least in non-seasonal tropical regions, a common life history trait in a substantial number of butterfly species.

Beck *et al*. (1999) experimentally investigated the attraction of adult butterflies to moist soil and dirt places (a behaviour termed 'mud-puddling') in two species-rich tropical communities in the island of Borneo. At a rain forest site, 227 individuals (46 species) were attracted to the baits, compared to 534 individuals (54 species) at a farmland site. With one single exception, all attracted butterflies were males. Of various salt and amino acid solutions, only sodium was accepted, but overall, albumin solutions turned out to be the most attractive puddling resource. Butterfly families differed consistently in their resource preferences. Representatives of the families Papilionidae and Pieridae often visited NaCl solutions more, but still accepted albumin, whereas representatives of the Nymphalidae, Hesperiidae and, in particular, Lycaenidae preferred the protein resource. In experiments using decoys prepared from pinned butterfly specimens, representatives of the Papilionidae and Pieridae were more strongly attracted to baits provided with decoys made from conspicuous, medium-sized yellow *Eurema* species (Pieridae), whereas dummies made from small, cryptically colored lycaenids (*Prosotas* and *Caleta* species)

were ineffective. Decoys did not influence the attraction of lycaenid butterflies towards baits. Hence, visual cues played an important role in locating puddling resources for papilionids and pierids, while searching nitrogen sources for lycaenid butterflies, olfactory cues emitted by decaying organic matter were more likely to be important. The strong attraction of male butterflies to nitrogen-rich resources suggested that, as in the case of sodium, these nutrients might increase reproductive success.

Bede *et al*. (2007) studied the role of neuropeptides in caterpillar nutritional ecology. The regulation of nutritional balance occurred at many levels through selecting and ingesting appropriate plant tissue and nutrient digestion, absorption and utilization. They reviewed evidence of nutritional requirements, particularly leaf protein to digestible carbohydrate ratios affect caterpillar herbivores. Authors proposed a model where midgut endocrine cells assessed and integrated hemolymph nutritional status and gut content, and released peptides which influenced digestive processes. Understanding the effects of diet on insect herbivore was essential for the rational design and implementation of sustainable pest management practices.

Behmer (2009) made comparative studies of nutrient regulation that occupied unique nutritional feeding niches for coexisting generalist herbivores. Work with pathogens and parasitoids have revealed the manner in which top-down pressures influence patterns of nutrient intake. Most insect herbivores strongly regulate their nutrient intake when given the opportunity. When they are restricted to imbalanced diets, they employ regulatory rules that govern the extent to which nutrients occurring in excess or deficit are eaten. Insect herbivores also regularly encounter allelochemicals as they eat, and insect herbivore performance is modified depending on a food's nutrient composition. Insect herbivores regulate their nutrient intake using pre and post-ingestive mechanisms, plus learning, and there is evidence that some of these mechanisms are shaped by natural selection.

Boggs (1988) examined the rates of sucrose ingestion that varied with sucrose concentration and butterfly sex, age and size for *Speyeria mormonia* (Lepidoptera: Nymphalidae). Peak rate of ingestion occurred between sucrose concentrations of 30% and 40%. Males fed at a faster rate than did females under most experimental conditions. Rates were also high for medium to large individuals as opposed to small individuals. Ingestion rates decreased with age for males but not for females.

Boggs (1997a) examined reproductive allocation of glucose and amino acids from adult and juvenile sources in two nymphalid butterflies, *Euphydryas editha* and *Speyeria mormonia.* For compounds abundantly available in the adult diet, incoming nutrients were used in preference to stored nutrients. For compounds present in low amounts in the adult diet, juvenile reserves were used throughout adult life, although adult sources were used if available. Nutrients received by the female from the male at mating, although expected to be treated as stored reserves, were immediately used in egg production. Thus, restriction of adult or juvenile feeding might cause different nutrient types (e.g., carbohydrates, nitrogenous compounds) to become limiting to reproduction. The experiment gave implications for understanding the evolution of nutrient types donated by males to females, the effects of a holometabolous lifestyle on age-specific fecundity, and the effects of using stored reserves vs. income in reproduction. The results allowed further predictions concerning effects of food supply perturbation on fecundity and suggested ways in which species and individuals would differ in sensitivity to those perturbations.

Boggs and Dau (2004) showed that montane butterfly species had feeding preferences among mud, herbivore dung, and carnivore dung, and that these preferences differed among butterfly species. Lepidoptera feed at mud puddles, dung, and carrion in a behavior known as puddling. The puddling substrates varied in soluble sodium content, with mud having the lowest concentrations and carnivore dung having the highest. Within one species, *Pieris napi* L., visit frequencies to mud versus dung matched visit frequencies to sand trays filled with sodium solutions matching the concentrations seen in mud or dung. They suggested that the preference hierarchy of that species was driven by soluble sodium concentration. Their results indicated that lepidopteran species specialize on different puddling substrates, likely obtaining different arrays of nutrients. Finally authors concluded that there were species-or family-specific roles for puddling nutrients in the overall nutrient budget of the insects.

Braby (1990) observed the life history and biology of *Paralucia pyrodiscus lucida* Crosby in Victoria at Eltham-Greensborough, Castlemaine and Kiata during 1987 and 1988. The author described the early stages and the life cycle of *P. p. lucida,* and compared with those of other species of *Paralucia*. *P. p. lucida* is uni- or bivoltine overwinters as larvae and adults fly from late October to mid-April, although the number of generations and flight period varied markedly with geographic location and prevailing climate. Larvae

associated with *Notoncus* spp. ants and fed at night on a particular size or form of the host plant *Bursaria spinosa* var. *spinosa.* Larvae did not appear to diapause during winter but remained quiescent within the attendant ants' nest at the base of the host plant. The effect of climatic constraints on larval activity, flight period and the life cycle of *P. p. lucida* were briefly discussed.

Cahenzli and Erhardt (2012a) examined feeding conditions over the whole life cycle of the small heath butterfly (*Coenonympha pamphilus* L., Satyrinae). They investigated that *C. pamphilus* females receiving nectar amino acids as adults, irrespective of larval food quality, produced heavier larvae and also increased the hatching success of their eggs over the oviposition period. Furthermore, females raised under nitrogen-poor larval conditions tended to use nectar amino acids to increase the number of eggs laid. Previous studies discussed that the nectar-feeding *Araschnia levana* benefited from nectar amino acids for fitness, and females of the fruit-feeding *Bicyclus anynana* also increased offspring quality when they were fed amino acids as adults. *C. pamphilus* females used nectar amino acids primarily to increase their offspring quality, and secondly tended to increase offspring quantity, if larval resources were scarce, showing a resource allocation pattern differing from both *B. anynana* and *A. levana.* Authors concluded that their findings supported the previous postulate that nectar amino acids generally enhance butterfly fitness.

Cahenzli and Erhardt (2013) showed that larval food conditions (nitrogen-rich vs. nitrogen-poor host plants) and adult diet quality (nectar with or without amino acids) affected the amount of consumed nectar in *Coenonympha pamphilus* males. Amino acids in the nectar diet of males increased progeny's larval hatching mass, irrespective of paternal larval reserves. Authors observed the whole reproductive cycle of male butterflies, and also considered the role of females in passing male nutrients to offspring, examining males' realized reproduction indirectly via nuptial gifts, by female performance. They demonstrated that nectar amino acids could improve male butterfly reproduction, supporting the old postulate that nectar amino acids generally enhance butterfly fitness.

Chang (1989) observed and described morphology of the adult, the egg, the larva and the pupa of the cycas blue butterfly, *Chilades pandava pandava* (Horsfield) with illustrations. It is an important pest of Cycas trees. Damaged plants showed wilt of top bud and could no longer grow. The larva bored young stem causing death of the seedling. Under 25-

32°C room temperature condition, the longevity from eggs to adults was 17-20 days. The average percentage of damage was found 17.76% while a survey was conducted on seedlings of *Cycas taiwaniana* in July, 1981 at Pishan Nursery, Taipei. In the laboratory, the 3rd and the 4th instars of the larva were incubated with an entomogenous fungus, *Paecilomyces javanicus* which gave 65% and 60% pathogenicity, respectively.

Chowdhury (2016) observed pre-mating and mating behaviour including territoriality, perching and patrolling activities during year round study period. 88 butterfly's species (429 times) were spotted in pre-mating and 26 species (65 times) were found in mating condition. Lycaenidae (7 species) was noticed the most dominant while Nymphalidae (1 species) was the least dominant families in case of mating occurrences. The other observed butterfly species was belonging to family Hesperidae (6 species), Satyridae (4 species), Papilionidae (3 species), Pieridae (3 species) and Danidae (2 species). The pre-mating success of observed butterflies was very low in case of all these families. Butterflies were spotted in both pre-mating and mating condition during March, August and November; and the relation is found strongly significant among each other. A strong significant relattion was also found in pre-mating and mating occurrences of butterflies with humidity and precipitation.

Corbet (2000) investigated interactions among the flowers and butterflies, using data from a field study in Cornwall. The profitability of butterfly foraging depends in part on the corolla depth and clustering of flowers, and the tongue length, body mass and wing loading of butterflies. The maximum corolla depth from which a butterfly can feed depends on tongue length, which correlates with the more easily measured attributes of body mass and wing loading. Small, short-tongued butterflies did not visit deep flowers. The quantity of nectar sugar per flower necessary for profitable foraging depends on foraging costs, which were expected to correlate with wing loading. Butterfly species with a high wing loading generally confined their visits to flowers that were clustered or very nectar-rich. Butterfly species with a low wing loading could include solitary and less nectar-rich flowers in their diet. Body mass and wing loading affect a butterfly's load-carrying capacity (limiting the distance between fuelling stops) and cooling rate (limiting the distance between stops for basking or endothermic warming), and would influence the capacity for floral selectivity, and for migration and dispersal. Body mass, wing loading and tongue length characterized families or subfamilies of butterflies. Vanessine nymphalids, with their long tongues and high wing loading, visited the deep, massed

flowers of *Buddleja davidii*, while lycaenids, with their short tongues and low wing loading, did not. These often visited members of the Asteraceae. *Eupatorium cannabinum*, with massed flowers offering abundant and accessible nectar, was visited by butterflies of all tongue lengths and both high and low wing loading.

Corbet (2003) described field techniques for sampling and measuring the standing crop and secretion rate of nectar in order to clarify some discrepancies and omissions in existing reviews of nectar measuring techniques. Slender microcapillary tubes (a fresh one for each sample) were recommended for withdrawing nectar, and a hand held sucrose refractometer, capable of operating with very small fluid volumes, was used for measuring concentration. The author discussed potential errors due to the presence of solutes other than sucrose, or to temperatures other than the calibration temperature. Finally, author considered how measurements of secretion rate were affected by reabsorption and by the nature of the bags used to exclude nectarivores.

Cushman *et al.* (1994a) examined interactions between the ant, *Iridomyrmex nitidiceps* and the lycaenid butterfly *Paralucia aurifera* in south eastern Australia, and presented data and supporting the hypothesis that both participants benefit from their association. In the field, lycaenids persisted only on those host plants that ants subsequently colonized. In the laboratory, lycaenid larvae reared with ants were 31-76% heavier, developed 37% faster, and commonly completed one or two fewer instars than larvae reared without ants. Ant tending also resulted in 20% heavier pupae, 69% shorter pupal duration, and 5% larger adults as measured by forewing length; adults were not significantly different as measured by body length. The positive effects occurred largely because ant-tended lycaenid larvae spent more time feeding than untended larvae did. Field data documented that ants colonized host plants only after lycaenid larvae were present, indicating that ants actively maintained the association. In laboratory experiments, 40% more ant workers survived when lycaenid larvae were present than when they were absent, although ant mass was not significantly affected. The survivorship effects occurred because ants consumed the lycaenid's nectary glands secretions, which contained considerable amounts of glucose and amino acids. Their results showed that lycaenids benefited from ants in ways other than, or in addition to, protection from natural enemies and that they in cur minimal developmental costs from associating with ants.

Cushman *et al*. (1994b) estimated life time reproductive success of *Euphydryas editha bayensis* (Nymphalidae), a federally listed threatened butterfly, based on age-specific

fecundity and both adult and offspring survival. Their findings indicated that the relative timing of adult emergence and larval host plant senescence strongly influenced reproductive success of females. For 1992, authors estimated that only 8-21% of the eggs laid by females emerging on the 1st day of the 4 week flight season would produce larvae that reach diapause. This figure dropped to 1-5% for females emerging 7 days into the flight season. Within their entire sample, they estimated that 64-88% of the females produced offspring with less than a 2% probability of reaching diapause. These estimates were particularly striking given that they were based on only one source of larval mortality-pre-diapause starvation due to host plant senescence. This dependence of reproductive success on the relative timing of female emergence and host plant senescence might reduce effective population size and rendered *E. editha bayensis* especially vulnerable to local extinction events.

D'Amico (2009) experimented on a long-term study (from 1999 to 2008) of the flower preferences of feeding adult butterflies in the Po Plain area. Examination of 2040 observations of nectar-feeding within the partially wooded plains protected or naturalistic areas clearly confirmed that butterflies feed on floral nectar from a very wide variety of plant species and they could differ in their range flower use. Butterflies preferred certain biotopes, flower species, flower families, colours of corollas, corolla-types, inflorescence-types, over others for nectar-feeding. Some butterfly species used host plants species for both adult and larval nutrition. Butterfly conservation management activities within the Po Plain were discussed.

Degroote *et al*. (2014) examined the body temperature and behavioural differences between light and dark butterflies in the tropical dry forest. Light and dark butterflies could differ in their distribution across light conditions and use of postural mechanisms because of their varying heat absorption capacities. Variable ambient temperatures require ectotherms such as butterflies to use behavioural mechanisms to regulate their body temperatures. Dark butterflies spent less time in the sun and closed their wings more often than light butterflies, because dark phenotypes depended more strongly on behavioural cooling mechanisms. Such differences might have important implications for the foraging capacities of butterflies as well as other ectotherms.

Dennis and Shreeve (1989) described the transformation in phenotypes of butterfly wing morphology (colour, pattern, size) to the north and west of Britain in relation with climatic impact, especially ambient temperatures and radiation levels as infra-specific

units in *Devensian refugia*. In cooler, less predictable summer conditions to the north and west, selection favoured modifications in adult phenotypes that maintain efficiency in thermoregulation, mate advertisement and predator escape. The form that wing modifications depended mainly on basking posture (lateral, dorsal absorption and reflectance), which determined the allocation and interaction of functions on different wing surfaces. It was also dependent on host plant-habitat structure, which influences thermal stability and other behavioural norms (mate-locating behaviour) and biological attributes (size, robustness, speed and mode of flight, chemical defences) which affect their relationships with predators and conspecifics. The significance of Quaternary palace-environments to phenetic transformations was discussed as it was the relevance of the model to the development of phenotypes in arctic endemic butterflies. Differences in phenotypes of butterflies which occupy arctic and temperate montane environments were also predicted.

Dicke (2000) carried out both mechanistic and functional studies predominantly restricted to bitrophic aspects to understand the host-plant selection by herbivorous arthropods. Author selectively reviewed how information from organisms at different trophic levels varied in space and time and how herbivores could integratively exploit this information during host selection. In doing so, research areas were identified that were likely to provide important new insights to explain several of the questions in herbivore host selection that remain unanswered so far. These research areas were at the interface of evolutionary ecology, behavioural ecology and chemical ecology.

Duara and Kalita (2014) detected butterflies as the main pollinators of *Ixora coccinea* in Nambor Wild Life Sanctuary, Assam. The family of Papilionidae (6 species), Pieridae (3 species) and Nymphalidae (2 species) were found as insect visitors. The time of the day had a significant effect on the number of butterflies that visited the flowers. Afternoons had more visitors than mornings suggesting that the butterflies became active as the day warms up. The frequency of butterflies visited the flowers was high during 09:00-13.00 hour and month of April to August. Flower colour had a positive influence on the number of visitors. The flowering season of *I. coccinea* was mainly summer and butterflies were deriving most of their heat from the sun.

Erhardt and Baker (1990) investigated the increase of the amino acid concentration over different time intervals in artificial nectar (i.e. a sucrose solution) due to pollen contamination in four Californian plant species (*Aesculus californica, Amsinckia lunaris,*

Brodiaea pulchella, *Carduus pycnocephalus*), which were important nectar resources for a Californian colony of the butterfly *Battus philenor* as well as for other insects. The increase of the amino acid concentration in the medium was different in all four species and determined by a variety of factors including permeability of the pollen grain wall and presence or absence of pores. From the results they suggested a passive diffusion process of the free pollen amino acids into the medium rather than an active release. They also discussed implications from the experiments for *Battus philenor* and for other nectar feeding pollinators. Authors proposed a possible complementary effect of free pollen and nectar amino acids for plant species in which pollen was likely to be knocked into nectar by their flower visitors. They concluded a possible evolutionary pathway from nectar feeding butterflies such as *Battus philenor* to the complex derived pollen feeding habit in the Heliconius butterflies.

Erhardt and Rusterholz (1998) experimented the preferences for nectar amino acids, urea and ammonium ions of peacock butterflies, *Inachis io*. Females clearly preferred a mimic of *Lantana camara* nectar containing amino acids to an otherwise similar plain sugar solution, whereas males did not discriminate between these test solutions. Neither males nor females discriminated between the full mixture of amino acids in a mimic of *L. camara* nectar and similar test solutions containing only the single amino acids arginine or proline. Furthermore, the butterflies were not able to detect methionine in the test solutions. Both sexes detected and preferred ammonium ions in test solutions but showed no response to urea. Their findings supported the hypothesis that butterflies could select for high amino acid concentrations in floral nectar, and unlikely selection for particular amino acids. The rather unspecific response of *I. io* males to the nectar constituents tested might result from their relatively low demand for nitrogen for spermatophore and sperm production, while their high activity could make energy supply (i.e. sugar) more important. The preference for ammonium ions suggested that *I. io* could also acquire nitrogen from ammonium-contaminated soil by puddling, as shown for sodium in swallowtail butterflies.

Fiedler (1995b) examined host plant ranges, scored as number of plant families' utilized by the caterpillars for 1068 species of the butterfly subfamily Lycaeninae. The majority of species were oligophagous, being restricted to one plant family or genus. Polyphagous species accounted for a significantly larger proportion among tropical species than in temperate zone faunas. This difference was independent of influences of myrmecophily

on host plant relationships. A strong correlation between polyphagy and use of woody host plants, as well as between oligophagy and connections with herbaceous host plants, suggested that the more strongly developed chemical defence of herbaceous plants constrains the simplification of host plant ranges of herb-feeding Lycaeninae butterflies. Specializations on unpredictable ephemeral food resources (young foliage, inflorescences) in unseasonal tropical environments, in contrast, had favoured the more frequent rise of polyphagy. The degree to which herbivorous insects were specific to certain host plants has played a central role in estimating tropical species richness, and hence global biodiversity.

Fiedler (1996) studied lycaenid butterflies and their interactions with plant chemistry of host plant. More than two thirds of the lycaenid species are restricted to one plant family or genus. Affiliations with 'toxic' plants are rare in the Lycaenidae, and excretion rather than sequestration of plant toxins appears to be their usual way of detoxifying host-plant compounds. Flavonoids are frequently sequestered by lycaenid larvae and are subsequently concentrated as pigments in the adults' wings, where they might play a role in visual communication. Mutualistic associations with ants occurred in the larvae of more than 50% of the extant Lycaenidae species. As a conflict between the nutrient demands of the larvae and the proportion of plant-derived resources allocated to maintain the mutualism with ants, variation in resource quality often translated into variation of mutualistic capacities of the caterpillars, in particular under nutrient stress.

Fiedler (2012) reviewed ant-associated butterflies that were parasites of ants. Numerous butterfly species in the family Lycaenidae maintain myrmecophilous associations with trophobiotic ants. *Camponotus*, *Crematogaster*, *Myrmica*, and *Oecophylla* are the most frequently parasitized ant genera. The distribution of ant-parasitic representatives of the Lycaenidae suggested that only *Camponotus* and *Crematogaster* have multiply been invaded as hosts by different independent butterfly lineages. A general linear model reveals that the number of associated nonparasitic lycaenid butterfly species is the single best predictor of the frequency of parasitic interactions to occur within an ant genus. Neither species richness of invaded ant genera nor their ecological prevalence or geographical distribution contributed significantly to that model. Some large and dominant ant genera, which comprise important visitors of ant-mutualistic lycaenids, have no (*Formica*, *Dolichoderus*) or very few ant-parasitic butterflies (*Lasius*, *Polyrhachis*) associated with them.

Fischeh and Fiedler (2001) examined effects of adult feeding on fecundity and longevity of butterfly. Adult females of the Purple-Edged Copper butterfly *Lycaena hippothoe* L. feed highly concentrated sucrose solution. They laid significantly more eggs (mean=464) than those individuals given water only (mean=65). Longevity was also three to five times greater, whereas hatching rate of the eggs was not affected by the mother's nutrient intake. Stored resources acquired during the larval stage supported the realization of only 14% of the fecundity of the fed females. Hence, *L. hippothoe* butterflies depended far more on adult-derived resources than other nectar-feeding butterflies for which comparable data exist. The authors got findings which being important for the population dynamics of the species, as reduced availability of nectar sources presumably constrains realized fecundity.

Fordyce *et al*. (2002) found that female wing patterns could act as an effective mate-recognition signal in some populations of two recently diverged lycaenid species. In field experiments, they observed that males from a *Lycaeides idas* population and an alpine population of *L. melissa* preferentially initiate courtship with conspecific females. A morphometric study indicated that at least two wing pattern elements were important for distinguishing the two species: hind wing spots and orange crescent-shaped pattern elements called aurorae. Authors examined that male *L. idas* initiate courtship with heterospecific females indicating that the wing pattern elements that defined the diversity of this group could be effective mate recognition signals.

Forister (2005) examined the influence of host plant phenology on the univoltine specialist lepidopteran herbivore *Mitoura nelsoni* using incense cedar, *Calocedrus decurrens* Torrey. New spring growth was an optimal resource for *M. nelsoni* was tested by rearing larvae on plants collected along an elevational gradient at two times in the spring (both before and during the typical flight period of *M. nelsoni*). The oviposition preferences of females were assayed with the same plants. *M. nelsoni* pupae grew to consistently greater pupal weights when reared on incense cedar branches in the earliest phenological stages, although females avoided ovipositing on pre-new growth branches. Trees in the earliest phenological stages, which resulted in the highest larval performance, were collected before the typical flight season of *M. nelsoni*. The phenology of *M. nelsoni* did not seem to be synchronized to host conditions. Those results were discussed within the context of host-associated speciation in the genus *Mitoura* and temporal isolation that

was an important component of reproductive isolation between *M. Nelson* and a closely related species in northern California.

Franklin and Bias (2008) presented a set of keys for identification of the 41 species of lycaenid butterfly known to occur in the monsoonal Kimberley and Top End regions of north-western Australia. Sizes were presented as average wingspans and as forewing length, measured as a straight line from the base of the leading edge to the apex. They described that the characteristics of the tail were useful for identification. Areas of the hind wing often critical for identification, tails and sub-terminal hind wing spots were particularly susceptible to damage. Iridescent scales within sub-terminal hind wing spots, a key character for a number of species could wear to obscurity. For those, some worn individuals couldn't be identified using the key. In addition, differences between the sexes were not always represented in the keys. Keys consisted of couplets and triplets arranged to form multiple-choice pathways leading to species. The groups and subsequent divisions were practical arrangements and didn't necessarily correspond with systematic relationships. Similarly, for the most part they kept the sexes and seasonal morphs of a species together.

Gardener and Gillman (2002) examined that different amino acids elicit different responses in insect taste receptors that were used to characterize nectar samples from 65 plant species from a wide range of families according to their amino acid profile (determined by high performance liquid chromatography). Amino acids are the second most abundant class of compound (after sugars) to be found in nectar. Although amino acids are detectable by insects, little work has focused on the role of taste in the ecology of pollination. In foraging for nectar, animals carry out the vital role of pollination. A ternary classification system was used to map the amino acids present in nectar samples. There was a wide range of taste profiles with most plant species having their own characteristic taste value. How nectar tastes to pollinating insects was of great importance in understanding the foraging choices of insect pollinators and there were many avenues that remain to be exposed.

Geister *et al*. (2008) focused on effects of adult diet on the number and/or size of the eggs produced, and the offspring viability by examining the fruit-feeding tropical butterfly *Bicyclus anynana*, highly dependent on adult-derived carbohydrates for reproduction. Adult diet of female *B. anynana* had pronounced effects on fecundity, egg composition and egg hatching success, with butterflies feeding on the complex nutrition of banana

fruit performing best. Adding vitamins and minerals to a sucrose-based diet increased fecundity, but not offspring viability. All other groups (plain sucrose solution, sucrose solution enriched with lipids or yeast) had a substantially lower fecundity and egg hatching success compared to the banana group. Effects of adult diet on egg composition were not straightforward, indicating complex interactions among specific compounds. The authors found some evidence that total egg energy and water content were related to hatching success, while egg protein, lipid, glycogen and free carbohydrate content did not seem to limit successful development. They exemplified the complexity of reproductive resource allocation in *B. anynana*, and the need to consider egg composition and offspring viability while trying to estimate the effects of adult nutrition on the fitness in this butterfly and other insects.

Ghazoul (2006) experimented to facilitate pollination displaying multiple floral species by attracting a greater number and/or diversity of pollinators. Flowers were morphologically distinct among co-flowering plants. Pollinator visited to *Raphanus raphanistrum*, a self-incompatible herbaceous plant, increased when it occurred with one or a combination of *Cirsium arvense*, *Hypericum perforatum* and *Solidago canadensis* than when it occurred alone. Enhanced visitation to *R. raphanistrum* in mixed species plots was reflected by increased seed production. Facilitative effects in pollination were conditional on the density and evenness of the floral mixture and graded into competition as the relative abundance of *R. raphanistrum* declined in a two-species mixture. Author proposed an alternative mechanism of differential but complementary floral rewards to explain facilitative attraction of pollinators. Facilitation of, and competition for, pollination had implications for regeneration by seed of rare or isolated plants, and of mitigating Allee effects that afflicted such populations.

Guddeti (2014) studied the co-evolutionary relationship of four butterfly pollinated flowers *Cadaba fruticosa*, *Caesalpinia pulcherrima*, *Clerodendrum infortunatum* and *Clerodendrum phlomidis.* Not only the floral morphology, nectar quality the main energy source of insects including butterflies is also a promiscuous character which excludes other insects than specified. So, nectar characters of these flowers were studied and found a good correlation with butterfly preferred nectars. It is one of the most significant events in organic evolution.

Hall *et al*. (1975) examined protein and amino acid contents of leaves from some tropical and subtropical plants. By dry weight, leaves of 23 plant types contained protein from 6%

to 41%, of which 14 types contained 20% or more. There were notably found castor bean (*Ricinus communis*) 41%, balsam pear (*Momordica charantia*) 33%, cowpea (*Vigna sinensis*) 32%, and cassava (*Manihot esculenta*) 32%. The leaves had large quantities of the essential amino acids lysine, leucine and isoleucine, moderate amounts of valine, threonine and phenylalanine, and minor amounts of methionine and tryptophan. Many nonessential amino acids were found in moderate quantities. Tyrosine and histidine were low, and cysteine and cystine were detected at levels that were less than 1% of the total amino acids recovered. Leaves were essentially similar in their amino acid compositions, although several cultivars showed notable variations in methionine.

Harinath *et al*. (2015c) conducted studies on the univalent and seasonal Lime blue butterfly *Chilades lajus* (Stoll) during January 2014 to December 2014 at Sri Lankamalleswara Reserve forest in the Eastern Ghats of Southern Andhra Pradesh. The butterfly was on wing almost throughout the year, breeding with high frequency during the periods of monsoon and post monsoon seasons. The growth from egg to adult was 19-22 days with four larval instar stages. There was no dormancy stage in the life history. Short life cycle and high success development of life stages suggested the production of more number of broods yearly. They also discussed the population index of *Chilades lajus* on same ovipostion host plant leaves.

Harinath *et al*. (2016) designated the life history and larval stages of the Lime blue butterfly, *Chilades lajus* (Stoll) in relations to diet consumption, exploitation and the length of life phase on its host plant *Citrus aurantifolia* for the first time. The study was conducted from January to December 2015 at Sri Lankamalleswara reserve forest, Kadapa, India. *Chilades lajus* completed its life cycle in 15-22 days (Eggs 2-3 days, Larvae: 8-12 days, Pre-Pupa: 2-3 days, Pupa: 3-4 days). The standards of food indices across the instars included approximate digestibility (AD): 66.64-96.01%; growth rate (GR): 0.29-0.99, consumption index (CI): 2.32-8.48, efficiency of conversion of digested food (ECD): 3.53-64.77%; efficiency of conversion of ingested food (ECI): 3.39-42.77% as measured in the laboratory. The relatively high values of ECD and ECI partially explain the ecological success of this butterfly in the study.

Heinrich (1990) tested the effects of wing posture on thoracic temperature in so-called 'reflectance' basking. Butterflies with pale yellow or white dorsal wing surfaces held with their wings at 45, 90 or 180° with respect to each other (or 22-23, 45 and 90° with respect to the solar radiation) heated to mean thoracic temperatures (T_{th}) of 38.2, 39.5 and

39.9°C, respectively, in direct sunlight. These closely similar values of T_{th} were significantly different ($P<0.02$) from each other, but the difference was in the opposite direction to that predicted by the solar reflectance hypothesis. The T_{th} of butterflies tested under a sun lamp in the laboratory showed the same trend of T_{th} with wing angle. Butterflies with wings at 45° that were heated from above with a sun lamp showed an immediate increase in T_{th} when turned at right angles to a gentle air stream. Thoracic temperature immediately declined when they were again turned to face the air stream. Those butterflies that were at right angles to the air stream showed an immediate increase in T_{th} when the wings were raised from 180 to 45°, and their T_{th} again declined to previous values when the wings were again lowered. However, little or no effect of wing angle on T_{th} was observed when the wing angle of butterflies parallel to the air stream was altered. These results indicated that wing elevation in basking butterflies did not increase T_{th} by way of solar reflection from the wings. Instead, the raised wings increased T_{th} by reducing convective cooling. Author concluded that 'Reflectance' basking is a form of dorsal basking used by species of butterflies that perch above vegetation rather than above a heated substratum.

Herrera (1990) examined the daily activity patterns of the pollinators of *Lavandula latifolia* (Labiatae), a summer-flowering, insect-pollinated evergreen shrub of Mediterranean woodlands. *L. Iatifolia* produced nectar uninterruptedly over daytime, and both flower production and nectar secretion rates were highest early in the morning and late in the afternoon. Pollen availability in the flower population, as estimated by the proportion of pollen-bearing, male-phase flowers, reached a maximum in late afternoon, while nectar and sugar availability peak around the middle of the day. There was considerable variation both among major groups (hymenopterans, dipterans, lepidopterans), and among species within groups, in the timing of foraging at flowers. The interspecific differences in pollen transfer effectiveness and average flight distance between consecutively visited flowers, the daytime period was not homogeneous with regard to the potential pollinating effectiveness of the pollinator active at a given time. There was not a good correlation between the daily cycles of floral resource production and availability, on one hand, and of components of pollinating effectiveness, on the other. Author suggested that both the plants and the pollinators' daily cycles largely represent independent responses to croak rhythmicity of the physical environment. The author also found that matches and mismatches between daily patterns of floral resources,

and aspects of pollinating effectiveness were epiphenomena lacking particular adaptive significance to the plant.

Hilker and Fatouros (2015) reviewed ecological effects of plant responses to insect eggs and differentiate between egg-induced plant defenses that directly harm the eggs and indirect defenses that involve egg parasitoids. They also discussed the ability of plants to take insect eggs as warning signals; the eggs indicate future larval feeding damage and trigger plant changes that either directly impair larval performance or attract enemies of the larvae. They argued how egg-associated cues elicit plant defenses, how the information that eggs had been laid was transmitted within a plant, and which molecular and chemical plant responses were induced by egg deposition. Finally, authors concluded evolutionary aspects of the interactions between plants and insect eggs and asked how the herbivorous insect copes with egg-induced plant defenses and might avoid them by counter-adaptations.

Hill and Pierce (1989) examined the effect of sugars and amino acids present in the adult diet of *Jalmenus evagoras* on its feeding behaviour (concerning female), somatic maintenance, longevity, fecundity and egg weight. The presence of sugars in adult food stimulated butterflies of this species to feed, and they appeared to compensate for low (1% wt/wt) sugar diets by feeding for longer periods. Thirteen butterflies were also more likely to feed on diets containing amino acids than on water controls. The availability of sugar allowed females to maintain or even increase their body weight and fat body size, but amino acids had no effect on these variables. Individuals on the medium (25% wt/wt) sugar diet attained the greatest longevity. Female fecundity was increased as much as threefold by the availability of sugar. However, amino acids in the diet had no effect on either longevity or fecundity. Egg weight was not affected by the concentration of sugars or amino acids in the adult diet, but was correlated with the weight of the female butterfly. They demonstrated the results that the availability of carbohydrates in the adult diet could play an important role in the population dynamics of this species. However, the presence of amino acids had little effect on most of the variables measured.

Inyama *et al.* (2015) examined palynological features of *C. sinensis, C. limon, C. aurantifolia, C. paradisi, C. reticulata* and *C. maxima* collected from various parts of Owerri and evaluated in order to determine the taxonomic value of the observed internal peculiarities. Features related to pollen shape showed circular to elliptic shapes in all the taxa while rectangular shape distinguished *C. limon, C. paradise* and *C. maxima.* Polar

view showed that *C. paradisi* and *C. maxima* have closer affinity than the other taxa studied.

Jablonski (2002) described a protocol to measure nectar secretion rate in flowers using the pipette method. The author regarded home-made glass micropipettes as the best tool to collect nectar as simple to use.

Janz and Nylin (1997) suggested by theoretical studies that host range in herbivorous insects restricted by constraints on information processing on the ovipositing females than by trade-offs in larval feeding efficiency. Females of the monophagous butterflies *Polygonia satyrus*, *Vanessa indica* and *Inachis io* and the polyphagous *P. c-album* and *Cynthia cardui* (all in Lepidoptera, Nymphalidae) were given a simultaneous choice of stinging nettles (*Urtica dioica*) of different quality. In addition, the same choice trial was given to females from two populations of *P. c-album* with different degrees of specificity. As predicted from the information processing hypothesis, all specialists discriminated significantly against the bad quality nettle, whereas the generalists laid an equal amount of eggs on both types of nettle. There were no corresponding differences between specialist and generalist larvae in their ability to utilize poor quality leaves. Their study therefore suggested that female host-searching behaviour plays an important role in determining host plant range.

Janz *et al.* (2005a) experimented in a laboratory the preference of *Polyommatus icarus* females to oviposit on *Lotus corniculatus* plants with flowers over those without flowers. There was a connection between choice of nectar sources and choice of oviposition host plant. Observations of behavioural sequences also revealed that oviposition often followed immediately after nectaring. Neural limitations on information processing had been shown to play an important role for host plant specialization in herbivorous insects. The necessity of fast and accurate decisions favours the adoption of a few high-contrast signals, which selects against the use of multiple resources. Many species face a similar problem when searching for adult food sources and the simultaneous need to fulfil both search tasks could lead to a potential conflict. Some insects used the same host plant species for both adult and larval nutrition, which made it possible to decrease the number of search images and thus potentially increased efficiency of the choices. The results of the experiment suggested that nectar availability played an important role in oviposition decisions of *P. icarus* and provided an explanation to why some phytophagous insects not always chose the host plant that gave the best offspring performance.

Jordano *et al.* (1989) described the life-history of *Tomares ballus* in southern Spain. *T. ballus* was monophagous and feeds on flowers and fruits of *Astragalus lusitanicus* (Lam., 1783) (Fabaceae), despite the availability of other potential host plants in Sierra Morena. The phenological coupling between *T. ballus* and *A. lusitanicus* was considerable in Sierra Morena, whereas the flowering period of the remaining potential host plant species was approximately one month later. Butterflies showed preferences for *Medicago polymorpha* (L., 1753) in the Guadalquivir Valley. Other aspects of the life-history of *T. ballus* were discussed in relation to the morphological and productive features of *A. lusitanicus*.

Kaminski and Freitas (2010) described the natural history and morphology of immature stages of *Allosmaitia strophius* (Godart) for the first time, using both light and scanning electron microscopy. The available host plant records for the genus were reviewed suggesting a feeding specialization on reproductive structures of Malpighiaceae. Both concentration of resources in the reproductive tissue of Malpighiaceae and the existence of sequential flowering periods might be important factors involved in the evolution of oligophagy in *Allosmaitia*. Field and laboratory observations showed that larvae of *A. strophius* were ignored by tending ants besides the presence of the dorsal nectar organ (DNO). Additionally, larvae presented some behavioural and morphological adaptations that were proposed as preventing ant attacks, such as dendritic setae, thick cuticle, perforated cupola organs and absence of a "beat reflex".

Kamrunnahar *et al*. (2018) conducted a thorough study on the basking behaviour of some nymphalid butterflies in the fields of Bhawal national park, Rema-Kalenga, Zoological and Botanical Gardens of the University of Dhaka. The basking time budget and the wing-posture activities of butterflies (*Junonia atlites, J. almana, J. iphita, Neptis soma, Labadea martha, Ergolis ariadne, Phalantha phalantha, Hypolimnas bolina* and *Athyma perius*) were studied. Different types of wing postures (viz. appressed, horizontal, angled and closed type) were also recorded. It was found that butterflies took maximum time for their basking during winter season. Most of the examined butterflies preferred the month of November and December for their basking. The observations revealed that thermal basking increased the temperature in the butterfly body. It directly implied how thermoregulation associated with behavioural activities in different abiotic conditions. The results also showed the importance of wing postures for thermoregulation.

Kemp and Krockenberger (2002) investigated a potential fourth mechanism whereby individuals perched with their wings fully spread and angled downwards such that the margins are appressed to the substrate. Adult butterflies exhibit three thermoregulatory mechanisms, termed dorsal, lateral and reflectance basking. They found that mate-locating male *Hypolimnas bolina* (L.) (Nymphalidae) adopted appressed posture when operational thoracic temperatures are lowest (less than approximately 34°C). As thoracic temperature increases, males perch with wings increasingly closed and ultimately select shaded microhabitats. Using thermocouple-implanted dead models, they showed that appressed posture individuals warm faster than those adopting the conventional dorsal-basking (horizontal wing) posture. This thermal advantage was not mitigated by shading of the outer 60-70% of the wing area, which suggested that as with the conventional dorsal posture, only the basal wing surfaces contribute to heat gain via the absorption of solar irradiation. These investigations suggested that appression represents a novel extension of conventional dorsal basking behaviour in butterflies.

Kharouba and Vellend (2015) used a broad-scale approach utilizing collection records to compare the temperature sensitivity of the timing of adult flight in butterflies vs. flowering of their potential nectar food plants (days per °C) across space and time in British Columbia, Canada. On average, the phenology of both butterflies and plants advanced in response to warmer temperatures. However, the two taxa were differentially sensitive to temperature across space or time, indicating the additional importance of non-temperature cues and/or local adaptation for many species. Across butterfly-plant associations, flowering time was significantly more sensitive to temperature than the timing of butterfly flight. The findings indicated that warming-driven shifts in the relative timing of life cycle events between butterflies and plants were likely to be prevalent, but that predicting the magnitude and direction of such changes in particular cases was going to require detailed, fine-scale data.

Kingsolver (1985b) studied that many butterflies regulate their body temperature in order to meet the thermal requirements for flight. He provided a conceptual framework by which to categorize the diversity of thermoregulatory characteristics in butterflies. The mechanisms of thermoregulation in moths and other insects also briefly described. Author used this framework to examine the relation of weather, body temperature and flight. Finally, author summarized recent work in butterfly demography that illustrated the importance of thermoregulation and flight in the population ecology of butterflies.

Kitahara *et al*. (2008) examined the relationships between the diversities of vegetation, adult nectar plants, and butterflies in and around the Aokigahara primary woodland on the northwestern foot-slopes of Mount Fuji, central Japan. The results showed that the nectar resource utilization by adult butterflies was significantly biased to herbaceous plants, especially to perennials, compared to woody species, although most of the study area was in and near a primary woodland. There were greater nectar plant species in sites with greater plant species richness. The strongest correlation was found between butterfly species richness and nectar plant species richness at each site. Another close correlation was also detected between the species richness of nectar plants and herbaceous plants at each site. Having this results author suggested that herbaceous plant species richness in a habitat plays a central role in its nectar plant species richness, and the nectar plant richness is a highly important factor supporting its adult butterfly species richness. Consequently, author proposed that the maintenance and management of herbaceous plant species richness in a butterfly habitat, which lead to those of its nectar plant species richness, are very important for conservation of butterfly diversity even in and around woodland landscapes of temperate regions.

Knolhoff and Heckel (2014) reviewed behavioural assays of insect herbivores with host plants or the volatiles they emit, with special consideration given to design, analysis, and interpretation to maximize ecological relevance. A toolkit of robust assays helped to address fundamental issues at the intersection of ecology and evolution, such as the underpinnings of plant-insect interactions and the identification of genes involved in host race formation. Behavioural assays of insects were usually designed to measure attraction for feeding or oviposition in relation to their host plants or specific chemistry.

Kornev *et al*. (2009) used the principles of interfacial flows to analyze the feeding mechanism of butterflies and moths. They documented the feeding rates and proboscis behaviour of monarch butterfly (*Danaus plexippus*) in different situations: when butterfly fed from droplets, from vials modeling floral cavities, and from porous materials modeling fruits, wet soils, or dung. Using high speed imaging and simple models, they also proposed a scenario of butterfly feeding which was based on capillary action. According to the proposed mechanism, the trunk of butterflies and moths works like a fountain pen where the air bubbles played a significant role in controlling fluid flow.

Krenn (2010) reviewed the form and function of the mouthparts in adult Lepidoptera and their feeding behaviour from evolutionary and ecological points of view. The formation

of the suctorial proboscis encompassed a fluid-tight food tube, special linking structures, modified sensory equipment, and novel intrinsic musculature. The evolution of these functionally important traits could be reconstructed within the Lepidoptera. Author explained the proboscis movements by a hydraulic mechanism for uncoiling, whereas recoiling was governed by the intrinsic proboscis musculature and the cuticular elasticity. Fluid uptake was accomplished by the action of the cranial sucking pump, which enabled uptake of a wide range of fluid quantities from different food sources. Nectar-feeding species exhibited stereotypical proboscis movements during flower handling. The behavioural modifications and derived proboscis morphology were often associated with specialized feeding preferences or an obligatory switch to alternative food sources.

Kunte (1997) monitored the diversity and seasonal patterns in butterfly communities in northern Western Ghats (India), four tropical habitats with different disturbance levels. Species richness was highest in late monsoon and early winter. Majority of the butterfly species also showed abundance peaks in these seasons. Fire played a significant role in determining species composition in fire-afflicted areas and affected flight periods of some species but did not affect species richness. Grazing had a major impact on species composition and it favoured only those Lycaenids and Nymphalids whose caterpillars feed on herbs. In case of one of the sites where phenophases of larval food plant and population trend of a small Lycaenid was documented, the population showed rapid increase at the time when the plants were in suitable phenophase for growth of the caterpillars. A possible evolutionary interaction between herb-feeding and non-herb-feeding Lycaenids was proposed.

Kunte (2007) hypothesized that species with disproportionately long proboscides had a functional cost in terms of higher handling time (amount of time spent per flower), been at a competitive disadvantage compared to butterflies that had shorter proboscides and lower handling times. This hypothesis was tested using Costa Rican butterflies, and measured body length, proboscis length and handling time on *Lantana* and *Wedelia*, two nectar plants with generalist pollination systems which attracted large numbers of nectar-feeding butterfly species. There was a strong positive relationship between ‘relative proboscis length’ (proboscis length in relation to body size) and handling time per flower on both nectar plants. Species with greater relative proboscis length had up to three time’s longer handling time per flower. Thus, butterflies with relatively long proboscides should harvest less nectar per unit time from the same flower than butterflies with normal

proboscides. Reduced foraging efficiency in the face of competition from other nectarivores might be a functional constraint that limits the evolution of disproportionately long proboscides in generalist nectar-feeding butterflies.

Kuussaari *et al.* (2000) studied host plant abundance, host use, and oviposition preference in meta-populations of the butterfly *Melitaea cinxia* within an area of 3500 km^2 in the A° land islands, south western Finland. In the study area, *M. cinxia* had 400 small local populations on dry meadows with the larval host plants, *Plantago lanceolata* and *Veronica spicata. Plantago lanceolata* occurred in practically all meadows otherwise suitable for the butterfly, whereas the distribution of *V. spicata* was largely restricted to the north western part of the study area. Based on observations of 6500 pre-diapause larval groups during 1993-1996, they documented spatial variation in host plant use in relation to their abundance (electivity). The fraction of larval groups found on *V. spicata* increased disproportionally with the relative cover of *V. spicata* in the habitat patches. Additionally, the probability of *Veronica* use in a population increased with increasing number of larval groups found on *Veronica* in the surrounding populations but decreased with increasing use of *Plantago* in the neighbourhood. This regional effect on host use at the scale of migrating butterflies caused either by spatial variation in the insect (in either preference or performance) or by spatial variation in plants (in resistance to attack by the butterflies). To study the first possibility, they conducted oviposition preference experiments using butterflies from five meta-populations located 2-55 km from each other and characterized by differences in host plant availability and host use. They found clear genetic differences in oviposition preference between the five meta-populations consistent with the observed host use patterns in the field. They concluded that the spatial host use patterns of *M. cinxia* in the study area were driven both by direct effects of local host abundance and by indirect effects mediated through meta-population level adaptation to the regionally more abundant host plant.

Lanza *et al*. (1995) collected nectar from *Impatiens capensis* in a nested design: three flowers from each of three plants from each of three populations. The design enabled them to quantify variation within individual plants, among plants within populations, and among populations. Using high performance liquid chromatography, the authors analyzed the sugar and amino acid composition of the 27 flowers. Analysis of variance showed that none of the parameters (volume, concentrations of three sugars and 24 amino compounds) varied within individuals. Variation in nectar volume was not significant among plants

but was nearly significant among populations. Of the three sugars detected (sucrose, glucose, and fructose), the only significant variation was that of sucrose among populations. Concentrations of 12 amino compounds varied significantly at the plant level while 7 amino compounds varied among populations. They found that pooling of nectar samples from flowers of individual plants could be an acceptable methodology for those seeking to understand within species variation; amino compounds appeared to vary more than either volumes or sugar concentrations. Future studies should assess how much of the observed variation is due to genetic versus environmental differences; and additional studies should examine the geographic variation in nectar parameters and pollinators of *I. capensis* in order to assess the role of different pollinators play in shaping nectar composition.

Le Gall and Behmer (2014) conducted two experiments using nymphs of the generalist grasshopper *Melanoplus differentialis*. Grasshoppers and caterpillars differ in a number of important ways, which might affect their feeding and physiological responses to foods with variable content of protein and carbohydrates. Authors measured performance and related this to the self-selected intake of nutrients. No differences were found for duration of development across treatments, but increase in mass was lower on a diet of low macronutrient concentration. Consumption of protein was always tightly regulated, but intake of carbohydrate was significantly reduced when consuming diluted food. In the second experiment, insects were constrained to one of nine diets and they plotted performance and consumption using a fitness-landscape approach that mimics the natural variation of nutrients in plants. Significant effects were found in protein and carbohydrate content on increasing in mass and in duration of development. The concentration of macronutrients in the food had more pronounced effects than did the protein-to-carbohydrate ratio. The protein-carbohydrate content also significantly affected the intake of food and energy (calories), production of frass, and digestive efficiency. Foods with low macronutrient concentration consumption were high, but digestive efficiency was low. The results suggested that insects favoured protein biased foods when the total macronutrient content of available foods was low, and that in the short-term compensatory feeding responses could overcome nutritional deficits and/or imbalances. However, over the long term, insect herbivores paid substantial costs when eating foods that were nutritionally suboptimal.

Lederhouse *et al*. (1990) studied newly emerged laboratory-reared males of the tiger swallowtail butterfly, *Papilio glaucus* L. (Lepidoptera: Papilionidae), that were allocated to four adults diets: dilute honey-water (20% by weight); honey solution supplemented with electrolytes (lepidopteran Ringer's); honey solution supplemented with amino acids (0.5% casein hydrolysate); or honey solution supplemented with electrolytes and amino acids. They attempted to hand-pair males after 2 days of feeding ant then at 2-day intervals to a maximum of four pairings. Males of both electrolyte treatments were more likely to couple than honey-water controls. Males receiving electrolytes plus amino acids produced seven times more hatching larvae than control males. This was chiefly attributable to improved number and success of matings subsequent to the first mating. Spermatophore size was correlated with male pupal mass for the first adult mating; diet affected the size of second and later spermatophores. Male diet had little effect on the longevity of males or their mates.

Lehnert *et al*. (2016) quantified the proboscis architecture of butterfly to test the hypothesis that proboscis structure relates to feeding guild. They used scanning electron microscopy to elucidate the fine structure of the proboscis of both sexes and to quantify dimensions, cuticular patterns, and the shapes and sizes of sensilla and dorsal legulae. Sexual dimorphism was not detected in the proboscis structure of any species. A hierarchical clustering analysis of overall proboscis architecture reflected lepidopteran phylogeny, but did not produce a distinct group of flower visitors or of puddle visitors within the flower visitors. Specific characters of the proboscis, nonetheless, could indicate flower and non-flower visitors, such as the configuration of sensilla styloconica, width of the lower branches of dorsal legulae, presence or absence of dorsal legulae at the extreme apex, and degree of proboscis tapering. They suggested that the overall proboscis architecture of Lepidoptera reflects a universal structural organization that promotes fluid uptake from droplets and films. On top of this fundamental structural organization, the diversity of floral structure was selected for structural adaptations that facilitate entry of the proboscis into floral tubes.

Liu *et al*. (2010) reported the preference and performance on flowering and non-flowering host plants of the generalist herbivore *Helicoverpa armigera* to explore whether there were such behavioural trade-offs between moth and their caterpillars offspring. They found that the adult moths had a strong oviposition preference for flowering tobacco and sunflower plants. Young caterpillars preferred to feed on the

inflorescences. Adult-realized fecundity was almost 10 times higher when ovipositing on flowering plants. Weight at pupation, which was correlated with potential future fecundity of the caterpillars, was also higher when feeding on flowers. They found no evidence for a behavioural trade-off and determined that a general preference for flowers by *H. armigera* was highly beneficial from a nutritional perspective for both adults and larvae. They concluded that the manipulation of flowering plants for the attraction of oviposition was relevant to pest control of this polyphagous species.

Marler *et al*. (2016) studied oviposition preferences of *Chilades pandava* female adults among host Cycas species in two choice tests, counting 39,420 eggs among assays from 4 butterfly populations. A naive butterfly population from *Cycas nongnoochiae* habitat oviposited 2.2-fold more eggs on leaves of Cycas species that were susceptible to butterfly herbivory than on leaves of its native host *Cycas nongnoochiae*. In contrast, *Chilades pandava* populations experienced with novel Cycas species in Thailand, Philippines, and Guam exhibited no preference in choice tests between leaves of susceptible and leaves of minimally damaged Cycas species. The results indicated that oviposition deterrents and/or stimulants partly mediated the sustainable relationship between an endemic Cycas species and the naive *Chilades pandava* population from its habitat. Alternatively, differences in info chemicals among Cycas species did not enable discrimination in oviposition choices for *Chilades pandava* populations having experienced Cycas species exhibiting no evolutionary history with *Chilades pandava*.

Marler *et al*. (2017) studied larval food quality of *Chilades pandava* (Lepidoptera: Lycaenidae) to determine its influence on adult life history traits. A wild population from *Cycas nongnoochiae* (Cycadales: Cycadaceae) endemic habitat behaved similarly to the population collected from a garden setting. *Cycas micronesica, Cycas revoluta* and *Cycas seemannii* leaves were used as high-quality food, whereas *C. nongnoochiae, Cycas taitungensis* and *Cycas condaoensis* leaves were used as low-quality food. The daily oviposition rate was not influenced by food quality, but longevity and lifetime fecundity of females were increased by high-quality larval food. They found that in situ *Cycas* species impose a physiological constraint on the genetic capacity produced offspring by *C. pandava*. The removal of that constraint by high-quality novel *Cycas* species led this butterfly to increase in population rapidly after an invasion event expressing greater herbivory of *Cycas* species within invaded regions.

Mayhew (1997) studied adaptive patterns of host plant selection by phytophagous insects. Host-plant selection by phytophagous insects is largely determined by adult insects choosing the developmental location of offspring. The theoretical basis of adaptive host-selection is quite strong, but several challenges remain. Models are lacking which are both general enough to be applicable to a wide range of species, and easy to test. The role of variability in plant abundance and other stochastic forces requires clarification. Empirically, good field studies of the effect of host-plants on insect fitness are rare, but without them little progress can be made. The assessment of host-preference also requires attention. Quantitative, tests of theory are rare, probably because general models do not encompass enough relevant natural history for each particular species. A challenge for the future is to assess the adaptive value of particular mechanisms of host-selection, and to relate these to the predictions made in simple adaptive models.

Mevi-Schutz and Erhardt (2003) examined how larval conditions affect nectar amino acid preferences of butterflies. Larvae of *Araschnia levana* were raised on low and high food quality diets. Female butterflies raised on the low quality larval diet were smaller and showed a significant preference for the nectar mimic with amino acids, whereas females raised on the high quality diet were larger and showed no preference. Larval food quality did not affect male mass, and male butterflies were indifferent to nectar amino acids. Consequently, female butterflies compensated for poor larval nutrition by selectively feeding on nectar containing amino acids. These results demonstrated the nutritional plasticity of holometabolous insects and the potential evolutionary significance of nectar amino acids for both plants and their pollinators.

Mevi-Schutz and Erhardt (2005) examined that amino acids in nectar had a positive effect on fecundity of one butterfly species, supporting the existence of a relationship between nectar preferences and fitness benefits. Map butterflies (*Araschnia levana* L.) raised under natural larval food conditions laid more eggs when they were feed nectar containing amino acids, whereas nectar amino acids had no effect on the number of eggs laid by butterflies raised on larval food rich in nitrogen. Uptake and utilization of nectar amino acids by map butterflies appeared to be compensatory mechanisms enabling them to override impacts of poor larval food. The results provided strong support for the long-standing postulate that nectar amino acids benefit butterflies.

Miah *et al*. (2015) examined developmental stages in the life cycle of lycaenid butterfly, *Lampides boeticus* (Lepidoptera: Lycaenidae) both in the laboratory under 29±3ºC

temperature with RH 78±2% and field conditions. The oviposition behaviour, incubation and larval-pupal period of the butterfly and its association with *Lupinus nanus* (Fabaceae) were studied. Duration of life cycle (egg to adult) was 19-21days. Eggs, four larval instars and pupal stages were distinct. The association with host plant was characterized and evidenced by the use of host leaves, flowers, buds and seeds (pods) in the larval (11-13 days) and pupal (4-6 days) stages. The incubation period, different larval instars and pupal stage were found to be associated deeply with the phenological phases of the host plant.

Molleman (2010) observed to puddle representatives of a wide range of herbivorous and detrivorous terrestrial arthropods (Lepidoptera, Orthoptera, Blattodea, Hymenoptera, Hemiptera, Diptera, and Diplopoda). It appears that those species with diets low in sodium (e.g., folivorous larvae) puddle for sodium whereas those with diets low in nitrogen (e.g., detritivores) puddle for nitrogen. Sex differentials in puddling behavior can usually be explained by transfers of nutrients from males to females during mating. Puddling is rare or absent in immature stages and there is some evidence that nutrients from puddles increase female reproductive success. Strong evidence for the widely cited hypothesis that sodium from puddles is used to enhance neuromuscular activity is still lacking. High mobility and long life spans could be associated with puddling behavior, whereas insects that are concealed or well-defended are less likely to puddle (e.g., beetles). It is still largely unclear how puddling (in particular for sodium) affects fitness despite the growing knowledge of insect physiology at the cellular level. The role that risks of pathogen and parasite infection as well as predation at puddling substrates might play in the evolution of puddling remains virtually unexplored.

Molleman *et al*. (2005c) investigated puddling behaviour of males and females on carrion and dung together with sodium preferences, polyandry, relative wing-size, sexual size dimorphism and sodium concentrations in the bodies and spermatophores of several species. They found that sodium as a nuptial gift explained the sexual division in puddling in some species, but not in all. Species in which both sexes puddle transfer little sodium in the nuptial gift, which was consistent with the nuptial gift theory. Wing loading and puddling were not significantly correlated, but the trend followed the direction predicted by the activity hypothesis. However, the sodium concentration in the species with the smallest wing area to thoracic volume (WA/TV) ratio (the largest *Charaxes* spp.), was relatively low. Moreover, in all investigated species, the sodium concentration

was higher in the abdomen than in the thorax. Authors discussed the results in the light of differences between the sexes in foraging behaviour in both larvae and adults, and with respect to alternative explanations for puddling.

Monaenkova *et al*. (2011) described that the proboscis promotes capillary pull of liquids from diverse sources owing to a hierarchical pore structure spanning nano- and microscales. X-ray phase-contrast imaging reveals that Plateau instability causes liquid bridges to form in the food canal, which were transported to the gut by the muscular sucking pump in the head. The dual functionality of the proboscis represented a key innovation for exploiting a vast range of nutritional sources. They suggested that future studies of the adaptive radiation of the Lepidoptera take into account the role played by the structural organization of the proboscis. A transformative two-step model of capillary intake and suctioning was applied not only to butterflies and moths but also potentially to vast numbers of other insects such as bees and flies.

Morrant *et al*. (2009) investigated nectar sampling and storing methods from the flowers of species with low floral nectar volumes (<1 µL) using the flowers of Eucalyptus species. Sampling with microcapillary tubes, blotting up with filter paper, washing and rinsing were compared to determine masses of sugars recovered and differences in sugar ratios. Storage methods included room temperature, refrigeration and freezing treatments; the addition of antimicrobial agents' benzyl alcohol or methanol to some of these treatments was also evaluated. The masses of sucrose, glucose and fructose in each sample from analyzed nectar samples using high-performance liquid chromatography were determined. Masses of sugars varied significantly among sampling treatments, but the highest yielding methods, rinsing and washing, were not significantly different. Storage trials showed that the sugar concentration measurements of nectar solutions changed rapidly, with the best results achieved for refrigeration with no additive (sucrose and fructose were stable for at least 2 weeks). Sugar ratios, however, remained relatively stable in most treatments and did not change significantly across 4 weeks for the methanol plus refrigerator and freezing treatments, and 2 weeks for the refrigeration treatment with no additive. Washing was recommended for nectar collection from flowers with low nectar volumes in the field, as was immediate analysis of sugar mass. In view of the great variation in results depending on nectar collection and storage methods, caution should be exercised in their choice, and their accuracy should be evaluated. The use of

pulsed amperometric detection, more specific than refractive index detection, might improve the accuracy of nectar sugar analysis.

Mumu *et al*. (2017) isolated the melittin content of Asian honey bee (*Apis cerana* F.) venom and quantified by reversed phase-high performance liquid chromatography (RP-HLPC) in Bangladesh. Melittin content was found to present in 59.3% of total venom content in Asian honey bee venom. Venom compounds were investigated at 254 nm and the retention time of venom-melittin was compared with an external standard (Sigma-Aldrich). A projection has been made on the quantification of melittin compound following the ivestigation.

Nimbalkar *et al.* (2011) recorded a total of 64 butterfly species from Bhor Tahsil of Pune District, Maharashtra, India, during August 2007 to August 2009. Family Nymphalidae dominates in the study area, followed by Lycaenidae, Pieridae, Hesperiidae and Papilionidae. Floral attributes were well known to influence nectar feeding butterflies. However, there was paucity of information on food resources of adult butterflies as compared to that of larvae. Nineteen nectar food plants were identified belonging to 10 plant families. Plants of the Asteraceae family were more used by butterflies as nectar food plants. Visits of butterflies were more frequent to flowers with tubular corollas than to non-tubular ones, to flowers coloured red, yellow, blue and purple than those coloured white and pink and to flower sources available for longer periods in the year. Species abundance reached the peak in the months during August to November. A decline in species abundance was observed from the months December to January and continued up to the end of May.

Nishida (2014) reviewed the ecological significance of such plant secondary metabolites in the highly diverse interactions between insects and plants. Plants produce a diverse array of secondary metabolites as chemical barriers against herbivores. Many phytophagous insects are highly adapted to these allelochemicals and use such unique substances as the specific host-finding cues, defensive substances of their own, and even as sex pheromones or their precursors by selectively sensing, incorporating, and/or processing these phytochemicals. Insects also serve as pollinators often effectively guided by specific floral fragrances.

Nuru *et al.* (2015) studied the floral phenology, nectar secretion dynamics, and honey production potentials of two naturally growing lavender species (*Lavandula dentata* and

L. pubescens), in southwestern Saudi Arabia. In both species, flowering was continuous. When open flowers on a spike were shaded, new flowers emerge. Such a flowering pattern was advantageous to the plant to minimize competition for pollinators and promote efficient resource allocation. The flowering periods of the two species overlap. Both species secreted increasing amounts of nectar from early morning to late afternoon. The mean maximum volumes of accumulated nectar from bagged flowers occurred at 15:00 for *L. pubescens* (0.50±0.24 μL/flower) and at 18:00 for *L. dentata* (0.68±0.19 μL/flower). The volume of the nectar that became available between two successive measurements (three-h intervals) varied from 0.04 μL/flower to 0.28 μL/flower for *L. pubescens* and from 0.04 μL/flower to 0.35 μL/ flower for *L. dentate*. This variation reflected the differences in the dynamics of nectar secretion by these species, and indicated the size of the nectar that was available for flower visitors at given time intervals. The distribution of nectar secretions appeared to be an adaptation of the species to reward pollinators for longer duration. Based on the mean amount of nectar sugar secreted by the plants, the honey production potentials of the species were estimated to be 4973.34 mg and 3463.41 mg honey/plant for *L. dentate* and *L. pubescens*, respectively.

Nylin and Janz (2009) explored the possibility that the diversification of phytophagous insects might have occurred through such a process, using examples from nymphalid butterflies. They discussed the ways in which host plant range was connected to plasticity. Their interpretation presented how West-Eberhard's scenario might result in speciation driven by plasticity in host utilization. They reviewed some of the evidence that diversity of plant utilization has driven the diversification of phytophagous insects and finally discussed whether this suggested a role for plasticity-driven speciation. Authors found a close conceptual connection between their theory that the diversification of phytophagous insects had been driven by oscillations in host range, and their interpretation of the most efficient way in which West-Eberhard's theory could account for plasticity-driven speciation. A major unresolved issue was the extent to which a wide host plant range was due to adaptive plasticity with dedicated modules of genetic machinery for utilizing different plants.

O'Brien *et al*. (2005) investigated whether the amino acids of eggs derived from larval diet or were synthesized from nectar sugar in four species of butterflies *Colias eurytheme, Speyeria mormonia, Euphydryas chalcedona,* and *Heliconius charitonia*. These species exhibited a range of life history and differed in degree of shared phylogeny. They used

13C differences among plants to identify dietary sources of amino acid carbon, and measured amino acid 13C using compound specific stable isotope analysis. Egg essential amino acids derived solely from the larval diet, with no evidence for metabolic carbon remodeling. Carbon in nonessential amino acids from eggs derived primarily from nectar sugars, with consistent variation in amino acid turnover. There was no relationship between the nonessential amino acids of eggs and host plants, demonstrating extensive metabolic remodeling. Differences between species in carbon turnover were reflected at the molecular level, particularly by glutamate and aspartate. Essential amino acid 13C varied in a highly consistent pattern among larval host plants, reflecting a common isotopic "fingerprint" associated with plant biosynthesis. These data demonstrated conservative patterns of amino acid metabolism among Lepidoptera and the power of molecular stable isotope analyses for evaluating nutrient metabolism in situ.

Oke (2014) collected and qualitatively analysed *Cajanus cajan* (Pigeon pea) leaves from 'ita osu' market of Ijebu Ode, Ogun state, Nigeria, for identification of phytochemical constituents. The results showed the presence of bioactive constituents of carbohydrates, alkaloids, flavonoids, tannins, saponins, and terpenes. The proximate analysis of the leaves revealed a composition of 11.20% moisture, 8.22% ash, 22.4% crude protein, 2.74% crude fat, 7.25% crude fibre, 63.39% NFE, 9.8% alcohol soluble extractive value, 4.32% water soluble extractive value and 0.65% acid insoluble ash value. The significance of this plant was discussed in relation to the presence of these metabolites as well as the proximate values. The presence of some phytochemicals like saponins and flavonoids explained the medicinal action of the plant encountered in its therapeutic uses.

Pec (2008) reviewed the case of *Euphydryas editha* (Edith's checkerspot) to illustrate the mechanistic basis and conservation significance of recent and projected shifts in global climatic regimes. Levels of carbon dioxide and other greenhouse gases are rising at accelerating rates, leading to warmer temperatures, altered precipitation regimes and increasingly likelihood of extreme weather events. These climatic changes affect biotic systems and individual species dynamics through diverse mechanisms. Butterflies are particularly sensitive and responsive to these environmental changes; because butterflies are also well-studied historically; they present an effective model system for understanding biotic responses to climate change. In particular, differential life history responses of butterflies and their host plants to changing climate can disrupt their phenological synchrony.

Pivnick and McNeil (1985) observed the adult European skipper, *Thymelicus lineola* (Ochs), feeding on concentrated nectars (40-65% sucrose) from a variety of flower species because butterflies feed primarily, and most effectively, on dilute nectars. Rate of sucrose solution intake, volume consumed and feeding duration were measured for males and females at 25 and 35°C under laboratory conditions. A new mathematical model was developed to describe the rate - concentration relation based on the Hagen-Poiseuille equation for laminar fluid flow through pipes. This model differed from previous models principally in that the power output of the insect's cibarial pump remains relatively constant while the pressure drop created by the pump to induce suction is highly variable. This change results in a very different feeding rate- sucrose concentration function with the optimal rate of sucrose intake at a concentration of approximately 40%. The model indicated that the same relation should hold for a wide range of proboscis shape and size and type of suction pump, and should therefore be applicable to all other nectar feeders with sucking mouth parts. Independent verifications of the model were carried out by measuring the rate of uptake of sucrose solutions of the adult common armyworm, *Pseudaletia unipuncta* (Haw.), and of human subjects using a volumetric pipette, both of which gave an excellent fit. Nectar concentrations which corresponded to optimal rates of sucrose intake should be highly preferred by insects with high feeding costs, those which were time-limited, or which were very vulnerable while feeding. High transport costs and severe water stress might shift preferences to higher and lower concentrations, respectively.

Rabasa *et al*. (2005) studied egg placement in a rare European butterfly, *Iolana iolas*, whose larvae specifically fed on seeds of plants of the genus *Colutea*, using a hierarchical approach and Generalized Linear Mixed Modelling. The study was carried out in 2002 and 2003 in a 60 km^2 area in southern Madrid province, Spain, where the host plant, *Colutea hispanica*, had a highly fragmented distribution. They monitored in detail 132 plants in 24 patches and estimated the abundance of butterflies over the whole reproductive period of *C. hispanica*. Authors measured phenological, morphological and landscape variables potentially affecting egg-placement at three hierarchical levels: fruit, plant and host plant patch. Using egg presence-absence on mature fruits as the response variable, they also found that eggs were more likely to be laid on fruits aged 1-2 weeks at the middle of the flowering period (fruit level), on large plants with a small number of shoots at the base (plant level), and in well-connected host plant patches (patch level).

They concluded that egg-placement was a process determined by factors operating at different levels: fruit, plant and host plant patch. Because egg-placement studies were often made with spatially correlated data, neglecting their intrinsic hierarchical nature could lead to equivocal conclusions.

Rajbangshi (2016) examined foraging behavioural strategies of some selected butterflies in Bhawal National Park, Gazipur; Zoological Garden, Botanical Garden and Curzon Hall Campus of Dhaka University from May, 2015 to April, 2016. Role of butterflies in pollination with their related plants also recorded. Structure, size and shape of the pollen grains of butterfly related plants were studied. Variation in proboscis length of the experimental butterflies was examined. Taxonomy and morphology of the butterfly related plants analyzed in the Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka. The result showed a good indication of pollen-butterfly relation which carries vital role in carrying out gene-flow mechanism in nature.

Raju (2009) studied nesting behaviour of the Baya Weaver bird and life cycle of Plains Cupid butterfly on two *Cycas* species. The Baya Weaver bird, *Ploceus philippinus* utilizes the well-developed leaves of *Cycas sphaerica* for nest construction and offspring production. It constructs nest on the leaftips of this species; the nest material used is exclusively *Dendrocalamus strictus*. This bird species does not utilize *Cycas beddomei* for nest construction and offspring production. The Plains Cupid butterfly, *Chilades pandava* utilizes the newly emerging leaves of both *C. sphaerica* and *C. beddomei* for raising its offspring. In both the *Cycas* species, the new leaves emerge as a crown at the top of the plant; the larvae of *C. pandava* feed on these leaves and make the plant as leafless until the next leaf flushing season. New leaf production occurs after coning event in *Cycas* species; coning is not annual event. In consequence, the plants utilized by *C. pandava* for the production of its offspring remain leafless until the next coning season and their survival during this period depends on the nutrient status within the shoot system and in the soil system. By this examination the author suggested that there is no direct or indirect interaction between *C. pandava* and *P.philippinus*. *C. sphaerica* serves as a host plant for these two animal species at different times; but the interaction of these animal species is dependent on the leaves only; *C. pandava* on newly emerging leaves while *P. philippinus* on well-developed leaves.

Ram and Mathur (1984) studied the biology of pollination in *Lantana camara*, pernicious weed. The colour variant used in the study bear yellow flowers at anthesis which was subsequently changed to orange, scarlet and magenta. Lantana is self-compatible but needs insects for pollination. Thrips found to be consistent and regular pollinators, and visited only yellow flowers and avoid flowers of other colours. Colour change was triggered by pollination and functions in the partitioning of the pollinator and consequently conserving pollinator energy. Whereas butterflies visited lantana in two seasons, thrips were associated with it all through the year playing an important role in seed production. By adapting to thrips pollination *Lantana* became highly widespread. The authors concluded that the extent of interdependence regulated by phenology, floral characters as well as by fore, structure and behaviour of pollinators.

Rausher (1978) studied the butterfly *Battus philenor* that formed search images for leaf shape when searching for its two larval host plants in southeast Texas. This behaviour increased the rate of discovery of host plants and permits females to track changes in relative host plant suitability for larval growth. Apostatic selection resulting from search image formation was a likely explanation for divergence in leaf shape by the two plants.

Rausher (1979a) examined ovipositing females of the pipevine swallowtail butterfly, *Battus philenor* that detected the presence of eggs laid by other females on their host plants. The presence of eggs on a plant inhibited oviposition by a female that discovered it. The selection pressure responsible for the evolution and maintenance of discrimination against plants with eggs appeared to be lower survival from egg to adult of eggs laid on plants already containing eggs than on plants without eggs.

Rausher (1979b) studied three Aristolochia-feeding swallowtail butterflies (Papilionidae: Troidini) to evaluate the habitat choice by ovipositing butterflies as females preferred to lay eggs on best juvenile growth and survival of plants. Author found that the eggs and larvae of all three butterfly species survived significantly better in shady habitats than in sunny habitats. Pupal survival was similar in the two habitats for at least one species. Larval growth rates were similar in the two habitats for all three species. Thus, for all three species shady habitats appeared to be more suitable for juvenile development and survival than sunny habitats. Only *Parides montezuma* laid most of eggs in shady habitats, however, *Battus philenor* and *B. polydamus* females laid most of eggs in sunny habits. Author suggested three alternative explanations for the discrepancy between the

relative suitability of habitats for the juvenile stages and habitat choice by ovipositing females.

Rayalu *et al*. (2012) described the life history of the Monkey puzzle butterfly, *Rathinda amor* and larval performance in terms of food consumption and utilization, and the length of life cycle on its host plant *Ixora arborea* for the first time. The study was conducted in 2008 at Visakhapatnam (17°42' N and 82°18' E), South India. *R. amor* completes its life cycle in 19-21 (19.80±0.84) days (Egg: 3; Larva: 8-10; Pupa: 8 days). The values of nutritional indices across the instars were AD (Approximate digestibility) 56.71-89.02%; ECD (Efficiency of conversion of digested food) 2.61-16.83%; ECI (Efficiency of conversion of ingested food) 2.32-13.93%, measured at the temperature of 28±2°C and RH of 80±10% in the laboratory. The relatively high values of ECD and ECI explain at least partially the ecological success of *R. amor* in the urban environment of Visakhapatnam.

Reddi and Bai (1984) studied Heliconius butterflies and their pollination biology. Most butterflies with the characteristics long proboscis fed on floral nectar, and the Heliconius butterfly fed on pollen as well. This butterfly rarely mostly depended on flower colour for locating and identifying the flowers. This butterfly carried pollen on their body parts during foraging on nectar. *Leptidea synapis* foraged at the flowers of *Viola* and *Lathyrus* without performing the reciprocal pollination service. The butterflies as a group had the tendency to visit a few flowers on a plant and then fly to another plant with the result of maximizing xenogamy.

Robbins (1981) made a hypothesis that the ventral wing pattern of lycaenid butterflies (Lepidoptera: Lycaenidae) creates an impression of a head at the posterior end of the butterfly that diverts predator attacks towards the less vulnerable end of the insect. The components of wing pattern and morphology that contribute to an impression of a head vary markedly among lycaenid species. Consequently, the deceptiveness of these wing patterns should vary and should be positively correlated with the frequency of deflected predator attacks. Author confirmed the prediction of the "false head" hypothesis, and showed that predators attack various wing patterns differently.

Robbins and Aiello (1982) recorded larval food plant and female oviposition for 15 Panamanian butterfly species in the Lycaenidae and Riodinidae. Many of these species fed on reproductive parts of plant, e.g. flowers, rather than foliage. Some species were

facultatively myrmecophilous, and one species might have an obligate relationship with ants. They discussed possible biological consequences of flower-feeding for lycaenid butterflies.

Roeder and Behmer (2014) reared newly hatched caterpillars of *Heliothis virescens* Fabricus (Lepidoptera: Noctuidae) on diets containing different protein/carbohydrate (p/c) ratios. They recorded larval survival, time to pupation, pupal mass, eclosion success, time to eclosion and pupal body lipid content. Additionally, for each treatment, they also mated eclosed males and females and measured egg production and egg viability. Larval performance (survival to pupation and time to pupation) was similar across all except the two most extreme treatments. In contrast, pupal performance (mass, eclosion success and time to eclosion) was best on diets that were balanced or slightly protein-biased. However, eclosion success differed between sexes. For males, it was best on diets with balanced p/c ratios, while female eclosion was strong across all but the most carbohydrate-biased diet. Pupal body lipid content in both males and females increased as the food p/c ratio decreased. Egg production was best on diets with balanced or slightly protein-biased p/c ratios. Authors also estimated the effect of food p/c ratio at the population level, using the data generated in this study. Population size was largest on diets with a balanced p/c ratio and declined steadily and strongly as the food p/c ratio became increasingly more imbalanced. Their findings showed the effect of food p/c content over an insect herbivore's entire life. The data indicated that there was a narrow range of p/c ratios that maximize lifetime performance, and for *H. virescens*, this range coincided with its self-selected p/c ratio.

Rumpa (2016) studied nectar feeding behaviour and genitalic structures of butterflies in Bhawal National Park, Gazipur; Botanical Garden, Bangladesh Agricultural University, Mymensingh; Zoological Garden, Botanical Garden and Curzon Hall Campus of Dhaka University from May, 2015 to April, 2016. Nectar was collected from selected plant species and nectar feeding behaviour of butterflies on these plants was recorded. The proboscis length of butterflies and corolla tube lengths of the flowers were measured in field. The differences in the male genitalic structure among each species of seven families of butterflies were examined and measured. Data assessment was carried out at the Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka.

Rusterholz and Erhardt (1997) tested Peacock butterflies, *Inachis io*, experimentally for their preferences for nectar sugars. In tests with different plain sugar solutions (25%, weight to total weight) the butterflies strongly preferred sucrose and fructose over glucose. They also preferred sucrose over fructose. In tests with mixed sugar solutions the butterflies clearly preferred both sucrose-dominant (sucrose:hexoses=5:1) and balanced sugar solutions (sucrose:glucose:fructose = 1:1:1) over hexose-dominant sugar solutions, (sucrose:hexoses = 1:5). Females consumed significantly more of the balanced sugar solution. Authors discussed their findings with respect to previous experiments on nectar preferences of butterflies, nectar sugar composition of butterfly-pollinated flowers, and flower preferences, physiological and reproductive aspects of butterflies.

Rutowski (1984) examined the mating systems and courtship behaviour patterns of butterflies from the perspective of sexual selection theory. Particular attention was devoted to the effects of resource and female distributions on male mate-acquisition techniques and the occurrence and consequences of mate choice by males and females.

Rutowski and Gilchrist (1988) described the mating system of the dessert hackberry butterfly, *Asterocampa leilia*, with special reference to the site tenacious mate-locating behaviour of the males. Males occupy perches on or next to the larval food plant, desert hackberry (*Celtis pallida*). Other males were not tolerated within several meters of a male's perch site and were chased away when they flied nearby. Males occupied perch sites in the morning. Some hackberry trees were more likely to be used as perch sites than others and males at these sites experienced the highest rate of contacts with females and other males. Females passing a perch site were chased, courted, and, if receptive, mated. Their findings indicated that males defend perch sites as a means of maximizing potential contacts with newly-emerged, virgin females leaving the plant adjacent to their perch site.

Rutowski *et al*. (1994) studied the impact of the thermal environment on the behaviour of male insects waiting for females at encounter sites. In the morning, males of the desert hackberry butterfly, *Asterocampa leilia*, perch and wait for females on or adjacent to the larval food plant. Over the course of a morning as temperature increases, male body posture (wing position and orientation to sun) and perch preferences (perch height and perch insolation) are changed. The results showed that the body temperature of males at perch sites is largely independent of air temperature (i.e. they thermoregulate) and the body posture and perch preferences change with air temperature. The thermocouple-implanted models indicated that the observed changes in behaviour led to be decreased in

operative thoracic temperature. They found that changes in wing position, perch height preferences, and insolation preferences have adaptive thermal consequences that may constrain mate detection.

Schmitz (1994) determined spectral integral reflectance, transmittance and the resulting absorption of intact and descaled butterfly wings of the black-winged *Pachliopta aristolochiae* (Papilionidae), the white-winged *Pieris brassicae* (Pieridae), and the yellow-winged *Gonepteryx rhamni* (Pieridae) between 350 and 800 nm. Whereas in the black forewing of the dorsal basking *Pachliopta*, almost all incidents light was absorbed nearly independent of the wavelength and thus converted into heat, the white forewing of the body basking *Pieris* absorbed less than 20% in the visible range of the spectrum. The yellow hind wing of the lateral basking *Gonepteryx* absorbed to a higher degree than the Pierid wing, but due to the sparsely arranged scales-transmittance was clearly increased (40-50% between 525 and 800 nm). He also discussed the varying thermal characteristics of the different wings with reference to the colour and arrangement of the scales and the different basking strategies of the butterflies.

Scriber and Feeny (1979) reared larvae of 9 species of swallowtail butterflies (Papilionidae), 10 species of bombycoid moths (Saturniidae and Bombycidae), and of the southern armyworm (Noctuidae: *Spodoptera eridania*) under standardized conditions on mature leaves of many of their typical food plants. Growth rates, feeding rates and efficiencies of food and nitrogen utilization of larvae in their penultimate and final instars were measured by standard techniques. The study revealed a clear relationship between larval growth and growth form of the food plants quantified as leaf water content. Larvae grew faster and more efficiently on herbaceous plants than on the foliage of shrubs and trees. These differences were greater than could be accounted for variation in the degree of feeding specialization among the insect species tested. The particular leaf characteristics responsible for the relationship between plant growth form and larval growth were not known, but they probably included leaf water content, nitrogen content, toughness, and fiber content. The extent to which the low food value of mature tree leaves was actually a consequence of the selective action of herbivores remained an open question.

Sculley and Boggs **(**1996) examined sex- and age-specific puddling patterns in seven montane butterfly species. They also tested the hypothesis that among species in which young males predominate at puddles, differences in age- and sex-specific puddling

patterns for a given species were related to mean female lifetime mating numbers. For five species, young males fed proportionately more at puddles than other sex and age classes. Two species showed anomalous feeding patterns. In one, young females predominated at puddles; in the other, butterflies were rarely found at flowers. Among the five species in which young males feed proportionately more at puddles, mean number of lifetime matings by females was negatively correlated with frequency of mud puddling by older females. On the other hand, mean number of lifetime matings by females was positively correlated with frequency of mud puddling by older males was not supported. Their findings provided support for interspecific variation in division of responsibility between the sexes for resource acquisition for female reproduction, indicating close coordination between the sexes of foraging and life-history tactics.

Sharma *et al.* (2016) identified larval host plants and recorded host ranges of 67 butterfly species in and adjacent to the Gir National Park, Gujarat, India. They found 74 host-plants species (viz. 22 annuals, 3 biennial and 49 perennials) categorizing as different plant categories which included 21 trees, 22 herbs, 24 shrubs, six climbers and one species of plant parasite. The findings revealed that the plant species belonging to families Mimosaceae, Capparaceae and Caesalpiniaceae were found most suitable food for butterfly species belonging to the four different families of butterflies in GNP. A number of significant differences were also identified between butterfly families and their host use patterns such as perination, host specificity etc. Correlation coefficient ($r = 0.785$) confirmed a strong correlation between host plants and butterflies and was found significant at 1% level ($p = 0.01$). Hence, more number of host-plant species attracts significantly more species of butterflies.

Singer and Stireman (2001) evaluated patterns of host-plant use by the polyphagous caterpillar *Grammia geneura* (Lepidoptera: Arctiidae) in relation to host-plant availability and foraging tactics of individuals. Field surveys of caterpillar feeding and plant abundance carried out across several sites, seasons, and years showed that *G. geneura* consistently preferred forbs to grasses and woody plants, forb-feeding was opportunistic, supporting the idea that caterpillars sample were locally available host-plants, and there were consistent patterns of host-plant use that were not explained by host-plant availability (electivity). An independent set of 7-h observations of 11 caterpillars showed that electivity for a subset of caterpillar-host associations could be explained by variation in the probability of initiating feeding and the average duration of feeding bouts on

different hosts but not by variation in the probability of encountering different hosts, thus providing a behavioral basis for the observed variation in host-plant use. The use of detailed foraging tactics by larvae to explain host-plant use at the population level was a novel contribution of the study.

Smedley and Eisner (1995) examined puddling behaviour of the notodontid moth *Gluphisia septentrionis.* Males routinely puddle for hours, imbibing hundreds of gut-loads and voiding the fluid as repetitive anal jets. Cationic analyses showed puddling to lead to systemic sodium gain, a potential benefit to *Gluphisia*, whose larval food plant was low in sodium. Male *Gluphisia* were specialized for puddling, possessing a wide oral slit and a highly expanded enteric surface. Males transferred the acquired sodium to the female at mating, for eventual incorporation into the eggs. Sodium acquisition might be the primary function of puddling in Lepidoptera.

Sultana *et al*. (2017) made an attempt to examine butterfly proboscis length and their significance in carrying out activities of the butterflies in relation to their nectar plants. Observations were made in seven selected areas (viz. Satchari, Modhupur, Rema-kalenga, Shaltila, Bhawal National Park, and Botanical and Zoological gardens of the Curzon hall area) from July 2014 to June 2015. Thirty four butterfly species of seven families (viz. Hesperiidae, Nymphalidae, Danaidae, Papilionidae, Pieridae, Lycaenidae and Satyridae) have been considered for this study. The strategic activities of proboscis in different butterflies were examined when they were used in foraging activity. The proboscis length of butterflies was measured during the study period. Nectar plants were identified at the laboratory. The corolla length of the nectar plants was measured and found a good relation with the proboscis length of the butterflies. Hesperiid butterflies could visit flowers up to 28 mm long corolla tube whith comparatively long proboscis. This study was indicated that the butterfly proboscis had significant role in co-evolution between the butterfly species and the flowers of the nectar plants.

Sunose and Nakagawa (1984) described egg-laying behaviour of *Narathura bazalus turbata* and the spatial distributions of their eggs. The hibernated females prefer the host buds in the spotlight of sunshine as an egg-laying target and mainly lay their eggs on old leaves attached to the twigs provides with buds of at least 8 mm in length. The buds are more numerous on higher branches of host trees; however, a large number of eggs are laid on lower parts.

Talsma *et al.* (2008) examined the oviposition choice of an insect herbivore is based on a complex set of stimuli and responses. The effect of secondary chemistry (the iridoid glycosides aucubin and catalpol) of the plant *Plantago lanceolata* on the oviposition behaviour of the specialist butterfly *Melitaea cinxia* was detected. Iridoid glycosides are known to deter feeding or decrease the growth rate of generalist insect herbivores, but can act as oviposition cues and feeding stimulants for specialized herbivores. However, the association could have been the cause (butterfly choice) and consequence (plant induction) of oviposition. A positive association was found between the pre-oviposition level of aucubin and the number of ovipositions. The association reflects the butterfly oviposition selection rather than plant induction that follows oviposition. The size of the plant appeared to be more important stimulus than iridoid glycoside content, with bigger plants receiving more oviposition than smaller plants, regardless of their secondary chemistry. Their results illustrated the rank of a cue used for oviposition might be dependent on environmental context.

Thakur and Mattu (2010) conducted a study on different flowering plants (garden, cultivated, semi wild & wild) visited by butterflies, foraging activity and abundance at different elevations of Shiwalik hills. Shiwalik hills symbolize one of the most fragile ecosystems (29-33 N latitude to 74-80.5 E longitude), these hills represent the southernmost zone of about 8-40 km width stretching for about 800 km length in the Himalaya. During the study, 87 species of butterflies were collected as flower visitors on 51 species of flowering plants (garden, cultivated, semi-wild and wild) in Shiwalik hills. Of these, Nymphalids visited to 18 species of plants; Pierids to 18 species; Lycaenids to 13 species; were studied, flowers of the family Asteraceae were most attracted to different butterflies' species. Hesperids to eight species and Papilionids and Danaids visited to four species each among all the flowering plants.

Thompson (1988) observed the relationship between oviposition preference and growth, survival, and reproduction of offspring in the evolution of host associations between phytophagous insects and plants. The relationship between oviposition preference and performance of offspring was ranged from good to poor. At least four hypotheses had been suggested to explain observed use of particular host plants that might not be resulted in the fastest growth rates or greatest pupal masses: time, patch dynamics, parasite versus grazer lifestyles, and enemy-free space. Authors recognized these relationships were hampered by an almost complete lack of data on how preference and performance were

related genetically. The data was needed to understand the origin of covariance between preference and performance, and constraints on the evolution of host associations.

Tiple *et al*. (2009a) investigated butterfly-flower morphological interrelationship for 108 butterfly species and 20 plants in Nagpur, India. Distinct clusters of higher taxa (families) were disclosed for butterfly morphology and significant morphological and taxonomic associations occurred in nectar exploitation. Flower corolla depth was found to restrict exploitation by butterflies in relation to proboscis length and butterflies with high wing load indices biased their feeding to plants with massed flowers. A substantial number of butterflies were examined to feed on plants with massed flowers though their proboscises were of marginal length for corolla depths. These butterfly species were significantly smaller, lighter, with lower wing loading and shorter proboscis indices than species which easily accessed the same flowering plant species. Authors suggested that small size and short proboscises could give them a competitive advantage (increased rate of nectar uptake) for exploiting nectar in such situations. This finding is significant for conservation.

Tiple *et al.* (2009b) presented seasonal polyphenism in *Chilades pandava* from central India, documenting patterns of population dynamics of alternative seasonal forms as well as of total population size. They showed that relative humidity explained most of the variation in population size, whereas precipitation negatively influenced the proportion of dry season forms in the population. They also found dry season forms were more abundant during winter than during summer. This study revealed the multitude of ways in which the Indian monsoon governed aspects of butterfly biology, from population dynamics to wing colouration.

Tiple *et al*. (2011) recorded the male mate locating behaviour of 70 butterfly species; 23 exhibited both perching and patrolling behaviour, 31 were strict perchers, 16 solely patrol, 22 displayed male territorial defence and nine established aggregations (leks). They tested two issues relating morphology to mate location behaviour: perching and patrolling males differ in morphology, and in wing colour. It was found that, within species, individual perching males had shorter bodies, greater wing spans and greater weight than patrolling males, and that within and between species perching males were duller/paler in colour than patrolling males. They discussed and considered reasons for these distinctions to relate to the different activities of perchers and patrollers, the former significantly associated with territorial defence.

Trager *et al*. (2013) assessed ant-related oviposition and larval performance in the Miami blue butterfly (*Cyclargus thomasi bethunebakeri*). Ant tending had sex-dependent effects on most measures of larval growth: female larvae generally benefitted from increased tending frequency whereas male larvae were usually unaffected. The larger size of female larvae tended by ants resulted in a substantial predicted increase in lifetime egg production. Oviposition by adult females that were tended by *C. floridanus* ants as larvae was similar between host plants with or without ants. However, they laid relatively more eggs on plants with ants than those females did which raised without ants, laid less than a third of their eggs on plants with ants present. Author found conditional benefits for larvae tended by ants that were not accompanied by oviposition preference for plants with ants present, which was a reasonable result for a system in which ant presence at the time of oviposition was not a reliable indicator of future ant presence. This finding emphasized the importance of considering the consequences of variation in interspecific interactions, life history traits, and multiple measures of performance when evaluating the costs and benefits of mutualistic relationships.

Vargas (2014) studied three Neotropical Polyommatini (Lepidoptera, Lycaenidae, Polyommatinae): *Hemiargus ramon* (Dognin, 1887), *Leptotes trigemmatus* (Butler, 1881) and *Nabokovia faga* (Dognin, 1895), and their feeding habit on host plant *Dalea pennellii* var. *chilensis* (Fabaceae), based on two collections performed in the western slopes of the northern Chilean Andes in two consecutive summers. These lycaenid caterpillars ate flowers of shrub *Dalea pennellii* var. *chilensis* (Fabaceae) in the northern Chilean Andes. The relative abundance was always above 90% for *N. faga* while it was always less than 5% for *H. ramon* and *L. trigemmatus*. Furthermore, *N. faga* was not found on inflorescences of other native Fabaceae examined in the study site. This pattern suggested a close relationship between *N. faga* and *D. pennellii chilensis*, at least at a local scale.

VenkataRamana (2010) carried out a study on biodiversity and conservation of butterflies in the Eastern Ghats nearly 200 Km radius. Four study sites have been chosen i.e., Visakhapatnam, Punyagiri, Ananthagiri, Ratnagiri vegetations. Nearly 70 butterfly species from 8 families identified. In which *Papilio polymnestor* was the largest one and *Castalius rosimon* was the smallest one. Migratory butterflies also recorded along with mating behaviour. Life cycle stages and its energetics for some species were also studied. Wing position, proboscis lengths, larval ovipositing and nectar host plants, population index of butterfly life stages were recorded.

Wallisdevries *et al*. (2012) provided the first analysis of changes in floral nectar abundance on a national scale and link these data to trends in butterfly species richness and abundance, because nectar supply constitutes one of the main resources determining habitat quality. Transect data from the Dutch Butterfly Monitoring Scheme was used. The results showed that butterfly decline could indeed be linked to a substantial decline in overall flower abundance and specific nectar plants, such as thistles. The decline was as severe in reported flower generalists as in flower specialists. They concluded that eutrophication was a main cause of the decline of nectar sources.

Wasserthal (1975) studied free and unnarcotized butterflies in a vertical basking position exposing to radiation from a halogen lamp. Warming rate and equilibrium excess temperatures were recorded by means of microthermistors on the cuticle. Living, dead, and dried specimens were irradiated partly and totally. If the wings were shaded, the excess body temperature was reduced about 30 per cent. The major portion of the heat transferred from the wing to the body originates from 15 per cent of the wing surface nearest to the body. There was no significant difference in excess thoracic temperatures of living and freshly dead specimens. After drying, the body temperature level rises about 1.4 to 2.2°C, remaining almost constant between 15°C (not radiated) and 37°C (radiated). The influence of air convection was tested with dried specimens under varying spatial orientation, keeping incident radiation constant. In an approximately horizontal position the heat arising from the wing increased to about 40 per cent by accumulation of warm air under the wing base. The ecological implications of heat supply by the wings and adaptive significance of wing pattern with respect to different modes of heat transport was discussed.

Wiklund (1984) studied the egg-laying behaviour in the wild of 51 butterflies in Sweden. Three different patterns emerged: Firstly, although the majority of butterflies deposited their eggs on the plants on which their larvae later fed, butterflies that overwinter in the egg stage and used herbaceous host plants tended to avoid laying their eggs on host plants. Secondly, butterflies which used host plants that were superabundant, notably the grass-feeding satyrids, also tended not to deposit their eggs on the leaves on which the larvae later fed. Among the Swedish satyrids, two of the three species which deposited their eggs on the larval hosts (over-winter in the pupal stage), thus necessitating rapid larval development. Thirdly, butterflies which used visually apparent host plants appeared to find their host plants without having to alight on non-hosts, whereas butterflies that

used hosts those were visually non-apparent frequently alight on non-host plants during the oviposition search before they found the appropriate plants. Author discussed the possible adaptive significance of these egg-laying patterns.

Wong (2013) investigated whether the incorporation of pollen analysis could provide a more accurate representation of the total pollinator-plant interactions than visual surveys alone. Pollen on 75 butterfly specimens collected from five meadows in the Madrean Sky Islands was analyzed and compared the pollinator-plant interactions recorded in the pollen to the interactions observed in the field. The pollen data provided a record of more pollinator-plant interactions than the observation data. The pollen data revealed that most species were more generalized than they appeared in the observation data, because she was able to identify additional floral interaction partners that visual surveys missed. The incorporation of pollen data created a more complex network structure, and as a result should be taken into consideration when conducting network studies to allow for more clarity on the level of pollinator specialization within the network.

Zalucki *et al*. (2002) confronted neonate Lepidoptera with the daunting task of establishing themselves on a food plant. The factors relevant to this process need to be considered at spatial and temporal scales relevant to the larva. Neonates had to cope with an array of plant surface characters as well as internal characters once the integument was ruptured. These characters, as well as microclimatic conditions, varied within and between plant modules and interacted with larval feeding requirements, strongly affecting movement behaviour, which might be extensive even for such small organisms. In addition to those factors, there was an array of predators, pathogens, and parasitoids with which first instars contended. Mortality in neonates was high but varied widely. Experimental and manipulative studies were vital if the subtle interaction of factors responsible for this high and variable mortality was to be understood. The study was essential for an understanding of theories linking female oviposition behaviour with larval survival, plant defense theory, and population dynamics, as well as modern crop resistance breeding programs.

LYCAENID BUTTERFLIES AND THEIR RELATED PLANTS

3.1 Introduction

Plants and animals have a close interrelationship for their survival, propagation and control (Duara and Kalita 2014). The plants are not only used as the nutritional sources for animals, but both are used as ecological sources and ecological niche sources (Bashar 2014). A significant majority of insects have strong interactions with plants and other biotic components of any ecosystem (Ehrlich and Raven 1964, Huffaker *et al*. 1999). Among insects, butterflies have evidential capabilities to recognize the plant sources as food (Suzuki *et al*. 1987). Flowering plants provide butterflies food and shelter; butterflies lay their eggs on the underside of leaves; caterpillars (larvae) eat the foliage; leaves provide camouflaging agents and protection for butterflies during the pupal stage; and butterflies sip nectar and forage pollens from flowers (Bashar 2014). For the reason, each of the vegetation type can make unique contribution to measure the butterfly diversity and the butterflies for the plant diversity (Stohlgren and Bachand 1997). Thus, herbivorous insects (i.e. butterflies) and plants are united by intricate relationships (Schoonhoven *et al*. 1998).

Fothergill and Levy-Boyd (2008) classified butterfly-plant interactions as nectaring, ovipositing, larval feeding, sugaring from fluids associated with wounds, buds about to open, or extra floral nectaries, and finally strong association with plants. The butterfly acts as a gene-flow carrier for the host plant together with other plants in wide range. The gene-flow carrier stands as an agent for the plant's existence (Bashar 2014). Since larvae feed on host plants, adults need nectar rich plants, and shade plants are required for taking shelter in the driest day when it is too hot or in the wet days when it rains, vegetation change may affects butterfly communities (Van Halder *et al.* 2008). Lycaenid butterflies seek nectar from many types of plants such as ground covers, annuals, perennials, shrubs and trees (New 1993). They use hedges and vine, bushes as rest sites. The presence of lycaenid butterflies is highly related to the presence of associated plants (Akand 2012). When plant populations are ensured in an ecosystem, the successive trophic levels, meaning the availability of different kinds of consumer animals is ensured. Consequently, flora and fauna are ensured to have their well-established habitats (Bashar 2017). Altogether such situation establishes multiplication of "Plant-Butterfly" association in nature. Such establishment is the 'natural tool' for healthy sustenance of both flora and

fauna in any area especially in a wild state of a terrestrial ecosystem (Bashar 2014). Considering all the above mentioned thought, the present investigation is envisaged by following objectives.

3.1.1 Objectives

- ✓ To identify lycaenid butterflies;
- ✓ To assess the status of lycaenid butterflies in Bangladesh context;
- ✓ To find out the lycaenid associated plants;
- ✓ To categorize related plants in necessity dimension of butterflies; and
- ✓ To view the role of interrelationship between lycaenid butterflies and their related plants.

3.2 Material and methods

Depending on the stated objectives, the following procedures are adopted to complete the current investigation.

3.2.1 Studied species

The butterflies of the family Lycaenidae are small to medium sized with or without tiny tail at hind wing. These butterflies are found in different forest and cultivated areas of Bangladesh. They demonstrate immense association with varieties of plants. Lycaenids and their related plants have been selected for present investigation to explore their interrelationship.

3.2.2 Study period

Observations were made and data were recorded in natural environment. The research work has been carried out during the period from January 2015 to December 2017.

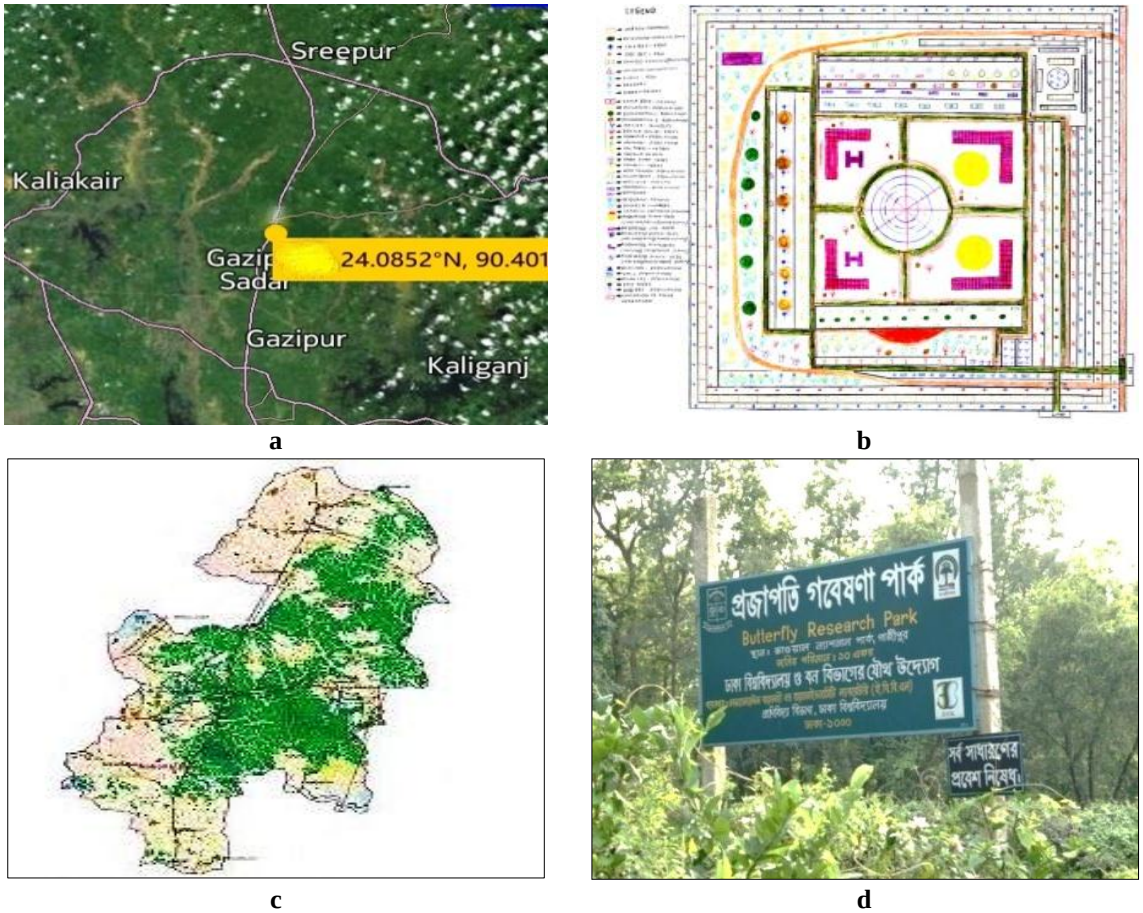
3.2.3 Selected sites

Butterflies are seen almost in all areas of Bangladesh either cultivated or non-cultivated (forest areas) areas, because they need such an ecological condition where they find their required plants (Bashar 2015). Lycaenid butterflies are seen in a wide variety of habitats. Several experimental stations have been selected to record data on the different aspects of

lycaenid butterflies like behaviours, etho-ecological information, plant-butterfly interactions, gene-flow activity determination and their survivals. The principal field study was carried out in Butterfly Research Park, Bhawal National Park, Gazipur. Part of this research investigation has done in three natural forests viz. Madhupur National Park, Tangail district; Satchori National Park and Rema-Kalenga Wildlife Sanctuary of Habigonj district. Several field studies have also been conducted in Botanical Garden, Bangladesh Agricultural University; Krishibari Butterfly Park at Savar, Dhaka; and also in Botanical and Zoological gardens of Curzon Hall, University of Dhaka. The selection and description of study site was followed by GoB (1993), Gain (2004), Kabir and Ahmed (2005), Uddin and Mukul (2007), Uddin and Roy (2007), Alam (2008), Mia *et al.* (2012), Bashar (2014), Bashar *et al*. (2015a) and Shakil (2016).

3.2.3.1 Butterfly Research Park (Bhawal National Park)

The Bhawal National Park (BNP) is located in Gazipur, under Dhaka Division of Bangladesh, approximately 40 km north of Dhaka city, only 20 km drive from Gazipur and 20 km from Kapasia. It is situated in between 24°5′44.98″ N and 90°24′14.4″ E.



a **b**

c **d**

Plate 1. Pictorial view of Butterfly Research Park (Bhawal National Park): **a**. location of BRP; **b**. area sketch of BRP; **c**. satellite image of Bhawal National Park area map; and **d** vegetation of BRP.

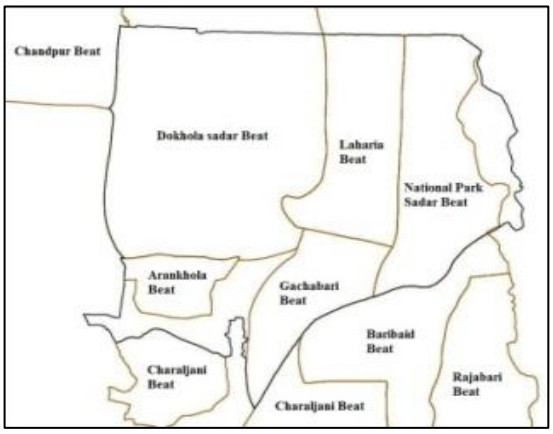
The core area of the park covers 940 hectares but extends to 5,022ha of surrounding forest. The topography of the Bhawal National Park is characterized by low hills about 3.0 to 4.5m high; the soil is yellow-red comprising sandy clay mixed with magniferous iron ores. The area experiences an annual rainfall of about 2500 mm. The vegetation is semi-deciduous; the upper canopy contains the deciduous species. This area is home to an incredibly diverse array of flora and fauna. The park has 220 plant species, including 43 different tree species, 19 shrubs, 3 palms, 27 grasses, 24 vines, and 104 herbs. The most common flora is the unique coppice Sal (*Shorea robusta*) forest. Most of this area was covered by forests 50 years ago and the dominant species was Sal. The wildlife in the park includes 13 mammals, nine reptiles, five birds and five amphibians. The diversity of fauna in the Bhawal National Park is low. Species include fox (*Vulpes bengalensis*), jackal (*Canis aureus*), small indian civet (*Viverricula indica*), wild boar (*Sus scrofa*) and black-naped hare (*Lepus nigricollis*). In addition the Forest Department has recently introduced peacocks, deer, pythons, and cat fishes. Once, the Bhawal National Park was renowned for housing quite wonderful indigenous varieties of creatures, such as leopard, elephant, black panthers, tigers, peacocks and sambar deer.

Butterfly Research Park (BRP) is an area of 3 acres (100×42 m^2) of allotted 10 acres land area in the premises of Bhawal National Park (Plate 1). The area is situated in between longitude 90˚24′06″E and latitude 24˚05′06″N. This area is designed with four area-components as hedge-boundary (10%), canopy-tree area (30%), jungle-bush hedges (30%) and multimorphic beds-area (30% of total experimental area). The hedge boundary has been prepared with the composition of approximate 30±5 essential different natural floral species. The Canopy-tree area has been designed and prepared with tall-trees and their associated vines and climbers. It is a typical area with canopy-covering and man-height supportive bushes. The Jungle-bush hedge is a bushy area that has been prepared with biotic composition of vines, herbs, shrubs, climbers, trees, grasses and also with the canes population. The area ensures safe pupation and quick sheltering (due to sudden extreme changes in weather) for the butterflies. Different kinds of soil beds have been prepared for the growth and maintenance of host, nectar and shelter plants. The plantation in these areas provides with various blooming flowers in relation to the seasonal variation. In addition to that, the area components show a decorative value that attracts social visitors also. The above biotic conditions constitute a suitable assemblage for the survival of considerable number of fecund butterflies in the park area.

3.2.3.2 Madhupur National Park

The Madhupur National Park (MNP) is one of the earliest national parks of Bangladesh. The Park (Plate 2) is deciduous with a slight mixture of evergreen forest, interspersed with hillocks. It is situated in the northern part of Bhawal-Madhupur Sal (*S. robusta*) forest tract, somewhat 50 km south of the Garo Hills of the Meghalaya State of India, and about 151km north of Dhaka, the capital of Bangladesh. Geographically, it lies between 24º45' N and 90º5' E. The altitude of the park is about 20m above the mean sea level. The southeast boundary of the park lies on both sides of the Tangail-Mymensingh Highway. Madhupur Sal forest includes an area of about 24,150 ha, but the Madhupur National Park (wildlife and recreation area) encompasses an area of 8,430 ha distributed partially over Jatiya Uddan and Dokhola Ranges.

a



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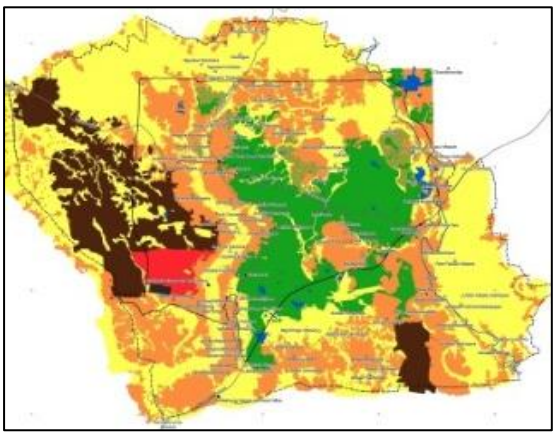

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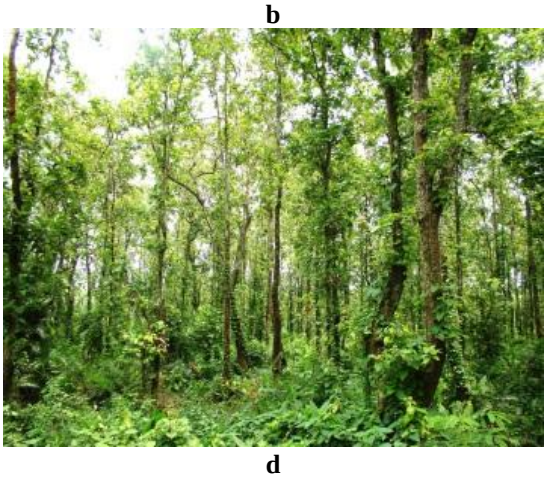


d

Plate 2. Pictorial view of Madhupur National Park: **a**. location; **b**. area map; **c**. satellite image of area map; and **d**. vegetation.

The climate of the tract varies slightly from north to south, the northern being much cooler in winter. Average temperatures vary from 28°C to 32°C in summer, falling to 20°C in winter, with extreme lows of 10°C. Rainfall ranges between 1,000 mm and 1,500

mm annually. The soil of the park has developed largely on Madhupur clays; which are nutrient poor and somewhat acidic. They are red or brown in colour. In most places the changes from the floodplains to the tract is quite sharp, but in some places the floodplain soils gently overlie the inclining edges.

Of its 176 botanical species, 73 are trees, 22 shrubs, 1 palm, 8 grasses, 27 climbers and 45 medicinal plants. The main plant species of the Park is Shal, *Shorea robusta*. Most of this tract was used to be covered by forests as recently as fifty years ago and sal (*S. robusta*) was the dominant species. Due to illegal deforestation only about 600 sq km of forest remains and new woodlands planted with exotic species, such as akashmoni (*Acacia auriculiformis*) and eucalyptus (*Eucalyptus camaldulensis*) have transformed the ecosystem in many areas. Most of the park is afforested with valuable trees, such as were gazari, karai and garjan. At present, the Park has about 190 types of animals of which 21 are mammals, 140 birds and 29 snakes. Notables among them are entellus, monkeys, phantom deer, porcupines, wild pigs, and different types of birds. The leopard cat, fishing cat, jungle cat and small Indian civet are still to be found. The peacock was at one time quite plentiful but became extinct thirty years ago.

3.2.3.3 Satchari National Park

The Satchari National Park (ScNP) is the newest among the protected areas of Bangladesh. This Park (Plate 3) is situated in Raghunandan hill, under Paikpara Union, Chunarughat Upazila, Habiganj District of Sylhet Division. It is 130 km from the capital city of Bangladesh, Dhaka. After the 1974 Wild Life Preservation Act, Satchari National Park was built on 243 hector land in 2005. It occupies longitude 91°27′2.52″ E and latitude 24°7′12″ N. Literally 'Satchari' in Bengali means 'Seven Streams'. There are seven streams flowing in this jungle, and the name 'Satchari' came from there. There are nine tea gardens nearby. Approximately 24 families of Tipra Tribe are living now in the Tipra village.

The Park originally supported a vegetation cover of mixed tropical evergreen forests. Soil texture of the park area is generally sandy loam to silty clay and soils are more acidic than in adjoin ecological zones. The topography is undulating with slopes and hillocks, locally called tila, ranging from 10 to 50 meters in elevation.

A number of small, sandy-bedded streams drain the forest, all of which dry out in the winter dry season after November. The total annual average rainfall is 4162 mm. July is the wettest month, having an average of about 1250 mm of rain, while December is the

driest, with no rainfall. The hottest months are May and October with an average maximum temperature of around 32°C, and January is the coldest month, when the minimum temperature drops to about 12°C. The relative humidity is about 74% during December while it is over 90% during July-August.

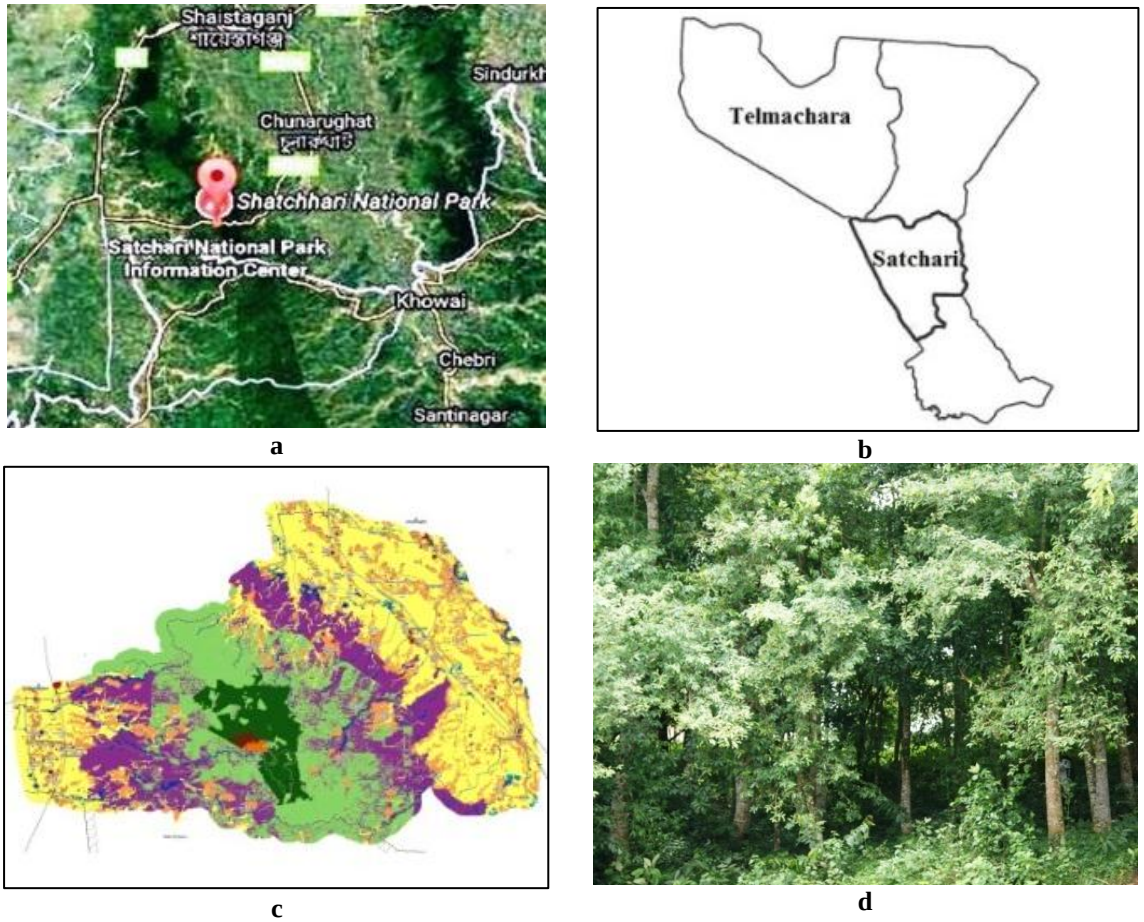


Plate. 3. Pictorial view of Satchari National Park: **a**. location; **b**. area map; **c**. satellite image of area map; and **d**. vegetation.

3.2.3.4 Rema-Kalenga Wildlife Sanctuary

Rema-Kalenga Wildlife Sanctuary (RKS) (Plate 4) is situated in the southern side of Habiganj district and continued up to Tripura of India. The sanctuary lies between 24°10′53″N and 91°38′13″E. It is a tropical forest with natural and cultivated plantations under Kalenga beat.

In this spot 330 hectare cultivated forests were planted with the mehgoni (*Swietenia mahagoni*), dhakijam (*Syzygium grandis*), gorjan (*Dipterocarpus costatus*), chapalish (*Artocarpus chapalasha*). It was established in 1997. Thirty acre forests were established in 1992 with the Golla ojalii plantation. 10.66 hectare cultivated forests were established in 2004 where the jam (*Syzyzium cuminii*), gorjan (*Dipterocarpus costatus*), chapalish (*Artocarpus chaplasha)*, mehgani (*Swietenia mahagoni*) etc. were planted.

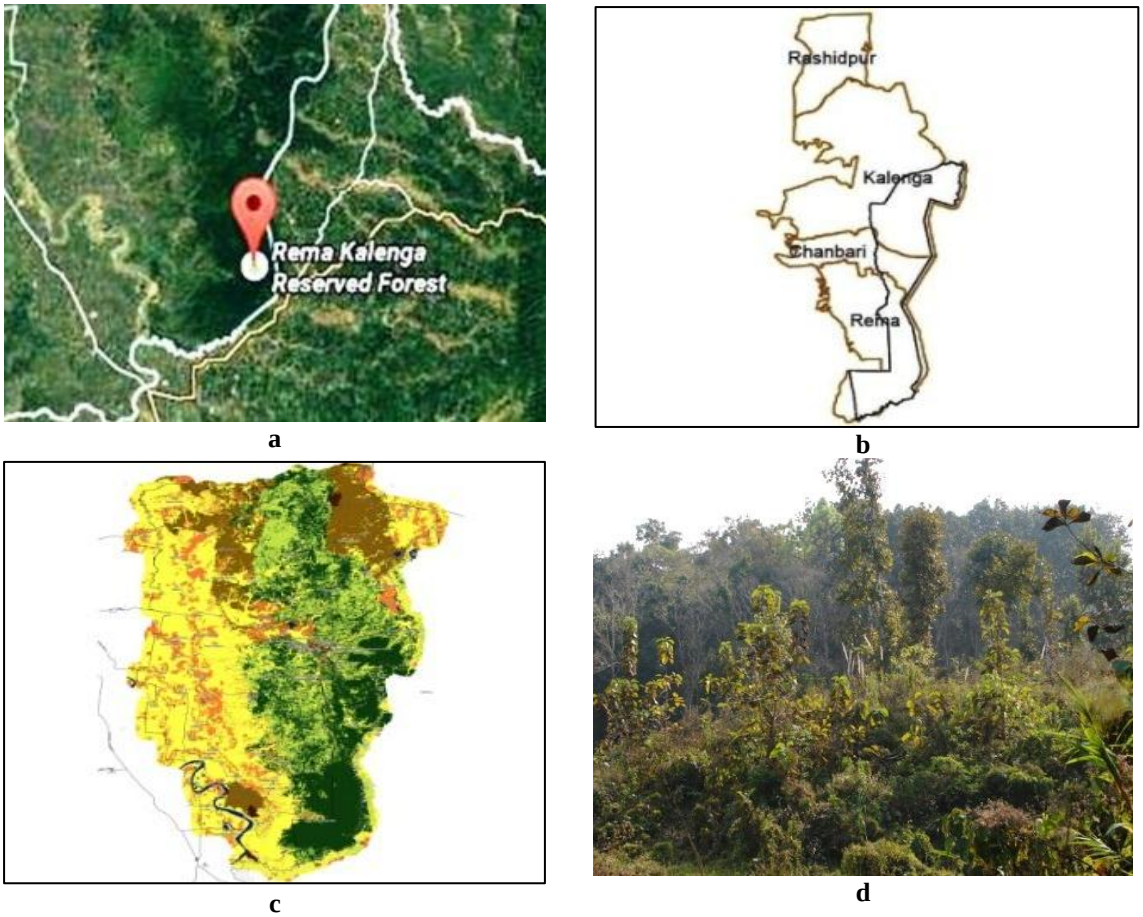


Plate. 4. Pictorial view of Rema-Kalenga Wildlife Sanctuary: **a**. location; **b**. area map; **c**. satellite image of area map; and **d**. vegetation.

Almost in all our experimental forest stations, destruction of the forests has started seriously from the end of the 1990s. But out of all forests under the experimentation of the EBBL, butterfly population in the forest of Rema-Kalenga is less disturbed by the humans. In some regions of the forests, the undergrowth vegetation was found untouched and undisturbed. Butterfly estimation is poorly studied in the forest still today. So far the estimation is made by the researchers of the EBBL, the population volume may stand with more than 200 species of butterflies. This forest shows mixed characters of butterfly populations derived from characters of the Lawachara and Satchari forest areas.

3.2.3.5 Krishibari Butterfly Park, Savar

Krishibari Butterfly Park (KBP) is situated at Savar of Dhaka district near Dhaka-Aricha Highway from 30 Km north of Dhaka City. The KBP (Plate 5a, Plate 5b) covers an area of 76×30m^2 which lies in between longitude 90˚31′69″ E and latitude 23˚76′74″ N. It primarily serves the purpose of recreation for tourists. This park is covered by planted or cultivated plant species except a very few of naturally originated plants. There are about 120 plant species representing 25 families and 40 genera. Medicinal plants, timber trees,

poisonous and toxic plants, palms, climbers, ornamentals as well as native and exotic plants are found available here.

a **b**

c **d**

Plate. 5. Pictorial view of study spots: **a**. location, and **b**. vegetation of Krishibari Butterfly Park, Savar; and **c**. location, and **d**. vegetation of Botanical Garden of Bangladesh Agricultural University, Mymensing.

3.2.3.6 Botanical Garden, Bangladesh Agricultural University

Botanical Garden (Plate 5c, Plate 5d) of Bangladesh Agricultural University is situated in Mymensingh district, 120 Km North of Nation's Capital City, Dhaka. It lies in between longitude 90˚13′85″ E and latitude 24˚68′88″ N. There are about 1,200 plant species representing 125 families and 350 genera. The available plants are medicinal plants, timber trees, fuel plants, poisonous and toxic plants, palms, bamboos, cacti, aquatic plants, climbers, ornamentals as well as native and exotic plants, and endemic plants of Bangladesh.

3.2.3.7 Zoological Garden, Curzon Hall, DU

Zoological garden (Plate 6a, Plate 6b) is situated at the Curzon Hall premises in University of Dhaka. This garden is under the Department of Zoology, University of Dhaka. It primarily used in research purposes for the students and faculty of the university.

Plate. 6. Pictorial view of study spots: **a**. location, and **b**. vegetation of Zoological Garden; and **c**. location, and **d**. vegetation of Botanical Garden, Curzon Hall, University of Dhaka.

The garden is about 60 m in length and 20 m in width land area. It is a calm, quite, and green shady place. The reddish brown soil of this place contains medium amount of iron and water content. An artificial water source presents here. There are about 50 plant species which include trees, shrubs and herbs, and also bushes. Several species of grasses are also found in this garden. Various species of herbs and shrubs (viz. milkweed, isharmul, lebu, lantenna, cosmos, panica, botumphul etc.) are planted here.

3.2.3.8 Botanical Garden, Curzon Hall, DU

The Botanical Garden (Plate 6c, Plate 6d) is situated on the Curzon Hall premises in the University of Dhaka. It is about 200 m long and 41 m wide. This garden belongs to the Department of Botany, University of Dhaka. It is calm and quite place with green shady areas. There are about 170 plant species are available here. Among them 90 are trees, 25 shrubs, 35 herbs and 20 medicinal plants. This garden is also served research field for the students and faculty members of the university. The butterflies and other foragers (viz. honey bees, aphids, grasshoppers, various types of beetles and hymenopterans) are

attracted with colour and scent of different plants. For this, it is an ideal place to study 'butterfly-plant interaction'.

3.2.4 Choice of study sites

The selected study sites of forests are the protected areas. The areas are shielded from developmental pressures or other anthropogenic influences though some areas are exposed to human activities such as tourism. In spite of this all care has been taken to select sites with minimal as well as more or less equal degrees of disturbance. Organisms can thus be studied in their natural surroundings which lend more credibility to the accuracy of observed habitat preferences (Kitching *et al*. 2000). The selection of study sites has been done following the procedures of Marsh and Greer (1992), Wood and Samways (1992).

3.2.5 Sampling procedures

The sampling method was designed in such a way that sampling effort and area were equal at all sites and during all periods (Blair 1999). This made direct assessment among butterfly-plant interaction, butterfly population richness and other indices between sites and between times possible. There are various methods for the sampling of butterfly from the wild areas (Southwood 1971, Cooper and Whitemore 1990, Diraviam and Uthamasamy 1992). Many of them have become very popular. Several standard sampling procedures with slight modifications were practiced in the present investigation. These procedures are also suit the local environment for the sampling of butterflies and their related plants. The adopted sampling procedures using in current study are detailed below-

3.2.5.1 Transect sampling

The transect counting is the most popular and universally accepted method for monitoring butterfly population, etho-ecological studies and their abundance in an area. Transect routes are chosen to sample evenly the habitat types and management activity on sites. Care is taken in choosing a transect route as it must then remain fixed to enable butterfly sightings. In brief, this is a fixed-route walk which is established at a site on which butterflies are recorded along the route on a regular basis. One transect count along the fixed transect route of 1 km is considered as a unit sampling effort. It is practical to divide transect into smaller sections which makes it easier to keep an overview and process the

data. Bashar (2017) modified the experimental transect as 100×100 m^2 that were used for estimating butterfly populations. In this observation topographic variations of transect and other abiotic fluctuations within transect are recorded during reading-period from 8.30 to 15.30 hrs. Observation and recoding was made while walking along transects. Transect walks are undertaken when weather conditions are suitable for butterfly activity. All the butterflies on either side were recorded. The sampling considered butterfly-plant association and abundance of understory butterfly species. While it ignored the canopy and underestimated the fast-flying mid-level to canopy species, it was consistent between transects (Fermon *et al*. 2001). Observations as well as species was collected using a butterfly net whenever possible in case of mid-level to canopy layer during the same sampling period permitted an assessment of butterflies. The methodology and development of transect monitoring for butterflies have been adopted following Pollard (1977), Thomas (1983), Ishii (1993), Pollard and Yates (1993) and Natuhara *et al.* (1996).

3.2.5.2 Sweep sampling

Sweep sampling was done from the herb and shrub layers of the vegetation using a sweep net. A sweep net is funnel-shaped cotton net having a mouth diameter of 40cm and an approximate mesh size of 2 mm attached to a long-handled frame that is swept back and forth through the foliage. Sweep-netting is commonly used because the equipment is lightweight and simple to use (Southwood and Henderson 2000). This technique can vary with respect to sweep form, number of sweeps per sample, and the equipment used to take samples (Buffington and Redak 1998). Sweep samples are often taken under different weather conditions and the method of sweep sample implementation can vary. Each passage of the net is considered one sweep. In short vegetation, swing the net as deeply as possible. In taller vegetation, sweep only deeply enough to keep the upper edge of the sweep net opening even with the top of the plants. The sweeps were done while walking along the transect that passes through the different habitat types present within the study area. This procedure is followed according to Southwood (1971).

3.2.5.3 Latin squares design (LSD) of sampling

LSD is very helpful and applicable method for assessing biodiversity monitoring and biodiversity sampling application. This design produces data accumulation for the numerous small-sized organisms like butterflies in the wild state. This design has got some advantage in taking measures to analyze data statistically. Observation and data

recoding was made during reading-period from 8.30 to 11.30 hours by group wise pattern with four groups simultaneously. All groups followed the recording process in a cyclic manner by using the blocks in A-B-C-D chronology. Block means the unit area for butterfly recording in a region of the forests (North, South, East or West). This technique has adopted following Rao and Richard (2006) with modifications (Bashar 2017).

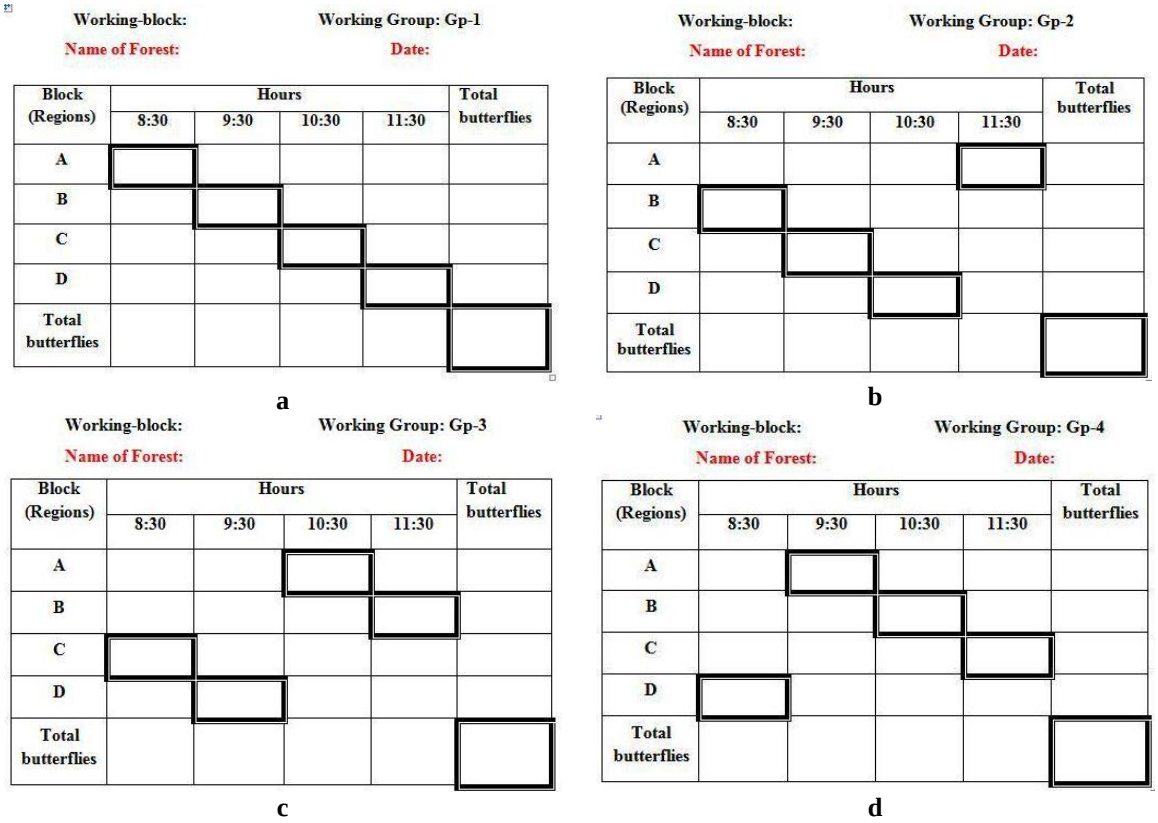


Fig. 1. Modulation of 'Latin squares design of sampling' in the working blocks with groups of assessor: **a**. exercise of Gp-1; **b**. exercise of Gp-2; **c**. exercise of Gp-3; and **d**. exercise of Gp-4.

3.2.5.4 Butterfly-Plant assessment model

The 'butterfly-plant assessment model' is dealt with the practice to record butterflies; and in addition to record the number of plant species in each experimental square area. By this procedures the butterflies and their associated plants is easily marked in the field. Sampling procedure on the butterfly plant assessment practice in the field was exercised in the way as it is show in below. In practice, four assessors were assigned in the field (100 m^2 area) as shown on working pattern. In this procedure assessor-1 will count the butterfly and as well as the number of plants species in the target area; and will continue from his standing point to the standing point of the assessor-2. Similarly the assessor-3 will do the same to the assessor-4. This procedure is followed according to Bashar (2017).

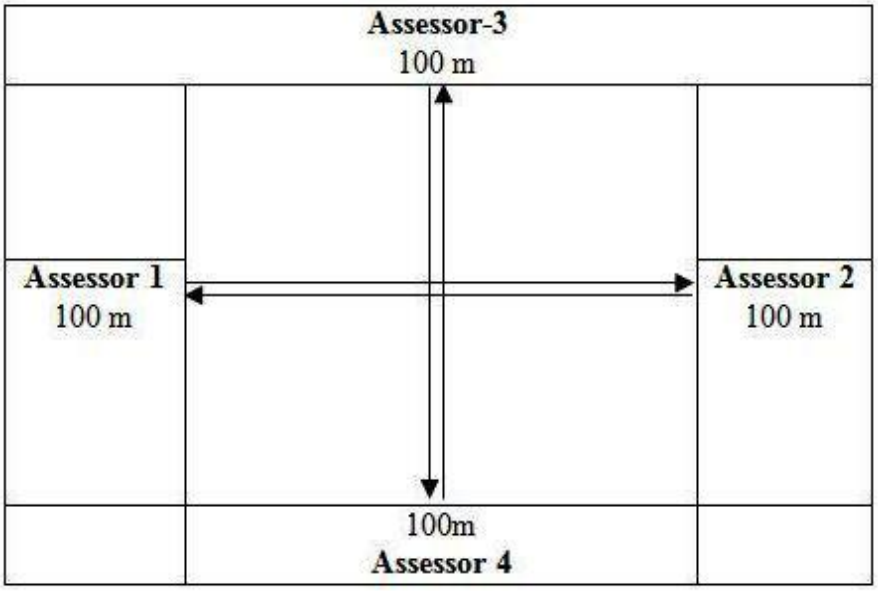


Fig. 2. Practice of Butterfly-Plant assessment model in four assessors-modeling techniques.

3.2.6 Field observations and data recording

The above mentioned methods have been widely used to answer questions of butterfly abundance, community composition, species richness, dominance and diversity (Murphy and Weiss 1988, Swengel 1996, Thomas 2005, Swengel and Swengel 2013). Butterfly presence and abundance has been assessed in specific survey using the same transects used for vegetation surveys. Observations were made twice in a month during the time between 9.30 a.m. and 4.30 p.m. According to Holl (1996) and Gardiner *et al*. (2005) this is the period within which most butterfly species are probably active. The lycaenids activities in the study sites were recorded through a "constant walk" for 10-15 minutes over the experimental field (Akand *et al*. 2016). After transect walk is complete, a time-constrained opportunistic walk will be conducted to look for other butterflies not seen along transect. Transects were split into sections based on vegetation type and topography so that observations could be analyzed by habitat type (Natuhara *et al.* 1996). Butterflies were caught in sweep net if identification could not be done immediately. If so, the transect walk was stopped and resumed again after identification. Photographs of the butterflies and plants were also taken for further identification if failed to identify in the field. The repetitions within sites were conducted in such a manner that all transects were sampled. Examination also made in the developmental stages of butterflies engaged with plants.

3.2.7 Procedures for species identification

Several procedures have been anticipated to identify the lycaenid butterflies and their related plants in field conditions as well as in some cases at the laboratory. These procedures are labeled as following headings-

3.2.7.1 Materials for identification

Digital camera (SONY Cyber-Shot DSC-H50 and SONY Alpha α290 DSLR) (Plate 7a, Plate 7b) was used to photograph butterfly and plant specimen in the field condition. Trinocular Light-Microscope (X20) (Plate 7c) and a magnifying glass were also used for the identification of collected butterflies particularly to observe the wing venation and other morphological characteristics.

a **b** **c**

Plate 7. Materials for species identification: **a**. SONY Cyber-Shot DSC-H50 camera; **b**. SONY Alpha α290 DSLR camera; and **c**. Trinocular Light-Microscope (X20).

3.2.7.2 Methods for identification

The lycaenid butterflies and their related plants were identified directly in the field and from the photographs taken during observation. Identification of butterfly was done following the procedure of Bingham (1907), Eliot (1973), Borror *et al.* (1981), Akand (2012) and Bashar (2014). Plant species were identified following Jensen (1999), Ahmed *et al.* (2009) on the basis of leaf characteristics, flower arrangements, and fruit types and shapes.

3.2.7.2.1 Identifying characteristics of lycaenid butterflies

Characteristics that are used in identification of family Lycaenidae are tabulated here in three broad categories: head characteristics, wing characteristics, and leg characteristics.

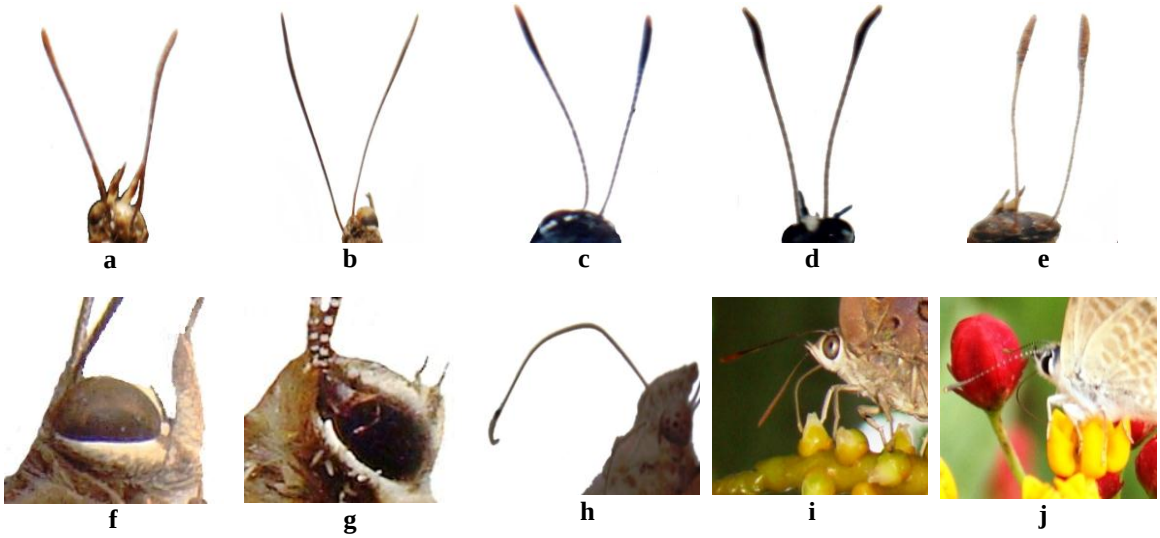


Plate 8. Different head characteristics of lycaenid butterflies: antenna of subfamily **a**. Curetinae, and tribes **b**. Arhopalini, **c**. Hypolycaenini, **d**. Polyommatini and **e**. Lycaenesthini; **f**. smooth and **g**. hairy eyes; probosies of two subfamilies, **h**. and **i**. Theclinae: *Arhopala amantes*, and **j**. Polyommatinae: *Lampides boeticus*.

Head characteristics (Plate 8) **-** These characteristics consist of eyes, proboscis and antennal shape. Antenna is a fundamental character for the identification of lyceanid butterfly at subfamily level, also in generic level. The antennal club, shape of nudum, and the number and length of the segments are fairly good characteristics to identify lycaenid species. Hairy and smooth eyes are the characters that help in the classification at the generic level. The important diagnostic feature is being the development and absence of sensory hairs on the outer surface and sides of the shaft of the proboscis. This character is quite useful to identify the butterflies of family Lycaenidae.

Characteristics of the wings (Plate 9) **-** These characteristics are based on shape, pattern, colouration and venation of wing. The wings are flattened, membranous expansions, strengthened by a system of thickened hollow ribs called veins or nervures. The wing shape is very variable. The absence or presence of hind wing tornal lobe and tails or teeth, number and position of tails, and hind wing cilia are important characters to identify them. Hind wing tails and cilia give a 'false head' impression for the lycaenids helping them to protect from predators. Wing colouration of species is important to identify sexual dimorphism. Dorsal side is dissimilar in wing colouration while ventral side is same colour in case of lycaenid butterflies. The Lycaenids is well known for its vivid dorsal wing colouration, which represents practically the entire visible spectrum. The number and arrangement of the wing veins is of great value in identification.

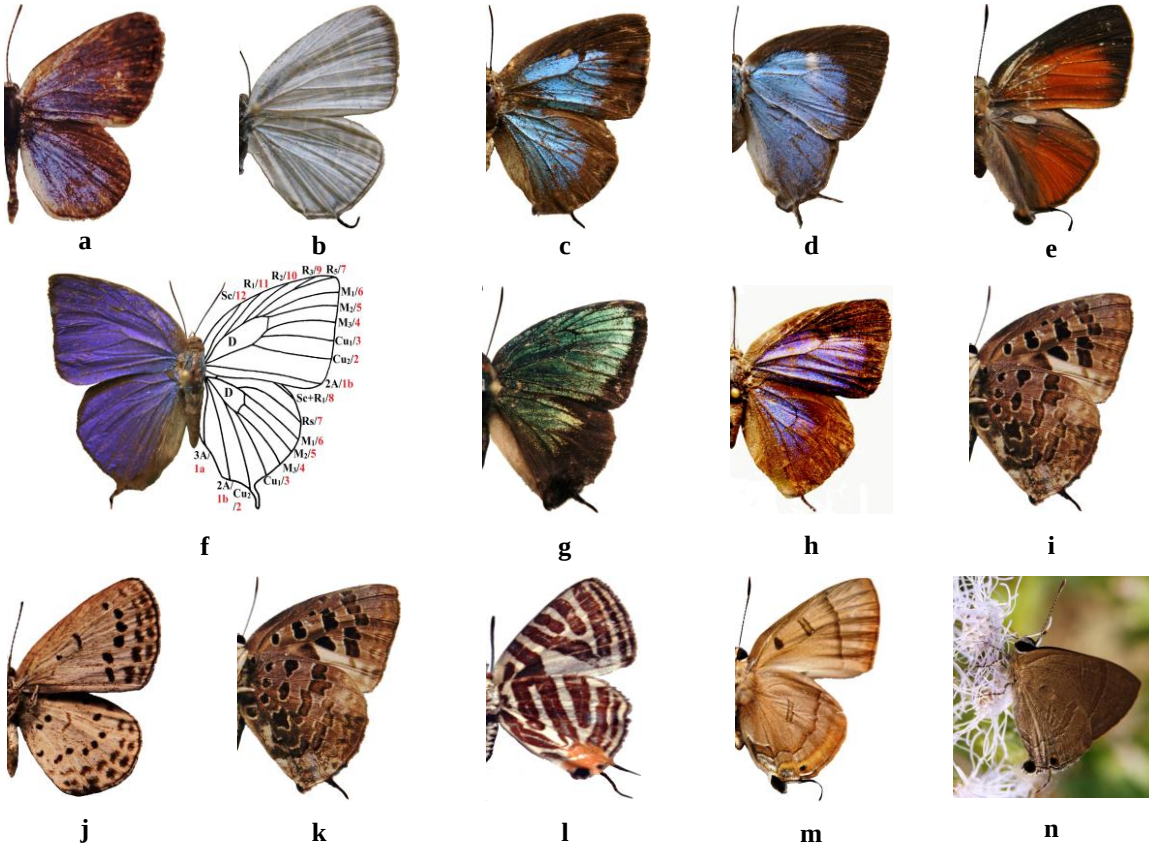


Plate 9. Wing characteristics for identification of lycaenid butterflies: wing shape of different tribes- **a**. Polyommatini (tailless), **b**. Polyommatini (tailed), **c**. Arhopalini, **d**. Iolaini, and **e**. subfamily Theclinae (hind wing lobed); **f**. wing vein notation of lycaenid butterfly; wing colouration e.g. *Arhopala eumolphus* **g**. male, **h**. female and **i**. male (ventral); and wing patterns- **j**. Polyommatini (tailless), **k**. Arhopalini, **l**. Amblypodini, **m**. Deudorixini, and **n**. 'false head' impression.

A typical butterfly forewing has twelve veins, the first and last arising from the base, the others from the cell. The hind wing has eight veins, arising in the same way as those of the fore wing. Within the family there is a standard wing pattern which has been analyzed by Schwanwitsch (1949). It consists of the markings on the ventral surface of both wings, the terms are a fine marginal line, a double series of sub-marginal markings, the outer often macular, the inner often lunulate or linear, a post-discal macular, linear, catenulate or banded series, a bar or spot at end cell astride the disco-cellular vein, a series passing through the markings internal to the end cell bar are often absent or distorted and the other markings give more important and easily used characters.

Characteristics of the legs (Plate 9) - These characteristics include fore, mid and hind leg structures. The leg characters of value in identification include the form of the tibial spurs and the tarsal claws. Lycaenidae invariably have female fore tarsus unmodified, the aborted male fore-tarsus must be a sex-controlled character. The type of ending the aborted male fore-tarsus that is 'produced to a ventrally curved point or hook' is

sometimes a useful character. Structure of tarsal ending, presence or absence of spurs at tibiae is also important.

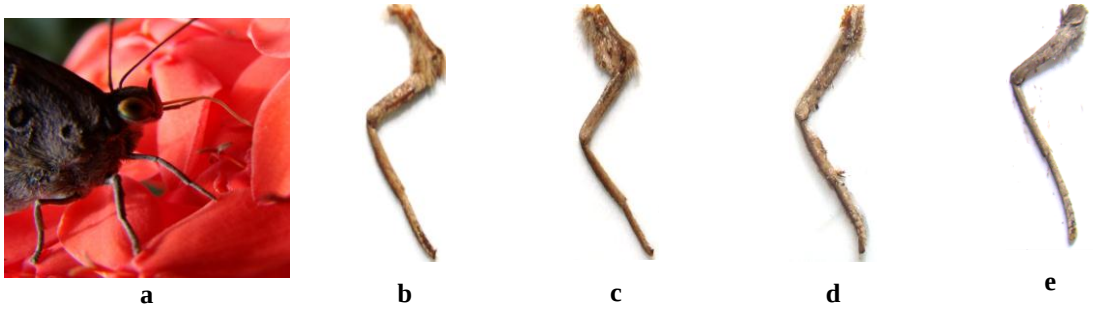


Plate 10. Leg characteristics of lycaenid butterflies, e.g. *Arhopala pseudocentaurous*: **a**. image of legs; **b**. fore leg (♀); **c**. fore leg (♂); **d**. mid-leg; and **e**. hind leg.

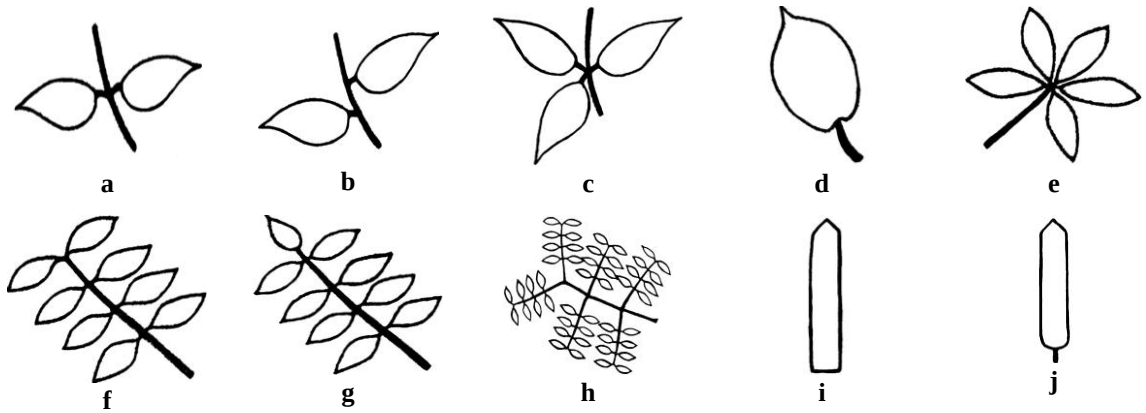
3.2.7.2.2 Precaution during handling

A great care is taken during observation and examination of specimens. All sorts of handling the specimen is done so carefully that wings, legs or antennae cannot be broken and the scales of the wings and the body of the specimen cannot be removed.

3.2.7.2.3 Identifying characteristics of plant species

Plant species has been identified on the basis of leaf characteristics including arrangement of leaves, leaf structure, leaf shape, leaf margin, leaf tip and leaf base, flower arrangements and fruit types and shapes. Identification of plant has done according to Dey (1995), Ahmed (1997), Jensen (1999), Ahmed *et al*. (2009) and Yusuf *et al*. (2009). Different identifying characters of plant are described below-

Characteristics of leaves (Fig. 3A, Fig. 3B) - Leaves are an organ of a vascular plant. Typically a leaf is a thin, flattened organ borne above ground and specialized for photosynthesis. External leaf characteristics are important for identifying plant species (Haupt 1953). Leaf arrangement on stem is one of key factor in plant species identification.



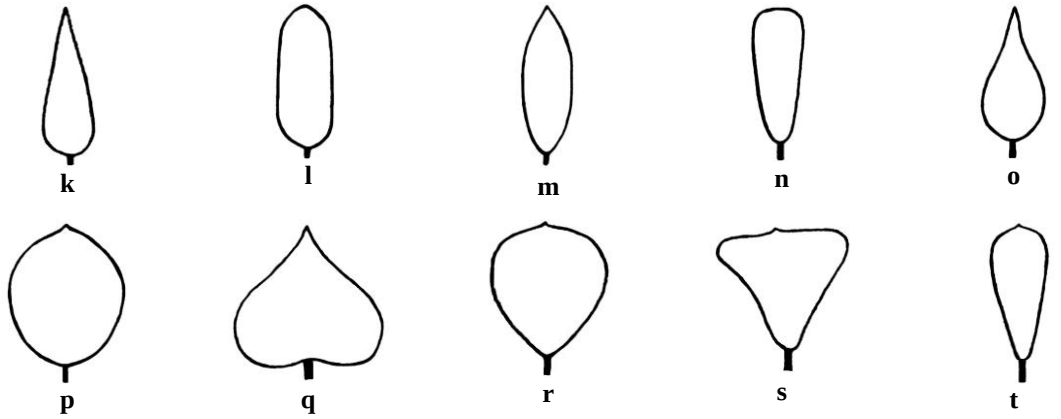


Fig. 3A. Characteristics of leaves (source: Jensen 1999): arrangements of leaf- **a**. opposite, **b**. alternate, and **c**. whorled; structures of leaf- **d**. simple **e**. palmately compound, **f.** even pinnately compound, **g**. odd-pinnately compound, and **h**. bipinnately compound; leaf shapes- **i**. simple, **j**. linear, **k**. lanceolate, **l**. oblong, **m**. elliptical, **n**. spatulate, **o**. ovate, **p**. orbicular, **q**. cordate, **r**. obovate, **s**. cuneate and **t**. oblanceolate.

Leaves are arranged on stem as opposite or alternate or whorled pattern. Structure of leaves is simple and compound. Various types of compound leaves are important for plant identification. Plant species is identified according to their leaf shapes and leaf margins. Tips and bases as well as venation of leaf are also important in identification of plant species.

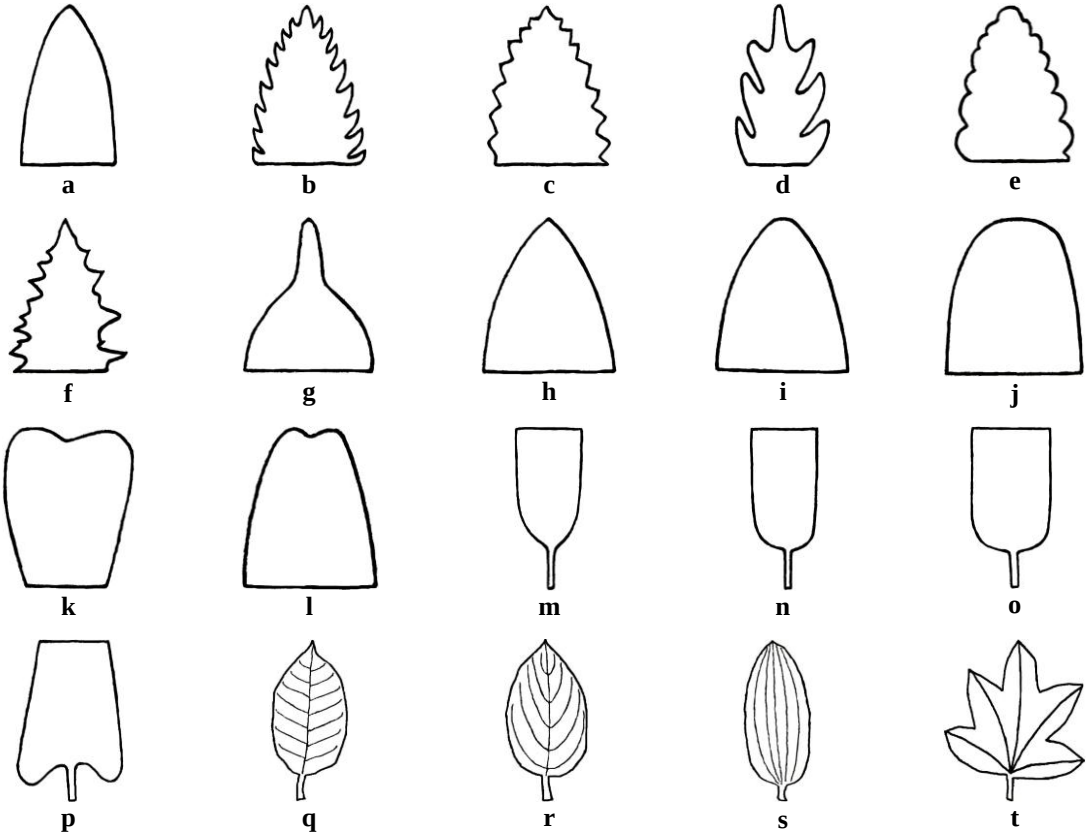


Fig. 3B. Characteristics of leaves (source: Jensen 1999): leaf margins- **a**. entire, **b**. serrate, **c**. dentate, **d**. lobed **e**. crenate, and **f**. incised; leaf tips- **g**. acuminate, **h**. acute, **i**. obtuse, **j**. rounded, **k**. truncate, and **l**. emarginate; leaf bases- **m**. acute, **n**. obtuse, **o**. rounded and **p**. auriculate; leaf venation- **q**. pinnate, **r**. arcuate, **s**. parallel, and **t**. palmate.

Characteristics of flowers (Fig. 4) - Flowers are the reproductive organs of plants and their characteristics are often important for plant identification in traditional flora. Flower characteristics define a plant's placement in the taxonomic system. When flowers are available they can provide valuable clues to the identification of a plant (Jensen 1999). Arrangements of flowers on plant are used in identification of species.

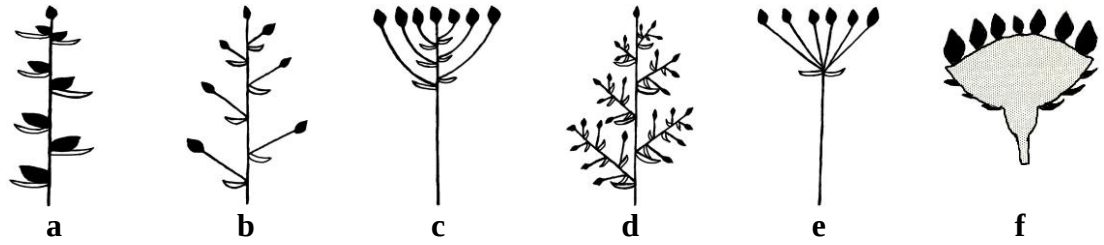


Fig. 4. Arrangement of flowers (source: Jensen 1999): **a**. spike, **b**. raceme, **c**. corymb, **d**. panicle, **e**. umbel, and **f**. head.

Characteristics of fruits (Fig. 5) - Fruit is a part of a flowering plant that derives from specific tissues of the flower, mainly one or more ovaries. Fruits are the means by which many plants disseminate seeds. Many plants bearing edible fruits, in particular, have propagated with the movements of humans and animals in a symbiotic relationship as a means for seed dispersal and nutrition, respectively; in fact, humans and many animals have become dependent on fruits as a source of food (Lewis 2002). Types of fruit and fruit shapes are used in plant identification.

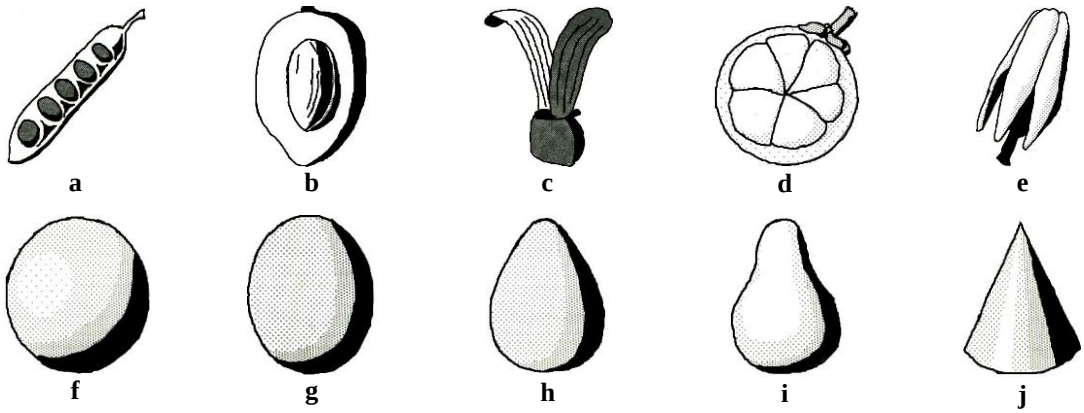


Fig. 5. Characteristics of fruits (source: Jensen 1999): types of fruit- **a**. pod, **b.** stone fruit, **c**. winged nut, **d**. berry, and **e**. capsule; fruit shapes- **f**. globose, **g**. ellipsoid, **h**. ovoid, **i**. pyriform, and **j**. conical.

3.2.8 Categorization of butterflies

The observed lycaenid butterflies in the study site have been categorized in different status according to "*The EBBL-modulated formula for category determining*" followed by Bashar (2015). The status of butterflies in Bangladesh was being assessed based on the results obtained from the field data. Six categories (Table 1) have been suggested in the

context of categorizing 'vulnerability stages' of identified species from the experimental stations (forest areas).

Table 1. The EBBL-modulated formula for category determining

Conservation Status	Number of forest station(s)	Number of butterfly(s) per station
Available	>5	>5
Rare	≤5	≥5
Near Threatened	>5	≤5
Threatened	≤5	≤2
Critically Threatened	<5	1
Endangered	1	≤3

Note: >5 = more than '5'; ≤5 = equal or less than '5'; ≥5 = equal or more than '5'; ≤2 = equal or less than '2'; <5 = less than '5'; ≤3 = equal or less than '3'

The categories are as follows:

***Available (Av) -** A species is designated as 'Available' in Bangladesh at that case when it was recorded in more than 16% of total (5) forest stations and as well as the recorded butterfly-individuals belonging to the species per station were more than 16% of total (5) in number.

***Rare (Rr) -** When a species was found in not more than 16% of total (five or, less than in five) stations; but on the other hand, the butterfly-individuals of the species per station were recorded not less than 16% of total (five or, more than five) in number; then it is termed as 'Rare'.

***Near Threatened (Nt) -** The status 'Near Threatened' is applied in case of those species which might be found available in more than 16% of total (five) forest stations but the butterfly-individuals per species per station had not been exceeded more than 16% of total (five) in number.

***Threatened (Tr) -** A species is said to be held the status 'Threatened' when the number of butterfly-recorded forest stations had not been exceeded more than 16% of total (five). And the butterfly-individuals belonging to that species per station also had not been exceeded more than two 6% of total (two) in number.

***Critically Threatened (Ct) -** When only a single butterfly-individual of a species was recorded per station in less than 16% of total (five) forest stations but in more than one station, then it is designated as 'Critically Threatened' species.

****Endangered (En) -** When less than 11% of total (three or, less than three) butterfly-individual(s) of a species was recorded only in 3% of total (one) experimental station;

then the species is designated as 'Endangered' species in Bangladesh perspectives. The species is supposed to be no longer existed in Bangladesh if immediately measure(s) for its conservation is not to be taken.

Table 2. Example of EBBL model-exercise for assessment of butterfly vulnerability-status

Forest	Number of species (individual)																IPF
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	-	-	12	8	-	-	-	9	-	-	3	-	-	-	-	7	39
2	-	-	4	2	12	2	-	2	3	-	-	1	-	-	-	12	38
3	-	-	10	3	-	-	-	4	8	-	-	-	-	-	-	9	34
4	-	-	3	8	-	-	5	-	13	-	2	-	-	-	-	2	33
5	-	1	-	2	-	-	-	7	2	-	-	-	-	-	-	5	17
--																	--
32	-	-	8	4	-	-	-	1	-	-	1	-	-	-	-	5	19
TI	18	3	71	107	14	20	33	114	142	2	37	1	7	23	2	139	
TFE	9	3	25	23	2	7	4	26	21	1	14	1	5	3	2	23	

To assess the butterfly vulnerability-status, four points have been given priority in counting of butterflies in the field condition. These points are: *counts on foraging condition*; *counts on resting condition*; c*ounts on pre-mating/mating condition*; and c*ounts on maintaining territoriality*. And three points viz. e*gg laying condition; butterflies on long-distance flight;* and s*hort-moving/temporary moving butterflies* were not considered for counting butterflies in the field.

3.2.9 Categorization of plants

On the basis of necessity dimension, EBBL has categorized the plants into four categories. Four types of butterfly behaviours viz. foraging (**F**), resting (**R**), basking (**B**) and egg laying (**El**) were selected. This has been made for studying the butterflies and their related plants in Bangladesh only. This study is done following Akand *et al*. (2015). The categories are as stated below–

- **Excellent biotic resource potential:** The plant belongs to this category has no sub-category but includes all types of behavioural activities (**F-R-B-El**) on it.
- **High biotic resource potential:** In this category, plant provides three types of behavioural activities on it, and it is divided into four sub-categories (viz. **F-R-B, F-R-El, F-B-El** and **R-B-El**).
- **Mid biotic resource potential:** The plant belongs to this category contains two types of behavioural activities on it, and it is divided into six sub-categories (viz. **F-R, F-B, F-El, R-B, R-El** and **B-El**).

- **Poor biotic resource potential:** The plant belongs to this category include single activity of butterflies on it and it is divided into four sub-categories (viz. **F, R, B** and **El**).

3.2.10 Analysis of data

The Pearson's rank correlation has been used to assess the relationship between lycaenid butterflies and their activity-related plants. The statistical analysis has been performed using SPSS software (version 16). Graph, table, and figure have been drawn using Microsoft Office Excel 2010.

3.3 Results

The results of the present study have been accumulated following the procedures adopted in the material and methods. Butterfly presence depends on specific plants, the diversity of habitat structure, and community composition may also strongly influence butterfly dynamics by providing shelter and additional food resources (Akand 2012). Butterfly activities deal with the determination of status of butterflies in relation to their associated plant-abundance, status of forests and the various aspects of environmental soundness (Bashar 2015). Many species, both common and rare, can be reliably identified in the field without killing the individuals (Padhey *et al.* 2006). This study has focused on getting the fundamental information of lycaenid butterfly resources and their activities in relation to the associated plants within the forests in Bangladesh. Taking this interpretation in front this chapter has been described in several sub headings-

3.3.1 Lycaenid butterflies

Lycaenid butterflies visit flowers regularly or hovering around the food plants. Some of them are weak fliers with low, erratic, and up and down flight as well as difficult to follow while others are fast flyers (Wauer 2002). Some of small lycaenids are seen in open grassy areas and drier deciduous forest and others occur in dense forests. Comparatively large sized lycaenids are fully forest dwellers and found in the forests that are more stable conditions and undisturbed (Kehimkar 2008). The common lycaenid species has been observed in the present investigation.

A total of 6728 individuals under 25 species of lycaenid butterflies were observed and recorded in different experimental sites from 2015 to 2017 (Appendix 1). These butterflies were spotted in egg laying, foraging, basking and resting on related plants in described experimental stations during the study period. Among the examined butterflies only 10 species was found in laying eggs on their host plants. The rest of the species was observed performing three other behavioural activities (viz. foraging, basking and resting). The 'vulnerability status' of the recorded species in Bangladesh context is also given following Bashar (2015). All the examined lycaenid species are tabulated below marking behavioural activities with their 'vulnerability status' (Table 3).

Table 3. Examined lycaenid butterflies marking behavioural activities on related plants during the study period along with their 'vulnerability status'.

Lycaenid butterflies	Behavioural activities*				Status**
	Egg laying	Foraging	Basking	Resting	
Pseudozizeeria maha	+	+	+	+	Available
Zizina otis	-	+	+	+	Rare
Chilades lajus	+	+	+	+	Available
Chilades pandava	+	+	+	+	Available
Catochrysops strabo	+	+	+	+	Available
Tarucus callinara	+	+	+	+	Rare
Castalius rosimon	+	+	+	+	Available
Caleta decidia	-	+	+	+	Near Threatened
Jamides alecto	-	+	+	+	Threatened
Jamides celeno	-	+	+	+	Available
Lampides boeticus	+	+	+	+	Available
Euchrysops cnejus	+	+	+	+	Available
Anthene emolus	-	+	+	+	Rare
Arhopala pseudocentaurus	-	+	+	+	Available
Arhopala amantes	-	+	+	+	Available
Loxura atymnus	-	+	+	+	Available
Rapala manea	-	+	+	+	Available
Rapala pheretima	-	+	+	+	Available
Rapala iarbus	-	+	+	+	Rare
Spindasis syama	-	+	+	+	Available
Spindasis lohita	-	+	+	+	Threatened
Remelana jangala	+	+	+	+	Available
Hypolycaena erylus	-	+	+	+	Rare
Rathinda amor	+	+	+	+	Rare
Tajuria cippus	-	+	+	+	Rare

*Behavioural activities of examined lycaenid butterflies in related plants expressed as present (+) and absent (-); **Status of examined lycaenids are given following Bashar (2015).

3.3.1.1 Outline of examined lycaenid butterflies

The examined lycaenids are described here as information cell along with physical features, habit and habitat, distribution, and eco-biotic information. This description is done following Bingham (1907), Eliot (1973), Pinratana (1981), Ek-Amnuay (2006), Akand (2012), Bashar (2014) and Bashar (2016b).

***Pseudozizeeria maha* (Kollar, 1848)** (Pale Grass Blue/নীলদূর্বা)

a **b** **c**

Plate 11. Pictorial view of *Pseudozizeeria maha*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

In dorsal side, male is pale bluish white with broad dark border on fore wing and costal area of hind wing. Dark veins present at post discal areas of both wings. Female is pale bluish brown with broader dark borders and diffused inwardly. In ventral side, both sexes are brownish-gray. Forewings have a spot in space 2A and a cell spot, post discal series dark and prominent. Hind wings have black spots. It prefers open grassy areas, more abundant on hilly areas of Bangladesh. This butterfly is weak flier and remains close to the ground on grassy patches as well as visits flowers. It is distributed in South Asian region including India, Pakistan, Nepal, Bhutan, Bangladesh, Myanmar and Sri Lanka as well as South East Asia including Singapore and Thailand. This small butterfly is found almost everywhere in Bangladesh including different forest areas of Dhaka, Chittagong and Sylhet division and even in urban areas. **Length of Antenna:** 4-6 mm; **Wing-Spread:** 18-24 mm; **Forewing:** 10-12 mm; **Hind wing:** 8-10 mm.

***Zizina otis* (Fabricius, 1787)** (Lesser Grass Blue/পঞ্চতিলা)

a **b** **c**

Plate 12. Pictorial view of *Zizina otis*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

In dorsal side, male is dark purplish blue with broad blackish border on fore wing and costal area of hind wing. Female is pale bluish brown with broader dark borders. In

ventral side, both sexes are brownish-gray. No cell spot or a sub costal spot present in forewing. Hind wings have black spots. It flies fast and flight close to ground, flying often endlessly before settling to feed on flowers. This butterfly prefers open clearings and obtains nourishment from the flowers of small herbs. This species is found in South Asian region including Bangladesh, Myanmar, India, Pakistan, Nepal, Bhutan and Sri Lanka; this butterfly also found in Singapore, Thailand and Philippines. This tiny butterfly is available in Karerhat, Mirsarai, Fashiakhali and other forests of Chittagong Division; Ramakalenga, Satchori and other forests of Sylhet division; Madhupur and Bhawal forests of Dhaka division in Bangladesh. It also found in urban areas. **Length of Antenna**: 4-6 mm; **Wing-Spread:** 16-22 mm; **Forewing:** 8-10 mm; **Hind wing:** 6-8 mm.

***Chilades lajus* (Stoll, 1780)** (Lime Blue/তিলামদন)

a **b** **c**

Plate 13. Pictorial view of *Chilades lajus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Chilades lajus is commonly known as Lime Blue butterfly. The adults are dimorphic, the males and females being different. Dorsally, male is purplish-blue with narrow dark border. Female is pale bluish-brown with broader dark borders. Basal areas are tinted with iridescent blue on both wings. Hind wings have a series of white-ringed marginal black spots. Both are brownish-gray in ventral side. A costal spot at the angle formed by veins R_3 and R_5 on the forewing. Hind wing post discal spot present in space 6 shifted inwards. It has fluttering flight, usually close to ground. It visits flowers, bird droppings and damp patches. Though this butterfly prefers forested areas, it is seen in gardens and citrus orchards. It is more common in drier, open habitats. This blue butterfly is available in Bangladesh, Sri Lanka, Pakistan, India, Nepal, Bhutan, Myanmar, Thailand and Philippines. It is abundant in Mirsarai, Fashiakhali, Karerhat forests of Chittagong division; Laowachar, Anarashbari, Satchari forests of Sylhet division; Madhupur and

Bhawal forests of Dhaka division in Bangladesh. It is found in agricultural areas. **Length of Antenna:** 6-7 mm; **Wing-Spread:** 22-26 mm; **Forewing:** 12-14 mm; **Hind wing:** 10-12 mm.

***Chilades pandava* (Horsfield, 1829)** (Plain Cupid/রূপমদন)

a **b** **c**

Plate 14. Pictorial view of *Chilades pandava*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

In dorsal side, male is purplish-blue with narrow black border. Female is paler but shining blue with broader dark borders. Basal areas are tinted with iridescent blue on both wings. Hind wings have a black tornal spot and a short tiny tail. Ventrally, both are brownish. Tornal spots of hind wings are orange-crowned. Males are more often seen on damp patches than on flowers. Females fly low among grasses. This butterfly prefers moist wooded areas. It is distributed in Nepal, Bhutan, Bangladesh, Pakistan, Myanmar, India including Andaman and Nicobar Islands, Sri Lanka, Malaysia, Singapore, Philippines and Thailand. This butterfly is available in different forest areas of Chittagong division including Sitakunda, Fashiakhali and other forest areas of Sylhet and Dhaka division in Bangladesh. It is sometimes found in urban areas. **Length of Antenna:** 6-7 mm; **Wing-Spread:** 26-30 mm; **Forewing:** 12-14 mm; **Hind wing:** 10-12 mm.

***Catochrysops strabo* (Fabricius, 1793) (**Forget-me-not/শঠ আরুণি**)**

a **b** **c**

Plate 15. Pictorial view of *Catochrysops strabo*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

In dorsal side, male is purplish-blue. Female is brownish-blue, forewings have very broad dark borders and tinted with iridescent blue at bases. Hind wings have a black tornal spot in space 2. Both male and female are pale brown ventrally with slightly darker markings. Forewing costal spot placed midway between the spot at cell-end and the post-discal band. Hind wings have two prominent black costal spots in space 7 and have black tornal spot with orange cap. It has fast flight, flying busily across open grounds and gardens to visit flowers and wet patches. This species is a great basker, especially during early hours of the morning. This butterfly prefers open dry habitats of scrub and dry deciduous forests. It is common along roadside and degraded areas. This butterfly is distributed in Bangladesh, India, Pakistan, Sri Lanka, Nepal, Bhutan, Singapore, Malaysia, Thailand and Philippines. This is abundant in Karerhat, Eidgaon, Chunati, Mirsarai forests of Chittagong division; Habigonj forest of Sylhet division; Bhawal forests of Dhaka division and Dhaka University area in Bangladesh. **Length of Antenna:** 7-8 mm; **Wing-Spread:** 22-28 mm; **Forewing:** 14-16 mm; **Hind wing:** 10-12 mm.

***Tarucus callinara* Butler, 1886 (**Spotted Pierrot/তিলুইপ্রভা**)**

a **b** **c**

Plate 16. Pictorial view of *Tarucus callinara*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Male is violet blue dorsally with a conspicuous black spot at the cell end of the forewing, cilia of both wings dull sullied white with a brownish-black band along their bases. In ventral side, pale yellowish-white with dark spots and streaks on both wings, including a streak from base to mid-costa, post-discal band of linked spots and sub marginal spots along the borders. Female is slightly paler, but borders darker with clearer markings and with iridescent blue at basal half of both wings at dorsal side. It flies fast but tends to settle quite often, preferring tips of twigs as its perch. It flies low over grasses and shrubs. This butterfly prefers wet and open forest areas. It is distributed in Bangladesh, India,

Pakistan, Sri Lanka, Nepal and Thailand. This butterfly is found in Bhawal forest of Dhaka division and Dhaka University area in Bangladesh. **Length of Antenna:** 6-7 mm; **Wing-Spread:** 20-22 mm; **Forewing:** 12-14 mm; **Hind wing:** 10-12 mm.

***Castalius rosimon* (Fabricius, 1775) (**Common Pierrot/তৃণ বিদূষক**)**

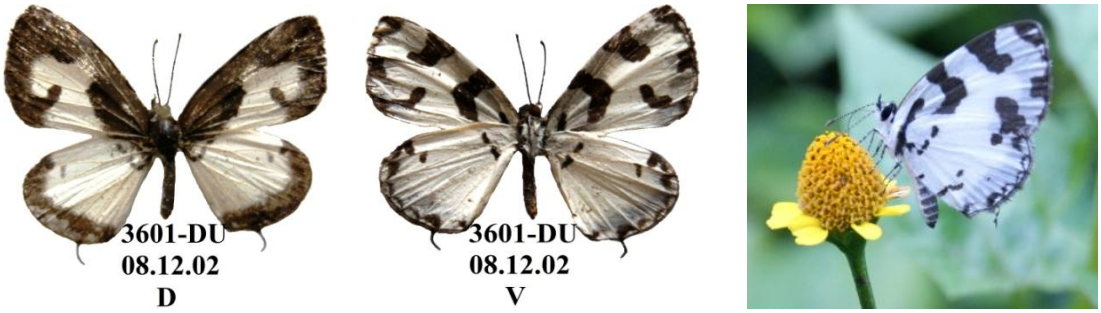
a **b** **c**

Plate 17. Pictorial view of *Castalius rosimon*: **a**. dorsal view; **b**. ventral view; and **c**. active form

Information Cell

Dorsally, both are ground colour in white with brownish black margins and black spots. The bases of wings broadly blue. There are large brown spots in the fore wing and irregular post-discal spots some of which touching the margins. Hind wings have sub-marginal series of lunules on the broad black border. Ventrally, they are white with black spots on both wings. Some streaks on the discal region of forewing and a series of blue spots on the margins of the hind wing. Female is similar to male but in female dorsal side basal area of wing is darker brown with some blue scales and all spots are larger. It has fluttering flight, flies close to the ground. This butterfly takes nectar from flowers frequently with a choice of wide range of plants with small flowers. When settled once, it moves about a great deal in a slow deliberate manner. This species visits dead insects and bird droppings. It is fond of sunshine and mud puddles. This is a common butterfly, seen in open country as well as in forested areas. It is more common during the rains. This butterfly is available in Bangladesh, Nepal, Bhutan, India, Pakistan, Sri Lanka, Myanmar, Malaysia, Singapore, Philippines and Thailand. This butterfly is found almost everywhere. It is abundant in Fashiakhali, Chunati, Karerhat, Eidgaon, Sitakunda, Mirsarai forest of Chittagong division; Laowachara, Satchari forests of Sylhet division; Madhupur, Bhawal forests of Dhaka division and Dhaka University area in Bangladesh. **Length of Antenna:** 6-7 mm; **Wing-Spread:** 26-32 mm; **Forewing:** 14-16 mm; **Hind wing:** 10-12 mm.

***Caleta decidia* (Hewitson, 1876) (**Angled Pierrot/জলমাদল**)**



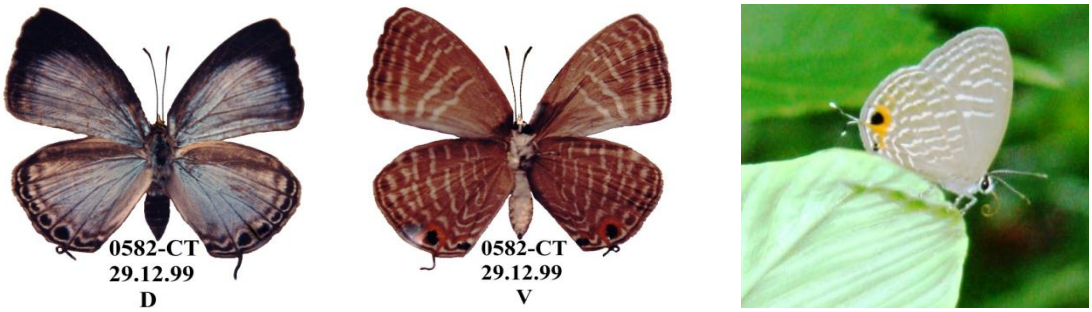
a **b** **c**

Plate 18. Pictorial view of *Caleta decidia*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Dorsally, both sexes are dark brown to black with narrowest black boarders. A black sub-marginal and post discal black spot present. Ventrally, forewings are white with a basal streak joining a sub apical streak at mid Costa, but the basal streak evenly curved but not right angled at Cu_1. Hind wings have no black spot in inter space 4. It has low fluttering weak flight. It tends to fly closer to ground and settles frequently on damp patches, flowers and bird droppings as well as other wild animal's dung and droppings. This butterfly prefers open evergreen forest to mixed deciduous forested region with heavy to moderate rainfall. This butterfly is distributed in Bangladesh, Nepal, Bhutan, Myanmar, India, Sri Lanka, Philippines and Thailand. It is found in different forest areas of Dhaka division and Dhaka university area in Bangladesh. **Length of Antenna:** 6 mm; **Wing-Spread:** 26 mm; **Forewing:** 14 mm; **Hind wing:** 10 mm.

***Jamides alecto* (C. Felder, 1860) (**Metallic Cerulean/জলদ আকাশী**)**



a **b** **c**

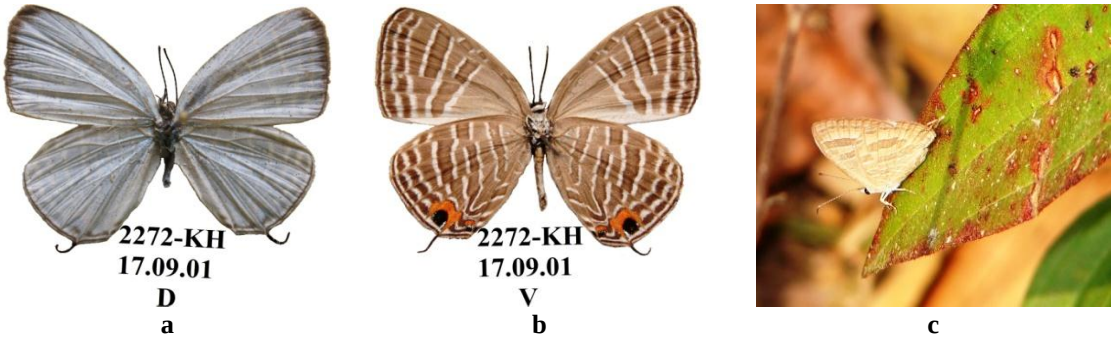
Plate 19. Pictorial view of *Jamides alecto*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Dorsally, both are purplish-blue, male has a narrow diffused black border on forewing. Hind wings have sub-marginal markings. Female has a broad black border, extending along with the costal margin to the base of fore wing. Hind wing's sub-marginal markings

are broad and dark. In dry season form, wing colour is white. In ventral side both are gray to brown with distinct markings. Forewings have no costal spots. It has weak fluttering flight, flies low along the forest clearings. This butterfly prefers hill forests, especially with plantation of its food plants. This species is available in Bangladesh, Nepal, Bhutan, India, Sri Lanka, Myanmar, Thailand, Philippines and Singapore. This butterfly is found in Tonkabati and Chunati forests of Chittagong division as well as Laowachara and Satchori forests of Sylhet division in Bangladesh. **Length of Antenna:** 8-9 mm; **Wing-Spread:** 30-34 mm; **Forewing:** 16-18 mm; **Hind wing:** 12-14 mm.

***Jamides celeno* (Cramer, 1775) (**Common Cerulean/আনত আকাশী**)**



a **b** **c**

Plate 20. Pictorial view of *Jamides celeno*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Both sexes are bluish-white dorsally, male forewing has black border narrow at termen and expending towards apex. Hind wings are without sub-marginal spot. Female forewing border is broader up to 5mm. Hind wings have light sub-marginal markings. In ventral side, forewing post discal band continuous from vein Cu_1 to R_5. Hind wings have a pair of sub basal white lines. In the dry season forms, darker markings are forming continuous bands. It has weak fluttering low flight, flies around the bushes and stays near the ground. Females fly higher after egg-laying. Males visit damp patches. This butterfly comes to flowers for taking nectar. It also loves to settle on the tips of leaves of bushes or tress at some height and bask in the sun with its wings slightly opened and prefers partial shade to full sun. This butterfly prefers wooded habitats, both in hills and in the plains. It is distributed in Bangladesh, India, Pakistan, Afghanistan, Sri Lanka, Nepal, Bhutan, Myanmar, Singapore, Malaysia, Philippines and Thailand. This butterfly is found in Fashiakhali, Karerhat forests of Chittagong division; Laowachara, Rama-Kalenga, Anarashbari forests of Sylhet division; Bhawal forest of Dhaka division and Dhaka

University area in Bangladesh. **Length of Antenna:** 7-9 mm; **Wing-Spread:** 24-34 mm; **Forewing:** 14-18 mm; **Hind wing:** 10-14 mm.

***Lampides boeticus* (Linnaeus, 1767) (**Pea Blue/ইন্দ্রশিশির**)**

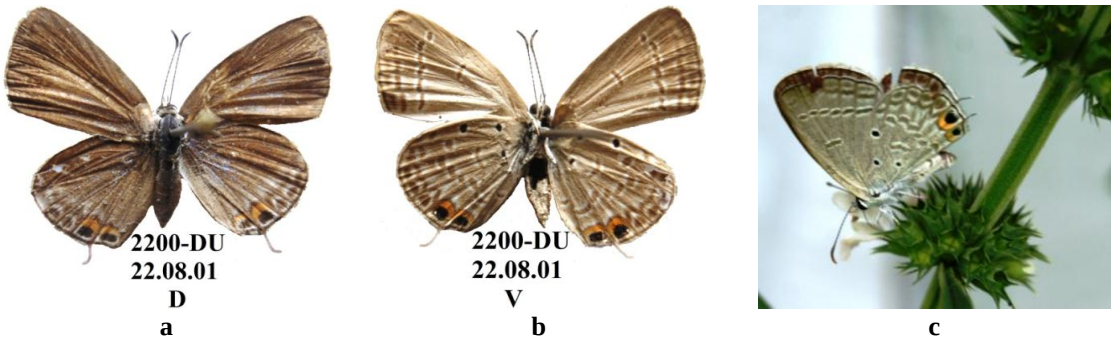
a **b** **c**

Plate 21. Pictorial view of *Lampides boeticus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

In dorsal side, male is dull purple blue with black tornal spots on the hind wing. Female is brown, wing bases tinted with iridescent pale blue, hind wing with greyish-white inter-nervular streaks in almost all spaces. Ventrally, both are pale brown with dark brown markings. Two tornal metallic orange-crowned spots present in spaces 1c and 2 of hind wing. It has strong flight, flies close to ground. This butterfly is very active but are also seen basking in the mornings with its wings partially opened. It visits a variety of flowers. The males frequently settle on damp soil to pick up essential salts and minerals. It is a migratory species. This species is common in agricultural and cultivated areas as well as hilly areas. This butterfly is available in Bangladesh, India, Pakistan, Afghanistan, Sri Lanka, Nepal, Bhutan, Myanmar, Thailand, Malaysia, Philippines and Singapore. It is found in Bhawal forest of Dhaka division and Dhaka University area in Bangladesh. **Length of Antenna:** 6 mm; **Wing-Spread:** 24-28 mm; **Forewing:** 16 mm; **Hind wing:** 12 mm.

***Euchrysops cnejus* (Fabricius, 1798) (**Gram Blue/আকাশদূত**)**



a **b** **c**

Plate 22. Pictorial view of *Euchrysops cnejus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Male is purplish-blue with narrow black borders dorsally. Hind wings have white-ringed, narrowly orange-crowned tornal spots in spaces 2A and Cu_2. Female is dark brown tinted with iridescent blue at basal half, except broad costal margins of both wings. Hind wings have broadly orange-crowned two tornal spots. Ventrally, both are pale yellowish-brown. Hind wings have two tornal spots edged with metallic green. It has strong flight around bushes and fond of flowers. It visits wet patches for mud puddling. This butterfly prefers open drier regions and more commonly seen around cultivation. It is distributed in Bangladesh, India, Sri Lanka, Pakistan, Nepal, Bhutan, Myanmar, Malaysia, Singapore, Philippines and Thailand. This butterfly is found in Mirsarai and other forest areas of Chittagong division, forest areas of Dhaka division and also found in urban areas and cultivation land in Bangladesh. **Length of Antenna:** 6-7 mm; **Wing-Spread:** 24-34 mm; **Forewing:** 14-16 mm; **Hind wing:** 10-12 mm.

***Anthene emolus* (Godart, 1824) (**Common Ciliate Blue/আকষি তুঁতী**)**

a **b** **c**

Plate 23. Pictorial view of *Anthene emolus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

In dorsal side, male is dark purple blue with traces of black borders. Female is brown, paler at discal areas and tinted with iridescent blue at bases. Hind wings have dark marginal spots. Ventrally, both are pale brown. Hind wings have a large sub basal spot near space 7 and slightly darker than background, a tornal spot with an orange crown in space 2. This species is not a strong flier, keeps to bushes and small tress near forest streams. It comes to damp patches for mud puddling. This butterfly prefers evergreen forests at low elevations. This butterfly is found in Bangladesh, Myanmar, India, Nepal, Bhutan, Thailand, Singapore, Philippines and Malaysia. This butterfly is available in Cox's Bazar, Fashiakhali, Karerhat, Chunati forests of Chittagong division; Laowachara

forests of Sylhet division in Bangladesh. **Length of Antenna:** 8-9 mm; **Wing-Spread:** 24-34 mm; **Forewing:** 14-16 mm; **Hind wing:** 10-12 mm.

***Arhopala pseudocentaurus* (Doubleday, 1847) (**Common Oakblue/পাবনী রেণু**)**

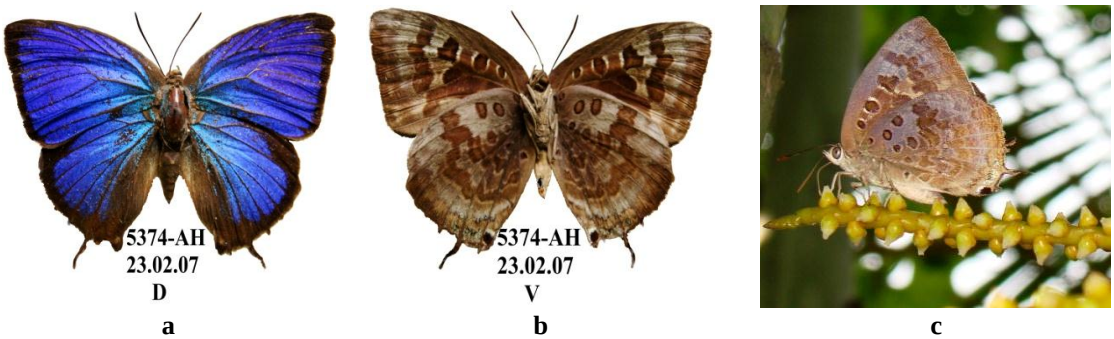
a **b** **c**

Plate 24. Pictorial view of *Arhopala pseudocentaurus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Male is violet blue with narrow border in dorsally and female is more purple with broader border; in ventral side both sexes are pale brown and paler on forewing dorsum. Forewing has three cell spots which are edged by silver scales, a costal spot present in space 10 and post-discal band is continuous to vein Cu_2; discal cell of forewing is shorter than half length of the wing. It has rapid dodging flight, remains among foliage most of the time perched on broad leaves and making occasional brief sorties. This butterfly visits flowers and comes to damp patches occasionally. It prefers moist forests. This species is distributed in Bangladesh, Myanmar, India, Sri Lanka, Pakistan, Nepal, Bhutan, Philippines, Singapore and Thailand. This butterfly is found in Cox's Bazar, Fashiakhali, Eidgaon, Karerhat and Chunati forests of Chittagong division; Laowachara, Anarashbari forests of Sylhet division; Madhupur, Bhawal forests of Dhaka division in Bangladesh. **Length of Antenna:** 10-12 mm; **Wing-Spread:** 42-60 mm; **Forewing:** 24-30 mm; **Hind wing:** 18-24 mm.

***Arhopala amantes* Hewitson, 1862 (**Large Oakblue/ময়ূরী রেণু**)**



a **b** **c**

Plate 25. Pictorial view of *Arhopala amantes*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

In dorsal side, male is shining blue with broad borders and female is lighter with more broad borders. Ventrally both are pale brown with whitish washed; forewing cell spots have white or silvery edge, no costal spot in space 10, and post-discal spot in space 4 out of line with those below and above it. It is very wary, flies extremely fast and usually remains among foliage. This butterfly flies about a great deal during the day but often with long periods of resting in between flights. To rest, it usually selects a leaf exposed to full sun at a considerable height above ground. It is commonly seen at damp patches, and occasionally on exuding tree sap. This prefers forested regions. It is a butterfly of the canopy of small trees, occasionally coming down to settle on shrubs and low bushes. This butterfly is found in Bangladesh, Nepal, Bhutan, Sri Lanka, India, Myanmar and Thailand. It is available in Fashiakhali, Eidgaon, Karerhat forests in Chittagong division; Laowachara forest in Sylhet division; Bhawal forest of Dhaka division in Bangladesh. **Length of Antenna:** 10-12 mm; **Wing-Spread:** 36-58 mm; **Forewing:** 22-28 mm; **Hind wing:** 18-24 mm.

***Loxura atymnus* (Stoll, 1780) (**Yamfly/হল্‌দে সাম্রী**)**

a **b** **c**

Plate 26. Pictorial view of *Loxura atymnus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Both wings are fulvous dorsally, the intensity of the tint varying in different individuals; forewings have apical and terminal blackish-brown border; female tornal area of hind wing is dark-dusted than male. In ventral side, both wings are covered with a yellow ochraceous pulverulent tint which is uniformly diffused over the whole surface; forewing with an obscure series banded discal spots partially dislocated at vein M_2. It has a gentle fluttering flight and is considered as a graceful butterfly which settles frequently. This butterfly mostly avoids open spaces. It prefers high rainfall and dense vegetated forested areas in lower elevations. This butterfly distributed in Bangladesh, India, Nepal, Bhutan,

Myanmar, Thailand, Philippines, Singapore and Malaysia. This butterfly is abundant in Karerhat, Chunati, Eidgaon, Fashiakhali, Mirsarai forests of Chittagong division; Madhupur and Bhawal forests of Dhaka division in Bangladesh. **Length of Antenna:** 6-8 mm; **Wing-Spread:** 20-38 mm; **Forewing:** 14-20 mm; **Hind wing:** 10-16 mm.

***Rapala manea* (Hewitson, 1863) (**Slate Flash/বেগুনী বউল**)**

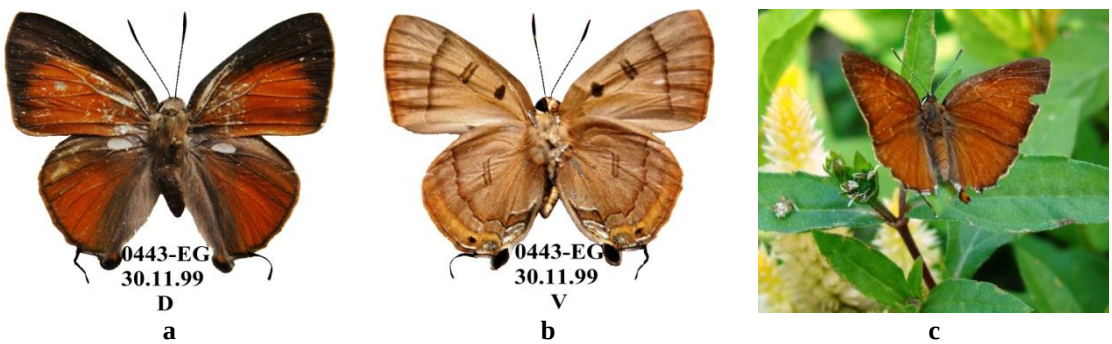
a **b** **c**

Plate 27. Pictorial view of *Rapala manea*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

In dorsal side, male is shining slate-blue with the basal and border regions of the forewing as well as the hind wing is dark blue; female is blue confined to the upper part of the forewing where the rest of the forewing and the hind wing is dusty purple. Ventrally, male is pale slate-brown sometimes with a purple wash, female is pale brown, hind wings have narrow post discal band, tornal lobe is black. It has rapid flight, comes to flowers and damp patches. This butterfly is often seen often resting on the undersides of leaves. It prefers both hilly forests and plains. It is distributed in Bangladesh, Myanmar, Nepal, Bhutan, India, Pakistan, Sri Lanka, Philippines, Singapore and Thailand. This butterfly is found in Laowachara forest of Sylhet division; Madhupur and Bhawal forests of Dhaka division in Bangladesh. **Length of Antenna:** 8-10 mm; **Wing-Spread:** 28-34 mm; **Forewing:** 14-18 mm; **Hind wing:** 10-14 mm.

***Rapala pheretima* (Hewitson, 1863) (**Copper Flash/ভাটুরে বউল**)**



a **b** **c**

Plate 28. Pictorial view of *Rapala pheretima*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Male is reddish brown dorsally, forewing has a dark brown costal border above the cell, broader at apex, extending narrowly to tornus; female is shining steely blue with dark diffused borders. In ventral side, male is pale reddish-brown, cell-end bar edged with brown, post-discal line is brown, outwardly white-edged and a central cell spot present; female is yellowish-brown with a sub marginal band. It is a strong flier, flies to visit flowers. This butterfly prefers plains to lower elevation of hilly forests. This butterfly is found in Bangladesh, India, Nepal, Bhutan, Myanmar, Thailand and Singapore. It is available in Fashiakhali, Eidgaon forests of Chittagong division; Bhawal forest of Dhaka division in Bangladesh. **Length of Antenna:** 8-10 mm; **Wing-Spread:** 36-42 mm; **Forewing:** 18-20 mm; **Hind wing:** 14-16 mm.

***Rapala iarbus* (Fabricius, 1787) (**Common Red Flash/শিখা বউল**)**

a **b** **c**

Plate 29. Pictorial view of *Rapala iarbus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Dorsally, male is scarlet red, forewing has a narrow border at Costa, reaching the upper edge of the cell, narrowly at termen and not continue along dorsum, hind wings are all red except in space 7, tornal lobe is prominent orange; female is uniform coppery brown, forewing is slightly convex below apex. In ventral side, both are pale brownish-grey, double white-edged bar present at the end of cell, forewing post-discal line is outwardly white-edged, slightly curved inwards at upper end, hind wing tornal lobe has large black spot. It has rapid and strong flight, flies to shrubs and bushes as well as visits flowers. This butterfly prefers plains than hilly forests. This species is abundant in Bangladesh, India, Pakistan, Sri Lanka, Nepal, Bhutan, Myanmar, Thailand and Singapore. This butterfly is found in Madhupur and Bhawal forests of Dhaka division in Bangladesh. **Length of Antenna:** 8-10 mm; **Wing-Spread:** 34-40 mm; **Forewing:** 14-18 mm; **Hind wing:** 10-14 mm.

***Spindasis syama* (Horsfield, 1829) (**Club Silverline/কিন্নর রূপডোর**)**

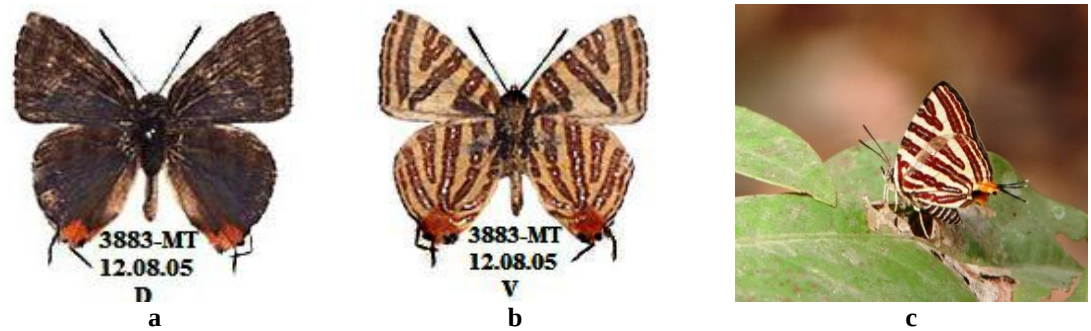
a **b** **c**

Plate 30. Pictorial view of *Spindasis syama*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Male is brown in dorsal side and tinted with iridescent purplish-blue on both wings; female is brown without a blue tinge. Both are pale yellowish-brown ventrally with brownish-orange markings, forewing cell has a club-like streak rising from the base, hind wing sub basal band is broken into spots. It is a swift flier, flies in sunshine and prefers forested areas. This species is distributed in Bangladesh Nepal, Bhutan, India, Myanmar, Thailand and Singapore. It is availble in Mirsarai, Eidgaon, Fashiakhali, Chunati forests of Chittagong division; Bhawal forest of Dhaka division in Bangladesh. **Length of Antenna:** 6-8 mm; **Wing-Spread:** 24-30 mm; **Forewing:** 14-18 mm; **Hind wing:** 10-14 mm.

***Spindasis lohita* (Horsfield, 1829) (**Long-banded Silverline/লোহিত রূপডোর**)**



a **b** **c**

Plate 31. Pictorial view of *Spindasis lohita*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Dorsally they are similar to *Spindasis syama* but tornal orange area of hind wing is smaller and not extending inwardly along the space 2A. In ventral side, wing markings are darker, on the forewing the streak below the cell is joined by a bar across the cell, the two sub apical bars meet to form a v-shaped marking; on the hind wing, the sub basal band extends along vein 2A to touch the discal band and its end. It is swift flier, flies in sunshine. This butterfly is often seen perched among shrubs. It prefers forests with heavy

rainfall. This species is abundant in Bangladesh, India, Sri Lanka, Nepal, Bhutan, Myanmar, Singapore and Thailand. It is found in Madhupur and Bhawal forests of Dhaka division in Bangladesh. **Length of Antenna:** 8 mm; **Wing-Spread:** 36 mm; **Forewing:** 18 mm; **Hind wing:** 14 mm.

***Remelana jangala* (Horsfield, 1829) (**Chocolate Royal/নীল খয়ের**)**

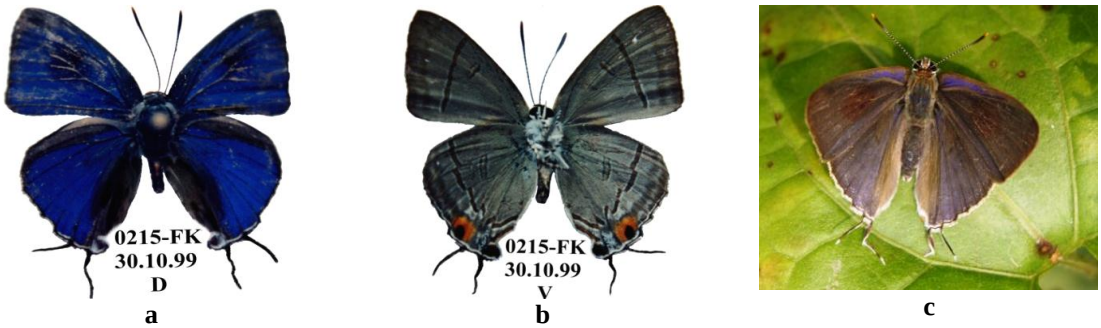
a **b** **c**

Plate 32. Pictorial view of *Remelana jangala*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Male is brown to brownish-black in dorsal side with a bright purple-blue patch in the forewing cell and lower portion of cell, hind wing patch is confined to basal two-thirds in anal space; female is paler brownish-black, the patches on both wings are bluer. Ventrally, both are dark brown to dark reddish-brown with a prominent dark post-discal line and conspicuous end-cell bars on both wings; hind wing tornal metallic green scales are distinct. It is swift flier, flies at lower elevations. This butterfly visits flowers and comes to damp patches in hot weather. It prefers forested areas. It is distributed in Bangladesh, India, Nepal, Bhutan, Myanmar, Thailand, Malaysia, Singapore and Philippines. This butterfly is available in Laowachara forest of Sylhet division and Bhawal forest of Dhaka division in Bangladesh. **Length of Antenna:** 8-10 mm; **Wing-Spread:** 34-42 mm; **Forewing:** 18-20 mm; **Hind wing:** 14-16 mm.

***Hypolycaena erylus* (Godart, 1824) (**Common Tit/ঘনশ্যাম**)**



a **b** **c**

Plate 33. Pictorial view of *Hypolycaena erylus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Dorsally, male is deep purple with a prominent darker rounded brand at end of cell in forewing, female is dull brown, both sexes have orange tornal area bearing black spots on the hind wing. In ventral side, they are grey with a yellow-brown post-discal band, double bars end cells of both wings, hind wing has black tornal orange-crowned spot in space 2. It is active flier, visits flowers and comes to damp patches. This butterfly prefers forested areas at lower elevation. This butterfly is found in Bangladesh, Myanmar, Nepal, Bhutan, India, Singapore, Malaysia, Philippines and Thailand. It is abundant in Fashiakhali, Karerhat, Chunati, Sitakunda and Tonkabati forests of Chittagong division; Laowachara, Habigonj and Anarashbari forests of Sylhet division; Madhupur and Bhawal forests of Dhaka division in Bangladesh. **Length of Antenna:** 7-8 mm; **Wing-Spread:** 26-38 mm; **Forewing:** 14-18 mm; **Hind wing:** 12-16 mm.

***Rathinda amor* (Fabricius, 1775) (**Monkey puzzle**)**

a **b** **c**

Plate 34. Pictorial view of *Rathinda amor*: **a**. dorsal view; **b**. active ventral view; and **c**. active in basking.

Information Cell

Dorsally, male is brownish-black with a violet-tint with forewing having a white spot (sometimes slightly ochreous) beyond the end of the cell, with two smaller spots in an outwardly oblique row from it. Hind wing with two black lunular spots between the tails and indications of a third black spot in the next upper interspace, all three capped with orange, with a fine blue thread on their outer sides; three tails black, tipped with white. Ventral side is white to dark yellowish brown with the forewings bearing irregular dark basal markings, curved white discal line and a broad, rich brown apical patch. The underside hind wings are marked with irregular dark spots and lines and a silver marginal line. Female is like the male both dorsally and ventrally except the white spots on the fore wing in dorsal side. The monkey puzzle is a weak flier, prefers the undergrowth but can be seen along forest paths and clearings. It keeps low to the ground and generally does

not stay airborne for long. When it lands, it tends to turn around, sidestep, and waggle its tail filaments. This may serve to confuse predators as to which end is the butterfly's head. It thrives in jungles of moderate to heavy rainfall. This butterfly is endemic to south Asia specifically India's Western Ghats, the southern Indian plains, Bangladesh and Sri Lanka. It is found in Madhupur and Bhawal forests of Dhaka division as well as plain land areas in Bangladesh. **Length of Antenna:** 8-10 mm; **Wing-Spread:** 24-28 mm; **Forewing:** 14-16 mm; **Hind wing:** 10-12 mm.

Tajuria cippus **(**Peacock royal/ময়ূরীপর্ণা**)**

a **b** **c**

Plate 35. Pictorial view of *Tajuria cippus*: **a**. dorsal view; **b**. ventral view; and **c**. active form.

Information Cell

Male is dark cyaneous-blue, shining blue-green in certain lights with a broad, black border on both wings, whilst the female is in light pale blue and has a post-discal and a marginal series of black spots on its hind wing. Ventrally, both sexes are greyish white. Both wings have a post-discal series of black, disjoint striae, and diffuse/obscure marginal and submarginal fasciae. The hind wing has two large, black tornal spots in spaces 1a and 2 which are orange-crowned; white-tipped tails at end of veins 1b and 2, and a short tooth at end of vein 3. This butterfly can be found in urban parks and gardens, forested areas, as well as the nature reserves. They have a rapid flight and are typically skittish when approached. It is distributed in Bangladesh, India, Nepal, Bhutan, Myanmar, Thailand, Malaysia, Singapore and Philippines. This butterfly is available in Laowachara forest of Sylhet division; Madhupur and Bhawal forest of Dhaka division in Bangladesh. **Length of Antenna:** 8-10 mm; **Wing-Spread:** 30-32 mm; **Forewing:** 16-18 mm; **Hind wing:** 12-14 mm.

3.3.1.2 EBBL model for assessing 'vulnerability status' of lycaenid butterflies

Bashar (2015) examined 202 butterfly species of seven major families (viz. Hesperiidae, Papilionidae, Danaidae, Pieridae, Nymphalidae, Satyridae and Lycaenidae) in the

experimental stations (forests), and listed with their status in Bangladesh context. Among the total 202 examined butterfly species from the seven mentioned families the family Lycaenidae was occupied top position in the volume of species number. Earlier, Akand (2012) and Bashar (2014) identified 45 species of family Lycaenidae in Bangladesh.

Table 4. 'Vulnerability status' of the lycaenid butterflies in Bangladesh context.

Total species examined	Available (Av)	Rare (Rr)	Near Threatened (Nt)	Threatened (Tr)	Critically Threatened (Ct)	Endangered (En)	Reference
45 (22.27%)	15(33.33%)	12(26.66%)	3(6.66%)	9(2%)	6(13.33%)	0	Bashar 2015
25 (55.56%)	15(60%)	7(28%)	1(4%)	2(8%)	0	0	Present study

Bashar (2017) has revealed that the family Lycaenidae contained 22.27% species of the total species recorded in the relative frequency analysis. In this case 33.33% and 26.66% species hold the status 'Available' and 'Rare', respectively. Species was recorded 6.66%, 2% and 13.33% as 'Near Threatened', 'Threatened' and 'Critically Threatened', respectively. No butterfly was found as 'Endangered' belonging to the family Lycaenidae. Within 25 lycaenid species in present study, 15(60%) species hold the status 'Available' and 7(28%) was 'Rare', respectively. Only 1(4%) species is found as 'Near Threatened' while 2(8%) species was recorded as 'Threatened'. No species was found as 'Critically Threatened' or 'Endangered' in the present investigation (Table 4).

3.3.2 Activity-related plants of lycaenid butterflies

Three types of plants (viz. host plants, nectar plants and shelter/shade plants) are pre-requisite for healthy diversity of butterflies (Bashar 2014). Larval host plants are the plants on which larval development of butterflies takes place. Nectar plants are those on which adult butterflies depend on nutrition for their growth and development. These are flowering plants capable to produce nectar. Shelter/shades plants are those on which butterflies take rest on a particular time. The assemblage of three types of plants is needed absolutely without interference of human beings. Distribution and abundance of these plants are closely associated with the butterflies (Kitahara *et al.* 2008, Van Halder *et al.* 2008). All these plants are the vegetation of soil surface layer, undergrowth layer and the canopy layer in the forest(s), especially in the tropical rain forests. Bashar (2014) examined that as butterflies have equal access to the plants of all the three layers of vegetation, they are very much actively related with gene-flow and diversification of plant populations in the forest.

Table 5. Observed plant species which were supporting behavioural activities of lycaenid butterflies.

Family	Scientific name	Plant type	Supporting lycaenid behaviours			
			El	F	B	R
Cycadidae	*Cycas pectinata*	Palm-like tree	+	-	+	+
Acanthaceae	*Nelsonia canescens*	Herb	-	+	-	-
Amaranthaceae	*Gomphrena globosa*	Herb	-	+	-	-
	Celosia cristata	Herb	-	+	-	-
	Celosia argentea	Herb	-	+	-	-
Apocynaceae	*Catharanthus roseus*	Shrub	-	+	-	+
Asclepiadaceae	*Asclepias curassavica*	Herb	-	+	-	-
Asteraceae	*Chromolaena odorata*	Under shrub	-	+	+	+
	Mikania cordata	Herb	-	+	+	+
	Spilanthes calva	Herb	-	+	+	-
	Wedelia chinensis	Herb	-	+	+	+
	Wedelia trilobata	Herb	-	+	+	+
	Ageratum conyzoides	Herb	-	+	-	-
	Cosmos bipinnatus	Herb	-	+	+	-
	Helianthus debilis	Herb	-	+	+	-
	Vernonia cinerea	Herb	-	+	+	-
Caesalpiniaceae	*Senna obtusifolia*	Tree	-	+	+	+
	Senna tora	Under shrub	-	-	+	+
Dipterocarpaceae	*Shorea robusta*	Herb	-	+	+	+
Fabaceae	*Cajanus cajan*	Low Shrub	+	+	+	+
	Lupinus polyphyllus	Shrub	+	+	+	+
	Vigna unguiculata	Herb	+	+	+	+
Lamiaceae	*Leonurus sibiricus*	Herb	-	+	-	-
	Leucas aspera	Herb	-	+	-	-
	Ocimum tenuiflorum	Herb	-	+	-	-
Leeaceae	*Leea macrophylla*	Herb	-	+	-	+
Malvaceae	*Urena lobata*	Herb	-	+	+	-
	Hibiscus rosa-sinensis	Shrub	-	-	+	+
Melastomataceae	*Melastoma malabathricum*	Shrub	-	-	+	+
Myrtaceae	*Callistemon citrinus*	Small tree	-	+	-	+
	Syzygium fruticosum	Large Shrub	-	-	+	+
Oxalidaceae	*Oxalis corniculata*	Herb	+	+	+	+
	Oxalis corymbosa	Herb	-	+	+	+
Plumbaginaceae	*Plumbago zeylanica*	Herb	-	+	-	-
Rhamnaceae	*Ziziphus mauritiana*	Tree	+	+	+	+
	Zizyphus oenoplea	Shrub	+	-	+	+
Rubiaceae	*Ixora coccinea*	Shrub	+	+	+	+
	Pentas lanceolata	Herb/ Under shrub	-	+	+	+
	Mussaenda frondosa	Shrub	-	+	+	+
Rutaceae	*Glycosmis pentaphylla*	Shrub/ small tree	-	+	+	+
	Citrus aurantifolia	Tree	+	+	+	+
	Micromelum minutum	Tree	-	+	+	+
Sapotaceae	*Madhuka longifolia*	Tree	-	+	-	+
Verbenaceae	*Lantana camara*	Shrub	-	+	-	+
	Duranta repens	Shrub	-	-	+	+
Araceae	*Colocasia esculenta*	Herb	-	-	+	+
Arecaceae	*Chrysalidocarpus lutescens*	Palm	-	+	-	+
Poaceae	*Paspalum scrobiculatum*	Grass/ Herb	-	-	+	+
	Axonopus compressus	Grass/ Herb	-	-	+	+
	Setaria palmifolia	Grass/ Herb	-	-	+	+
	Imperata cylindrica	Grass/ Herb	-	-	+	+
	Punica hybrida	Herb	-	+	+	+
Zingiberaceae	*Curcuma aromatica*	Herb	-	-	+	+

Note: **El** = Egg laying, **F** = Foraging, **B** = Basking and **R**= Resting.

Lycaenid butterflies perform behavioural activities in association with enormous numbers of plants. Some specific plants are utilized as egg laying support where larva takes nutrition for development and inactive pupa remain attached and camouflage on leaves or other plant parts. Selective plants are exploited by the adults to collect flower nectar as their primary food sources. Some trees and hedges are used for resting and sometimes for basking. In the present investigations 53 plant species representing 25 plant families were examined in different experimental study sites. Among them family Asteraceae and Poaceae comprise nine and five plant species, respectively. Family Amaranthaceae, Lamiaceae, Fabaceae, Rubiaceae and Rutaceae contain three plant species each. The rest of the families have single or two plant species (Table 5).

The recorded 53 plant species serving as activity-related plants of lycaenid butterflies in the study sites. Among the plant species 24 species were found as wild species whereas 21 species were recorded as cultivated species. The remaining 8 species were either cultivated or found in wild form. It has also been observed that out of 53 examined plant species 41 species belong to perennials, and remaining 12 species are annual category of plant species.

3.3.2.1 Description of activity-related plants

As mention earlier, a total 53 plant species was recorded supporting the lycanid butterflies to perform their behaviours in the experimental sites. The examined plant species are described with physical features, habit and habitat, distribution and economic values following Dey (1995), Ahmed *et al*. (2009) and Yusuf *et al*. (2009).

***Cycas pectinata* (Nepal Cycas/ মনিরাজ) (Table 6, page no. 137)**

Information cell - This plant is an evergreen, palm-like tree, up to 3 m tall, often forked, glabrous throughout. Leaves are long, recurved, petioles about 46 cm long with a few small distant spines, leaflets up to 25 cm long, linear, ending in minute spines. Megasporophylls densely tawny, silky, blade almost orbicular, margins deeply pectinate with spinous subulate teeth, stalk about equal in length to blade. Seeds are ovoid to globose, glabrous, orange-red or yellow. Male cone is cylindric-ovoid. Flowering and fruiting: November- January. This plant is propagated by seeds. It is exposed slopes of hill, up to an altitude of 700 m. This plant is distributed in eastern India, Myanmar and Nepal. In Bangladesh, it is confined to a few hills near Baraiyadhala in Chittagong and

also seen in the Sal forests of northern Mymensing albeit rarely. The leaves of this plant are used for making bouquets. The megasporophylls are sold in the market as the seeds are thought to be aphrodisiac.

***Gomphrena globosa* (Globe amaranth/বোতামফুল) (Table 6, page no. 137)**

Information cell - *Gomphrena globosa* is an erect or ascending annual herb, up to 50 cm tall, branched from the base and also above, striate or sulcate, with usually thickened nodes. Leaves are elliptic, obovate-oblong or broadly lanceolate, base attenuate, tip acute, dorsal side stellate but midvein woolly, ventral side hirsute, shortly pinkish petioled. Inflorescence is sessile above the uppermost pair of leaves, usually solitary, large globose head, purple, 1-2 cm in diameter. Fruit is a capsule, oblong-ovoid, compressed. Seeds are compressed-ovoid, brown, shining, almost smooth. Flowering and fruiting: June-October. This plant is found in gardens and homesteads. It is a native of tropical America but cultivated in the warmer regions of the world. In Bangladesh, it is cultivated as an ornamental plant.

***Celosia cristata* (Crested Cock's comb/লাল মোরগফুল) (Table 6, page no. 137)**

Information cell - *Celosia cristata* is an erect, much branched, annual herb or sub-shrub, 45-92 cm tall, stem slender, glabrous, striped, and sometimes slightly woody. Leaves are linear to ovate, base attenuate, tapering into a short petiole or sessile, acute or acuminate. Inflorescence is variously branched, cock-comb like terminal and axillary spikes, and long. Flowers are red or yellow, and glistening. Fruit is a circum scissile capsule, thin, ovoid to almost globular. Seeds are few, sub-reniform, compressed, black, shining, and finely reticulate. Flowering and fruiting: throughout the year. This plant is found in gardens. It is distributed throughout India, tropical Asia, Africa and America. In Bangladesh, it is cultivated as a garden plant in almost all parts of the country.

***Celosia argentea* (Cock's comb/সাদা মোরগফুল) (Table 6, page no. 137)**

Information cell - *Celosia argentea* is an annual, erect, glabrous herb with simple or ascending branches, stem and branches strongly ribbed and often sulcate. Leaves are linear, linear-lanceolate or lanceolate-oblong, rarely ovate, upper and branch leaves smaller, base much tapering into a short petiole, tip obtuse or acute, entire, glabrous. Inflorescence is a white or light pink spike. Flowers are solitary, sessile, closely

imbricate, white and glistening. Fruit is a circumscissile capsule. Seeds are few, lenticular, black, and shining. Flowering and fruiting: September-January. It is found in gardens, homesteads and pots. This plant is distributed throughout India and Sri Lanka, introduced in most of the tropical countries of the world. In Bangladesh, it is grown in almost the whole country as an ornamental plant.

***Nelsonia canescens* (Not known/পরামূল) (Table 6, page no. 138)**

Information cell - *Nelsonia canescens* is a trailing or diffuse herb, stem 30-50 cm long. Leaves are elliptic-oblong or suborbicular, obtuse to rounded at the apex, entire, rounded at the base, villous, lower leaves larger, upper ones smaller, sub-sessile. Spikes are long, sub-sessile to sessile, terminal on lateral branches, glandular-villous. Capsule is long, oblong, acute, glabrous, 2-valved, tip of the valves recurved, 8-12 seeded, bearing from the base, barren upwards. Seeds are roundly ellipsoid, brown-chocolate, rugose with granular marks, attached on minute points without retinacula. Flowering and fruiting: October-February. It is found in hilly and plain lands. This plant is distributed in Southeast Asia, Australia, Africa and America. In Bangladesh, it grows throughout the country.

***Catharanthus roseus* (Rose Periwinkle/নয়নতারা) (Table 6, page no. 138)**

Information cell - *Catharanthus roseus* is a perennial sub-shrub. Leaves glabrous, eglandular petioles 0.8-1.3 cm long, with glands in the axil, lamina obovate, oblanceolate or elliptic-lanceolate, widest above the middle, cuneate at the base, apex rounded. Cymes are axillary, solitary or paired. Flowers are white or pink. Calyx is 5-lobed, eglandular within, linear subulate, pubescent. Corolla salver shaped, tube cylindrical, usually greenish, throat constricted, pubescent within, lobes overlapping to the left in buds. Stamens 5, inserted at about the middle of the tube, included. Flowering and fruiting almost throughout the year. It is cultivated in the gardens. This plant is a native of Madagascar, widely cultivated and naturalized in the tropics and subtropics of both hemspheres. In Bangladesh, it is grown in many gardens as an ornamental plant and also cultivated for medicinal use.

***Asclepias curassavica* (Blood flower/দুধআগাছা) (Table 6, page no. 138)**

Information cell - *Asclepias curassavica* is an erect perennial herb, up to 1 m tall; stem branched from the base, branches terete, slightly woody near the base. Leaves are petiole,

lamina narrowly lanceolate, tapering towards both ends, acute, thin, membranous, and glabrescent. Cymes are umbel-like with 8-10 flowers, solitary at the nodes, peduncles up to 6.5 cm long, puberulous, pedicels up to 1.5 cm long, pubescent. Corolla rotate, bright crimson, glabrous, lobes elliptic, Flowering and fruiting: almost throughout the year. It is found in river bed or sides of streams, waste lands and foot hills. It is a native of the West Indies, naturalized and growing wild in the East Asian tropics including Bangladesh, India, Malaysia, Myanmar and Thailand. This plant is found in many parts of Bangladesh.

***Chromolaena odorata* (Paraffin weed/আসামলতা) (Table 6, page no. 138)**

Information cell - *Chromolaena odorata* is an erect or straggling herb or undershrub, up to 2.1 m tall with striate branches and sparsely pubescent. Leaves are petioled, lamina is mostly ovate, terminal ones broadly lanceolate, acuminate or acute at the apex, cuneate-truncate at the base, sparsely dentate with few coarse teeth, few terminal ones subentire, pubescent on both surface. Inflorescence is a capitulum, in terminal corymbs, peducled, bracteates, and involucre up to 8×3 mm at the base. Flowers are bluish-white. Corolla is up to 5.5 mm long. Fruit is a cypsela, hairy, pappus hairy, minutely barbellate. Flowering and fruiting: November-May. It is found in open sandy places, dry exposed slopes, banks of the ponds and hedges. This plant is a native of the West Indies, now spread widely in South Asia and tropical America. In Bangladesh, it is found throughout the country.

***Mikania cordata* (Heartleaf hempvine/তারালতা) (Table 6, page no. 138)**

Information cell - *Mikania cordata* is a glabrous or sparsely puberulous, twing perennial herb. Leaves are petiolate, lamina is usually cordate, sometimes deltoid-ovate, acuminate or acute at the apex, margin entire-sinuate or crenate-dentate, usually glabrous. Inflorescence is a capitulum, cylindrical, numerous in terminal corymbose panicles on axillary branches. Corolla is white, 2.0-2.5 mm long, lobes glabrous. Fruit is a cypsela, narrowly oblong, glabrous, pappus white. Flowering and fruiting: October-February. This plant is propagated by seeds. It is found in roadsides, bank of ponds, hills and bushy jungles. This plant is distributed in tropical Asia, the Philippines, Papua New Guinea and tropical Africa. In Bangladesh, it is found all over the country.

***Spilanthes calva* (Paracress/সূর্য কন্যা) (Table 6, page no. 138)**

Information cell - *Spilanthes calva* is an annual herb, stem glabrous, sparsely pubescent, up to 55 cm tall. Leaves are ovate, petiolate, lamina is obtuse or acute at the apex,

abruptly or gradually attenuate at the base, margin entire or undulate, serrate or sub-crenate, usually glabrous on both surfaces. Inflorescence is a capitulum, heterogamous, peduncled, involucres ovoid or campanulate. Fruit is a cypsela, obovate, glabrous but ciliate at the margin, pappus absent. This plant is propagated by seeds or cuttings. Seasonality of flowering and fruiting is throughout the year. It is found in open sunny places in Jhums, sandstones, dry soil, riversides, waste places and open clearings. This plant is originated from Brazil and has migrated to the West Indices, China, South Asia, Thailand, Malaysia and tropical Africa. In Bangladesh, it is found all over the country.

***Wedelia chinensis* (Trailing daisy/মহাভৃঙ্গরাজ) (Table 6, page no. 138)**

Information cell - *Wedelia chinensis* is a procumbent or decumbent herb, stem suberect, frequently rooting at the nodes, glabrous, often reddish, puberulous at the apex, glabrous at the base. Leave are sessile or subsessile, rarely with very short petioles, elliptic-oblanceolate, rarely obovate-oblong, acute at the apex, attenuate at the base, obscurely trinerved, margin subentire or upper half irregularly crenate-serrate, rarely bifid at the base, appressed hispid on both surfaces. Inflorescence is a capitulum, solitary, terminal heterogamous, peduncled. Flowers are yellow. Fruit is a cypsela, obovoid, tubercled or slightly pubescent at the upper part, pappus with a short irregularly margined bristly or withered cup. Flowering and fruiting period from February to August. It is found in crop fields, sea beach and the edge of wet fallow lands. This plant is distributed in India, Sri Lanka, Malaysia and china. In Bangladesh, it occurs in Chittagong, Sylhetm Pirojpur, Sherpur, Netrokona and Tangail districts.

***Wedelia trilobata* (Creeping daisy/Not known) (Table 6, page no. 138)**

Information cell - *Wedelia trilobata* is a creeping, mat-forming perennial herb, rooting at the nodes, stem glabrous or pubescent. Leave are elliptic-obovate, 3 angular lobes with toothed margin, acute at the apex, basally cuneate, glabrous to sparingly pubescent, short petiolate. Inflorescence is a capitulum, yellow, heterogamous, solitary on 3-10 cm long peduncles, involucres campanulate, hemispherical. Corolla of ray-florets yellow with 2-3 fid limb, that of disc-florets with 5-fid limb. Fruit is a cypsela, cypsela of ray-florets 3-angled, sub-terete or sub-truncate, tuberculate, pappus a crown of short fimbriate scales. Flowering and fruiting period from March to August. It is cultivated in the road islands

and gardens. It is a native of Central America, now widely distributed in the tropics. In Bangladesh, it is planted in the islands of Dhaka city streets and in private gardens.

***Ageratum conyzoides* (Billy goat weed/ফুলকুঁড়ি) (Table 6, page no. 139)**

Information cell - *Ageratum conyzoides* is an annual, aromatic herb, stem terete, erect, hispidly hairy. Leaves are ovate, petiolate, hirsute, lamina 2.0-6.5×1-4 cm, palmately 3-nerved, subacute at the apex, truncate-rounded or cuneate at the base, margin dentate, crenate or serrate, hirsute on both surfaces. Inflorescence is a cpitulum, homogamous, in dense terminal corymbs, pubescent peduncles. Corolla is white, light pink or whitish-blue. Fruit is a cypsela narrowly oblong. Flowering and fruiting is November to June. It is found in open fields, roadsides, secondary forests, forest clearings, tea gardens and hillocks. This plant is a native of South America, now widely spread throughout warm countries of the world. In Bangladesh, it is a common weed of waste places, especially in moist situations.

***Cosmos bipinnatus* (Winter cosmos/কসমস) (Table 6, page no. 139)**

Information cell - *Cosmos bipinnatus* is an erect, pubescent annual herb. Leaves are very much dissected. Inflorescence is a capitulum, heteroganous, long peduncled, solitary, loosely corymbose, rayed, involucre sub-hemispheric. Corolla is ray-florets ligulate, white, crimson, pink or rosy, with a spreading, those of disc-florets tubular, white, yellowish or rosy. Fruit is a cypsela, narrow, pappus absent. Flowering and fruiting is from December to February. It is harvested in Gardens. This plant is a native of North America and Mexico. In Bangladesh, it is widely cultivated in the gardens.

***Helianthus debilis* (Cucumber leaf Sunflower/Not known) (Table 6, page no. 139)**

Information cell - *Helianthus debilis* is a bushy, sparsely hairy, freely branching perennial herb, growing up to 90 cm tall and 60 cm across. Leaves are glossy-green, cordate, serrate, petiolate. Inflorescence is a capitula, heterogamous, long peduncled, solitary at the branchlets, rayed, involucres broadly hemispheric. Corolla of ray-florets ligulate, yellow with a spreading, entire limb, that of disc florets tubular, yellow with a 5-fid limb. Fruit is a cypsela, hairy, compressed, silky, long scales, awned. Flowering and fruiting throughout the year. It is harvested in Gardens. This plant is a native of North America. In Bangladesh, it is cultivated in the gardens.

***Vernonia cinerea* (Little Ironweed/শিয়াললতা) (Table 6, page no. 139)**

Information cell - *Vernonia cinerea* is an erect, rarely decumbent, more or less pubescent annual herb, stem and branches striate, up to 90 cm to 1.8 m tall. Leaves are variable in size and shape, petiolate or sub petiolate, lamina is ovate- elliptic, obovate-lanceolate, membranous, rounded or alternate at the base, acute, obtuse and rarely rounded at the tip, margin subentire, crenate or repand, dentate, sparsely pubescent above or glabrescent, moderately or densely pubescent beneath. Inflorescences are capitulam, numerous or few in terminal corymbs, peduncled. Corolla is lobes hairy. Fruit is a cypsela, oblong. Its seasonality for flowering and fruiting is throughout the year. The habitat of this plant is sandy soil, roadside, dry exposed slopes, waste places, open forests and fields. It occurs all over tropical Asia, Africa, Arabia, the West Indies, South America, tropical Australia and Polynesia. In Bangladesh, it is found all over the country.

***Shorea robusta* (Sal tree/শাল) (Table 6, page no. 139)**

Information cell - *Shorea robusta* is a large, gregarious, semi-deciduous tree, attaining a height up to 35 m and a girth of 3.5 m with spreading crown. Young shoots and inflorescence greyish, stellate-tomentose, bark of old trees dark grey to dark brown, thick, rough, longitudinally fissured. Young leaves are pinkish or reddish and mature leaves dark green to pale yellow. Inflorescences are axillary to sub-terminal panicles. Flowers are yellowish on short pedicles. Fruit is a samara with 5 wings, ovoid, indehiscent, enclosed by the acrescent calyx lobes. Its seasonality for flowering and fruiting is from February to July. Deciduous forests are in diverse climate and tropical wet evergreen, semi-evergreen and moist deciduous forests. This plant is found in India, Sikkim and Nepal. In Bangladesh, it is distributed in the Sal forests of Dhaka, Madhupur, Gazipur, Mymensingh, Jamalpur, Tangail and Dinajpur districts. Also there are small patches of natural Sal forests at Saltillah in Sylhet and Moinamoti in Comilla districts.

***Senna obtusifolia* (Java bean/চাকুন্দা) (Table 6, page no. 139)**

Information cell - *Senna obtusifolia* is an erect herb or undershrub, sub-glabrous. Leaves are paripinnately compound, stipulate, linear, subulate, channeled above with long erect gland between the two lower leaflet pairs. Leaflets 3 pairs, obovate, rounded at the top and often minutely acute at the apex, base tapering, cuneate to acute, slightly oblique, entire, membranous, glabrous above, thinly pubescent beneath. Inflorescence is short

pedunculate axillary racemes, peduncles 1 to 2-flowered. Flowers are yellow. Fruit is a pod, oblong, subterete, glabrous to subglabrous, septate within, dehiscent, 20-40 seeded. Seeds are rhomboidal, dark brown, areoles on both surfaces of the seeds very narrow, linear, placed diagonally. Its seasonality for flowering and fruiting is from August to February. It is found in open waste places and fallow lands, sporadically along roadsides of village thickets, and bank of ponds. This plant is native to South America and distributed in the tropical region of the world including Africa, Bhutan, China, India, Nepal, Pakistan, Thailand, except Polynesia and Australia. In Bangladesh, it occasionally grown in association with *Senna tora* population as found in Dhaka district.

***Senna tora* (Metal seed/দাদমারি) (Table 6, page no. 139)**

Information cell - *Senna tora* is a perennial, erect, foetid, often profusely branched herb or undershrub. Leaves are paripinnately compound, stipulate, stipules 2, linear, falcatem pubescent, sub-persistent, rachis 5-10 cm long, channeled above with linear oblong, erect gland in between the two lower pairs of leaflet. Leaflets 3 pairs, obovate-oblong, finely pubescent or glabrous, cureate to broadly rounded at the apex, oblique at the base, membranous, upper pairs always larger than the lower. Inflorescence is axillary racemes, peduncles short, pubescent, with a pair of flowers or solitary. Flowers are yellow. Fruit is a pod, linear-oblong, straight or curved, dehiscent, 20-30 seeded. Seeds are glossy, rhomboidal, dark brown. Its seasonality for flowering and fruiting is from July to December. It is found in fallow lands, roadsides of village thickets, and along sides of railway tracks. In shady habitat, it grows densely. This plant is distributed in Bhutan, India, Malaysia, Nepal, Pakistan, the Philippines and Thailand. In Bangladesh, the species is commonly found all over the country.

***Leonurus sibiricus* (Motherwort/রক্তদ্রোন) (Table 6, page no. 139)**

Information cell - *Leonurus sibiricus* is an erect, stout herb. Stem is bluntly 4-angled, grooved, and pubescent. Leaves are petiolate, pubescent, lower lamina broadly ovate, truncate, palmatisect, segments linear, upper lamina narrower, lobes less divided, all pubescent on both surfaces including nerves on the ventral surface. Inflorescence is axillary whorls, dense-flowered. Corolla tube is naked, upper lip hooded, tomentose, lower lip spreading, dull red, often white, mid-lobe cordate. Its seasonality for flowering and fruiting is almost throughout the year. It is a common weed growing profusely in

waste places. This plant is distributed in India, Myanmar, tropical Asia, Africa and America. In Bangladesh, it is found almost throughout the country.

***Leucas aspera* (Not known/শ্বেতদ্রোন) (Table 6, page no. 140)**

Information cell - *Leucas aspera* is a stout, erect or diffuse herb, hirsute or scabrid. Stem is much branched, 4-angled, grooved, hirsute below, and more or less woolly above. Leaves are petiolate, lamina oblong-lanceolate, often entire or slightly serrate, acute to obtuse, base narrowed into a petiole, pubescent on the dorsal and tomentose on the ventral surface. Inflorescence is with terminal and axillary whorls, very dense and many-flowered. Corolla is white, 5-lobed, upper lip villous, lower lip typically 3-lobed, longer than the upper. Its seasonality for flowering and fruiting is almost throughout the year, but abundantly during the winter. It is usually found in dry sandy soil. This plant is distributed throughout the Indian subcontinent, extending from the Punjab to Assam and southwards up to Peninsular India. In Bangladesh, it is common in the districts of Chittagong, Cox's Bazar, Bandarban, Khagrachari and Rangamati, growing near sea beach or hill slope, it is also seen in other parts of the country where it grows around sand heaps and on broken masonry work.

***Ocimum tenuiflorum* (Sacred basil/কৃষ্ণতুলসী) (Table 6, page no. 140)**

Information cell - *Ocimum tenuiflorum* is an aromatic perennial herb. Stem is quadrangular, grooved, patenly hairy, often purplish, woody below. Leaves have 1-3 cm long petiole, hirsute, lamina broadly elliptic, serrate, subacute, and pubescent to puberulent on both surfaces. Inflorescence is branched, hirsute, whorls with 6 to 8-flowers, pedicels as long as the calyx, pubescent. Corolla is with 5 petals, petals c 0.5 cm long, white, often purplish, upper lip pubescent on the back. Its seasonality for flowering and fruiting is throughout the year, but flowering more noticeable in winter. It is found in gardens, especially near temples and dwellings. This plant is distributed throughout the Old tropics, extending from Arabia to Malay Peninsula, China and Japan up to Pacific Islands and Australia. In Bangladesh, it is cultivated the country.

***Leea macrophylla* (Not known/হস্তিকর্ণ) (Table 6, page no. 140)**

Information cell - *Leea macrophylla* is a perennial herb or low shrub with switchy annual shoots. Stem is deeply sulcate, root is tuberous, perennial, red. Leaves are simple,

broadly ovate, cordate, acute or acuminate, coarsely serrate or sublobed, nearly as broad as long, the lower leaves up to 60 mm long, the upper 15-23 cm long, dark green and glabrous above, cano-pubescent beneath, main nerves opposite, 8-10 pairs, prominent, almost straight, each giving off 1-6 branches terminating in teeth on the margin, petioles long, stout, glabrous, channeled halfway from beneath with adnate stipules. Flowers are polygamous, white, and small in terminal much-branched puberulous corymbose cymes, buds oblong, peduncles deeply grooved, and pedicels short. Fruit is berry, black, 3-6 celled, depressed-globose, usually 3 to 6- lobed. Its seasonality for flowering and fruiting is from July to February. It is found in forest floor. This plant is distributed in India, Myanmar, Thailand and Laos. In Bangladesh, it is available in Chittagong district, the Chittagong Hill Tracts and northern parts of the country.

***Cajanus cajan* (Pigeon pea/অড়হড়) (Table 6, page no. 140)**

Information cell - *Cajanus cajan* is an erect woody, annual or short-lived perennial shrub or small tree, 2-5 m tall with much branched. Stems are angled and pubescent. Leaves are pinnately trifoliolate, alternate and set in a spiral around them. Rachis is short. Leaflets are elliptic to lanceolate, acute and velvety pubescent above and pilose beneath, both surfaces with scattered yellow transparent glands. Inflorescence is a terminal panicle, peduncles 2-7 cm long. Flowers are yellow, bracteate, pedicels are pubescent. Corolla is bright yellow with reddish-brown lines, wing petals yellow, and keel petals yellowish-green. Fruit has a pod, linear-oblong, inflated, beaked, and yellow or green, striped with maroon or purplish-black, straight, pubescent and glandular, dehiscent, 3-6 seeded. Seeds are rounded, compressed, and brown when dry. Its seasonality for flowering and fruiting is from December to April. It is cultivated in plain lands, along the margin of crop fields, grasslands, roadsides, gravelly river beds and gardens, grows in a wide range of soil from sands to heavy black soil, at altitude up to 1600 m. it is propagated by seeds. *Cajanus cajan* (L.) is native of tropical Africa and widely distributed in India, Pakistan, New Guinea and other tropical and subtropical countries. In Bangladesh, it is widely cultivated. Pigeon pea is cultivated as a pulse crop. The foliage may be cut and fed to livestock fresh or conserved. Stems are used for firewood. Good nitrogen fixation makes it a useful green manure at young stage but most of fixed nitrogen is transferred to the developing seed after flowering. It is also important medicinally. Tender leaves are reported chewed in case of ophthalmia and spongy gums of the mouth. The poultice made

by seeds is used to reduce swelling and treat snakebites. In Bangladesh, fresh leave juice is popularly used for the treatment of jaundice.

***Lupinus polyphyllus* (Lupins/লুপিন) (Table 6, page no. 140)**

Information cell - *Lupinus polyphyllus* is a perennial herb, some are annual and few are shrubs. Stem is hollow and glabrous. Leaves are soft green to grey-green bearing silvery hairs and have easily recognizable leaf shape. Leaves are palmately compound, leaflets are 7-17, lanceolate, acuminate, glabrous above, pubescent beneath, petioles at least twice the length of leaflets, stipules pubescent, adnate to the base of petiole. Inflorescence is very long, erect raceme, many flowered. Flowers are blue, violet, rose or white. Corolla is exerted, about 3 times as long as the calyx. Fruits are compressed, black at maturity, densely pubescent, hairs appressed. This plant is propagated by seeds. Its seasonality for flowering and fruiting is from December to March. It grows in dry and sunny gardens. The genus *Lupinus* comprises between 200 to 600 species, with major centers of diversity in South America and western North America, in the Mediterranean region and Africa. In Bangladesh, it is introduced as an ornamental herb and cultivated as seasonal plant. It is popular ornamental garden plant. Lupin can fix nitrogen from the atmosphere into ammonia via a rhizobium-root nodule symbiosis, fertilizing the soil for other plants, this adaptation allows lupin to be tolerant of infertile soils and capable of pioneering change in barren and poor quality soils. Lupin contains significant amounts of certain secondary compounds like isoflavones and toxic alkaloids, e.g. lupinine and sparteine.

***Vigna unguiculata* (Cow pea/বরবটি) (Table 6, page no. 140)**

Information cell - *Vigna unguiculata* is an annual climbing, herbaceous, prostrate, or sub-erect to erect legume. It is also erect and bushy to prostrate and creeping growth habits exist depending on cultivar and growing conditions. The stems have circular sections and are pock marked. They are sometimes slightly grooved and are glabrous. The texture is fibrous and hard, firm and not inflated when young. Leaves are alternate and trifoliolate and the leaflets are broadly or narrowly oval, pointed and 6.5-15.0 cm long. They are generally entire and sometimes lobed, petioles stout, grooved, stipules ovate to lanceolate, persistent. All cultivated cowpeas are less glabrous than other legumes such as common bean and soybean. Flowers are few in sub-capitates racemes, peduncles often exceeding the leaves, bracts are attached above the base, 3-5 mm long and deciduous.

Fruit is a pod. Pods usually occur in pairs forming a V, and are non-dehiscent. Pod orientation is mostly pendant and vertical. Pod is 10-40 cm long, slightly depressed between the seeds, glabruos or minutely pilose and the width ranges from 3-12 mm. Each pod holds from 8 to 20 seeds in a crowded orientation. Seed length is between 6-11 mm and the width is from 4-9 mm. This plant is propagated by seeds. Its seasonality for flowering and fruiting is almost throughout the year. It grows in dry lands. It does not tolerate extended flooding or salinity. *Vigna unguiculata* (L.) is native of West Africa and now widely cultivated throughout the tropics and subtropics. In Bangladesh, it is cultivated in many parts of the country. Cowpea is one of the most important grain legumes in Africa and in parts of the Americas and Asia. Immature pods and seeds are eaten as vegetable. The dried seeds are important for pulse.

***Urena lobata* (Congo jute/বনওকড়া) (Table 6, page no. 140)**

Information cell - *Urena lobata* is a highly variable annual or perennial undershrub, densely covered with minute stellate hairs and scattered simple hairs. Leaves have petioles, lamina angular to shallowly lobed or deeply irregularly incised of which the bases narrower and dilated towards the apex, sometimes upper ones unlobed, ovate, shallowly cordate or truncate at the base, sometimes cuneate, 5-7 veined at the base, obtuse to acute, serrate to crenate, both sides densely stellately hairy to glabrescent, stipules 2-4 mm long, linear. Flowers are 5-merous, campanulate, axillary, solitary or in clusters of 2-3, pedicels 1-5 mm long. Epicalyx segments 3-10×1-3 mm, linear to lanceolate, spreading or appressed with the calyx in mature fruits. Corolla is 2-3 cm across, petals 5, obovate, apex truncate or notched, rose-pink. Fruit is a sub globular schizocarp, composed of 5 trigonous, indehiscent, l-seeded mericarps, covered with barbed bristles and a thick cover of stellate hairs dorsally and laterally, reticulately veined. Seeds are reinform, hairy to glabrous, brown. Its seasonality for flowering and fruiting is not on record. This plant is found in roadsides and waste places, fallow lands, edge of forests, near rivers and ponds, hill slopes, rarely marshy places. It is distributed throughout the tropics of both hemispheres. In Bangladesh, it occurs all over the country.

***Hibiscus rosa-sinensis* (China rose/জবাফুল) (Table 6, page no. 140)**

Information cell - *Hibiscus rosa-sinensis* is a shrub. Stem is profusely branched, woody, and glabrous. Leaves have petioles, glabrous or minutely stellate and simple hairy, lamina

ovate to ovate-lanceolate or elliptic, cuneate, acuminate, serrate to dentate, sometimes entire or crenate towards the apex, palmately 3-5 veined at the base, glabrous or sparsely minutely stellately hairy beneath, stipules long, linear to linear-lanceolate or subulate, glabrous. Flowers are solitary, axillary, erect or subpendent, pedicels more or less equal to the length of petioles, jointed above the middle, pubescent. Corolla 5-10 cm across, petals 5, obovate, variously coloured, usually red, rose-yellow. Fruit is not set in Bangladesh. Flowering and fruiting season is from January to December. It is found in house gardens and parks, grown as an ornamental. This plant is a native of China, planted as an ornamental throughout the tropical and subtropical regions of the world. In Bangladesh, it is an ornamental bush, planted in most flower gardens all over the country.

***Melastoma malabathricum* (Rhododendron/বনতেজপাতা) (Table 6, page no. 141)**

Information cell - *Melastoma malabathricum* is a shrub, up to 3 m high, branchlets quadrangular and densely covered with appressed to spreading, fimbriate, brownish scales. Leaves are elliptic to lanceolate, acute or shortly acuminate at the apex, acute or rounded at the base, with short appressed hairs on both surfaces. Inflorescence is compact or loose cymes of 3-7 flowers, terminal or in the upper leaf axils. Flowers are 5-merous, pink to mauve or purple. Fruit is a capsule, dark purple. Seeds are numerous. Its seasonality for flowering and fruiting is almost throughout the year. It is found in open places, disturbed grounds, roadsides, thickets and river banks. This plant is distributed in South East Asia and Malaysia to New Guinea, the Philippines and North Australia. In Bangladesh, it is found throughout the country, especially in the hilly areas of r Sylhet, Chittagong, Dhaka, Mymensingh and Tangail districts and the Chittagong Hill Tracts.

***Callistemon citrinus* (Red bottle brush/বোতলব্রাশ) (Table 6, page no. 141)**

Information cell - *Callistemon citrinus* is a small evergreen tree with slender drooping twigs, bark grayish-brown, very rough, deeply cleft vertically into narrow ridges, branchlets pubescent. Leaves are alternate, linear-lanceolate, old leaves glabrous, young one hairy, thickly coriaceous, glandular narrow, clustered near the ends of the twigs, entire, apex sharply pointed, midrib prominent, lateral nerves not prominent, inter marginal nerve single tiered, prominent, base attenuate, petioles short or subsessile, pubescent. Inflorescence is a cylindrical, terminal spike, the axis produced as a leafy shoot. Flowers are sessile, cylindrical, axillary, bracteates. Fruit is a cup-shaped capsule,

small, woody, contracted and truncate at the apex. Seeds are numerous, minute and ovate. Flowering and fruiting season is from January to December. It is found a wide variety of soil, is well adapted to wet zone and other climatic conditions. This plant is a native of Australia, cultivated in India, Bhutan and Nepal. In Bangladesh, it is cultivated in gardens and roadsides in many districts, in smaller Hill Tracts of Sylhet and Chittagong districts.

***Syzygium fruticosum* (Not known/বনজাম) (Table 6, page no. 141)**

Information cell - *Syzygium fruticosum* is a large shrub to a small tree, bark pale grayish-brown with minute vertical fissures, all parts glabrous. Leaves are coraceous, elliptic, elliptic oblong to oblong-lanceolate, dark green, apex shortly acuminate or acute, sometimes lower leaves rounded or semi-cordate, base cuneate. Flowers are small, sessile, bracteoles minute. Fruit is a globose or ellipsoid berry, crowned by the cup-shaped limp. Flowering and fruiting season is not on record. It is found in wet to semi-dry soil, villages, gardens, park, roadsides and smaller hill tracts, naturalized along the forest margins. This plant is distributed India, Myanmar, China and Thailand. In Bangladesh, it is common in Sylhet, Chittagong, Comilla, Mymensingh and Dhaka districts.

***Oxalis corniculata* (Indian sorrel/আমরুল) (Table 6, page no. 141)**

Information cell - *Oxalis corniculata* is a perennial, procumbent herb with long, slender, creeping stem, rooting at the nodes. Stem is adpressed pubescent. Leaves are palmately 3-foliolate with 1-9 cm long petioles that are slender, pubescent; stipules are oblong and adnate to the petiole. Leaflets are obcordate, cuneate at the base, sub sessile, glabrous or with few adpressed hairs and with ciliate margin. Flowers are auxiliary, sub umbellate on solitary long peduncles; petals yellow, oblong, rounded and emarginated. Capsules are linear-oblong, 5-angled, shortly beaked and tomentose. Seeds are numerous, brown, ovoid, acute, transversely ribbed, aril ejaculatory, often remaining attached to the seed. All parts of the plant are sour. This plant is propagated by seeds, stolon and stem cuttings. Its seasonality for flowering and fruiting is from September to May. This plant is a common lawn and garden weed, where it can be quite invasive and difficult to completely eradicate. *Oxalis corniculata* is cosmopolitan in its distribution and its place of origin is unknown. It is found in desert, upland, mountain and riparian. It is found in fallow lands throughout Bangladesh. The plant is very rich in ascorbic, dehydro-ascorbic, glyoxalic and phosphoric acids; it also contains tartaric, citric and malic acids. It is a good source of

calcium. The plant is known to possess antibacterial activity. The plant is considered a good medicine against scurvy; leaves are taken as a remedy for intestinal complaints.

***Oxalis corymbosa* (Pink wood sorrel/গোলাপী আমরুল) (Table 6, page no. 141)**

Information cell - *Oxalis corymbosa* is a stem less herb producing tuberous rootstock with brownish scales. Leaves are radical; petioles are sparsely to densely pilose, leaflets sessile, obcordate, glabrous above, pilose beneath with blackish spots. Inflorescence is 1.0-1.5 cm long. Petals are oblanceolate, apex truncate to rounded, entire, with fine darker striations, glabrous within, minutely pubescent without, rose coloured. The flowering is from January to April. The habitat of this plant is partially shady places, edges of flowerbeds and hill slopes. It is very common in different part of Bangladesh.

***Plumbago zeylanica* (White flowered leadwort/চিতা) (Table 6, page no. 141)**

Information cell - *Plumbago zeylanica* is a perennial herb or straggling undershrub, branches with long internodes and longitudinal ridges, cylindrical, glabrous, and straight with many axillary bud developments. Leaves are ovate to elliptic, entire, acute to acuminate, base rounded to cuneate, glabrous, petioles, dilated to form rounded, amplexicaul stipule like auricle. Inflorescence is a branched spike. Flowers are white on short pedicels, slenders, sparsely branched, persistent with membranous margin. Corolla tube is less than 2.2 cm long. Flowering and fruiting season is from October to December. It is cultivated in waste places. In Bangladesh, it is cultivated all over the country.

***Ziziphus mauritiana* (Jujube/বরই, কুল) (Table 6, page no. 141)**

Information cell - *Ziziphus mauritiana* is a small to medium-sized deciduous to semi-evergreen tree with spreading, rounded crown; branches drooping, armed with stipular spines. Leaves are simple, petiolate, alternate, elliptic-ovate to oblong-elliptic, entire or slightly crenate, glossy and glabrous above, white-tomentose to rusty-tomentose beneath, three prominent veins from the base. Inflorescence is cymose, axillary. Flowers are small, greenish-yellow, in short axillary or nearly sessile cymes. Flowers are bisexual, pedicellate. Fruit is a drupe, globose to ovoid, green when young and yellowish to reddish when ripe. Seed is single and surface is tubercled. This plant is propagated by seeds. Seeds remain viable for few years with the declined of germination rate. At present the most common practices are budding and grafting. Seasonality for flowering and fruiting

is from September to March. It is cultivated in plain land to highland (sea level up to 1000 m elevation). It can thrive under rather dry conditions. *Ziziphus mauritiana* is perhaps originated in the Middle East or in the Indian subcontinent. Now, it is cultivated throughout the tropics and subtropics. In Bangladesh, it is cultivated throughout the country. The fruits are astringent, stomachic and laxative, check biliousness, nausea and vomiting, improve digestion and purify blood. Young leaf paste is applied to boils, abscesses and carbuncles. Bark is astringent and used as a remedy for diarrhoea, powder is used as a dressing for wounds and ulcers.

***Zizyphus oenoplea* (Wild jujube/বনবরই) (Table 6, page no. 141)**

Information cell - *Zizyphus oenoplea* is a thorny straggling shrub, often with climbing branches, young branches strigose or rusty tomentose. Leaves are simple, alternate, ovate to ovate-lanceolate, crenate-serrate, acute or subacute, base oblique, soft pubescent above, silky appressed hairy beneath, prickles solitary, short and recurved. Flowers are bisexual, in sessile axillary cymes. Fruit is a drupe, globose or obovoid, black and shining. Seasonality for flowering and fruiting is from August to December. It is found in secondary forests. This plant is distributed in tropical Asia and Australia. In Bangladesh, it is very common in secondary forests and the Barind Tracts.

***Ixora coccinea* (Flame of the Woods/রঙ্গন) (Table 6, page no. 142)**

Information cell - *Ixora coccinea* is a branched shrub. Stem is relatively stout, glabrous, bark light greyish. Leaves are sessile, stipulate, stipules narrowly triangular, cuspidate, drawn out into a long thin point, lamina elliptic or obovate, acute, obtuse or rounded and shortly mucronate, base cordate or rounded, glabrous on both surfaces, paler beneath with prominent veins. Inflorescence is sessile, very compact, few-flowered, branches scurfy-pubescent. Flowers are sessile, large, bright scarlet, glabrous. Corolla is yellow, scentless, tube up to 4.0×1.5 mm, glabrous, twisted in buds, ovate or elliptic, acute, spreading. Fruits are globose, crowned with calyx teeth. Seeds are plano-convex, rough and scaly. Flowering and fruiting: throughout the year. This plant is propagated by seeds and cuttings. It is found in gardens. This plant is distributed in Sri Lanka, India, Pakistan and Burma. In Bangladesh, it is commonly cultivated in gardens. Roots are used medicinally and have a horticultural value.

***Pentas lanceolata* (Egyptian Starcluster/পেন্টাস) (Table 6, page no. 142)**

Information cell - *Pentas lanceolata* is an erect perennial herb. Leaves are stipulate and petiolate, stipules divided up to 9 filiform setae, petioles up to 0.5 mm long, lamina ovate, lanceolate, decussate, membranous, apex acute, base attenuate, soft pubescent. Inflorescence is terminal and axillary, consisting of many-flowered cymes in corymb to umbel-like arrangement. Flowers are 5- merous, mostly heterostylous. Corolla is white to pinkish, lilac, mauve or magenta, infundibular, tube narrowly cylindrical. Filaments included in long styled flowers and exerted in short styled flowers. Fruits are capsular, triangular, splitting into 2 valves. Flowering and fruiting is from March to May. It is propagated by seeds and cuttings. It grows in fertile soils. It is a native of tropical Africa and Arabia, cultivated in gardens. In Bangladesh, it has been introduced in Chittagong district and elsewhere.

***Mussaenda frondosa* (Wild Mussenda/কালাসোনা) (Table 6, page no. 142)**

Information cell - *Mussaenda frondosa* is a scandent shrub, branchlets hirsute. Leaves stipulate and petiolate, stipules ovate, triangular, densely hairy, apex bifurcate, petioles up to 1 cm long, lamina ovate to lanceolate, elliptic to orbicular or obovate, above sparsely to densely hirsute, below densely soft pallid tomentose, apex acute, base cuneate to obtuse. Large showy sepals surround the yellow flowers. Inflorescence is a few-flowered cyme. Calyx lobes narrowly linear, up to 15 mm long, deciduous, more than twice the length of the ovary, petaloid sepal creamy-white, ovate, hypanthium obconical to turbinate, 3-4 mm, hairy. Corolla tube up to 2.8 mm long and densely hairy. Anthers up to 5.5 mm long, filaments adnate to the corolla tube. Stigmas up to 2.5 cm long including styles. Fruits globose, up to 4 mm long, sparsely hirsute. Flowering and fruiting throughout the year. It is cultivated in gardens. Its natural habitat is secondary forests. In Bangladesh, it has been reported from Chittagong and Rangamati districts, Sri Lanka, India, Nepal and Myanmar.

***Glycosmis pentaphylla* (Tooth-brush plant/মটকিলা) (Table 6, page no. 142)**

Information cell - *Glycosmis pentaphylla* is an evergreen shrub or small tree, branches woody, cylindric, glabrous, young parts finely rusty puberulent. Leaves are petiolate, usually 3-5 foliolate, rarely 7-foliolate, leaflets opposite and alternate, oblong-elliptic, coraceous, cuneate or obtuse at the base, acute, acuminate, obtuse or rounded at the apex, minutely serrate or sometimes obscurely crenate or denticulate or rarely entire along

margin, glabrous. Inflorescence is axillary and terminal, paniculate, peduncles elongated, greyish or rusty puberulent. Flowers are usually in dense clusters, mostly 5-merous, subsessile, ovate, rusty-puberulent abaxillary, glabrous adaxillary, margin ciliolate. Fruit is a berry, subglobose, cream to crimson-red or pinkish when ripe. Seeds are round to plano-convex, suboblong, green. Flowering and fruiting is throughout the year. It is propagated by seeds or semi-ripe cuttings. It grows in forest margins, roadsides and village thickets. It is distributed in South and South East Asia, the Philippines, southern China and Australia. In Bangladesh, it is found all over the country.

***Citrus aurantifolia* (Common lime/লেবু) (Table 6, page no. 142)**

Information cell - *Citrus aurantifolia* is an evergreen, densely and irregularly branched, small, spiny tree. Leaves are alternate, elliptic-oblong, crenate, petioles winged. Inflorescence is short axillary racemes. Flowers are white, small, bisexual and staminate. Fruit is a globose-ovoid berry, shortly mamillate, greenish-yellow when ripe. Seeds are small, ovoid, pale, and smooth with white embryos. Flowering and fruiting is from March to September. This plant is propagated by seeds and also by air layering. It is found in gardens. Lime is believed to have originated from the East Indies. Now it is cultivated throughout the tropics and in warm subtropical areas. In Bangladesh, it is found all over the country. Fruit juice is antiscorbutic, appetizer, stomachic and anthelmintic, and is used in the treatment of dyspepsia, flatulence, biliousness, nausea and irritations of skin. The juice mixed with water is drunk as a cooling, soothing and nutritious drink in mitigating viral fevers, cold and catarrh. Leaves are used as a flavouring agent in tea and curries.

***Micromelum minutum* (Lime Bery/বনকুচ) (Table 6, page no. 142)**

Information cell - *Micromelum minutum* is a small to medium sized, unarmed tree, twigs and buds densely short hairy. Leaves are alternate, imparipinnate, alternate, ovate-lanceolate to ovate, base obtuse and asymmetrical, apex attenuate-acuminate, margin entire to irregularly undulate- crenate. Inflorescence is terminal, cymose-paniculate. Flowers are bisexual. Flowering and fruiting throughout the year. It is found in primary and secondary forests, up to 1000 m altitude. This plant is distributed in India, throughout South East Asia to Australia and the Pacific. In Bangladesh, it is found in the forests of Sylhet, Chittagong, Comilla, Rangpur, Maulvibazar, Mymensingh, Kishoreganj, Jamalpur and Sherpur districts.

***Madhuka longifolia* (Butter tree/মহুয়া) (Table 6, page no. 142)**

Information cell - *Madhuka longifolia* is a medium-sized to large deciduous tree, milky latex present, bark grey to greyish-brown. Leaves are simple, alternate, petiolate, clustered at the end of branches, elliptic-oblong, entire, thickly coriaceous, base broad, apex acuminate. Leaves fall off in spring for flowers to bloom soon thereafter. Flowers appear in cluster near the end of the branches, pedicellate, bisexual, always directed downwards, Corolla with 8 petals, succulent, colour off-white, with strong pleasant scent. Fruit is a berry, egg-shaped, greenish. Flowering and fruiting is from March to August. It is indigenous in the Sub-Himalayan Tracts of India, also planted elsewhere. In Bangladesh, the plant is grown the Santal ethnic people. It is also found throughout the country in gardens and along avenues. This plant is distributed in India, Mynmar, Sri Lanka and Pakistan. In Bangladesh, it occurs almost throughout the country.

***Lantana camara* (Lilac lantana/ল্যান্টানা) (Table 6, page no. 142)**

Information cell - *Lantana camara* is prickly evergreen, rambling or straggling shrub, branches minutely or inconspicuously pubescent, conspicuously prickly with hooked spines. Leaves are simple, opposite-decussate, ovate to ovate-oblong, crenate-serrate, acute to shotly acccuminate, rugose, scabrous. Inflorescences are axillary to terminal compact umbellate or peduncled heads. Flowering head axil, peduncles subterete, elongated, subtended by reduced leaves, bracts lanceolate to linear, acute to subacute. Flowers are mostly yellow, turning to red, later on scarlet. Corolla is tubular, pubescent enlarged and curved above the middle, limbs 4 lobed with rounded and spreading petals. Flowering and fruiting period of this plant are throughout the year. It is found in waste lands, pastures and gardens. In Bangladesh, it is very common in Chittagong districts and the Chittagong Hill Tracts and also found throughout the country.

***Duranta repens* (Pigeon berry/কাঁটা মেহেদী) (Table 6, page no. 143)**

Information cell - *Duranta repens* is an extremnely variable and polymorphic, erect to subscandent shrub to small tree, branches slender, unarmed or spiny, often drooping branch lets tetragonal. Leaves are simple, decussate-opposite, numerous, vary variable in shape, size and texture, obovate-elliptic, rarely oblong-lanceolate, serrate to entire, acute to acuminate or obtuse at the apex, cumeate at the base into a very short petiole, slender. Inflorescences are axillary to terminal raceme, laxly many-flowered. Flowers are blue,

lilac, violet, light violet to lavender or purple, scented, bracts minute. Corolla tube long, limb subequally 5-lobed, lobes pubescent on both sides, towards the throat within. Fruit is a drupe, globose, orange or orange-yellow, enclosed by the accrescent, beaked, persistent calyx. Flowering and fruiting is almost throughout the year. It is found in plain and high lands, along the roads and margins of the gardens, even everywhere as planted. This plant is a native of South America and West Indies, naturalized in many parts of tropical Africa, Asia and Australia. In Bangladesh, it is found all over the country.

***Colocasia esculenta* (Coco-yam/কচু) (Table 6, page no. 143)**

Information cell - *Colocasia esculenta* is a perennial herb with underground tubers, large main tuber or corn with a few side tubers, tuber usually cylindrical; sometimes stolons are produced from the main tuber or corn. Leaves are petiolate, petiole long, sheathing for about 25-35 cm at the base, leaf blade peltate, ovate, acute, cordate, dark green above and light green beneath, base shallowly cordate, glaucous, venation pinnately reticulate. Inflorescences are axillary peduncle, shorter than the petiole, solitary-many. Female flowers are naked, many crowded at the base of the spadix. Male flowers are numerous, cream coloured anther lobes, dehiscence by apical pores, appendage shorter than the male portion, cream in colour, subcylindric, tapering towards the tip. Fruit is a berry, ovoid, seeds elongate. It can be easily propagated by suckers or corm tops or branch tubers. Flowering and fruiting is from May to October. It is found in sides of streams, ditches, water-logged low-lying areas, paddy fields, shady secondary forests and plantations. This plant is distributed in Pan-tropical area. In Bangladesh, it is very common and found throughout the country.

***Chrysalidocarpus lutescens* (Yellow areca palm/এরিকা পাম) (Table 6, page no. 143)**

Information cell - *Chrysalidocarpus lutescens* is a dioecious palm with many trunks, slender, annulate. Leaves are pinnate, spreading, pinnatisect, arching. Petiole long, deeply furrowed near the blade, expanded at the base into a broad leaf sheath, leaf sheath smooth, leaf blade consisting of 40-60 pairs of leaflets, leaflets narrowly lanceolate, long-acuminate, unequally bifid, wide with a prominent midrib, glabrous. Inflorescences are interfoliar, male and female inflorescence borne on separate plants, much branched, greenish-yellow, branches slender, greenish-yellow, bearing the flowers densely set around them. Male and female inflorescences are similar. Flowers unisexual, white,

numerous. Fruit is baccate, ellipsoid-turbinate, resupinate, black-violaceous when ripe. Seeds are oblong, long with a hard smooth seed coat. Flowering and fruiting is from December to April. It is found in gardens. This plant is a native of Madagascar and is now planted in the tropical regions of the world. In Bangladesh, it is found in many gardens of Dhaka city and on the Dhaka University campus.

***Paspalum scrobiculatum* (Kodo millet/গোইচা) (Table 6, page no. 143)**

Information cell - *Paspalum scrobiculatum* is an annual or perennial grass, culms tufted, erect, sometimes prostrate, nodes commonly exposed, rooting at the lower nodes, nodes glabrous. Leaf blades are linear-lanceolate, lanceolate or linear, tapering to a filiform tip, rounded or shallowly cordate at the base, glabrous except near the base, margin rough, stiff hairy. Inflorescence is composed of 2 (rarely 3 or 4) racemes, digitate or borne on an axis up to 8 cm long, the lowest raceme 4-15 cm long, with spikelets borne singly on a ribbon-like rachis. Flowering and fruiting is throughout the year. It is found in open waste ground of lowlands. This plant is distributed throughout the Old World tropics. In Bangladesh, the species commonly occurs throughout the country.

***Axonopus compressus* (Savannah grass/রমনা ঘাস) (Table 6, page no. 143)**

Information cell - *Axonopus compressus* a rhizomatous perennial grass, culms, creeping or stoloniferous, erect when flowering, sometimes rosette-like and forming mats, with a prominent thickened nerves, glabrous, smooth, rooting at the nodes, with pubescent or bearded nodes. Leaf blades are linear-oblong, oblanceolate, linear-lanceolate or lanceolate, flat or rarely laterally folded, obtuse to subacute. Inflorescence is composed of 2-6 racemes, binate, digitate or alternate on a stalk, peduncles filiform, widely spreading, pubescent, rachis with a prominent winged midrib, flexuous, usually glabrous, and smooth. Flowering and fruiting is throughout the year. It is propagated by seeds and rooted tillers. It is found in a wide range of habitat and soils growing as a ruderal and weed. This plant is a native of tropical America, introduced widely and now naturalized in many warm countries. In Bangladesh, it commonly occurs throughout the country.

***Setaria palmifolia* (Palm grass/উরুধান) (Table 6, page no. 143)**

Information cell - *Setaria palmifolia* is a perennial grass, culms 1-2 m tall, erect or decumbent at the base, internodes hollowed or solid, flattened, pubescent or glabrous,

nodes appressed pubescent. Leaf blades are elliptic or elliptic-lanceolate, acuminate, base strongly narrowed or rounded, plicate, glabrous to pubescent, sometimes nearly petiolate, margin scaberulous, sheaths rounded, usually sparsely hispid, margin hyaline, glabrous, ciliate at the tip, collar pubescent to nearly glabrous. Inflorescence is a laxly panicle, branches usually spreading, rachis scabrous, and bristle solitary below the terminal spikelets of each branchlet, antrorsely scabrous. Flowering and fruiting is from August to December. It is found in fringe or forests, banks of streams and rivers, open shoals and other shady places. This plant is distributed in tropical Asia, West Africa and America. In Bangladesh, the species commonly occurs almost throughout the country.

***Imperata cylindrica* (Cotton wool grass/উলুখড়) (Table 6, page no. 143)**

Information cell - *Imperata cylindrica* is a perennial grass, culms tufted, erect, smooth, unbranched, usually with a ring of silky hairs, strongly rhizomatous with stout, scaly underground shoots. Leaf blades are rigid, flat, erect, gradually tapering to a point, midrib prominent, margin very rough with tiny teeth, ligule a tuft of silky hairs at either margin, membranous, apex truncate, sheaths loosely hairy, often persistent as a fibrous mass at the base, rounded. Inflorescence is a cylindrical, spike-like panicle, fluffy in appearance due to the long silky hairs concealing the spikelets. Flowering and fruiting is throughout the year. This plant is propagated by seeds and rhizomes. It is found in forest clearings, open forests, roadsides, and as a weed of pasture. This plant is distributed in warm and temperate parts of Asia, extending to Australia, East and South Africa. In Bangladesh, the species very commonly occurs throughout the country.

***Punica hybrida* (Not known/পানিকা) (Table 6, page no. 143)**

Information cell - *Punica hybrida* is perennial herb. Leaves are simple, opposite or nearly so, entire, elliptic or oblong, narrower at both ends especially at the base, intra marginal nerves distinct or obscure. Flowers are solitary, axillary or terminal, Flowers are purple in colour. Flowering and fruiting season is throughout the year. It is found in gardens. In Bangladesh, it is found in garden as ornamental plant throughout the country.

***Curcuma aromatica* (Not known/বনহলদি) (Table 6, page no. 144)**

Information cell - *Curcuma aromatica* is a leafy rhizomatous herb, rhizome yellow within, strongly aromatic. Leaves are 5-7, petioles equaling lamina in length, lamina

lanceolate, acuminate or caudate, shortly pubescent beneath or glabrous, pure green. Spike radical, appearing before leaves or central with leaves in the late season, Fertile bracts ovate, pale green in the lower portion and mauve-tipped in the upper, recurved at the tip, minutely pubescent at least in the upper half, adnate to each other in the lower third, coma bracts pink, sparsely pubescent, white. Flowers are included in the bracts. Corolla tube is long, pinkish-white, laterals oblong, upper longer, broadly ovate, hooded, apiculate. Fruits are not formed. Flowering and fruiting is from March to July. It is found in margins of the forest and shady forest floors. This plant is distributed in Bhutan, India, Nepal, Sri Lanka and Thailand. In Bangladesh, it is found in Chittagong district.

The recorded plants are tabulated here with their scientific, common and local name, as well as belonging family; images of vegetative and flowering/fruitification stages; and the interaction with lycaenid butterflies (Table 6).

Table 6. A tabular presentation of activity-related plants and interaction with lycaenid butterflies.

Activity-related plants			Interaction between butterfly and plant
Name	**Image of different stages**		
	Mature/vegetative	**Flowering/fruitification**	
Cycas pectinata Nepal Cycas/ মনিরাজ			
Gomphrena globosa Globe amaranth/ বোতামফুল			
Celosia cristata Crested Cock's comb/ লাল মোরগফুল			
Celosia argentea Cock's comb/ সাদা মোরগফুল			

Nelsonia canescens Not known/ পরামূল			
Catharanthus roseus Rose Periwinkle/ নয়নতারা			
Asclepias curassavica Blood flower/ দুধআগাছা			
Chromolaena odorata Paraffin weed/ আসামলতা			
Mikania cordata Heartleaf hempvine/ তারালতা			
Spilanthes calva Paracress/ সূর্য কন্যা			
Wedelia chinensis Trailing daisy/ মহাভৃঙ্গরাজ			
Wedelia trilobata Creeping daisy/ Not known			

Ageratum conyzoides Billy goat weed/ ফুলকুঁড়ি			
Cosmos bipinnatus Winter cosmos/ কসমস			
Helianthus debilis Cucumber leaf Sunflower/ Not Known			
Vernonia cinerea Little Ironweed/ শিয়াললতা			
Shorea robusta Sal tree/ শাল			
Senna obtusifolia Java bean/ চাকুন্দা			
Senna tora Metal seed/ দাদমারি			
Leonurus sibiricus Motherwort/ রক্তদ্রোন			

Leucas aspera Not known/ শ্বেতদ্রোন			
Ocimum tenuiflorum Sacred basil/ কৃষ্ণতুলসী			
Leea macrophylla Not known/ হস্তিকর্ণ			
Cajanus cajan Pigeon pea/ অড়হড়			
Lupinus polyphyllus Lupins/ লুপিন			
Vigna unguiculata Cow pea/ বরবটি			
Urena lobata Congo jute/ বনওকড়া			
Hibiscus rosa-sinensis China rose/ জবাফুল			

Melastoma malabathricum Rhododendron/ বনতেজপাতা			
Callistemon citrinus Red bottle brush/ বোতলব্রাশ			
Syzygium fruticosum Not known/ বনজাম			
Oxalis corniculata Indian sorrel/ আমরুল			
Oxalis corymbosa Pink wood sorrel/ গোলাপী আমরুল			
Plumbago zeylanica White flowered leadwort/ চিতা			
Ziziphus mauritiana Jujube/ বরই, কুল			
Zizyphus oenoplea Wild jujube/ বনবরই			

Ixora coccinea Flame of the Woods/ রঙ্গন			
Pentas lanceolata Egyptian Starcluster/ পেন্টাস			
Mussaenda frondosa Wild Mussenda, White Flag Bush/ কালাসোনা			
Glycosmis pentaphylla Tooth-brush plant/ মটকিলা			
Citrus aurantifolia Common lime/ লেবু			
Micromelum minutum Lime Bery/ বনকুচ			
Madhuka longifolia Butter tree/ মহুয়া			
Lantana camara Lilac lantana/ ল্যান্টানা			

Duranta repens Pigeon berry/ কাঁটা মেহেদী			
Colocasia esculenta Coco-yam/ কচু			
Chrysalidocarpus lutescens Yellow areca palm/ এরিকা পাম			
Paspalum scrobiculatum Kodo millet/ গোইচা			
Axonopus compressus Savannah grass/ রমনা ঘাস			
Setaria palmifolia Palm grass/ উরুধান			
Imperata cylindrica Cotton wool grass/ উলুখড়			
Punica hybrida Not known/ পানিকা			

Curcuma aromatica Not known/ বনহলদি			

3.3.2.2 Categorization of resource potentiality among lycaenid related plants

According to plants "category determining assessment", fifty three plants have been grouped into the four categories. Among them, seven plants were found under the category 'Excellent Biotic Resource Potential'. These plants served as all the behavioural activities as foraging-resting-basking-egg laying (F-R-B-El) of butterflies. The plants are *Ziziphus mauritiana, Ixora coccinea, Oxalis corniculata, Citrus aurantifolia, Cajanus cajan, Lupinus polyphyllus* and *Vigna unguiculata*.

Fourteen plants have been found in the category 'High Biotic Resource Potential' of which twelve plants (viz. *Shorea robusta, Chromolaena odorata, Mikania cordata, Wedelia chinensis, Wedelia trilobata, Senna obtusifolia, Oxalis corymbosa, Pentas lanceolata, Mussaenda frondosa, Glycosmis pentaphylla, Micromelum minutum* and *Punica hybrida*) were categorized under the sub-category foraging-resting-basking (F-R-B) whereas *Cycas pectinata* and *Zizyphus oenoplea* was categorized under the sub-category resting-basking-egg laying (R-B-El).

Twenty two plants have been labeled in 'Mid Biotic Resource Potential'. Among them six plants (viz. *Catharanthus roseus, Leea macrophylla, Callistemon citrinus, Madhuka longifolia, Lantana camara* and *Chrysalidocarpus lutescens*) were sorted out in the sub-category foraging-resting (F-R); five species like *Spilanthes calva, Cosmos bipinnatus, Helianthus debilis, Vernonia cinerea* and *Urena lobata* was placed in the sub-category foraging-basking (F-B); and eleven plants such as *Senna tora, Hibiscus rosa-sinensis, Melastoma malabathricum, Syzygium fruticosum, Duranta repens, Colocasia esculenta, Paspalum scrobiculatum, Axonopus compressus, Setaria palmifolia, Imperata cylindrica* and *Curcuma aromatica* were tagged in the sub-category resting-basking (R-B).

Ten plants (viz. *Gomphrena globosa, Celosia cristata, C. argentea, Nelsonia canescens, Asclepias curassavica, Ageratum conyzoides, Leonurus sibiricus, Leucas aspera, Ocimum tenuiflorum* and *Plumbago zeylanica*) were categorized in the sub-category foraging (F) under the category 'Poor Biotic Resource Potential'.

3.3.3 Exploration of the relationship between lycaenid butterflies and plants

A single plant species can provide materials to perform different activities for lycaenid butterflies. Among 53 plant species, 40 species were found as nectar producers. At the same time, those plants utilized as resting and basking support, and other support plant also involved in above mentioned behaviour. In the same way, lycaenids were found to visit 38 and 37 plant species for resting and basking support, respectively. Only nine species were identified as host plants for oviposition and as larval-pupal supports. In the experimental site, the population of lycaenids was focused to vary in different activities, maximum (57%=3,836) lycaenids were busy in foraging and minimum (3%=203) in egg-laying, whereas, 24% (1,624) and 16% (1,065) butterflies were found to act resting and basking behaviours, respectively (Fig. 6).

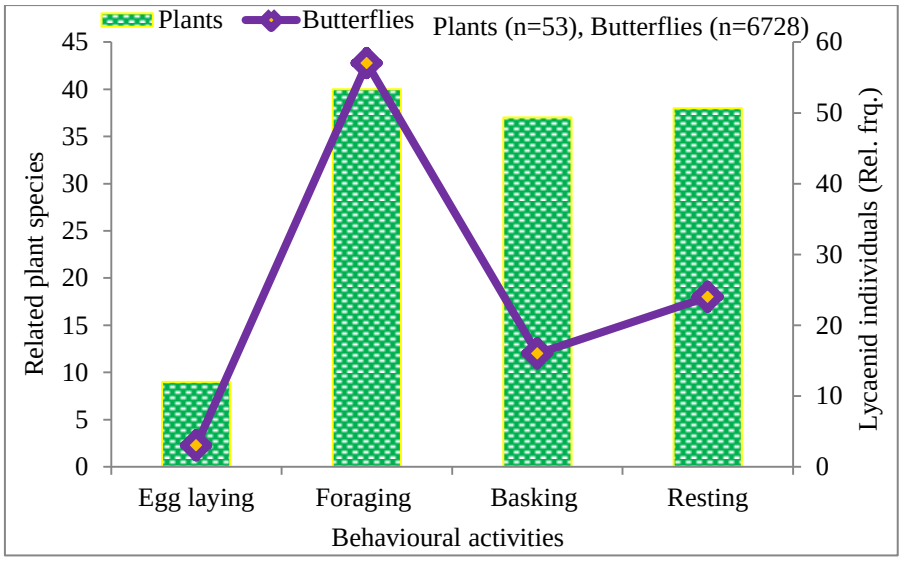


Fig. 6. Lycaenid individuals and their activity-related plants in the experimental sites.

As lycaenids utilized same plants for different-activity performance, plants were counted separately in different number on butterfly-activity basis but the total number of plants was fixed in fifty three species. It was assessed that lycaenid butterflies were more abundant on flowering plants than other plants.

Table 7. Correlation between lycaenid butterflies and related plant species.

Variable	Lycaenid species	Plant species	Plant families
Lycaenid species	1		
Plant species	0.13	1	
Plant families	0.04	0.12	1

Behavioural activities of lycaenid butterflies with their related plants was also found very strong at 1% significant level of correlation coefficient, r = 0.31. Correlation coefficient (r = 0.13) confirms a strong correlation between lycaenid butterflies and plant species, and was found significant at 1% level (Table 7). That is, lycaenid butterflies are highly attracted to plant species. Similarly, correlation coefficient (r = 0.04) between lycaenid butterflies and plant families was also found significant at 1% level, and also shows that more plant families are attracted by lycaenids as their number increases. Whereas correlation coefficient (r = 0.12) between plant species and plant families shows medium correlation between them but it was significant at 0.5% level. This interrelationship produced interesting findings to study the identification of biotic resources in a certain ecosystem.

3.4 Discussion

Butterflies and plants have co-evolved over time and depend on each other for survival (Ehrlich and Raven 1964). The butterflies deeply provide vital backward-support to the plants for their multiplication and sustenance to form the final shape of an ecosystem especially in Bangladesh forests (Bashar 2015). Butterflies and their larva are dependent on specific host plants for foliage, nectar and pollen as their food (Guiterrez and Mendez 1995). Thus, butterfly diversity indirectly reflects overall plant diversity, especially that of herbs and shrubs, in the given area (Nimbalkar *et al.* 2011). Akand *et al.* (2016) found in an experiment that lycaenid butterfly was more synchronized with the flowers of ground vegetation, herbs and shrubs than that of canopy trees.

This is an inclusive investigation collecting basic information of lycaenid butterflies and their activity-related plants in the selected areas of Bangladesh. This study also gives us data on plant types, perennation and their distribution as well as the supporting factors for lycaenid activities. Previously, Akand *et al.* (2015b) examined 29 species of lycaenid butterflies and 44 species of their activity-related plants. Among 44 plant species, 31 species were identified as nectar producers whereas 34 and 30 plant species were used for resting and basking support, respectively. But only nine were identified as host plants for egg laying support. Sharma *et al*. (2016) investigated host plants of butterflies in Gujarat, India. Their findings revealed that 67 butterfly species of four selected families were utilizing 74 plant species of 32 families for butterfly's activity basis.

Butterflies confine on the especial types of plants for their life-style maintenance. While butterflies require more than just nectar and larval host plants (other resources include roosts, thermoregulation sites, mate location sites, hibernation sites, etc.), these are two main resources that can influence the distribution of butterflies on the landscape (Tudor *et al*. 2004) and may be good measures of habitat quality (Dennis *et al*. 2006a). Bashar (2015) stated that the butterfly host species (plants) richness shows the butterfly species richness in an ecosystem principally. And additional factor is equally necessary for butterfly species richness as the richness of non-host plant species of butterflies provide shelter plants, nectar plants, mating plants, egg-laying plants and sometimes sources of various other behavioural support plants. Bashar (2015) also indicated that when interactions between plants and animals, and animals and plants stand very normal in a forest then the ecosystem remains sound. And that ecosystem can produce a balanced environment. Environmental soundness or environmental disturbance starts at atomic or very micro level, but it shows its vital impact at the species and community levels.

The present study supplies firm information on lycaenid butterfly resources and the resources used by them. This study also provides the facts of interactions among life history and biotic variables to ensure the resources that are allocated in an efficient, holistic manner to conserve and build butterfly communities in suitable sites.

ABUNDANCE AND POPULATION DYNAMICS OF LYCAENID BUTTERFLIES

4.1 Introduction

Butterflies are distinct and easily noticeable in the field. Thus, it is tranquil to evaluate the ecological state and the value of concrete territory on the basis of their diversity and abundance (Kumar *et al*. 2017). Butterflies occur in all major terrestrial ecosystems (Caldas and Robbins 2003). Variation in insect abundance in tropical regions is a well-established fact (Wolda 1978, 1980, Wolda and Fisk 1981, Pinheiro *et al.* 2002). Food resources and climate conditions vary in space and time, directly affecting the diversity and distribution of insect populations (Morais *et al.* 1999, Kittelson 2004, Bispo *et al.* 2006, Bispo and Oliveira 2007, Goldsmith 2007). Climate is one of the determining factors in insect population fluctuations during the year (Wolda 1978, Torres and Madi-Ravazzi 2006). Since butterflies are phytophagous insects through the larval and adult stages, butterfly distribution sensitively reflects changes in vegetation (Ehrlich *et al.* 1972, Weiss *et al.* 1987, Hill *et al.* 1995, Blair and Launer 1997, Wood and Gillman 1998). In addition, they are able to exist in disturbed as well as undisturbed areas, are responsive to changes in habitat characteristics, closely track environmental conditions due to short life-cycles (Mac Nally *et al*. 2003, Debinski *et al*. 2006). Their value as indicators of biotope quality is being increasingly recognized because of their sensitivity to minor changes in micro-habitat (Kremen 1992).

The amplitude of population fluctuations varies greatly among species and is affected by the degree of synchrony among different parts of the population (Pimm *et al*. 1988, McArdle *et al*. 1990). Spatial synchrony of population dynamics can be attributed to spatially correlated variation in weather (Hanski and Woiwod 1993) and habitat quality (Bellamy *et al*. 2003). Weather may influence vegetation in terms of quality (i.e. new growth, flowering), phenology and quantity (White 2008, Boggs and Inouye 2012). Consequently, weather may indirectly limit population size for herbivorous insects (Harrison *et al*. 2015). Sei-Woong (2003) described that weather variables can help in detecting potential butterfly population changes following changes in climatic factors (changes in temperature, relative humidity, rainfall patterns etc.). It is more challenging to understand the effect of temperature variation on butterfly population dynamics (Harrison *et al*. 2015). Temperature may impact both directly via physiological or behavioural

changes, and indirectly through influencing interspecific interactions (Kingsolver 1989, Roy and Sparks 2000). It is believed that weather variables affect species richness, abundance and distribution of butterflies negatively or positively in locally as well as regionally (Sei-Woong 2003, Kivinen *et al*. 2007).

Butterfly species prefer specific habitats (Padhye *et al*. 2006), many of them are strictly seasonal (Kunte 1997), and their population dynamics are generally considered to be governed by environmental factors (Hussain *et al.* 2011). They are common for only a few months and rare or absent in other months of the year (Kunte 2000). The relative abundance of butterflies varies with the number of the host plant species in unit area (Yamamoto *et al*. 2007). Butterfly population is fluctuated monthly. Some butterfly species are observed in more numbers and a few of them are seen at particular season (Kunte 2001). The composition of butterfly community varies highly among seasons than among habitats (Akand *et al*. 2016). The seasonal abundance might be controlled by the complex interactions with various biotic and abiotic factors (Cushman and Murphy 1993). Plant phenology and climate are the key factors that affect butterfly population dynamics (Murphy *et al.* 1990, Spitzer *et al.* 1993, Barlow *et al.* 2007). Seasonal availability of food plants has a marked correspondent in abundance of lycaenid butterflies (Akand *et al*. 2016). Such seasonal availability may be an important feature facilitating the use of lycaenids as indicators of habitat quality (Robbins and Aiello 1982). They prefer suitable abiotic factors and their entire life directly depend on temperature, relative humidity and other abiotic factors. The abundance of lycaenid species varies according to its own ecological requirements (Akand *et al*. 2016). The present study has been visualized with an outlook to examine the dynamics of lycaenid population through temporal and spatial pattern. In view of the foregoing account, the present investigation has been undertaken with several objectives as stated below-

4.1.1 Objectives

The present investigation was envisaged to examine

- the diversity of lycaenid butterflies in the experimental sites;
- the spatial pattern of lycaenid population dynamics;
- the temporal pattern of lycaenid population dynamics; and
- the role of abiotic factors on lycaenid population.

4.2 Material and methods

Depending on objectives the current investigation has been adopted procedures and materializes to find out the results. These are described as below-

4.2.1 Studied species

Butterflies are most tantalizing and beautiful creatures, among the insect groups. Lycaenid butterflies have been selected to study the population dynamics and abundances in current experiment.

4.2.2 Study period

The present research work has been carried out during the period from January 2015 to December 2017. The findings have been accumulated based on the observation of four different experimental forest areas.

4.2.3 Selected sites

Four experimental sites have been selected to study the population dynamics of lycaenid butterflies. The field study has finalized in Butterfly Research Park (BRP), a semi natural ecosystem and three natural forests viz. Madhupur National Park (MNP), Tangail; Satchori National Park (ScNP) and Rema-Kalenga Wildlife Sanctuary (RKS) of Habigonj district. The experimental sites are described details in Chapter 3.

4.2.4 Materials for recording and data collection

Paper rmaterials and other supporting apparatus have been used for data collection. Different digital cameras (described in Chapter 3) were used to photograph the activity of live butterflies and their abundance recording. Thermo hygrometer has been used to record temperature and relative humidity.

4.2.5 Sampling procedures

The population abundance of lycaenids has investigated using several sampling methods. The assented sampling procedures practicing in current study have been described in Chapter 3.

4.2.6 Observation, counting and data recording

The presence, abundance and population dynamics of lycaenid butterflies has been assessed following Akand *et al*. (2016). The butterfly activities in the study sites were recorded through a "constant walk" for 10-15 minutes over the experimental sites. Observations were made twice in a month during the time between 9.30 a.m. and 4.30 p.m. and recorded the individual numbers of lycaenid species. The pre mating, mating, egg laying, foraging, basking, resting, puddling and flying activities of lycaenids have been considered for counting to assess their abundance. Only ocular observations have been made for counting. It was possible some of butterflies were counted more than once each site was visited in observation day. Visual census of butterfly was used to show species richness. Butterfly species have been identified directly in the field or in difficult cases following photography. The daily readings of abiotic factors (temperature and relative humidity) on sampling day were used for the calculation of monthly mean temperature and relative humidity.

4.2.7 Analysis of data

One-way ANOVA is used to calculate the differences and Pearson's rank correlation is used to assess the relationships of abundance within experimental sites and months during study period. The Spearman rank correlation is used to assess relationship between butterfly abundance and abiotic factors. The statistical analysis is performed by SPSS for windows (Version 16). Microsoft Office Excel 2010 is used to draw graph, table and figure.

4.3 Results

Butterfly species encounter a vast temporal and spatial variability in the natural conditions (Kocsis and Hufnagel 2011). They are sensitive insects which react quickly to any kind of disturbance like changes in the habitat quality and environmental variation (Eleanor *et al*. 2015, Evangeline and Santhi 2016, Priyamvada 2016). The different species of lycaenid butterflies has been observed during present investigaion. A total of 6724 individuals representing 25 lycaenid species have been counted in four experimental forests from January 2015 to December 2017. Among them, maximum (2721) lycaenids were recorded from Butterfly Research Park and minimum (673) from Satchori National

Park. The rest 2482 and 848 butterflies was counted from Madhupur National Park and Rema-kalenga Wildlife Sanctuary, respectively.

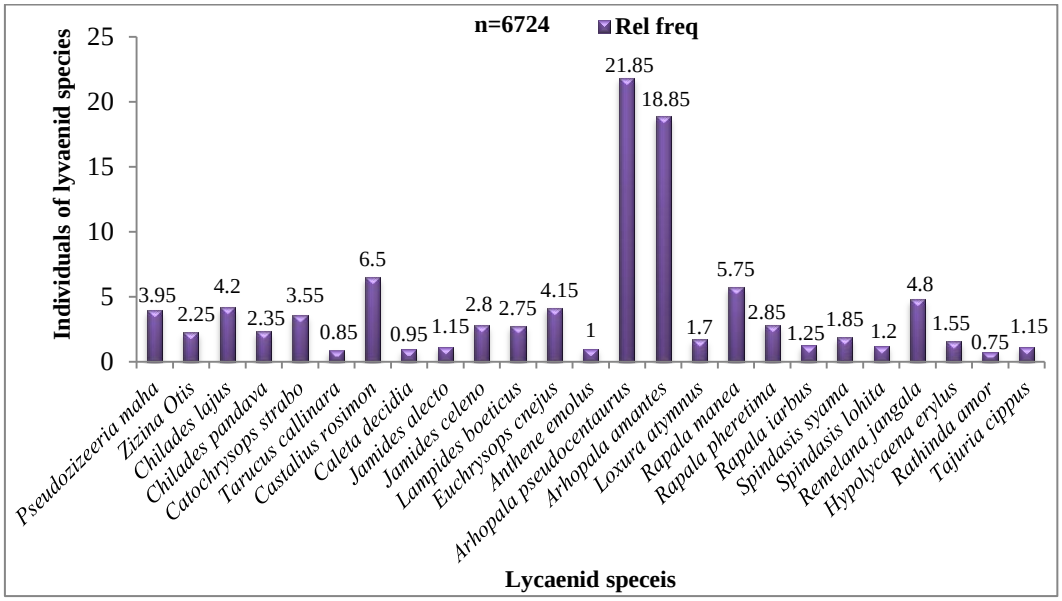


Fig. 7. Relative abundance (%) of examined lycaenid species in different forest areas.

The relative abundance of a species was compared to other species in the study sites. In the analysis of relative abundance (Fig. 7), it has been found that the dominant species was *Arhopala pseudocentaurus* with relative frequency of 21.85% (1467) and the least abundance was observed in case of *Rathinda amor* with relative frequency of 0.75% (50). Moderate population was recorded in *Castalius rosimon* (6.5%), *Rapala manea* (5.75%), *Remelana jangala* (4.80%), *Chilades lajus* (4.20%), *Euchrysops cnejus* (4.15%), *Pseudozizeeria maha* (3.95%) and *Catochrysops strabo* (3.55%). The population dynamics of lycaenid butterflies in experimental stations during the three year study period has been tabulated in Table 9.

Suitable abiotic and biotic factors such as climate, temperature and wind exposure, availability of host and larval plants (Barlow *et al*. 2007), food and vegetation (Ravindra *et al*. 1996, Khan *et al*. 2004, Jain and Jain 2012, Kharat *et al*. 2012, Kumaraswamy and Kunte 2013), topographic features (Amala *et al*. 2011), habitat quality (Barlow *et al*. 2007) are some of the most important parameters to determine butterfly population in an ecosystem. It is very important to keep assessing the change in their abundance and distribution to evaluate biodiversity trends in a large scale.

4.3.1 Role of biotic factors on lycaenid population

Butterfly diversity is largely dependent on the rich floral diversity. And plants have importance in increasing the butterfly population and their abundance in the specific area. Earlier description (Chapter 3) has been detected that 53 plant species representing 25 families were related to lycaenid activities like pre mating, mating, egg laying, foraging, basking, and resting condition. It has also been stated earlier that butterflies are associated with plants for food and shelter. In determining the pattern of butterfly community, relative abundance of butterfly and plant resources was an important aspect that characterizes butterfly community (Yamamoto *et al.* 2007). Activity-related plants of lycaenid butterflies are listed depending on examined species (Table 8).

Table 8. Recorded activity-related plants exploited by examined lycaenid species.

Examined lycaenids	Recorded activity-related plant species
Pseudozizeeria maha	*Gomphrena globosa, Celosia cristata, C. argentea, Nelsonia canescens, Spilanthes calva, Wedelia chinensis, W. trilobata, Ageratum conyzoides, Helianthus debilis, Vernonia cinerea, Senna obtusifolia, Leonurus sibiricus, Leucas aspera, Ocimum tenuiflorum, Leea macrophylla, Urena lobata, Oxalis corniculata, O. corymbosa, Plumbago zeylanica, Pentas lanceolata, Lantana camara, Duranta repens, Paspalum scrobiculatum, Axonopus compressus* and *Punica hybrida*.
Zizina otis	*Gomphrena globosa, Celosia cristata, C. argentea, Nelsonia canescens, Spilanthes calva, Wedelia chinensis, W. trilobata, Ageratum conyzoides, Helianthus debilis, Vernonia cinerea, Leonurus sibiricus, Leucas aspera, Leea macrophylla, Urena lobata,Oxalis corniculata, O. corymbosa, Plumbago zeylanica, Pentas lanceolata, Paspalum scrobiculatum, Axonopus compressus* and *Punica hybrida*.
Chilades lajus	*Gomphrena globosa, Celosia cristata, C. argentea, Catharanthus roseus, Chromolaena odorata, Mikania cordata, Wedelia trilobata, Helianthus debilis, Senna obtusifolia, Leonurus sibiricus, Leucas aspera, Ocimum tenuiflorum, Leea macrophylla, Ziziphus mauritiana, Z. oenoplea, Glycosmis pentaphylla,Citrus aurantifolia, Lantana camara, Syzygium fruticosum, Setaria palmifolia, Imperata cylindrica, Punica hybrida* and *Curcuma aromatica.*
Chilades pandava	*Cycas pectinata, Gomphrena globosa, Wedelia chinensis, W. trilobata, Senna obtusifolia, Cajanus cajan, Ziziphus mauritiana, Mussaenda frondosa, Glycosmis pentaphylla, Citrus aurantifolia, Lantana camara, Setaria palmifolia, Imperata cylindrica* and *Punica hybrida.*
Catochrysops strabo	*Gomphrena globosa, Celosia cristata, C. argentea, Catharanthus roseus, Spilanthes calva, Cosmos bipinnatus, Wedelia chinensis, W. trilobata, Cajanus cajan, Lupinus polyphyllus, Vigna unguiculata, Leonurus sibiricus, Leucas aspera, Ocimum tenuiflorum, Leea macrophylla, Oxalis corniculata, O. corymbosa, Plumbago zeylanica, Pentas lanceolata, Mussaenda frondosa, Citrus aurantifolia, Axonopus compressus, Punica hybrida* and *Curcuma aromatica.*
Tarucus callinara	*Gomphrena globosa, Catharanthus roseus, Spilanthes calva, Cosmos bipinnatus, Helianthus debilis, Wedelia chinensis, W. trilobata, Leea macrophylla, Hibiscus rosa-sinensis, Oxalis corniculata, O. corymbosa, Plumbago zeylanica, Ziziphus mauritiana, Z. oenoplea, Citrus aurantifolia, Lantana camara, Duranta repens, Paspalum scrobiculatum, Imperata cylindrica, Punica hybrida* and *Curcuma aromatica.*
Castalius rosimon	*Nelsonia canescens, Gomphrena globosa, Celosia cristata, C. argentea, Catharanthus roseus, Chromolaena odorata, Mikania cordata, Spilanthes calva, Wedelia chinensis, W. trilobata, Ageratum conyzoides, Cosmos bipinnatus,*

	Helianthus debilis, Vernonia cinerea, Senna obtusifolia, S. tora, Cajanus cajan, Lupinus polyphyllus, Vigna unguiculata, Leonurus sibiricus, Leucas aspera, Leea macrophylla, Urena lobata, Hibiscus rosa-sinensis, Melastoma malabathricum, Oxalis corniculata, O. corymbosa, Plumbago zeylanica, Ziziphus mauritiana, Z. oenoplea, Glycosmis pentaphylla, Lantana camara, Duranta repens, Axonopus compressus, Setaria palmifolia, Imperata cylindrica and *Punica hybrida.*
Caleta decidia	*Celosia cristata, C. argentea, Spilanthes calva, Wedelia chinensis, W. trilobata, Cosmos bipinnatus, Helianthus debilis, Senna obtusifolia, Vigna unguiculata, Leonurus sibiricus, Leucas aspera, Leea macrophylla, Oxalis corymbosa, Ziziphus mauritiana, Z. oenoplea, Citrus aurantifolia, Pentas lanceolata, Glycosmis pentaphylla, Lantana camara, Duranta repens, Paspalum scrobiculatum, Setaria palmifolia* and *Punica hybrida.*
Jamides alecto	*Chromolaena odorata, Mikania cordata, Ageratum conyzoides, Hibiscus rosa-sinensis, Ziziphus oenoplea, Ixora coccinea, Citrus aurantifolia, Micromelum minutum, Lantana camara, Duranta repens, Setaria palmifolia, Imperata cylindrica* and *Curcuma aromatica.*
Jamides celeno	*Vernonia cinerea, Senna tora, Shorea robusta, Urena lobata, Hibiscus rosa-sinensis, Melastoma malabathricum, Syzygium fruticosum, Ziziphus mauritiana, Ixora coccinea, Glycosmis pentaphylla, Citrus aurantifolia, Micromelum minutum, Lantana camara, Duranta repens, Colocasia esculenta, Setaria palmifolia, Imperata cylindrica* and *Curcuma aromatica.*
Lampides boeticus	*Gomphrena globosa, Celosia cristata, C. argentea, Catharanthus roseus, Asclepias curassavica, Spilanthes calva, Wedelia chinensis, W. trilobata, Cosmos bipinnatus, Helianthus debilis, Shorea robusta, Senna obtusifolia, Leonurus sibiricus, Leucas aspera, Leea macrophylla, Lupinus polyphyllus, Vigna unguiculata, Plumbago zeylanica, Ziziphus mauritiana, Ixora coccinea, Pentas lanceolata, Glycosmis pentaphylla, Mussaenda frondosa, Lantana camara, Chrysalidocarpus lutescens, Axonopus compressus, Punica hybrid* and *Curcuma aromatica.*
Euchrysops cnejus	*Gomphrena globosa, Celosia cristata, C. argentea, Catharanthus roseus, Spilanthes calva, Wedelia chinensis, W. trilobata, Cosmos bipinnatus, Helianthus debilis, Senna obtusifolia, Leonurus sibiricus, Leucas aspera, Ocimum tenuiflorum, Cajanus cajan, Vigna unguiculata, Oxalis corniculata, O. corymbosa, Plumbago zeylanica, Ziziphus mauritiana, Pentas lanceolata, Glycosmis pentaphylla, Mussaenda frondosa, Citrus aurantifolia, Lantana camara, Chrysalidocarpus lutescens, Axonopus compressus, Imperata cylindrical* and *Punica hybrida.*
Anthene emolus	*Nelsonia canescens, Chromolaena odorata, Mikania cordata, Wedelia chinensis, Ageratum conyzoides, Urena lobata, Ziziphus mauritiana, Z. oenoplea, Glycosmis pentaphylla, Micromelum minutum, Lantana camara, Imperata cylindrica* and *Curcuma aromatica.*
Arhopala pseudocentaurus	*Asclepias curassavica, Chromolaena odorata, Mikania cordata, Wedelia chinensis, W. trilobata, Shorea robusta, Senna obtusifolia, Hibiscus rosa-sinensis, Melastoma malabathricum, Callistemon citrinus, Syzygium fruticosum, Ziziphus mauritiana, Z. oenoplea, Ixora coccinea, Glycosmis pentaphylla, Citrus aurantifolia, Micromelum minutum, Madhuka longifolia, Lantana camara, Colocasia esculenta, Chrysalidocarpus lutescens* and *Axonopus compressus.*
Arhopala amantes	*Asclepias curassavica, Chromolaena odorata, Mikania cordata, Wedelia chinensis, W. trilobata, Shorea robusta, Senna obtusifolia, Senna tora, Hibiscus rosa-sinensis, Melastoma malabathricum, Callistemon citrinus, Syzygium fruticosum, Ziziphus mauritiana, Z. oenoplea, Ixora coccinea, Glycosmis pentaphylla, Citrus aurantifolia, Micromelum minutum, Madhuka longifolia, Lantana camara, Duranta repens* and *Chrysalidocarpus lutescens.*
Loxura atymnus	*Chromolaena odorata, Mikania cordata, Shorea robusta, Hibiscus rosa-sinensis, Melastoma malabathricum, Callistemon citrinus, Syzygium fruticosum, Ziziphus mauritiana, Ixora coccinea, Lantana camara* and *Duranta repens.*
Rapala manea	*Gomphrena globosa, Celosia cristata, C. argentea, Chromolaena odorata, Mikania cordata, Spilanthes calva, Wedelia chinensis, W. trilobata, Cosmos bipinnatus,*

	Helianthus debilis, Senna obtusifolia, Senna tora, Leonurus sibiricus, Leucas aspera, Cajanus cajan, Hibiscus rosa-sinensis, Melastoma malabathricum, Syzygium fruticosum, Ziziphus mauritiana, Z. oenoplea, Ixora coccinea, Glycosmis pentaphylla, Citrus aurantifolia, Lantana camara, Duranta repens, Paspalum scrobiculatum, Imperata cylindrical and *Curcuma aromatica.*
Rapala pheretima	*Gomphrena globosa, Celosia cristata, C. argentea, Chromolaena odorata, Mikania cordata, Spilanthes calva, Wedelia chinensis, W. trilobata, Cosmos bipinnatus, Helianthus debilis, Senna obtusifolia, Leonurus sibiricus, Leucas aspera, Melastoma malabathricum, Syzygium fruticosum, Ziziphus mauritiana, Z. oenoplea, Ixora coccinea, Glycosmis pentaphylla, Micromelum minutum, Lantana camara* and *Imperata cylindrica.*
Rapala iarbus	*Gomphrena globosa, Celosia cristata, C. argentea, Chromolaena odorata, Mikania cordata, Wedelia chinensis, W. trilobata, Senna obtusifolia, Leonurus sibiricus, Leucas aspera, Melastoma malabathricum, Ziziphus mauritiana, Ixora coccinea, Glycosmis pentaphylla, Lantana camara* and *Setaria palmifolia.*
Spindasis syama	*Chromolaena odorata, Mikania cordata, Shorea robusta, Melastoma malabathricum, Syzygium fruticosum, Glycosmis pentaphylla, Micromelum minutum, Lantana camara* and *Duranta repens.*
Spindasis lohita	*Chromolaena odorata, Mikania cordata, Senna obtusifolia, Ixora coccinea, Glycosmis pentaphylla, Micromelum minutum* and *Lantana camara.*
Remelana jangala	*Chromolaena odorata, Mikania cordata, Wedelia chinensis, W. trilobata, Senna obtusifolia, Senna tora, Hibiscus rosa-sinensis, Melastoma malabathricum, Syzygium fruticosum, Ziziphus mauritiana, Ixora coccinea, Glycosmis pentaphylla, Citrus aurantifolia, Micromelum minutum* and *Lantana camara.*
Hypolycaena erylus	*Chromolaena odorata, Mikania cordata, Wedelia chinensis, W. trilobata, Shorea robusta, Senna obtusifolia, S. tora, Syzygium fruticosum, Ixora coccinea* and *Glycosmis pentaphylla.*
Rathinda amor	*Chromolaena odorata, Hibiscus rosa-sinensis, Syzygium fruticosum, Ziziphus mauritiana, Ixora coccinea, Glycosmis pentaphylla* and *Lantana camara.*
Tajuria cippus	*Asclepias curassavica, Chromolaena odorata, Mikania cordata, Wedelia trilobata, Hibiscus rosa-sinensis, Syzygium fruticosum, Ixora coccinea* and *Lantana camara.*

Types of vegetation may reflect the difference in the composition of butterfly populations among habitats at the generic and family level (Beccaloni 1997). The lycaenid butterflies are found more abundant in collecting nectar on flowering plants. They were used to spend less time on other plants (not at flowering stage) for their other behavioural activities. Nectar and shelter plants are more available than host plants for lycaenid butterflies in the experimental sites. Akand (2012) studied that lycaenid butterfly was more synchronized with herbs and shrubs than tree as well as with ground level vegetation. In the present investigation, the similar phenomenon was found where lycaenid species interacts with herbs and shrubs than tree (Table 8). Incidence of natural enemies is also important. Butterflies are food to birds and other predators and are hosts of parasitoides. These animals have affected the butterfly population. Long term butterfly monitoring (both spatially and temporally) is required for better understanding the influences of habitat elements on butterfly population structure.

4.3.2 Spatial fluctuation of lycaenid population

The relative abundance of insects varied significantly among the habitats (Akand 2012). The present investigation reveals similar pattern during the study periods. The population fluctuation might depend on biotic factors (viz. plant availability and flowering periods of plants) as stated earlier by Akand *et al*. (2016). The recorded data on butterfly abundance showed a similar array of seasonal fluctuation in all the four experimental sites (Fig. 8).

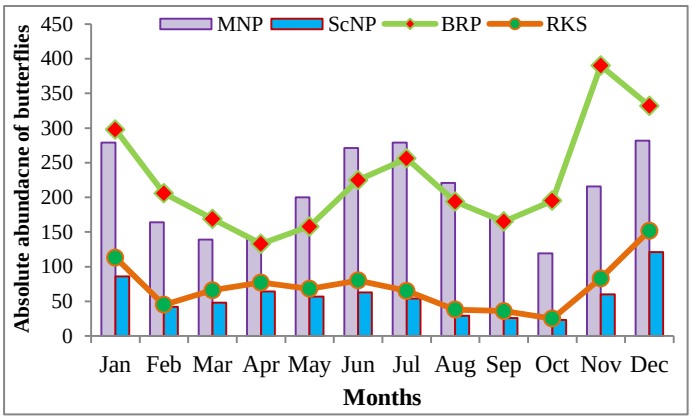


Fig. 8. Pattern of fluctuation in butterfly availability on different experimental sites during study period (2015-2017).

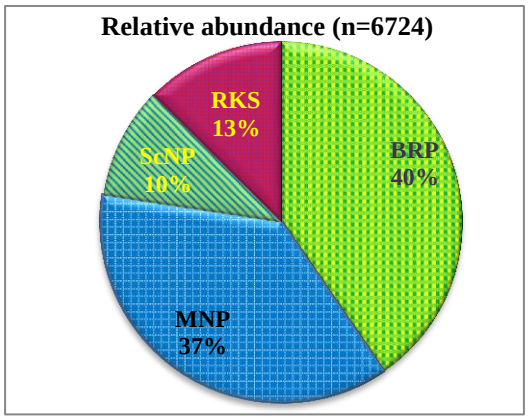


Fig. 9. Spatial pattern of lycaenid abundance in different experimental sites during study period (2015-2017).

The relative abundance of butterflies showed much temporal fluctuation during the study period in all the forests (Fig. 9). BRP showed the maximum amount of butterfly individuals with a covariance of 40% followed by MNP (37%), RKS (13%) and ScNP (10%).

In a habitat comparison of lycaenid butterflies, sixteen species of 25 examined species has been found available in all the experimental forest sites. Six species including *Tarucus callinara*, *Caleta decidia*, *Rapala airbus*, *Spindasis lohita*, *Rathinda amor* and *Tajuria cippus* was not found in ScNP and RKS when did sampling during study period. On the other hand, *Jamides alecto* was not found in BRP and MNP. No individual of *Rapala pheretima* and *Anthene emolus* has been observed in ScNP. Lycaenid individuals showed mark variation in numbers among different habitats. *Arhopala pseudocentaurus* was found the dominant species by its number in all the experimental sites. The least variation of lycaenid individuals has been marked in different forests. *Hypolycaena erylus* was recorded least number in BRP whereas *Rathinda amor* has fewer individuals in MNP. *Loxura atymnus* and *Anthene emolus* was assessed least numbers in ScNP and RKS, respectively (Table 9).

Table 9. Spatial pattern of lycaenid availability in different experimental sites.

Species	BRP	MNP	ScNP	RKS	Total
Pseudozizeeria maha	80	72	46	66	264
Zizina Otis	46	38	30	32	146
Chilades lajus	94	77	49	75	295
Chilades pandava	62	51	22	22	157
Catochrysops strabo	93	63	37	45	238
Tarucus callinara	38	22	-	-	60
Castalius rosimon	164	127	69	77	437
Caleta decidia	38	24	-	-	62
Jamides alecto	-	-	36	41	77
Jamides celeno	29	38	49	59	175
Lampides boeticus	67	42	26	38	173
Euchrysops cnejus	101	100	36	48	285
Anthene emolus	29	23	-	15	67
Arhopala pseudocentaurus	619	695	71	82	1467
Arhopala amantes	516	621	59	72	1268
Loxura atymnus	42	27	18	25	112
Rapala manea	178	122	33	42	375
Rapala pheretima	108	71	-	20	199
Rapala iarbus	61	36	-	-	97
Spindasis syama	39	39	22	25	125
Spindasis lohita	60	32	-	-	92
Remelana jangala	158	87	40	37	322
Hypolycaena erylus	25	22	30	27	104
Rathinda amor	31	19	-	-	50
Tajuria cippus	43	34	-	-	77
Total	2721	2482	673	848	6724

A significant difference (F=3.52, p-value=0.02) has been assessed using 'One-way ANOVA' test. The difference in the availability of butterflies among different habitats may indicate the differences in plant diversity among the forests. The highest numbers in BRP indicated the rich floral diversity related to lycaenid butterflies. The least amount of the butterfly numbers in ScNP may be because of the relatively less vegetation diversity associated with lycaenid butterflies.

Table 10. Correlation among the butterfly abundance in different study sites.

Study sites	BRP	MNP	ScNP	RKS
BRP	1			
MNP	0.99	1		
ScNP	0.61	0.59	1	
RKS	0.59	0.58	0.96	1

Though, the overall abundance of lycaenid population was varied among all the habitats, Pearson's rank correlation coefficient indicates a significant (95% confidence level) interhabitat relationship in the examined species (Table 10).

4.3.3 Temporal fluctuation of lycaenid population

The temporal fluctuations in the abundance are an important manifestation of populations' reponse to the environmental conditions (Arun and Vijayan 2004). Such seasonal variation in the abundance of a species is an adaptive phenomenon evolved through evolution to take maximum advantage from the ambient environmental conditions (Arun 2000). Regarding temporal abundance, lycaenid butterflies displayed highest abundance (13.19%) in December and lowest (5.38%) in October from three year data recording in all experimental forest sites (Fig. 10 and Fig. 11). But this phenomenon is altered in years (2015, 2016 and 2017) among habitats.

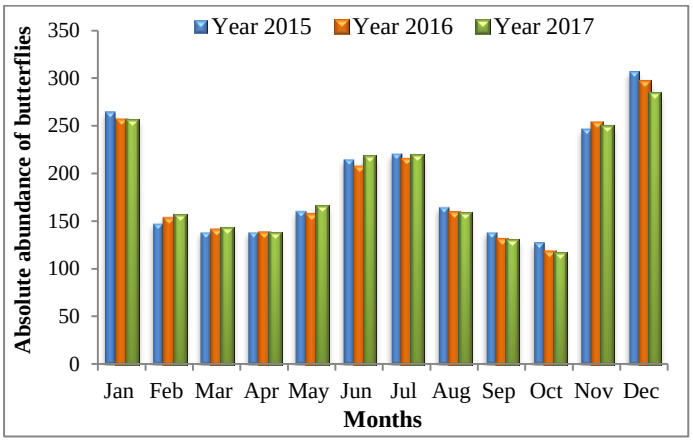


Fig. 10. Comparison of temporal fluctuation in butterfly availability in three year study period (2015-2017).

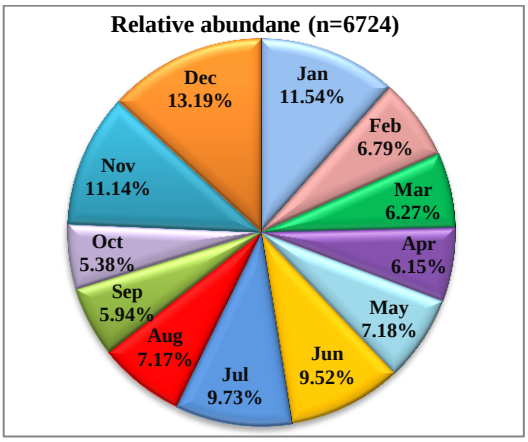


Fig. 11. Temporal pattern of lycaenid abundance during study period (2015-2017).

In 2015, highest number (125) of butterfly was recorded in November in BRP. On the otherhand, December was the lycaenid dominating month with 96, 42 and 52 individuals in MNP, ScNP and RKS, respectively. Similar pattern is found in BRP (November: 130 and 135), ScNP (December: 44 and 35) and RKS (December: 48 and 51) duing the year 2016 and 2017 except MNP. In MNP, the highest abundance was found in July (96) in 2016 and January (92) in 2017 (Appendix 6). The temporal fluctuation is independent on habitat type (Akand 2012). This pattern has also been found in the present investigation (Table 11).

Butterflies are short-lived insects and most of the species are found only in few months throughout the year. The present investigation reveals similar pattern in lycaenid species. The species abundance is varied in different months (Table 11). *Arhopala amantes*, *A. pseudocentaurus* and *Castalius rosimon* were common and found all the year round, whereas rest of the examined species were confined from three to six months in a year.

Table 11. Temporal pattern of lycaenid availability during study period from 2015 to 2017.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pseudozizeeria maha	39	3	-	-	29	66	38	-	-	-	37	52
Zizina Otis	22	-	-	-	4	49	23	-	-	-	12	36
Chilades lajus	-	6	37	70	25	-	-	43	76	38	-	-
Chilades pandava	23	-	-	-	-	-	-	-	-	26	50	58
Catochrysops strabo	-	9	78	119	32	-	-	-	-	-	-	-
Tarucus callinara	-	-	-	3	8	30	19	-	-	-	-	-
Castalius rosimon	61	45	21	19	18	6	21	30	17	51	78	70
Caleta decidia	14	3	-	-	-	-	-	-	-	-	14	31
Jamides alecto	14	-	-	-	15	18	6	-	-	-	6	18
Jamides celeno	21	-	-	-	27	26	13	-	-	2	32	54
Lampides boeticus	4	41	82	46	-	-	-	-	-	-	-	-
Euchrysops cnejus	-	17	53	100	92	23	-	-	-	-	-	-
Anthene emolus	12	2	-	-	-	-	-	-	-	-	15	38
Arhopala pseudocentaurus	97	59	43	23	114	206	273	218	162	131	93	48
Arhopala amantes	77	59	33	24	104	173	241	191	144	103	86	33
Loxura atymnus	30	-	-	-	-	-	-	-	-	-	23	59
Rapala manea	92	52	31	10	-	-	-	-	-	-	88	102
Rapala pheretima	51	29	11	-	-	-	-	-	-	-	50	58
Rapala iarbus	20	13	4	-	-	-	-	-	-	-	29	31
Spindasis syama	47	22	5	-	-	-	-	-	-	-	26	25
Spindasis lohita	27	35	3	-	-	-	-	-	-	-	13	14
Remelana jangala	63	48	21	-	-	-	-	-	-	11	74	105
Hypolycaena erylus	49	13	-	-	-	-	-	-	-	-	13	29
Rathinda amor	13	1	-	-	-	-	-	-	-	-	10	26
Tajuria cippus	-	-	-	-	15	42	20	-	-	-	-	-

This study has also disclosed that variation among months in a particular habitat was more prominent compared to that of other habitats in a particular months (Appendix 2, 3, 4 and 5). Depending on the species availability in the overall abundance data, January is the richest month including highest number (20) of species. On the other hand, August and September were the pitiable months containing only four species (Table 11).

In BRP, the maximum (19) species was being visible in January and minimum (3) in September (Appendix 2), whereas highest (18) species was appeared in November, December and January, and lowest (4) in the month of August and September in MNP (Appendix 3). In ScNP, maximum species (13) was found in January and minimum (4) in August, September and October (Appendix 4) while highest species (15) was noticed in November, December and January; and lowest in August and September in RKS (Appendix 5). Invariably in all the experimental forests lycaenid species showed their peak abundance in January and less number of species was visible in August and September.

'One-way ANOVA' was used to measure the butterfly availability among different months throughout the study period in overall species abundance. There was no significant difference (F=0.72, p-value=0.71) though highest number was recorded in

December. The differences in the availability of butterflies may specify the differences in plants availability and also the impacts of abiotic factors.

4.3.4 Role of abiotic factors on lycaenid population

Lycaenids prefer suitable abiotic factors and their entire life directly depend on temperature, relative humidity and other abiotic factors (Akand *et al*. 2016). An attempt was made to assess the relationship between selected abiotic factors (temperature and relative humidity) and the lycaenid abundance (individuals of species) in different habitats. Monthly temperature and relative humidity in different experimental forests has been tabulated in Appendix 8. During study period it was observed that the average temperature and relative humidity influences the presence of lycaenid butterflies. It has also been found that lycaenid butterflies demonstrated highest abundance (887) in 26.9°C temperature and 64% relative humidity whereas, least abundance (362) has been recorded at 31.7°C temperature and 77% relative humidity (Fig. 12).

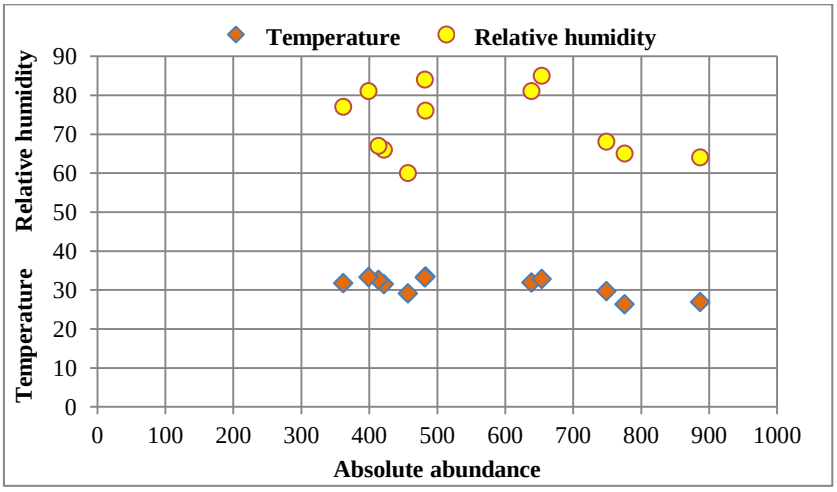


Fig. 12. Overall abundance of lycaenid butterflies with temperature and relative humidity.

The relationship between butterflies and climate is complex. The correlation between abiotic factors (temperature and relative humidity) and butterfly abundance (individual of specis) was calculated through the Spearman's rank correlation coefficient. The significant negative correlation found in between lycaenid abundance and temperature (r=−0.45, p-value=0.14). Similar correlation has also calculated in between lycaenid abundance and relative humidity (r=−0.19, p-value=0.54). The butterfly population increased with decreasing temperature and relative humidity in case of overall lycaenid abundance with average temperature and relative humidity during study period.

Changes in climate have a considerable effect on different stages in the life cycle of butterflies. Daily fluctuations in temperature and relative humidity are very important to butterflies and when they are subjected to extremes heavy mortality may result (Bashar 2015). It was observed that different climatic condition prevailed among different habitats due to their topographic and floral variation. That's why, lycaenid abundance has showed mark variation in different experimental forests depending variation of temperature and relative humidity (Fig. 13). In BRP, the highest temperature was recorded 35.2°C in September, 2015 and lowest temperature was 22.3°C in January, 2016. The highest relative humidity was 83% in June, 2017 and the lowest was 52% in February, 2015 (Fig. 13a, Appendix 8). This experiment reveals that, the butterflies show two peaks of abundance in a year; once is noticed in November and another during the months of June-July of the year. Of the two peaks the November-peak shows always with the greater in number of butterflies than that of the June-July peak. But the greater duration of the peak was recorded in the second peak (June-July) time. The significant negative correlation found in between lycaenid abundance and temperature (r=−0.56, p-value=0.003) while a positive correlation assessed in between lycaenid abundance and relative humidity (r=0.26, p-value=0.13). The butterfly abundance increased with decreasing temperature and increasing relative humidity. Similar patteren has been experienced by Akand *et al*. (2015b) and Akand *et al*. (2016) in Butterfly Research Park.

In MNP, the maximum temperature was recorded 34.6°C in May, 2017 and minimum temperature was 24.3°C in January, 2016. The uppermost relative humidity was 92% in September, 2017 and the lowermost was 57% in February, 2017 (Fig. 13b, Appendix 8). This study exposes that the butterflies display two peaks of abundance in a year; once in December-January and another during the months of June-July of the year. Of the two peaks the December-January peak indicates the greater in number of butterflies than that of the June-July peak. But the greater duration of the peak was recorded in the second peak (June-July) time. The significant negative correlation found in between lycaenid abundance and temperature (r=−0.28, p-value=0.11) while a positive correlation assessed in between lycaenid abundance and relative humidity (r=0.24, p-value=0.16). According to the current examination similar pattern has been found in Butterfly Research Park (BRP).

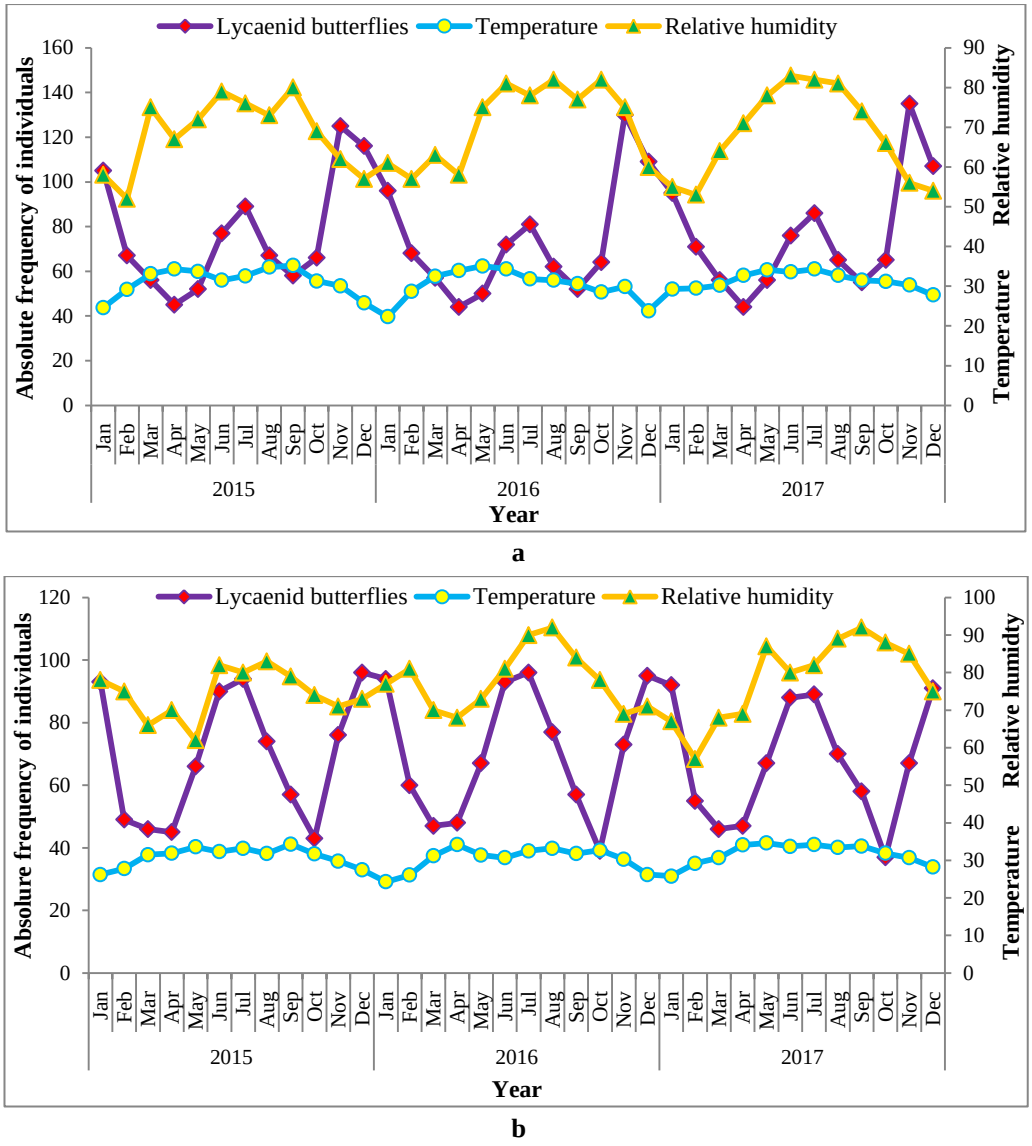
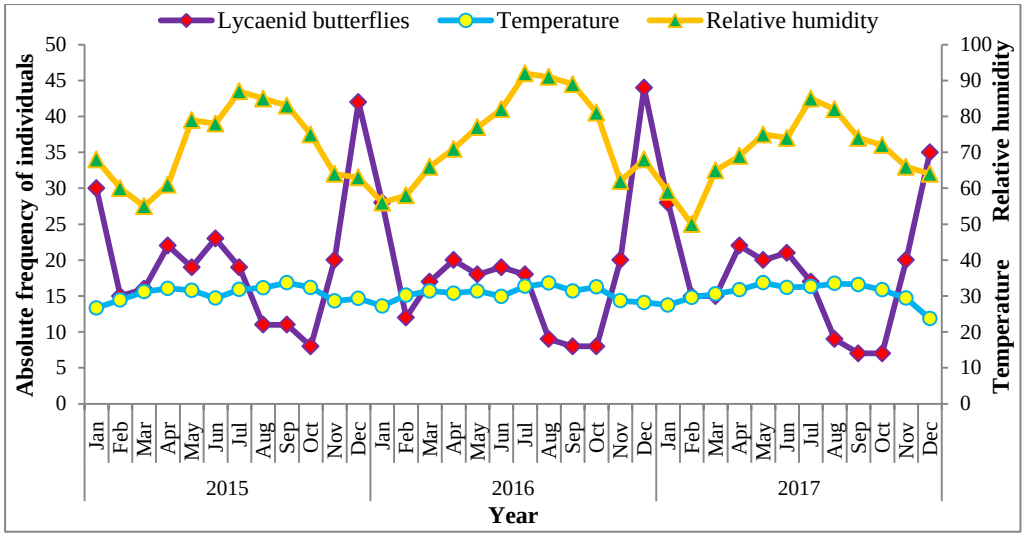


Fig. 13. Abundance of lycaenid butterflies with temperature and relative humidity in experimental forests: **a**. BRP; and **b**. MNP.

In ScNP, the highest temperature was recorded 33.7°C in September, 2015 and lowest was 23.7°C in December, 2017. The maximum relative humidity was 92% in July, 2016 and minimum was 50% in February, 2017 (Fig. 13c, Appendix 8). The present investigation discloses that the butterflies exhibit three peaks of abundance in a year. Among them the topmost one was found in December including the greater number of butterflies while two small peaks were observed during the months of April and June of the year. There was a strong and significant negative correlation found in between lycaenid abundance and temperature ($r=-0.61$, p-value<0.001). A significant negative correlation assessed in between lycaenid abundance and relative humidity ($r=-0.38$, p-value=0.02). The lycaenid population increased with decreasing temperature and relative humidity. But different pattern has been found in BRP and MNP by this experiment.



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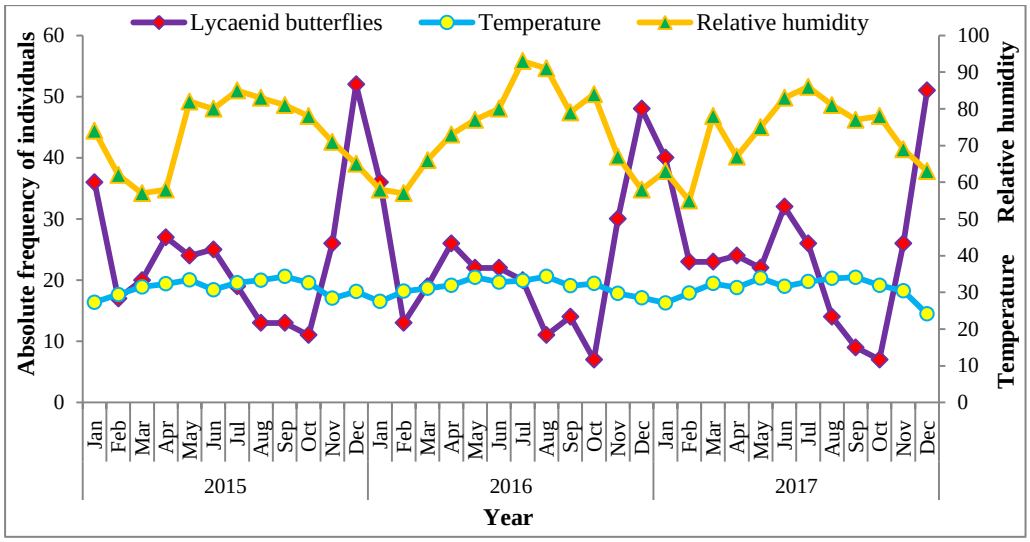


d

Fig. 13. Abundance of lycaenid butterflies with temperature and relative humidity in experimental forests: **c**. ScNP; and **d**. RKS.

In RKS, the maximum temperature was recorded 34.3°C in September, 2015 and August, 2016; and lowest was 24.1°C in December, 2017. The highest relative humidity was 93% in July, 2016 and lowest was 55% in February, 2017 ((Fig. 13d, Appendix 8). This examination reveals that the butterflies demonstrate three peaks of abundance in a year. Among them the highest one was found in December with the greater in number of butterflies while two small peaks were observed during the months of April and June of the year. There was a strong and significant negative correlation found in between lycaenid abundance and temperature ($r=-0.63$, p-value<0.001). A significant negative correlation measured in between lycaenid abundance and relative humidity ($r=-0.41$, p-

value=0.02). The lycaenid population increased with decreasing temperature and relative humidity. Similar pattern has been observed in ScNP by this experiment.

The comparison of population fluctuation among different habitats reveals that the lycaenid population may be controlled by the common microclimatic factors. Although individually insignificant, abiotic environmental factors such as temperature and relative humidity in combination displayed a significant relation with butterfly abundance (Arun 2000, Akand 2012). These factors influence the plant-flowering stages in the forest ecosystem. The flower abundance is the major factor affecting the seasonal fluctuation of butterfly population. The lycaenid species fluctuates along with its own ecological necessities.

4.4 Discussion

With quantitative data on lycaenid populations gathered from different habitats, the current investigation has demonstrated the dynamics of butterfly population across seasons and habitats. Understanding the spatial and temporal scales at which environmental variation affects populations of plants and animals is an important goal for modern population biology (Pardikes *et al*. 2015). The present study is intended to reveal the seasonal patterns in butterfly populations, and interactions among them, the plants on which they depend, and their ecoclimate. Among the experimental forest sites, lycaenids were more abundant in Butterfly Research Park than others. It indicates the availability of lycaenid related plants and favourable microclimatic conditions. Each habitat has a specific set of microenvironment suitable for a species as stated by Ramesh *et al*. (2010).

Lycaenid butterflies in all habitats displayed a highly seasonal trend as examined by Kunte (1997). The peak of species richness and abundance of butterflies was recorded in the month of November and December. Researchers reported the similar findings of lycaenid abundance (Kunte 1997, Arun 2000, 2003, Arun and Vijayan 2004, Mathew and Anto 2007, Tiple and Khurad 2009, Hussain *et al*. 2011, Akand 2012, Akand *et al*. 2015b, 2016). Temporal changes in the abundance of lycaenid butterflies can be related to the adult food sources (Hill 1992). Most of the observed species was associated with herbs and shrubs. These plants are in flowering stage in the month of November, December and January of a year. The lycaenids were synchronizing with the presence of their adult food plants. Butterflies of other family were less abundant and not herb feeder equally in this

period (Kunte 1997). It is a consequence of resource-based interspecific competition for nectar-sources in adult butterflies (Akand 2012).

Butterfly plays a great deal in maintaining the ecosystem. They are sensitive to the changes in habitat and climate, which influence their distribution and abundance (Wynter-Blyth 1957). Butterfly species should be continuously monitored to observe any kind of changes in an ecosystem. Bashar (2010) described climatic change affects phenological changes in plants. And plant's phenological, temporal and seasonal alterations influence the life cycle of the butterflies. Any abnormal change in the life cycle of buterflies affects the butterfly populations in an area. So, by observing the population fluctuation visiually, 'climate change' forecasting can be measured. Evangeline and Santhi (2016) indicated that long term assessment and monitoring of both butterfly abundance along with environmental factors are warranted to achieve better understanding and to arrive at factors responsible for abundance. Bashar (2010) has found very significant result on the question of utilizing butterflies as "biotic indicators" for monitoring climatic change impacts on biodiversity of forest ecosystems in Bangladesh. Bashar (2015) also contended that abundance of characteristic status of butterflies and their activities indicate very distinctly the healthiness of a forest. They can indicate the dominating plant species in a forest and also can indicate whether the forest is going to be critical stage very soon or not. Therefore, the present study is a special effort for knowledge amalgamation about the fluctuation pattern of lycaenid population in different habitats with biotic and abiotic influence. Further researches on lycaenid diversity in forest ecosystem and the factors that affect their population dynamics will be rewarding experience.

BEHAVIOURS OF LYCAENID BUTTERFLIES AND THEIR SIGNIFICANCE WITH THE RELATED PLANTS

5.1 Introduction

A tremendous field lies open in the study of Lepidopteran behaviour (Krishnakumar 2008). The butterfly behaviours are resulted from the functional activities evidenced in every stages of life cycle (Bashar 2015). At any specific time, encompasses a butterfly's behaviours in singular and variable order, with local modulations of circumstance, and manifesting the distinctive expressions of the individual animal (Akand 2012). Various ethological activities of a butterfly performing during its life time are categorically arranged in this text.

Emergence of a butterfly from its pupa is to describe as eclosion. The patterns of adult emergence are important considerations in biological design at the population level. Temporal variability in patterns of adult emergence is caused by a number of factors ((Taylor 1981). In relatively uniform habitats emergence times are determined primarily by weather conditions and temperature dependent development rates (Taylor 1981, Currey and Feldman 1987). Variability in emergence times in such environmentally homogeneous settings is determined largely by genotypic and phenotypic variation among individuals (Currey and Feldman 1987). In more heterogeneous habitats, microclimatic gradients also can affect development rates and timing of emergence of individuals distributed across those gradients (Waterhouse 1960, Allen and McCoy 1979, Williams 1981). Availability of mates, avoidance of weather extremes, access to resources, and offspring survival all depend upon synchrony between adult emergence and resource availability (Allen and McCoy 1979, Stedinger *et al.* 1985).

Adult insects must look for and find suitable nutrients to enhancement their diets sustaining daily life activities and reproduction (Tang *et al*. 2013). Insects like butterflies are known to exploit a variety of sensory modalities in foraging, and the integration of visual, olfactory, and gustatory cues are usually involved in their orientation to and finding of food sources (Barth 1991). They are considered as representatives of flower-visiting insects (Jennersten 1984). One of the most characteristic behavioural traits of adult butterflies is that they visit flowers to feed on nectar (Stefanescu and Traveset 2009). Floral nectar is the most common type of food for adult butterflies in general (Krenn 2008). Butterflies possess long and coilable proboscis which enables the insects to

suck liquid food (Krenn and Muhlberger 2002). Proboscis is very adaptive and vital organ in the adult butterflies (Bashar 2014). Butterflies visit a wide range of flowers (Sharp *et al*. 1974). They can forage the vegetation of the soil surface layer, undergrowth layer and also the plants of the canopy layer (Bashar *et al.* 2015a).

The flower-visiting behaviour of adult butterflies is affected by the colour and odour of flowers, which provide specific information for adults (Weiss 1997, Andersson and Dobson 2003, Borges *et al*. 2003). Flower scent is an olfactory stimulus that influences butterfly visits to flowers (Andersson 2006, Omura 2006). The other factors responsible for different flower preferences of butterflies include proboscis length (Cruden and Hermann-Parker 1979, Porter *et al.* 1992), corolla tube length of flowers, and nectar quality, quantity and concentration (Ilse 1928, Erhardt 1991a, Weiss 1995). The effectiveness of butterfly foraging depends in part on corolla depth, clustering of flowers, but also on proboscis length, which limits the range of flowers from which nectar can be extracted (Porter *et al.* 1992, Corbet 2000).

Butterflies frequently visit flowers that are rich in nectar. The quantity of nectar sugar per flower is necessary for successful foraging (Akand 2012). Many important life-table parameters, including longevity, fecundity, egg weight, fertility, and mating success, are positively affected by adult nutrition (Boggs 1997b).

Butterflies are important component of ecosystem mainly because of their pollination activities (Daily *et al.* 1997). The foraging activity of butterflies benefits the plant species to achieve pollination (Rani and Raju 2016). During feeding, pollen grains stick to pollinators allowing their transportation to conspecific plants thus increasing genetic variability (Price 1984). In exchange for pollen transportation, pollinators often receive a nectar reward (Pellmyr 2002). The behaviour of pollinators (visit frequency and movement between flowers) is influenced by the quality and quantity of rewards offered by flowers (Waser 1983, Real and Rathcke 1988).

Fruit feeding butterflies feed on rotting fruits, tree sap and some other decaying organic matter (Young 1975, DeVries 1987). Two potential feeding techniques in fruit-feeding butterflies are ‘piercing’, when the proboscis is inserted into fruits and ‘sweeping’, when the proboscis tip is applied to the fruit surface (Young 1975, Krenn *et al*. 2001). Fruit-feeding butterflies, in contrast to nectar-feeding butterflies, appear not to have distinctive preferences for amino acids or salts, but do share a common primary preference for

sucrose (Dierks and Fischer 2018). In butterflies, changing between nectar feeding and fruit feeding requires major changes in key variables of foraging behaviour (Molleman *et al*. 2005a). A diet shift is likely to be accompanied by adaptations that optimize foraging and feeding behaviour on novel food. This kind of dietary shift of butterflies is likely the result of evolutionary stratagem to reduce resource competition among them (DeVries 1988).

'Puddling' behaviour is commonly seen in butterflies. This behaviour is usually predominantly shown by young males (Adler 1982, Larsen 1996) as a means of acquiring salts, most commonly sodium, as well as other nutrients (i.e. amino acid) (Beck *et al*. 1999, Molleman 2010). It is thought to be a form of supplementary feeding, not targeted at obtaining energy, but at specific micronutrients (Molleman 2010). Sodium gathered by male butterflies during puddling is transferred, sometimes in large amounts, to their female mates via nuptial gift that increases reproductive success (Adler and Pearson 1982, Pivnick and McNeil 1987, Smedley and Eisner 1996). The nutrients absorbed during puddling play various roles in butterfly physiology and eco-ethological activities.

Butterflies have been used extensively as model animals for the study of thermoregulation and the coevolution of morphology and thermoregulatory behaviour (Clench 1966, Wasserthal 1975, Kingsolver 1985c, 1985d, Rutowski *et al*. 1994, Srygley 1994). The physical structures (viz. wing size and thorax) ultimately limit thermoregulatory capacity; and behavioural changes (i.e. basking, body postures) greatly affect heat gain and loss (Heinrich 1972, Kingsolver and Moffat 1982). These allow butterflies to keep their body temperature close to the ideal for flight, foraging, etc. (Kingsolver and Wiernasz 1987, Kleckova *et al*. 2014). Butterflies regulate their heat gain by behavioural changes including microhabitat selection, frequency of basking and subtle changes in basking posture (Kingsolver 1983a, Kingsolver and Watt 1984).

Basking is a vital factor of butterfly biology. Butterflies raise their body temperature by basking in sunlight (Casey 1988, Dennis 1993). During basking, the wings are held vertically over the dorsum; and the body and wings are oriented perpendicular to solar radiation; during heat-avoidance behaviour, the butterfly orients parallel to radiation (Kingsolver and Watt 1984). In lycaenid butterflies, basking may be dorsal basking when the heat absorption is increased by spreading the wings, angling the exposed surface and making a more direct contact with the substrate which is warmer or lateral basking when the wings are clasped above the bodies and their ventral surface perpendicular to the sun's rays (Akand 2012).

Behavioural thermoregulation works mainly by changes in the timing of daily activities or exploration of various (micro) habitats (Turlure *et al*. 2010, Lawson *et al*. 2012, Bennett *et al*. 2015). The ability to use locally suitable microhabitats facilitates species survival under ongoing climate change (Sunday *et al*. 2014). Behavioural thermoregulation could also limit physiological adaptation, which is necessary for species' long-term survival (Buckley *et al*. 2015, Bogert 1949, Huey *et al*. 2003). Interspecific differences in behavioural thermoregulation could modify the effect of extreme air temperatures and lead to different responses to external thermal constraints (Kleckova and Klecka 2016).

Butterflies remain inactive during a particular period in a day. This is known as resting behaviour (Bashar 2015). This happened at night or at low intensity of sun light or adverse weather condition. Sometimes they may take rest for a while in between egg laying condition or in between foraging from different flowers. Butterflies hang themselves on the upper side or underside of leaves of the bushes, hedges or trees to take rest (Bashar 2012a).

Butterflies reproduce the way other animals do. For this purpose, both sexes should come in contact through a process known as 'mating'. It is biologically interactive process between male and female exchanging genetic materials through the rhythmically function of related organs (Bashar 2014). So, the mating process is very much characteristic to the species concerned. The adult butterfly spends much of its time in search of a mate. Male butterflies adopt four main mate location strategies i.e. perching, patrolling, territorial defense, and lek assembly (Shields 1967, Baker 1984, Scott 1974, Davies 1978, Rutowski 1991). Perching males initiate mating by flying up from perch sites to court females that enter the mating area, while patrolling males fly to locate mates (Shreeve 1984). Males perching on or near to key resources waiting for females to approach, whether it is a host plant, patch of nectar flowers, or sunspot, can readily be observed establishing and defending territories from other males (Lederhouse *et al*. 1992, Takeuchi and Imafuku 2005). Males may also employ a strategy known as 'hilltopping' or lekking (Prieto and Dahners 2009). Hilltopping involves males congregating in areas with few or no classic resources (i.e. consumer resources, such as host or nectaring plants) (Bennett *et al*. 2010). Visual factors are important during courtship include movement, size and general colour (Scott 1973). Chemical cues, such as the pheromones commonly used among butterflies (Estrada *et al*. 2010). Butterflies show several courtship behaviours to initiate mating process. Courtship leading to copulation began when a male approached a perched or

flying female (Opler and Wright 1999). A flying female was chased by a male until she alit on vegetation. A perched receptive female usually remained still with her wings folded as a male approached. The male then alit behind the female and moved alongside her with his head oriented in the same direction as hers. The male then curled his abdomen toward the female, probing between her hind wings until he attained genital contact. After coupling, the male turned to face away from the female. During mating, some females took flight, carrying the male with his wing close, suspended head-down from her abdomen. Mating ended when the pair uncoupled.

Egg laying is considered a major force in the evolution of behaviour in Lepidoptera (Renwick and Chew 1994, Rausher 1979b). Female butterflies usually oviposit only on those plants, which are suitable for larval growth and survival. Sight, smell, touch and taste are involved in selection for oviposition (Arnyas *et al.* 2006). Once a host plant is accepted, females have to find the best place on (or near) the plant where they can lay their eggs; nevertheless they are often found to oviposit on sites not optimal for the fitness of their offspring (Rausher 1979b, Chew and Robbins 1984, Higashiura 1989). The relation between adult oviposition preference, and on one hand larval host choice, as well as larval success on the other, is closely related and both are taken into account in studies of plant-insect relationship (Nylin and Janz 1993, Pires *et al.* 2000, Craig *et al.* 2000, Harris and Griffin 2001).

The butterfly larva of family Lycaenidae is involved in association of ants, termed myrmecophily, which ranges from co-existence to specific mutualistic, sometimes even parasitic interactions. These interactions are mediated by secretions of specialized epidermal glands. The dorsal nectar organ and the paired tentacle organs are the two most important of these glands. The dorsal nectar organ secretes food droplets which contain nutrients like carbohydrates and amino acids from the larvae to the ants. A second way to achieve these interactions is through manipulative communication with the aid of odour signals which is done by tentacle organs (Baumgarten and Fiedler 1998). Myrmecophily allows the butterflies to avoid ant predation and some species gain protection through attendant ants or even get developmental benefits from ant-attendance (Fiedler *et. al.* 1996).

On the basis of all above mentioned thought the present investigation has been envisaged by following objectives.

5.1.1 Objectives

The present study has been designed

- to examine the eclosion of lycaenid butterflies and their emerging duration;
- to recognize the behavioural changes of lycaenid butterflies with related plants;
- to study the feeding behaviour of lycaenid butterflies;
- to observe the foraging behaviour with time budget;
- to know about the nectar production of plants;
- to assess the nectar volume of flowers;
- to examine the effects of floral nectar quantity on butterfly visit to plants;
- to observe the structural variation of proboscis length in lycaenid butterflies;
- to ascertain the structure of pollen grains of lycaenid related plants;
- to observe puddling behaviour of lycaenid butterflies;
- to perceive the basking behaviour and variation of wing postures;
- to record basking time budget of lycaenid butterflies;
- to distinguish how thermoregulation associates with other behavioural activities;
- to observe the resting behaviour of lycaenid butterflies;
- to study the courtship and mating behaviours;
- to examine the egg laying behaviour of lycaenid butterflies on their host plants; and
- to know the myrmecophilous behaviour of immature lycaenid butterflies.

5.2 Material and methods

The following techniques and procedures have been adopted to alleviate the results to complete the present investigation. These are described as below-

5.2.1 Studied species

Lycaenids are small to medium-sized butterflies which are easy to observe. They found in all habitats including forests and open cultivated areas. Lycaenid butterflies have been selected to explore their behaviours and their significant related plants in the present chapter. Species were identified following the procedure of Bingham (1907), Eliot (1973), Akand (2012), Bashar (2014) and Ahmed *et al*. (2009).

5.2.2 Study period

The present study has been carried out during the period from January 2015 to December 2017. The findings have been amassed based on laboratory and field investigation.

5.2.3 Selected sites

The field study has firm up in Butterfly Research Park, Madhupur National Park, Satchori National Park and Rema-Kalenga Wildlife Sanctuary. Several observations have been completed in Botanical Garden of Bangladesh Agriculture University, Mymensing, and Curzon Hall area in University of Dhaka. The experimental sites are described details in Chapter 3.

5.2.4 Materials for data collection and observation

Several materials have been employed for this experiment including paper and pencil for data collection along with measuring scale to assess proboscis length of butterfly and flower corolla length. Different digital cameras (describe in Chapter 3) were essential equipment for this study to catch photo of live butterfly's activities.

5.2.5 Experimental procedures

The behavioural activities of lycaenids in the study sites were observed and recorded through a constant walk for 10-15 minutes. The study was made twice in a month between 9.30 a.m. and 4.30 p.m. This observation was done using the transect method followed by Pollard and Yates (1993) and Latin square method by Rao and Richard (2006). The methods described details in Chapter 3. The behavioural activities of some lycaenid butterflies were examined following the procedures of Jones (1983), Price *et al*. (1991), Kemp and Krockenberger (2002), Kingsolver (1985a, 1985b), and Bashar (2015). The observations of behavioural activities of butterflies on their related plants were studied throughout the year in different experimental sites.

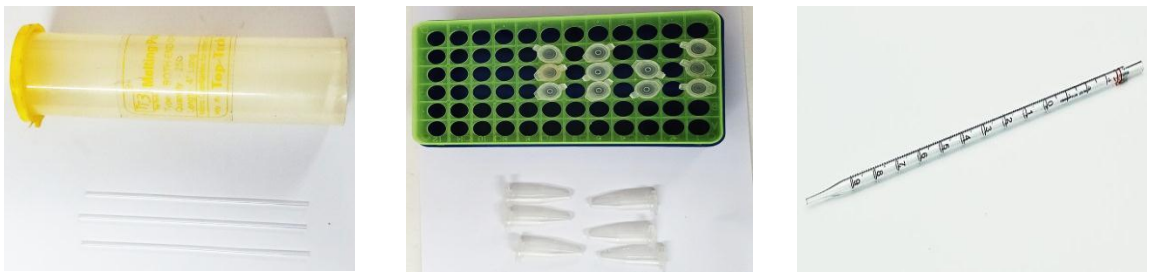
5.2.5.1 Observation on the visit of butterflies to flowers for nectar collection

Over the course of study keen observation has been made on the nectar flower visits of lycaenid butterflies in the experimental sites. The records were kept on the flower visit of butterfly species for nectar feeding, how many species visit the flowers at a time or in a day of the same species. The activities of lycaenids during nectar feeding were also

witnessed. The visit duration on flowers has been determined. The nectar searching duration was recorded by observing their wing movements. The visit duration for nectar feeding has been calculated from the moment of dipping the proboscis into the flower corolla till the moments of its withdrawal. The total range of each individual's nectar feeding behaviour was noted on a field recording sheet plan. The number and species of all butterflies on each plant were also recorded. The separate pages of sheet plan were used to record the separate individual nectar feeding behaviours of butterflies.

5.2.5.2 Procedures followed in nectar collection

Methods to measure the volume, sugar contents and energy value of nectar are used in the study of many ecological processes (Dungan *et al*. 2004), in particular the study of plant-animal interactions (Bolten and Feinsinger 1978, Kearns and Inouye 1993). Several methods are available to sample nectar, and selecting the best one can be difficult (Lloyd *et al*. 2002). Floral nectar was collected from five different plant species between 11 am to 3 pm during present investigation. The presence of nectar in a flower was detected by gently pulling the flower from its calyx and firmly pressing its corolla base against a hard surface. A droplet of nectar appeared when a flower contained it. Micro capillary tubes and micro tubes are commonly used in the field for collecting and measuring nectar volume, respectively (Morrant *et al*. 2009). Micropipettes and micro syringes can be used instead of micro capillary tubes to achieve similar results (Kearns and Inouye 1993). Nectar can be collected in different ways depending on the structure of flowers. During present investigation, material like micro capillary, micro tubes, and glass pipette were used for nectar collection and measuring the nectar volume, respectively (Plate 36).



a **b** **c**

Plate 36. Materials used for nectar collection: **a**. capillary tubes; **b**. micro tubes; and **c**. glass pipette.

Floral nectar has been collected through a series of collecting process using micro capillary and micro tubes following 'EBBL-model for nectar collection' (Plate 37). First, an inflorescence or a flower has been plucked off from the plant to collect nectar (Plate 37a). Then the corolla tube of the flower was pressed off from upper to lower part

through two fingers and the drop of nectar was taken in capillary tube (Plate 37b, 37c, 37d, 37e). The nectar collected in the capillary tube was taken in a micro tube by whipping (Plate 37g). After repeating the process an amount of nectar was collected from a number of flowers, e.g. *Ixora coccinea.* A glass pipette was used to measure the volume of collected nectar. The collection of nectar can be done depending on the placement of nectary. The described process is suitable if the nectary present inside corolla tube of flowers. All the examined flowers have the nectary inside corolla tube.

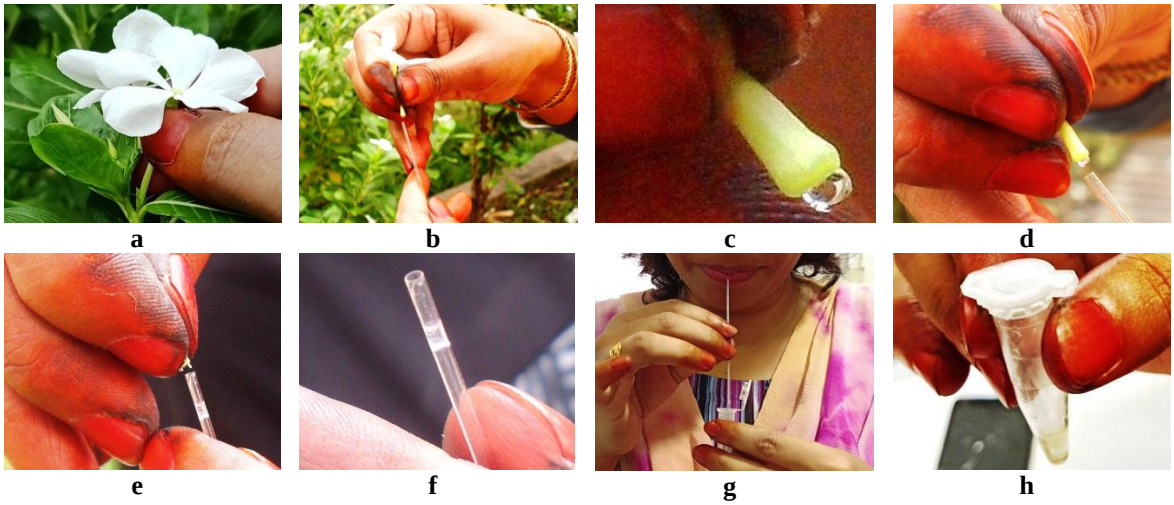


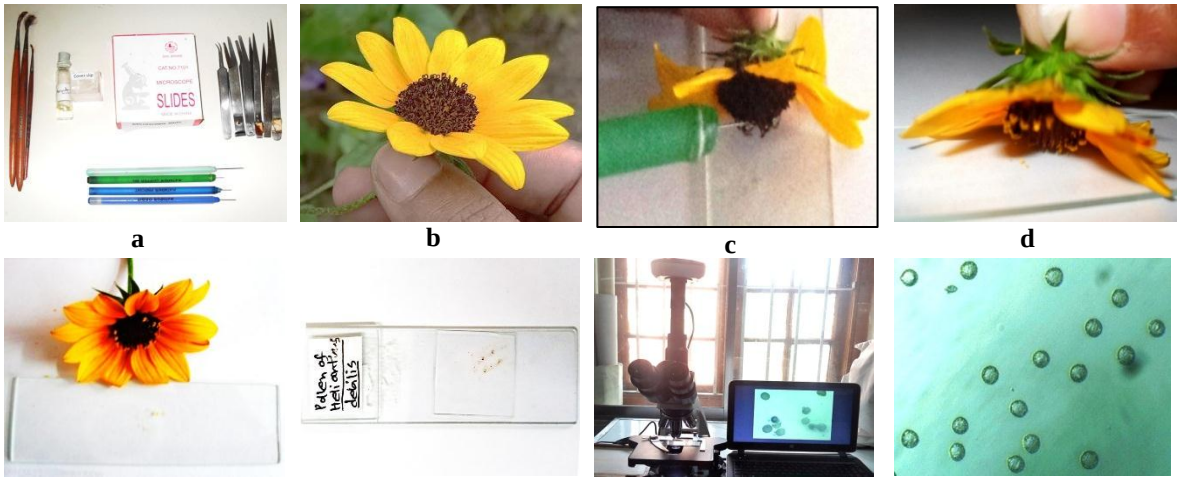
Plate 37. Procedural illustration displays nectar collection through capillary tube technique: **a**. pluck a flower from plant (*Catharanthus roseus*); **b**. corolla tube pressed off through two fingers; **c**. the drop of nectar; **d**. and **e**. nectar drop transfer to capillary tube; **f**. capillary tube with nectar; **g**. transfer nectar from capillary tube to micro tube by whipping; and **h**. micro tube with nectar for further procedure.

The effectiveness of a chosen technique for nectar collection is influenced by floral morphology, nectar characteristics and sampling regime (Bolten and Feinsinger 1978, Kearns and Inouye 1993, Lloyd *et al*. 2002). Prior to the preservation nectar was kept in microtubes. After that it should be stored at -20˚C until ready for further analysis.

5.2.5.3 Collection and examination of pollen grains

For the study of pollen grains, pollen samples were collected from the study areas. Several materials (viz. forceps, needles, brush, slides and cover slips) have been used to complete this procedure (Plate 38a). Selected flowers have been plucked off from the plant (Plate 38b) and brought to the laboratory for further process. With the help of dissecting needles the anthers were removed from the filaments and placed on a glass slide to release pollen grains on the slide (Plate 38c, Plate 38d). After the releasing of pollen grains on the glass slide the extra part of the anthers was cleaned. Then the Canada bolsom was added to the glass slide and the cover slip was placed on it. Then the glass

slide was labeled (Plate 38f). The prepared slides with pollen grains were studied under the complex light microscope (Plate 38g). After that their size, shape were observed by using the HP laptop connected with the microscope (Plate 38h). The sizes of pollen grains were measured by using the µm scale. Photographic presentation (Plate 38) indicates the sequence of pollen collecting process and observation.



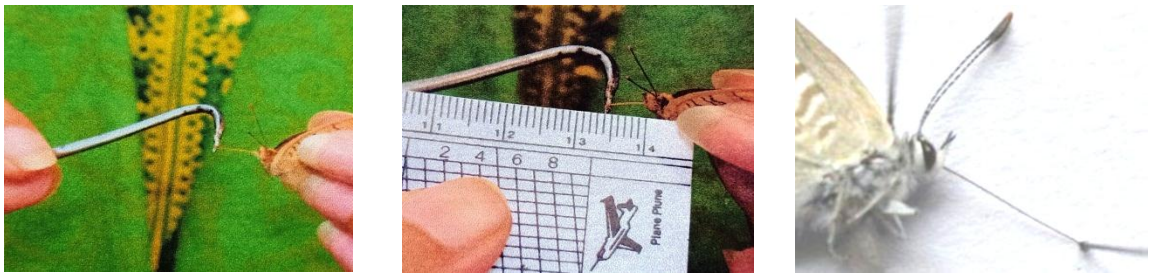
a **b** **c** **d**

e **f** **g** **h**

Plate 38. Process of preparing slides with pollen grains from flower and observation: **a**. pollen collecting materials; **b**. pluck a flower from plant (*Helienthus debilis*); **c**. remove anthers from flowers by needle; **d**. releasing pollen grains on slide; **e**. pollen grains on slide; **f**. prepared slide with pollen grains; **g**. observation of pollen grains in prepared slide under microscope connected with laptop; and **h**. capture picture through camera connected with microscope.

5.2.5.4 Measurement of the proboscis length

The proboscis length of lycaenid butterflies has been measured by capturing them in the field during study period (Plate 39). In live butterfly, a needle has been inserted in the centre point of coiled proboscis and straightening the proboscis out. Then the length was measured as the distance between the base of labial palps and the tip of the proboscis.



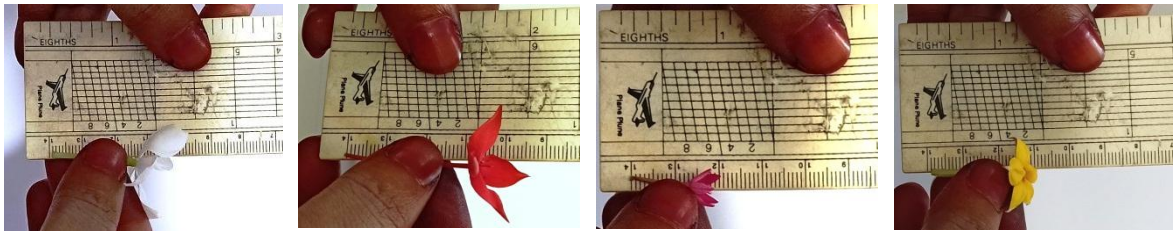
a **b** **c**

Plate 39. Procedure for the measurement of proboscis length: **a**. insertion of a needle into the centre point of the coiled proboscis; **b**. measuring through a scale; and **c**. straightened proboscis.

5.2.5.5 Measurement of flower corolla length

To measure the flower corolla lengths, flowers have been collected in plastic bags and kept them moist until they could be examined. The length of the corolla tube of flower

was measured from the base to the top of the corolla (Plate 40). The top is the entrance of the corolla at the point where only a proboscis can enter. The procedure of corolla length measurement has been followed by Kunte (2007). Photographic presentation (Plate 40) indicates the corolla length measurements of some selected flowers.



a **b** **c** **d**

Plate 40. Measurement of flower corolla length: **a**. *Catharanthus roseus*; **b**. *Ixora coccinea*; **c**. *Pentas lanceolata*; and **d**. *Mussaenda frondosa*.

5.2.5.6 Procedures for the observation of basking behaviour

Basking posture of a butterfly is described in terms of two parameters: the position of the wings relative to the body; and the position of the body relative to the sun. The various basking postures of butterflies can categorize using these parameters of wing angle (**θ**) and body orientation angle (**γ**). Following the methodology, butterflies represent five different types of wing postures for the regulation of thoracic temperature. The postures are appressed, horizontal, angled, closed sun and closed shade wing patterns (Plate 41). Appressed posture occurs when wings tip downwards to ground. Individuals bask in the sun with their wings fully spread and angled downwards so that the distal edges are appressed to the substrate (the 'appression' posture). This posture creates a tent-like area between the wing surface and the basking substrate. In horizontal posture, wings are flat or fully open at 180° or 90° angle to the solar radiation. The dorsal surfaces of the thorax and the wings are positioned perpendicular to the sun (γ=0° θ=90°). Wings tip are opposite to ground (less than 180°) in angled posture and the forewings are only open at a small angle (γ=0° $\theta \geq 5°$). Butterfly opens its wings at 5-90° angles to the incident solar radiation and involves the wings as solar reflectors that reflect radiation onto the body.

a **b** **c** **d** **e**

Plate 41. Different basking postures of butterfly: **a**. Appressed (*Junonia atlites*: Nymphalidae); **b**. horizontal; **c**. angled; **d**. closed sun (b, c, d-*Lampides boeticus* (♂): Lycaenidae); and **e**. closed shade (*Melanites leda*: Satyridae).

Closed posture takes place when wings are closed together at 90° angle from the ground. In this case, the wings are folded tightly over the dorsum and orient the body and ventral wing surfaces perpendicular to the sun (γ=90° θ=0°). In closed sun posture, butterfly exposes its body and wings to direct sunlight. In closed shade posture, only the body and a small part of the wings are exposed to sunlight from the above. The description of basking postures is given here following the methodology of Kingsolver (1985c), Kemp and Krockenberger (2002), Bashar (2015), and Kamrunnahar *et al*. (2018). The butterfly basks with horizontal, closed and angled wing posture is designated as dorsal, lateral and reflectance basker, respectively (Kingsolver 1985b).

5.2.6 Time budget procedures

Time budget is a system of indexes characterizing the distribution of time expenditure (by days, weeks, months, years). To determine the time budget, special studies are conducted, in the process of which the time expenditures are considered for specific time intervals and in accordance with an accepted classification system (in hours, minutes and seconds of the given fund of time). To assess the foraging time budget of lycaenid butterflies respective walks has been undertaken around the study areas. Observation was made by following the selected butterflies with their related plants. Visit frequency and the duration of each visit were also recorded. A time frame was made ranging from 0-6, 7-12, 13-18, 19-24, 25-30, 31-36, 37-42, 43-48, 49-54, 54-59, 60-66, 67-72, 73-78, 79-84 and 85-90 seconds. A special time frame is maintained in case of *Spindasis lohita* during its visit on the plant *Micromelum minutum* (Family: Rutaceae). This butterfly spent maximum 900 seconds or 15 minutes on the respective plant. The lycaenid butterflies and their puddling duration on different substratum were recorded. Each individual was examined at least for 10-15 minutes while butterfly was performing puddling behaviour.

Different types of basking posture and the duration for their basking were also recorded over the study period. A time frame was made ranging from 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-100, 101-110, and 111-120 seconds. The number of basking in different status, such as horizontal, angled and closed sun were counted based on the time frame. A time frame ranging 9.00-10.00, 10.00-11.00, 11.00-12.00, 12.00-13.00, 13.00-14.00, 14.00-15.00 and 15.00-16.00 was also made in day time from 9 am to 4 pm. Observation was done in each hour to record pre-mating and mating frequencies of lycaenid butterflies in different experimental sites.

5.2.7 Analysis of data

The Pearson's rank correlation and ANOVA has been practiced to assess relationship and differnces between different events of lycaenid behaviours. Average and standard deviation was also calculated. All these statistical analyses were done by SPSS for windows (Version 16). Microsoft Office Excel 2010 was used to draw graph, table and figure.

5.3 Results

Butterflies are full of mysterious activities during different stages (from egg to adult) of life cycle (Bashar 2015). The adults exhibit a surprising range of behaviour including courtship and mating, egg-laying, basking, resting, puddling, and most common foraging behaviour (Akand 2012). Immature stages (larva or pupa) of lycaenid butterflies are attendant with ants, exhibit a special type of behaviour known as myrmecophilous behaviour. Male and female butterflies of any given species usually behave very differently. In most species the males are highly active, and their behaviour follows a predictable cycle of feeding, basking, and patrolling in search of females. Female butterflies live entirely different lives.

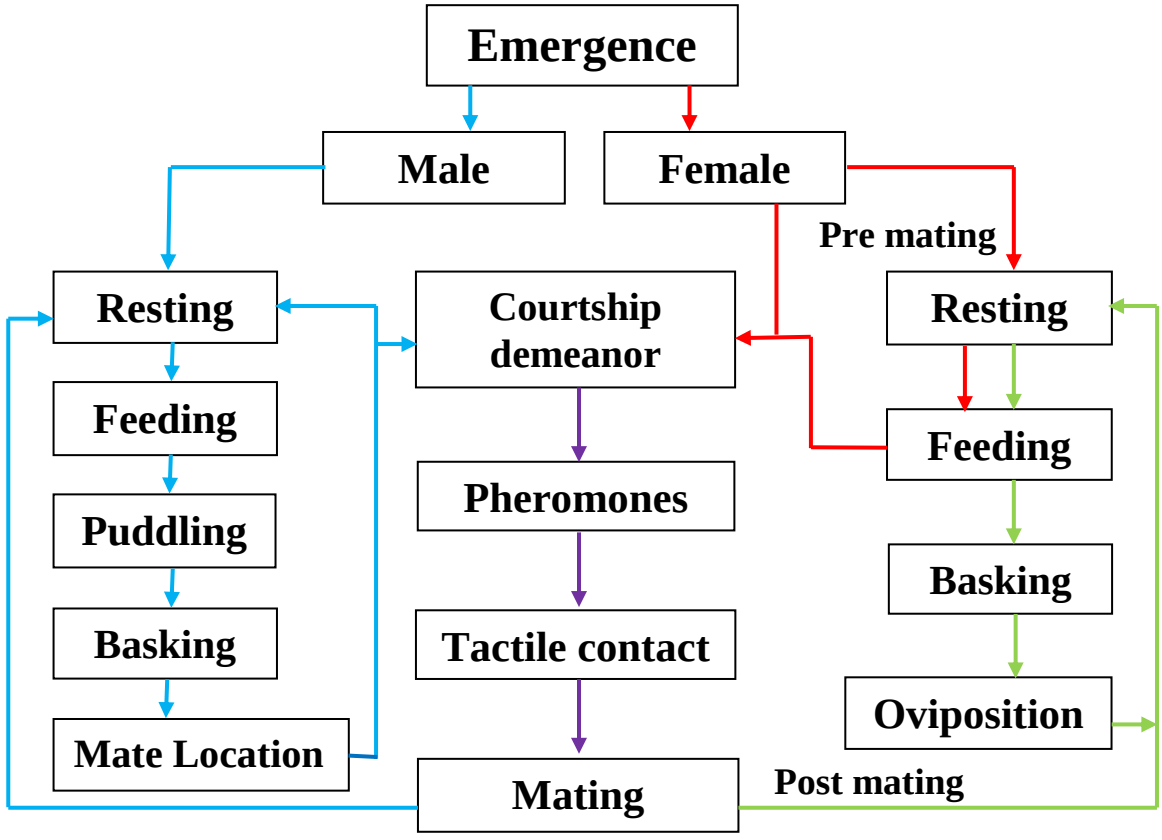


Fig. 14. Flowchart (revised) of butterfly's behavioural cycle (source: http://www.learnaboutbutterflies.com).

Prior to mating they are often sedentary, remaining very close to the spot where they emergd from the pupa. After mating they seek places to lay their eggs, but usually fly only short distances between each bout of egg laying. The ethological activities of adult butterflies are categorically arranged in the flowchart (Fig. 14).

Behavioural activities of adult butterflies are strongly associated with plants. Their egg-laying, basking and resting as well as foraging behaviours depend on specific plants because butterflies are highly selective for plant association. These behaviours evidence the ways in which butterflies carry important role in the gene-flow mechanism of the plant kingdom and create good microclimatic condition in different ecosystem, especially in the forest ecosystem (Bashar 2015). The present investigation has been focused on the lycaenid behaviours under the following sub-headings: the behaviour of adult emergence; feeding behaviour; puddling behaviour; basking behaviour; resting behaviour; mating behaviour; egg-laying behaviour; and myrmecophilous behaviour.

5.3.1 'Eclosion' – the emergence of adult butterflies

When the butterfly emerges from its pupa, the process is termed as eclosion. The process is controlled by hormones which switch to soften the pupal shell and to initiate the central nervous system begin the movements needed to complete eclosion. The pupal shell has lines along which it will split. In the day or so before eclosure (emergence of the butterfly) those lines become more obvious. The spiracles of the butterfly within the pupa are linked by short tubes to the spiracle openings on the pupal shell. Just prior to emergence air is drawn in through these tubes, enabling the butterfly to pump up its body during the last couple of hours, which causes the shell of the pupa to split, just behind the head. The butterfly then forces its way out, using its legs to pull itself clear of the empty pupal shell. Having emerged and settled into position, the butterfly then spends several minutes hanging virtually motionless. Once completely out of the pupa, the wings appear folded or crinkled and the butterfly must begin the process of expanding and drying its wings before flight is possible. The butterfly will pump meconium (metabolic product) into the venation structures of the wings by wing movement and the help of gravity. Wings will soon fully expand and dry off allowing the butterfly to take flight. Once the wings have fully expanded, the meconium will be pumped back into the body of the butterfly. The small amounts still in the veins of the wings will dry and harden giving the wings a more sturdy structure that will allow flight. It can take 30 minutes to 2 hours

for a butterfly's wings to completely dry, this is usually varied according to size and species. After the wings have dried but before the butterfly will take its first flight it will dispel the excess meconium from its body. Male butterflies usually fly off as soon as their wings are hardened, but females of many species tend to stay within a few metres of the emergence site until mated. Emergence of the adult butterfly from the pupa is prompted by factors including humidity, temperature, light level and time of day. Pictorial view of some newly emergerd lycaenid butterflies have been arranged in Plate 42.

a **b** **c**

Plate 42. Newly emerged lycaenid butterflies: **a**. *Chilades lajus*; **b**. *Chilades pandava*; and **c**. *Rathinda amor*.

During present investigation, adult emergence process of 53 individuals belong to five lycaenid butterflies has been observed (Appendix 9). These butterflies are *Chilades lajus*, *C. pandava*, *Catochrysops strabo*, *Remelana jangala* and *Rathinda amor*. Ten butterflies of *Chilades lajus*, and eight butterflies of *C. pandava* has been observed. The observed individuals of *Catochrysops strabo*, *Remelana jangala* and *Rathinda amor* were thirteen, sixteen and six, respectively.

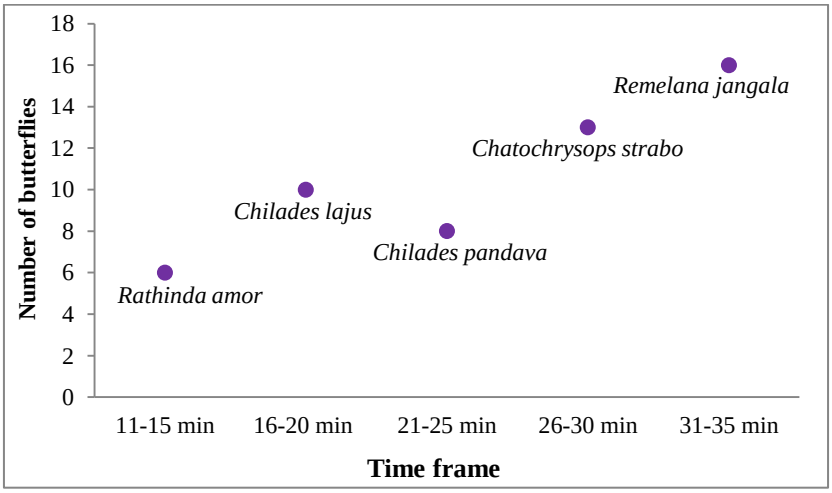


Fig. 15. The emergence duration of examined lycaenid butterflies in different time frame.

It was seen that examined lycaenids were emerged at morning from 7.30 to 11.00 am. The time of emergence has been varied among different species ranging 10-35 minutes (Fig. 15). It has been recorded that the emerging time of *Chilades lajus* and *C. pandava* was

16-20 min and 21-25 min, respectively. *Catochrysops strabo* was also emerged within 26-30 minutes. *Remelana jangala* need 31-35 minutes to emerge as adult whereas the emerging time of *Rathinda amor* was only 11-15 minutes.

The average time spent for eclosion of adult lycaenid has also been calculated. *Chilades lajus* spent 18.2±1.39 minutes while *C. pandava* need 22.88±1.55 minutes for eclosion. *Catochrysops strabo* used 28.23±1.42 minutes to emerge as adult. *Remelana jangala* spent 32.81±1.47 minutes whereas the emerging time of *Rathinda amor* was 12.83±1.47 minutes. Reproductive success of examined butterflies is largely determined by examining the adult emergence time. The present phenological studies would offer valuable comprehensions into population dynamics which can be used in the progression of butterfly conservation.

5.3.2 Feeding behaviour

Feeding behaviour of adult butterflies is very characteristic in their life style. This behaviour aids in taking energy directly from the plants especially from the flowers as well as provides great role in the gene-flow of the plant to which it is related (Bashar 2015). This vibrant activity provides impacts on survival, growth, reproduction and movement in an insect's life (Slansky 1982). The amount, rate and quality of food consumed by adult insects influences their fecundity, movement and survival (Shorey 1963, Jensen *et al*. 1974, Slansky 1980a, 1980b). A schematic diagram has been drawn presenting the interaction between feeding behaviour and other key behaviours (Fig. 16).

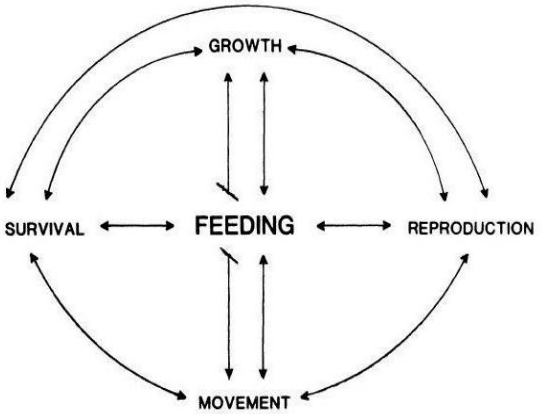


Fig. 16. Schematic diagramme indicating the interaction of feeding behaviour with other key behaviours (source: Slansky 1982).

Adult butterflies feed primarily on nectar from flowers (Gilbert 1972, Singer and Parmesan 1993, Singer 1984). Though some butterflies have been observed to feed on

ripe or rotten fruits, tree saps and other decaying organic matters (Young 1975, DeVries 1987). Depending on food type adult butterflies are divided into three categories: nectar-feeding butterflies, fruit feeding butterflies and a combination of both (Gilbert 1972, DeVries 1988, DeVries and Walla 2001, Molleman *et al*. 2005a, 2005b, Omura and Honda 2009). Colour-displays of flower fascinate nectar-feeding butterflies mainly while fruit feeding butterflies are usually attracted to the volatiles produced by the fermentation process of their food sources (Sourakov *et al.* 2012). The current investigation sketches the feeding behaviour involving different sources of food for lycaenid butterflies observing in different experimental sites. During field investigation, it has been found that lycaenid butterflies are predominantly nectar-feeding butterflies (Plate 45), a few species displays fruit feeding behaviour (Plate 48).

5.3.2.1 Feeding mechanism and the feeding pattern of lycaenid butterflies

Most butterflies and moths (Lepidoptera) use modified mouthparts, the proboscis, to acquire fluids (Lehnert *et al*. 2016). More than 95% of the Lepidoptera acquire fluids by means of a tubular proboscis (Krenn 1990, 2010). Butterfly possesses a long and very flexible proboscis to imbibe liquid foods by suction (Krenn 2008). A functional proboscis is widely considered a sealed tube that operates similar to a drinking straw (Krenn 2010, Bauder *et al*. 2013). The lepidopteran proboscis is composed of two elongated maxillary galeae that are connected by overlapping dorsal and interlinking ventral structures (i.e., legulae) to form a food channel (Fig. 2d) (Eastham and Eassa 1955, Krenn *et al*. 2005, Krenn 2010). The merging of the galeae into a functional proboscis takes place after adult eclosion from the pupa, and consists of coiling and uncoiling actions of the proboscis accompanied by the presence of saliva droplets (Krenn 1997). Plate 43 presents the pictorial view of positional structure found in lycaenid proboscis.

a **b** **c** **d**

Plate 43. Pictorial view of proboscis structure (*Arhopala amantes*): **a**. dorsal and **b**. lateral view of coiled proboscis; **c**. proboscis in extended position; and **d**. schematic representation of proboscis cross-section perpendicular to the food channel (source: Kornev *et al*. 2009).

In the resting position, proboscis is coiled up and stored under the head; it is coiled into a spiral of 2.5 to 7 turns (Krenn 1990, Kristensen 1968). The proboscis is tightly wound

onto itself so that there is no space between the coils. It lies against the labium between the labial palps (Krenn 1990). During feeding, proboscis uncoils in a split second by an increase in blood pressure (Krenn 1990). This organ employs capillarity via interlegular spaces to build liquid bridges in the food channel for the sucking pump to act on when feeding from liquid films and porous substrates (Monaenkova *et al*. 2011). Liquids are sucked from the organ's tip through a row of small slit-like openings into the head and finally the digestive tract (Paulus and Krenn 1996, Krenn 2008). Proboscis solely rely on a sucking pump located in the head produces the necessary pressure gradient to transport liquids into the esophagus (Kingsolver and Daniel 1995, Eberhard and Krenn 2005). The distal 5-20% of the proboscis has dorsal legulae that are elongated and more widely spaced (Krenn *et al*. 2001) (i.e., the drinking region), which facilitates fluid uptake (Lehnert *et al*. 2013); otherwise it is putatively a fluid-tide tube sealed with glandular secretions (Krenn 2010, Monaenkova *et al*. 2011). It occur lack of distinct terminal opening (Monaenkova *et al*. 2011). Lehnert *et al*. (2013) stated that fluid uptake is regulated by wettability dynamics (i.e., hydrophilicity and hydrophobicity) of proboscis structures (i.e., hydrophilic dorsal legulae, chemosensilla, and the food channel) and surface roughness (i.e., micro bumps that create an overall hydrophobic surface).

Proboscis morphology and functions are interconnected; hence its design is complex to offer different modes of operation (Kornev *et al*. 2009). The main proboscis function is to probe and deliver liquids to the sucking pump where it can be further transported to the digestion canal (Eastham and Eassa 1955, Kingsolver 1985a, Krenn 1990, Borrell and Krenn 2006). The probing movements of proboscis show a characteristic pattern which can be especially well observed when lycaenid butterflies feed on nectar from flowers. The pattern of behaviour can be most easily examined and compared at different flowers and inflorescences of examined nectar plants that are frequently visited by lycaenid butterflies. A series of probing behaviour of lyceanid butterflies has been described following Eastham and Eassa (1955), Kristensen (1968), Banziger (1971), Krenn (1990, 1998, 2008, 2010), Kunte (2007), Kornev *et al*. (2009) and Monaenkova *et al*. (2011).

Butterflies approach flowers with a loosely coiled proboscis and uncoil it after landing. This means that before landing on the flower, the proboscis has been released from its tightly coiled position of rest and is unwound to a few large coils. The proboscis is then flexed upward at its attachment point to the head capsule and uncoils in a fast movement. In the feeding position, the proboscis shows a distinct bend after approximately one third

of its length, enabling the proboscis to adjust to various flower depths (Plates 44b, 44c, 44f, 44g). The region of the inflection of the proboscis, called the bend region, separates the proximal region of the proboscis, which is held forward, from the distal region of the proboscis which extends to the tip and points downward (Plates 44b, 44c, 44f, 44g). The shape of the bend region in individual species depends on the length and the proportions of the regions of the proboscis.

The entire proboscis can be lifted and lowered at its jointed connection to the head; the bend region also functions like a joint, so that the distal proboscis can be stretched out or retracted by stronger flexion. Characteristic sequences of these movements allow butterflies to probe flowers for nectar with the tip of the proboscis. A typical sequence of probing movements consists of an elevation of the proboscis at the basal joint until the tip loses contact with the surface, followed by extension or flexion of the bend region to move the tip of the proboscis forward or backward, and lowering of the proboscis until its tip again contacts the flower at another location (Plate 44).

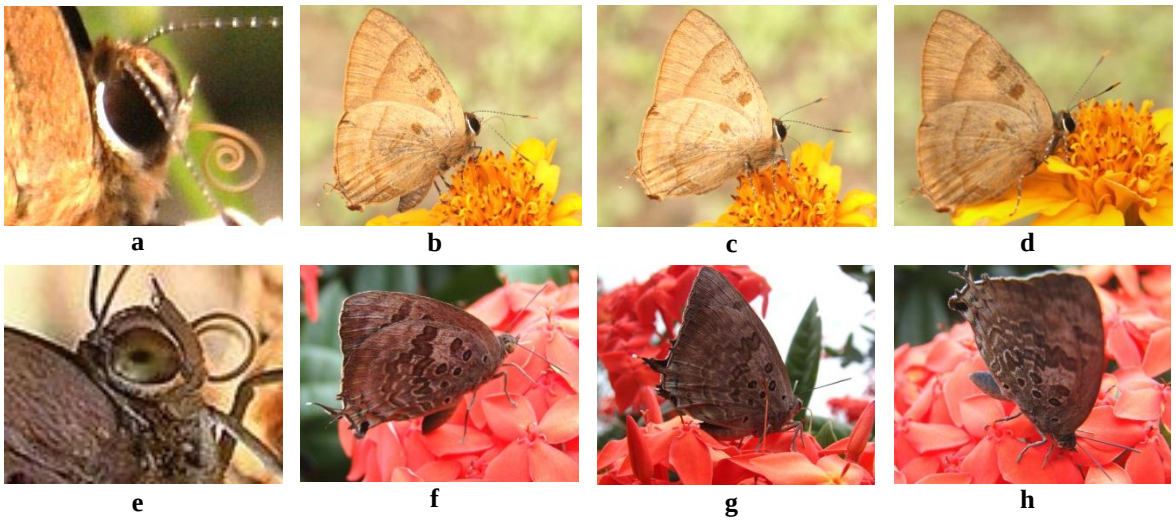


Plate 44. Feeding pattern of lycaenid butterflies (**a**-**d**: *Rapala pheretima* feeding on *Wedelia trilobata*; and **e**-**h**: *Arhopala amantes* taking nectar from *Ixora coccinea*): **a**. and **e**. landing on flower with loosely coiled proboscis; **b**. and **f**. butterfly probes flower by the distal region of the proboscis with the turning movements of the body; **c**. and **g**. the flexed proboscis probes flower with vertical movements; and **d**. and **h**. proboscis completely introduced into a floret during nectar uptake.

Butterflies often performs several short series of such probing behaviour lasting few moments and consisting of 2-5 cycles, until the butterfly has found the tubular opening of the flower (Plates 44b, 44c, 44f, 44g). Once a butterfly has located the entrance to a flower, it pulls down its proboscis at the base, enabling the tip to project into the flower (Plates 44d, 44h). Depending on the length of the proboscis and depth of the flower corolla, the proboscis is inserted up to the bend region or even further. It can often be

seen that the head bows downward and the legs flex; these are movements associated with the pulling down of the proboscis into the flower (Plates 44d, 44h).

After the proboscis is introduced into the flower, brief poking movements often follow in which the proboscis is partially lifted and immediately inserted again. During flower probing, the sensory structure (i.e. sensilla styloconica) presumably provides information on both nectar and the position of the tip of proboscis inside a flower. The proboscis remains motionless for a moment when nectar is sucked out of the corolla tube in the flower. When the flower is depleted of nectar, the proboscis is pulled out. If the butterfly is visiting an inflorescence, it rapidly turns to the next flower and repeats the flower-probing sequence. In this manner, a butterfly can swiftly exploit one flower after another by simply rotating its body. Lycaenid butterflies often sit in the middle of an inflorescence (Plate 44f), and are surrounded by the numerous corollas of the individual flowers. From one location, the butterfly can insert its proboscis successively into many individual flowers whereby the bending of the proboscis assumes the same curvature as the corolla of the flower. Lycaenids sit in the side of a single flower to probe flower following the described sequence to uptake nectar. Then they fly away to locate another flower to follow the feeding sequences. This sequence of movements during nectar feeding is relatively uniform, stereotypical and differs little within the examined species. Differences were evident due to the different lengths and proportions of the proboscis in the various species.

In case of fruit feeding butterflies, the proboscis is often extended straight or bent sideways in contrast to the feeding behaviour of nectar-feeding butterflies. It is thus possible for the butterfly to scan the entire substrate beneath the tarsi of the middle legs to the tips of the antennae without having to move. If the butterfly finds a favourable location to imbibe liquids, it may remain still for several minutes. The butterflies sometimes perform a particular sequence of probing movements so that the tip is not lifted completely from the surface but repeatedly returned to the same position. Compared to the rapid feeding movements of flower-visiting species, which quickly work flower after flower, the movements of non-flower-visiting species proceed at a more leisurely pace. While otherwise remaining motionless and holding the wings in the closed position, feeding behaviour of non-flower-visiting butterflies alternates between two phases of proboscis movements. In one, the butterfly performs long series of probing movements with its proboscis. In the second phase, the butterfly remains completely motionless while

it sucks liquid from the moist surface. This behaviour can be described as mopping/sucking, whereby the liquid must first accumulate on the tip region of the proboscis by adhesion to sensilla before it can be drawn through the food-tube by suction.

5.3.2.2 Foraging behaviour and the flower visit assortment of lycaenid butterflies

Foraging is a characteristic function in butterfly's life style to take energy directly from the plants especially from the flowers. The flowers are exploited by the butterflies for nectar, the energy source for them (Baker and Baker 1973a, 1973b). Butterfly foraging activity largely depends on temperature and intensity of light (Bhuyan *et al.* 1999). Adult lycaenid commonly seek nectar from flowers of very restricted ranges of food plants (New 1993). Present investigation has been steered concerning the foraging activity of lycaenid butterflies and their visited flowering plants along with their flower visiting pattern and foraging time budget. Nectar of selected flowers was collected. The nectar volume was measured to study the influence of nectar volume on the butterfly visits to flowers. This experiment has also envisaged examining pollen grain structure of lycaenid visited flowers to assemble information on the role of butterflies in plant pollination.

Table 12. Floral characteristics of examined nectar plants of lycaenid butterflies.

Plant	Habit	Flowering period	Flower colour	Flower mass	Corolla shape	Corolla length (mm)
Gomphrena globosa	Herb	June to October	Purple	Sparse	Not tubular	3.0-4.0
Catharanthus roseus	Shrub	Throughout the year	White/pink	Sparse	Tubular	25.0-35.0
Chromolaena odorata	Shrub	November to May	Bluish white	Dense	Tubular	4.5-5.5
Mikania cordata	Herb	October to February	White	Dense	Tubular	2.5-3.5
Spilanthes calva	Herb	Throughout the year	Yellow	Sparse	Not tubular	2.0-2.5
Wedelia chinensis	Herb	February to August	Yellow	Sparse	Tubular	3.0-4.0
Wedelia trilobata	Herb	March to August	Yellow	Sparse	Tubular	3.0-4.0
Helianthus debilis	Herb	Throughout the year	Yellow	Sparse	Not tubular	2.5-3.5
Vernonia cinerea	Herb	Throughout the year	Purple	Moderate	Not tubular	4.0-5.0
Leea macrophylla	Herb	July to February	Cream	Dense	Not tubular	2.0-2.5
Oxalis corniculata	Herb	September to May	Yellow	Sparse	Tubular	2.0-2.5
Oxalis corymbosa	Herb	January to April	Pink	Sparse	Tubular	2.5-3.0
Ziziphus mauritiana	Tree	September to March	Cream	Dense	Not tubular	3.0-3.5
Ixora coccinea	Shrub	Throughout the year	Red	Dense	Tubular	22.0-32.0
Pentas lanceolata	Herb	March to May	Pink	Dense	Tubular	12.0-16.0
Mussaenda frondosa	Shrub	Throughout the year	Yellow/orange	Sparse	Tubular	22.0-28.0
Micromelum minutum	Tree	Throughout the year	Cream	Dense	Tubular	2.5-3.5
Lantana camara	Shrub	Throughout the year	Yellow/ white/ pink/ red	Dense	Tubular	8.0-14.0
Chrysalidocarpus lutescens	Palm	December to April	Cream	Dense	Not tubular	2.0-3.0
Punica hybrida	Herb	Throughout the year	Purple	Sparse	Tubular	3.0-4.0

During the course of study, a total of 3,836 lycaenid butterflies belonging to 25 species have been spotted in foraging in the different experimental sites (Chapter 3). Among them, 473 individuals of 20 lycaenid species have been taken under consideration to

collect data from the field observation. The examined lycaenids are *Pseudozizeeria maha, Zizina otis, Chilades lajus, C. pandava, Catochrysops strabo, Tarucus callinara, Castalius rosimon, Caleta decidia, Lampides boeticus, Euchrysops cnejus, Anthene emolus, Arhopala amantes, A. pseudocentaurus, Rapala manea, R. pheretima, R. iarbus, Spindasis lohita, Remelana jangala, Rathinda amor, Tajuria cippus* (Table 13). These butterflies were observed in foraging to exploit 20 plant species (Table 13) under 11 families. The plant family Amaranthaceae and Apocynaceae contains single species *Gomphrena globosa* and *Catharanthus roseus*, respectively. Seven species (viz. *Chromolaena odorata, Mikania cordata, Spilanthes calva, Wedelia chinensis, W. trilobata, Helianthus debilis* and *Vernonia cinerea*) belongs to family Asteraceae. The family Leeaceae is represented by single species *Leea macrophylla* whereas family Oxalidaceae comprises two species *Oxalis corniculata* and *O. corymbosa. Ziziphus mauritiana* belongs to family Rhamnaceae while *Ixora coccinea, Pentas lanceolata* and *Mussaenda frondosa* placed under the family Rubiaceae. The family Rutaceae, Verbenaceae, Arecaceae and Poaceae comprises single plant species *Micromelum minutum, Lantana camara, Chrysalidocarpus lutescens* and *Punica hybrida*, respectively. Floral structure and texture is a good reason of butterfly to visit flowers. Floral characteristics of examined nectar plants have been charted (Table 12).

Among the plant species, nine species are in flower throughout the year and rests of the species are seasonal. Most of the lycanids visits herbs and shrubs. Ghosh and Saha (2016) stated that visits of butterflies are more frequent to flowers of herbs and shrubs, rather than to the flowers of trees. Butterflies rely on several visual cues like colour, shape and depth of corolla tubes (Andersson and Dobson 2003, Faegri and van der Pijl 1979). The maximum examined flowers are brightly coloured with tubular corolla (Table 12). The maximum corolla length (25-35 mm) has been observed in *Catharanthus roseus* and minimum (2.0-2.5 mm) in *Spilanthes calva*, *Leea macrophylla* and *Oxalis corniculata*. Brightly coloured (yellow, orange, red) flowers with a landing pad reported to offer abundant rewards (Weiss 1997, Goulson and Derwent 2004). Though butterfly visits almost all the flowers, some flowers are especially attractive to them (Bashar 2012a). A butterfly species is classified as specialist or generalist with respect to their choice of flowers (Yarrish 2011). During field observation, it has been found that lycaenid butterflies visits differently coloured flower ranging from white to cream, pink to purple/blue, yellow to orange or even red (Plate 45).

From the present experiment, it has been found that a total of 473 individuals of 20 lycaenid species visit 2,585 times on different examined flowers and engaged 85,052 seconds in foraging. Flowers of *Chromolaena odorata* and *Ziziphus mauritiana* has been foraged by highest (9) species whereas *Catharanthus roseus* and *Mussaenda frondosa* visited by only one species.

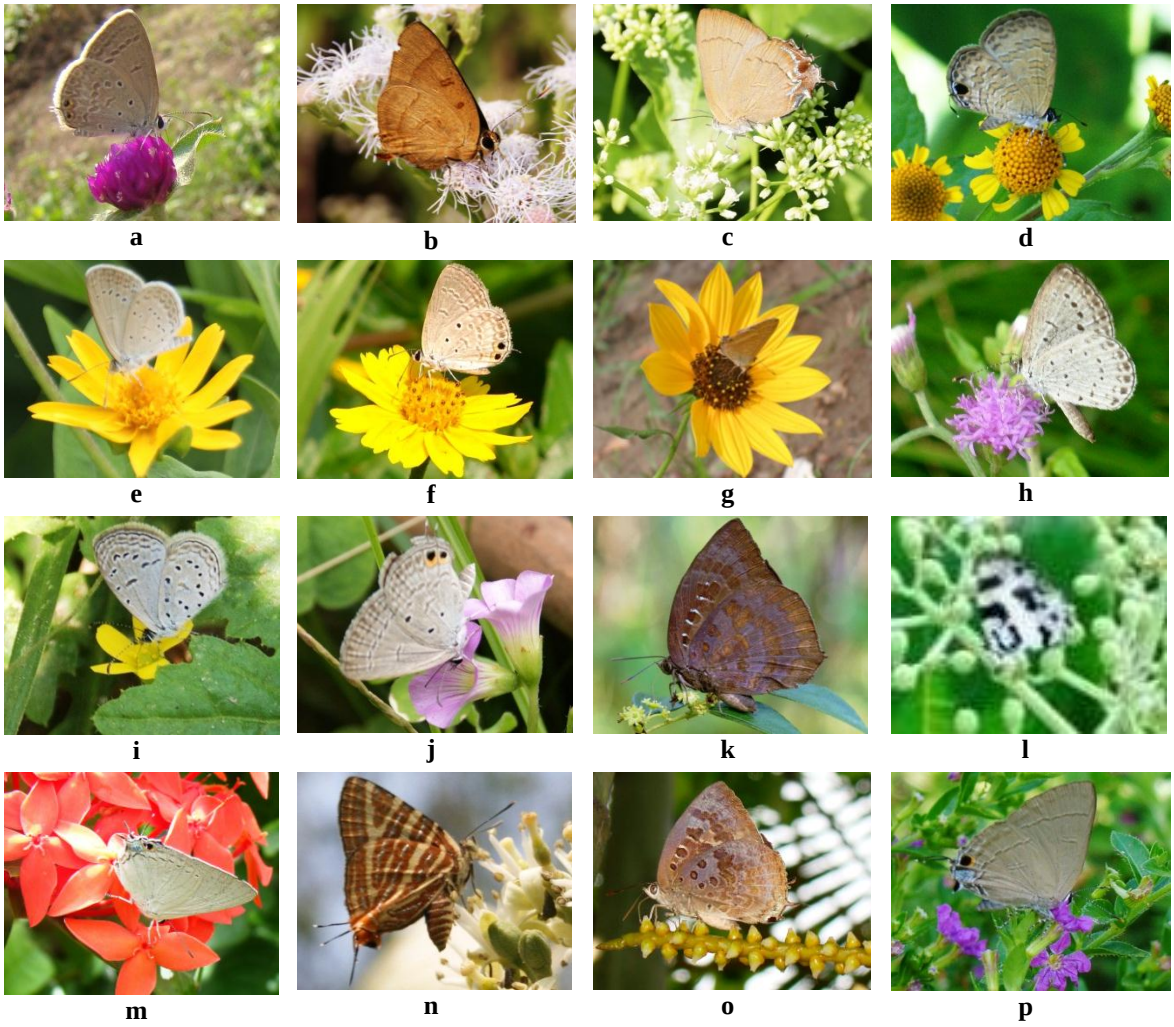


Plate 45. Photographic presentation of foraging lycaenids with flowers: **a**. foraging *Euchrysops cnejus* on *Gomphrena globosa*; **b**. *Rapala pheretima* on *Chromolaena odorata*; **c**. *Remelana jangala* foraging on *Mikania cordata* flowers; **d**. *Anthene emolus* on *Spilanthes calva*; **e**. Zizina otis on *Wedelia chinensis* flower; **f**. *Euchrysops cnejus* on *Wedelia trilobata*; **g**. *Lampides boeticus* on *Helianthus debilis* flower; **h**. *Pseudozizeeria maha* on *Vernonia cinerea*; **i**. *Pseudozizeeria maha* on of *Oxalis corniculata* flowers; **j**. *Euchrysops cnejus* on *Oxalis corymbosa*; **k**. *Arhopala pseudocentaurus* on *Ziziphus mauritiana* flowers; **l**. *Caleta decidia* on *Leea macrophylla*; **m**. *Tajuria cippus* on *Ixora coccinea*; **n**. *Spindasis lohita* on *Micromelum minutum*; **o**. *Arhopala amantes* on *Chrysolidocarpus lutescens* flowers; and **p**. *Rapala manea* on *Punica hybrida*.

Lycaenid butterflies are very tender of the plant species like *Chromolaena odorata, Mikania cordata, Spilanthes calva* and *Wedelia chinensis* of family Asteraceae; *Gomphrena globosa* of family Amaranthaceae; and *Lantana camara* of family the Verbenaceae. Larger lycaenids such as *Arhopala pseudocentaurus* and *A. amantes* tender

in foraging the flowers of *Ziziphus mauritiana*, *Chrysalidocarpus lutescens* and *Ixora coccinea*. Among the studied plants, flowers of the family Asteraceae have been found most attractive to lycaenid butterflies. Akand (2012) was found similar result in an experiment in Butterfly Research Park, Gazipur during 2010-2011. A total of 245 individuals belong to 16 lycaenid species spent 31,152 seconds in foraging for 1,373 times visit to flowers of family Asteraceae.

Table 13. Foraging time budget of examined lycaenid butterflies in different nectar plants.

Plant	Butterfly	Individual number	Visit frequency	Duration of visits (sec)	
				Total	Avg.±SD
Gomphrena globosa	*Chilades lajus*	3	18	270	15.00±10.34
	Castalius rosimon	6	33	558	16.91±12.88
	Lampides boeticus	8	48	978	20.38±12.11
	Euchrysops cnejus	3	18	347	19.28±11.96
Catharanthus roseus	*Euchrysops cnejus*	11	55	1200	21.82±15.03
Chromolaena odorata	*Castalius rosimon*	5	27	559	20.71±14.21
	Chilades lajus	3	19	486	25.58±16.64
	Anthene emolus	2	14	288	20.57±13.41
	Arhopala amantes	7	39	1317	33.77±23.15
	A. pseudocentaurus	22	119	4270	35.88±21.11
	Rapala manea	10	62	1309	21.11±13.27
	Rapala pheretima	4	22	531	24.14±15.01
	Rapala iarbus	3	16	334	20.88±13.83
	Remelana jangala	15	79	2016	25.52±18.15
Mikania cordata	*Caleta decidia*	3	19	377	19.84±14.53
	Anthene emolus	5	34	769	22.62±14.97
	A. pseudocentaurus	8	43	1359	31.60±24.55
	Arhopala amantes	9	45	1398	31.07±21.96
	Rapala manea	10	59	1248	21.15±13.41
	Rapala iarbus	3	17	448	26.35±16.58
	Remelana jangala	11	65	1530	23.54±15.91
Spilanthes calva	*Pseudozizeeria maha*	12	61	1008	16.52±11.64
	Zizina otis	8	40	559	13.98±9.84
	Castalius rosimon	11	57	982	17.23±13.16
	Caleta decidia	18	106	1995	18.82±12.64
	Rapala manea	3	17	346	20.35±13.21
Wedelia chinensis	*Pseudozizeeria maha*	6	30	454	15.13±11.89
	Zizina otis	5	29	359	12.38±9.05
	Lampides boeticus	6	28	535	19.11±11.88
	Euchrysops cnejus	7	39	886	22.72±17.01
Wedelia trilobata	*Catochrysops strabo*	7	42	1055	25.12±16.46
	Castalius rosimon	5	30	433	14.43±10.48
	Tarucus callinara	3	19	332	17.47±10.79
	Lampides boeticus	7	37	871	23.54±16.28
	Euchrysops cnejus	9	45	1060	23.56±16.02
Helianthus debilis	*Lampides boeticus*	6	34	728	21.41±14.39
	Euchrysops cnejus	4	30	573	19.10±13.47
Vernonia cinerea	*Pseudozizeeria maha*	5	29	459	15.83±11.76
	Zizina otis	3	21	278	13.24±10.08
Leea macrophylla	*Castalius rosimon*	2	17	324	19.06±12.89
	Caleta decidia	2	13	195	15.00±9.30
Oxalis corniculata	*Pseudozizeeria maha*	3	23	287	12.48±8.91
	Zizina otis	2	18	247	13.72±9.65
Oxalis corymbosa	*Euchrysops cnejus*	3	17	407	23.94±14.41
	Catochrysops strabo	2	14	287	20.50±13.62

	Chilades lajus	5	25	550	22.00±15.21
	Castalius rosimon	7	34	784	23.06±15.89
	Tarucus callinara	3	17	356	20.94±14.51
	Euchrysops cnejus	3	18	445	24.72±15.31
Ziziphus mauritiana	*Arhopala amantes*	7	41	1077	26.27±21.58
	A. pseudocentaurus	8	45	1332	29.60±21.99
	Rapala manea	3	17	366	21.53±12.71
	Rathinda amor	2	10	184	18.40±9.09
	Tajuria cippus	2	13	270	20.77±11.27
	Lampides boeticus	9	31	853	27.52±17.12
	Arhopala amantes	15	51	1358	26.63±22.41
Ixora coccinea	*A. pseudocentaurus*	17	55	1434	26.07±22.47
	Remelana jangala	7	37	762	20.59±14.01
	Tajuria cippus	5	33	632	19.15±13.25
Pentas lanceolata	*Lampides boeticus*	5	29	466	16.07±9.88
	Euchrysops cnejus	3	19	326	17.16±8.87
Mussaenda frondosa	*Chilades pandava*	3	15	240	16.00±7.03
	Caleta decidia	2	17	604	35.53±18.77
	Rapala manea	2	17	693	40.76±19.30
Micromelum minutum	*Rapala pheretima*	2	16	529	33.06±19.49
	Rapala iarbus	3	21	907	43.19±19.05
	Spindasis lohita	12	60	24864	414.40±232.06
	Arhopala amantes	6	25	623	24.92±15.52
Lantana camara	*A. pseudocentaurus*	8	33	856	25.94±15.67
	Remelana jangala	3	17	324	19.06±10.83
	Arhopala amantes	5	43	2620	60.93±31.69
Chrysalidocarpus lutescens	*A. pseudocentaurus*	7	41	2734	66.68±34.35
	Rathinda amor	2	13	336	25.85±16.22
	Pseudozizeeria maha	5	22	271	12.32±9.05
	Chilades lajus	5	30	509	16.97±11.53
	Castalius rosimon	7	35	519	14.83±11.31
Punica hybrida	*Catochrysops strabo*	3	19	359	18.89±12.70
	Lampides boeticus	2	11	157	14.27±10.65
	Euchrysops cnejus	2	12	174	14.50±9.64
	Rapala manea	3	16	286	17.86±11.12

It is very often found that a single butterfly species visit different flowers of different plants in different pattern and posture (Bashar 2015). In present experiment, *Euchrysops cnejus* has been found to visit highest (9) plant species to forage flowers. 45 individuals of this species visit flowers 253 times with the duration of 5,418 seconds. This butterfly also spent highest 24.72±15.31 seconds while foraging on flowers of *Ziziphus mauritiana* and lowest 14.50±9.64 seconds on *Punica hybrida* flowers. *Chilades pandava* and *Spindasis lohita* visit a single plant species though their visit frequency and visit duration have been found dissimilar. In case of *Chilades pandava*, three individuals visit to flowers of *Mussaenda frondosa* for 15 times and spent 240 seconds while 12 individuals of *Spindasis lohita* spent 24,864 seconds on flowers of *Micromelum minutum* through 60 visits (Table 13). Visit frequency on different flowers reflects a qualitative assessment of flower preference by the dependent butterflies. The flower plants preference of butterfly species has been to maximize net energy gain during foraging (Hainsworth and Hamill

1993). In case of *Arhopala pseudocentaurus*, 70 individuals visit six plants for 336 times and spent 11,985 seconds. This butterfly visits 119 times by 22 individuals on *Chromolaena odorata* for 35.88±21.11 seconds; 43 times by 8 individuals for 31.60±24.55 seconds on *Mikania cordata*; 45 times by 8 individuals on *Ziziphus mauritiana* for 29.60±21.99 seconds; 55 times by 17 individuals for 26.07±22.47 seconds on *Ixora coccinea*; 33 times on *Lantana camara* by 8 individuals for 25.94±15.67 seconds; and 41 times by 7 individuals for 66.68±34.35 seconds on *Chrysalidocarpus lutescens*. *Tarucus callinara* visit two plants for 36 times by six individuals and spent 688 seconds. This butterfly spent 17.47±10.79 seconds when visit *Wedelia trilobata* for 19 times by three individuals; and it visits *Ziziphus mauritiana* for 17 times by three individuals and spent 20.94±14.51 seconds. The average "time-spent" by individual species on a single host plant during a single visit provides a qualitative measure to estimate the host-dependence (Harinat *et al*. 2015a).

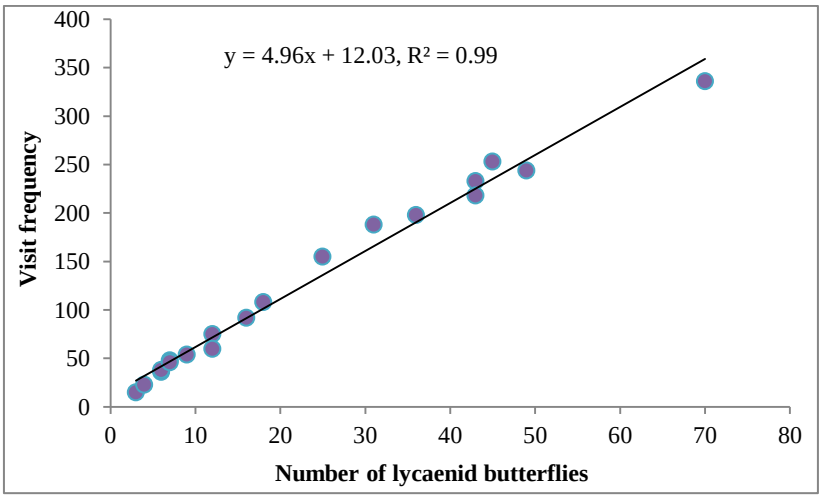


Fig. 17. Regression between the number of examined lycaenid butterflies and their visit frequency.

Whether lycaenid butterflies has been observed visiting flowers is to determine as often as anticipated from their flower visit frequency in the study sites. The number of lycaenid species and individual butterflies visiting flowers with visit frequencies of them on different plant species including the number of exploiting plants has been incorporated in this examination (Table 13). To ascertain the size of lycaenid butterfly in relation to flowering plants, the number of butterfly species has been regressed on their visit frequency (Fig. 17). A significant relationship is found ($F = 1223.24$, $R^2 = 0.99$, p-value = 0.04). To determine the range of nectar plants used by lycaenid butterflies, a total of 195 plants (20 species) have been regressed against the visit frequency of examined butterflies (Fig. 18). A significant relationship is also found ($F = 74.03$, $R^2 = 0.81$; p-value = 0.23).

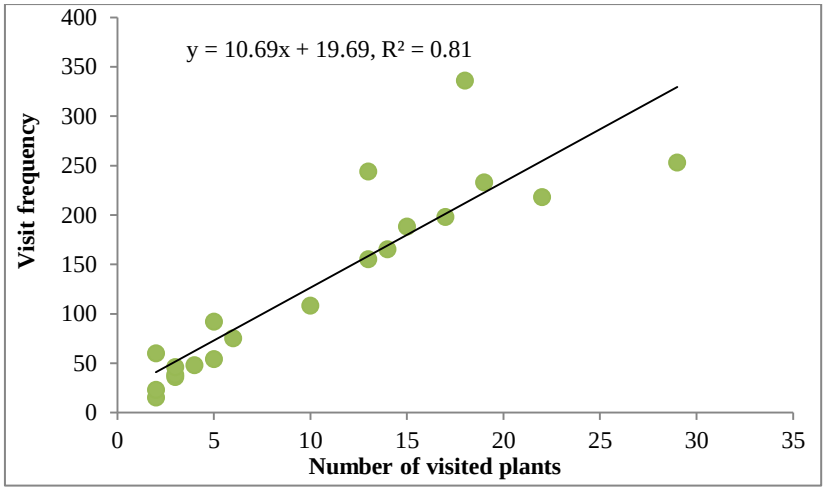


Fig. 18. The number of nectar plants visited by butterflies in relation to visit frequency.

This field observation on foraging activities and foraging time budget on related plants encompass flower visit assortment of lycaenid butterflies and the functional role of nectar plants.

5.3.2.2.1 Factors regulate the flower visits of lycaenid butterflies

Butterfly species show distinct flower preferences (Erhardt and Thomas 1991). The flower visits of butterfly is regulated by factors such as plants habit, flowering period in addition to floral colour, shape, size, position and arrangement in the inflorescence (Faegri and van der Pijl 1979, Raju *et al*. 2011). The present exploration has been focused on regulating factors of flower visit by lycaenid butterflies. For analysis of present study, factors including plants habit (herb, shrub, tree, and palm), flowering period (throughout the year and restricted period of the year), flower colour (white/cream, pink/purple/violet, yellow/orange, and red), flower mass (sparse, moderate, and dense) and flower corolla shape (tubular and non tubular) have been considered based on Table 12. Visits to herbs and shrubs were more frequent than visits to flowering trees, which are found very significant (F = 0.07, p-value = 0.04). Flowering period has a significant impact on visits to flowers (F = 0.36, p-value = 0.28); plants flowering with restricted period have more visits by lycaenid butterflies than the plants flowering throughout the year. Flower colour has significant (F = 0.41, p-value = 0.01) effect on visits to flowers with preference of bright colour; though the individual visit of examined lycaenid butterflies is different and made a preference white/cream>pink/purple/violet>yellow>red. But this experiment indicated that lycaenid butterflies visited more yellow coloured flower. Flower corolla shape also significantly influences visits to flowers (F = 0.04, p-value = 0.06); tubular shaped corollas have more visits than those that do not. A significant (F = 1.29, p-value =

0.18) effect also found between flower mass and flower visits. Lycaenid butterflies visit dense flowers than sparse. Pearson's rank correlation coefficient indicates a significant (95% confidence level) relationship between nectar plant features and the flower visit frequency of lycaenid butterflies (Table 14).

Table 14. Connotations among nectar plant features and flower visit frequencies of lycaenid butterflies. Plant habit: Herb = 1, Shrub = 2, Tree = 3, Palm = 4; Flowering period: throughout the year = 1, restricted period of the year = 2; Flower colour: white/ cream = 1, pink/purple/violet = 2, yellow/orange=3, red = 4; Flower shape: tubular =1, non tubular = 2; and Flower mass: sparse =1, moderate = 2, dense= 3.

Variable	Visit frequency	Plant habit	Flowering period	Flower colour	Flower shape
Plant habit	0.06				
Flowering period	0.14	– 0.02			
Flower colour	– 0.15	– 0.39	– 0.33		
Flower shape	– 0.05	0.06	0.03	– 0.19	
Flower mass	0.29	0.58	0.16	– 0.43	0.04

Visit frequency has positive correlation with plant habit (0.06), flowering period (0.14) and flower mass (0.29) but negatively correlated with flower colour (– 0.15) and flower corolla shape (– 0.05). Plant habit has negative correlation with flowering period (– 0.02) and flower colour (– 0.39) but positive correlation has found with flower shape (0.06) and flower mass (0.58). A significant negative correlation has marked between flowering period and flower colour (– 0.33). But flowering period is positively correlated with flower corolla shape (0.03) and flower mass (0.16). Flower colour is negatively correlated with flower corolla shape (– 0.19) and flower mass (– 0.43). A significant positive correlation has been observed between flower corolla shape and flower mass (0.04). The present investigation confirms that flower colour and structure, adds plant habit and flowering period regulate the flower visit of butterflies. Earlier, Bashar (2015) stated that flower structure and texture, colour, corolla length all influence the butterfly foraging behaviour together. This study has also got a vital think-point to investigate biotic-biotic interaction in nature.

5.3.2.2.2 Floral nectar and the nectar intake of adult lycaenid butterflies

Floral nectar is the most common and widespread food source for adult butterfly (Gilbert and Singer 1975). A butterfly should select nectaring flowers in a way that maximizes either its energetic efficiency or its net rate of energy gain, that is, the difference between the gross rate of gain and the rate of energy expenditure in foraging (Corbet 2000), because nectar consumption increases fitness (Porter 1992). Nectar provides energy for flight, which is vital to find mates and to disperse the species (Deepika *et al*. 2014). All

regular flower-visiting butterflies are nectar feeders. Lycaenid butterflies use different types of flowering plant species such as herb, shrubs, and trees for their nectar sources (Akand 2012).

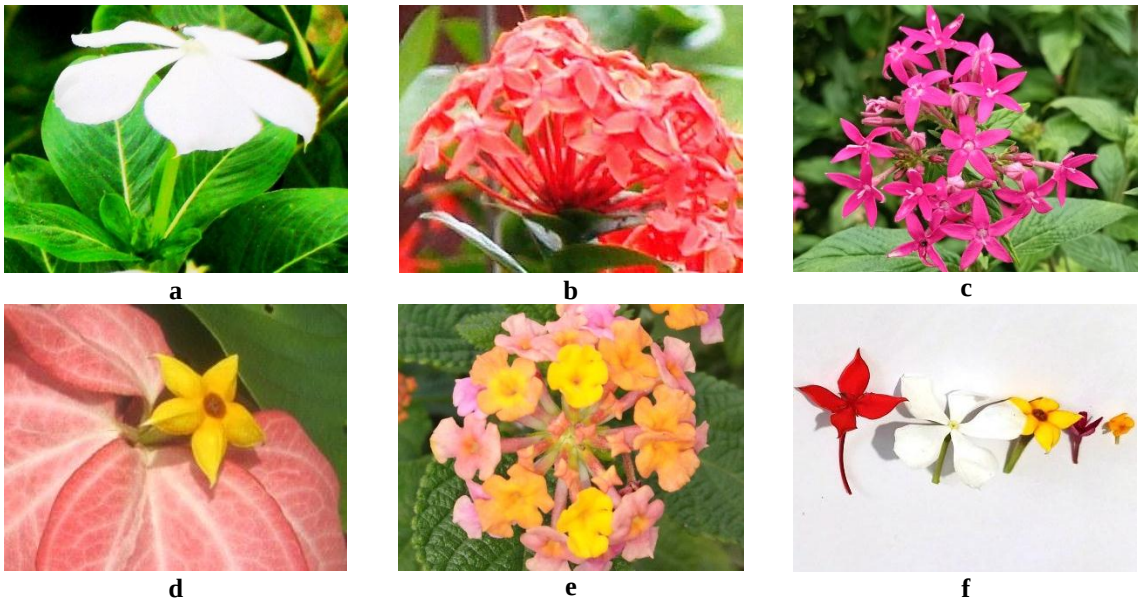


Plate 46. Selected flowers for nectar collection: **a**. *Catharanthus roseus*; **b**. *Ixora coccinea*; **c**. *Pentas lanceolata*; **d**. *Mussaenda frondosa*; **e**. *Lantana camara*; and **f**. single flower of examined flora.

In the present investigation, nectar has been collected from five selected plants and measured the volume of nectar as well as nectar visit activities. All the examined flowers are brightly coloured with long tubular corolla and arranged in clustered state. The selected flowers are *Catharanthus roseus*, *Ixora coccinea*, *Pentas lanceolata*, *Mussaenda frondosa* and *Lantana camara* (Plate 46). Data has been obtained from 67 individuals of seven lycaenid butterflies (viz. *Chilades pandava, Lampides boeticus*, *Euchrysops cnejus*, *Arhopala amantes, A. pseudocentaurus, Remelana jangala* and *Tajuria cippus*) visited selected nectar flowers. Flowers of *Catharanthus roseus* and *Mussaenda frondosa* was visited by single lycaenid species (*Euchrysops cnejus* and *Chilades pandava*, respectively) while five lycaenids exploited flowers of *Ixora coccinea* (Table 14). Among the observed butterflies *Lampides boeticus* spent more time in nectar searching (16.86±11.08 seconds) and nectar feeding (33.71±16.68 seconds) whereas *Tajuria cippus* spent less time in nectar searching (8.50±4.79 seconds) and nectar feeding (17.25±10.64 seconds) during exploiting the flowers of *Ixora coccinea*. In case of *Pentas lanceolata*, the maximum period of nectar searching (10.36±6.20 seconds) and nectar feeding (12.09±6.09 seconds) has been documented for *Euchrysops cnejus*; but *Lampides boeticus* has busy in foraging for the minimum period of nectar searching (9.80±5.05 seconds) and nectar feeding (10.47±6.95 seconds). *Arhopala pseudocentaurus* lingered

the highest phase of nectar searching (11.52±6.65 seconds) and nectar feeding (27.67±16.36 seconds) whereas the lowest phase of nectar searching (8.59±4.06 seconds) ensued by *Arhopala amantes* but nectar feeding (18.89±10.86 seconds) occurred by *Remelana jangala* (Table 15). Among the observed plants, flowers of *Ixora coccinea* are the maximum visited flowers by lycaenid butterflies. The bright red colour and clustering state of flowers, suitable landing platform, minimum travel cost, accessible corolla tubes and high amount of nectar makes this flower most striking to the butterflies. The large showy sepals of *Mussaenda frondosa* is attracted by butterflies and often mistaken as being the flower. Consequently most of the butterflies visit the extra-large sepals and the yellow flowers visited by butterflies rarely. This might be the reason of less visit of flowers in *Mussaenda*. Having varicolored flowers, accessible corolla tubes, clustering of flowers, adequate landing platform makes *Lantana camara* more attractive to butterflies.

The clustered state of the flowers is energetically profitable for butterflies to reduce search time and also flight time to collect a good amount of nectar (Raju *et al*. 2011). Cruden (1976) stated that the length of foraging visits depends to the amount of the accumulated nectar. When little nectar is available the visits are short, but many flowers are visited. When relatively large amounts of nectar accumulate, the butterfly requires more time to extract the nectar, and fewer flowers are visited.

Table 15. Lycaenid visitors and their visit duration for nectaring on experimental flowers.

Plant	Active lycaenid butterfly	Individual number	Visit frequency	Duration of nectar searching (sec)		Duration of nectar feeding (sec)	
				Avg.±SD	Total	Avg.±SD	Total
Catharanthus roseus	*Euchrysops cnejus*	7	35	11.06±6.89	387	11.20±6.97	392
Pentas lanceolata	*Lampides boeticus*	3	15	9.80±5.05	147	10.47±6.95	157
	Euchrysops cnejus	2	11	10.36±6.20	114	12.09±6.09	133
Ixora coccinea	*Lampides boeticus*	7	21	16.86±11.08	354	33.71±16.68	708
	Arhopala amantes	11	37	10.14±7.34	375	27.19±22.29	1006
	A. pseudocentaurus	14	41	11.71±9.42	480	27.68±23.09	1135
	Remelana jangala	5	23	9.61±5.34	221	18.74±13.28	431
	Tajuria cippus	3	16	8.50±4.79	136	17.25±10.64	276
Mussaenda frondosa	*Chilades pandava*	2	8	12.25±5.85	98	13.25±4.49	106
Lantana camara	*Arhopala amantes*	5	17	8.59±4.06	146	25.76±14.82	438
	A. pseudocentaurus	6	21	11.52±6.65	242	27.67±16.36	581
	Remelana jangala	2	9	10.11±6.66	91	18.89±10.86	170

The volume of nectar in flowers is a limiting factor in nectar intake by nectarivores (Bolten *et al*. 1979). Nectar volume influence pollinators' behaviour, which governs pollen receipt and donation (Ladio and Aizen 1999, Manetas and Petropoulou 2000, Lasso and Naranjo 2003, Wolff *et al*. 2006). Effective pollination is guaranteed when

nectar reward is abundant enough to attract the pollinator but small enough to force the pollinator to visit various individuals (Wolff 2006). During study period, the number of flowers along with inflorescence has been recorded and the corolla tube length of flowers also measured. The number of flowers sampled per plant was variable because of differences in the availability of open flowers. Flowers of five plants have been sampled to collect nectar (Table 15). Nectar of examined flowers has been collected from four experimental sites (viz. CH, DU; SMH, DU; BG, BAU; and BRP) during the month of September, October and November 2015 and April 2016 (Appendix 11).

Table 16. Nectar quantities of examined flowers (inflo indicates inflorescence).

Plant	Inflo number	Flowers on inflo	Flowers per inflo	Corolla lengths (mm)	Nectar volume (µL) from total flowers	Nectar volume per flower (µL)
Catharanthus roseus	85	166	1.91±1.1	27.63±2.59	320	1.85±0.35
Pentas lanceolata	23	214	9.54±3.78	13.59±0.56	240	0.92±0.88
Ixora coccinea	17	554	32.82±5.54	27.04±0.15	1230	2.24±0.91
Mussaenda frondosa	6	7	1.5±0.70	24.71±2.12	20	2.92±0.59
Lantana camara	31	443	17.91±3.81	10.78±1.53	60	0.13±0.04

The nectar amount of *Catharanthus roseus* was 320 µL collected from two sites. A total of 166 flowers from 85 inflorescences have been sampled for the nectar collection. The corolla lengths of flowers were 27.63±2.59 mm and counted 1.91±1.1 flower per inflorescence. The amount of nectar produced per flower of *Catharanthus roseus* was 1.85±0.35 µL (>1 µL), and variability of nectar production is high in this plant. A total of 214 flowers from 23 inflorescences have been tested to collect 240 µL nectar of *Pentas lanceolata* from single spot. The amount of nectar produced per flower of this plant was 0.92±0.88 µL (<1 µL). *Pentas lanceolata* produces less variability in nectar. Each inflorescence bears 9.54±3.78 flowers and the corolla lengths of flowers were 13.59±0.56 mm. The collected nectar of *Ixora coccinea* was 1,230 µL. A total of 554 flowers from 17 inflorescences have been sampled from three experimental sites. It has been estimated that each flower produces 2.24±0.91 µL (>1 µL) and the variability of nectar production is high. The corolla lengths of flowers were 27.04±0.15 mm and 32.82±5.54 flowers was present in each inflorescence. A total of 7 flowers from 6 inflorescences of *Mussaenda frondosa* have been sampled from single spot and collected 20 µL nectar. 2.92±0.59 µL nectar (>1 µL) has been assessed from each flower of *Mussaenda frondosa***,** and the nectar production is highly variable. Each inflorescence contains 1.5±0.70 flowers and flowers corolla length has been measured as 24.71±2.12 mm. Collected nectar amount of *Lanatana camara* was 60 µL. A total of 443 flowers from 31 inflorescences have been

sampled from single spot. It has been assessed that each flower produces 0.13±0.04 µL (>1 µL), and variability of nectar production is less in *Lanatana camara*. 17.91±3.81 flowers have been counted from each inflorescence and the corolla lengths of flowers were 10.78±1.53 mm (Table 16).

Nectar resources are dynamic and vary across time and space as well as within and across years (Yarrish 2011). Nectar production also varied from habitat to habitat due to interaction of biotic and abiotic factors, microclimatic condition etc. (Nicolson and Thornburg 2007). The amount and quality of nectar were affected by microclimatic conditions and varied between populations at different habitats (Farkas *et al.* 2012). Rewards per flower vary greatly between plants of a single species and between flowers on a single plant also in response to the pattern of depletion of reward by foragers (Corbet 1978, Shreeve 1992). It has been found that nectar volume varied enormously from species to species ranging from 0.13±0.04 µL in *Lantana camara* and 2.92±0.59 µL in *Mussaenda frondosa*. The effect of nectar quantity on butterfly visit is ambiguous and it can be assured that nectar volume alone does not only influence the visit of butterflies (Neff *et al.* 1977). If higher nectar volume per flower enhances pollinator visits, the low nectar producing *Lantana camara* flower should experience a drop in butterfly pollinator visits. The volume of nectar provided by a flower is just a secondary consideration within certain limits and the primary determinant of their preference is the concentration of energy giving chemicals and quality of amino acids in nectar (Neff *et al.* 1977, Baker and Baker 1975). The volume of nectar also determines its concentration (Kulloli *et al*. 2011).

Floral nectar is the key reward offered by flowering plants to their pollen vectors, and that the behaviour of pollinators can be influenced by the quality and quantity of such rewards (Waser 1983, Real and Rathcke 1988). The amount of nectar produced by a flower is closely related to the metabolic needs of the pollinator (Heinrich and Raven 1972, Heinrich 1975). Because of the low energy demands of butterflies, nectar availability of butterfly flowers tends to be low relative to other pollinator types (Opler 1980). Floral nectar provides a rich source of easily accessible carbohydrate for butterflies (Boggs 1997b). In addition nectar also contain low levels of amino acids, proteins, lipids, vitamins, secondary plant compounds, as well as other organic compounds and minerals (Baker and Baker 1983b). Butterflies generally visited flowers that offer nectar with richer amino acids concentration than flowers which are pollinated by other insects (Baker and Baker 1973a). Nectar carbohydrates are composed of sucrose, fructose and

glucose mainly with trace amounts of other sugars (Baker and Baker 1975, 1979, Romeis and Wackers 2002). The sugar composition and concentration of floral nectar vary extensively among plant species (Nicolson and Van Wyk 1998, Nicolson 2002). A wide range exists in the concentration of nectar sugars utilized by butterflies as reported by different investigators: 15-25% (Watt *et al*. 1974), 13-44% (Baker and Baker 1975), 16-40% (Baker and Baker 1983a), 20-25% (Kingsolver and Daniel 1979) and 40-65% (Pivnick and McNeil 1985). Butterflies generally seem to prefer sucrose over fructose and glucose (Watt *et al*. 1974, Erhardt 1991a, 1991b, 1992, Rusterholz and Erhardt 1997). They prefer flowers with nectar concentrations of 20-25% sucrose, as these nectars should provide the maximal rate of energy intake during feeding (Kingsolver and Daniel 1979, Heyneman 1983). Data obtained from literature also specifies the similar flower preferences by butterflies (Table 17).

Table 17. Sugar concentrations of floral nectar among four families of nectar plants*.

Plant family	Nectar sugar concentration (%)		
	Sucrose	**Glucose**	**Fructose**
Apocynaceae	41.2 ± 7.7	21.3 ± 2.7	3.8 ± 0.9
Asteraceae	51.3 ± 6.5	15.3 ± 4.1	11.1 ± 2.1
Rubiaceae	47.3 ± 5.4	19.7 ± 3.3	13.2 ± 1.8
Verbenaceae	44.8 ± 4.9	15.8 ± 5.3	6.2 ± 3.2

*Source: Nacua *et al*. 2014.

Data on the chemical composition of nectar may give significant clues to ascertain the pollinator groups. The families Rubiaceae and Asteraceae contain the greatest concentrations of nectars may explain for the high preference of butterflies to these two families. The present investigation informs that flowers of these families are significantly exploited by lycaenid butterflies. Hence, lycaenid butterflies serve as pollinators for respective plants.

Literature consultation reveals that nectar resources for adult butterflies are likely important limiting factors (Gilbert and Singer 1975). Energy is the main outcome of sugar ingestion and is used in flight or other activities (Kevan and Baker 1983). Male butterflies assemble amino acid-rich food sources in their adult diet (floral nectar) in order to produce of spermatophores for reproductive success (Cahenzli and Erhardt 2012b, 2013). Female butterflies prefer nectars with amino acids when they lack alternative nitrogen sources or reserves (Mevi-Schutz and Erhardt 2005). The availability of amino acid-rich nectar in the adult diet can increase female butterfly reproduction (Cahenzli and Erhardt 2012a). Female butterflies also received nitrogen-rich nutrients by nuptial gifts during mating (Wiklund *et al*. 1993, Karlsson 1998, Arnqvist and Nilsson 2000). Female

butterflies can incorporate male-derived nutrients almost immediately into eggs (Boggs and Gilbert 1979, Boggs and Watt 1981, Boggs 1997b). Quantity and quality of adult uptake directly affect longevity, which could influence fecundity (Stern and Smith 1960, Murphy 1983, Pivnik and McNeil 1985, Watanabe 1992). Therefore, nectar resources should be recognized as essential resources affecting butterfly fecundity and butterfly populations (Mevi-Schutz and Erhardt 2005).

The present study has been exclusively focused on floral nectar and nectar feeding activities of adult lycaenids. This study has also been designed by the analysis of quantity and quality of floral nectar exploited by lycaenid butterflies. This experiment may provide new evidence supporting the idea that may be functional for stabilizing butterfly-plant interactions.

5.3.2.2.3 Relationship between butterfly proboscis length and floral corolla length

Butterflies possess a suctorial proboscis that serves to ingest fluids (Hikl and Krenn 2011). Proboscis is coilable, long and very flexible (Scoble 1992). In butterflies body size is a strong predictor of proboscis length (Corbet 2000, Agosta and Janzen 2005). The length of the butterfly's proboscis is in relation to the depth of the flower corolla (Dennis 1992, May 1992, Kunte 2007). Butterflies with longer proboscises are presumed to be specialized on longer corolla flowers (Proctor *et al.* 1996). The species with longest proboscis utilize the highest range of corolla tube depths. Thus, a long proboscis permits feeding on a greater variety of flower species (Ranta and Lundberg 1980). Butterflies with short proboscises can only access nectar from small corolla flowers (May 1992), are unable to feed on deep flowers, and corolla depth has been shown to place a limit to exploitation by nectar feeding butterflies (Corbet 2000). The present study has been investigated the functional activities of the proboscis and textural adaptation of the flowers.

Lycaenids are small sized butterflies with small proboscis. They chose flowers having similar and nearly similar corolla tube length compare to their proboscis length. The proboscis length of lycaenid butterflies has been measured during the experiment. Proboscis length varied among the examined butterflies. Longer proboscis (10 mm) was found in *Arhopala amantes* and *A. pseudocentaurus* while short proboscis (5 mm) has been identified in *Pseudozizeeria maha, Zizina otis* and *Anthene emolus* (Fig. 19). The length of the proboscis is determined for which flowers can be used to obtain nectar.

Among the examined flowers the length of corolla ranges from 2-35 mm. *Spilanthes calva*, *Leea macrophylla* and *Oxalis corniculata* contain short corolla with 2-2.5 mm length while flowers of *Catharanthus roseus* comprises long corolla (25-35 mm) (Table 12). Generally butterfly with short proboscis did not visit the flowers with long corolla. This present study reveals that lycaenid butterflies visits flowers with short corolla (Table 13). The observed lycaenids usually visited their nectaring flowers with corolla tube between 2.5 and 10 mm long.

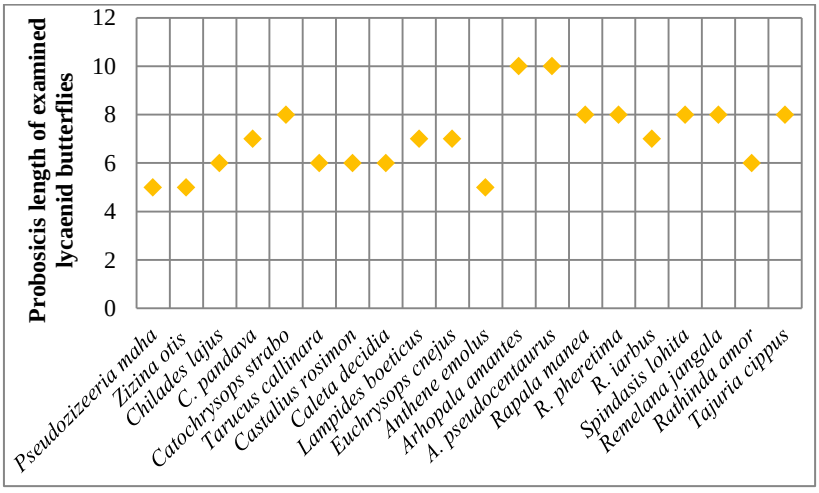


Fig. 19. Proboscis length of examined lycaenid butterflies.

The success of butterfly foraging depends, in part, on corolla length and clustering of flowers, and the proboscis length of butterflies (Akand 2012, Sultana *et al*. 2017). The butterflies with short proboscis can have better access to the nectar from short corolla tube. Similarly, the butterflies with longer proboscis can have also better access to the nectaring plants with flowers having long corolla and can gain greater energy from nectaring plants (May 1992). During foraging, they also provide higher energetic reward to the nectar plants (May 1988). A single species of butterfly can visit different flowers during foraging (Bashar 2015). Foraging activities and proboscis uses are not only the functional keys for butterfly-sustenance, but they can enhance more gene-flow mechanism in plant kingdom (Bashar *et al.* 2006). This creates good co-evolutive status both for plants and butterflies (Bashar 2015). The present study demonstrates that the relative proboscis sizes (lengths variations) are useful means for explaining the variation of foraging efficiency in butterfly nectar intake process.

5.3.2.2.4 Flower visit of lycaenid butterflies and the plant pollens

Butterflies are very often found to visit different flowers of same/different plants by a single species during foraging. At the same time, they also transmit pollen from flower to flower (Bashar 2015). Butterflies are important as pollinators for some species of plants. They are capable of carrying pollens over greater distances (Bashar 2015, Goulson *et al.* 1997).

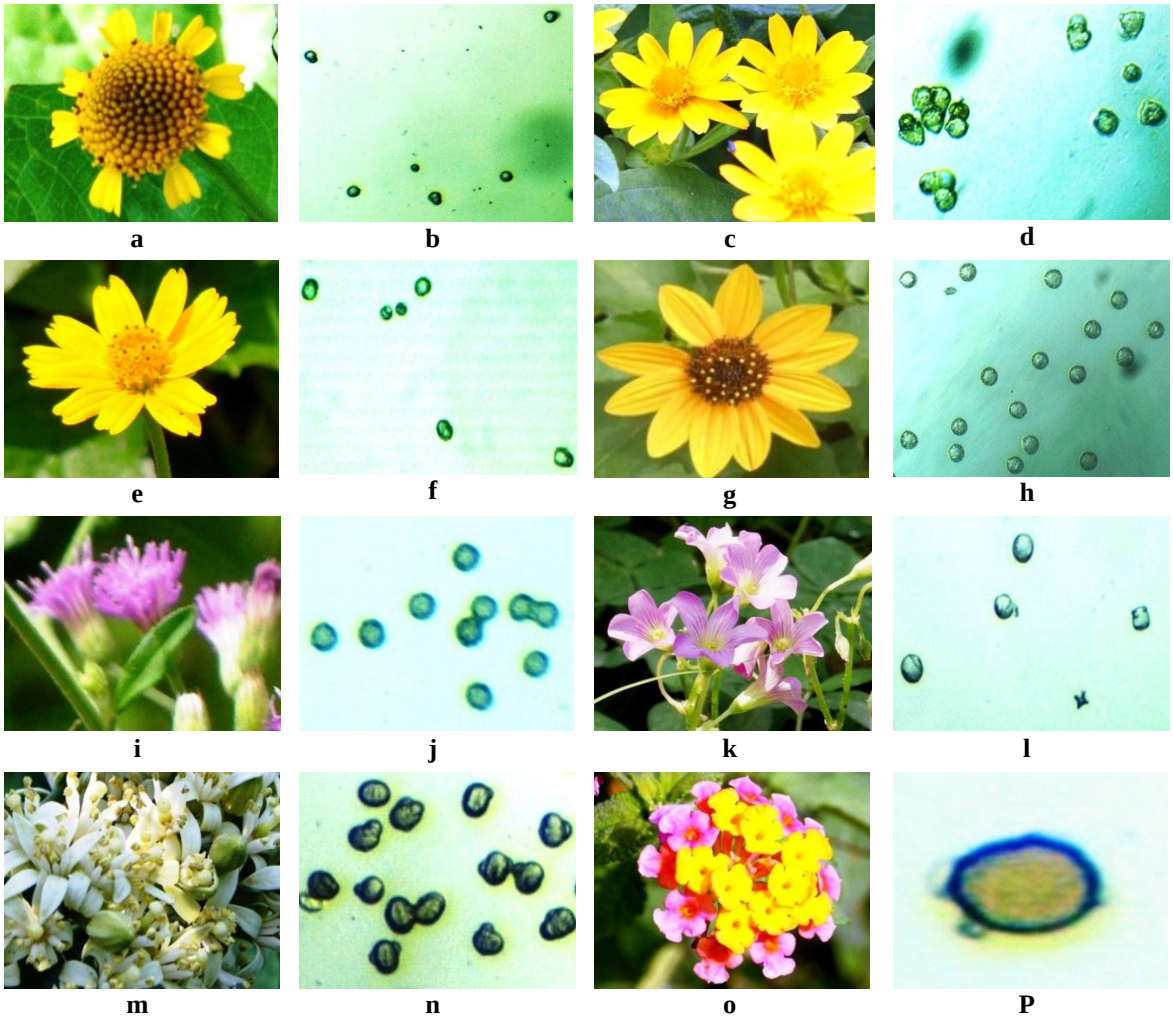


Plate 47. Pictorial presentation of examined flowers and pollen grains: **a**. flower, and **b**. pollen grains of *Spilanthes calva*; **c**. flowers, and **d**. pollen grains of *Wedelia chinensis*; **e**. flower, and **f**. pollen grains of *Wedelia trilobata*; **g**. flower and h. pollen grains of *Helianthus debilis*; i. flowers and j. pollen grains of *Vernonia cinerea*; k. flowers and l. pollen grains of *Oxalis corymbosa*; m. flowers and n. pollen grains of *Micromelum minutum*; and o. flowers and p. pollen grains of *Lantana camara*.

When a butterfly lands on a flower to sip nectar, the flower's pollen becomes attached on butterfly's body and as the butterfly moves from flower to flower intake more nectar, the pollen is transferred. Butterflies hold the position next to the bees as the efficiency of pollen transfer concerned, still, many plant species, particularly those bearing the wild flowers, would be unable to reproduce without the assistance of these beautiful insects

(Ghosh and Saha 2016). This study investigates the flower visit activities of lycaenid butterflies that influence in transferring plant pollens.

Butterfly pollinators select different floral characteristics to express higher level of floral selectivity and specialization (Bluthgen *et al*. 2006). The pollen analysis data incorporates the butterfly-plant interactions. During the present investigation, flowers and pollens of eight plants have been examined. The plants are *Spilanthes calva*, *Wedelia chinensis*, *W. trilobata*, *Helianthus debilis*, *Vernonia cinerea* of family Asteraceae; *Oxalis corymbosa* of family Oxalidaceae; *Micromelum minutum* of family Rutaceae; and *Lantana camara* of family Verbenaceae (Plate 47).

Pollen is a fine coarse powdery substance comprising pollen grains which are male micro gametophytes of seed plants, that produce male gametes (sperm cells). A pollen grain is a microscopic body. These tiny bodies are swirling in the air and on the legs of insects so that they can join the female part of the plant to create a new seed. In angiosperms, pollen is produced by the anther, which sits on the filament in the center of the flower. Pollen grains of various species can vary quite a lot in size (from about 10 to 100 micrometer, exceptions are the thread shaped pollen grains of some eelgrass) and in aspect: round, ovale, disc or bean-shaped and sometimes filamentous. The natural colour is mostly white, cream, yellow or orange. The shape of all examined pollen grains is spheroidal. The pollen grains are varied in sizes found in different flowers. The area of pollen grains is measured as 9155.15±3469.51 μm^2 in *Oxalis corymbosa*. This measurement indicates that the pollen grain is big sized. On the other hand, *Spilanthes calva* contains small sized pollen grains with 429.87±63.21 μm^2 area (Table 18).

Table 18. Structural variations in pollen grains of the different plant-flowers related to the lycaenid butterflies.

Plant	Shape of pollen grains	Size of pollen grains		
		Radius (µm)	Perimeter (µm)	Area (μm^2)
Spilanthes calva	Spheroidal	11.62±0.93	73.37±5.39	429.87±63.21
Wedelia chinensis	Spheroidal	48.07±4.75	302.05±29.85	7326.38±1416.43
Wedelia trilobata	Spheroidal	34.63±4.11	217.53±25.76	3816.12±929.39
Helianthus debilis	Spheroidal	36.03±5.13	226.41±32.27	4156.49±1078.75
Vernonia cinerea	Spheroidal	37.73±1.58	237.07±9.93	4481.46±371.55
Oxalis corymbosa	Spheroidal	53.19±9.58	334.21±60.15	9155.15±3469.51
Micromelum minutum	Spheroidal	41.21±3.62	253.88±18.62	5188.08±781.47
Lantana camara	Spheroidal	20.21±3.26	126.96±20.48	1287.70±462.07

In order to complete fertilization, pollen must make its way to another plant. Pollen grains represent the male portion of the reproductive process in plants. Once the pollen from one flower is brushed off onto another flower, it is caught on the female part of the

flower, called the pistil. The pollen then grows down the pistil to fertilize the ovule, located at the end of the pistil. A fertilized ovule becomes a seed, and the ovary swells up to produce a fruit. During pollen gathering, butterflies remain at a single flower longer than during nectar feeding (Gilbert 1972). More pollen is attached on the body parts of butterflies if they visit flowers for long duration. For this, the visit frequency and visit duration of lycaenid butterflies has been assessed during the present investigation (Table 13). More pollen is attached with proboscis while butterfly intake nectar. When proboscis is extracted from narrow corolla, pollen grains adhere to the outer surface of the proboscis. Most of the pollen grains accumulate ventrally in the basal third of the proboscis (Boggs and Watt 1981). When butterflies visit flower to flower for nectar inserting proboscis into corolla, the attached pollen grains transmitted to the flowers. Thus, the pollination of plant is ensued. Pollination efficiency of plants should increase, if butterflies should exhibit increased effective foraging. The present investigation provides an informative idea indicating the pollination services of lycaenid butterflies that resulted butterfly-plant interactions.

5.3.2.2.5 Lycaenid butterflies with the pollination and gene-flow activities

Pollination is one of the most fascinating aspects of interaction between plants and insects. The extent of interdependence is regulated by phenology, floral characters as well as by form, structure and behaviour of the pollinator (Ram and Mathur 1984). Approximately two-thirds of all flowering plants are pollinated by insects so that their reproductive success and in part their population structure are determined by insect behaviour (Goulson 1999, Schoonhoven *et al*. 2006). Butterflies are considered to be an important bio-resource and pollinating agent for the conservation of natural gene-flow in plant kingdom (Akand *et al*. 2015b). Gene-flow mechanism is a dynamic phenomenon in establishing genetic biodiversity to maintain species diversity in any certain ecosystem (Futuyma and Peterson 1985). In the plants, with the entomophilous pollens, the pollen movement is the major component of gene-flow rather than the movement of seeds (Ehrlich and Murphy 1988). Pollen transfer among flowers is a fundamental component of gene-flow activity on plants; and the pollen dispersal is happened by the behavioural activities of pollinators (Price and Waser 1979). Flower pollens become attached on body parts of butterfly when they visit from flower to flower for sucking nectar; thereby the pollen is transferred onto another flower causing pollination (Gilbert 1972). For a butterfly to be an effective pollinator, it has to remain constant in its visits to a plant

species (Andersson and Dobson 2003). The visit of butterflies to flowers is more versatile, starts from ground level vegetation to the canopy layer of trees. That is why almost all plants are visited and pollinated by the butterflies in an ecosystem (Bashar 2015).

Insects like bees as well as butterflies are strong and versatile pollinators, respectively. Though bees are densely pollinators, but they are confined to selective plants. On the other hand, butterflies are diverse pollinators because of their diverse and distance covering mobility. An experiment has been conducted on the mobility of the butterflies and the honey bees to assess their gene-flow activities to the related plants. This experiment was done in Krishibari Butterfly Park (KBP), Savar, Dhaka during the year of 2015. The site is covered with plants of different layers of vegetation.

Table 19. Examination of mobility of butterflies and bees to the experimental plants to assess their status as pollinators in Krishibari Butterfly Park (KBP), Savar, Dhaka during the year of 2015.

Pollinators	Counted visits-range/ experimental plants	Foraging-range on the experimental plants	Range of plant species visited	Characteristics of visits	Types of plants/total plants area	Status of pollinators/ relations
Butterflies	1-42	1-62(s)	15-46 at a time	Foraging, nectaring, mating, egg-laying, patrolling (diversely)	All types (from grasses to trees) 55 plants of 60 experimental plants	Diverse pollinators: Relations of visits with the plant at almost all the parts of plants like barks, young stems, leaves, buds, flowers, fruits and sometimes with roots even.
Honey bees	102-300	300×60(s) together	1-2 mainly 1 at a time	Mainly collection of nectar and pollens (densely)	5 plants out of 60 experimental plants. But one plant more than 90% time of total budget time.	Confined pollinators but densely pollinators: Associated with only the flowers. But on the few or/and on the selective plants; and moreover of the seasonal plants preferably.

Table 19 explains that, 60 plants were selected to study the behavioural activities of butterflies and bees during the experiments. Out of 60 plant species, 55 plants were visited by butterflies. On the other hand, honey bee visited only 5 plants out of 60 species. But number of visits made by the bees varied on plants (flowers) and it was 102-300 times/individuals per hours. In case of butterflies, number of visits by them varied on plants (both flowers and vegetative parts) from 1-42 times/individuals per hours. Butterflies visited plant species from 15 to 46 mainly at a time and their foraging time ranges 1-62 seconds; whereas 1-2 plants mainly single plants at a time were visited by bees and their foraging time ranges 300×60 seconds; and continuously occurred the visits

by the bees (Table 19). Lycaenids like *Lampides boeticus*, *Euchrysops cnejus*, *Arhopala pseudocentaurus* and *A. amantes* have a wide range of flower visit pattern, and aid in pollination for those plants. Small lycaenids such as *Pseudozizeeria maha*, *Zizina otis*, *Caleta decidia* visit *Spilanthes calva*, *Punica hybrida* and *Gomphrena globosa* are responsible for the pollination of respective plants.

The butterfly's mobility is distance-covering and more diverse than that of the bee visits (Herrera 1987). Their pollination activities maintain the plant population healthy in an area more than the other animal can do it. The diversity of pollination and diversity in gene-flow in the plant kingdom made by the butterflies are much wider and broadly functional (Bashar 2015, Herrera 1987). Richness in gene-flow in any ecosystem is directly proportional for the dimension of successive trophic level (Jermy 1984). Therefore, it requires a strong interaction between plants and animals in order to establish a stable ecosystem (Wiense 1976). The knowledge of pollination process is a pre-requisite in a plant breeding and for obtaining better yield of plants. And the plant-insect interaction is an essential factor for pollination process of plants. So an adequate care should be taken to conserve both flora and fauna of nature for future generation.

Hence, the present investigation is an attempt to analyze the interaction between butterflies and plants accessing the relationship between lycaenid butterflies and plants based on foraging behaviour, flower visit pattern, nectar intake activities and pollen transfer movements of lycaenid butterflies in relation to plants. Further studies in this fascinating and challenging field of inquiry are required for a proper evaluation of butterflies as utilizers of floral nectar and as pollen carriers.

5.3.2.3 The lycaenid butterflies and fruit feeding behaviours

Adult butterflies feed from various substrates that contain sugar and/or mineral substances such as flower nectar, fruits, honeydew, tree sap, mud, carrion, and dung (Smedley and Eisner 1995, Beck *et al*. 1999, Omura *et al*. 2000). Some butterflies use only one of these substrates, others a combination (Molleman *et al*. 2005a). The butterflies that attract to fruits for feeding purpose are termed as fruit feeding butterflies. Adult feed on the damaged and ripened fruit helps them in obtaining proteins and carbon sources with such nutrient uptake improving egg productivity (Fischer *et al*. 2004). The behavioural adaptations of fruit feeding in butterflies can occur at different levels

including location of searching behaviour, cues used during searching, selection of fruit, uptake of food, and digestion (Dierks and Fischer 2018).

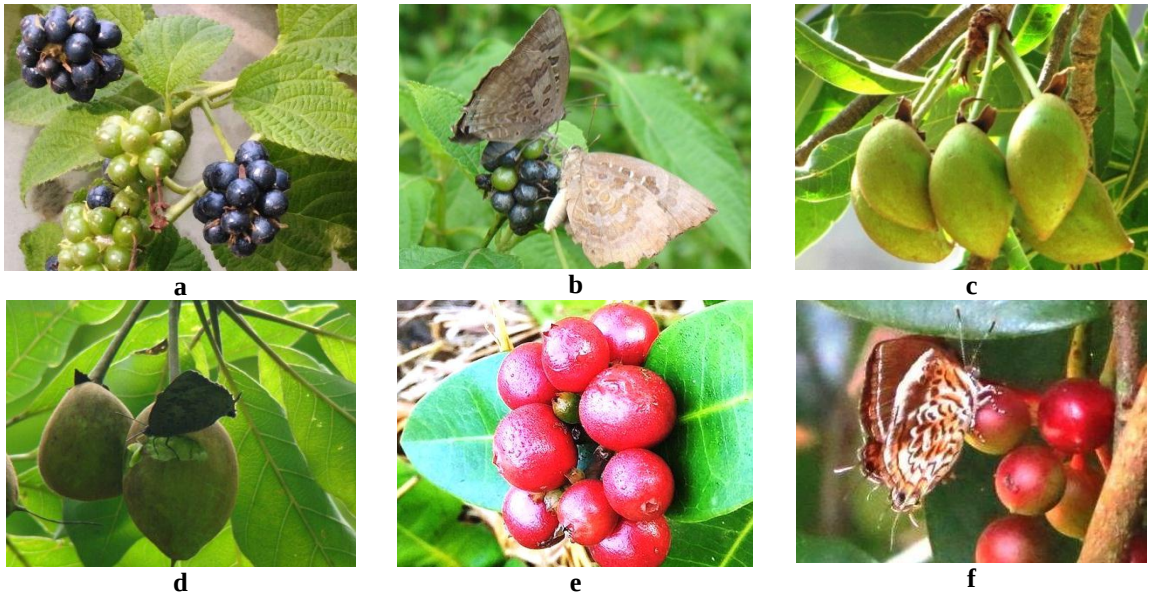


Plate 48. Fruit feeding activities of lycaenid butterflies: **a**. young and ripe fruits of *Lantana camara*; **b**. *Arhopala amantes* foraging on fruits of *Lantana camara*; **c**. Fruits of *Madhuka indica*; **d**. *Arhopala pseudocentaurus* foraging on eaten fruits of *Madhuka indica*; **e**. Fruits of *Ixora coccinea*; and **f**. *Rathinda amor* forging on fruits of *Ixora coccinea*.

Fruit feeding behaviours of butterflies are recorded as piercing and sweeping. According to Molleman *et al*. (2005b), sweeping butterflies are able to take up nutrients from surfaces commonly found in the forest, and thus may not be as dependent on high quality food such as sugar-rich and juicy fruits. The piercing technique was most efficient for feeding on soft fruits, whilst the sweeping technique was also used on lower quality food. Sweeping butterflies applied the dorsal side of the tip region of the proboscis to the feeding surface and either lifted the tip and placed it elsewhere, or swept it over the surface. They have a characteristic bend region and use it while sweeping. Proboscis movements differed greatly in frequency across substrates, probably depending on the texture and fluidity of the fruit.

During the present investigation three lycaenid butterflies *Arhopala amantes, Arhopala pseudocentaurus* and *Rathinda amor* have been observed feeding fruits in BRP (Plate 48). These lycaenids was observed to forage on fruits of *Lantana camara, Madhuka indica* and *Ixora coccinea*, respectively. The accessibility of juice from particular fruits can be greatly enhanced by activities of other animals. Once the fruits have been fed on that remove the skin and seed before eating the flesh, butterflies can feed on them. *Arhopala pseudocentaurus* has been observed to feed on *Madhuka indica* that already eaten or

damaged by other animals. The present study provides brief information on behavioural observations on fruit feeding lycaenid butterflies in the experimental sites.

5.3.3 Puddling behaviour of lycaenid butterflies

Puddling behaviour is a special type of feeding behaviour by which adult butterfly suck water and dissolved nutrients from mud, dung and carrion. Puddling is to serve as a means of acquiring essential adult sources, particularly sodium. Sometimes butterflies mud puddles in aggregation and sometimes singly. In general, young males are most frequently found puddling (Collenette 1934, Adler 1982, Adler and Pearson 1982). Occasionally, female butterflies visit mud puddles tend to be older individuals (Berger and Lederhouse 1985, Launer *et al.* 1993, Sculley and Boggs 1996). Female butterflies collect minerals from male through mating as nuptial gift. Females that mate several times were rarely seen puddling themselves, whereas females that mate only once were more often seen puddling when old, presumably because their male-derived sodium reserves had been depleted (Boggs and Jackson 1991**)**. However, if females mate multiple times throughout their lives, they may receive multiple inputs of puddle nutrients and never need to puddle. In these cases, males are foraging for nutrients for females (Sculley and Boggs 1996). The butterflies puddle for several seconds to an hour at a time. All this behaviour leads up to the main purpose of a butterfly's life for successful reproduction.

During the present investigation, a total of 356 individuals of lycaenid butterflies were seen to puddle in the different experimental sites. Data has been obtained from 107 lycaenid butterflies belonging to 12 species when they puddles on different substratum. The observed species were *Psedozizeeria maha*, *Zizina Otis*, *Chilades lajus*, *Catochrysops strabo*, *Castalius rosimon*, *Caleta decidia*, *Tarucus callinara*, *Jamides celeno*, *Euchrysops cnejus*, *Arhopala pseudocentaurus*, *Arhopala amantes* and *Rapala pheretima* (Table 20). In different ecological condition lycaenid butterflies are seen to puddle characteristically (Plate 49). When temperature rises in day time butterflies are engaged to puddle. In forest areas where water-bodies are not available nearby, butterflies use water-supply in different sources of organic matters or in the watery or dump soils (Bashar 2015). Lycaenid butterflies used different substratum such as moist ground, mud, moist pitch, wet sand, debris, decaying materials, and mammalian dung to puddle.

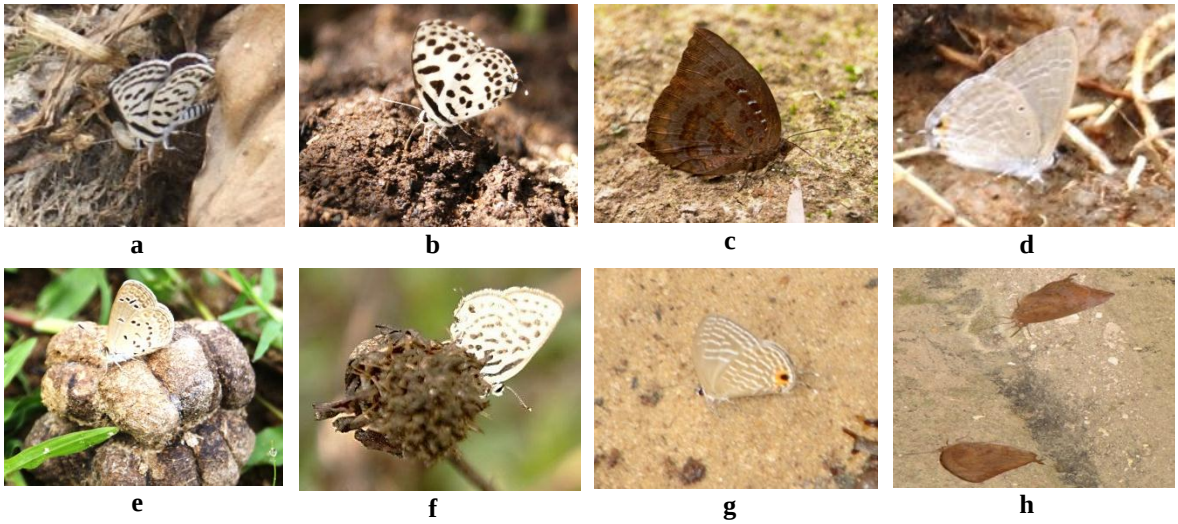


Plate 49. Puddling of lycaenid butterflies on different substratum: **a**. *Tarucus callinara* on debris; **b**. *Castalius rosimon* on mud; **c**. *Arhopala pseudocentaurus* puddles on moist ground; **d**. *Euchrysops cnejus* on moist ground; **e**. Zizina otis puddles on mammalian dung; **f**. *Tarucus callinara* on decaying flower; **g**. *Jamides celeno* on wet sand; **h**. *Arhopala pseudocentaurus* puddles on moist pitch floor.

It has been identified that 63 male lycaenid butterflies was puddle on different substratum while female lycaenid was 29 only. Among 107 observed lycaenid butterflies, 15 individuals was having unidentified sexes (Table 20).

Table 20. Examined lycaenid butterflies in puddling behaviours.

Species	Individuals	Male (♂)	Female (♀)	Unidentified sex
Psedozizeeria maha	8	5	2	1
Zizina Otis	6	4	2	-
Chilades lajus	11	7	3	1
Catochrysops strabo	9	5	3	1
Castalius rosimon	11	5	4	2
Caleta decidia	6	3	1	2
Tarucus callinara	7	4	2	1
Jamides celeno	8	5	2	1
Euchrysops cnejus	10	7	3	-
Arhopala pseudocentaurus	13	8	2	3
Arhopala amantes	11	6	3	2
Rapala pheretima	7	4	2	1
Total	107	63	29	15

It was found that 107 lycaenid butterflies puddles 138 times for the duration of 656 minutes on different substratum. Maximum 10 species puddles on moist ground while minimum 2 species was found on the moist pitch. But highest number (31) of individual butterfly puddles on moist ground whereas lowest (7) on dung. The lycaenid spent maximum time (194 min) on moist ground while minimum (33 min) on mud (Table 21).

Table 21. Puddling duration of examined lycaenid butterflies on different substratum.

Puddling substratum	Number of species	Individual number	Puddling duration (minutes)	
			Avg.±SD	Total
Moist ground	10	31	5.38±3.26	194
Mud	3	10	2.53±1.45	33
Moist pitch	2	8	5.5 ± 3.61	66
Wet sand	5	21	4.67±2.85	112
Debris	7	18	5.36±3.08	134
Decaying materials	5	12	4.06± 2.30	69
Dung	3	7	4.36±1.86 2	48

Actual use of each substrate by a species will depend not only on preference but also on encounter rate. Likewise, substrate condition, and availability or concentration of nutrients in the dung or mud, will vary through time and among patches and may affect usage (Boggs and Dau 2004). The present investigation provides brief information of puddling behaviour of lycaenid butterflies in the experimental sites.

5.3.4 Thermoregulation and basking behaviour

Thermoregulation is an important component to initiate behavioural activities of butterflies (Kingsolver and Moffat 1982, Kamrunnahar *et al*. 2018). As butterflies are cold blooded insects, they are unable to maintain a constant body temperature that is independent of their environment. The flight of butterflies requires high muscle temperature, and their activity is strongly affected by thermoregulation (Watt 1968, Heinrich 1993, Wickman 2009). When the environment is cool a butterfly is cool and its metabolism works at a slower rate. But when it is warm the butterfly's metabolic rate is higher, creating sufficient energy for flight and other activities (Akand 2012). Butterfly raises its body temperature through basking. Butterflies open their wings in the sunlight in order to keep flight muscle warm to sufficient temperature. When temperatures are get to warm, butterflies seek shade (Bashar 2015). The rates of thermoregulation are dependent on basking posture, basking methods, body size and wing colouration (Heinrich 1986).

The basking behaviour in lycaenid butterflies has been well observed in different forest sites throughout the study period. The principal way that lycaenids regulate their heat gain has been recorded. Heat gain of butterflies takes place by behavioural orientation and posture relative to the sun. Three different basking postures among five described wing postures has been observed and recorded in this investigation. The recorded basking postures are horizontal, angled, and closed sun. The lycaenid butterflies have been documented as active in basking using three wing postures in the study areas.

5.3.4.1 Examined lycaenids and the basking behaviours

During field examination, 172 individuals belonging to sixteen lycaenid species has been observed in basking. The recorded species were *Psedozizeeria maha*, *Zizina otis*, *Chilades lajus*, *C. pandava*, *Catochrysops strabo*, *Castalius rosimon*, *Caleta decidia*, *Jamides celeno*, *Lampides boeticus*, *Euchrysops cnejus*, *Arhopala pseudocentaurus*, *Loxura atymnus*, *Rapala manea*, *R. pheretima*, *Remelana jangala* and *Hypolycaena erylus*. All examined butterflies have been marked showing horizontal, angled and closed sun basking postures (Table 22). The lycaenids has been observed in basking at 2748 times in different study areas and noted basking time length. Recorded basking time length was found 69,113 seconds during examination. Butterflies spent 20,429 (29.56%) seconds in basking with horizontal wing posture and the frequency was 819 (29.8%).

Table 22. Examined lycaenid butterflies with different basking postures.

Species	Horizontal	Angled	Closed sun
Psedozizeeria maha			
Zizina otis			
Chilades lajus			
C. pandava			
Catochrysops strabo			

Castalius rosimon			
Caleta decidia			
Jamides celeno			
Lampides boeticus (♀)			
Euchrysops cnejus			
Arhopala pseudocentaurus			
Loxura atymnus			
Rapala manea			

Rapala pheretima			
Remelana jangala			
Hypolycaena erylus			

The recorded basking frequency with angled wing posture was 943 (34.32%) and butterflies used 22,110 (31.99%) seconds for basking. On the other hand, basking frequency with closed sun posture was counted as 986 (35.88%). In this case, butterflies engaged 26,574 (38.45%) seconds in basking (Fig. 20).

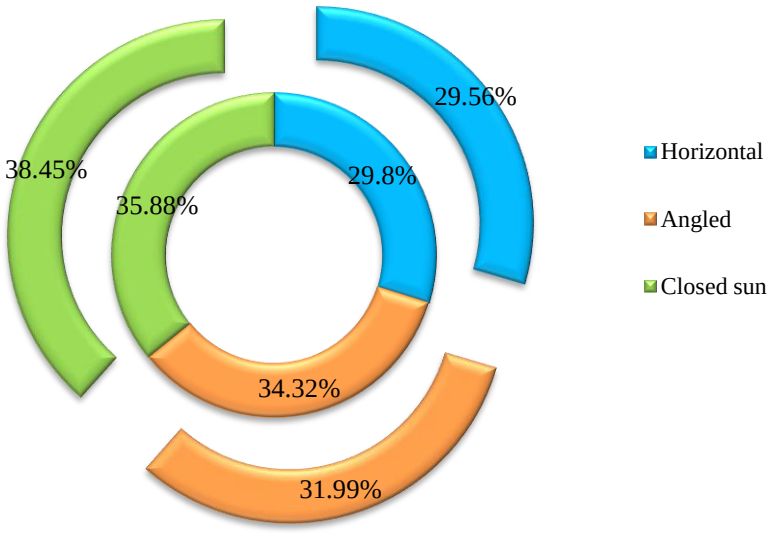


Fig. 20. Duration (broken circle) and frequency (regular circle) of basking with different wing postures.

Examined lycaenids with different basking postures along with basking time budget are tabulated in Table 23. Species-wise statements are made accordingly as stated below-

Eleven individuals of *Psedozizeeria maha* have been found to bask 486.57±269.29 seconds for 146 times. This butterfly basks maximum 53 and minimum 2 seconds in

horizontal position; maximum 52 and minimum 2 seconds in angled position; and maximum 63 and minimum 5 seconds in closed sun position. The basking time budget of this species was 132.17±71.71, 188.50±79.57 and 223.14±117.31 seconds for horizontal, angled and closed sun position, respectively. It has been noted that *Psedozizeeria maha* basks highest 15 times within 11-20 seconds time frame in angled position whereas lowest only one time at 51-60 seconds time frame in horizontal position.

Total 25 individuals of *Zizina otis* has been observed and recorded their basking data. This species spent 452.67±228.84 seconds per 133 times in three basking position. The maximum duration was 54, 53 and 55 seconds; and minimum was 2, 2 and 3 seconds in horizontal, angled and closed sun position, respectively. This butterfly has its time budget for basking status was 128.5±70.22 seconds in horizontal, 128.50±70.22 seconds in angled, and 170.16±99.37 seconds in closed sun. It basks highest 15 times within the range of 11-20 seconds in angled position, and lowest only one time within 51-60 seconds both in horizontal and angled position.

In case of *Chilades lajus*, 21 individuals have been examined during study period. It basks 190 times with duration of 559.57±304.33 seconds. This butterfly has been found basking in maximum 54 and minimum 2 seconds in horizontal; maximum 53 and minimum 3 seconds in angled; as well as maximum 62 and minimum 2 seconds in closed sun position. The basking time budget was recorded as 194.5±87.19, 222.5±89.82, and 202.14±86.45 seconds for horizontal, angled and closed sun position, respectively. This species has the highest 21 times for basking within 11-20 seconds time frame in angled position whereas the lowest only one time both in horizontal and closed sun position with the range of 41-50 seconds and 61-70 seconds frame, respectively.

Fourteen members of *C. pandava* species have been noticed to bask for 456.71±233.31 seconds per 147 times. It spent maximum 53, 52 and 61 seconds in addition to minimum 2, 3 and 2 seconds in horizontal, angled and closed sun position, respectively. The time budget of three basking status has been calculated as 158.67±74.71 seconds in horizontal, 159.67±67.99 seconds in angled and 183.86±68.54 seconds in closed sun. This lycaenid used the highest 15 times for basking within 1-10 seconds and 11-20 seconds time frame in angled and closed sun position, respectively. On the other hand, the lowest was only one time under the time frame of 51-60 seconds in horizontal position.

During the present investigation *Catochrysops strabo* has been examined and counted 180 times with the period of 670.14±430.01 seconds for their basking behaviour. Seven butterflies were tallied for this examination. This butterfly used 57, 54 and 63 seconds in maximum as well as 3, 3 and 6 seconds in minimum for horizontal, angled and closed sun position, respectively. The basking status and time budget of this species was horizontal: 238.83±108.77 seconds; angled: 261±123.36 seconds and closed sun: 241.71±166.64 seconds. *Catochrysops strabo* spent highest18 times with the range of 11-20 seconds time frame in angled position whereas lowest was only one time for 61-70 seconds range.

Nine butterflies of *Castalius rosimon* species have been noticed and calculated 501.71±228.77 seconds per 141 times for basking condition. This lycaenid spent maximum 52 and minimum 3 seconds in horizontal position whereas maximum 55 and minimum 5 seconds in angled position. On the other hand maximum 62 and minimum 3 seconds was recorded in closed sun position. It used total 139.33±82.55, 170.33±63.11, and 222±79.83 seconds for basking in horizontal, angled and closed sun position, respectively. The highest 15 times within 11-20 seconds range in angled position, and lowest 3 times within 1-10 seconds range both in horizontal and closed sun position for basking was also recorded.

Caleta decidia spent 460.67±241.47 seconds for 147 times basking. The data from only five individuals has been aggregated. This small lycaenid used maximum 46, 51 and 52 seconds for basking in horizontal, angled and closed sun position, respectively as well as minimum 2 seconds for each status. The basking time budget per status was calculated as 151±59.97 seconds in horizontal, 174.67±96.21 seconds in angled, and 160.17±80.98 seconds in closed sun. This species spent highest 23 times and lowest only one time with the range of 1-10 seconds and 51-60 seconds in angled position.

Jamides celeno utilized 139 times for basking with 418.63±239.38 seconds duration. Five butterflies were examined for this study. It spent maximum 54, 56 and 72 seconds as well as minimum 3, 3 and 2 seconds for basking in horizontal, angled and closed sun position, respectively. It was calculated that *Jamides celeno* was active in horizontal, angled and closed sun position for basking with time length of 156.16±65.75, 165.83±56.06 and 177.13±73.55 seconds, respectively. This butterfly was found to bask highest 14 times within 11-20 seconds and lowest only one time within 71-80 seconds in closed sun position.

Twelve individuals of *Lampides boeticus* were observed and noted data for their basking behaviour. This lycaenid spent 635±397.48 seconds per 177 times. It used 54, 62 and 53 seconds in maximum for horizontal, angled and closed sun position in addition to minimum 3 seconds for horizontal and 2 seconds each for angled and closed sun position. The calculated time budget per basking status was 252.33±126.74 seconds in horizontal, 251.43±125.79 seconds in angled, and 194.67±115.44 seconds in closed sun position. This butterfly was spotted to bask highest 16 times within 11-20 seconds time frame in angled position whereas lowest was only one time within 51-60 seconds time frame in closed sun position.

Euchrysops cnejus has been noticed to bask 179 times for time length of 629.14±407.11 seconds. Data on eleven individuals has been accumulated for this investigation. This species spent maximum 52 seconds in horizontal and angled position, and 62 seconds in closed sun position as well as minimum 2 seconds each for three basking status. The basking status and time budget of *Euchrysops cnejus* was calculated as horizontal: 239±138.49 seconds; angled: 254.5±116.77 seconds; and closed sun: 206.14±112.69 seconds. This lycaenid has been spotted in basking highest 17 times with the range of 11-20 seconds in angled position and lowest only one time with 61-70 seconds range in closed sun position.

Arhopala pseudocentaurus was seen in basking for 235 times with 935±583.46 seconds time length. Eleven butterflies of this species have been studied for basking data recording. This butterfly was active maximum 72, 61 and 76 seconds in horizontal, angled and closed sun position, respectively whereas minimum was 3 seconds in both horizontal and closed sun, and 2 seconds in angled position. The estimated time budget for this lycaenid was 294±184.82 seconds in horizontal, 350.43±202.29 seconds in angled, and 334.38±192.35 seconds in closed sun position. It spent highest 17 times within 21-30 seconds time frame in angled position and lowest only one within 71-80 seconds time frame in horizontal position.

In *Loxura atymnus*, the basking behaviour of seven individuals has been examined during study period. This lycaenid was active 372.29±220.81 seconds to bask 127 times. It spent 41, 52 and 61 seconds in maximum for horizontal, angled and closed sun position, respectively whereas minimum was 2 seconds each for above mentioned three basking position. The calculated time budget for horizontal, angled and closed sun position was 77.2±34.97, 178.5±83.95 and 164.14±83.61 seconds, respectively. This butterfly spotted

in basking for highest 17 times in the time frame of 1-10 seconds for angled position. On the other hand lowest was marked only one in the time frame of 41-50 and 61-70 seconds for horizontal and closed sun position, respectively.

Rapala manea has been noticed to spent 856.50±588.29 seconds in basking for 251 times. Recorded data on thirteen butterflies of this species was tallied in this study. This butterfly was active maximum 65, 55 and 74 seconds in horizontal, angled and closed sun position, respectively. On the other hand it expended minimum 2 seconds each for above mentioned basking position.

Rapala manea bask 303.57±169.87 seconds in horizontal position, 284.83±149.72 seconds in angled position, and 377.25±244.82 seconds in closed sun position. This lycaenid was noticed highest 23 times basking within 31-40 seconds range and lowest two times within 61-70 seconds range in closed sun position.

Six butterflies of species *R. pheretima* have been examined in the field and recorded their basking behaviour. This lycaenid was engaged 662.71±333.87 seconds to bask 170 times. It spent maximum 57 seconds and minimum 2 seconds in horizontal and angled position. On the other hand, this butterfly was active 64 seconds in maximum and 3 seconds in minimum for closed sun position. The basking status and time budget was calculated as horizontal: 207.5±74.01seconds; angled: 211.67±75.89 seconds; and closed sun: 303.43±161.88 seconds. It was spotted to bask highest 15 times with the time frame of 1-10 seconds in angled position, whereas lowest was marked 4 times within 51-60 seconds frame in horizontal and angled position as well as within 61-70 seconds frame in closed sun position.

Remelana jangala has been found busy 205 times for spending 693.25±439.22 seconds in basking. Total eight individuals of this butterfly were examined to record data. It spent 58, 54 and 72 seconds in maximum for horizontal, angled and closed sun position, respectively as well as 2 seconds each in minimum for all three basking positions. This butterfly showed basking in horizontal, angled and closed sun position with estimated time budget of 275.5±140.23, 269.33±142.04, and 284.62±169.83 seconds, respectively. This lycaenid has been found to engage highest 21 times with the range of 11-20 seconds in angled position and lowest only one with 71-80 seconds range in closed sun position.

Table 23. Recorded lycaenids with duration and frequency of basking per status.

Examined species	Individuals	Horizontal posture		Angled posture		Closed sun		Total	
		Duration (sec)	No.	Duration (sec)	No.	Duration (Sec)	No.	Duration (Sec)	No.
Psedozizeeria maha	11	132.17±71.71	41	188.50±79.57	53	223.14±117.31	52	486.57±269.29	146
Zizina otis	25	128.5±70.22	40	128.50±70.22	49	170.16±99.37	44	452.67±228.84	133
Chilades lajus	21	194.5±87.19	58	222.5±89.82	66	202.14±86.45	66	559.57±304.33	190
C. pandava	14	158.67±74.71	47	159.67±67.99	47	183.86±68.54	53	456.71±233.31	147
Catochrysops strabo	7	238.83±108.77	56	261±123.36	64	241.71±166.64	60	670.14±430.01	180
Castalius rosimon	9	139.33±82.55	40	170.33±63.11	41	222±79.83	60	501.71±228.77	141
Caleta decidia	5	151±59.97	40	174.67±96.21	60	160.17±80.98	47	460.67±241.47	147
Jamides celeno	5	156.16±65.75	43	165.83±56.06	42	177.13±73.55	54	418.63±239.38	139
Lampides boeticus	12	252.33±126.74	60	251.43±125.79	67	194.67±115.44	50	635±397.48	177
Euchrysops cnejus	11	239±138.49	57	254.5±116.77	64	206.14±112.69	58	629.14±407.11	179
Arhopala pseudocentaurus	11	294±184.82	74	350.43±202.29	82	334.38±192.35	79	935.00±583.46	235
Loxura atymnus	7	77.2±34.97	22	178.5±83.95	54	164.14±83.61	51	372.29±220.81	127
Rapala manea	13	303.57±169.87	71	284.83±149.72	72	377.25±244.82	108	856.50±588.29	251
R. pheretima	6	207.5±74.01	49	211.67±75.89	55	303.43±161.88	66	662.71±333.87	170
Remelana jangala	8	275.5±140.23	59	269.33±142.04	71	284.62±169.83	75	693.25±439.22	205
Hypolycaena erylus	7	294.43±182.25	62	271.33±199.04	56	272.86±178.95	63	799.86±547.24	181

Table 24. Basking status of examined lycaenids in time frame with calculated time budget.

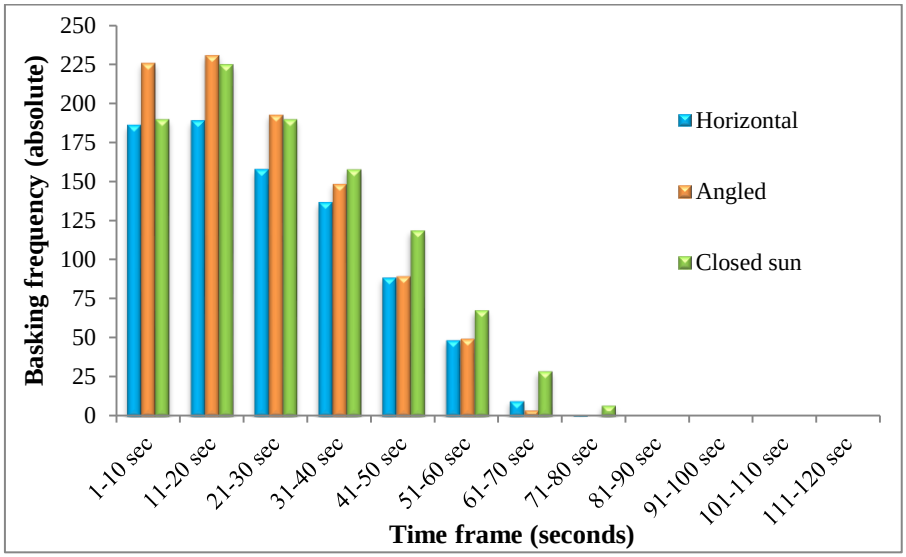
Time frame	Horizontal		Angled		Closed sun		Total	
	Duration (Sec)	Frequency	Duration (Sec)	Frequency	Duration (Sec)	Frequency	Duration (Sec)	Frequency
1-10 sec	73±19.63	186	84.75±23.03	226	74.88±23.46	190	232.63±53.75	602
11-20 sec	188.69±52.15	189	226.5±63.47	231	220.94±47.69	225	636.13±122.93	645
21-30 sec	249.38±81.83	158	304.44±74.33	193	302±70.21	190	855.81±187.67	541
31-40 sec	303±144.81	137	329.56±119.05	149	349.94±168.16	158	992.5±404.36	444
41-50 sec	252.94±147.83	89	255.19±129.4	90	338.19±160.59	119	846.31±387.99	298
51-60 sec	189.21±153.44	49	166.13±110.6	50	228.56±139.2	68	560.25±366.15	167
61-70 sec	212±32.23	10	122.5±0.71	4	141.08±85.67	29	193.93±165.44	43
71-80 sec	72	1	--	--	127±69.31	7	145±84.31	8
81-90 sec	--	--	--	--	--	--	--	--
91-100 sec	--	--	--	--	--	--	--	--
101-110 sec	--	--	--	--	--	--	--	--
111-120 sec	--	--	--	--	--	--	--	--

Hypolycaena erylus was seen in basking for 181 times with the period of 799.86±547.24 seconds. Seven members of this species has been observed and counted basking data. This butterfly was active for basking maximum 64, 53 and 63 seconds in horizontal, angled and closed sun position, respectively. It spent minimum 3 seconds each in horizontal and angled position as well as 5 seconds in closed sun position. This species was engaged 294.43±182.25 seconds in horizontal, 271.33±199.04 seconds in angled, and 272.86±178.95 seconds in closed sun position. This lycaenid was spotted to bask highest 16 times within 31-40 seconds time frame in angled position whereas lowest 2 times within 61-70 seconds time frame in closed sun position. The collected basking data from the field condition has been arranged detail in Appendix 15.

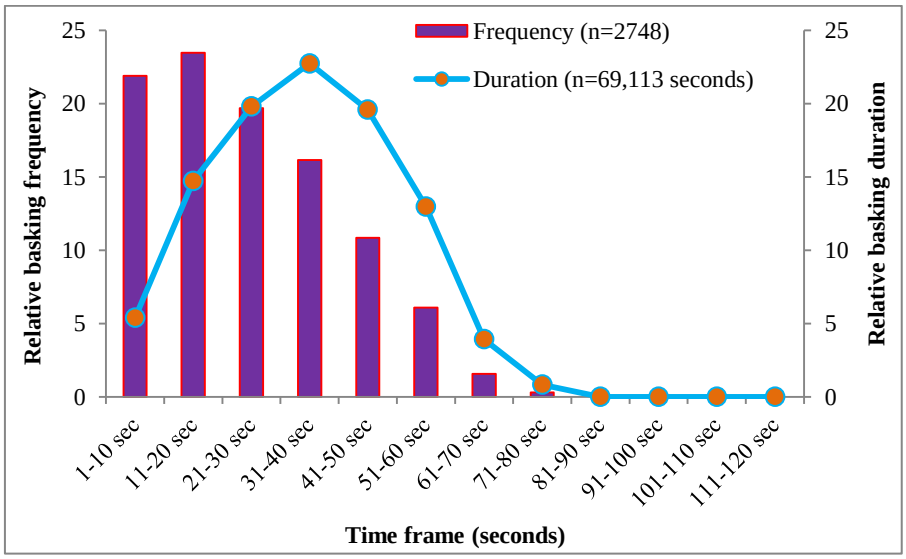
5.3.4.2 Basking of examined lycaenid butterflies with time frame and day time

The time budget within time frame has been calculated from accumulated data of 172 individuals belonging to sixteen lycaenid butterflies. Twelve time frames were prepared within 1-120 seconds (2 minutes). The basking frequencies and time budget in different status were counted based on the time frame (Table 24). It has been estimated that the examined lycaenids spent 232.63±53.75 seconds for 602 times within 1-10 seconds time frame. It is also calculated that butterflies were engaged 73±19.63 seconds for 186 times in horizontal position, 84.75±23.03 seconds for 226 times in angled position and 74.88±23.46 seconds for 190 times in close sun position within this time frame. Within 11-20 seconds time frame lycaenids were basking 645 times with the period of 636.13±122.93 seconds. Butterflies have found to bask 188.69±52.15 seconds per 189 times in horizontal position, 226.5±63.47 seconds per 231 times in angled position, and 220.94±47.69 seconds per 225 times in closed sun with the range of 11-20 seconds time frame. It was estimated that butterflies bask 541 times in 855.81±187.67 seconds time budget for 21-30 seconds time frame. It is also found that lycaend used 249.38±81.83, 304.44±74.33 and 302±70.21 seconds in basking for 158, 193 and 190 times in horizontal, angled and close sun position, respectively in this time range. The butterflies showed basking behaviour in the time frame of 31-40 seconds with 992.5±404.36 seconds duration per 444 times. Within this time frame lycaenids also spent 303±144.81 seconds per 137 times in horizontal position, 329.56±119.05 seconds per 149 times in angled position, and 349.94±168.16 seconds per 158 times in closed sun position. Butterflies were spotted to bask 298 times with the period of 846.31±387.99 seconds within the range of 41-50 seconds. Within this range butterflies also engaged to bask in horizontal,

angled and closed sun for 89, 90 and 119 times with 252.94±147.83, 255.19±129.4 and 338.19±160.59 seconds time period, respectively.



a



b

Fig. 21. Basking time frame for examined lycaenid butterflies: **a**. absolute frequency marking horizontal, angled and closed sun position; **b**. relative basking frequency and duration within time frame.

The basking time budget was calculated 560.25±366.15 seconds for 167 times in 51-60 seconds time frame. Lycaenid was marked in basking 49 times for 189.21±153.44 seconds in horizontal position, 50 times for 166.13±110.6 seconds in angled position, and 68 times for 228.56±139.2 seconds in closed sun position within 51-60 second time frame. With the range of 61-70 seconds, butterflies spent 193.93±165.44 seconds at 43 times basking. Within this time range, lycaenid engaged 212±32.23 seconds at 10 times, 122.5±0.71 seconds at 4 times, and 141.08±85.67 seconds at 29 times for horizontal, angled and closed sun position, respectively. The estimated time budget was 145±84.31

seconds for 8 times basking within 71-80 seconds time frame. In this time frame, butterflies was found to bask in horizontal and closed sun position with 72 seconds per only one time and 127±69.31 seconds per 7 times, respectively. No lycaenid was recorded within the rest of time frames. These time frames are 81-90, 91-100, 101-110 and 111-120 seconds. The absolute basking frequencies marking three basking position has been plotted demonstrating time frame (Fig. 21a). It has been observed that lycaenids engaged in basking at highest frequencies within 11-20 seconds time frame in examined basking position.

Basking time frame has been designed indicating relative basking frequencies along with relative basking duration (Fig. 21b). Through the recorded data, the basking time has been accelerating from 1-10 seconds time frame, and then a prominent peak was made within time frame 31-40 seconds. After that basking time was decreasing along with frequencies. It is mention earlier that the examined lycaenids have been spent 69,113 seconds in basking for 2748 times in different study areas during present investigation.

Lycaenid starts basking their wings from morning at 8.00 am. This tendency is extending with basking frequency towards 11.00 am. Then basking rate is declined. Generally butterfly basks to sun before noon (Akand 2012). Under relatively cool conditions as in the early morning or in late afternoon no lycaenids were visible during the study period.

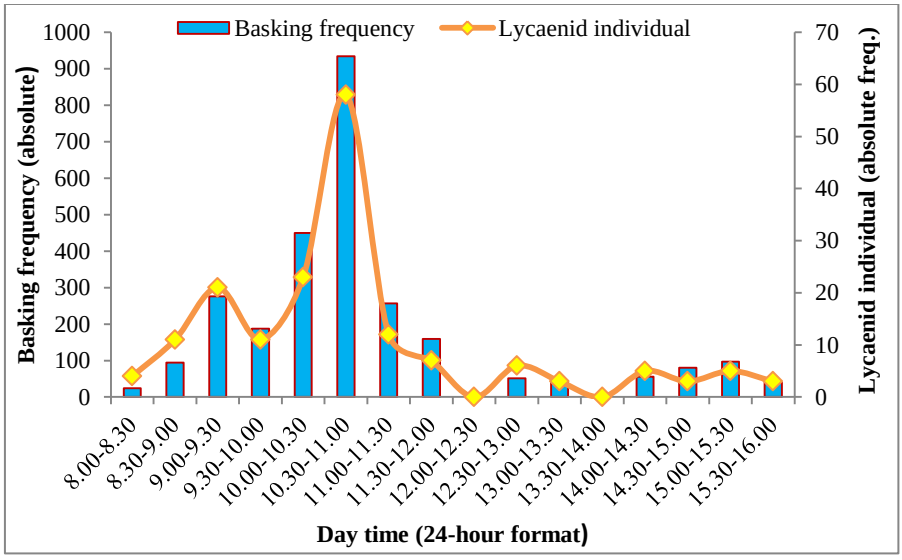


Fig. 22. Lycaenid basking in relation to different day time.

From the field data, it was found that lycaenid individuals along with basking frequencies have the tendency to accelerate from morning hours to subsequent hours before noon. Basking is decreasing after noon though a lesser numbers of individuals were seen to bask

till 2-4 pm. The highest basking was recorded from 10-11 am and made a highly evident peak (Fig. 22). At this stage 1384 basking was recorded from 81 individuals. Akand (2012) stated that lycaenid butterflies bask their wings during 9.30-11.30 am and few lycaenids were seen to bask during 2.00-3.00 pm in winter. Similar result has been found from the present investigation. Lycaenid basks at 8-9 am during summer with high frequency almost similar to 10-11am during winter. This condition happens depending on abiotic factors specially temperature status.

5.3.4.3 Relation of lycaenid basking with abiotic factors

Butterflies will often bask in the sun in the morning or on a cloudy day to get their temperature up (Bashar 2015). If the temperature gets too hot, they will reposition their wings to minimize exposure to the sun (Akand *et al*. 2015b). Generally lycaenid butterflies take more time for their basking during winter. Most of them prefer the month of November, December and January. In the present investigation, twenty observations were taken under consideration to collect basking data. The highest basking was visible during observation no. 4 was made and lowest at observation no. 11 (Fig. 23). It was noted that basking was highest (345) at 10.30-11.00 am in 4th December, 2015. Temperature and relative humidity was marked as 26.8°C and 48%, respectively. On the other hand, lowest (24) basking was counted at 8.00-8.30 in 9th May, 2017 where prevailing temperature and relative humidity was 29.1°C and 45%, respectively.

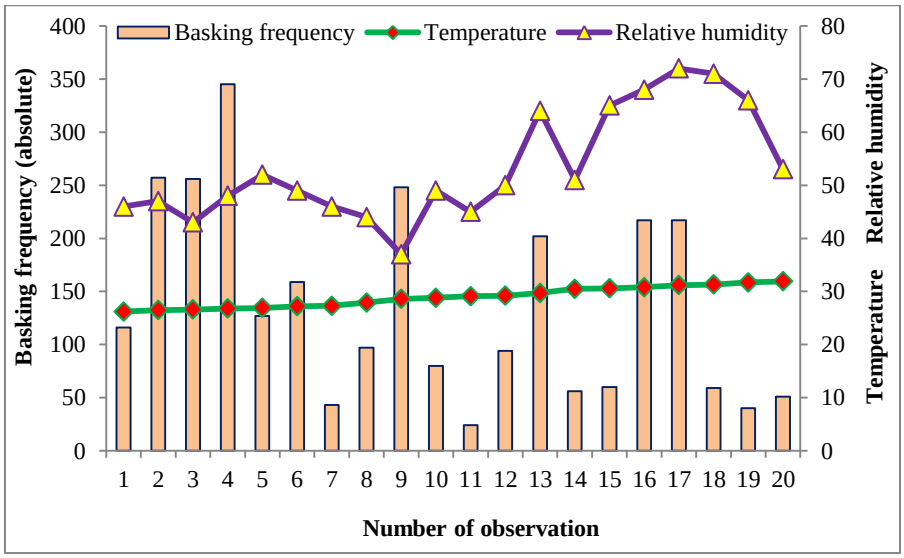


Fig. 23. Relation of basking with abiotic factors.

Different wing postures in response to various abiotic factors found significant in basking behaviour. Pearson rank correlation was used to assess the relationship between basking

frequencies and abiotic factors (viz. temperature and relative humidity). This analysis suggests that lycaenid basking is negatively correlated with temperature (r = – 0.41) and relative humidity (r = – 0.13). The basking is increased with decreasing temperature. This consequence indicates that an optimum condition of abiotic factors especially temperature and relative humidity is highly essential for lycaenid basking.

5.3.4.4 Plants or basking supportive agents other than plants

A butterfly that wants to bask will find a sunny and safe place to sit where it can spread open its wings and catch the sun's warming rays (Akand 2012). It has been noticed that lycaenid butterflies are strongly associated with plants for their basking supports. The plants that situated on direct sunlight or where sunlight is available butterflies were found active on basking (Akand *et al*. 2015b). There are 37 plant species have been identified as basking related plants. Detail descriptions of basking supporting plants have given in Chapter 3. The described data was collected from examined lycaenids when they utilized 21 plant species for basking. The plant species are *Cycas pectinata, Chromolaena odorata, Mikania cordata, Wedelia trilobata, Shorea robusta, Cajanus cajan, Lupinus polyphyllus, Vigna unguiculata, Melastoma malabathricum, Ziziphus mauritiana, Ixora coccinea, Citrus aurantifolia, Lantana camara, Duranta repens, Colocasia esculenta, Chrysalidocarpus lutescens, Punica hybrida, Curcuma aromatica, Paspalum scrobiculatum, Axonopus compressus, Setaria palmifolia*.

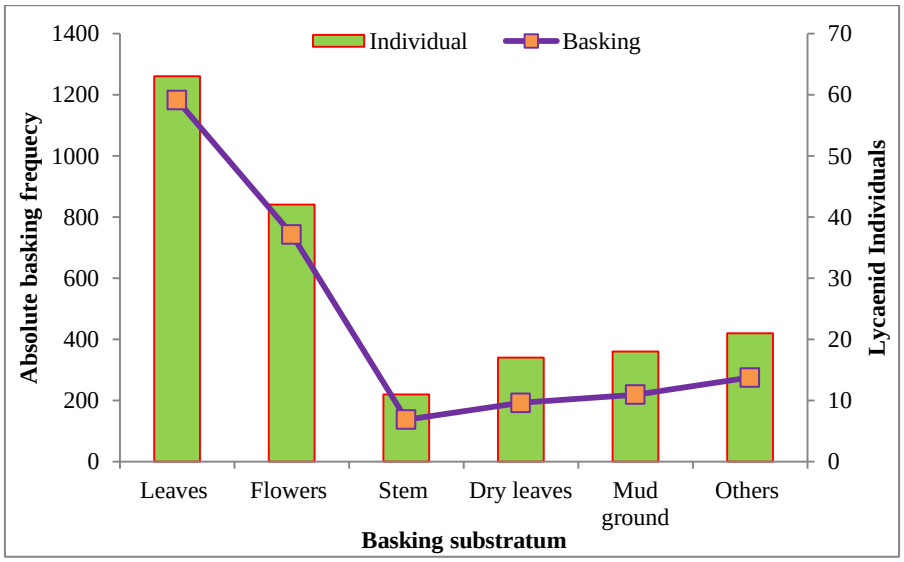


Fig. 24. Different basking substratum that used by lycaenid butterflies during study period.

Lycaenids take a position on leaves or other plant parts or other supportive spreading their wings under direct sunlight (Akand *et al*. 2015b). The observation of lycaenid basking

bahaviour on their related plants, herbs, shrubs and other dry materials were studied throughout the study period from different experimental sites. It was seen that lycaenid basking took place on leaves, flowers and stems of plants. Sometimes they also used dry leaves or other dry materials or even mud ground.

In present investigation, it has been noted that maximum (63) individuals using plant leaves as substratum at 1182 time basking. On the other hand plant stem has been exploited by minimum (11) butterflies with 137 time of basking (Fig. 24). Lycaenids usually sit on top leaves to bask their wings. When they used flowers as substratum for basking, they were observed nectaring in maximum occasion. And sometimes lycaenid butterflies showed puddling behaviour when using mud ground as basking substratum.

This study reveals that thermoregulation and basking is a complex and dynamic interactions of morphology, physical status and activities of butterflies along with influences of abiotic factors. Basking behaviour could be used to assess the status of butterflies as the indicators of climatic change and its impact on biodiversity.

5.3.5 Resting behaviour

Butterfly remains inactive in cloudy days or on dark or shaded place. This is the resting behaviour of butterfly. In resting condition, the butterflies sit on the upper surface or under surface of plant leaves. Sometimes they take rest on the other parts of plants beside leaves or dry supportive parts. In compare to the density of nectar plants and food plants area, the shade/resting plant area must be more dense and with assemblage of high species composition. Resting plants are mainly trees and hedges. It is found to happen that they take rest under/on the leaves of hedges under a big shade tree (Bashar 2012a, Bashar 2015). Like other butterflies lycaenid also take rest for some time after foraging, and female lycaenid butterflies are seen taking rest for a while between each egg-laying interval time (Akand *et al*. 2015b).

During this investigation, a total of 1624 lycaenid butterflies have been found in resting condition in different experimental sites (Appendix 1). The hedges, vines and bushes are suitable vegetation for serving as resting sites for lycaenid butterflies. Plants such as *Imperata cylindrica*, *Setaria palmifolia*, *Axonopus compressus* and *Paspalum scrobiculatum* of family Poaceae were seen to use by some small lycaenids only for resting and basking. *Chromolaena odorata*, *Ixora coccinea*, *Shorea robusta*, *Syzygium*

fruticosum and *Glycosmis pentaphylla* were found as favourable plants to lycaenids as their resting supports.

5.3.6 The lycaenid butterflies and mating behaviour

The life cycle of a butterfly is dependent on its ability to find a mate and then to reproduce. The adult butterfly spends much of its time searching for a mate, courting, and mating (Wiklund *et al*. 2001). Courtship and mating behaviours in butterflies are very characteristic and attractive (Wedell 2010, White and Ruxton 2015). Total period of mating behaviour can be categorized in chronological steps as pre-mating, mating fact and post mating stages (Bashar 2014). Pre-mating is also termed as mate location behaviour. Mating is performed through abdomen raising and coupling followed by post-mating activities. Courtship as a whole an overall behavioural activity incorporates all stages of mating, along with other activities.

Lycaenid butterflies were spotted frequently active in pre-mating and mating condition throughout the year during study period. During study period, a total of 240 lycaenid butterflies have been observed while they were in courtship (pre-mating and mating behaviour). While observing on pre-mating and mating activities, eight lycaenid species (viz. *Pseudozizeeria maha*, *Chilades lajus*, *Chilades pandava*, *Catochrysops strabo*, *Tarucus callinara*, *Castalius rosimon*, *Lampides boeticus* and *Euchrysops cnejus*) were considered for recording data.

5.3.6.1 Mate location behaviour (Pre-mating activities)

Mate location behaviour is defined as behaviour which brings the sexes together for mating. It includes the methods used to find mates, the location of mating, and the time of day for initiation of mating (Scott 1973). Butterflies mate-locating system is important to promote the population of butterflies. The mate-locating strategies employed by males are correlated with the availability of 'receptive' females (Rutowski 1991). There are several methods or approaches have been used by male butterflies to searching and determining whether he has found the right female of his own species. Perching males use movement in the initial approach to a potential female. Perching species usually mate in limited areas of the habitat, often during only part of the day. Females seem to know where the males will be perched; hence it is common to see them fluttering in that habitat waiting for a male. Perching males often return to a place near the previous site after investigating

a passing female. Patrolling behaviour in male butterflies is different from perching behaviour. In patrolling, the males butterfly fly above regions where the female butterflies are present, and when males found them with the same size and colour, males fly more closer to examine it. Perching is often combined with territorial behaviour with males defending sites. The butterflies find the females of the same species by releasing their pheromones (Andersson *et al*. 2007). When butterflies get closer to each other they use pheromones.

a **b** **c**

Plate 50. Lycaenid butterflies in pre-mating condition: **a**. *Pseudozizeeria maha*; **b**. *Castalius rosimon*; and **c**. *Chilades pandava*.

During investigation, 126 individuals (63 pair) of lycaecid butterflies was found in pre-mating activities (Appendix 1). Three pairs of examined lycaenids has been captured in pre-mating activities during experiment (Plate 50). Both perching and patrolling behaviours have also been found to appear in different times of the whole study period. In case of *Castalius rosimon*, females used to release pheromones and males use to show their different pre-mating art-posture (dance) to impress the female. Competition between different males to mate with the female was quite a common phenomenon among different lycaenid butterflies.

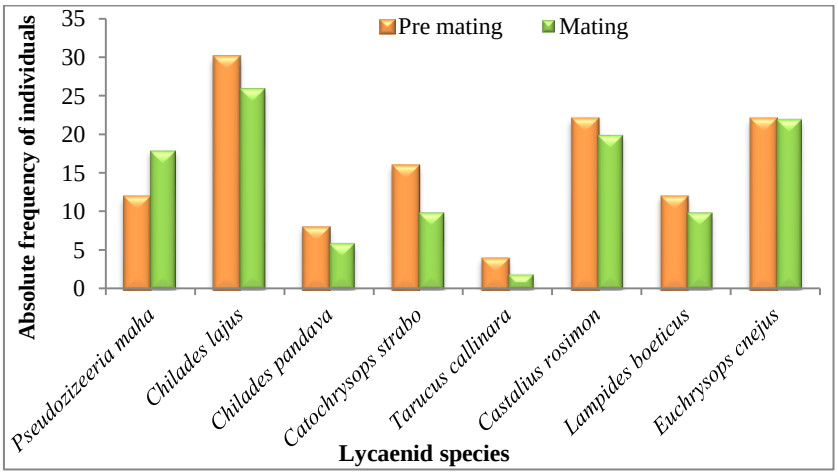


Fig. 25. Examined lycaenid butterflies marking pre-mating and mating frequency.

Chilades lajus were observed in maximum (30 individuals) performing pre-mating activities, while minimum (4 individuals) in *Tarucus callinara* (Fig. 25). The highest (24 individuals) number of butterflies was found in pre-mating during the month of March and lowest (2 individuals) in January and August (Fig. 26).

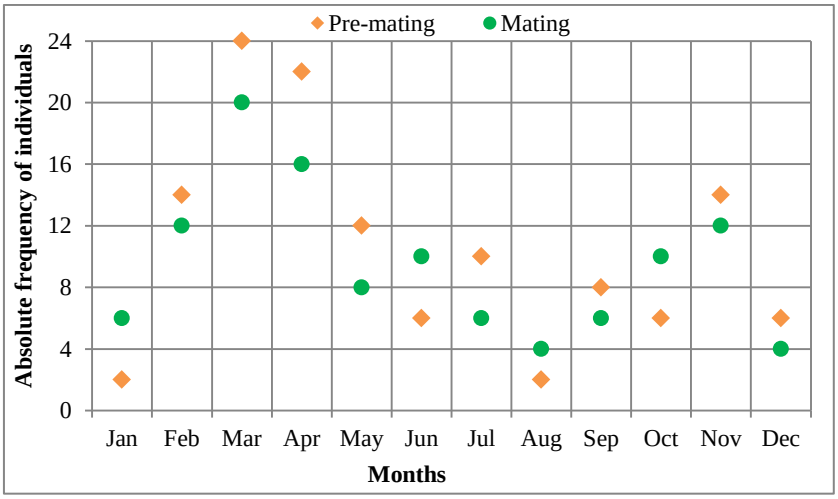


Fig. 26. Pre-mating and mating pattern of lycaenid butterflies in different month.

The lycaenid butterflies in pre-mating condition was observed maximum (38 individuals) in BRP and minimum (4 individuals) in ScNP (Fig. 28). It was found that lycaenid butterflies were active in pre-mating during various periods in day time. Maximum number of butterflies (36 individuals) were found in between 11.00 am and 12.00 pm whereas minimum (6 individuals) were spotted from 15.00 to 16.00 pm in pre-mating activities (Fig. 29). Mate location strategy varies significantly between and within butterfly species (Shreeve 1992). Such differences can be permanent or change over time (i.e. daily or seasonally), and several factors influence the proportions of males exhibiting each searching behaviour at any point (Wiklund 2003).

5.3.6.2 Courtship behaviour

Courtship behaviours in butterflies are very characteristic and attractive (Bashar 2014). There is a tremendous diversity of courtship behaviour. Courtship serves two functions: to promote mating between individuals of the same species; and to prevent mating with other species. Most of the events during courtship have no useful function other than as token stimuli. The male initiated entire process of mating through perching and established a territory. Males spent most of their time in establishing territory, chasing intruder males and courting females. In an ascending circular territorial flight between

residents and conspecific intruder males, resident males won and intruders were chased away. But, in short flight an intruder male was chased away without contest. An active male attracted a virgin female within 30 min after establishing a territory. In courtship pattern the male releases pheromone and dances around the female by moving its wings spreading pheromone to the female's antennae. The pair alighted after 1-4 rounds of courtship lights at an interval of 4-5 min; each courtship flight last for about a minute. The courtship can take minutes or few hours that depends on species of butterflies and the female can accepts or rejects the male in courtship pattern. Sometimes pairs made one or more alighting attempts before final settling. If the female is interested to mate, then male use their clasping organs to grasp the abdomen of that female (Fatouros *et al.* 2008). The typical pattern of courtship and mating has been plotted in sequence (Fig. 27).

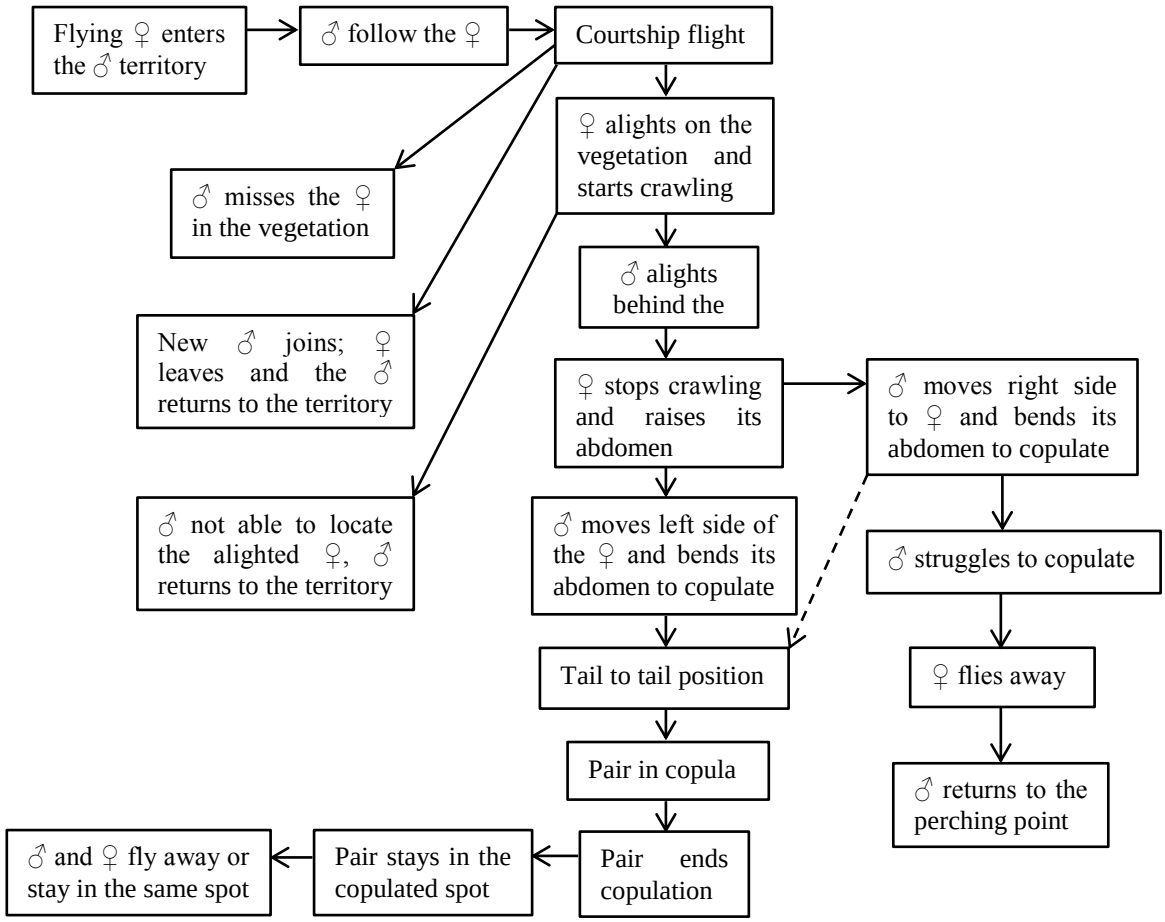


Fig. 27. Diagrammatic presentation of various events ensues in courtship and mating behaviour of butterflies (source: Dinesh and Venkatesha 2013).

Consecutive events of courtship have been described here following Cordero (1993), and Dinesh and Venkatesha (2013). A female flies near (<1 m) a flying or, more frequently, a perching male. The male flies following the female and a courtship flight along a route

parallel to the ground begins; during the courtship flight the male flies near (<10 cm), slightly behind and a few cm above the female. Female and male alight on vegetation close to each other; there were a few cases in which one or more alighting attempts preceded final settling of the pair. Immediately after the couple alights on vegetation, the male walks in front of the female until reaching a head to head position, while fluttering vigorously; meanwhile, the female stays motionless with her wings closed. It is possible that during this phase the male emits pheromones from androconia located near the forewing costal border. After a few seconds, and still fluttering, the male walks beside the female until reaching a parallel, head to head and tail to tail position. The male moves the tip of his abdomen toward that of the female, and after making genital contact, stops fluttering; immediately after beginning copulation the male moves until reaching the "tail to tail" position, typical of Lepidoptera. During copulation the couple stays motionless, unless some perturbation, such as strong wind or people coming too close to the mating pair, makes them fly *in copulo* to a different place on vegetation. The end of copulation begins with the female starting to move, turning and occasionally walking short distances (less than 20 cm); these movements are intercalated with female turnings around her longer body axis, until the pair ends genital contact. After separation the female and/or the male may remain in the mating place for a few minutes or they may fly away almost immediately. In few occasions the male found the female again, after seconds or a couple of minutes, and a short pursuit flight followed, which ended when the male returned to perch and the female left the area. Courtship is mostly initiated inside territories. Copulations can take place inside territories, and may also occur outside, if the courtship flight takes the pair out of the territory.

During courtship flight males were very persistent and ceasing their activity only after females alighted. Duration of overall flight activity (perching and territorial activity, chasing an intruder male, and courtship flight) of males was longer than that of females. For a successful mating, butterfly process significant courtship behaviour. Because courtship is prerequisite for pairing and the pairing is prerequisite for mating (Bashar 2015).

5.3.6.3 Field observation in mating behaviour (lycaenid butterflies)

Mating is the longest phase of mating activity. If a female is ready to mate, the male will wait until she lands. Then the maie will quickly mate with her without any complicated mating ritual (Ferris and Brown 1981). The two may fly in a zigzag pattern or hover beside each other before mating. Mating is characterized by the great immobility of the

couple at the mating site. Copulation is always terminated by slight movement of females. As mention earlier eight species of lycaenid butterflies such as *Pseudozizeeria maha*, *Chilades lajus*, *Chilades pandava*, *Catochrysops strabo*, *Tarucus callinara*, *Castalius rosimon*, *Lampides boeticus* and *Euchrysops cnejus* found in mating condition during the study period (Plate 51). During present investigation, maximum (26) number of *Chilades lajus* were found busy in mating activities while minimum (2 individuals) in *Tarucus callinara* (Fig. 25). The highest (20) number of butterflies was found in mating during the month of March and lowest (4 individuals) in August and December (Fig. 26).

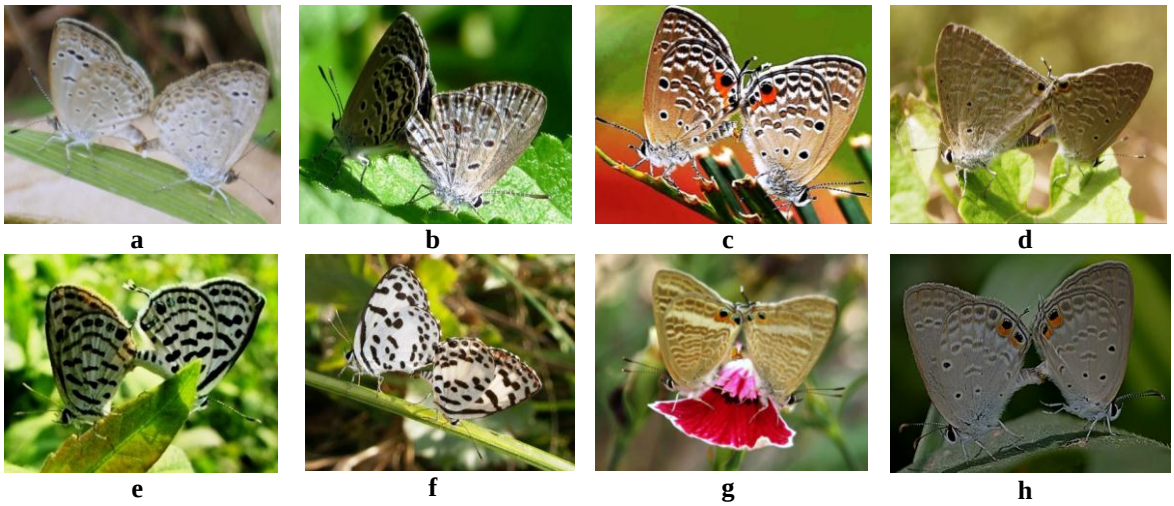


Plate 51. Observed lycaenid butterflies in mating condition: **a**. *Pseudozizeeria maha*; **b**. *Chilades lajus*; **c**. *Chilades pandava*; **d**. *Catochrysops strabo*; **e**. *Tarucus callinara*; **f**. *Castalius rosimon*; **g**. *Lampides boeticus*; and **h**. *Euchrysops cnejus*.

The highest (32) lycaenid butterflies was spotted in BRP whereas lowest (8) butterflies were found in MNP (Fig. 28). Pre-mating and mating activities of lycaenid butterflies were varied in the different periods of day time. Maximum (34) lycaenid butterflies were recorded in mating condition from 11.00 am to 12.00 pm whereas minimum (6 individuals) were spotted in between 15.00 and 16.00 pm (Fig. 29).

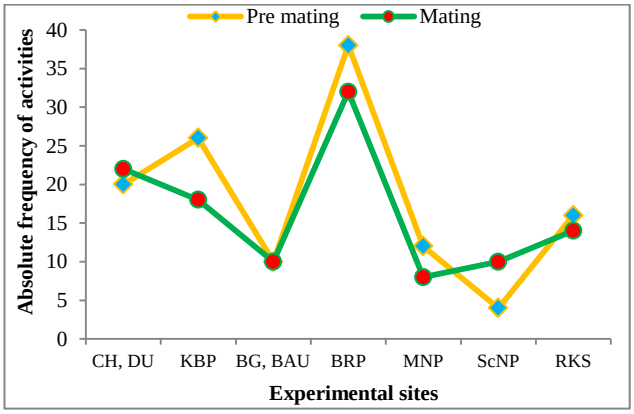


Fig. 28. Lycaenid butterflies marking pre-mating and mating condition in different experimental sites.

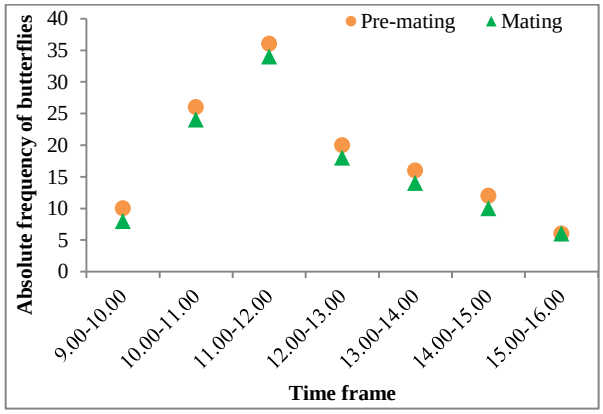


Fig. 29. Pre-mating and mating frequency of lycaenid butterflies in different experimental sites.

Duration of mating period is varied among examined lycaenid butterflies. It has been noticed that *Chilades lajus* and *Chilades pandava* spent 35 to 40 minutes in mating condition whereas *Castalius rosimon* and *Lampides boeticus* required 50-55 minutes to complete mating activities. *Pseudozizeeria maha* and *Tarucus callinara* were observed busy 40-45 minutes in mating while *Catochrysops strabo* and *Euchrysops cnejus* engaged 45-50 minutes to perform mating activities (Fig. 30).

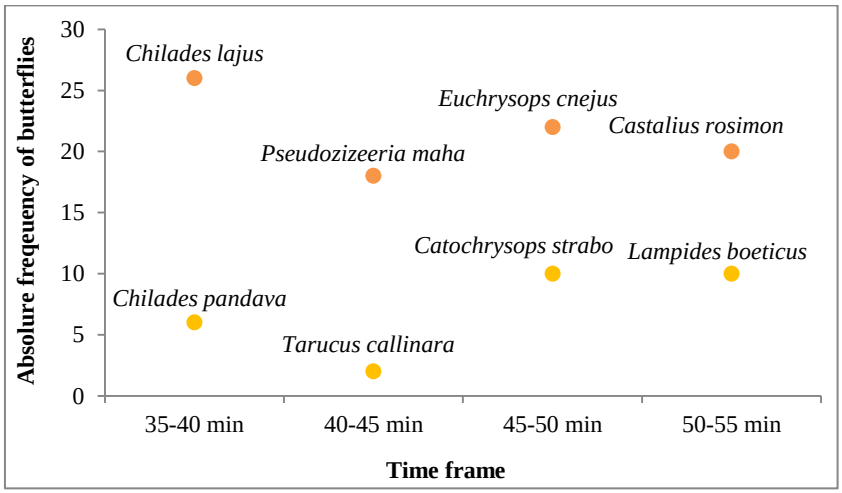


Fig. 30. Mating duration of observed lycaenid butterflies.

The process of courting and mating is highly variable among different species. Knowledge of mating in butterflies is crucial in developing an understanding of the behaviours that each species exhibits.

5.3.7 Egg laying behaviour and the lycaenid butterflies

Egg laying is one of the major processes involved in the ecology and evolution of interactions between insects and plants (Rabasa *et al*. 2005). The behaviour leading to oviposition, i.e. selection of oviposition site, is a complex process, because successful oviposition greatly contributes to individual fitness (Schowalter 2006). The quality and the quantity of host plants received much emphasis and considered as crucial factors that predominantly determine host plant choice of ovipositing females (Kareiva 1983, Awmack and Leather 2002, Rhainds and English-Loeb 2003, Stiling and Moon 2005). When a number of potential host plants are available, a female butterfly will lay most eggs on her most preferred plant species (or habitat or plant part), fewer eggs on her next preferred plant, and so on (Thompson and Pellmyr 1991). Females obtain cues and make choices at three different levels of resolution when searching for a potential host: choice

of habitat in which to search for host plants, choice of specific plants on which to land within a habitat, and the decision to oviposit or not after landing on a plant (Chew and Robbins 1984, Douwes 1968, Papaj and Rausher 1987, Renwick and Radke 1980). Once a female lands on a plant, she may still reject it; physical (Ramaswamy *et al*. 1987, Sosa 1988) and chemical factors may affect her decision whether to oviposit or not. In some species, females drum the plant surface with some or all tarsi and, only then, do they either oviposit or fly off (Feeny *et al*. 1983, Ilse 1937).

A total of 203 female belonging to 10 lycaenid species has been spotted in egg laying condition during study period. Data of egg-laying behaviour has been obtained from 17 females of three lycaenid butterflies (viz. *Chilades lajus*, *Catochrysops strabo* and *Remelana jangala*) in this investigation. Female lycaenid lays eggs singly on young buds and leaves of host plant. Usually they do not lay huge number of eggs. It was found that maximum butterflies among the experimental species lay their eggs during 9.30 am to 12.00 pm; and some species laid eggs at afternoon between 3.00 pm and 5.00 pm. Before egg-laying, the female lycaenids need to have 'found' plant(s) and the perfect site of plant(s) for oviposition, and it visits and searches the host plants by vibrating its wings rapidly and repeatedly (Akand *et al.* 2015b).

5.3.7.1 Host plant selection for oviposition

The host plant selection behaviour has been divided into several sequential steps comprising habitat finding, host plant finding, host plant recognition and acceptance which are in turn connected to host plant suitability (Prokopy and Owens 1983, Jones 1991). During host plant location, phytophagous insects employ a specific 'host plant search image' which is based on representative chemical and visual characteristics of their host plants (Stadler 2002). They use both chemical and visual cues to locate host plants and to discriminate host from non-host plants in diverse habitats (Jones 1991, Bernays and Chapman 1994, Schoonhoven *et al*. 2005, Fernandez and Hilker 2007). After a female detects the existence of a potential host plant (Miller and Strickler 1984), factors that influence choice of a host for oviposition can be divided into cues for pre alighting and post alighting behaviour (Knolhoff and Heckel 2014). The plant recognition process followed by the gravid female is similar in most butterfly species (Renwick and Chew 1994). Hern *et al*. (1996) stated that pre alighting behaviour consists of searching, orientation and encounter; and post alighting behaviour is discrimination characterized by landing, plant evaluation and acceptance or rejection. Females are attracted to their host

plant by chemical cues and/or visual cues. Cues used prior to alighting may act mostly to maximize oviposition rate and the overall chance of larval survival (Rausher 1983, Papaj and Rausher 1987). Post alighting cues may be used primarily to assess the suitability for larval growth of a particular plant relative to other plants of the same species in the population (Thompson and Pellmyr 1991). Landing on a plant by a gravid female is the transition between pre-and post-alighting behaviour. Information obtained by females prior to landing upon a plant may be quite different from that obtained by females after landing (Rausher 1983, Papaj and Rausher 1987). Females may search for a nutritive or oviposition host, which may be the same or a different plant. This sequence assumes females are freely mobile and have the ability to choose a host plant. The sequence of events is probabilistic, and females may opt out of the sequence at any step. Experience may influence future choices; the first completion of the sequence may shorten the time taken to make subsequent decisions. A diagrammatic presentation indicates the oviposition behaviour of female butterfly involved in sequence to find out potential host plants or plant parts (Plate 52).

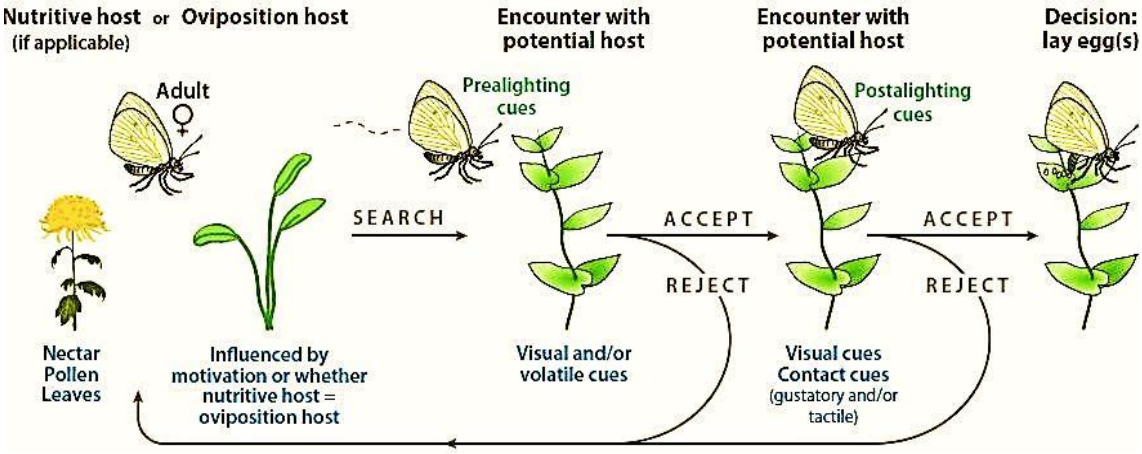


Plate 52. Events leading to oviposition by a gravid female butterfly (source: Knolhoff and Heckel 2014).

Prior to oviposition, butterflies drum the surface of the plant parts with the chemosensory organs located on of the forelegs, proboscis, antennae and ovipositor. The contact evaluation on the plants' surfaces proceeds very rapidly in order to detect plant compounds that stimulate oviposition (Tsuchihara *et al*. 2009). Nakayama and Honda (2004) found that contact chemical stimuli from the host plants play the decisive role at the final step of egg laying process.

During investigation, it was observed that gravid female lycaenid butterflies showed drumming behaviour in search of perfect oviposition sites on their host plants. The female *Remelana jangala* were observed to drum the inflorescence of its host plant *Ixora coccinea* by antenna, forelegs and abdomen (Plate 53).

a **b** **c** **d**

Plate 53. Drumming behaviour of lycaenid butterfly (*Remelana jangala*): a. antenna; b. forelegs; c. and d. abdomen (ovipositor).

A female butterfly may reject several plants before selecting the target one. Once a host plant is accepted, females have to find the best place on (or near) the plant where they can lay their eggs. The selection of plant parts by ovipositing females can influence how an interaction evolves between a particular insect species and its host plant (Thompson and Pellmyr 1991). Some butterflies are more likely to lay their eggs on the underside of leaves rather than the upper side of leaves (Moore 1986, Tiritilli and Thompson 1988, Williams 1981) or those receiving particularly high levels of sunlight (Grossmueller and Lederhouse 1985). If the female is disturbed by any reason during stirring egg laying process, it would flee up from the oviposition sites at once. After a few minutes later, the female will come back to the oviposition site of the host plant to complete the egg laying process.

5.3.7.2 Egg laying behaviour of gravid female lycaenids – field observation

Gravid female lycaenids are easily distinguished while they are seen onto the egg laying. This is evidently identified by marking their 'slow flight' and 'host plant searching'. They use young buds and leaves of the host plant as egg laying support to lay eggs singly. Female usually touches the bud or leaves with antennae and then takes a very short flight. It bends its abdomen to touch the plant parts and moves forward. Finding a suitable place female lays egg.

Soon after the oviposition, it quits the place frequently basks or taking rest for a certain period on leaf of various plants or the host plants or even on other supportive elements. Then the female comes back again to the host plant and lays another egg. In this manner female lycaenid lays several eggs in a short duration. The examined lycaenid butterflies

Chilades lajus, *Catochrysops strabo* and *Remelana jangala* were spotted to lay eggs on different parts of their host plants (Plate 54).

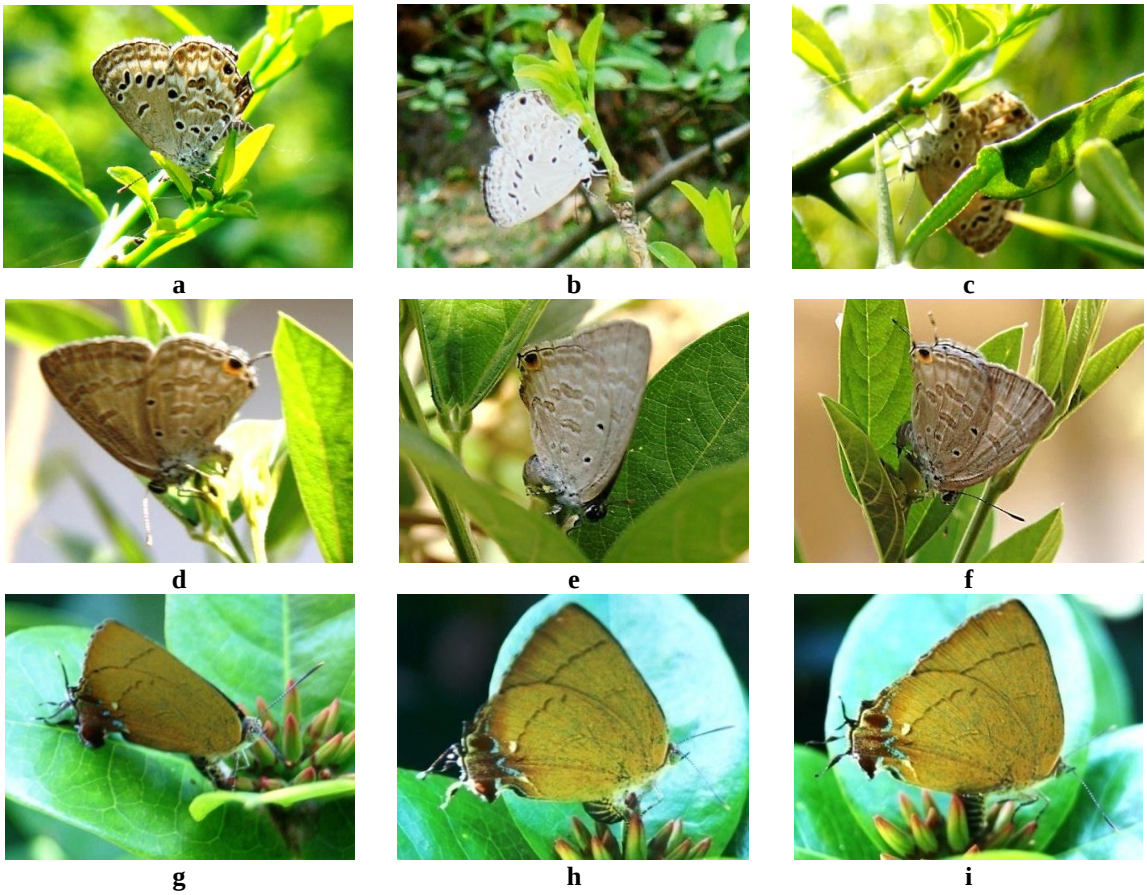


Plate 54. Egg laying condition of examined lycaenid butterflies (**a-c**: *Chilades lajus*; **d-f**: *Catochrysops strabo*; **g-i**: *Remelana jangala*): **a**. on young leaf; **b**. on leaf axial; **c**. on base of young stem; **d**. on young bud; **e**. on young shoot; **f**. on young leaf; **g**. on leaf base; **h**. on tip of young flower bud; and **i**. on axial of young flower buds.

During the present investigation, it was examined that how many times a female spent to lay an egg. The egg laying duration of lycaenid females was noted from 0.5 to 2 seconds time range (Fig. 31).

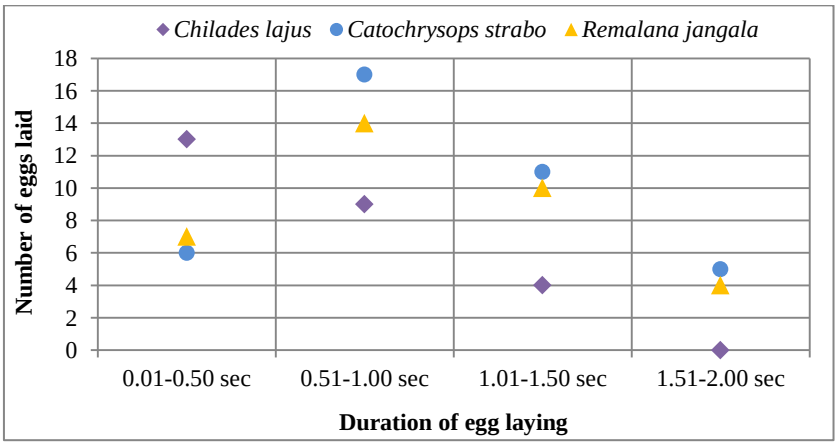


Fig. 31. Egg laying duration of examined lycaenid butterflies.

The time budget of egg laying and egg deposition was recorded from field when eggs were laid by *Chilades lajus* (26), *Catochrysops strabo* (39) and *Remelana jangala* (35). The duration of egg laying or egg deposition done by *Chilades lajus* was between the time range of 0.01-0.50 seconds in maximum (13) eggs and that of the 1.01-1.50 seconds in minimum (4) eggs while *Catochrysops strabo* and *Remelana jangala* laid maximum (17 and 14) eggs within 0.51-1.00 seconds and minimum (5 and 4) eggs between 1.51 to 2 seconds, respectively. No *Chilades lajus* was spotted to lay eggs within 1.51-2.00 seconds (Fig. 31).

5.3.7.3 Egg laying bout and egg deposition by female lycaenid butterflies

After laying an egg female lycaenid moves to a very short distance taking rest or bask, then come back again to lay another egg. A very short duration took place in between each egg-laying. Then the female butterfly flies away. After some time the same female come again to previous egg laying site or other site of the same plant or neighbouring plant to start its next bout of egg-laying. The female butterfly flies comparatively short distance and sitting on other plant or dry materials in between two bout of egg-laying. Gravid female was observed 40-50 minutes from its first egg-laying bout.

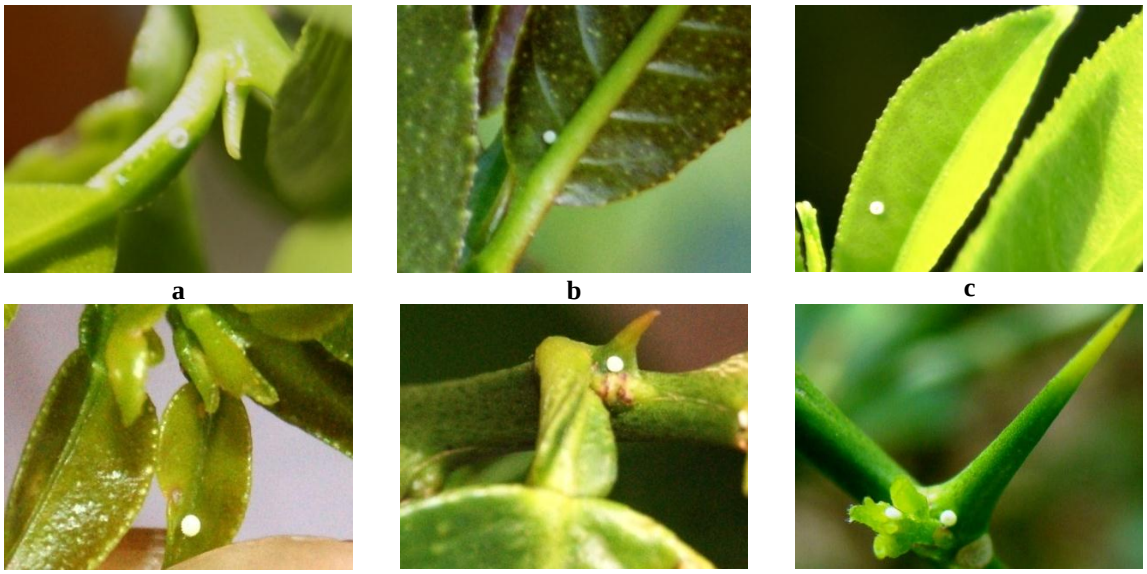
Table 25. Egg laying bout and egg deposition by female lycaenid butterflies.

Species	Number of observation	Number of eggs deposited on each egg laying bout			Total egg deposition
		1st bout	2nd bout	3rd bout	
Chilades lajus	Female-1	2	4	1	7
	Female-2	1	3	2	6
	Female-3	3	2	-	5
	Female-4	4	3	1	8
Catochrysops strabo	Female-1	2	3	2	7
	Female-2	3	2	1	6
	Female-3	2	2	-	4
	Female-4	1	3	1	5
	Female-5	4	2	-	6
	Female-6	2	1	3	6
	Female-7	3	1	1	5
Remelana jangala	Female-1	3	2	-	5
	Female-2	2	3	2	7
	Female-3	1	3	-	4
	Female-4	5	3	-	8
	Female-5	3	1	2	6
	Female-6	3	2	-	5

Four females of *Chilades lajus*, seven females of *Catochrysops strabo* and six females of *Remelana jangala* were observed separately in their different egg laying bouts during present investigation (Table 25). In a short duration of one to two seconds *Chilades lajus* and *Catochrysops strabo* laid maximum four eggs at one bout while *Remelana jangala*

laid maximum five eggs at one bout. Female butterflies complete 2-3 egg laying bouts in short period and then fly away from the oviposition site.

While observing the egg laying behaviour, it was found that a gravid female has come to the oviposition site, then did curve its abdomen and laid eggs on its preferred site of host plant. *Chilades lajus* bends its abdomen to touch the plant-parts and moves forward, and then lays eggs singly. It was observed that female visits its host plant *Citrus aurantifolia* and deposited eggs on leaf petiole, mid rib and lamina of leaf, base of stipule or base of young stems (Plate 55).



a **b** **c**

d **e** **f**

Plate 55. Deposited eggs of *Chilades lajus* on different part(s) of host plant: **a**. on leaf petiole; **b**. near to mid rib leaf; **c**. on leaf lamina; **d**. on mid rib of leaf; **e**. on base of stipule; and **f**. on base of young stem.

While observing the oviposition of the female *Catochrysops strabo*, the butterfly was spotted to deposit eggs on young flower bud, mid rib and lamina of leaf, young stem or base of young stems of the host plant *Cajanus cajan* (Plate 56).

a **b** **c**

Plate 56. Deposited eggs of *Catochrysops strabo* on different part(s) of host plant: **a**. on young flower bud; **b**. on young stem; and **c**. on leaf lamina.

During present investigation female *Remelana jangala* was found to lay eggs on the different parts of its host plant *Ixora coccinea*. The laid eggs were deposited on axial of

bud, petioles of young or mature unopened flower, sepals of bud or on the leaf base of the host plant (Plate 57).

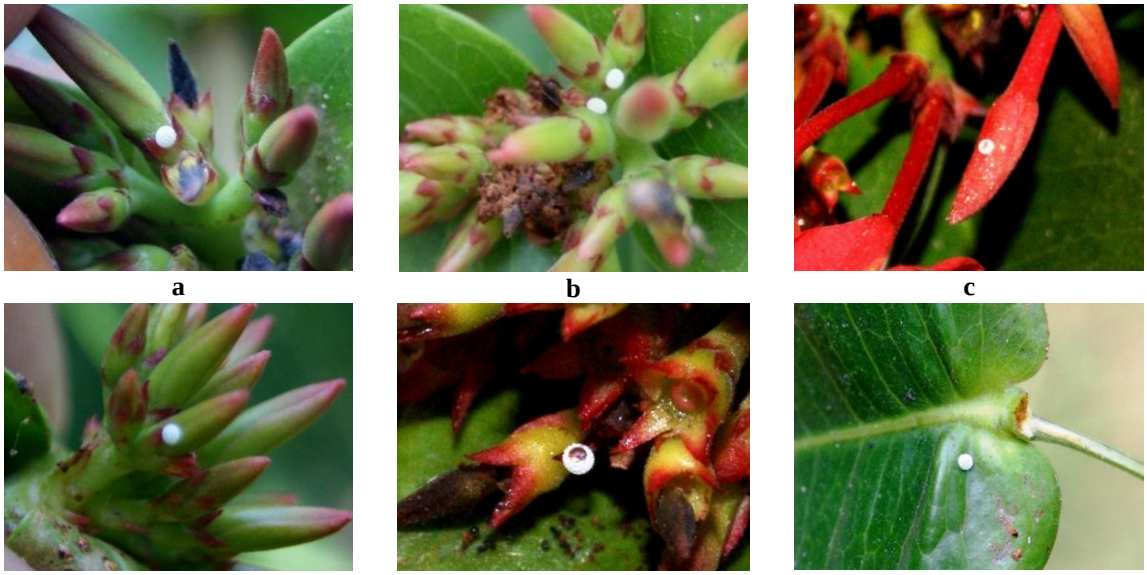


Plate 57. Deposited eggs of *Remelana jangala* on different part(s) of host plant: **a**. on the base of flower bud, **b**. on the axial of flower bud, **c**. on unopened petal, **d**. on tip of sepal, **e**. on middle of sepal, **f**. on leaf lamina.

During experiment, it was observed that 26 eggs of *Chilades lajus* deposited on different sites of plant(s) parts. Among them maximum (8) number of eggs were found on the base of young stem and minimum (2) on the leaf lamina (Fig. 32). No eggs were found on buds, petals, and sepals of its host plants.

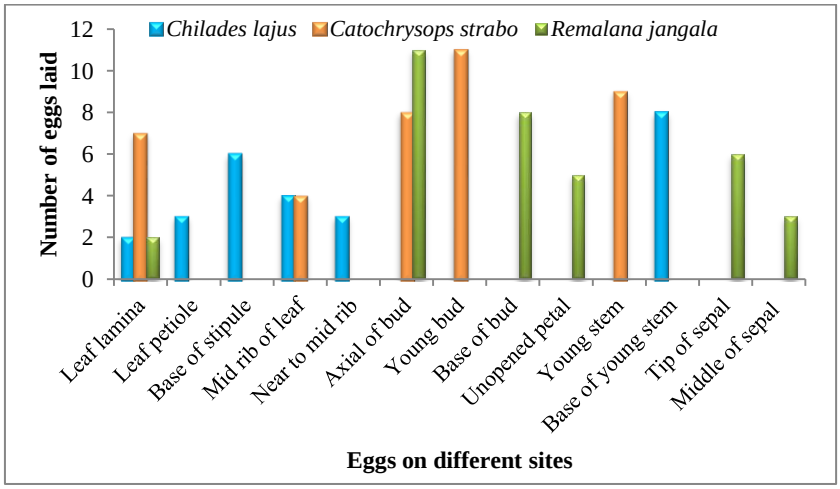


Fig. 32. Number of eggs laid by examined lycaenid butterflies on different site of host plant(s) parts.

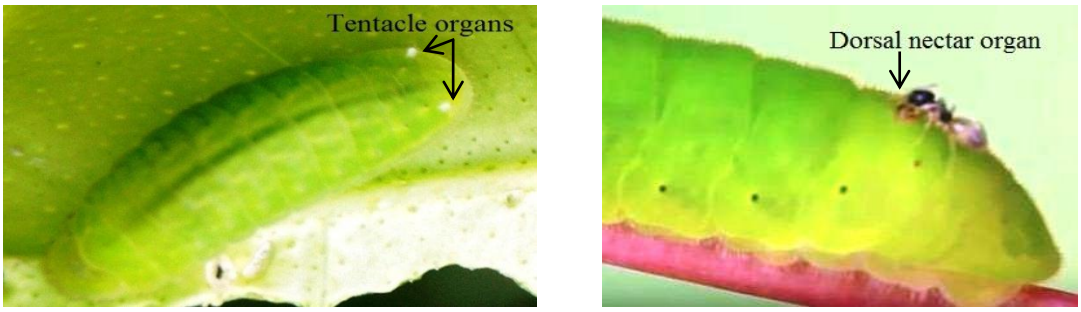
In case of *Catochrysops Strabo*, 39 eggs deposited on different sites of plant part(s). Among them, maximum (11) eggs were found on the young bud and minimum (4) eggs were spotted on mid rib of the leaf (Fig. 32). No eggs were found on leaf petioles, petals,

and sepals of its host plants. On the other hand, 35 eggs of *Remelana jangala* was spotted on different sites of plant part(s). Among them, maximum (11) eggs were deposited on axial of bud whereas minimum (2) eggs were found on the leaf lamina (Fig. 32). No eggs were found on stipules, mid rib of leafs, or even on stem.

This examination provides the knowledge available on the egg laying behaviour of lycaenid butterflies on their host plants. This study also indicates the strong relationship of two biotic factors in nature. This relationship may be helpful in conservation of biodiversity.

5.3.8 Myrmecophilous behaviour

In family Lycaenidae, immature stages of butterflies show a special kind of behaviour termed as myrmecophilous behaviour. In this case, larvae and sometimes pupae have an interaction with ants. Larva passes sugary secretion from its body. Ants are attracted by these secretions and make relation with the larva. Through this association ants protect larva from predation in return. The sugary secretion is mediated by specialized epidermal glands a single dorsal nectar organ and the paired tentacle organs. Dorsal nectar organ secretes sugary droplets and tentacle organs make signals for ants. Plate 58 indicates the tentacle organs and dorsal nectar organ of lycaenid larva.



a **b**

Plate 58. Lycaenid larvae showing tentacle organs and dorsal nectar organ: **a**. *Chilades lajus*; b. *Remelana jangala.*

During this experiment, myrmecophilous behaviour of lycaenid larvae has been observed in different study sites. It has been found that larvae of *Chilades lajus*, *Castalius rosimon*, *Lampides boeticus* and *Remelana jangala* were attendant by ants. Generally last instar larvae were to be attendant by ants. Lycaenid larva produces vibrations and sounds that are perceived by the ants. Ants are social insects of the family Formicidae belong to the order Hymenoptera under class Insecta. It has been found that most of the lycaenid larvae

were attendant by ant *Camponotus* sp. Pictorial view of three examined larvae present in Plate 59.

a **b** **c**

Plate 59. Lycaenid larvae are attendant by ant *Camponotus* sp: **a**. *Chilades lajus*; **b**. *Castalius rosimon*; and **d**. *Lampides boeticus*.

The coexistence of both butterflies and ants influences community structure. Thus, myrmecophilous behaviour plays an important role in the ecology of two biotic (Butterfly-Ant) groups. This is an ideal model system of mutualism in nature.

5.4 Discussion

Throughout the life, a butterfly should have gone through different behavioural activities for their nutrition, reproduction and defence. The butterflies use analytical time-budget for their different and respective activities (Bashar 2015). It has been observed that adult lycaenid butterflies exhibit different behaviours associated with enormous numbers of plants. Behavioural studies provide insight into important species specific information including possible preferences and basic resource requirements (Dennis *et al*. 2006a).

Investigation of feeding behaviour and flower visit patterns of butterflies are important for understanding the significance of adult feeding for reproductive success and longevity of butterflies (Thomas 1995). Foraging strategies are considered in terms of the degree to which butterflies maximize the net nutrient gain from feeding, and to which they minimize the risks to survival (Hassell and Southwood 1978). The foraging and flower visit acitivities of 20 lycaenid species have been examined in experimental sites. 20 plant species of family Amaranthaceae, Apocynaceae, Asteraceae, Leeaceae, Oxalidaceae, Rhamnaceae, Rubiaceae, Rutaceae, Verbenaceae, Arecaceae and Poaceae were exploited by lycaenid butterflies to collect floral nectar. Maximum number of lycaenid butterflies was found to attact to the flowers of family Asteraceae. Floral nectar of five plant species was collected and the nectar volume was also measured. The basis for studies of foraging strategies has been formed by quantitative analysis of nectar sugars for the amount of

energy produced. Nectar volume production is important in floral evolution and probably influenced by the most effective pollinator (Wolff 2006). Foraging from the flowers is a natural biotic technique which is not only essential for butterflies to use in the livelihood, but it is the vital tool for natural use in the plant gene-flow for the plant kingdom. Butterflies are considered for their potential mobility in the adult stage for the gene flow of plant population by acting as best pollinators. This mechanism provides rhythmic synchronization between the flight activity of the butterflies in a flowering place and arrangement of flower-producing plants in that place (Bashar 2012a). Fruit feeding behaviour of some lycaenid butterflies was also observed. Several lycaenid butterflies were found to puddle in moist ground as well as other substratum to collect additional nutients. Differential use of puddling resources among species implies that puddling may play quantitatively and qualitatively different roles in the resource budgets of different species (Boggs and Dau 2004).

Thermoregulation and basking is an important behavioural activity in adult butterflies. Butterflies regulate body temperature through basking behaviour. Different wing postures in response to different abiotic conditions found significant in this behaviour. Most species of lycaenids have been found to take long time to bask with closed basking posture for dark spots on their ventral side. The butterflies were found to use all types of plant, and other substratum like dry materials for basking. They were seen on the top leaves of plants during their basking. The flight of butterflies requires high muscle temperature, and their activity is strongly affected by thermoregulation (Heinrich 1993, Wickman 2009). The efficiency of flight and the capacity of butterflies to sustain flight activity are related to the initial thoracic temperature on take-off and rates of heat production and loss (Watanabe and Imoto 2003).

The main task of the adult butterflies is to mate and continue generation. Therefore, finding a suitable mate and reproducing them is the vital event of butterfly's life cycle (Wiklund *et al*. 2001). Different types of pre-mating behaviour including perching, patrolling and territoriality have been spotted during study period. The examined lycaenid butterflies prefer specific time schedules of a day as well as particular period of a year for pre-mating and mating activities. Maximum lycaenids have been observed in pre-mating and mating within a time range between 11 am and 12 pm of a day. The highest number of butterflies has been spotted active in pre-mating and mating during March and April. Variation is found in mating duration among different examined lycaenid butterflies. The

studies of pre-mating and mating behaviour of butterflies provide substantial evidences which are helpful to conserve lycaenid species in nature.

Being host specific, butterflies are very selective for egg laying activities. Host plant selection is prerequisite for egg laying. Various activities are involved in selecting preferred host plants. Settling on the host plant the females are active in drumming on the surface of plant part(s) for the selection of perfect place to lay eggs. Lycaenid butterflies have been found in drumming activities. *Remelana jangala* has been observed utilizing antenna, forelegs, and abdomen for drumming activities. Butterflies lay eggs on various part(s) of host plants. During investigation, deposited eggs of lycaenid butterflies have been spotted on different part(s) of host plants. The egg laying duration of examined lycaenids has been recorded. Egg laying bout of lycaenid butterflies has also been noticed and recorded. Study of egg laying behaviour provides the evidences of strong relationship between lycaenid butterflies and their host plants in the experimental sites.

The presence of lycaenid butterflies is highly related to the presence of activity-related plants. It has been stated earlier that three types of plants (viz. host plant, nectar plant and shelter plant) are required for butterflies to sustain their life style. It is important to note that each of the vegetation types can make unique contribution to the measured butterfly diversity and the butterflies for the plant diversity (Stohlgren and Bachand 1997, Suzuki *et al*. 1997, Faegri and van der Pijl 1979).

Butterflies activities deal with the determination of status of butterflies in relation to their associated plants-abundance, status of forests and the various aspects of environmental soundness (Wiklund 1975, 1984, Wiklund and Fridberg 2008). The behavioural study of butterflies has got a vital think-point to investigate biotic-biotic interaction in nature. Further researches are highly necessary to advance in this line of the biotic-biotic interaction study.

FIVE SELECTED LYCAENID BUTTERFLIES AND THEIR INTERACTING HOST PLANTS

6.1 Introduction

Butterflies are the taxonomically best-known phytophagous insects in tropical ecosystems (Ackery *et al.* 1999). One key factor in the ecology of phytophagous insects is the interaction with their natural host plants, thus maternal host choice is a particularly important step in the life-cycle of all herbivorous insect species (Rabasa *et al*. 2005, Janz *et al*. 2005b, Batary *et al*. 2008). Due to the low dispersal ability of the juvenile stages compared to adults; especially during the young instars; the selection of optimal quality host plants and suitable habitats is a critical step in the life-cycle of all Lepidoptera (Fartmann and Timmermann 2006, Eichel and Fartmann 2008). Recognition and selection of the best quality foods available by ovipositing females is crucial for optimal and successful larval performance (Liu *et al*. 2006, Ngu *et al*. 2008, Talsma *et al*. 2008). Generally host plant choice has been shaped by the selection of insects to maximize fitness, i.e. the opportunities of survival and growth of a female's offspring (Strausz 2010).

The process of host selection in specialist insects is governed primarily by volatile chemical signals, later by visual stimuli, and finally by non-volatile chemical signals (Hern *et al.* 1996, Hooks and Johnson 2001). Butterflies demonstrate a hierarchy in host preferences, discriminating among plant species, among genotypes, among individuals with different phenological and physiological conditions, and even among plant parts (Wiklund 1984), although not all discriminate at the finer scales (Wiklund 1975, Thompson and Pellmyr 1991, Bernays and Chapman 1994). Many butterflies prefer groups of very closely related plants where the larvae obtain the entire set of nutrients required for growth and development, as well as chemicals for display (colours) and defence as adults (Boppre 1984).

Appropriate egg laying sites and thus larval habitats are of imminent importance for the persistence of butterfly populations (Strausz 2010). Visual and chemical stimuli that are used during host plant selection include plant height, the size of the leaves, and the phenological or nutritional status of the plant (Thompson and Pellmayr 1991, Fartmann and Hermann 2006). The relative abundance of the favoured host and the time available

for oviposition play an important role in the correlation between oviposition site selection and offspring performance (Janz and Nylin 1997).

Being fundamental for reproduction, the larval host plants are the key resource among all the resources required by butterflies that comprise a habitat (Dennis *et al*. 2003, 2006a, 2006b, Dennis 2010). Thus, the relationship between any given butterfly species and its host plant is very specific (Tiple *et al.* 2010). According to Bashar (2014) butterflies require different phenological stages of the related plants in different seasons within the range of tolerance-suitability for their survivals in different stages of the life cycle. They have got strong coincidental synchronization between their life cycle and the phenological stages of the related plants.

Lycaenidae are the second largest family of butterflies. Like other butterfly, they are phytophagous and host specific. Life cycle changes in butterflies are deeply related with phenology of the host plants (Bashar 2010, Akand 2012). It has been necessary as the way together technical adaptation for understanding relation between phenology of the host plants and the life-stages of lycaenid butterflies. Knowledge of butterfly host plants and the relationship of plant-butterfly is a prerequisite for any butterfly conservation as well as biodiversity conservation programme (Tiple *et al.* 2010). Therefore, it is necessary to know the exact needs of the immature stages to make conservation successful (New *et al.* 1995). This research work has been undertaken to acquire knowledge on some base-points on the biology of some lycaenid butterflies and their host plants. Keeping the ideas in front the present study has been envisaged to carry out several objectives as stated below-

6.1.1 Objectives

- ✓ To examine the developmental stages of selected lycaenid butterflies;
- ✓ To observe the phonological stages of host plants; and
- ✓ To record the coincidence between the life cycle of lycaenids and their host plant phenology.

The objectives have been attempted to materialize by adopting methods and procedures as follows.

6.2 Material and methods

6.2.1 Studied species

During the study period, five lycaenid butterflies have been reared in laboratory and examined their interaction with host plants' phenology in the experimental sites. These butterflies were *Chilades lajus, C. pandava, Catochrysops strabo, Remelana jangala* and *Rathinda amor*. The above mentioned lycaenid butterflies are common and found everywhere in Bangladesh because their host plants are available. By this experiment, the interacting process of two biotic factors (butterfly-plant) has been studied. Selected butterfly species have been identified following the procedure of Bingham (1907), Eliot (1973), Akand (2012), and Bashar (2014).

6.2.2 Host plant species

Butterfly species are incapable of building populations without larval host plants, because plants are the prime consumer resource. Plants that are potentially utilized by larvae of *Chilades lajus, C. pandava* and *Catochrysops strabo* are *Citrus aurantiifolia, Cycas pectinata* and *Cajanus cajan*, respectively. Larva of *Remalana jangala* and *Rathinda amor* share *Ixora coccinia* as their host plant. Among these plants *Citrus aurantiifolia* belongs to the family Rutaceae while *Cajanus cajan* belongs to family Fabaceae and *Ixora coccinia* belongs to family Rubiaceae. All these plants represent the plant division angiosperm. *Citrus aurantiifolia* is an evergreen, densely and irregularly branched, small, spiny tree. *Cajanus cajan* is an erect woody, annual or short-lived perennial shrub or small tree with much branched. *Ixora coccinea* is a branched shrub notable for its bright coloured flowers. *Cycas pectinata*, the host plant of *Chilades pandava* belongs to family Cycadaceae which represents the plant division gymnosperm. *Cycas pectinata* is an evergreen, palm-like tree, often forked and glabrous throughout. Plant species has been identified according to Ahmed *et al.* (2009).

6.2.3 Selected sites

Eggs of studied species have been collected from different experimental sites. Egg-laying behaviour of examined butterflies has been observed there. Eggs of *Catochrysops strabo* have been collected from Zoological Garden of Curzon Hall in University of Dhaka. Eggs of *Chilades lajus, Remalana jangala* and *Rathinda amor* have been collected from

Butterfly Research Park (BRP) in Bhawal National Park, Gazipur. Eggs of *Chilades pandava* have been collected from Botanical Garden of Bangladesh Agriculture University, Mymensing. Few eggs of *Chilades lajus* was also collected from Rema-Kalenga Sanctuary, Habigonj. Collected eggs were reared in an ambient condition in the laboratory, Environmental Biology and Biodiversity Laboratory (EBBL), Department of Zoology, University of Dhaka. Description of study sites has given in Chapter 3.

6.2.4 Rearing procedure

Subsequent rearing procedures have been followed to examine the larval development and metamorphosis of butterflies from egg to adult, are described as below-

6.2.4.1 Rearing materials in laboratory

The larvae hatched from collected eggs were reared in a rectangular plastic box (36×30×15 cm^3). 250 ml conical flask filled with water was used to allow the plant stems wet and to be placed into the rearing box. Larval moulting took place within the box. The larvae pupated inside the rearing box. The inactive pupae with rearing box were shifted into a bigger rectangular and iron-rod framed adult emergence cabinet (53×46×92 cm^3) being covered all sides with mosquito net so that the newly emerged butterfly cannot fly away. The pupae inside the plastic box were left in the emergence cabinet undisturbed until adult emergence (Plate 60). The rearing boxes containing the larvae were cleaned daily by sterilized brush, forceps, sprayer, scissor etc. for keeping the larvae free from fungal infections. Regular and periodic cleanliness of larval faeces and other debrises from the rearing boxes performed to make rearing successful in the laboratory.

6.2.4.2 Collection of eggs and larval rearing

Freshly laid eggs were collected directly from the food plants without causing any damage, following females in the field until oviposition took place. Larvae were fed with plants of the same species from where the female laid eggs. All collected eggs along with host plant part(s)/stem or basal leaflet with rachis were placed into conical flask with enough water to keep the base of stem or the rachis wet so that the young leaves, flowers and fruits will not die due to desiccation. The mouth of conical flask was sealed with cotton girdled around plant stem otherwise the larva might be died dripping in to the water. Then the conical flask were confined in transparent plastic containers or larval rearing cages of assorted sizes and brought to the laboratory for rearing in captivity. The

containers were kept in a naturally ventilated room with no direct sun light. Plant stem with fresh young leaves, flowers and fruits were kept in conical flask inside cage for larval feeding. Larval food was supplied every alternative day and water of conical flask was also changed. The rearing boxes were examined daily to observe instar changes and behaviour, and also to control the moisture inside. The moulting of the larvae was confirmed by examining the rearing box for exuviae and head capsules. Following larval growth and pupation, the pupae were left in the cages undisturbed until adult eclosion. Although some larvae and broads were lost to mortality, larvae were often sufficiently distinct to identify to species. To be treated as a verified host, the plant had to support at a minimum one moult, the final instar and successful pupation. Sometimes fruits were cut open to determine the presence of larvae/pupae.

Plate 60. Rearing materials in laboratory: **a**. larva rearing apparatus; **b**. and **c**. larva with host plants parts in conical flask inside larval rearing cage; **d.** adult emergence cabinet; **e**. and **f**. larval rearing cage with pupa inside adult emergence cabinet.

6.2.4.3 Data recording

Collected eggs were placed in larval rearing cages where larva emerged and developed until reaching to pupal stage. The collection date and time was noted. The incubation period of eggs, and the period of larval, pre-pupal and pupal development was recorded. The number of instars in a life cycle of butterflies was also noted. Duration of larval

instars was examined very carefully. This duration was not fixed. Length of each morph was measured. External morphologies of the egg, each larval instar, pre-pupa, pupa and adult were also studied, and photos taken of the whole process. Pertinent data was recorded every morning. The species has been reared a number of times from the egg.

6.2.5 Analysis of data

Lycaenid butterflies could not lay huge number eggs and collection of their eggs was a little bit difficult job. For this reason, experiment has been conducted by only several numbers of eggs. Number of successful emergence of adult from eggs has been obtained for analysis. Average and standard deviation has been calculated. The statistical analysis has been performed using SPSS software for windows (version 16). Microsoft Office Excel 2010 has been used to draw graph, table and figure.

6.3 Results

The life time pattern of growth, development, storage and reproduction of a species is referred to as its 'life history' (Begon *et al.* 1996). Perennial plants may grow for many years before producing a few seeds and then continue to grow and reproduce for many years, whereas annual plants grow rapidly, reproduce many seeds at once and then die within the period of a year (Braby 1994). Butterflies are holometabolous insects with distinct developmental stages as egg-larva-pupa-adult. The life cycle of butterflies vary in duration with seasonality, host plant availability, host plant phenology, nectar plants availability and shelter plant availability (Bashar 2015).

Bashar (2014) described different developmental stages of butterflies. Butterfly eggs vary in size from species to species, but they are all spherical or ovate in shape. Eggs are protected by a hard-ridged outer layer of shell, called the chorion. In the crevices the eggs are protected from rain and sunshine, and to some extent from predators. The term 'larva' may be defined as a free-living embryo distinctly different from the adult and incapable of sexual reproduction. This is the pre-adult stage in the life cycle that occurs after hatching from the egg; and is motile and capable of feeding itself. In butterflies, the young larva gnaws its way through the egg shell and after hatching continues to eat the shell until only the base is left. At the end of larval life, it is marked by another moult which gives rise to a pupa or chrysalis. Pupa is the third stage in the life cycle of a butterfly. During this stage an insect remains relatively passive and immobile whilst its

internal organs undergo a complete metamorphosis or transformation within the chrysalis skin. In butterflies, adults are not only sexually mature but as soon as an adult emerges from pupa gets fully ready to fly. The emergence of the adult is preceded by the colour pigment appearing in the wing scales, so that the wing patterns of the adult can be seen through the pupal case. The skin of the pupa splits behind head and the insect first frees its legs and antennae and after a short while withdraws the rest of its body. Immediately after emergence the wings are soft and crumpled. The butterfly moves to a place because its wings can hang downwards and blood is forced into them. The wings expand by the flattening of the numerous tiny folds and soon become the typical thin sheets supported by hollow veins. Once they have reached their full size the insect holds them apart until they are completely dry and hardened. The excretory material which has accumulated in the closed digestive tract during the pupal period is ejected from the anus. It is found that butterflies do not have long life spans. In their adult stage, butterflies can live from a week to nearly a year depending on the species. Many species have long larval stages while others can remain dormant in their pupal or/and egg stages.

Lycaenid eggs are turban-shaped with flattened base and a depression at the top which containing micropyle. Eliot (1973) indicated three characters of the immature stages (larval and pupal) of the family Lycaenidae. Larva is onisciform or differently shaped; larval feeding exclusively on green plants or eating a different diet (e.g. carnivorous or eating lichens); girdled and reclining or ungirdled pupa. Most lycaenid butterflies have four or five larval instars (Elmes *et al.* 2001). Butterflies and their caterpillars are dependent on specific host plants for foliage, nectar and pollen as their food (Gutierrez and Mendez 1995). Their development and growth is dependent along with the growth and development of its host plants. The relationship between butterfly and its larval host plant is unique. The present study contemplated to carry out experiments on the biology of five lycaenid butterflies and their host plant's phenology. This study was done following Baker (1984), Chang (1989), Corbet and Pendlebury (1992), Zalucki *et al*. (2002), Patel *et al*. (2003), Barua and Slowik (2007), Rayalu *et al*. (2012), Abu-Shall *et al*. (2014), Alam *et al*. (2014), Akand *et al*. (2015a), Harinath *et al*. (2015a, 2015b, 2015c), Aich *et al*. (2016), Harinath *et al*. (2016) and Alam *et al*. (2017). All the examined life cycles are studied in normal conditions. No variation has been taken under consideration which are occurred because of seasonal changes or/and for the cause of coincidental relations with their host plant's phenologies.

6.3.1 Biology of *Chilades lajus* (Stoll, 1780)

6.3.1.1 Systematic position

Kingdom Animalia

Phylum Arthropoda

Class Insecta

Order Lepidoptera

Family Lycaenidae

Subfamily Polyommatininae

Genus *Chilades* Moore, 1881

Species *Chilades lajus* (Stoll, 1780)

Plate 61. *Chilades lajus* taking nectar from *Panica hybrida*

Chilades lajus is commonly known as Lime Blue butterfly. Detail information of this butterfly has given in Chapter 3.

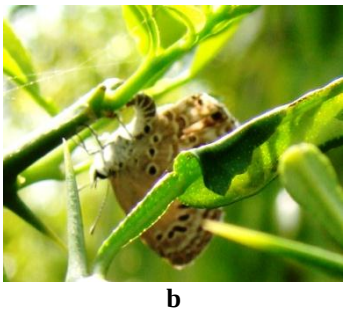
6.3.1.2 Life cycle

Life cycle of *Chilades lajus* starts through mating following egg laying and consists of egg, four instars of larva, pre-pupa, pupa and ends as adult (Plate 66).

6.3.1.2.1 Mating

Males are seen to slowly flutter beneath the food plant looking for newly emerged females with which to mate (Plate 62a). Males have unusual long, hair-like scales on the dorsal sides of the wings which comprises androconia. These are specialized wing scales on the dorsal sides of the wings used for courtship. During mating they do not fly because of the overweight of female abdomen. It has been observed that duration of mating period was 35 to 40 minutes.

a



b

c

Plate 62. Adults and eggs of *Chilades lajus*: **a.** mating; **b**. egg laying; and **c**. egg.

6.3.1.2.2 Egg laying

This butterfly vibrates its wings rapidly and repeatedly visits the plants when it searches host plants. It bends abdomen to touch the plant parts for searching host plants and moves forward. Finding a suitable place it lays egg (Plate 62b) singly. After laying one egg it flies away to take rest for a while, then start to lay next egg. In this way this butterfly lays several numbers of eggs at day light. In this experiment, it was found that the female laid eggs at late morning to evening from 10 am to 4pm.

6.3.1.2.3 Egg

Eggs (Plate 62c) of Lime Blue are typically laid on young shoots, leaf bases, petiole and lamina of leaves, stipule, leaf node or in the vicinity of flower buds of the host plants. Egg is greenish with blue tinge when freshly laid. The small egg is disc-like strongly flattened top and bottom with a depressed micropylar at the pole and a surface reticulated with rather large hexagonal pits. The egg hatches within 2 to 3 days in laboratory condition.

6.3.1.2.4 Larva

The free living larva hatched after egg incubation. There are four larval instars of the Lime Blue butterfly. Duration and length of different larval instars has been tabulated in Table 26.

a **b** **c**

Plate 63. Different stages of metamorphosis: **a**. first instar larva splits egg shell; **b**. first instar larva; and **c**. second instar larva.

First instar larva - The young larva (Plate 63a) emerges after nibbling away the polar portion of the egg shell to emerge, and eat the egg shell remnant. The freshly larva is measured at a length of about 0.7 to 1.2 mm, its yellowish green body is cylindrical in shape, sporting long fine setae (hairs) and a brown prothoracic shield and head capsule. As it grows, the body assumes the more typical onisciform (woodlouse) shape (Plate 63b). The newly hatched larva hatched grazes on the surface of young leaves feeding the phloem of leaf undersurface. After 2 to 3 days of growth, it looks pumped up at a length

of about 3 mm. After a period of immobility of about half a day, it moults to the second instar.

Second instar larva - This larva (Plate 63c) is covered with numerous setae; the body of the second instar larva could in light yellowish green colouration with a light green mid dorsal line. Setae found at the dorsal and lateral margins are longer and stiffer. Black head is present. The dorsal nectary organ is present but still inconspicuous. The second instar larva reaches a length of about 5 to 6 mm, and after about 2 to 3 days in this stage, it moults again.

Third instar larva - The third instar (Plate 64a) was green in colour and has greenish brown hair with the mid-dorsal line. The larva has numerous short and fine body setae. Its body is now uniformly coloured in green. The prothoracic shield is same to the body base colour and the head retain the black coloration. The dorsal nectary organ is now more conspicuous. The third instar takes 2 to 3 days to complete with the body length reaching about 9 to 10 mm.

a **b** **c**

Plate 64. Different stages of metamorphosis: **a**. third instar larva; **b**. fourth instar larva; and **c**. pre-pupa.

Fourth instar larva - The fourth and final instar larva (Plate 64b) is closely similar in appearance to the third instar larva. But its body is green to dark green in colour covered with numerous tiny setae and with a dark green mid dorsal line. The prothoracic shield is retained the same body base colouration. The prominent dark green colour dorsal nectary organ is seen at the posterior end. The tentacle organs are like white tiny spot. When an ant approaches, the dorsal nectary organ can be observed to protrude and exude droplets of clear nectary fluid. After 3 to 4 days this larva reaches a maximum body length of about 12 to 14 mm and ceases to development for next moult. Larvae feed openly during the day. The presence of larvae on the food plant is discernible by the eaten leaves but the larva camouflages to the leaves.

6.3.1.2.5 Pre-pupa

Nearing the end of the final instar, the larva ceases feeding. The body of the larva gradually shrinks, and finally takes on a green colouration. It chooses a site on the sheltered surface of a leaf for its pupation site and takes up a position on the surface to become an immobile pre-pupa (Plate 64c). At the chosen site, the larva readies itself for pupation by spinning a silk girdle and a silk pad. The larva secures itself to the silk pad via claspers on its posterior end. In laboratory duration of pre-pupal phase is about 1 to 2 days.

a **b** **c**

Plate 65. Immature and mature *Chilades lajus*: **a**. pupa; **b**. adult female; and **c**. adult male.

6.3.1.2.6 Pupa

Pupation takes place after one day of the pre-pupal stage. The pupa (Plate 65a) is predominantly yellowish green in colour and has numerous small whitish speckles. The stout pupa has a typical lycaenid shape with a short abdomen. Abdomen is broader than the anterior part. The pupa has a length of about 8 to 9 mm. The pupa gradually changes its colour into dark brown. After six to seven days, the pupa turns black signaling the imminent emergence of the adult mostly in the thorax and wing pads. The bluish patches on the forewing dorsal sides become visible through the now transparent pupal skin. The next day the pupal stage comes to an end and the adult butterfly emerges from the mature pupa. In laboratory the duration from pupa to adult emergence is about 6 to 8 days.

6.3.1.2.7 Adult

The adult (Plate 65b, Plate 65c) was observed to emerge from the pupa by splitting open the case vertically on the dorsal side. The time taken for emergence is about 16-20 minutes. In laboratory experiment the total duration from egg to adult emergence is about 20 to 22 days.

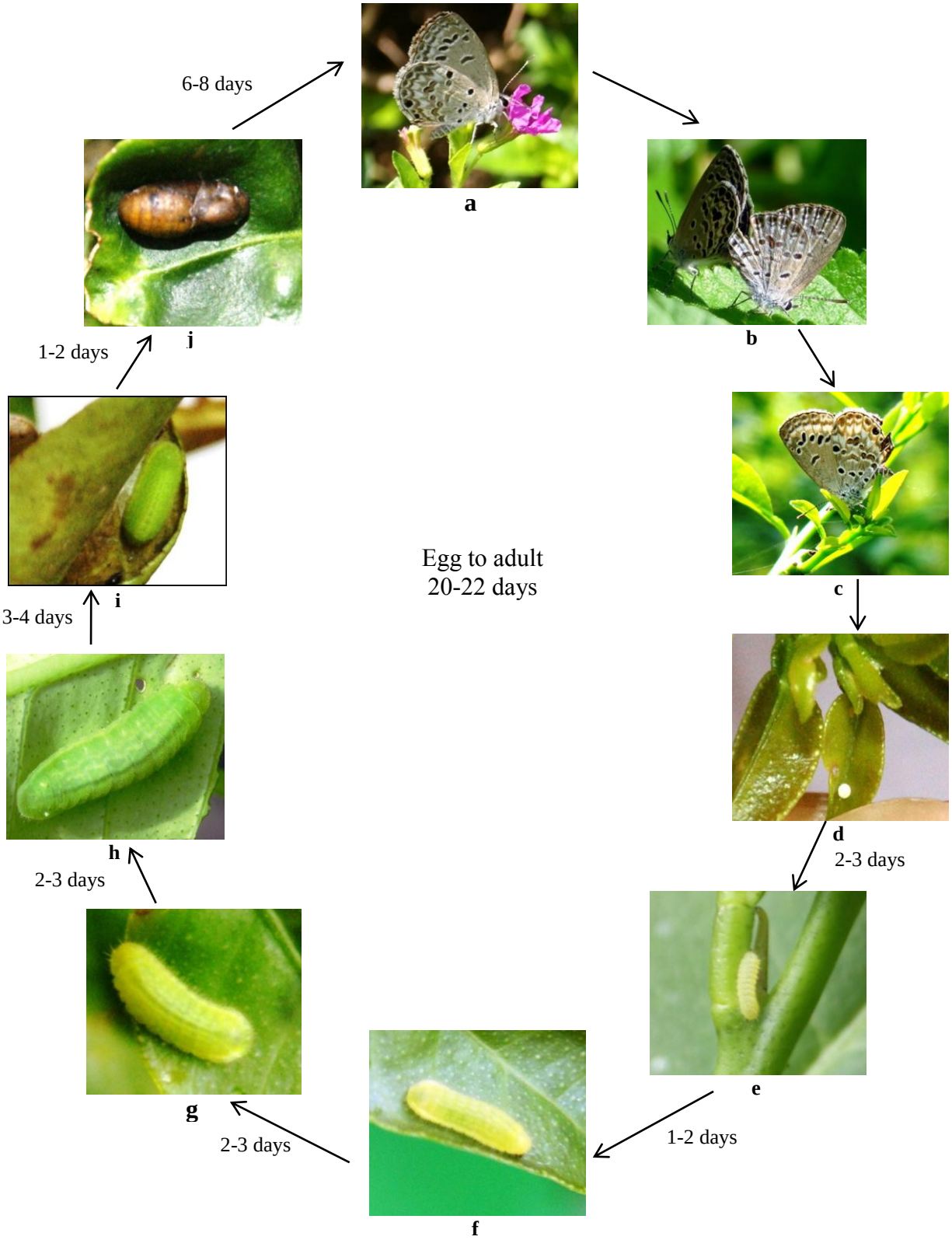


Plate 66. Life cycle of *Chilades lajus*: **a**. adult butterfly; **b**. mating; **c**. egg-laying; **d**. egg; **e**. first instar larva; **f**. second instar larva; **g**. third instar larva; **h**. fourth instar larva; **i**. pre-pupa; and **j**. pupa.

Assuming a short life span of 3-6 days for the adults with more number of broods produced yearly (Gunathilakaraj *et al*. 1998, Kunte 2000).

6.3.1.3 Life cycle stages of *Chilades lajus* – a laboratory assay

The experiment was done in an ambient environment of the laboratory where temperature prevailed 28°C to 31°C and the relative humidity was 73% to 77%. Twenty freshly laid eggs were collected and rear in laboratory. Among them fourteen eggs completed their metamorphosis to emerge as adult butterfly. First, second, third and fourth instar larva was 2-3 mm, 5-6 mm, 9-10 mm and 12-14 mm long, respectively. Pre-pupa was 9-10 mm whereas pupa was 8-9 mm long. Average length of first, second, third and fourth instar larva was 2.57 mm, 5.54 mm, 9.36 mm and 12.86 mm, respectively. The length of pre-pupa was 9.5 mm and pupal length was 8.43 mm (Table 26).

Table 26. Lengths and duration of the developmental stages of *Chilades lajus* in an ambient environment of the laboratory (Temp. 29 ± 2˚C and 75 ± 2% RH).

Developmental stages	Length (mm)		Incubation/ stage duration (days)	
	Avg. ± SD	Range	Avg. ± SD	Range
Egg			2.43±0.51	2-3
Larval instar				
1st instar	2.57±0.36	2-3	1.71±0.47	1-2
2nd instar	5.54±0.42	5-6	2.64±0.49	2-3
3rd instar	9.36±0.41	9-10	2.71±0.49	2-3
4th instar	12.86±0.66	12-14	3.64±0.49	3-4
Larval duration			10.71± 0.73	10-12
Pre-pupa	9.5±0.41	9-10	1.57±0.51	1-2
Pupa	8.43±0.51	8-9	6.71±0.61	6-8
Egg to adult emergence			21.43±0.65	20-22

In laboratory condition, the incubation period was 2-3 days. First instar larva required average 1-2 days for next moulting whereas second instar larva needed 2-3 days. Within 2-3 days third instar larva reached into fourth instar larva. It required 3-4 days to moult into pre-pupal stage. A short transitional and immovable pre-pupal stage required only 1-2 days for moulting to inactive pupa. This inactive stage requires 6-8 days to emerge as adult butterfly (Table 26).

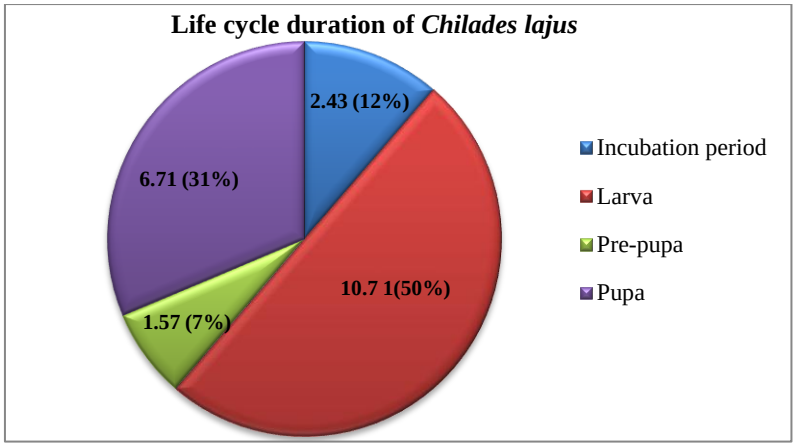


Fig. 33. Duration of life cycle of *Chilades lajus*

It has been found that average duration for incubation period, larval duration, duration for pre-pupal stage and pupal stage was 2.43 (12%) days, 10.71 (50%) days, 1.57 (7%) days and 6.71 (31%) days, respectively (Fig. 33). This butterfly required average 21.43 days for metamorphosis from egg to adult in laboratory condition.

Female *Chilades lajus* was spotted to lay eggs on the young foliage of common lime plant (*Citrus aurantiifolia*) and several larval instars was also found to eat young and tender leaves. Hence, this plant is identified as the host plant of *C. lajus.*

6.3.2 *Citrus aurantifolia* (Host plant of *Chilades lajus)*

6.3.2.1 Systematic position

Kingdom Plantae

Superdivision Spermatophyta

Division Magnoliophyta

Class Asterids

Subclass Malvids

Order Sapindales

Family Rutaceae

Genus *Citrus*

Species *Citrus aurantifolia*

Plate 67. *Chilades lajus* basks on the leaf of its host plant *Citrus aurantifolia*.

Detail description including morphological characters, distribution and habitat, and economic value of *Citrus aurantifolia* was given in Chapter 3.

6.3.2.2 Phenology of the host plant (Plate 68)

Citrus aurantifolia is a small, densely and irregularly branched, evergreen tree; twigs armed with short stiff sharp spines. This plant is grown all over Bangladesh, though its production is concentrated in Sylhet, Chittagong and the Chittagong Hill Tracts; cultivated in homestead as well as in orchard. It is sensitive to cold but is quite drought-resistant. High incidence of bacterial canker is a limiting factor in the wet tropics; under dry conditions irrigation is necessary to obtain good quality fruits. Limes can grow on poor soils and tolerate heavier soils than oranges, provided that good drainage prevents waterlogging. This plant is propagated from seed; alternatively, vegetative propagation from cuttings. Digging around a mature tree to sever roots will encourage new sprouts that can be transplanted to another location. It is often advisable to graft the plants onto rootstocks with low susceptibility to gummosis, because seedlings generally are highly vulnerable to the disease. The lime tree does best in sunny sites, well-drained soils, good air circulation, and protection from cold wind. Because its root system is shallow, the lime is planted in trenches or into prepared and broken rocky soil to give the roots a better anchorage and improve the trees' wind resistance. Pruning and topping should be planned to maximize the circulation of air and provide plenty of sunlight. This keeps the crown healthily dry, improves accessibility for harvesting, and discourages the organisms that cause gummosis. The juvenile phase lasts about five years. Flowering and fruiting from March to September.

a **b** **c**

Plate 68. Phenological stages of *Citrus aurantifolia*: **a**. vegetative stage; **b**. flowering stage; and **c**. fruitification stage.

6.3.3 Synchronization of coincidences between *Chilades lajus* and its host plant

The plant *Citrus aurantifolia* is a perennial shrub found almost all the year round. Flowering and fruiting are found throughout the year. The lime blue butterfly *Chilades lajus* depends on this plant to complete its life cycle. Larvae of this butterfly eat very young tender leaves of *Citrus aurantifolia* for their maturation. This butterfly is found during the period of early February to May and early August to October. Lime blue is seen very poorly in the other months of the year. But Harinath *et al.* (2015c) examined that there was a higher frequency of occurrence of the life stages during August to November and March to May which corresponds with the warmer temperature.

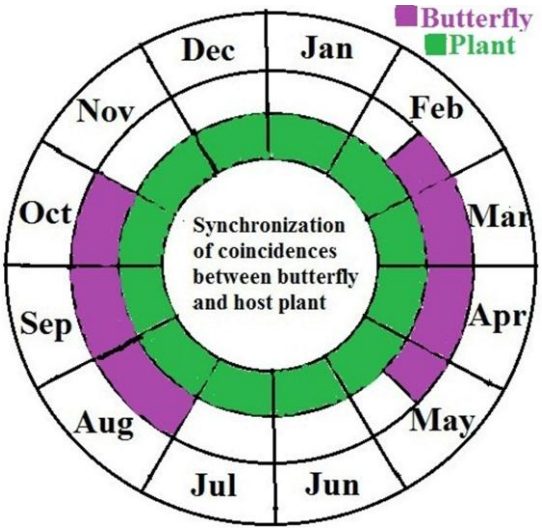


Fig. 34. Coincidence between life cycle of *Chilades lajus* and its host plant's phenology.

It was observed that coincidence of *Chilades lajus* and its host plant is occurred from mid-February to mid-May and August to October (Fig. 34) and the peak abundance of butterfly is recorded during this season. In this period lime blue butterfly completes several life cycle. The availability of *Chilades lajus* with its year round distribution showing up better during March-May and August-December with the prediction of Owen (1971) that tropical butterflies breed thought the year with better performance in a certain period of the year.

6.3.4 Biology of *Chilades pandava* (Horsfield, 1829)

6.3.4.1 Systematic position

Kingdom Animalia

Phylum Arthropoda

Class Insecta

Order Lepidoptera

Family Lycaenidae

Subfamily Polyommatininae

Genus *Chilades* Moore, 1881

Species *Chilades pandava* (Horsfield, 1829)

Plate 69. *Chilades pandava* is foraging *Lantana camara* flower.

Chilades pandava is commonly known as Cycad Blue butterfly. Detail information of this butterfly has given in Chapter 3.

6.3.4.2 Life cycle

Life cycle of *Chilades pandava* starts through mating following egg laying and consists of egg, four instars of larva, pre-pupa, pupa and ends as adult (Plate 74).

6.3.4.2.1 Mating

Males are seen to slowly flutter beneath the food plant looking for newly emerged females with which to mate (Plate 70a). Males have unusual long, hair-like scales on the dorsal sides of the wings which comprises androconia. These are specialized wing scales on the dorsal sides of the wings used for courtship. During mating they do not fly because of the overweight of female abdomen. It has been observed that duration of mating period was 35 to 40 minutes.

a **b** **c**

Plate 70. Adults and eggs of *Chilades pandava*: **a.** mating; **b**. egg laying; and **c**. egg.

6.3.4.2.2 Egg laying

This butterfly vibrates its wings rapidly and repeatedly visits the plants when it searches host plants. It bends abdomen to touch the plant parts for searching host plants and moves forward. Finding a suitable place it lays egg (Plate 70b) singly. After laying one egg it flies away to take rest for a while, then start to lay next egg. In this way this butterfly lays several numbers of eggs. This butterfly lays eggs at day light. In this experiment, it was found that the female laid eggs at late morning to evening from 10 am - 4pm.

6.3.4.2.3 Egg

Eggs of Cycad Blue are laid singly on the undersides of young leaves or attached to their edge. Egg also laid on emerging young shoots of the host plant when they are still covered in brownish hair or when green fleshy leaves are still at the stage of being unfurled. Egg (Plate 70c) is greenish with blue tinge when freshly laid. The small egg is disc-like strongly flattened top and bottom with a depressed micropylar at the pole and a surface reticulated with rather large hexagonal pits. The egg hatches within 2 days in laboratory condition.

6.3.4.2.4 Larva

The free living larva hatched after egg incubation. There are four larval instars of the Cycad Blue butterfly. Duration and length of different larval instars has been arranged in Table 27.

First instar larva- The young larva (Plate 71a, Plate 71b) emerges after nibbling away the polar portion of the egg shell to emerge. The newly hatched larva does not consume the rest of the egg shell after its emergence. The freshly larva is measured at a length of about 0.8 to 1 mm, its pale yellowish body is cylindrical in shape, sporting long fine setae (hairs) and a bleak prothoracic shield and head capsule. As it grows, the body assumes the more typical onisciform (woodlouse) shape. The newly hatched larva hatched grazes on the surface of young leaves and feeds by nibblying away a layer of the leaf lamina. After 1 to 2 days of growth, it looks pumped up at a length of about 2 mm. After a period of immobility of about half a day, it moults to the second instar.

Second instar larva-This second instar larva (Plate 71c) is covered with moderately long setae which occur dorso-laterally and along with body fringe; the body of this larva is in light yellowish green colouration with a light green mid dorsal line. Short and fine setae cover the body surface. Black head is present. The dorsal nectary organ is present but still

inconspicuous. The second instar larva reaches a length of about 3 to 5 mm, and after about 2 to 3 days in this stage, it moults again.

a **b** **c**

Plate 71. Different stages of metamorphosis: **a**. first instar larva (early); **b**. first instar larva (late); and **c**. second instar larva.

Third instar larva-The third instar (Plate 72a) was green in colour and has greenish brown hair with the mid-dorsal line. The larva has numerous short and fine body setae. Its body is now uniformly coloured in green. The prothoracic shield is deep to the body base colour. The head retain the black coloration. The dorsal nectary organ is now more conspicuous. It takes 2 to 3 days to complete with the body length reaching about 6 to 8 mm.

a **b** **c**

Plate 72. Different stages of metamorphosis: **a**. third instar larva; **b**. fourth instar larva; and **c**. pre pupa.

Fourth instar larva-The fourth and final instar larva (Plate 72b) is closely similar in appearance to the third instar larva. But its body is green to dark green in colour covered with numerous tiny setae and with a dark green mid dorsal line. The prothoracic shield is retained the same body base colouration. The prominent dark green colour dorsal nectary organ is seen at the posterior end. The tentacle organs are like white tiny spot. When an ant approaches, the dorsal nectary organ can be observed to protrude and exude drop lets of clear nectary fluid. After 3 to 4 days this larva reaches a maximum body length of about 11 to 12 mm and ceases to development for next moult. Larvae feed openly during the day. The larva can either feed by grazing the leaf surface or devouring the lamina along the leaf edge. The presence of larvae on the food plant is discernible by the eaten leaves but the larva camouflages to the leaves.

6.3.4.2.5 Pre-pupa

Nearing the end of the final instar, the larva ceases feeding. The body of the larva gradually shrinks, and finally takes on a green colouration. It chooses a site on the sheltered surface of a leaf for its pupation site and takes up a position on the surface to become an immobile pre-pupa (Plate 72c). At the chosen site, the larva readies itself for pupation by spinning a silk girdle and a silk pad. The larva secures itself to the silk pad via claspers on its posterior end. In laboratory duration of pre-pupal phase is about 1 to 2 days and the body length is 10 to 11 mm.

6.3.4.2.6 Pupa

Pupation takes place after one day of the pre-pupal stage. The pupa (Plate 73a) is predominantly yellowish green in colour and has numerous small black speckles. The stout pupa has a typical lycaenid shape with a short abdomen. Abdomen is broader than the anterior part. The pupa has a length of about 9 to 10 mm. The pupa gradually changes its colour into dark brown. After six to seven days, the pupa turns black signaling the imminent emergence of the adult mostly in the thorax and wing pads. The bluish patches on the forewing dorsal sides become visible through the now transparent pupal skin. The next day the pupal stage comes to an end and the adult butterfly emerges from the mature pupa. In laboratory the duration from pupa to adult is about 6 to 7 days.

a

b

c

Plate 73. Immature and mature *Chilades pandava*: **a**. pupa; **b**. adult female; and **c**. adult male.

6.3.4.2.7 Adult

The adult ((Plate 73b, Plate 73c) was observed to emerge from the pupa by splitting open the case vertically on the dorsal side. The time taken for emergence is about 21-25 minutes. In laboratory experiment the total duration from egg to adult emergence is about 19 to 21 days. *C. pandava* is able to produce several generations per year (Kunte and Tiple 2009).

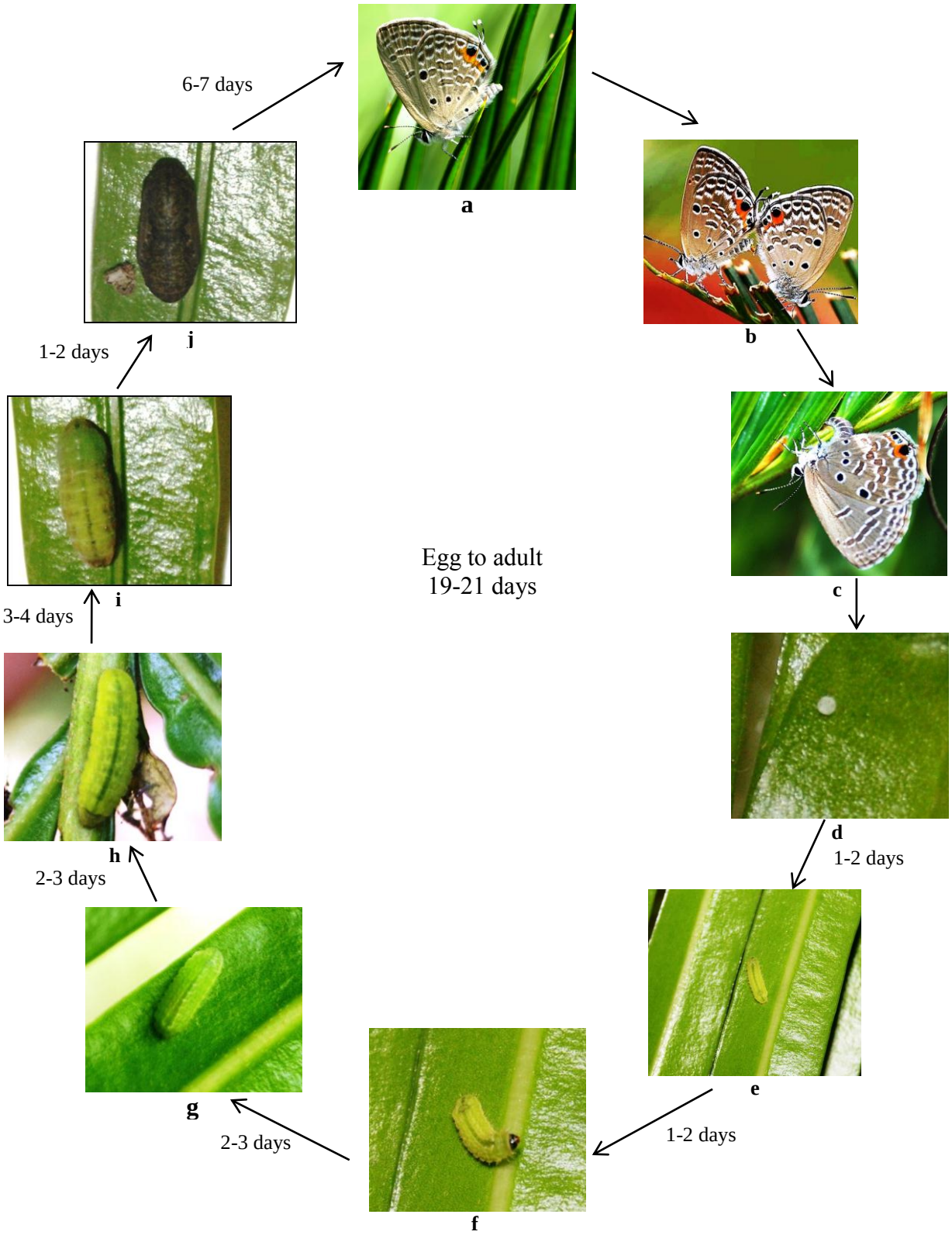


Plate 74. Life cycle of *Chilades pandava*: **a**. adult butterfly; **b**. mating; **c**. egg-laying; **d**. egg; **e**. first instar larva; **f**. second instar larva; **g**. third instar larva; **h**. fourth instar larva; **i**. pre-pupa; and **j**. pupa.

6.3.4.3 Life cycle stages of *Chilades pandava* – a laboratory assay

The experiment was done in an ambient environment of the laboratory where temperature prevailed 27°C to 31°C and the relative humidity was 71% to 77%. Nineteen freshly laid eggs were collected and rear in laboratory. Among them thirteen eggs completed their metamorphosis to emerge as adult butterfly. First, second, third and fourth instar larva was 1.5-2 mm, 3-5 mm, 6-8 mm and 11-12 mm, respectively. Pre-pupa was 10-11 mm whereas pupa was 9-10 mm long. Average length of first, second, third and fourth instar larva was 1.75 mm, 4.02 mm, 6.97 mm and 11.43 mm, respectively. Pre-pupa was 10.46 mm, and pupa was 9.38 mm long (Table 27).

Table 27. Lengths and duration of the developmental stages of *Chilades pandava* in an ambient environment of the laboratory (Temp. 29 ± 2°C and 74 ± 3% RH).

Developmental stages	Length (mm)		Incubation/ stage duration (days)	
	Avg. ± SD	Range	Avg. ± SD	Range
Egg			1.69±0.48	1-2
Larval instar				
1st instar	1.75±0.2	1.5-2	1.38±0.51	1-2
2nd instar	4.02±0.67	3-5	2.54±0.52	2-3
3rd instar	6.97±0.68	6-8	2.31±0.48	2-3
4th instar	11.43±0.39	11-12	3.38±0.51	3-4
Larval duration			9.61± 0.65	8-10
Pre-pupa	10.46±0.45	10-11	1.62±0.51	1-2
Pupa	9.38±0.51	9-10	6.62±0.51	6-7
Egg to adult emergence			19.54±0.78	19-21

In laboratory, the incubation period was 1-2 days. First instar larva required average 1-2 days for next moulting whereas second instar larva needed 2-3 days. Within 2-3 days third instar larva reached into fourth instar larva. It required 3-4 days to moult into pre-pupal stage. A short transitional and immovable pre-pupal stage required only 1-2 days for moulting to inactive pupa. This stage requires 6-7 days for adult emergence (Table 27).

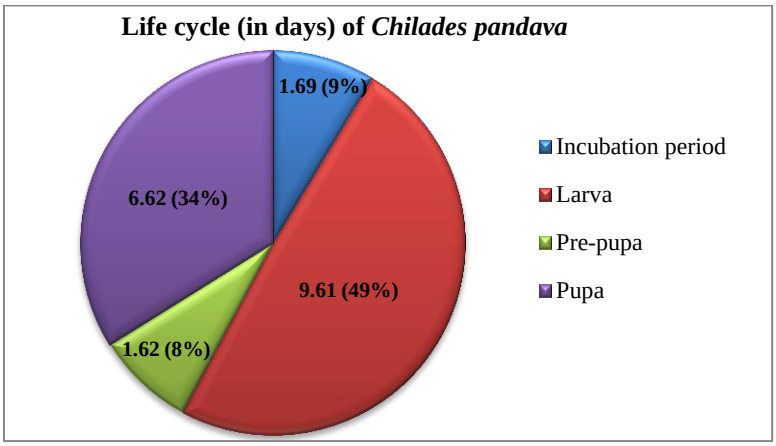


Fig. 35. Duration of life cycle of *Chilades pandava*

It has been found that average duration for incubation period, larval duration, duration for pre-pupal stage and pupal stage is 2.69 (9%) days, 9.61 (49%) days, 1.62 (8%) days, and 6.62 (34%) days, respectively (Fig. 35). This butterfly required average 19.54 days for metamorphosis from egg to adult in laboratory condition.

Female *Chilades pandava* was spotted to lay eggs on the young leaves and fronds of Nepal Cycas plant (*Cycas pectinata*) and several larval instars was also found to eat young and tender leaves. Hence, this plant is identified as the host plant of *C. pandava.*

6.3.5 *Cycas pectinata* (Host plant of *Chilades pandava*)

6.3.5.1 Systematic position

Kingdom Plantae

Superdivision Spermatophyte

Division Gymnospermae

Sub division Cycadophyta

Class Cycadopsida

Order Cycadales

Family Cycadaceae

Genus *Cycas*

Species *Cycas pectinata*

Plate 75. *Chilades pandava* basking on leaf of its host plant *Cycas pectinata.*

Detail description including morphological characters, distribution and habitat, and economic value of *Cycas pectinata* was given in Chapter 3.

6.3.5.2 Phenology of the host plant (Plate 76)

Cycas pectinata is an evergreen, palm-like tree. It is one of the most common and widespread cycads found in southeast and south Asia including Bangladesh. This species occurs in medium to tall closed forest in difficult terrains on deep, often clay-rich and more fertile soils, usually as part of the general shrub understorey in moderate to deep shade mostly but also in open areas where there is plenty of sunshine. It is recorded from a variety of substrates, but most frequently occurs on clay soils over limestone. This plant is an ornamental plant grown in gardens and at public places in tropical regions which

have a seasonally dry climate. It is easy to grow, tolerating dry periods. It is often the focal point in a large yard. Because of its growth habit, fertilize only when terminal bud begins to swell, indicating the start of the annual growth cycle.

a **b** **c**

Plate 76. Phenological stages of *Cycas pectinata*: **a**. plants with new young leaves; **b**. mature plant; and **c**. plants with fruits.

This plant needs a well-drained spot, with deep soil, but will still thrive in less than ideal conditions. Flowering and fruiting is occurred during November-January. This plant is propagated by seed. As a slow growing plant, the seed can take from 6-18 months to germinate. After fertile seeds are collected, they usually need several months of storage before the inner embryo is ready to germinate. Therefore, it is best to clean the seeds of external fruit and set them aside before attempting to propagate the seeds.

6.3.6 Synchronization of coincidences between *Chilades pandava* and its host plant

The plant *Cycas pectinata* is an evergreen, palm-like tree. Flowering and fruiting are found from November to January.

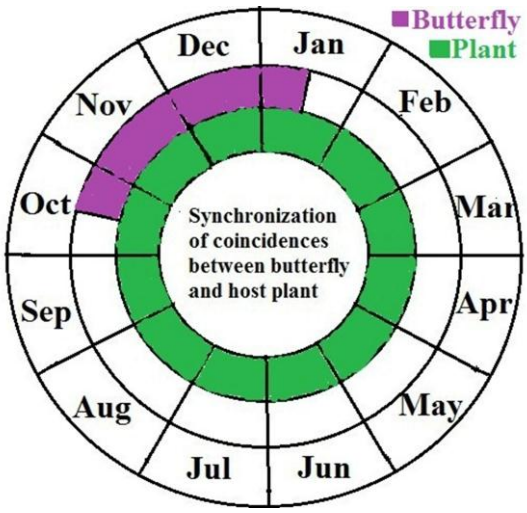


Fig. 36. Coincidence between life cycle of *Chilades pandava* and its host plant's phenology.

The cycad blue butterfly *Chilades pandava* depends on this plant to complete its life cycle. The larvae bore in young fronds making tunnels and feed through the leaf or tunnel tissues and also in young stems. The Cycad new leaves appear to be dwarfed, pale green or yellowish colour. This butterfly is found during the period of October to January. It is seen very poorly in the other months of the year. It was observed that coincidence of *Chilades pandava* and its host plant is occurred from late October to late January (Fig. 36) and the peak abundance of butterfly is recorded during this season. In this period cycad blue butterfly completes several life cycles.

6.3.7 Biology of *Catochrysops strabo* (Fabricius, 1793)

6.3.7.1 Systematic position

Kingdom Animalia

Phylum Arthropoda

Class Insecta

Order Lepidoptera

Family Lycaenidae

Subfamily Polyommatinae

Genus *Catochrysops*

Species *Catochrysops strabo* (Fabricius, 1793)

Plate 77. *Catochrysops strabo* taking nectar from *Ocimum sanctum* flower.

Catochrysops strabo is commonly known as Forget-me-not butterfly. Detail information of this butterfly has given in Chapter 3.

6.3.7.2 Life cycle

Life cycle of *Catochrysops strabo* starts through mating following egg laying and consists of egg, four instars of larva, pre-pupa, pupa and ends as adult (Plate 82).

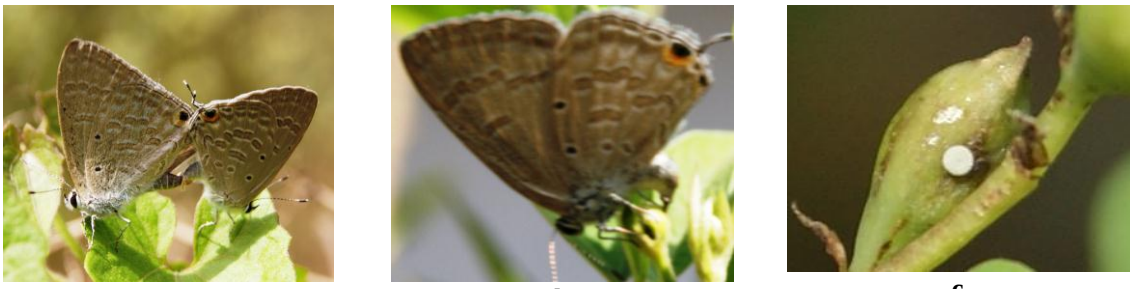
6.3.7.2.1 Mating

Males are seen to slowly flutter beneath the food plant looking for newly emerged females with which to mate. Males have unusual long, hair-like scales on the dorsal sides of the wings which comprises androconia. These are specialised wing scales on the dorsal sides of the wings used for courtship. During mating (Plate 78a) they do not fly

because of the overweight of female abdomen. In field observation, duration of mating period was recorded as 45-50 minutes.

6.3.7.2.2 Egg laying

Catochrysops strabo vibrates its wings rapidly and repeatedly visit the plants when it searches host plants. It bends abdomen to touch the plant parts for searching host plants and moves forward. Finding a suitable place it lays egg (Plate 78b) singly. After laying one egg it flies away to take rest for sometimes, then start to lay next egg. In this way this butterfly lays several numbers of eggs. This butterfly lays eggs at day light.



a **b** **c**

Plate 78. Adults and eggs of *Catochrysops strabo*: **a.** mating; **b**. egg laying; and **c**. egg.

6.3.7.2.3 Egg

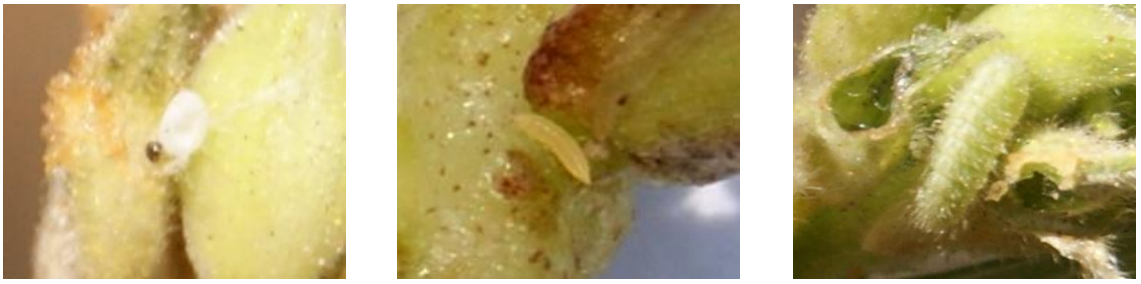
The eggs (Plate 78c) of Forget-me-not are small disc-like and hemispherical, strongly flattened top and bottom, slightly depressed on top with a small darker central micropylar area. Eggs are laid on young shoots, unopened buds and pedicels or leaves of the host plants. Freshly laid egg is yellowish green in colour. It decolourizes soon to light green within the next day and turns to a blue-white within few days. Mature eggs are white in colour. Eggs are ornamented with short blunt spines on the side, which are absent on the top of the egg. The reticulation facets are trigonal, which are grouped together in an orderly fashion to form large hexagons. The facets on the top of the egg are much smaller and are of irregular shape. The incubation period is 2 to 3 days in laboratory condition.

6.3.7.2.4 Larva

The free living larva hatched after egg incubation. There are four larval instars of the Forget-me-not butterfly. Table 28 marks the duration and length of different larval instars.

First instar larva- This larva comes out from the egg after nibbling away sufficiently large portion of the egg shell (Plate 79a). The freshly emerged larvae are pale yellow in colour with moderately long fine setae (Plate 79b). It has cylindrical body with a black

head capsule a dark pro-thoracic shield. The newly hatched larva is about 1.1 to 1.3 mm in length. It makes its way to a flower bud and starts to bore into it. First instar larva stays within the flower bud and feeds on the flower parts. After 2 to 3 days of development, it reaches at 3 to 4 mm in length and changing its colour in yellowish green to moult into next instar. Moulting from first instar to second instar typically takes place within flower bud.



a **b** **c**

Plate 79. Different stages of metamorphosis: **a**. first instar larva splits egg shell; **b**. first instar larva; and **c**. second instar larva.

Second instar larva- This larva (Plate 79c) is pale yellowish green in colour and more transparent; sometimes whitish bands are running dorsally. The head capsule is black with a dark-coloured pro-thoracic shield. The body is now more woodlouse-like in shape. Second instar larva maintains the habit of boring into flower buds and feeding within them. At the end of second instar the larva reaches to a length of 6 to 7 mm. It moults to next instar larva after about development of 2 to 3 days.

Third instar larva- The third instar larva (Plate 80a) shows brownish colour with prominent dorsal line. The head capsule is still black but the pro-thoracic shield has decolorized to the body base colour. Both the dorsal nectary organ and the tentacular organs are discernible in this instar. This larva migrates from flower parts to seed pods to eat developing seeds within it. After reaching about 11 to 12 mm in body length, the third instar larva takes 3 to 4 days and it moults again.

a **b** **c**

Plate 80. Different stages of metamorphosis: **a**. third instar larva; **b**. fourth instar larva; and **c**. pre pupa.

Fourth instar larva- The fourth or final instar larva (Plate 80b) is green in colour with a yellowish green dorsal line. But the posterior end is yellowish green in colour. The nectary organs are rather prominent in this instar. After 4 to 5 days this larva reaches a maximum body length of about 15 to 16 mm and ceases to development for next moult.

The body of larva is covered with fine hairs. The larvae feed on the floral buds by making a hole in the corolla and entering partly feeds on the inner contents. When the pod is attacked the larva makes a separate hole at each time for feeding on each seed in the pod.

6.3.7.2.5 Pre-pupa

After 13 to 14 days of larval growth and reaching the maximum length of 15 to 17 mm, the body of final instar larva gradually shrinks. The larva ceases eating and wanders around for a pupation site. It chooses to enter its pre-pupatory phase (Plate 80c) on a spot of the leaf surface within a pile of withered leaves. Then the larva readies itself for pupation by spinning a silk girdle and a silk pad. Some larva also chooses to pupate within seed pods. In laboratory, duration of pre-pupal phase is about 10 to 12 hours and its length is 10 to 11 mm.

6.3.7.2.6 Pupa

The full grown larva pupates on the leaf secured by a girdle of silken threads around the body at first abdominal segment. Pupation takes place within one day of the pre-pupal stage. The hairy pupa (Plate 81a) has the typical lycaenid shape; the pupa has a body length of about 10 to 11 mm and is dirty brown with black dots on the dorsal surface. Five days later pupa becomes darkened in colour signalling the imminent emergence of the adult. The next day the adult butterfly emerges from the mature pupa. In laboratory, the duration from pupa to adult is about 6 to 7 days.

a **b** **c**

Plate 81. Immature and mature *Catochrysops strabo*: **a**. pupa (early); **b**. adult female; and **c**. adult male.

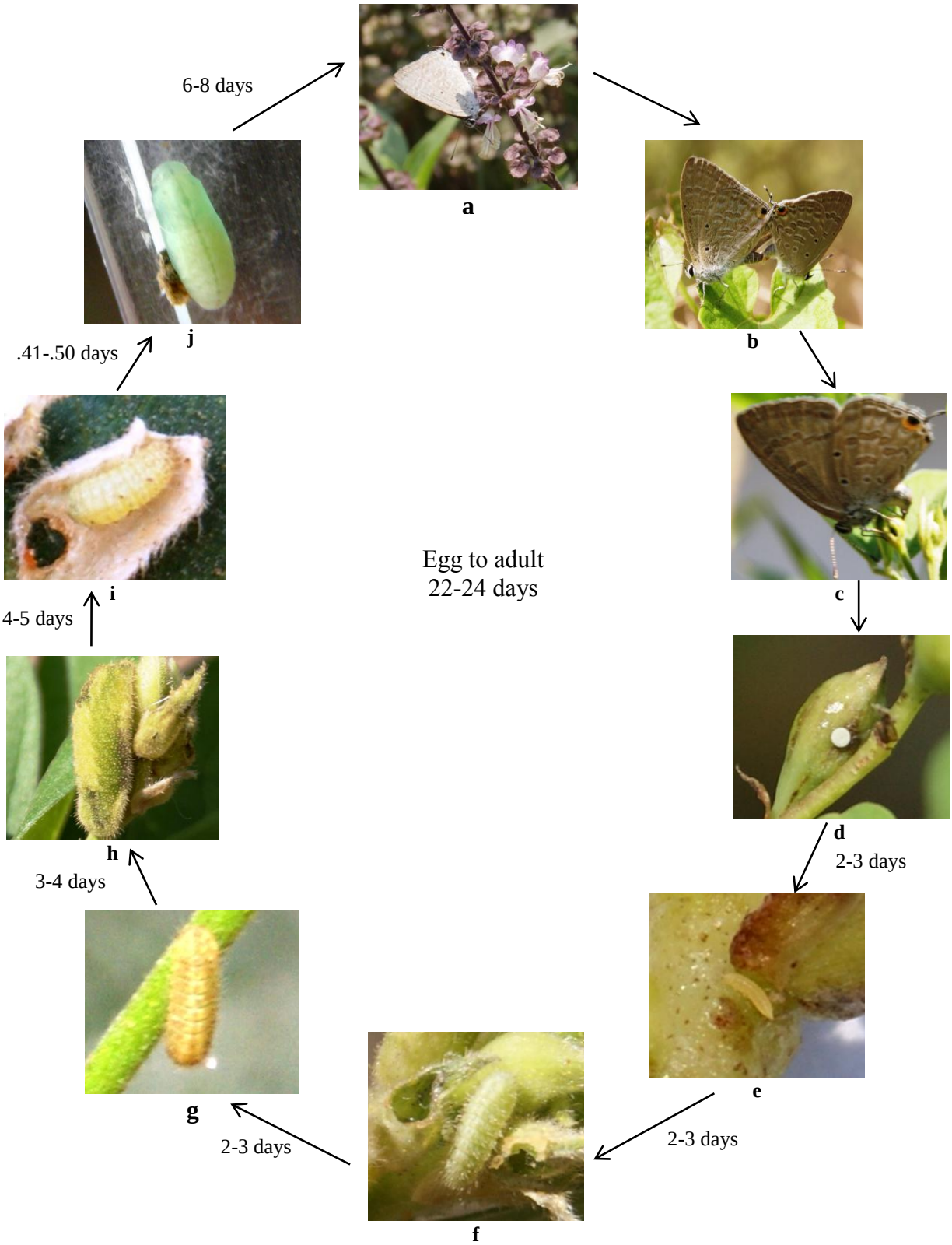


Plate 82. Life cycle of *Catochrysops strabo*: **a**. adult butterfly; **b**. mating; **c**. egg-laying; **d**. egg; **e**. first instar larva; **f**. second instar larva; **g**. third instar larva; **h**. fourth instar larva; **i**. pre pupa; and **j**. pupa.

6.3.7.2.7. Adult

The adult (Plate 81b, Plate 81c) was observed to emerge from the pupa by splitting open the case vertically on the dorsal side. The emergence time was about 26-30 minutes. In laboratory experiment the total duration from egg to adult emergence is about 23-25 days.

6.3.7.3 Life cycle stages of *Catochrysops strabo* – a laboratory assay

In my observation, eleven hatched eggs among fourteen eggs have completed its metamorphosis and emerged as adult butterfly. First, second, third and fourth instar larva was 3-4 mm, 6-7 mm, 11-12 mm and 15-16 mm, respectively. Both pre-pupa and pupa was 10-11 mm long. Average length of first, second, third and fourth instar larva was 3.63 mm, 6.32 mm, 11.45 mm and 15.41 mm, respectively. The pre-pupa was 10.37 mm long whereas pupa was 10.32 mm long (Table 28).

Table 28. Lengths and duration of the developmental stages of *Catochrysops strabo* in an ambient environment of the laboratory.

Developmental stages	Length (mm)		Incubation/ stage duration (days)	
	Avg. ± SD	Range	Avg. ± SD	Range
Egg			2.45±0.52	2-3
Larval instars				
1st instar	3.63±0.39	3-4	2.36±0.51	2-3
2nd instar	6.32±0.41	6-7	2.73±0.47	2-3
3rd instar	11.45±0.61	11-12	3.63±0.51	3-4
4th instar	15.41±0.44	15-16	4.72±0.47	4-5
Total duration			13.44± 0.49	13-14
Pre-pupa	10.37±0.41	10-11	0.47±0.05	.41-.50
Pupa	10.32±0.41	10-11	6.73±0.65	6-8
Egg to adult emergence			23.09±0.45	22-24

In laboratory condition, the incubation period was 2-3 days. First instar larva required average 2-3 days for next moulting whereas second instar larva needed 2-3 days. Within 3-4 days third instar larva reached fourth instar larva.

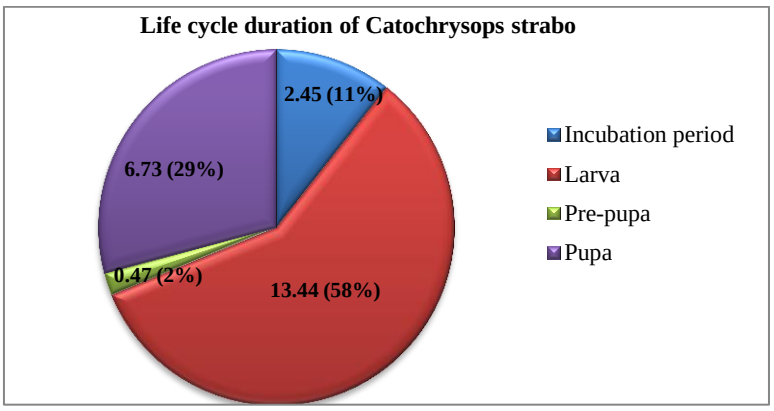


Fig. 37. Duration of life cycle of *Catochrysops strabo*

It required 4-5 days to moult pre-pupal stage. A short transitional and immovable pre-pupal stage required only 0.41-0.50 days for moulting to next developmental stage. The inactive pupa requires 6-7 days for emerging adult butterfly (Table 28)

So, average duration for incubation period, larval duration, duration for pre-pupal stage and pupal stage is 2.45 days, 13.44 days, 0.47 days and 6.73 days, respectively (Fig. 37). This butterfly required average 23.46 days for metamorphosis from egg to adult in laboratory condition.

6.3.8 *Cajanus cajan* (Host plant of *Catochrysops strabo*)

6.3.8.1 Systematic position

Kingdom Plantae

Subkingdom Tracheobionta

Super division Spermatophyta

Division Magnoliophyta

Class Magnoliopsida

Subclass Rosidae

Order Fabales

Family Fabaceae

Genus *Cajanus*

Species *Cajanus cajan* (L.)

Plate 83. *Catochrysops strabo* on its host plant *Cajanus cajan*.

Detail description including morphological characters, distribution and habitat, and economic value of *Cajanus cajan* was given in Chapter 3.

6.3.8.2 Phenology of the host plant (Plate 84)

Pigeon pea is a short-lived summer-growing perennial pulse crop. In Bangladesh, it is grown both as an annual or perennial crop. Pigeon pea has a reputation for drought resistance. Flowering is delayed under periods of extreme moisture stress. The crop can be grown on a wide range of soil types from lighter loams to the clay soils of the plains. Good surface and internal drainage is essential, as short periods of water logging will kill the plant, especially in the younger stages. Because of the susceptibility of the crop to

water logging, furrow irrigation during growth is not recommended, except in very well drained situations.

a **b** **c**

Plate 84. Phenological stages of *Cajanus cajan*: **a**. vegetative stage; **b**. flowering stage; and **c**. fruitification stage.

The planting time is from late November to early January. December is considered the best month to plant in normal seasons. The crop takes about 65 to 80 days to flower and a further 50 to 75 days for the pods to mature. The perennial nature of pigeon pea results in green leaves and often flowers being present on the plant when the older pods have matured and dried. Crops planted in December-January will generally be ready for harvest in May-June.

6.3.9 Synchronization of coincidences between *Catochrysops strabo* and its host plant

The seeds of *Cajanus cajan* start to swan from the last of December to early January. Within two months the plants mature enough for blooming flower with vegetative growth. In case of perennial plants, new leaves coming in this time and plants are ready for flowering. Inflorescence occurs from March.

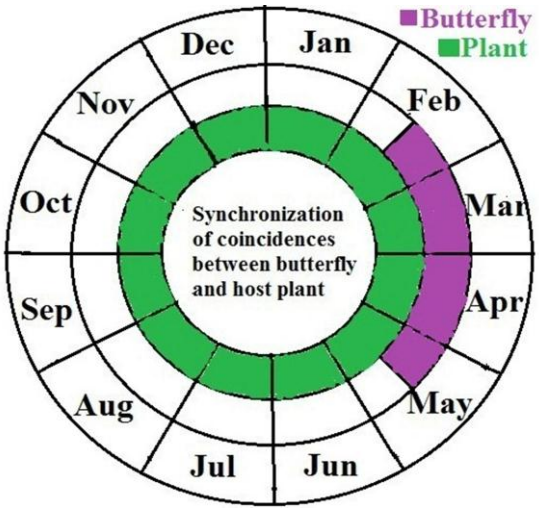


Fig. 38. Coincidence between *Catochrysops strabo* and its host plant.

The forget-me-not butterfly (*Catochrysops strabo)* lays eggs on flower buds or young leaves. Usually this butterfly appears from mid-February. Between the month of March and April this butterfly has peak abundance and also found to mid-May (Fig. 38).

6.3.10 Biology of *Remelana jangala* Horsfield, 1829

6.3.10.1 Systematic position

Kingdom Animalia

Phylum Arthropoda

Class Insecta

Order Lepidoptera

Family Lycaenidae

Subfamily Theclinae

Genus *Remelana* Moore, 1884

Species *Remelana jangala* Horsfield, 1829

Plate 85. *Remelana jangala* taking nectar from *Chromolaena odorata*.

Remelana jangala is commonly known as Chocolate Royal butterfly. Detail information of this butterfly has given in Chapter 3.

6.3.10.2 Life cycle

Life cycle of *Remelana jangala* starts through mating following egg laying and consists of egg, five instars of larva, pre-pupa, pupa and ends as adult (Plate 90).

6.3.10.2.1 Mating

Males are seen to slowly flutter beneath the food plant looking for newly emerged females with which to mate. Males have unusual long, hair-like scales on the dorsal sides of the wings which comprises androconia. These are specialized wing scales on the dorsal sides of the wings used for courtship. During mating they do not fly because of the overweight of female abdomen.

6.3.10.2.2 Egg laying

This butterfly vibrates its wings rapidly and repeatedly visits the plants when it searches host plants. It bends abdomen to touch the plant parts for searching host plants and moves forward (Plate 86a). Finding a suitable place it lays egg (Plate 86b) singly. After laying

one egg it flies away to take rest for a while, then start to lay next egg. In this way this butterfly lays several numbers of eggs. This butterfly lays eggs at day light. In this experiment, it was found that the female laid eggs at evening during 3-5pm.


a


b


c

Plate 86. Adults and eggs of *Remelana jangala*: **a**. Gravid female searching egg laying site; **b**. egg laying; and **c**. egg.

6.3.10.2.3 Egg

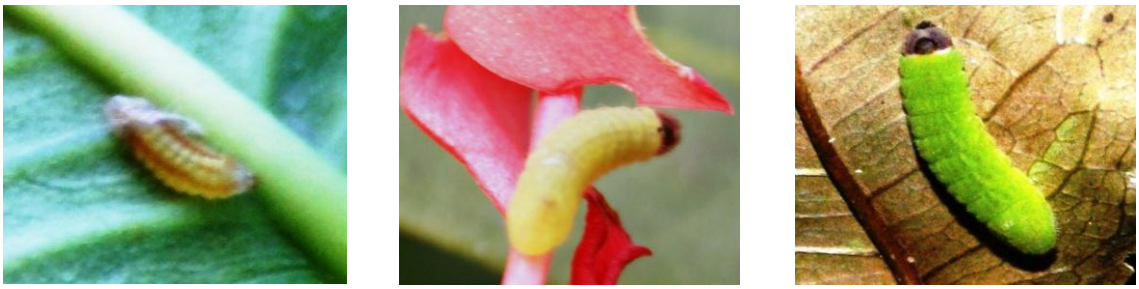
Eggs (Plate 86c) of Chocolate Royal are typically laid on flower petals, young shoots, base of young leaves or in the vicinity of flower buds of the host plants. Egg is white, but with a strong greenish tinge when freshly laid. The egg is disc-like strongly flattened top and bottom with a depressed micropylar at the pole and a surface reticulated with rather large hexagonal pits. The egg hatches within 2 to 3 days in laboratory condition.

6.3.10.2.4 Larva

The free living larva hatched after egg incubation. There are five larval instars of the Chocolate Royal butterfly. Table 29 tabulated the duration and length of different larval instars.

First instar larva- The young larva (Plate 87a) emerges after nibbling away the polar portion of the egg shell to emerge, and does not eat the egg shell remnant. The freshly larva is measured at a length of about 0.9 to 1.2 mm, its pale yellow body is cylindrical in shape, sporting long fine setae (hairs) and a brown prothoracic shield and head capsule. Yellowish brown bands run dorso-laterally along its body. As it grows, the body assumes the more typical onisciform (woodlouse) shape. The newly hatched larva finds its way to adjacent flower buds, feeding on the peduncle or the bud proper where it will bore a hole to reach the flower parts within. As it feeds and grows, its bands fade away into a yellowish green coloration. After 2 to 3 days of growth, it looks pumped up at a length of about 3 mm. After a period of immobility of about half a day, it moults to the second instar.

Second instar larva- This larva (Plate 87b) is covered with numerous setae; the body of the second instar larva could in light yellowish green colouration. Setae found at the dorsal and lateral margins are longer and stiffer. The prothoracic shield and the head are black, a significant change from the earlier pale brown coloration. The dorsal nectary organ is present but still inconspicuous. The second instar larva reaches a length of about 6 to 7 mm, and after about 3 to 4 days in this stage, it moults again.



a **b** **c**

Plate 87. Different stages of metamorphosis: **a**. first instar larva; **b**. second instar larva; and **c**. third instar larva.

Third instar larva- The third instar (Plate 87c) loses the contrasting lateral brown bands in the previous instars and larva has numerous short and fine body setae. Its body is now uniformly coloured in yellowish green to pale green. The prothoracic shield and the head retain the black colouration. The dorsal nectary organ is now more conspicuous. There is no visible sign of any tentacular organs. The third instar takes 3 to 4 days to complete with the body length reaching about 10 to 11 mm.

Fourth instar larva- The fourth instar larva (Plate 88a) is closely similar in appearance to the third instar larva. Its body is still yellowish green to dull green, covered with numerous tiny setae. The black colouration of the prothoracic shield is retained in some case but generally changed to a brown to pale brown colouration. The bar-like dorsal nectary organ is marked with two reddish brown marks around a central white speck, giving it a prominent appearance. After 3 to 4 days this larva reaches a maximum body length of about 15 to 16 mm and ceases to development for next moult. Larvae feed openly during the day. The presence of larvae on the food plant is discernible by the eaten flower buds.

Fifth instar larva- The fifth instar larva (Plate 88b) has similar markings as in the fourth instar. As it grows, the larva becomes more greenish in colouration. The prothoracic shield, together with rest of the prothorax, has faded further to pale yellowish brown. It takes about 5 to 6 days to complete with the body length reaching 22-24mm. When an ant

approaches, the dorsal nectary organ can be observed to protrude and exude droplets of clear nectary fluid.

a **b** **c**

Plate 88. Different stages of metamorphosis: **a**. fourth instar larva; **b**. fifth instar larva; and **c**. pre-pupa.

6.3.10.2.5 Pre-pupa

Near the end of the final instar, the larva ceases feeding. The body of the larva gradually shrinks, and finally takes on a pale greenish colouration. It chooses a site on the sheltered surface of a leaf for its pupation site and takes up a position on the surface to become an immobile pre-pupa (Plate 88c). At the chosen site, the larva readies itself for pupation by spinning a silk girdle and a silk pad. The larva secures itself to the silk pad via claspers on its posterior end. In laboratory duration of pre-pupal phase is about 1 to 2 days.

6.3.10.2.6 Pupa

Pupation takes place after one day of the pre-pupal stage. The pupa (Plate 89a) is predominantly green in colour and has numerous small whitish speckles. The stout pupa has a typical lycaenid shape with a short abdomen. The pupa has a length of about 12 to 14 mm. After six to eight days, the pupa turns black signaling the imminent emergence of the adult mostly in the thorax and wing pads. The bluish patches on the forewing dorsal sides become visible through the now transparent pupal skin. The next day the pupal stage comes to an end and the adult butterfly emerges from the mature pupa. In laboratory the duration from pupa to adult emergence is about 6 to 8 days.

a **b** **c**

Plate 89. Immature and mature *Remelana jangala*: **a**. pupa; **b**. adult female; and **c**. adult male.

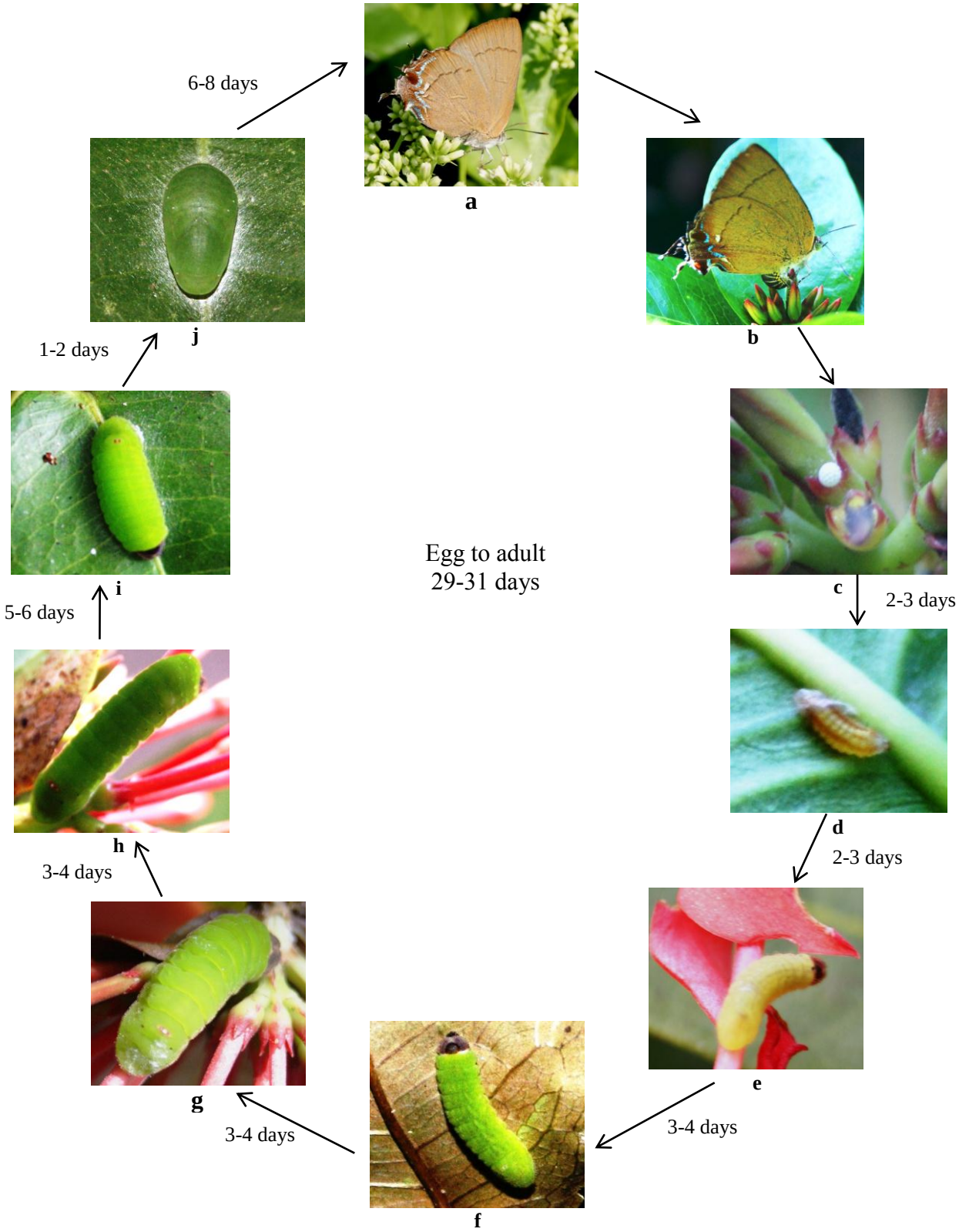


Plate 90. Life cycle of *Remelana jangala*: **a**. adult butterfly; **b**. egg laying; **c**. egg; **d**. first instar larva; **e**. second instar larva; **f**. third instar larva; **g**. fourth instar larva; **h**. fifth instar larva; **i**. pre-pupa; and **j**. pupa.

6.3.10.2.7 Adult

The adult (Plate 89b, Plate 89c) was observed to emerge from the pupa by splitting open the case vertically on the dorsal side. The time emergence was about 31-35 minutes. In laboratory experiment the total duration from egg to adult emergence is about 29 to 31 days.

6.3.10.3 Life cycle stages of *Remelana jangala* – a laboratory assay

The experiment was done in an ambient environment of the laboratory with 26°C to 30°C temperature and the relative humidity was 68% to 74%. Thirty freshly laid eggs were collected and rear in laboratory. Among them twenty eight eggs was hatched. It has been examined that twenty one eggs have completed its metamorphosis to emerge as adult butterfly and other hatched larvae was died. First, second, third, fourth and fifth instar larva was 2.5-3 mm, 6-7 mm, 10-11 mm, 15-16 mm and 22-24 mm, respectively. Pre-pupa was 13-15 mm whereas pupa was 12-14 mm long. Average length of first, second, third, fourth and fifth instar larva was 2.76 mm, 6.52 mm, 10.67 mm, 15.48 mm and 23.24 mm, respectively. Pre-pupa was 14 mm long while pupa was 13 mm long (Table 29).

Table 29. Lengths and duration of the developmental stages of *Remelana jangala* in an ambient environment of the laboratory (Temp. 28 ± 2°C and 71 ± 3% RH).

Developmental stages	Length (mm)		Incubation/ stage duration (days)	
	Avg. ± SD	Range	Avg. ± SD	Range
Egg			2.57±0.51	2-3
Larva instar				
1st instar	2.76±0.18	2.5-3	2.48±0.51	2-3
2nd instar	6.52 ±0.39	6-7	3.57±0.51	3-4
3rd instar	10.67±0.40	10-11	3.57±0.51	3-4
4th instar	15.48±0.37	15-16	3.52 ±0.51	3-4
5th instar	23.24±0.71	22-24	5.52±0.51	5-6
Larval duration			18.67± 0.48	18-19
Pre-pupa	14±0.77	13-15	1.62±0.49	1-2
Pupa	13±0.84	12-14	7.14±0.73	6-8
Egg to adult emergence			30.05±0.86	29-31

In laboratory condition, the incubation period was 2-3 days. First instar larva required average 2-3 days for next moulting whereas second instar larva needed 3-4 days. Within 3-4 days third instar larva reached to fourth instar larva. This instar required 3-4 days to moult into next developmental stage. The fifth and final instar larva needed 5-6 days to moult pre-pupal stage. A short transitional and immovable pre-pupal stage required only 1-2 days for moulting to inactive pupa. This inactive stage (pupa) needed 6-8 days to emerge as adult butterfly. The butterfly, *Remelana jangala* passed the period of 29-31 days to emerge as adult from egg.

By this experiment average duration of different developmental stages of *Remelana jangala* was also calculated under laboratory condition (Table 29). Among the total period from egg to adult emergence maximum period (62%) was spend as active larva and minimum period (5%) was passing as pre-pupal stage (Fig. 39).

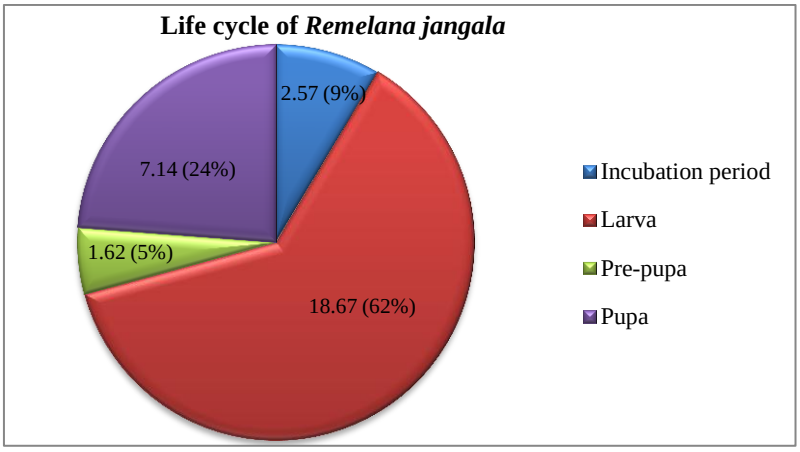


Fig. 39. Duration of life cycle of *Remelana jangala*

The inactive pupa spent 24% whereas egg incubated within 9% of total duration. This butterfly required average 30.05 days for metamorphosis from egg to adult in laboratory condition.

6.3.11 *Ixora coccinea* (Host plant of *Remelana jangala*)

6.3.11.1 Systematic position

Kingdom Plantae

Superdivision Spermatophyta

Division Magnoliophyta

Class Asterids

Subclass Lamiids

Order Gentianales

Family Rubiaceae

Genus *Ixora*

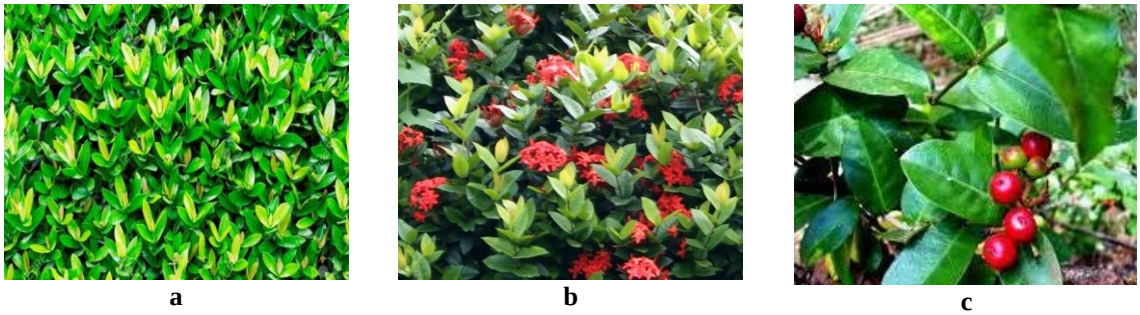
Species *Ixora coccinea* L.

Plate 91. *Remelana jangala* taking nectar from flower of *Ixora coccinea*.

Detail description including morphological characters, distribution and habitat, and economic value of *Ixora coccinea* was given in Chapter 3.

6.3.11.2 Phenology of the host plant (Plate 92)

Ixora coccinea is a low-growing tropical shrub notable for its bright coloured flowers which are composed of many small blooms massed together into dense, flat-topped flower heads. This plant is one of the few *Ixora* species that make good indoor plants along with several kinds developed from it. *Ixora coccinea* is found in a wide variety of habitats but cannot tolerate many variations from ideal growing conditions. It responds well to trimming, and is widely cultivated as an ornamental hedge. This plant has become one of the most popular flowering shrubs in gardens and landscapes. It grows in tropical areas within medium annual rainfall in well drained soils. *I. coccinea* is also grown in containers, looking very distinguished as a patio or poolside plant. In Bangladesh, it is commonly cultivated in gardens throughout the country. The plant usually flowers continually all the year round although normal flowering period is summer. Plants are tolerant of severe pruning. This plant is propagated by seeds and cuttings.



a **b** **c**

Plate 92. Phenological stages of *Ixora coccinea*: **a**. vegetative stage; **b**. flowering stage; and **c**. fruitification stage.

6.3.12 Synchronization of coincidences between *Remelana jangala* and its host plant

The plant *Ixora coccinea* is a perennial shrub present almost all the year round. Flowering and fruiting are found throughout the year. The chocolate royal butterfly *Remelana jangala* depends on this plant to complete its life cycle. Larvae of this butterfly eat flowers of *Ixora coccinea* for their maturation.

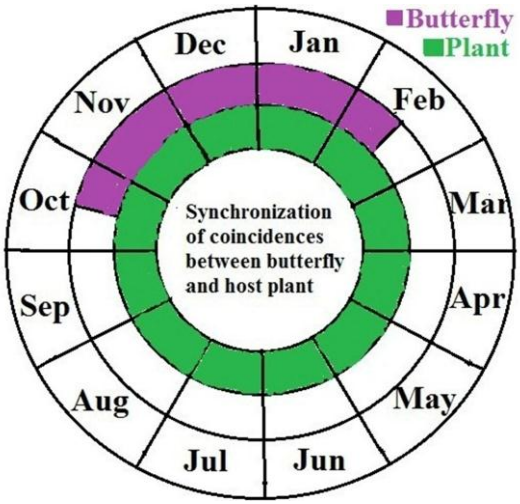


Fig. 40. Coincidence between *Remelana jangala* and its host plant.

This butterfly is found during the period of late October to early February (Fig. 40). It was observed that coincidence between *Remelana jangala* and its host plant is occurred from November to January and the peak abundance of butterfly is recorded during this season. In this period chocolate royal butterfly completes several life cycle.

6.3.13 Biology of *Rathinda amor* (Fabricius, 1775)

6.3.13.1 Systematic position

Kingdom Animalia

Phylum Arthropoda

Class Insecta

Order Lepidoptera

Family Lycaenidae

Subfamily Theclinae

Genus *Rathinda* Moore, 1881

Species *Rathinda amor* (Fabricius, 1775)

Plate 93. *Rathinda amor on its host plant Ixora coccinea*.

Rathinda amor is commonly known as Monkey puzzle butterfly. Detail information of this butterfly has given in Chapter 3.

6.3.13.2 Life cycle

Life cycle of *Rathinda amor* starts through mating following egg laying and consists of egg. It continues to larva, pre-pupa, pupa and ends in emergence of adult (Plate 98).

6.3.13.2.1 Mating

Males are seen to slowly flutter beneath the food plant looking for newly emerged females with which to mate (Plate 94a). Males have unusual long, hair-like scales on the dorsal sides of the wings which comprises androconia. These are specialized wing scales on the dorsal sides of the wings used for courtship. During mating they do not fly because of the overweight of female abdomen.

6.3.13.2.2 Egg laying

The gravid female vibrates its wings rapidly and repeatedly visits the plants when it searches host plants. It bends abdomen to touch the plant parts for searching host plants and moves forward. Finding a suitable place it lays egg (Plate 94b) singly. After laying one egg it flies away to take rest for a while, then start to lay next egg. In this way this butterfly lays several numbers of eggs. Oviposition takes place from 9 am to 2 pm.

a **b** **c**

Plate 94. Adults and eggs of *Rathinda amor*: **a.** mating; **b**. egg laying; and **c**. egg.

6.3.13.2.3 Egg

Eggs (Plate 94c) of Monkey puzzle butterfly are typically laid on the petioles at the axillary position, young shoots, base of young leaves, undersurface of the young leave, or in the vicinity of flower buds of the host plants. Egg is white, but with a strong greenish tinge when freshly laid. The small egg is disc-like strongly flattened top and bottom with a depressed micropylar at the pole and a surface reticulated with rather large hexagonal pits. The egg hatches within 2 to 3 days in laboratory condition.

6.3.13.2.4 Larva

The free living larva hatched after egg incubation. The larva of Monkey puzzle butterfly passed through four distinct instars. Table 30 charted the duration and length of different larval instars.

First instar larva- The young larva (Plate 95a) emerges after nibbling away the polar portion of the egg shell to emerge, and eat the egg shell remnant. The freshly larva is inactive and measured at a length of about 0.8 to 1.2 mm. Its pale yellow or cream coloured body is cylindrical in shape, sporting long fine setae (hairs) and yellowish head capsule. There are tiny black fleshly protuberances on dorsol side along the length of its body and paired protuberances present at the anal segment. As it grows, the body assumes the more typical onisciform (woodlouse) shape. The newly hatched larva hatched finds its way to adjacent flower buds, feeding on the peduncle or the bud proper where it will bore a hole to reach the flower parts within. After 2 to 3 days of growth, it looks pumped up at a length of about 3 mm. After a period of immobility of about half a day, it moults to the second instar.

a **b** **c**

Plate 95. Different stages of metamorphosis: **a**. first instar larva (late); **b**. second instar larva; and **c**. third instar larva (early stage).

Second instar larva- The body colour of this instar (Plate 95b) changed into yellowish green from the first instar larva. Cream coloured protuberances are eight in number now and a pair at the posterior end like first instar. Head is transparent in colour. The second instar larva attains a length of about 5 to 6 mm. After about 2 to 3 days, it moults again.

Third instar larva- After moults into third instar (Plate 95c) it turns brownish green colour. Body is triangular in shape, broad at the anterior region and becoming narrow towards posterior ends. As this instar matures the body colour change to green in dorsal side whereas light green in ventrally. The colour of protuberaces changes to thick orange. Head capsule is transparent colour like previous instar. The third instar takes 1 to 2 days to complete with the body length reaching about 7 to 9 mm.

Fourth instar larva- The fourth instar larva (Plate 96b) is closely similar in appearance to the third instar larva. Its body is dark green and protuberance is black in colour. The head retains green colour. Larvae feed openly during the day. After 3 to 4 days this larva reaches about 12 to 14 mm length and ceases feeding to development for next moulting.

a **b** **c**

Plate 96. Different stages of metamorphosis: **a**. third instar larva (late); **b**. fourth instar larva; and **c**. pre-pupa.

6.3.13.2.5 Pre-pupa

The body of the fourth instar larva gradually shrinks, and finally takes on a dark green colouration. It chooses a site on the sheltered surface of a leaf for its pupation site and takes up a position on the surface to become an immobile pre-pupa (Plate 96c). At the chosen site, the larva readies itself for pupation by spinning a silk girdle and a silk pad. The larva secures itself to the silk pad via claspers on its posterior end. In laboratory duration of pre-pupal phase is about 1 to 2 days.

6.3.13.2.6 Pupa

Pupation takes place after one day of the pre-pupal stage. The pupa (Plate 97a) is green in colour. A gray coloured triangular patch is present at the tail region. But there were no other markings or ornamentation. The pupa has a length of about 9 to 10 mm. After seven to eight days, the pupa turns black signaling the imminent emergence of the adult mostly in the thorax and wing pads. The next day the pupal stage comes to an end and the adult butterfly emerges from the mature pupa. Duration from pupa to adult is about 8 to 9 days in the laboratory condition.

a **b** **c**

Plate 97. Immature and mature *Rathinda amor*: **a**. pupa; **b**. adult in open wing; and **c**. adult with close wing.

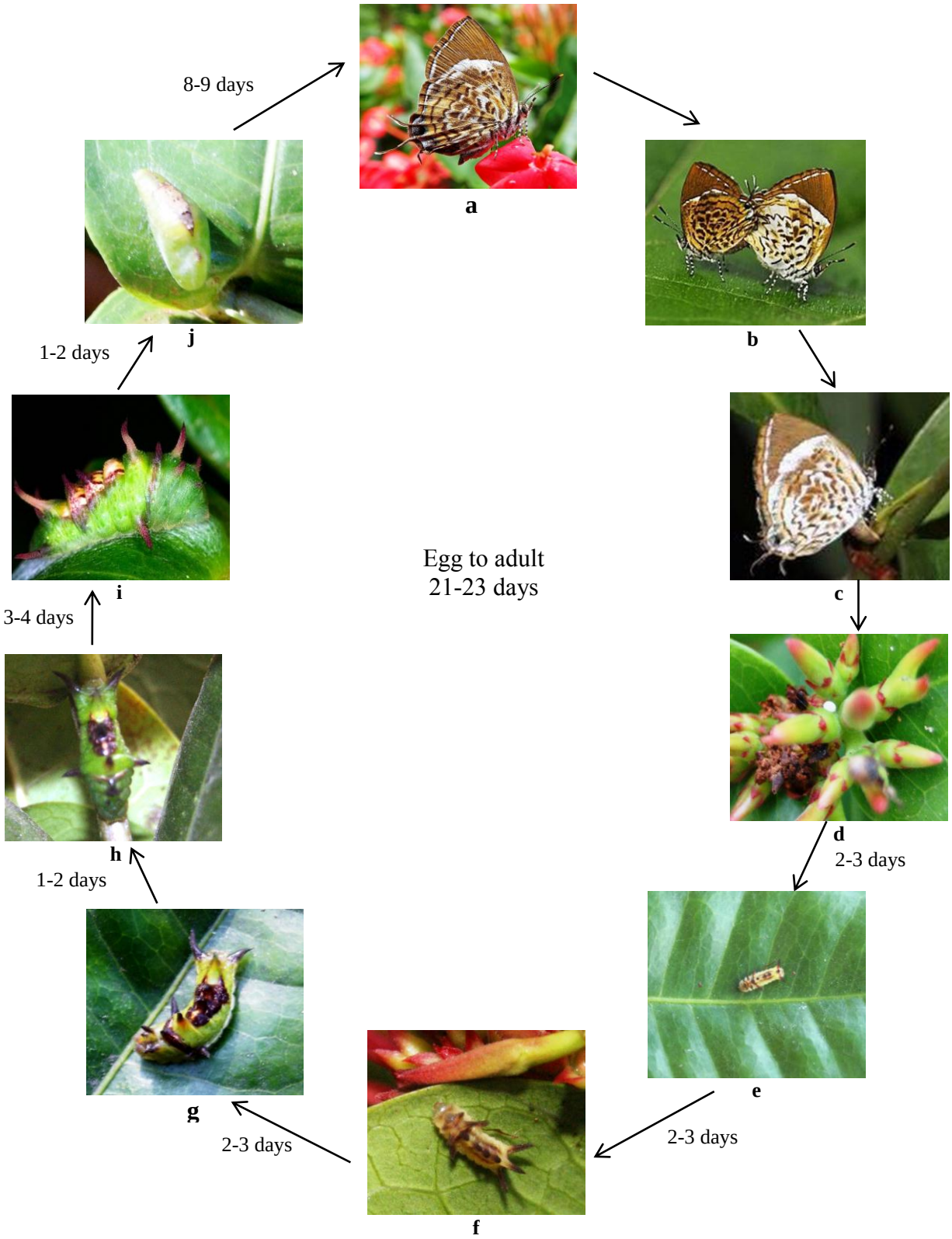


Plate 98. Life cycle of *Rathinda amor*: **a**. adult butterfly; **b**. mating; **c**. egg-laying; **d**. egg; **e**. first instar larva; **f**. second instar larva; **g**. third instar larva; **h**. fourth instar larva; **i**. pre pupa; and **j**. pupa.

6.3.13.2.7 Adult

The adult (Plate 96b, Plate 97c) was observed to emerge from the pupa by splitting open the case vertically on the dorsal side. The time taken for emergence is about 1 hour. In laboratory experiment the total duration from egg to adult emergence is about 21 to 23 days.

6.3.13.3 Life cycle stages of *Rathinda amor* – a laboratory assay

The experiment was done in an ambient environment of the laboratory where temperature prevailed 26°C to 30°C and the relative humidity was 68% to 74%. Eighteen freshly laid eggs were collected and rear in laboratory. Among them fifteen eggs was hatched. It has been examined that eleven eggs have completed its metamorphosis to emerge as adult butterfly and other hatched larvae was found dead. First, second, third and fourth instar larva was 1.5-2.5 mm, 4-6 mm, 7-9 mm and 12-14 mm long, respectively. Pre-pupa was 10-12 mm whereas pupa was 9-10 mm long. Average length of first, second, third and fourth instar larva was 2.13 mm, 5.43 mm, 8.22 mm and 13.1 mm, respectively. The length of pre-pupa was 11.09 mm and pupa was 9.45 mm long (Table 30).

Table 30. Lengths and duration of the developmental stages of *Rathinda amor* in an ambient environment of the laboratory (Temp. 28 ± 2˚C and 71 ± 3% RH).

Developmental stages	Length (mm)		Incubation/ stage duration (days)	
	Avg. ± SD	Range	Avg. ± SD	Range
Egg			2.45±0.52	2-3
Larva instar				
1st instar	2.13±0.32	1.5-2.5	2.36±0.50	2-3
2nd instar	5.43±0.61	4-6	2.64±0.50	2-3
3rd instar	8.22±0.63	7-9	1.73±0.47	1-2
4th instar	13.1±0.53	12-14	3.45±0.52	3-4
Larval duration			10.18± 0.71	9-11
Pre-pupa	11.09±0.66	10-12	1.36±0.50	1-2
Pupa	9.45±0.69	9-10	8.45±0.52	8-9
Egg to adult emergence			22.45±0.69	21-23

In laboratory condition, the incubation period was 2-3 days. Both first and second instar larva required average 2-3 days for next moulting. Within 1-2 days third instar larva reached fourth instar larva. The fourth and final instar larva needed 3-4 days to moult pre-pupal stage. A short transitional and immovable pre-pupal stage required only 1-2 days for moulting to inactive pupa. This inactive stage requires 8-9 days to emerge as adult butterfly (Table 30).

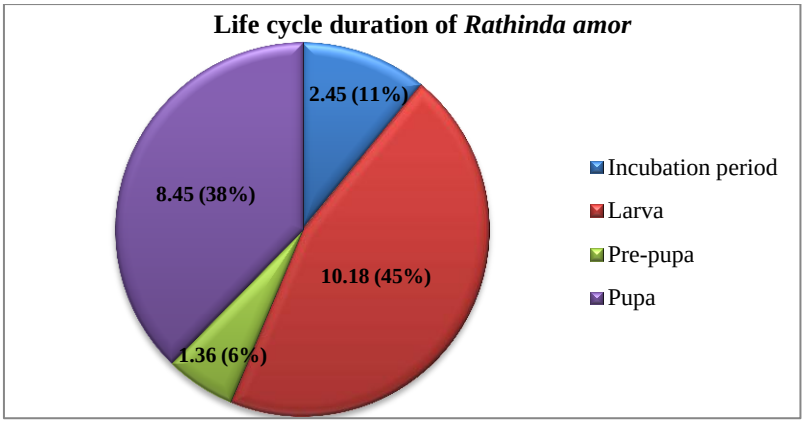


Fig. 41. Duration of life cycle of *Rathinda amor*

It has been found that average duration for incubation period, larval duration, duration for pre-pupal stage and pupal stage is 2.45 (11%) days, 10.18 (45%) days, 1.36 (6%) days and 8.45 (38%) days, respectively (Fig. 41). This butterfly required average 22.45 days for metamorphosis from egg to adult in laboratory condition.

Ixora coccinea is the larval host plant of monkey puzzle butterfly, *Rathinda amor*. Detail description including morphological characters, distribution and habitat, and economic value of *Ixora coccinea* was given in Chapter 3. Systematic position and phenology of this host plant is described as in the coincident study of *Remelana jangala.*

6.3.14 Synchronization of coincidences between *Rathinda amor* and its host plant

The plant *Ixora coccinea* is a perennial shrub present almost all the year round. Flowering and fruiting are found throughout the year.

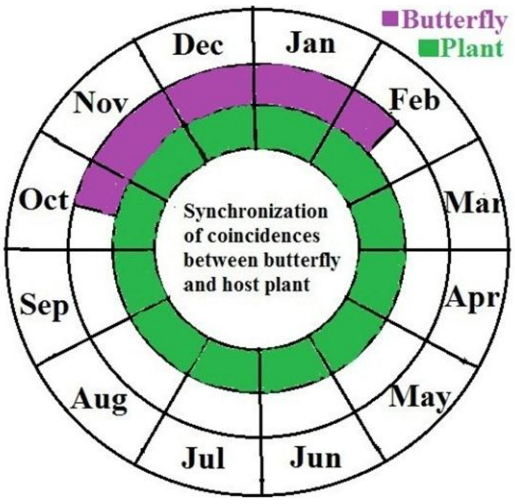


Fig. 42. Coincidence between *Rathinda amor* and its host plant.

The monkey puzzle butterfly *Rathinda amor* depends on this plant to complete its life cycle. Larvae of this butterfly eat flowers and young tender leaves of *Ixora coccinea* for their maturation. This butterfly is found during the period of late October to early February (Fig. 42). It was observed that coincidence of *Rathinda amor* and its host plant is occurred from November to January and the peak abundance of butterfly is recorded during this season. In this period monkey puzzle butterfly completes several life cycles.

6.3.15 "Life cycle of lycaenid"- a glimpse

Time constraint for metamorphosis from egg to adult as well as duration and size of developmental stages was found varies from one species to another in the laboratory (Appendix 16, Appendix 17). The maximum period for egg incubation and larval development was spent by *Remelana jangala* whereas minimum in *Chilades pandava*. In case of pupal growth, *Rathinda amor* was observed to have maximum spell of time and minimum in case of *Chilades pandava* (Table 31).

Table 31. Duration (in days) of immature stages among observed species.

Stages / Species	Incubation period		Larva		Pre pupa		Pupa	
	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Chilades lajus	2.43	2-3	10.71	10-12	1.57	1-2	6.71	6-8
Chilades pandava	1.69	1-2	9.61	8-10	1.62	1-2	6.62	6-7
Catochrysops strabo	2.45	2-3	13.44	13-14	0.47	0.41-0.50	6.73	6-8
Remelana jangala	2.57	2-3	18.67	18-19	1.62	1-2	7.14	6-8
Rathinda amor	2.45	2-3	10.18	9-11	1.36	1-2	8.45	8-9

In this experiment, *Remelana jangala* was found to attain the maximum larval and pupal length. Because this butterfly was go through metamorphosis with five larval instar and long duration. The minimum larval length was observed in case of *Chilades pandava* whereas minimum pupal length was spotted in *Chilades lajus* (Fig. 43).

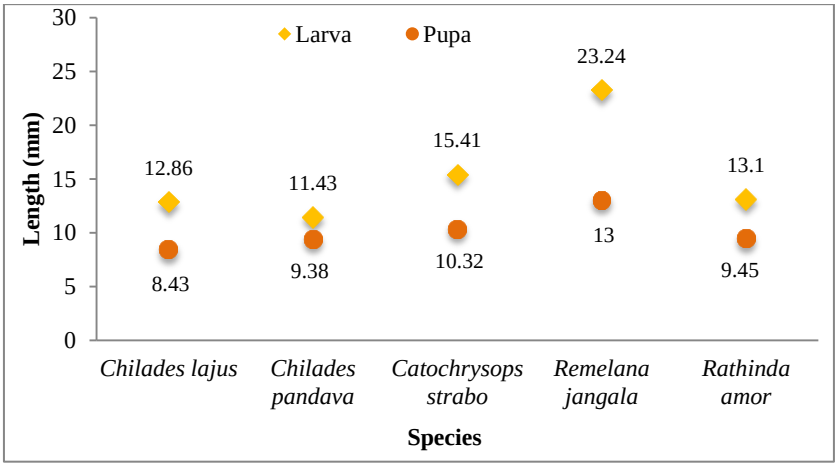


Fig. 43. Length of morphs among of observed species.

It was noticed that metamorphosis from egg to adult, or life cycle duration of examined species *Chilades lajus*, *Chilades pandava*, *Catochrysops strabo*, *Remelana jangala* and *Rathinda amor* required 21.43, 19.54, 23.09, 30.05 and 22.45 days, respectively (Fig. 44).

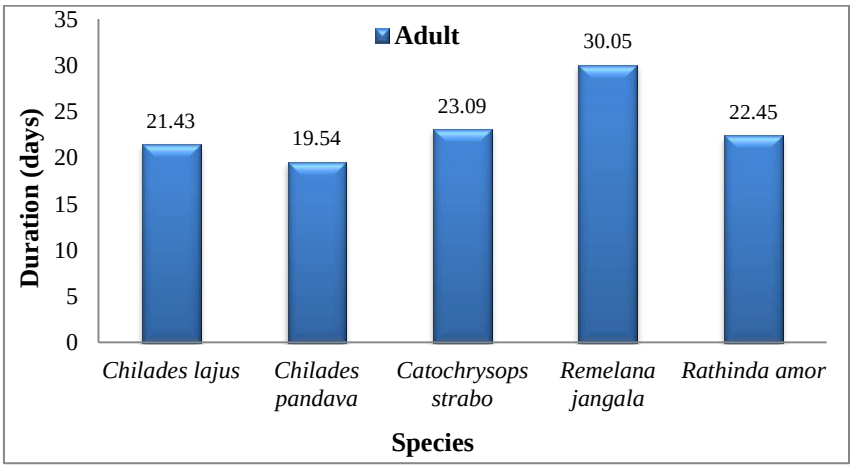


Fig. 44. Duration (in days) of metamorphosis among observed butterfly species.

6.4 Discussion

The study of natural history of butterflies is very essential to know the host plant relationship, habitat preference and life history information. Butterflies are an important model group for the study of natural history than any other groups of insects (Ackery and Vane-Wright 1984). Relationships between life-stages of butterflies and their host-plants are most vital interactive factor in forest ecosystem. This type of interaction has got special significance in the forests of tropics and sub-tropics (Bashar 2014).

Butterfly larvae have to depend on specific plants as food sources. They cannot develop on any other plants than the host plant(s). They feed on the specific plant organs like leaves and stems. In almost all the cases they use the two organs (Bashar 2014). The present investigation gives emphasis on the relationship between the developmental stages of lycaenid butterflies and their interacting host plant's phenology. This study also disclosed generous information on the time length of the life cycle stages (egg to adult).

All studied butterflies are found to lay their eggs in singly. Freshly laid eggs are pale greenish in colour and turn white before hatching. *Remelana jangala* and *Rathinda amor* have special preference of flowers or flower buds for oviposition. While *Chilades lajus* and *Chilades pandava* choose young tender leaves to lay eggs. On the other hand, *Catochrysops strabo* favours very young tender leaves and flower buds to oviposit.

Larval feeding is different among examined species. Larvae of *Remelana jangala* exclusively feed on flowers with unopened petals. *Chilades lajus* feed young tender leaves only while *Chilades pandava* feed on tender leaves and the undersurface of young/mature leaves leaving the upper epidermis intact. The larvae of *Catochrysops strabo* feed on young tender leaves, young buds, flowers, young pods and young seeds inside pods. And larvae of *Rathinda amor* feed on young tender leaves, young buds and flowers. Larval feeding of all species occurred during daytime in the field and sometime noticed at night in captivity. The larvae of all examined species are tended by ants in the field. Ants protect them from natural enemies in return for sugar-rich secretions that the larvae produce to attract and retain their ant guards (Trager and Daniels 2009). But ants were not required for the development of the larva when reared in laboratory.

The immature stages of lycaenid species documented in this study exhibit some variation in size, colour and pattern. In all instances the larval body colour is yellowish green and green specifically in case of final instar and pupa. All studied lycaenids have four larval instars except *Remelana jangala.* This butterfly has five larval instars. Larva of all examined species was found to pupate on the leaves of host plant in laboratory. Present investigation describes the biology along with the morphology and behaviour of immature stages of each species, as step in documenting their comparative life histories. More work is required to get a more detailed understanding of the biology of these species in the field.

Knowledge of immature stages and larval food plants is being important for conservation of butterflies (DeVries 1986). The coincidence of synchronization between two biotic factors (butterfly and plant) in 'dynamic situation' is the key fact of keeping a forest healthy and makes it sustainable (Bashar 2014). Knowledge of the immature stages is also important at a more practical level since it enables the identification of larvae and pupae in the field. Additionally, this knowledge is valuable in aiding the development of ecotourism (Van der Poorten and Van der Poorten 2013). Present investigation will create safeguard to assess the significance of relationship between the butterfly life cycle and their host plants phenology. This relationship helps to know the species abundance of both plant and butterfly in an area. Akand *et al*. (2015a) stated that prior to examine plant-butterfly association in an area, it is essential to take necessary steps for preventing species decline and increasing species richness. This study may be helpful in conserving floral and faunal assemblages and nature conservation.

LARVAL FEEDING ACTIVITIES AND THE NUTRITIONAL AGENTS IN THEIR HOST PLANTS

7.1 Introduction

Butterflies are important group of colourful insects. They have evidential capabilities to recognize the plant source of food (Suzuki *et al*. 1987). Insects have to obtain specific essential food substances, or nutrients, which are needed as nutritional requirements for body material and energy to do all the things attributed to life (House 1969). Phytophagous insects eat to satisfy their requirements for essential nutrients (Friend 1958). Host plant quality is a key determinant of the fecundity of herbivorous insects (Awmack and Leather 2002). Host-plant relationships of lycaenid butterflies show all characteristics as found among 'usual' insect herbivores (Fiedler 1996).

There is accumulating evidence that host plant quality is essential for larva to achieve optimal growth and survival (Scriber 2010). The ultimate consumption of plant material by phytophagous insects is preceded by a complicated series of behavioural interactions between the food plant and the insect (Sutherland 1977). This is especially true for insects such as butterflies that obtain most of the resources needed for adult maintenance and reproduction during the period of larval feeding (Wedell *et al*. 1997). Allocation patterns of nutrients at each developmental stage are not independent of each other and also interact with the nutritional environment (Simpson and Raubenheimer 1993, Boggs 2009). Most herbivorous insects actively regulate their intake of plants' primary metabolites or macronutrients such as proteins, carbohydrates, and lipids etc. by selectively eating foods that contain different blends of these nutrients (Behmer 2009, Nishida 2014). Protein is considered the most limiting nutrient for insect herbivores (Bernays and Chapman 1994, Schoonhoven *et al*. 2005). Carbon-based compounds, such as carbohydrates and lipids, also have a major impact on the performance of herbivorous insects (Awmack and Leather 2002).

Protein is seen as nitrogen (N) which is an essential macronutrient is necessary for structural purposes, enzymes, storage and transport, and for physiological functions (Behmer and Joern 2012, Heimann 2012). Carbohydrate (C) as provider for energy can also be synthesized from fats or amino acids, nevertheless they provide energy and their needed ratios can vary among herbivore species (Simpson and Simpson 1990, Heimann

2012). Proteins provide the amino acids needed to build new tissues, enzymes, and proteins, whereas carbohydrates are commonly used as the key energy source needed to fuel this biosynthesis (Thompson 2000, Thompson *et al*. 2002). Lipids are considered to cover the energetic demands of the developing embryo, while proteins are mainly structural components (Beenakkers *et al*. 1985).

Among the Lepidoptera, there is a general trend for larvae to self-select foods in such a way as to ingest more protein than carbohydrate, or at a minimum maintain a balanced protein/carbohydrate intake (Behmer 2009). While the immature stages of insects require much larger amounts of these components especially amino acids since they are more actively building up structural proteins necessary for normal growth and development (Offor 2010). Feeding behaviour and insect herbivore performance is changing due to chemical and biomechanical properties in the food plants; and food plant quality has an overwhelming effect on the development of insect herbivores (Heimann 2012). Many Lycaenidae feed on flowers and these butterflies may be unable to utilize the tough foliage of the same plants (Ehrlich and Raven 1964). Higher concentrations of proteins and amino acids, and lower levels of alkaloids have been mentioned as possible causes underlying the specialization of lycaenid larvae to feed on rapidly differentiating plant tissue, as flowers or developing fruits (Chew and Robbins 1984). Larvae of lycaenid butterflies are usually specialist feeders of young tender foliage or inflorescences (Fiedler 1996). The mature leaves are generally tougher, higher in fiber content and lower in water and nitrogen content (Slansky and Feeny 1977). Young leaves are nutritionally rich compared to mature leaves, as evidenced by higher soluble protein and total phenol content (Neog *et al*. 2011). Leaf nitrogen content in particular can have a significant influence on the growth of lepidopterous larvae (Slansky and Feeny 1977). A key challenge for the future is to link the considerable knowledge of the effects of host plant quality on the fecundity of individual insect herbivores to the larger-scale processes that determine the populations of herbivorous insects in natural ecosystems (Awmack and Leather 2002).

In order to understand the specific nutritional requirements of any given group of organisms, it is necessary to know the chemical composition of its diets, and be able to alter the constituents precisely in order to ascertain the effects of varying the components of the organisms. In prior point of views, the present investigation was envisaged to thrive

some experiments on larval feeding activities and the nutritional agents of their host plants with several objectives as stated below-

7.1.1 Objectives

The present investigation was visualized to examine

- the larval feeding habit and pattern of lycaenid butterflies;
- the relationship between food consumption and growth in lycaenid larva;
- the necessary nutritional agents in larval host plants; and
- the role of nutritional agents on lycaenid larva.

7.2 Material and methods

On the basis of above mentioned objectives the present exploration has been accepted techniques and procedures to firm up the results. These are described as below-

7.2.1 Studied species

Lycaenids are attractive butterflies among the butterfly groups. During the study period, five lycaenid butterflies have been selected to examine their larval feeding habit and their mode of feeding in laboratory and the experimental sites. These butterflies were *Chilades lajus, C. pandava, Catochrysops strabo, Remelana jangala* and *Rathinda amor*. The host plants were *Citrus aurantifolia*, *Cycas pectinata*, *Cajanus cajan* and *Ixora coccinea*. The lycaenid species were identified following the procedure of Bingham (1907), Eliot (1973), Akand (2012), and Bashar (2014).

7.2.2 Study period

The present investigation has been carried out during the period from January 2015 to December 2017. The findings have been assembled based on laboratory and field examination.

7.2.3 Selected sites

Larval feeding pattern was studied both in field and laboratory condition. The fresh parts of host plants were collected from different study sites. Preparation of the plant materials for chemical analysis and the analysis was finalized in the Enzymology laboratory,

Institute of Food Science and Technology, BCSIR, Dhaka. Fresh young leaves of *Citrus aurantifolia* and *Cycas pectinata* was collected from Butterfly Research Park (BRP) in Bhawal National Park, Gazipur and Botanical Garden of Bangladesh Agriculture University, Mymensing, respectively. Very young bud and leaves of *Cajanus cajan* have been collected from Zoological Garden of Curzon Hall in University of Dhaka. Flowers and leaves of *Ixora coccinea* have been collected from Butterfly Research Park (BRP) in Bhawal National Park, Gazipur. Plant species has been identified according to Ahmed *et al.* (2009). Description of study sites has given in Chapter 3.

7.2.4 Materials for data collection

Paper and pencil has been used for data collection. Measuring scale was used to record larval length. Different digital cameras (describe in Chapter 3) were used to catch photo of the larval activities.

7.2.5 Measurements of larval growth, food consumption and faeces

The larvae were supplied daily with weighed quantity of tender leaves, young buds or flowers of the host plants. The faeces and the leftover of the food was collected and weighed each day. The growing larvae were observed regularly and carefully to note the change instrar and features including length and weight measurements. The amount of food consumption and faeces were weighed (in gram) by using Precision Electronic Balances (Plate 99a). Five replications were maintained to the study of all parameters. Fresh weight measurements were used for the purpose.

Plate 99a. Precision Electronic Balance.

Plate 99b. HPLC amino acid analyzer (Shmadzu, Japan).

The larval feeding potential and larval excreta was observed following the methods of Barua and Slowik (2007). The larval performance in terms of food utilization indices:

Approximate digestibility (AD); Efficiency of conversion of digested food (ECD); and Efficiency of conversion of ingested food (ECI) were calculated following the methods of Waldbauer (1968).

$$\text{AD (Approximate digestibility)} = \frac{(\text{Weight of food consumed}) - (\text{Weight of faeces})}{(\text{Weight of food consumed})} \times 100$$

$$\text{ECD (Efficiency of conversion of digested food)} = \frac{(\text{Weight gain of instar})}{(\text{Weight of food consumed}) - (\text{Weight of faeces})} \times 100$$

$$\text{ECI (Efficiency of conversion of ingested food)} = \frac{(\text{Weight gain of instar})}{(\text{Weight of food consumed})} \times 100$$

7.2.6 Collection of the plant materials

The fresh plant materials were collected from experimental sites. Samples were brought to the laboratory zipped them with poly bags.

7.2.7 Procedures of sample preparation and their chemical analysis

Collected samples were washed by mineral water in laboratory. After proper washing, the samples were allowed to dry by air drier. The dried samples were grinded with mechanical grinder and made into powder. This powder is now ready for further analysis to find out different contents.

7.2.7.1 Determination of moisture content

Moisture content of samples was determined by drying them at 105^{o}C in a drying oven till a constant weight was attained. A known quantity of sample was taken in crucible (the weight of the crucible was noted first) and it was kept for six hours at 105^{o}C in a drying oven. After drying for six hours, the sample was kept in desiccators for an hour and the crucible with sample was weighted. Drying and desiccating processes were continuing until a constant weight obtained. Moisture content was determined by following the method of AOAC (2000). Moisture content was calculated by the following formula

$$\%\ \text{Moisture} = \frac{\text{Loss of weight}}{\text{Weight of samples}} \times 100$$

7.2.7.2 Determination of ash content

The empty crucible was taken and dried in an oven at 105^{o}C for an hour, removed and kept it in a desiccators and weighed up to constant weight. About 1 g of particular sample was taken in the weighted empty crucible. 1 drop of Nitric acid was added and then the

sample in the crucible was charred on a low flame and the crucible was then kept in muffle furnace and temperature was allowed to rise to 650^{o}C and kept it constant for five hours. Then it was removed, cooled and kept in a desiccators and weight of crucible was taken. Ash content was determined by following the method of AOAC (2000). Ash content was calculated by the following formula

$$\% \text{ Ash } = \frac{\text{Weight of residue}}{\text{Weight of samples}} \times 100$$

7.2.7.3 Determination of protein content

Protein content of different samples was determined by following the method of Micro-Kjeldahl (Wong 1923). For this, several reagents and equipment are necessary. These are- Solid Sodium Sulphate; Concentrated sulphuric acid; Mercuric Oxide; 0.02 N Hydrochloric acid; Concentrated sodium hydroxide solution (5N Approximately); 2% Boric acid; Few quartz chips; and Nitrogen determination apparatus according to Paranas-Wagner, made of JENA glass-all connections with inter changeable ground joints.

The principle of this procedure involves digestion of the sample with concentrated sulphuric acid (H_2SO_4) and digestion mixture, which causes oxidation and destruction of protein and conversion of the organic nitrogen to ammonia that remains in the acid mixture as ammonium bi sulphate. The amount of ammonia nitrogen is determined by making the digest alkaline followed by distillation of the liberate ammonia into standard acid solution and estimated titrimetrically. Cleaned and dried 100 ml Kjeldahl flasks were taken along with 0.5g sample in it with a piece of ash less filter paper. About 10 ml of concentrated H_2SO_4 and 1:1 gm digestion mixture (sodium sulphate and mercuric oxide) were added, then the digestion chamber was heated (6 hours) until the content become clean. After completing the digestion, the flask was cooled and digested mixture was transferred in a 100 ml volumetric flask and diluted up to mark with distilled water. Ten (10) ml of that solution was transferred in a micro kjeldahl distillation apparatus after adding 5 ml of 50% NaOH and 2.5 ml of 15% $Na_2S_2O_3$. The solution was distilled with steam for 10 minutes. The distillate was collected in excess of 2% boric acid solutions with indicator and was Titrated by 0.02 N HCl. At the same time, a similar blank digestion was carried out without the sample. The protein was extracted by Kjeldahl method. The percentage of nitrogen in the sample was calculated by the following equation

$$\% \text{ Nitrogen} = \frac{(S - B) \times N \times 14 \times 10}{W} \times 100$$

Where, S = Titration reading for sample; B = Titration reading for blank; N = Strength of HCl solution; 14 = Factor; 10 = Aliquot used; W = Weight of sample.

The total nitrogen content was then converted into percentage of crude protein by multiplying with the factor 6.25% of crude protein = N × 6.25.

7.2.7.4 Determination of fat content

The principle of this method lied in mixing the sample with a solvent n-Hexane which was then removed by distillation, and the residue was dried and weighted. The extraction procedure was carried out in Sox let apparatus. The fresh sample (5 gm) was weighted accurately. It was then taken in extraction thimble. The thimble was then placed in an n-Hexane for about eight hours. Fat content of samples was determined following the methods by Mehlenbacher (1960). Fat content was calculated by the following formula

$$\% \text{ of fat content } = \frac{W}{W_1} \times 100$$

Where, W= Weight of oil; W_1 = Weight of sample taken

7.2.7.5 Determination of carbohydrates content

The content of the available carbohydrate is determined by difference, i.e. by subtracting from 100, the sum of the values (per 100 gms) for moisture, ash, protein and fat. The total percentage carbohydrate content was determined by the difference method as described by Edeogu *et al.* (2007). Carbohydrate content was calculated by the following formula

$$\text{Carbohydrate } = 100 - (\text{Moisture } + \text{Ash } + \text{Protein } + \text{Fat})$$

7.2.7.6 Determination of energy content

The energy content of the sample was determined by calculating the amount of protein, fat and carbohydrate. The formula is

$$\text{Energy } = (\text{Protein } \times 4.1) + (\text{Fat } \times 9.3) + (\text{Carbohydrate } \times 4.1)$$

7.2.7.7 Sample preparation for amino acid analysis

For analysis of amino acid, crushed fat free sample was taken and a fine paste was made by mortar and pestle with 6N HCl. Then filtered in 250 ml round bottom flask and placed in a heating mantle at 110ºC for 22 hours for hydrolysis of protein. After hydrolysis, the

solution was kept in an evaporation dish to evaporate HCL on water bath. It was then filtered 25 ml volumetric flask through whatman No. 1 filter paper with 0.1N HCl, known as stock solution. Again, the stock solution filtered through 0.45 µm syringe filter. Then the stock solution and standard solution were run through an amino acid analyzer. The analyzer showed the standard curve for standard solution and another curve for stock (sample) solution. By comparing the two curves, the amount of amino acids were calculated. For analysis of amino acid standard procedure adopted from the method of AOAC (2000) using amino acid analyser (Anonymous 1993).

7.2.8 Analysis of data

The relation between food consumption and growth of larvae was analyzed by using Pearson's rank correlation equation. Average and standard deviation was calculated. All these statistical analyses have been performed by SPSS for windows (version 16). Microsoft Office Excel 2010 is used to draw graph, table and figure.

7.3 Results

Herbivores can overcome some of the variation in food protein/carbohydrate content by practicing selective feeding, either by eating a range of different plants, or by feeding on different vegetative tissues within a plant (Chambers *et al*. 1996, Singer *et al*. 2002, Villalba *et al*. 2002, Wright *et al*. 2003, Villalba and Provenza 2005, Clements *et al*. 2009, Felton *et al*. 2009). Butterflies larvae are choosy in selecting their food plant (Bashar 2014). They are extraordinarily specific in their feeding habits and usually will feed only on a small number of closely related plant species (Bashar 2015). More than two thirds of the lycaenid species are restricted to one plant family or genus (Fiedler 1996). If a suitable food plant is not available then the larvae will starve to death rather than eating something else (Bashar 2014). Butterfly larvae consume plant leaves and spend practically all of their time in searching of food (Bashar 2015). Flower-feeding larvae have been reported for many families of Lepidoptera (Morais *et al*. 2009, Chung *et al*. 2011), including Lycaenidae (Chew and Robbins 1984, Fiedler 1996). Phytophagous insects feed to generate energy required for movement, metabolism, reproduction and performance of physical activities that sustain development, growth and life (Bernays and Chapman 1994). Among the Lepidoptera, there is a general trend for larvae to self-select foods in such a way as to ingest more protein than carbohydrate, or at a minimum

maintain a balanced protein/carbohydrate intake (Behmer 2009). The present study has engrossed on getting the vital evidence of food habits and feeding activities of lycaenid larva in relation to the nutritional agents of their interacting host plants. Keeping this in front this chapter has been described in several sub headings-

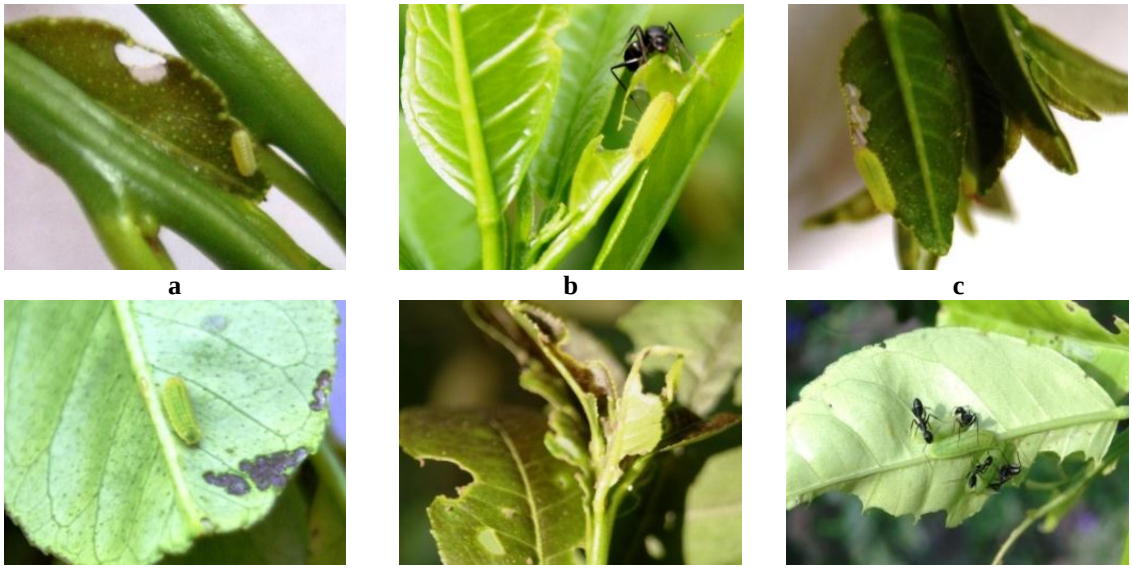
7.3.1 Feeding activities of lycaenid larvae

Feeding is an active, dynamic process with numerous feedback interactions and consequences throughout an insect's life, affecting and being affected by survival, growth, reproduction and movement (Slansky 1982). Butterfly larvae feed on the leaves of flowering plants and trees (Bashar 2015). They are very characteristic in feeding and food habits (Anthes *et al.* 2003). A single larva may consume an entire leaf before moving on to the next, but more often only a part of the leaf is eaten (Bashar 2014). The way in which a larva tackles a leaf is often characteristic of the species; some make holes in the leaf, whilst the others attack the leaf margin (Bashar 2015). During the present investigation, larval food habit and feeding pattern of five lycaenid species (viz. *Chilades lajus, C. pandava, Catochrysops strabo, Remelana jangala* and *Rathinda amor*) has been thoroughly observed and recorded data on their food consumption and growth rate. Among selected butterflies, larvae of *Chilades lajus* and *C. pandava* strictly fed on young tender leaves of their host plants. It was found that very young leaves, young bud and pods were eaten by the larvae of *Catochrysops strabo*. Larvae of *Remelana jangala* were observed to ingest inflorescences of host plant while the larvae of *Rathinda amor* were also found to consume flowers and sometimes young tender leaves of its host plant. The larvae of examined lycaenid species are described below marking their feeding activities, and food consumption along with their growth and development.

7.3.1.1 Larval food habit and feeding pattern of *Chilades lajus*

The larva of *Chilades lajus* feeds on young leaves and leaf phloem of its host plant *Citrus aurantifolia* almost exclusively in all instars. The first instar larva nibbles away the polar portion of the egg shell to emerge by feeding the egg shell remnant. The newly hatched larva finds its way to adjacent leaves. Then it started eating the leaf phloem and generally it occurs from the leaf margin. It was examined that all four instar larvae feed young tender and succulent leaves. It was noticed that larvae primarily eat leaf phloem, and then they entirely feed the leaves. Plate 100 specifies feeding condition of different larval

instars of Lime Blue butterfly. By this experiment, it was found that the immature stages of *Chilades lajus* are very much specific to tender and succulent leaves of host plants.



a **b** **c**

d **e** **f**

Plate 100. Larval feeding pattern of *Chilades lajus*: **a**. first instar larva; **b**. second instar larva; **c**. third instar larva; **d**. fourth instar larva; **e**. and **f**. eaten and damaged leaves.

7.3.1.2 Larval food consumption and growth of *Chilades lajus* on its host plant

Over the entire period of its growth, larva consumed on average over 0.18 g of leaf material increasing consumption in the last two instars. The data on the amount of food consumed by each of the four instars and the corresponding data on weight gained by different instars are given in Table 32.

Table 32. Larval food consumption, growth and food utilization efficiencies of *Chilades lajus.*

Larval instar	Weight of food consumption (mg)	Weight of faeces (mg)	Weight gained by larva (mg)	AD (%)	ECD (%)	ECI (%)
First	13.65±1.16	0.52±0.06	0.48±0.07	96.19	3.66	3.52
Second	25.12±6.19	2.61±1.67	3.15±0.83	89.61	13.99	12.54
Third	47.14±7.13	8.39±1.56	7.05±3.21	82.20	18.19	14.96
Fourth	92.83±8.17	27.14±3.06	32.15±3.12	70.76	48.94	34.63

Of the total amount of food consumed, the percentage shares of first, second, third and fourth instars larvae were 7.64, 14.05, 26.37 and 51.94%, respectively and the proportions of weight gained by the successive instars were 1.12, 7.35, 16.46 and 75.07%. Thus, there was over 78% of the total food consumption in the third and fourth instars together and over 91% of total weight gained in the third and fourth instars together. Data on AD, ECD, and ECI are also charted in Table 32. The estimated values of AD ranged between 70.76-96.19%, and the values decreased as the instars progressed. The values of ECD and ECI increased progressively from the first instar to the last instar. The values of ECD

varied from 3.66-48.94% and those of ECI from 3.52-34.63%. Thus, there was an inverse relationship was found between the values of AD and those of ECD and ECI. Plotting the weight gained from the food consumed resulted in a direct relationship between food consumption and growth across the four instars could be seen (Fig. 45).

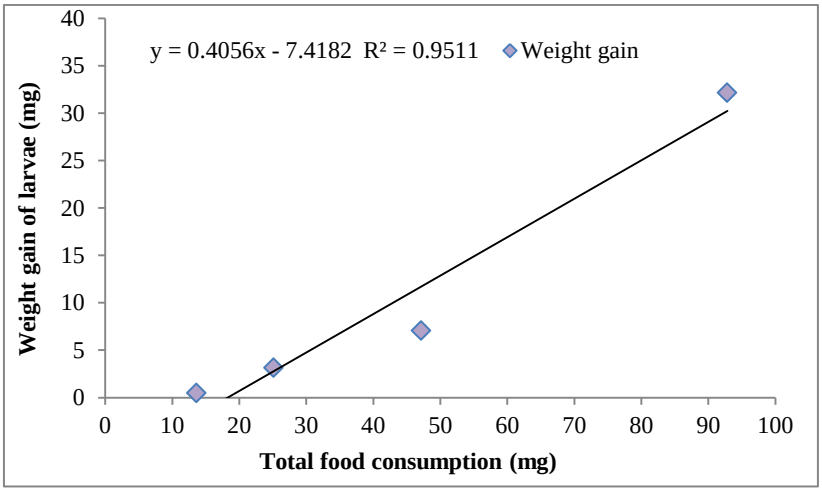


Fig. 45. Relationship between food consumption and growth in larva of *Chilades lajus*.

The present study provides information on the larval performance in terms of food consumption, growth and utilization of the lime blue butterfly *Chilades lajus*.

7.3.1.3 Larval food habit and feeding pattern of *Chilades pandava*

The larva of *Chilades pandava* feeds on phloem of succulent leaves of its host plant *Cycas pectinata*. The first instar larva nibbles away the polar portion of the egg shell to emerge but not feeds the egg shell remnant. The newly hatched larva grazes on the surface of young leaves and feeds by nibbling away a layer of the leaf lamina. Then it started eating the leaf phloem and generally it occurs from the leaf margin.

a **b** **c** **d**

Plate 101. Larval feeding pattern of *Chilades pandava*: **a**. third instar larva; **b**. fourth instar larva; **c**. and **d**. eaten and damaged leaves.

All four larval instars of this species were found to bore and eat the leaves causing the severe damage of the plants. The feeding pattern of different larval instars of *Chilades*

pandava as well as eaten and damaged leaves is presented in Plate 101. It was spotted that the immature stages of *Chilades pandava* are specific to succulent leaves of host plants.

7.3.1.4 Larval food consumption and growth of *Chilades pandava* on its host plant

Larvae consumed on average over 0.18g of leaf material during the entire period of development. Consumption rate was increased in the last two larval instars. Table 33 represents food consumption and the corresponding data on weight gained by each of the four instars.

Table 33. Larval food consumption, growth and food utilization efficiencies of *Chilades pandava*.

Larval instar	Weight of food consumption (mg)	Weight of faeces (mg)	Weight gained by larva (mg)	AD (%)	ECD (%)	ECI (%)
First	10.15±1.25	0.48±0.15	0.39±0.05	95.27	4.03	3.84
Second	27.86±5.35	4.55±1.45	3.82±0.68	83.67	16.39	13.71
Third	48.25±7.75	10.36±3.24	10.44±3.12	78.53	27.55	21.64
Fourth	99.34±11.65	29.16±5.86	38.95±5.35	70.65	55.50	39.21

The percentage of food consumed by successive larval instars were 5.47, 15.01, 25.99 and 53.53% and the proportions of weight gained by the first, second, third and fourth instars larvae were 1.12, 7.35, 16.46 and 75.07%, respectively. Thus, the third and fourth instars together feed 79.52% of the total consumed food and succeed 92.14% of total weight gained in together. Food utilization indices (viz. AD, ECD and ECI) data is also plotted in Table 33. The estimated values of AD ranged between 70.65-95.27%, and the values as the instars progressed. The values of ECD and ECI increased progressively from the first instar to the last instar. The values of ECD varied from 4.03-55.50% and those of ECI varied from 3.84-39.21%. It was noted that the values of AD was inversely related to those of ECD and ECI.

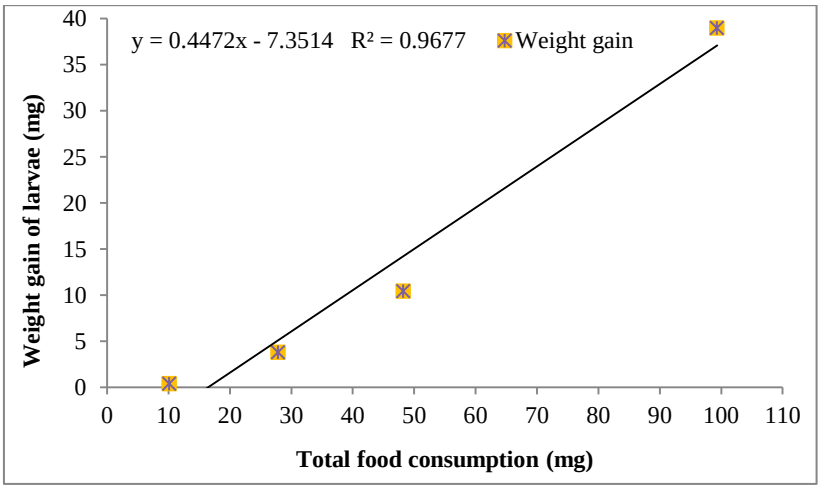


Fig. 46. Relationship between food consumption and growth in larva of *Chilades pandava*.

There was a direct relationship between food consumption and growth across the four larval instars of *Chilades pandava* (Fig. 46). From this investigation, the larval performance in terms of food consumption, growth and utilization of *Chilades pandava* on host plant *Cycas pectinata* was reported.

7.3.1.5 Larval food habit and feeding pattern of *Catochrysops strabo*

The larva of *Catochrysops strabo* feeds on young leaves and bud of its host plant *Cajanus cajan*. The first instar larva nibbles away the polar portion of the egg shell to emerge by feeding the egg shell remnant. The newly hatched larva finds its way to adjacent flower bud or very young leaf. Then it bore the flower bud or leaf eating the leaf phloem.

a **b** **c** **d**

Plate 102. Larval feeding pattern of *Catochrysops strabo*: **a**. first instar larva; **b**. second instar larva; **c**. third instar larva; and **d**. fourth instar larva.

It was examined that all four instar larvae fed young bud and pods as well as young tender leaves. It was observed that larvae primarily eat leaf phloem, and then they entirely feed the young leaves. They also bore young bud and pods, and eat entire flower and fruits. The feeding condition of four larval instars is presented in Plate 102. The present investigation identifies that the immature stages of *Catochrysops strabo* have specific feeding relation to young leaves, buds and pods of the host plant *Cajanus cajan*.

7.3.1.6 Larval food consumption and growth of *Catochrysops strabo* on its host plant

With increasing consumption in the last two instars, larva consumed on average over 0.23g of plant materials over the entire period of its growth. Food consumption and the corresponding data on weight gained by all the larval instars are charted in Table 34.

Table 34. Larval food consumption, growth and food utilization efficiencies of *Catochrysops strabo*.

Larval instar	Weight of food consumption (mg)	Weight of faeces (mg)	Weight gained by larva (mg)	AD (%)	ECD (%)	ECI (%)
First	15.42±1.17	1.72±0.51	0.55±0.09	88.85	4.01	3.57
Second	35.25±5.73	7.35±1.28	4.75±0.65	79.15	17.02	13.48
Third	65.58±9.13	16.42±3.17	10.25±2.12	74.96	20.85	15.63
Fourth	122.75±12.15	38.25±5.72	47.55±13.06	68.84	56.27	38.74

First, second, third and fourth instar larvae were consumed 6.45, 14.75, 27.44, and 51.36% of the total amount of food consumption, respectively, as well as the successive

instars gained 0.87, 7.53, 16.24, and 75.36% of weight during their growth. Hence, the third and fourth instar larvae together gained over 91% of total weight through the total food consumption of over 78% in the third and fourth instars together. The calculated data on AD, ECD, and ECI are also tabulated (Table 34). The AD values decreased from instar to instar from a highest 88.85% in first instar to lowest 68.84% in the last instar. On the other hand, ECD and ECI values increased gradually from the first instar to the last instar. The values of ECD ranged from 4.01-56.27% and those of ECI from 3.57-38.74%. Therefore an inverse relationship was observed between the AD values and those of ECD and ECI.

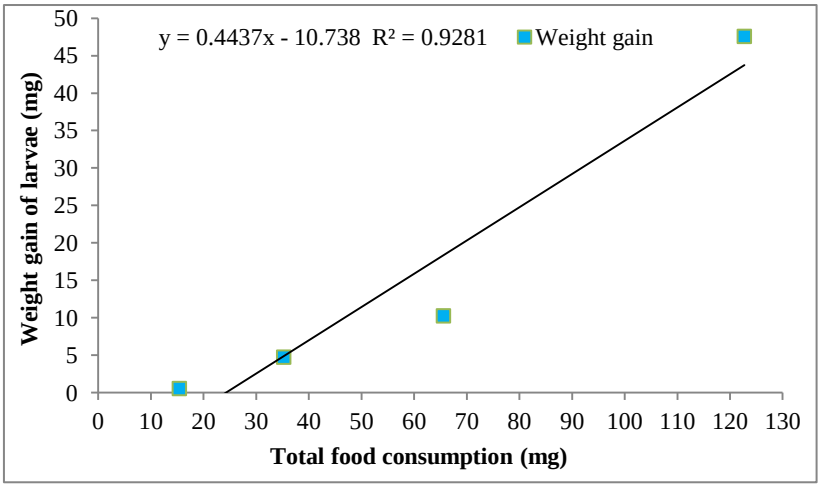


Fig. 47. Relationship between food consumption and growth in larva of *Catochrysops strabo*.

It was found that there was a direct relationship between food consumption and growth across the four larval instars (Fig. 47). Lycaenid butterfly, *Catochrysops strabo* demonstrates larval performance in terms of food consumption, growth and utilization in this experiment.

7.3.1.7 Larval food habit and feeding pattern of *Remelana jangala*

The larva of *Remelana jangala* feeds on flower buds of its host plant *Ixora coccinea* almost exclusively in all instars. The first instar larva nibbles away the polar portion of the egg shell to emerge but does not eat the egg shell remnant. The newly hatched larva finds its way to adjacent flower buds. Then it bores a hole of the peduncle or bud, feeding them to reach flower parts within.

It was found that all five instar larvae feed young buds or unopened flowers. When the flowers are being in full blossom, the larvae do not feed them. It was observed that some

larva made hole at the junction between the distal end of corolla and the base of petals. The petals split from the corolla through the continuous feeding of larvae.

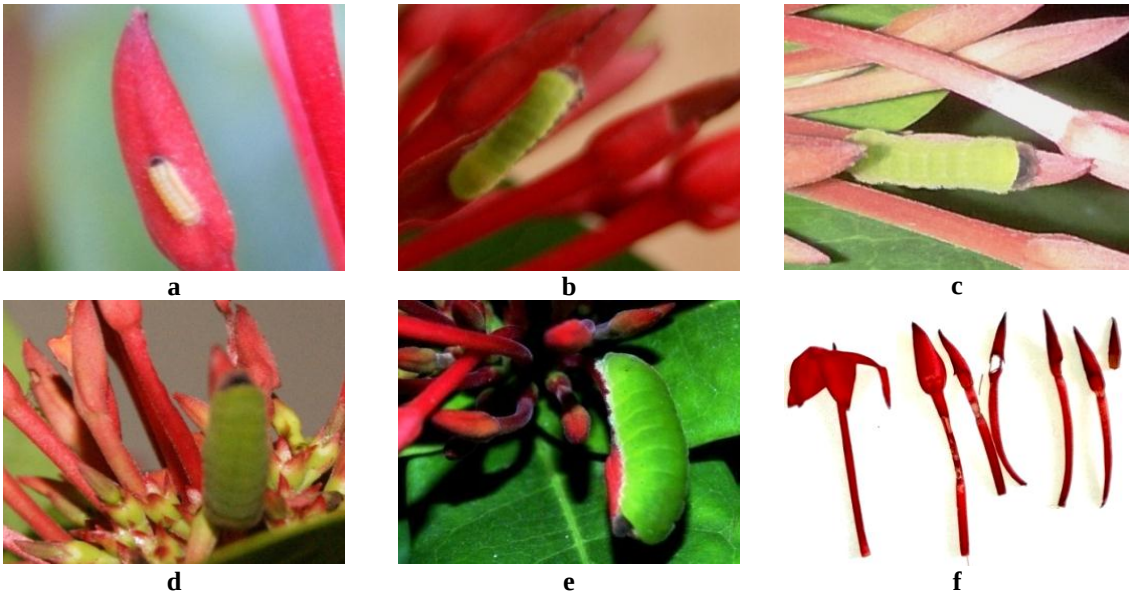


Plate 103. Larval feeding pattern of *Remelana jangala*: **a**. first instar larva; **b**. second instar larva; **c**. third instar larva; **d**. fourth instar larva; **e**. fifth instar larva; and **f**. eaten and damaged flower buds.

Plate 103 evidences the feeding condition of different larval instars of Chocolate Royal butterfly. By this experiment, it is assumed that the immature stages of *Remelana jangala* are very much specific to phenological stage (flowering stage) of host plants.

7.3.1.8 Larval food consumption and growth of *Remelana jangala* on its host plant

During the entire period of growth, larvae consumed on average over 0.37g of inflorescences of host plant with increasing consumption in the last two instars. Food consumption data by each of five larval instars with corresponding data on weight gained are given in Table 35.

Table 35. Larval food consumption, growth and food utilization efficiencies of *Remelana jangala.*

Larval instar	Weight of food consumption (mg)	Weight of faeces (mg)	Weight gained by larva (mg)	AD (%)	ECD (%)	ECI (%)
First	15.25±1.21	0.85±0.08	0.57±0.05	94.43	3.96	3.74
Second	38.45±6.12	7.35±1.28	4.85±0.72	80.88	15.59	12.61
Third	73.85±9.45	18.25±2.98	13.45±2.16	75.28	24.19	18.21
Fourth	105.75±10.46	30.25±4.08	47.88±3.15	71.39	63.42	45.28
Fifth	146.25±14.35	47.65±5.22	88.15±12.05	67.42	89.40	60.27

The five larval instars of *Remelana jangala* consumed consecutively 4.02, 10.13, 19.46, 27.86, and 38.53% of the total food consumption. Therefore, the instars gained 0.37, 3.13, 8.68, 30.91, and 56.91% of weight by the first, second, third, fourth and fifth larval instars respectively. Thus, the last two instars together consumed 66.39% of the total food

consumption and gained 87.82% of total weight in the fourth and fifth instars together. The values of AD, ECD, and ECI are also arranged in Table 35. The calculated values of AD decreased with successive instars, marking maximum 94.43% in first instar and minimum 67.42% in the final instar. The values of ECD and ECI increased progressively from the first instar to the last instar. ECD values extended from 3.96-89.40% and those of ECI from 3.74-60.27%. Hence, the values of AD related to those of ECD and ECI inversely.

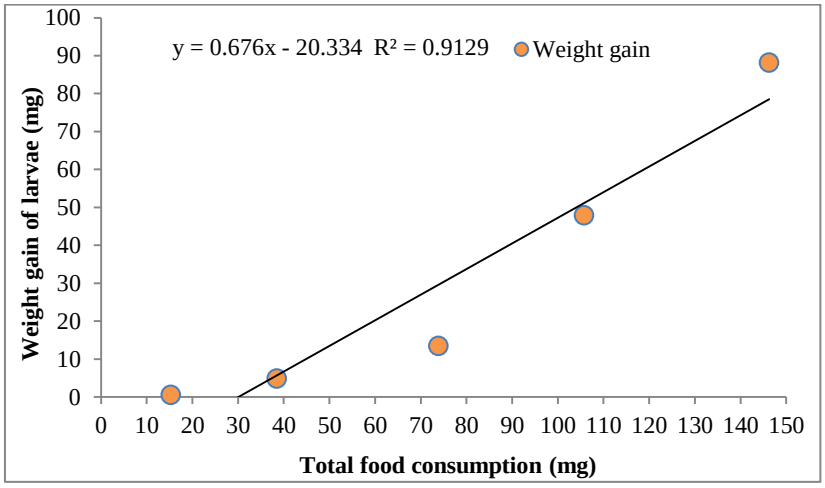


Fig. 48. Relationship between food consumption and growth in larva of *Remelana jangala*.

Food consumption and growth across the five instars was made a direct relationship when plotted the weight gained from the food consumption (Fig. 48). This experiment serves evidence on the larval performance (viz. food consumption, growth and utilization) of the chocolate royal butterfly *Remelana jangala*.

7.3.1.9 Larval food habit and feeding pattern of *Rathinda amor*

The larva of *Rathinda amor* feeds on young tender leaves and flower buds of its host plant *Ixora coccinea* almost exclusively in all instars.

a **b** **c** **d**

Plate 104. Larval feeding pattern of *Rathinda amor*: **a**. second instar larva eating sepals; **b**. second instar larva eating leaves; **c**. third instar larva eating leaves; and **d**. fourth instar larva eating petals.

The first instar larva nibbles away the polar portion of the egg shell to emerge and eat the egg shell remnant. The newly hatched larva finds its way to adjacent flower buds, feeding

on the peduncle or bud where it will bore a hole to reach flower parts within. The larvae also consumed young tender leaves of host plants as their food. During present investigation, it was observed that all larval instars fed young buds or unopened flowers. Larvae were also seen to eat young tender leaves and feeding started from leaf and or leaf margin. Some larva made hole at the junction between the distal end of corolla and the base of petals. The petals split from the corolla through the continuous feeding of larvae (Plate 104).

7.3.1.10 Larval food consumption and growth of *Rathinda amor* on its host plant

With increasing consumption in the last two instars larva consumed on average over 0.20g of plant materials over the entire period of its growth. Table 36 charted the data on the amount of food consumed by each of the four instars and the corresponding data on weight gained by different instars.

Table 36. Larval food consumption, growth and food utilization efficiencies of *Rathinda amor*.

Larval instar	Weight of food consumption (mg)	Weight of faeces (mg)	Weight gained by larva (mg)	AD (%)	ECD (%)	ECI (%)
First	11.55±1.73	0.88±0.46	0.38±0.05	92.38	3.56	3.29
Second	33.25±6.45	5.75±1.74	3.65±0.75	82.71	13.27	10.98
Third	57.85±9.74	12.24±2.62	12.74±1.36	78.84	27.93	22.02
Fourth	102.15±12.13	31.45±4.18	55.38±6.24	69.21	78.33	54.21

The consecutive larval instars share 5.64, 16.24, 28.25, and 49.87% of the total amount of food consumption as well as gained 0.53, 5.06, 17.66, and 76.75% of weight by first, second, third and fourth instars larvae, respectively. Hence, the third and fourth instars together fed 78.12% of the total food consumption while they gained 94.41% of total weight together. The calculated AD, ECD, and ECI values are also tabulated (Table 36).

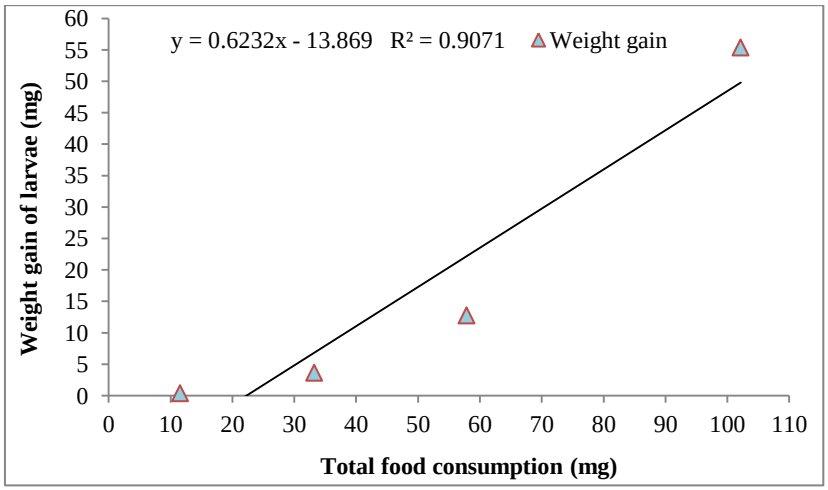


Fig. 49. Relationship between food consumption and growth in larva of *Rathinda amor*.

With succeeding instars the estimated values of AD was decreased. The highest AD value was noted 92.38% in first instar larva and lowest in 69.21% in fourth instar larva. The ECD and ECI values increased gradually from the first instar to the final instar. The values of ECD ranged from 3.56-78.33% and those of ECI from 3.29-54.21%. Thus, an inverse relationship was noticed between the values of AD and those of ECD and ECI. A direct relationship between food consumption and growth across the four instars was marked while plotting the weight gained from the consumed food (Fig. 49). So, the present exploration delivers clues on the larval performance such as food consumption, growth and utilization of the monkey puzzle butterfly *Rathinda amor.*

7.3.1.11 Larval performance of examined lycaenid butterflies on host plant

Larval performance indices (viz. AD, ECD, and ECI) of five examined lycaenid *Chilades lajus, C. pandava, Catochrysops strabo, Remelana jangala* and *Rathinda amor* have been reflected thoroughly in the above exploration. The tendency of greater consumption by the last two instars has been reported in lepidopteran larvae in general (Waldbauer 1968, Mathavan and Pandian 1975, Scriber and Slansky 1981, Palanichamy *et al*. 1982, Selvasundaram 1992, Gosh and Gonchaudhuri 1996). It also compensates the energy expenditure of non-feeding pupal stage (Pandian 1973). Food consumption rate depends on the conversion efficiency of ingested food to biomass (ECI), the rate increasing as the conversion efficiency decreases or vice versa (Slansky and Scriber 1985). Higher growth rates occur with penultimate than with final instars (Scriber and Feeny 1979). The values of AD that were obtained in this study are comparable with the range of values, 19－81% given for 60 species of lepidopteran larvae by Pandian and Marian (1986). The average AD percentage is 84.69, 82.03, 77.95, 77.88, and 83.03%, respectively and this high AD substantiate the statement of Slansky and Scriber (1985) that foliage chewers often attain high AD values. Such high AD values also are expected when food item is rich in nitrogen (and also water) (Pandian and Marian 1986). Similar results were repeated with *Pieris brassicae* (*Yadava et al*. 1979), *Euploea core* (VenkataRamana *et al*. 2001), *Ariadne merione merione* (Atluri *et al*. 2010), *Rathinda amor* (Rayalu *et al*. 2012), *Zizeeria karsandra* (Harinath *et al*. 2015b), and *Chilades lajus* (Harinath *et al*. 2016).

The values of ECD increase from early to late instars (Slansky and Scriber 1985). Such trend was broadly apparent with the ECD. The ECDs obtained are low compared to the ADs and such low values are not unusual (Waldbauer 1968). According to Waldbauer (1964) the ECD varies with the nutritional value of food and the level of intake, but is not

dependent upon digestibility. This is indicative of low efficiency of conversion of digested food to body tissues. The pattern of ECI values followed closely the pattern of ECD. The values (3.52-34.63, 3.84-39.21, 3.57-38.74, 3.74-60.27 and 3.29-54.21%, respectively) obtained are comparable with the range of values (9-34%) expected for tree foliage chewers (Slansky and Scriber 1985). The values of ECI may increase, decrease or show little changes depending on the extent to which the changes in AD and ECD compensate each other. They showed a continuous increase from first instar to final instar. The pattern of ECI followed that of AD as suggested by Waldbauer (1968). The values of ECD and ECI, particularly those of the last two instars, are also relatively high. Hence, this indicates tissue growth efficiency and ecological growth efficiency respectively, which enabled lycaenid butterflies to thrive successfully in an ecosystem.

7.3.2 The nutritional agents in larval host plants

Plant diet has strong impacts on the fitness of insect herbivores (Bede *et al*. 2007). Insects regulate the intake of nutrients and that multiple nutrients can be regulated simultaneously (Behmer 2009). Protein and carbohydrates are the most strongly regulated macronutrients for insect herbivores (Behmer *et al*. 2003). According to Behmer (2009) insect herbivores prioritize macronutrient regulation over micronutrient regulation. Schoonhoven *et al*. (1998) illustrated a schematic presentation of plant metabolites where micronutrients derive from macronutrients of plants (Fig. 50).

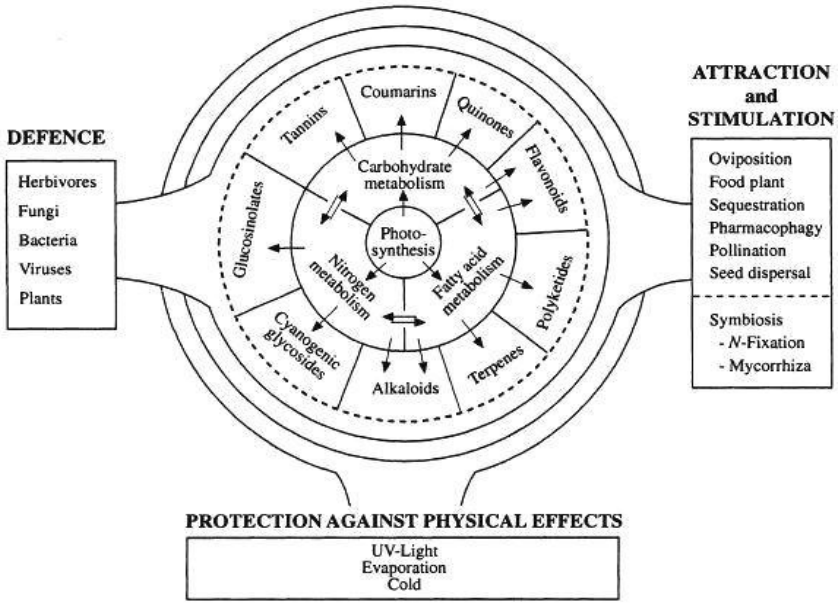


Fig. 50. Schematic presentation of plant metabolites: micronutrients derive from macronutrients of plants (source: Schoonhoven *et al*.1998).

While most of insects rely on plants' primary metabolites or macronutrients (e.g. carbohydrates, lipids, and proteins), plants have evolved a high diversity of secondary metabolites of micronutrients (e.g. alkaloids, terpenoids, and phenolics) to cope with heavy herbivory (Nishida 2014). Lepidopteran larvae can regulate protein/carbohydrate intake by feeding on different parts within a plant, or from different plants (Singer and Stireman 2001). The chemical composition of plants varies among species, as well as in space and time, and the nutritional requirements of insects vary between species and with developmental stage and environmental conditions (Schoonhoven *et al*. 1998). In the present investigation, larval food materials of host plants have been analyzed in the laboratory. The macronutrients were detected from feeding parts of host plants. Proximate composition of macronutrients has been arranged in Table 37.

Table 37. Proximate composition of macronutrients in the host plant.

Examined larval host plant	Consumed plant's part	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Energy (kcal.)*
Citrus aurantifolia	Leaves	8.30	8.33	26.53	0.20	56.64	285.20
Cycas pectinata	Leaves	9.10	4.54	24.06	0.24	62.06	278.89
Cajanus cajan	Buds and leaves	10.10	4.55	18.53	0.18	66.64	272.02
Ixora coccinea	Flowers	11.20	3.31	7.75	0.79	76.95	354.60
	Leaves	7.80	6.81	13.44	0.19	71.76	288.52

*g/100g

Though protein and carbohydrates are important nutrients driving the growth of herbivores, their content in plants is highly variable (Le Gall and Behmer 2014). The amounts of protein, certain amino acids, fatty acids, and sugars in insects depend on the composition of the food eaten (Kasting and McGinnis 1959). From the analyzed data, maximum amount of protein (26.53%) was detected from leaves of *Citrus aurantifolia*, the host plant of lycaenid, *Chilades lajus*. On the other hand, minimum amount (7.75%) was discovered from flowers of *Ixora coccinea*, the host plant of both *Remelana jangala* and *Rathinda amor*. The highest amount (76.95%) of carbohydrate was found in flowers of *Ixora coccinea* while the lowest amount (56.64%) was detected in leaves of *Citrus aurantifolia.* According to Simpson and Raubenheimer (2012) insects regulate intake in response not only to the total amount of protein and carbohydrate in food (nutrient concentration) but also with respect to the ratio of the two nutrients.

Proteins are biological macromolecules participating in the large majority of processes which govern organisms (Gaci and Balev 2009). Lepidopteran larvae feed high-protein diets are able to tolerate higher levels of alkaloids than those feed low-protein plus high-alkaloid diets. These effects are apparent in both growth rates and larval survivorship

(Bentley and Johnson 1991). Proteins have complex and irregular structures built up by amino acids (Gaci and Balev 2009). The dietary requirement for the majority of the amino acids constrains the types of diets insects can rely on for growth and reproduction (O'Brien *et al*. 2005). During laboratory test, fourteen amino acids (viz. Aspartic acid, Threonine, Serine, Glutamic acid, Glycine, Alanine, Valine, Methionine, Isoleucine, Leucine, Tyrosine, Histidine, Lysine and Arginine) were extracted from consumed materials of host plants. The detected amino acids with ratio have also been plotted (Table 38). Data obtained from HPLC amino acid analyzer (Plate 99b) indicating peaks of respective amino acid.

Table 38. Amino acid determination in feeding parts of examined host plants.

Host plant / ***Amino acid**	***Citrus aurantifolia***	***Cycas pectinata***	***Cajanus cajan***	***Ixora coccinea***	
	Leaves	Leaves	Buds and leaves	Leaves	Flowers
Aspartic acid	1.76	1.50	1.16	0.84	0.48
Threonine	0.81	0.87	0.64	0.42	0.29
Serine	1.18	0.98	0.78	0.49	0.25
Glutamic acid	1.65	1.37	0.96	0.68	0.46
Glycine	1.82	1.69	1.08	0.79	0.42
Alanine	0.98	1.44	0.95	0.52	0.27
Valine	1.23	0.98	0.83	0.77	0.36
Methionine	0.76	0.52	0.46	0.56	0.21
Isoleucine	0.87	0.79	0.51	0.44	0.23
Leucine	0.35	0.29	0.30	0.26	0.20
Tyrosine	0.67	0.57	0.44	0.28	0.32
Histidine	0.33	0.36	0.28	0.43	0.16
Lysine	1.28	1.35	1.14	0.65	0.52
Arginine	2.45	2.16	1.85	1.13	0.70

* Amino acid presents percentage (%) value

From the laboratory determination of amino acids, Arginine was detected highest amount in all the supplied plant samples. On the other hand, lowest amount of detected amino acids has been varied in different plant samples. Histidine is the lowest amount (0.33, 0.28 and 0.16%) in *Citrus aurantifolia*, *Cajanus cajan* and *Ixora coccinea* flowers, respectively. And leucine is the lowest (0.29 and 0.26%) in *Cycas pectinata* and *Ixora coccinea* leaves, respectively. Yeoh *et al*. (1992) stated that the quality of plant protein is highly variable among different species. Leucine, iso-leucine, histidine, arginine, lysine, threonine, and methionine are the essential requirements in the diet of most insects (Wigglesworth 1965). Methionine has often been noted as limiting factor in many proteins of different origin (Hall *et al*. 1975). In the present experiment, the amount of Methionine has been determined as 0.76, 0.52, 0.46, 0.56 and 0.21% from consumed materials of *Citrus aurantifolia*, *Cycas pectinata*, *Cajanus cajan*, leaves and flowers of *Ixora coccinea*, respectively.

Literature consultation reveals that insect can require micronutrients of plants for their fitness and gather them independently (Boppre 1986). Flavonoid is one of important micronutrient which sequestrated by butterfly from its host plant. Data obtained from reviewed literature reveals that flavonoid is good source in leaves of *Citrus aurantifolia* (Kawaii *et al*. 2000, Loizzo *et al*. 2012, Lawal *et al*. 2014), leaves and buds of *Cajanus cajan* (Oke 2014, Aja *et al*. 2015), as well as leaves and flowers of *Ixora coccinea* (Haridass *et al*. 2012, Nithiyasoundari *et al*. 2015). The larvae of butterflies belonging to the families Satyridae, Papliionidae and Lycaenidae frequently sequestrate dietary flavonoids from their host plants in the larval stages and store them in their wings (Wilson 1987, Geuder *et al.* 1997). Because flavonoid pigments strongly absorb ultraviolet (UV)-light (Mabry *et al.* 1970). The accumulated flavonoids contribute to the UV-absorbing wing patterns and are important for species recognition and mate selection (Wiesen *et al.* 1994, Geuder *et al.* 1997).

In this experiment, it was observed that the host plant of a butterfly helps its immature stage to grow and survive by providing enough nourishment as food. It was perceived that the examined lycaenid butterflies are strongly adapted to their respective host plants from the adult morphological behaviour to the larval nutrition, and completely depend upon them. The plant nutritional elements are thought to have played vital role in the development not only in the embryonic stage but also immature stages of butterfly. These essential elements transfer from the first trophic level to successive trophic levels. These elements also initiate different behaviour of butterfly. The larva depends upon its host plant for feeding and growth, and also for the survival in the nature.

7.4 Discussion

Feeding is a fundamental process, important to all animals. Insect herbivores have a suite of mechanisms available to overcome nutritionally suboptimal food (either as a function of low concentration or imbalanced macronutrient content relative to species-specific requirements). Insects show better performance when they have access to foods containing protein and digestible carbohydrate in the right ratio, and at high concentrations (Le Gall and Behmer 2014). Herbivores select the diet which optimizes their growth and development. This regulation of nutritional balance may occur through selecting and ingesting appropriate plant tissue and nutrient digestion, absorption, and utilization (Bede *et al*. 2007). Thus, herbivorous insects and plants are united by intricate

relationships (Schoonhoven *et al*. 1998). Most insect herbivores tightly regulate their intake of protein and digestible carbohydrate, each of which is regulated independently of one another (Behmer 2009). The protein-carbohydrate content also significantly affected the intake of food and energy, and digestive efficiency (Le Gall and Behmer 2014).

It is reported that butterfly is host specific. Host plant accumulates essential elements which are obligatory for butterflies. Bashar (2016a) described that plant can convert abiotic energy into biotic molecules and can manufacture its own food; the plant can store the energy in the biotic form; and the plant can transfer the energy (in organic form) to the higher trophic levels (to the consumers). This is occurred by the process of "being eaten". Phytopagous insects like butterflies need to fresh parts (leaf, stem, flower and fruits) of host plants for development of germ cells and somatic cell to initiate behavioural activities. The essential elements like carbohydrate, protein, fat etc. are accumulated in the fresh parts of the host plants. Protein acts on developments not only the germ cell but also the somatic cells of butterfly. Butterfly intakes these elements by 'being eaten' the fresh parts of the host plants.

The present experiment is an initial study on larval feeding activities of lycaenid butterflies as well as their obtained nutritional agents from host plants. This study has also provided some interesting evidences of larval feeding pattern, feeding performances of lycaenid butterflies and their intake of plant's macronutrients. Macronutrients balance may have been an important selective factor in butterfly. Further investigations are necessary in this field for better understanding of butterfly's requirements from its host plant. And this biotic-biotic relation may govern the populations of lycaenid butterflies in natural ecosystems.

CONCLUSION

Being highly decorative and colourful insects, butterflies are well known and fond of all. They have been the objects of natural history from time immemorial. Lycaenid butterflies exhibit diversified activities and behaviours with different phenological stages of related plants. Feeding is the substantial motion in animal life. Two distinct (viz. larval and adult) feeding periods has been distinguished in the life cycle of butterflies. Larvae of butterflies consume leaf, stem, flowers, and fruits of host plant(s) while adult butterflies prefer floral nectar. Essential nutrient resources are prerequisite in different amounts within larval and adult diet for survival and reproduction of a butterfly. The nutrient sources are accessible from the plant resources. Some nutrients need to be stored in the larval phase; while others can be supplemented in the adult stage. All these nutrients have great influence for the eco-ethological activities of butterflies during their short life period.

The interactive process between lycaenid butterflies and their related plants is important in the field of bio-resource identification. The synchronization between butterfly's activities and phenological functioning of the related plants stands as 'key tool' for the diversification of living beings in nature. The association of two biotic aspects (butterfly and plant) is co-existed in nature. It has got strong role in co-evolutive tree in the butterfly-plant relationship. Some lycaenids have considerable potential for use as indicator species as their incidence and abundance reflects rather small degrees of habitat change. Butterfly behaviours can detect one of the more attractive items to the tourists/visitors while 'visiting' the forest areas of Bangladesh. The present experiment has got a vital think-point to investigate biotic-biotic interaction in nature. This study is just a beginning and paves the way for further studies on this line. Further researches are necessary to develop techniques for conservation, use and maintenance of environmental soundness.

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APPENDIX

Appendix 1. Behavioural activities of lycaenid butterflies in different study sites.

Study sites	Flying	Pre mating	Mating	Egg laying	Foraging	Basking	Resting	Puddling	Total
CH, DU	139	20	22	29	266	137	115	39	767
KBP	77	26	18	33	165	78	93	15	505
BG, BAU	57	10	10	16	114	56	55	17	335
BRP	282	38	32	77	1400	323	493	76	2721
MNP	298	12	8	16	1307	258	475	108	2482
ScNP	73	4	10	11	267	90	172	46	673
RKS	81	16	14	21	317	123	221	55	848
Total	1007	126	114	203	3836	1065	1624	356	8331

[CH, DU = Curzon Hall, University of Dhaka; KBP = Krishibari Butterfly Park; BG, BAU = Botanical Garden, Bangladesh Agricultural University, Mymensing; BRP = Butterfly Research Park, Gazipur; MNP = Madhupur National Park, Tangail; ScNP = Satchori National Park, Habigonj; RKS = Rema-Kalenga Wildlife Sanctuary, Habigonj]

Appendix 2. Month-wise abundance of lycaenids in Butterfly Research Park (BRP) from 2015 to 2017.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pseudozizeeria maha	13	3	-	-	9	16	11	-	-	-	16	12	80
Zizina Otis	9	-	-	-	-	11	5	-	-	-	9	12	46
Chilades lajus	-	6	20	16	-	-	-	11	23	18	-	-	94
Chilades pandava	7	-	-	-	-	-	-	-	-	17	27	11	62
Catochrysops strabo	-	9	32	42	10	-	-	-	-	-	-	-	93
Tarucus callinara	-	-	-	3	7	17	11	-	-	-	-	-	38
Castalius rosimon	15	20	7	4	5	3	16	14	-	21	40	19	164
Caleta decidia	9	3	-	-	-	-	-	-	-	-	9	17	38
Jamides alecto	-	-	-	-	-	-	-	-	-	-	-	-	0
Jamides celeno	5	-	-	-	-	-	-	-	-	-	14	10	29
Lampides boeticus	4	16	27	20	-	-	-	-	-	-	-	-	67
Euchrysops cnejus	-	6	18	26	43	8	-	-	-	-	-	-	101
Anthene emolus	4	-	-	-	-	-	-	-	-	-	8	17	29
Arhopala pseudocentaurus	36	22	16	8	41	80	108	88	77	69	52	22	619
Arhopala amantes	23	17	11	7	32	67	96	81	65	59	44	14	516
Loxura atymnus	13	-	-	-	-	-	-	-	-	-	8	21	42
Rapala manea	36	28	15	7	-	-	-	-	-	-	52	40	178
Rapala pheretima	29	15	6	-	-	-	-	-	-	-	32	26	108
Rapala iarbus	12	7	4	-	-	-	-	-	-	-	15	23	61
Spindasis syama	15	6	1	-	-	-	-	-	-	-	6	11	39
Spindasis lohita	16	24	3	-	-	-	-	-	-	-	10	7	60
Remelana jangala	32	23	9	-	-	-	-	-	-	11	38	45	158
Hypolycaena erylus	13	1	-	-	-	-	-	-	-	-	3	8	25
Rathinda amor	7	-	-	-	-	-	-	-	-	-	7	17	31
Tajuria cippus	-	-	-	-	11	23	9	-	-	-	-	-	43
Total	298	206	169	133	158	225	256	194	165	195	390	332	2721

Appendix 3. Month-wise abundance of lycaenids in Madhupur National Park (MNP) from 2015 to 2017.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pseudozizeeria maha	7	-	-	-	9	20	12	-	-	-	8	16	72
Zizina Otis	6	-	-	-	1	15	6	-	-	-	1	9	38
Chilades lajus	-	-	6	21	10	-	-	13	20	7	-	-	77
Chilades pandava	7	-	-	-	-	-	-	-	-	9	13	22	51
Catochrysops strabo	-	-	22	32	9	-	-	-	-	-	-	-	63
Tarucus callinara	-	-	-	-	1	13	8	-	-	-	-	-	22
Castalius rosimon	23	12	8	5	3	-	-	8	12	16	18	22	127
Caleta decidia	5	-	-	-	-	-	-	-	-	-	5	14	24
Jamides alecto	-	-	-	-	-	-	-	-	-	-	-	-	-
Jamides celeno	4	-	-	-	9	4	3	-	-	-	5	13	38
Lampides boeticus	-	9	20	13	-	-	-	-	-	-	-	-	42

Euchrysops cnejus	-	5	15	41	29	10	-	-	-	-	-	-	100
Anthene emolus	4	2	-	-	-	-	-	-	-	-	5	12	23
Arhopala pseudocentaurus	49	31	21	14	65	103	125	109	74	46	37	21	695
Arhopala amantes	43	34	22	11	60	87	114	91	66	41	35	17	621
Loxura atymnus	9	-	-	-	-	-	-	-	-	-	3	15	27
Rapala manea	37	17	11	3	-	-	-	-	-	-	22	32	122
Rapala pheretima	16	12	5	-	-	-	-	-	-	-	14	24	71
Rapala iarbus	8	6	-	-	-	-	-	-	-	-	14	8	36
Spindasis syama	13	8	3	-	-	-	-	-	-	-	10	5	39
Spindasis lohita	11	11	-	-	-	-	-	-	-	-	3	7	32
Remelana jangala	17	13	6	-	-	-	-	-	-	-	20	31	87
Hypolycaena erylus	14	3	-	-	-	-	-	-	-	-	-	5	22
Rathinda amor	6	1	-	-	-	-	-	-	-	-	3	9	19
Tajuria cippus	-	-	-	-	4	19	11	-	-	-	-	-	34
Total	279	164	139	140	200	271	279	221	172	119	216	282	2482

Appendix 4. Month-wise abundance of lycaenids in Satchori National Park (ScNP) from 2015 to 2017.

Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Pseudozizeeria maha	7	-	-	-	1	14	8	-	-	-	6	10	46
Zizina Otis	4	-	-	-	-	12	7	-	-	-	-	7	30
Chilades lajus	-	-	5	15	4	-	-	7	13	5	-	-	49
Chilades pandava	5	-	-	-	-	-	-	-	-	-	5	12	22
Catochrysops strabo	-	-	11	20	6	-	-	-	-	-	-	-	37
Tarucus callinara	-	-	-	-	-	-	-	-	-	-	-	-	-
Castalius rosimon	11	7	3	7	4	-	1	3	2	6	9	16	69
Caleta decidia	-	-	-	-	-	-	-	-	-	-	-	-	-
Jamides alecto	8	-	-	-	9	4	3	-	-	-	3	9	36
Jamides celeno	6	-	-	-	12	7	3	-	-	-	6	15	49
Lampides boeticus	-	8	14	4	-	-	-	-	-	-	-	-	26
Euchrysops cnejus	-	3	7	15	9	2	-	-	-	-	-	-	36
Anthene emolus	-	-	-	-	-	-	-	-	-	-	-	-	-
Arhopala pseudocentaurus	4	-	3	-	6	16	17	8	5	9	3	-	71
Arhopala amantes	3	4	-	3	6	8	15	11	6	3	-	-	59
Loxura atymnus	3	-	-	-	-	-	-	-	-	-	5	10	18
Rapala manea	9	3	2	-	-	-	-	-	-	-	5	14	33
Rapala pheretima	-	-	-	-	-	-	-	-	-	-	-	-	-
Rapala iarbus	-	-	-	-	-	-	-	-	-	-	-	-	-
Spindasis syama	9	4	-	-	-	-	-	-	-	-	5	4	22
Spindasis lohita	-	-	-	-	-	-	-	-	-	-	-	-	-
Remelana jangala	6	8	3	-	-	-	-	-	-	-	7	16	40
Hypolycaena erylus	11	5	-	-	-	-	-	-	-	-	6	8	30
Rathinda amor	-	-	-	-	-	-	-	-	-	-	-	-	-
Tajuria cippus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	86	42	48	64	57	63	54	29	26	23	60	121	673

Appendix 5. Monthly data of lycaenids in Rema-Kalenga Wildlife Sanctuary (RKS) from 2015 to 2017.

Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Pseudozizeeria maha	12	-	-	-	10	16	7	-	-	-	7	14	66
Zizina Otis	3	-	-	-	3	11	5	-	-	-	2	8	32
Chilades lajus	-	-	6	18	11	-	-	12	20	8	-	-	75
Chilades pandava	4	-	-	-	-	-	-	-	-	-	5	13	22
Catochrysops strabo	-	-	13	25	7	-	-	-	-	-	-	-	45
Tarucus callinara	-	-	-	-	-	-	-	-	-	-	-	-	-
Castalius rosimon	12	6	3	3	6	3	4	5	3	8	11	13	77
Caleta decidia	-	-	-	-	-	-	-	-	-	-	-	-	-
Jamides alecto	6	-	-	-	6	14	3	-	-	-	3	9	41
Jamides celeno	6	-	-	-	6	15	7	-	-	2	7	16	59
Lampides boeticus	-	8	21	9	-	-	-	-	-	-	-	-	38
Euchrysops cnejus	-	3	13	18	11	3	-	-	-	-	-	-	48

Anthene emolus	4	-	-	-	-	-	-	-	-	-	2	9	15
Arhopala pseudocentaurus	8	6	3	1	2	7	23	13	6	7	1	5	82
Arhopala amantes	8	4	-	3	6	11	16	8	7	-	7	2	72
Loxura atymnus	5	-	-	-	-	-	-	-	-	-	7	13	25
Rapala manea	10	4	3	-	-	-	-	-	-	-	9	16	42
Rapala pheretima	6	2	-	-	-	-	-	-	-	-	4	8	20
Rapala iarbus	-	-	-	-	-	-	-	-	-	-	-	-	-
Spindasis syama	10	4	1	-	-	-	-	-	-	-	5	5	25
Spindasis lohita	-	-	-	-	-	-	-	-	-	-	-	-	-
Remelana jangala	8	4	3	-	-	-	-	-	-	-	9	13	37
Hypolycaena erylus	11	4	-	-	-	-	-	-	-	-	4	8	27
Rathinda amor	-	-	-	-	-	-	-	-	-	-	-	-	-
Tajuria cippus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	113	45	66	77	68	80	65	38	36	25	83	152	848

Appendix 6. Yearly abundance of lycaenid butterflies in different experimental sites from 2015 to 2017.

Months	Year 2015				Year 2016				Year 2017			
	BRP	MNP	ScNP	RKS	BRP	MNP	ScNP	RKS	BRP	MNP	ScNP	RKS
Jan	105	93	30	37	98	94	28	36	95	92	28	40
Feb	67	49	15	17	68	60	12	13	71	55	15	14
Mar	56	46	16	21	57	47	17	20	56	46	15	25
Apr	45	45	22	27	44	48	20	26	44	47	22	24
May	52	66	19	24	50	67	18	22	56	67	20	22
Jun	77	90	23	25	72	93	19	22	76	88	21	32
Jul	89	94	19	19	81	96	18	20	86	89	17	26
Aug	67	74	11	13	62	77	9	11	65	70	9	14
Sep	58	57	11	13	52	57	8	14	55	58	7	9
Oct	66	43	8	11	64	39	8	7	65	37	7	7
Nov	125	76	20	26	130	73	20	30	135	67	20	27
Dec	116	96	42	52	109	95	44	48	107	91	35	51

Appendix 7. Monthly abundance of lycaenid butterflies in different experimental sites from 2015 to 2017.

Study sites	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
BRP	298	206	169	133	158	225	256	194	165	195	390	332	2721
MNP	279	164	139	140	200	271	279	221	172	119	216	282	2482
ScNP	86	42	48	64	57	63	54	29	26	23	60	121	673
RKS	113	45	66	77	68	80	65	38	36	25	83	152	848
Total	776	457	422	414	483	639	654	482	399	362	749	887	6724

Appendix 8. Monthly temperature and relative humidity in experimental sites from 2015 to 2017.

Year	Month	BRP		MNP		ScNP		RKS	
		Temp (°C)	RH (%)	Temp (°C)	RH (%)	Temp (°C)	RH (%)	Temp (°C)	RH (%)
2015	January	24.6	58	26.2	78	26.7	68	27.3	74
	February	29.2	52	27.8	75	28.9	60	29.4	62
	March	33.1	75	31.5	66	31.2	55	31.5	57
	April	34.3	67	31.9	70	32.1	61	32.3	58
	May	33.7	72	33.6	62	31.6	79	33.4	82
	June	31.5	79	32.3	82	29.4	78	30.7	80
	July	32.6	76	33.2	80	31.8	87	32.6	85
	August	34.8	73	31.8	83	32.3	85	33.3	83
	September	35.2	80	34.3	79	33.7	83	34.3	81
	October	31.3	69	31.7	74	32.4	75	32.6	78
	November	30.1	62	29.8	71	28.6	64	28.4	71
	December	25.8	57	27.5	73	29.3	63	30.2	65
2016	January	22.3	61	24.3	77	27.2	56	27.5	58
	February	28.7	57	26.1	81	30.2	58	30.3	57

	March	32.5	63	31.2	70	31.4	66	31.1	66
	April	33.9	58	34.2	68	30.8	71	31.9	73
	May	35.1	75	31.4	73	31.4	77	34.1	77
	June	34.3	81	30.7	81	29.9	82	32.8	80
	July	31.8	78	32.5	90	32.7	92	33.2	93
	August	31.5	82	33.2	92	33.6	91	34.3	91
	September	30.6	77	31.8	84	31.4	89	31.8	79
	October	28.5	82	32.7	78	32.5	81	32.4	84
	November	29.9	75	30.3	69	28.7	62	29.7	67
	December	23.8	60	26.2	71	28.2	68	28.5	58
2017	January	29.3	55	25.8	67	27.5	59	27.1	63
	February	29.5	53	29.2	57	29.6	50	29.8	55
	March	30.2	64	30.7	68	30.6	65	32.4	78
	April	32.7	71	34.1	69	31.7	69	31.3	67
	May	34.1	78	34.6	87	33.7	75	33.9	75
	June	33.6	83	33.7	80	32.4	74	31.6	83
	July	34.3	82	34.2	82	32.6	85	32.9	86
	August	32.7	81	33.4	89	33.5	82	33.8	81
	September	31.5	74	33.8	92	33.2	74	34.1	77
	October	31.2	66	31.9	88	31.7	72	31.9	78
	November	30.3	56	30.7	85	29.4	66	30.4	69
	December	27.8	54	28.2	75	23.7	64	24.1	63

Appendix 9. Duration of adult emergence of lycaenid butterflies in laboratory condition.

Butterfly	**Individual number**	**Duration of emergence (minutes)**
Chilades lajus	10	16, 17, 17, 17, 18, 19, 19, 19, 20,20
C. pandava	8	21, 21, 22, 22, 24, 24, 24, 25
Catochrysops strabo	13	26, 26, 27, 27, 28, 28, 28, 29, 29, 29, 30, 30, 30
Remelana jangala	16	31, 31, 31, 31, 32, 32, 32, 33, 33, 33, 33, 34, 34, 35, 35, 35
Rathinda amor	6	11, 12, 12, 13, 14, 15

Appendix 10. Foraging visit duration of lycaenid butterflies on experimental flowers.

Plant	**Active lycaenids**	**Individual number**	**Place**	**Date and time**	**Duration of visits (sec)**
Gomphrena globosa	*Chilades lajus*	3	CH, DU	23.08.2015 12.00-1.00	2, 2, 4, 6, 6, 6, 8, 9, 11, 14, 17, 22, 22, 24, 26, 29, 30, 32
	Castalius rosimon	6	CH, DU	23.08.2015 12.00-1.00	2, 2, 3, 3, 3, 4, 5, 5, 6, 6, 6, 7, 8, 9, 11, 12, 14, 17, 17, 17, 22, 23, 23, 24, 26, 29, 30, 32, 32, 36, 39, 41, 44
	Lampides boeticus	3	BRP	09.04.2016 10.00-11.00	3, 4, 7, 9, 11, 11, 14, 14, 17, 18, 18, 20, 21, 24, 24, 27, 30, 36, 39
	Lampides boeticus	5	CH, DU	16.03.2016 10.30-11.30	3, 4, 5, 7, 9, 11, 11, 12, 14, 14, 14, 16, 17, 17, 17, 20, 20, 22, 25, 25, 28, 33, 33, 35, 39, 41, 44, 47, 48
	Euchrysops cnejus	3	CH, DU	24.05.2015 12.00-1.00	3, 4, 6, 8, 10, 10, 12, 14, 17, 20, 20, 22, 27, 28, 32, 35, 39, 40
Catharanthus roseus	*Euchrysops cnejus*	5	CH, DU	20.09.2015 1.00-2.00	3, 4, 5, 5, 6, 8, 9, 9, 10, 11, 11, 12, 15, 17, 19, 20, 22, 25, 28, 31, 35, 38, 40, 46, 52
	Euchrysops cnejus	6	SMH, DU	23.09.2015 10.00-11.00	2, 3, 5, 7, 8, 8, 10, 11, 11, 14, 15, 15, 18, 18, 19, 21, 21, 26, 29, 31, 31, 33, 36, 41, 41, 44, 47, 49, 51, 54
Chromolaena odorata	*Castalius rosimon*	5	BRP	11.12.2015 12.30-1.30	2, 2, 3, 5, 6, 6, 6, 8, 9, 11, 14, 16, 19, 19, 22, 24, 24, 27, 30, 30, 33, 33, 37, 40, 41, 44, 48
	Chilades lajus	3	BRP	11.12.2015 12.30-1.30	3, 3, 6, 8, 10, 12, 15, 18, 21, 25, 27, 30, 33, 38, 43, 45, 48, 50, 51
	Anthene emolus	2	BRP	11.12.2015 12.30-1.30	3, 4, 6, 8, 11, 15, 19, 22, 23, 27, 32, 36, 39, 43

	Arhopala amantes	7	BRP	08.01.2016 11.15-12.15	3, 4, 4, 7, 9, 9, 11, 11, 11, 13, 13, 16, 19, 20, 20, 20, 23, 26, 29, 29, 33, 33, 34, 38, 42, 42, 42, 47, 50, 53, 53, 56, 59, 65, 68, 71, 75, 78, 81
	Arhopala pseudocentaurus	9	BRP	10.02.2015 12.00-1.00	3, 4, 7, 10, 11, 11, 13, 14, 17, 19, 21, 21, 21, 21, 22, 23, 29, 31, 31, 32, 32, 34, 34, 37, 37, 37, 41, 42, 43, 43, 45, 48, 51, 51, 51, 56, 56, 61, 61, 65, 68, 71, 74, 77, 78, 83
	Arhopala pseudocentaurus	8	BRP	08.01.2016 11.30-12.30	4, 5, 5, 8, 10, 10, 12, 14, 15, 15, 15, 18, 20, 22, 22, 22, 25, 28, 31, 33, 33, 33, 36, 36, 39, 41, 42, 42, 43, 47, 48, 50, 53, 53, 57, 60, 62, 63, 67, 70, 73, 75
	Arhopala pseudocentaurus	5	BRP	20.01.2017 11.45-12.45	3, 3, 6, 9, 11, 14, 14, 17, 20, 20, 23, 23, 26, 30, 30, 33, 36, 36, 39, 42, 42, 45, 48, 50, 55, 58, 61, 66, 69, 72, 77
	Rapala manea	4	BRP	08.01.2016 11.15-12.15	3, 5, 5, 8, 10, 10, 13, 13, 15, 18, 18, 20, 23, 23, 27, 31, 31, 34, 37, 38, 41, 42, 45
	Rapala manea	3	BRP	20.01.2017 12.15-1.15	4, 4, 6, 7, 9, 11, 11, 13, 16, 16, 19, 21, 21, 25, 28, 33, 38, 40, 43, 46
	Rapala manea	3	BRP	10.02.2015 12.00-1.00	3, 3, 6, 7, 7, 8, 10, 14, 17, 17, 21, 23, 26, 30, 33, 36, 39, 41, 47
	Rapala pheretima	4	BRP	20.01.2017 12.30-1.30	3, 5, 5, 6, 9, 11, 11, 15, 17, 17, 22, 25, 28, 32, 32, 35, 38, 40, 43, 43, 46, 48
	Rapala airbus	3	BRP	11.12.2015 12.00-1.00	3, 4, 7, 7, 10, 12, 16, 16, 20, 23, 26, 30, 35, 38, 42, 45
	Remelana jangala	6	BRP	10.02.2015 11.00-12.00	3, 4, 4, 5, 7, 7, 8, 10, 10, 12, 12, 12, 15, 17, 17, 19, 20, 20, 23, 23, 23, 26, 31, 32, 34, 37, 40, 45, 45, 48, 51, 55, 58, 61, 65
	Remelana jangala	9	BRP	20.01.2017 12.15-1.15	3, 3, 5, 6, 6, 7, 9, 9, 9, 10, 11, 11, 11, 11, 12, 12, 15, 16, 16, 17, 18, 18, 20, 21, 21, 24, 27, 31, 31, 31, 33, 33, 37, 41, 41, 45, 46, 47, 50, 54, 58, 60, 64, 67
Mikania cordata	*Caleta decidia*	3	BRP	11.12.2015 12.30-1.30	2, 3, 3, 5, 6, 7, 9, 12, 15, 18, 21, 24, 27, 31, 31, 36, 38, 43, 46
	Anthene emolus	3	BRP	11.12.2015 12.30-1.30	3, 3, 4, 6, 6, 8, 12, 15, 18, 20, 23, 28, 31, 31, 35, 38, 43, 46, 50
	Anthene emolus	2	BRP	13.11.2015 11.30-12.30	3, 5, 7, 8, 13, 18, 19, 21, 25, 27, 34, 37, 40, 45, 47
	Arhopala pseudocentaurus	8	BRP	10.02.2015 12.00-1.00	3, 3, 4, 5, 5, 5, 8, 9, 9, 9, 10, 10, 11, 11, 11, 13, 15, 18, 21, 21, 21, 24, 29, 29, 32, 35, 37, 38, 38, 42, 47, 51, 55, 55, 58, 61, 64, 67, 70, 73, 74, 77, 81
	Arhopala amantes	9	BRP	08.01.2016 11.15-12.15	4, 4, 6, 6, 6, 9, 9, 10, 11, 11, 13, 13, 13, 13, 15, 15, 18, 19, 20, 20, 20, 24, 27, 27, 27, 28, 31, 34, 38, 38, 38, 41, 45, 49, 50, 53, 53, 58, 62, 64, 65, 67, 71, 75, 78
	Rapala manea	3	BRP	10.02.2015 12.00-1.00	3, 3, 6, 9, 10, 13, 18, 20, 25, 28, 32, 35, 38, 43, 47
	Rapala manea	2	BRP	09.02.2016 11.00-12.00	4, 5, 8, 9, 11, 11, 17, 21, 21, 27, 28, 34, 38, 40, 41
	Rapala manea	3	BRP	29.01.2016 11.00-12.00	3, 5, 7, 7, 10, 12, 15, 15, 16, 19, 23, 28, 33, 37, 43, 46
	Rapala manea	2	BRP	13.11.2015 10.30-11.30	4, 4, 7, 11, 14, 18, 22, 25, 28, 33, 36, 39, 43
	Rapala airbus	3	BRP	11.12.2015 12.00-1.00	3, 5, 5, 8, 11, 15, 18, 24, 28, 33, 33, 35, 40, 44, 47, 48, 51
	Remelana jangala	4	BRP	10.02.2015 11.30-12.30	2, 3, 3, 3, 5, 5, 8, 8, 11, 14, 17, 17, 20, 23, 26, 26, 29, 32, 32, 32, 34, 37, 40, 43, 43, 47, 52, 57
	Remelana jangala	7	BRP	13.11.2015 11.00-12.00	2, 2, 2, 3, 3, 4, 4, 6, 6, 9, 10, 11, 15, 16, 18, 20, 22, 24, 25, 25, 25, 26, 27, 31, 31,

					32, 33, 33, 33, 36, 41, 43, 43,46,48,51,55
Spilanthes calva	*Pseudozizeeria maha*	5	BRP	11.03.2016 2.00-3.00	2, 3, 3, 5, 5, 6, 7, 7, 8, 9, 11, 11, 14, 15, 15, 17, 17, 17, 19, 21, 21, 25,26,31,35,38
	Pseudozizeeria maha	7	CH, DU	24.05.2015 12.30-1.30	3, 3, 3, 4, 4, 6, 6, 6, 7, 8, 8, 8, 10, 10, 13, 13, 13, 16, 16, 16, 17, 18, 18, 20, 24, 25, 27, 29, 30, 34, 37, 38, 41, 44, 45
	Zizina otis	3	BRP	10.02.2017 12.00-1.00	2, 3, 3, 5, 6, 6, 8, 10, 11, 11, 14, 17, 20, 21, 25, 28, 32, 37
	Zizina otis	5	BRP	11.12.2015 12.00-1.00	2, 2, 2, 4, 4, 6, 8, 9, 10, 10, 10, 13, 13, 16, 16, 19, 20, 21, 24, 27, 31, 33
	Castalius rosimon	7	BRP	11.12.2015 12.15-1.15	2, 3, 3, 4, 4, 4, 5, 6, 6, 7, 7, 8, 8, 9, 10, 12, 12, 12, 15, 16, 17, 18, 20, 24, 28, 29, 31, 34, 35, 35, 39, 40, 43, 46
	Castalius rosimon	4	BRP	10.02.2015 12.30-1.30	2, 2, 4, 4, 6, 8, 8, 9, 9, 9, 11, 11, 13, 16, 18, 21, 25, 29, 32, 35, 35, 40, 43
	Caleta decidia	2	BRP	04.12.2015 2.00-3.00	2, 4, 4, 7, 9, 9, 10, 13, 16, 21, 29, 35, 40
	Caleta decidia	3	BRP	11.12.2015 12.30-1.30	3, 5, 5, 8, 11, 11, 13, 18, 23, 25, 28, 31, 36, 38, 41
	Caleta decidia	2	BRP	11.12.2015 12.00-1.00	2, 2, 6, 9, 10, 13, 17, 18, 21, 25, 35
	Caleta decidia	2	BRP	13.11.2015 12.30-1.30	4, 6, 8, 8, 11, 14, 16, 18, 23, 26, 29, 32, 37, 40
	Caleta decidia	4	BRP	13.11.2015 2.30-3.30	2, 3, 3, 5, 7, 9, 9, 12, 15, 15, 19, 22, 25, 25, 28, 31, 31, 34, 38, 41, 44, 45
	Caleta decidia	2	BRP	29.01.2016 11.45-12.45	3, 5, 8, 8, 12, 15, 18, 21, 25, 29, 32, 35, 35, 40, 43
	Caleta decidia	3	BRP	08.01.2016 11.45-12.45	2, 2, 3, 5, 8, 9, 11, 14, 17, 20, 24, 28, 31, 35, 38, 41
	Rapala manea	3	BRP	20.01.2017 12.30-1.30	3, 5, 5, 8, 11, 11, 14, 15, 17, 20, 23, 27, 31, 34, 37, 41, 44
Wedelia chinensis	*Pseudozizeeria maha*	6	CH, DU	24.05.2015 12.15-1.15	2, 3, 3, 4, 4, 5, 5, 6, 6, 7, 8, 8, 9, 10, 12, 14,15,16,16,17,17,17,18,22,23,29,34,37,42,45
	Zizina otis	5	CH, DU	15.05.2016 11.00-12.00	2, 2, 3, 3, 3, 4, 4, 5, 6, 6, 6, 8, 9, 9, 10, 11, 11, 15, 15,15,18,18,18,20,23,23,26,31,35
	Lampides boeticus	6	CH, DU	16.03.2016 10.30-11.30	3, 3, 5, 5, 8, 9, 10, 10, 12, 13, 13, 13, 15, 16,16,16,19,19,24,24,25,28,32,32,35,39,42,45
	Euchrysops cnejus	7	CH, DU	24.05.2015 11.15-12.15	2, 3, 3, 4, 4, 6, 6, 6, 8, 8, 8, 10, 10, 12, 12, 12, 13, 13, 18, 18, 18, 21, 24, 24, 26, 29,31,31,36,36,39,41,45,48,48,51,51,54,57
Wedelia trilobata	*Catochrysops strabo*	7	CH, DU	16.03.2016 10.30-11.30	3,3,3,5,5,6,7,7,8,8,11,11,11,14,16,16,17,18, 18,22,24,24,26,26,28,28,31,31,34,37,37,39,41, 41,44,47,48,48,51,52,52,57
	Castalius rosimon	5	BRP	13.11.2015 10.45-11.45	2, 3, 3, 4, 4, 5, 5, 6, 6, 7, 8, 8, 9, 10, 12, 13,15,16,16,16,17,17,18,21,26,29,30,33,35,39
	Tarucus callinara	3	BRP	19.05.2017 11.45-12.45	3, 4, 6, 6, 7, 9, 12, 13, 16, 16, 16, 18, 23, 23, 26, 30, 31, 35, 38
	Lampides boeticus	7	CH, DU	16.03.2016 10.30-11.30	3, 4, 4, 4, 5, 5, 8, 8, 8, 9, 10, 10, 11, 11, 13, 17, 17, 21, 22, 22, 24, 26, 29, 31, 31, 31, 35, 37, 37, 40, 41, 44, 44, 47,51,54,57
	Euchrysops cnejus	9	BRP	16.10.2015 2.00-3.00	2, 3, 4, 4, 4, 5, 7, 7, 7, 9, 9, 10, 10, 10, 12, 13, 13, 13, 16, 18, 18, 18, 21, 21, 24, 25, 25, 25, 28, 32, 32, 35, 37, 38, 38, 40, 40, 43, 44, 47, 47, 48, 51, 52, 55
Helianthus debilis	*Lampides boeticus*	6	CH, DU	30.03.2016 12.00-1.00	3, 4, 4, 5, 5, 7, 7, 9, 9, 9, 10, 10, 13, 13, 15, 16, 17, 22, 22, 22, 23, 26, 29, 30, 31, 31, 34, 37, 38, 41, 41, 45, 48, 52
	Euchrysops cnejus	4	CH, DU	30.03.2016 12.00-1.00	2, 3, 3, 5, 5, 5, 8, 8, 9,10,11,11,11,14,15,15, 15,18,21,24,27,31,33,33,36,37,37,38,42,46

Vernonia cinerea	*Pseudozizeeria maha*	5	CH, DU	24.05.2015 12.15-1.15	2, 3, 3, 4, 5, 5, 6, 7, 7, 9, 9, 10, 10, 10, 11, 14, 14, 15, 17, 17, 21, 25, 25, 30, 30, 34, 37, 38, 41
	Zizina otis	3	CH, DU	15.05.2016 11.00-12.00	2, 2, 3, 4, 4, 6, 7, 7, 9, 10, 11, 12, 12, 13, 15, 17, 22, 25, 31, 31, 35
Leea macrophylla	*Castalius rosimon*	2	BRP	11.12.2015 12.15-1.15	3, 3, 4, 7, 7, 9, 11, 15, 19, 23, 23, 25, 28, 33, 34, 39, 41
	Caleta decidia	2	BRP	04.12.2015 2.00-3.00	3, 4, 5, 8, 8, 10, 13, 18, 21, 21, 23, 28, 33
Oxalis corniculata	*Pseudozizeeria maha*	3	CH, DU	24.05.2015 12.15-1.15	2, 2, 3, 3, 3, 4, 5, 5, 7, 8, 10, 11, 11, 14, 17, 18, 19, 20, 21, 21, 24, 28, 31
	Zizina otis	2	CH, DU	15.05.2016 11.00-12.00	2, 2, 2, 3, 6, 6, 8, 9, 10, 13, 16, 19, 21, 22, 25, 27, 28, 28
Oxalis corymbosa	*Euchrysops cnejus*	3	CH, DU	17.05.2015 11.00-12.00	2, 4, 7, 9, 13, 17, 20, 20, 21, 25, 28, 32, 37, 40, 43, 43, 46
	Catochrysops strabo	2	CH, DU	03.03.2016 12.00-1.00	3, 3, 6, 8, 11, 14, 18, 21, 25, 30, 30, 35, 41, 42
Ziziphus mauritiana	*Chilades lajus*	5	BRP	16.10.2015 2.00-3.00	3, 3, 5, 6, 6, 9, 10, 10, 10, 13, 13, 18, 18, 21, 23, 27, 28, 33, 33, 36, 39, 42, 46, 47, 51
	Castalius rosimon	7	BRP	16.10.2015 2.00-3.00	3, 4, 5, 5, 5, 7, 8, 9, 9, 10, 11, 11, 11, 14, 16, 16, 19, 22, 22, 25, 26, 26, 28, 32, 34, 36, 39, 41, 43, 46, 46, 49, 52, 54
	Tarucus callinara	3	BRP	16.10.2015 1.30-2.30	2, 3, 3, 6, 8, 13, 13, 17, 20, 23, 27, 27, 31, 35, 38, 43, 47
	Euchrysops cnejus	3	BRP	16.10.2015 1.00-2.00	3, 5, 7, 10, 11, 14, 18, 18, 23, 23, 27, 32, 32, 36, 41, 45, 49, 51
	Arhopala amantes	7	BRP	14.10.2016 1.30-2.30	2, 4, 4, 5, 6, 6, 6, 8, 8, 9, 10, 10, 10, 12, 12, 12, 13, 14, 17, 19, 21, 21, 22, 23, 23, 26, 29, 31, 31, 35, 39, 42, 42, 42, 57, 60, 63, 65, 71, 72, 75
	Arhopala pseudocentaurus	8	BRP	14.10.2016 1.30-2.30	3, 4, 4, 4, 6, 7, 7, 9, 9, 10, 11, 11, 11, 12, 14, 17, 17, 17, 18, 21, 22, 22, 22, 24, 26, 28, 30, 30, 33, 35, 38, 41, 41, 44, 47, 51, 55, 58, 58, 60, 63, 65, 71, 77, 79
	Rapala manea	3	BRP	14.10.2016 2.00-3.00	3, 5, 8, 10, 13, 13, 16, 17, 20, 21, 24, 27, 33, 33, 38, 41, 44
	Rathinda amor	2	BRP	14.10.2016 2.00-3.00	5, 7, 12, 12, 17, 22, 25, 25, 28, 31
	Tajuria cippus	2	BRP	14.10.2016 1.45-2.45	4, 7, 7, 11, 16, 16, 21, 26, 29, 32, 33, 33, 35
Ixora coccinea	*Lampides boeticus*	9	BRP	16.10.2015 10.00-11.00	3, 4, 6, 8, 9, 11, 11, 13, 16, 17, 17, 18, 21, 22, 24, 25, 25, 28, 30, 30, 34, 36, 37, 39, 43, 48, 51, 55, 57, 60, 65
	Arhopala amantes	15	BRP	24.06.2016 10.15-11.15	2, 3, 3, 4, 5, 5, 6, 6, 7, 7, 9, 10, 10, 11, 11, 11, 12, 12, 13, 13, 13, 15, 16, 16, 16, 18, 19, 20, 20, 21, 22, 23, 25, 28, 32, 33, 35, 39, 41, 44, 49, 53, 53, 58, 61, 64, 67, 71, 74, 75, 77
	Arhopala pseudocentaurus	17	BRP	24.06.2016 10.30-11.30	2, 3, 3, 4, 4, 5, 5, 6, 6, 7, 7, 7, 8, 9, 9, 10, 10, 11, 11, 11, 12, 12, 12, 13, 15, 16, 16, 17, 19, 19, 20, 21, 22, 23, 26, 27, 31, 33, 36, 36, 38, 39, 42, 45, 48, 52, 53, 57, 60, 65, 67, 71, 74, 78, 81
	Remelana jangala	7	BRP	16.10.2015 10.30-11.30	3, 5, 6, 6, 7, 7, 8, 8, 8, 9, 9, 10, 11, 11, 11, 12, 14, 15, 15, 17, 19, 21, 22, 23, 25, 29, 31, 31, 33, 33, 36, 38, 42, 43, 45, 48, 51
	Tajuria cippus	5	BRP	24.06.2016 10.15-11.15	2, 4, 4, 5, 6, 6, 7, 8, 9, 9, 11, 12, 12, 13, 13, 14, 16, 17, 17, 17, 19, 21, 24, 24, 28, 31, 35, 37, 38, 41, 41, 44, 47
Pentas lanceolata	*Lampides boeticus*	5	CH, DU	03.03.2016 1.30-2.30	2, 2, 3, 5, 6, 6, 8, 9, 11, 11, 12, 12, 13, 15, 15, 15, 16, 16, 17, 18, 18, 23, 24, 26, 29, 31, 31, 34, 38
	Euchrysops	3	CH, DU	17.05.2017	3, 5, 7, 9, 10, 12, 12, 14, 15, 17, 18, 18,

	cnejus			12.30-1.30	19, 22, 25, 27, 28, 31, 34
Mussaenda frondosa	*Chilades pandava*	3	BG, BAU	27.10.2015 12.00-1.00	4, 7, 9, 10, 12, 12, 15, 16, 17, 19, 21, 21, 24, 25, 28
Micromelum minutum	*Caleta decidia*	2	BRP	09.03.2017 2.00-3.00	7, 10, 14, 14, 19, 25, 28, 31, 36, 42, 42, 47, 51, 56, 58, 61, 63
	Rapala manea	2	BRP	09.03.2017 11.00-12.00	5, 11, 17, 26, 26, 29, 37, 38, 43, 46, 50, 54, 57, 62, 63, 63, 66
	Rapala pheretima	2	BRP	09.03.2017 11.15-12.15	5, 10, 16, 16, 19, 23, 28, 33, 33, 38, 41, 45, 48, 53, 59, 62
	Rapala iarbus	3	BRP	09.03.2017 11.30-12.30	8, 14, 19, 19, 24, 28, 35, 35, 39, 42, 46, 50, 50, 55, 55, 58, 63, 63, 65, 68, 71
	Spindasis lohita	3	BRP	19.02.2016 10.00-11.00	65, 90, 110, 118, 145, 180, 210, 240, 290, 320, 370, 420, 460, 486, 520, 540
	Spindasis lohita	5	BRP	26.02.2016 10.00-11.00	85, 120, 160, 200, 230, 275, 290, 310, 340, 380, 430, 465, 510, 540, 580, 610, 670, 720, 750, 780, 810, 860, 900
	Spindasis lohita	4	BRP	09.03.2017 11.00-12.00	105, 130, 170, 210, 250, 280, 280, 320, 340, 370, 410, 450, 480, 530, 590, 620, 680, 710, 740, 790, 830
Lantana camara	*Arhopala amantes*	6	BRP	11.10.2016 10.15-11.15	3, 5, 8, 9, 10, 11, 13, 13, 16, 17, 18, 18, 21, 24, 25, 29, 32, 35, 35, 38, 41, 44, 49, 52, 57
	Arhopala pseudocentaurus	8	BRP	11.10.2016 10.00-11.00	4, 5, 7, 9, 9, 10, 12, 12, 12, 15, 15, 17, 17, 18, 21, 22, 22, 24, 27, 27, 29, 30, 31, 35, 38, 39, 42, 45, 48, 49, 52, 55, 58
	Remelana jangala	3	BRP	16.10.2015 10.00-11.00	3, 5, 8, 10, 11, 11, 14, 16, 16, 20, 21, 25, 28, 31, 32, 35, 38
Chrysalidocarpus lutescens	*Arhopala amantes*	5	BRP	03.07.2015 10.00-11.00	5, 11, 13, 13, 16, 21, 25, 25, 29, 34, 34, 38, 41, 41, 44, 47, 48, 53, 56, 56, 58, 63, 63, 66, 68, 69, 69, 74, 74, 78, 81, 83, 87, 91, 95, 99, 101, 101, 108, 108, 109, 110, 115
	Arhopala pseudocentaurus	7	BRP	03.07.2015 10.15-11.15	7, 10, 14, 20, 20, 27, 31, 31, 35, 39, 42, 43, 43, 46, 48, 52, 54, 57, 57, 61, 65, 68, 68, 71, 75, 79, 82, 87, 92, 96, 99, 100, 100, 105, 108, 108, 110, 115, 120, 123, 126
	Rathinda amor	2	BRP	24.06.2016 1.45-2.45	5, 7, 10, 10, 14, 19, 25, 31, 35, 38, 43, 48, 51
Punica hybrida	*Pseudozizeeria maha*	5	CH, DU	27.03.2017 10.45-11.45	2, 2, 2, 3, 4, 5, 5, 5, 7, 7, 9, 12, 14, 14, 16, 19, 19, 21, 21, 25, 28, 31
	Chilades lajus	3	BRP	09.04.2016 10.45-11.45	3, 3, 5, 6, 6, 9, 9, 9, 12, 17, 17, 22, 26, 29, 32, 37, 42
	Chilades lajus	2	CH, DU	27.05.2015 9.15-10.15	4, 7, 7, 9, 11, 11, 14, 17, 21, 26, 30, 33, 35
	Castalius rosimon	3	BRP	10.02.2015 12.00-1.00	2, 2, 4, 4, 5, 7, 8, 8, 12, 13, 17, 20, 25, 29, 33
	Castalius rosimon	4	BRP	05.11.2016 1.45-2.45	3, 3, 4, 5, 5, 6, 7, 7, 11, 11, 15, 18, 21, 21, 25, 29, 30, 33, 36, 40
	Catochrysops strabo	3	BRP	11.03.2016 9.15-10.15	3, 3, 5, 7, 7, 9, 10, 12, 15, 15, 18, 22, 25, 27, 32, 34, 35, 39, 41
	Lampides boeticus	2	CH, DU	09.03.2016 2.00-3.00	2, 3, 5, 7, 8, 11, 15, 20, 26, 29, 31
	Euchrysops cnejus	2	BRP	11.11.2016 10.00-11.00	3, 5, 5, 8, 8, 12, 14, 17, 19, 22, 27, 34
	Rapala manea	3	BRP	05.11.2016 2.15-3.15	3, 3, 5, 8, 9, 11, 14, 17, 17, 20, 23, 26, 28, 31, 33, 38

Appendix 11. Nectar visit pattern and visit duration of lycaenid butterflies on experimental flowers.

Plant	Active lycaenids	Individual number	Place	Date and time	Duration of nectar searching (sec)	Duration of nectar feeding (sec)
Catharanthus roseus	*Euchrysops cnejus*	3	CH, DU	20.09.2015 1.00-2.00	3, 3, 4, 6, 6, 8, 8, 9, 10, 11, 12, 12, 14, 19, 20, 25	3, 3, 4, 5, 5, 6, 7, 8, 9, 9, 11, 14, 15, 17, 17, 20
	Euchrysops cnejus	4	SMH, DU	23.09.2015 10.00-11.00	2, 3, 3, 4, 6, 7, 7, 8, 9, 10, 11, 11, 12, 15, 17, 18, 21, 25, 28	3, 4, 4, 5, 6, 7, 7, 8, 9, 11, 12, 14, 15, 18, 19, 20, 22, 25, 30
Ixora coccinea	*Lampides boeticus*	7	BRP	16.10.2015 10.00-11.00	2, 3, 3, 4, 6, 7, 9, 10, 12, 15, 17, 17, 19, 21, 24, 25, 28, 30, 31, 34, 37	8, 11, 11, 13, 18, 22, 23, 25, 27, 30, 33, 36, 39, 43, 45, 48, 51, 55, 57, 60, 63
	Arhopala amantes	11	BRP	24.06.2016 10.15-11.15	2, 3, 3, 3, 4, 4, 4, 5, 5, 5, 6, 6, 6, 6, 7, 7, 7, 7, 8, 8, 9, 9, 9, 10, 10, 10, 11, 11, 12, 13, 16, 21, 22, 23, 25, 28, 33	3, 4, 4, 5, 7, 8, 8, 9, 9, 10, 11, 12, 12, 13, 13, 13, 15, 16, 16, 18, 19, 20, 20, 32, 35, 39, 41, 44, 49, 53, 53, 58, 61, 64, 67, 71, 74
	Arhopala pseudocentaurus	14	BRP	24.06.2016 10.30-11.30	2, 2, 3, 3, 3, 4, 4, 4, 5, 5, 5, 6, 6, 6, 6, 7, 7, 7, 7, 8, 8, 8, 9, 9, 10, 10, 10, 11, 11, 12, 13, 15, 16, 19, 21, 22, 23, 26, 28, 33, 35, 38	3, 3, 4, 4, 5, 7, 8, 8, 9, 9, 10, 11, 11, 12, 12, 13, 13, 13, 15, 16, 16, 18, 19, 20, 20, 32, 35, 38, 39, 41, 44, 49, 53, 53, 58, 61, 64, 67, 71, 74, 77
	Remelana jangala	5	BRP	16.10.2015 10.30-11.30	3, 3, 4, 4, 5, 6, 6, 7, 7, 8, 8, 9, 9, 9, 10, 10, 11, 12, 14, 15, 18, 21, 22	3, 4, 6, 6, 7, 7, 8, 8, 9, 11, 11, 14, 17, 20, 23, 26, 29, 31, 31, 35, 38, 42, 45
	Tajuria cippus	3	BRP	24.06.2016 10.15-11.15	2, 3, 4, 4, 5, 6, 6, 7, 8, 9, 9, 12, 13, 15, 16, 17	4, 6, 7, 9, 9, 11, 12, 13, 17, 17, 18, 22, 27, 30, 35, 39
Pentas lanceolata	*Lampides boeticus*	3	CH, DU	03.03.2016 1.30-2.30	2, 3, 4, 6, 6, 8, 9, 11, 11, 11, 12, 13, 15, 17, 19	2, 2, 3, 5, 5, 6, 7, 10, 12, 14, 14, 15, 17, 21, 24
	Euchrysops cnejus	2	CH, DU	17.05.2017 12.30-1.30	3, 3, 5, 7, 7, 9, 11, 13, 17, 18, 21	4, 5, 7, 8, 10, 11, 13, 16, 17, 19, 23
Mussaenda frondosa	*Chilades pandava*	2	BG, BAU	27.10.2015 12.00-1.00	5, 6, 9, 10, 12, 17, 18, 21	7, 9, 11, 11, 14, 17, 17, 20
Lantana camara	*Arhopala amantes*	5	BRP	11.10.2016 10.15-11.15	3, 3, 4, 5, 6, 7, 7, 8, 8, 9, 9, 10, 11, 11, 12, 15, 18	5, 8, 10, 11, 12, 17, 17, 22, 25, 28, 31, 35, 35, 37, 42, 48, 55
	Arhopala pseudocentaurus	6	BRP	11.10.2016 10.00-11.00	3, 4, 4, 5, 6, 7, 8, 8, 8, 9, 10, 10, 11, 12, 13, 16, 18, 21, 21, 23, 25	5, 5, 7, 9, 11, 14, 15, 17, 21, 25, 27, 30, 35, 37, 37, 41, 44, 47, 48, 51, 55
	Remelana jangala	2	BRP	16.10.2015 10.00-11.00	3, 3, 4, 7, 9, 11, 15, 18, 21	4, 7, 11, 15, 17, 22, 28, 31, 35

Appendix 12. Measurement of nectar volume collected from examined flowers.

Plant	Place and date	Inflo number	Total flowers on inflo	Range of flower numbers per inflo	Variation of examined corolla lengths (mm)	Nectar volume (µL) from total flowers
Catharanthus roseus	CH, DU 20.09.2015	25	45	1-4	25-32	70
	SMH, DU 21.09.2015	60	121	1-4	27-30	250

Pentas lanceolata	CH, DU 1.11.2015	16	143	4-15	13-14.5	220
	CH, DU 12.11.2015	7	71	3-16	13.5-14	20
Ixora coccinea	BRP 16.10.2015	5	184	21-51	21-31	230
	BG, BAU 27.10.2015	6	159	31-64	23-30	480
	CH, DU 1.11.2015	6	211	32-43	22-30	520
Mussaenda frondosa	CH, DU 4.04.2016	2	3	1-2	22-27	10
	CH, DU 11.04.2016	4	4	1	23-27	10
Lantana camara	CH, DU 30.10.2015	16	250	12-28	8-13	40
	CH, DU 2.11.2015	15	193	9-17	9-13	20

Appendix 13. Measurement of pollen grains of examined flowers visited by lycaenid butterflies.

Plant	Radius (µm)	Perimeter (µm)	Area (µm^2)
Spilanthes calva	10.02	62.97	315.56
	11.33	71.21	403.52
	10.09	67.15	358.84
	12.82	80.57	516.62
	11.35	71.33	404.91
	12.74	80.03	509.63
	10.69	67.15	358.84
	11.64	73.15	425.86
	12.82	80.57	516.62
	12.67	79.59	504.05
	11.35	71.28	404.51
	12.07	75.89	457.99
	10.86	70.15	380.91
	11.76	73.86	434.29
	12.05	75.68	455.97
Wedelia chinensis	45.35	284.96	6461.91
	51.35	322.65	8284.03
	37.48	235.51	4413.59
	44.47	279.43	6213.38
	51.13	321.23	8211.43
	46.67	293.22	6841.70
	57.52	361.43	10395.17
	46.58	292.68	6816.56
	51.47	323.38	8321.74
	48.71	306.04	7453.26
	47.03	295.5	6948.68
	51.41	323.02	8303.23
	42.03	264.09	5549.85
	50.99	320.43	8169.36
	48.90	307.23	7511.77
Wedelia trilobata	37.62	236.00	4447.11
	30.73	193.09	2967.06
	29.34	184.35	2704.56
	31.68	199.04	3152.77
	43.34	272.30	5900.60
	38.05	239.05	4547.63

	32.06	201.45	3229.56
	34.32	215.63	3700.10
	32.17	202.15	3251.90
	36.96	232.24	4292.12
	37.29	234.12	4365.17
	31.83	199.99	3182.84
	31.87	200.25	3190.98
	31.45	197.62	3107.57
	40.69	255.68	5201.81
Helianthus debilis	39.33	247.14	4860.40
	22.71	142.66	1619.66
	39.42	247.71	4882.73
	36.74	230.84	4240.45
	34.68	217.88	3777.77
	44.60	280.24	6249.41
	35.23	221.34	3898.72
	38.00	238.76	4536.46
	33.73	211.96	3575.13
	35.90	225.58	4049.51
	37.62	236.36	4445.93
	28.22	177.31	2501.84
	38.71	243.24	4707.91
	35.96	226.09	4065.09
	39.64	249.06	4936.37
Vernonia cinerea	38.01	238.80	4537.86
	38.69	243.09	4702.61
	34.67	217.86	3776.89
	36.02	226.35	4077.09
	39.79	250.00	4973.48
	39.54	248.41	4910.65
	38.78	243.61	4724.26
	39.24	246.55	4838.05
	35.34	222.11	3926.99
	37.23	233.93	4375.16
	37.62	236.37	4446.12
	37.02	232.60	4305.43
	36.95	232.21	4290.08
	37.40	234.98	4394.12
	39.67	249.21	4943.08
Oxalis corymbosa	51.44	323.22	8313.34
	46.00	289.06	6649.01
	40.20	252.58	5076.81
	74.97	471.03	17655.75
	57.04	358.36	10219.60
	53.24	334.49	8903.27
	63.00	395.84	12468.98
	45.04	283.02	6347.29
	50.86	319.59	8127.65
	50.11	314.86	7888.89
	50.78	319.04	8100.42
	48.43	304.33	7369.35
	42.62	267.80	5706.82
	68.98	433.44	14949.34
	55.14	346.42	9550.79
Micromelum minutum	48.28	253.07	5096.36
	40.93	257.16	5262.52

	39.21	246.39	4831.07
	37.77	237.29	4480.61
	44.98	282.64	6357.18
	46.58	292.68	6816.56
	39.29	246.89	4850.62
	39.63	248.98	4933.02
	36.72	230.73	4236.26
	38.67	242.99	4698.42
	43.48	248.03	5392.17
	38.83	243.95	4736.28
	39.42	247.68	4881.77
	38.53	242.09	4663.86
	45.78	287.66	6584.54
Lantana camara	13.60	85.43	180.85
	19.52	122.26	1196.60
	22.16	139.24	1542.87
	21.50	135.08	1452.11
	24.15	151.72	1831.90
	22.82	143.40	1636.42
	16.67	104.72	872.66
	15.35	96.43	740.02
	21.18	133.06	1408.83
	25.18	158.21	1991.77
	19.39	121.82	1181.04
	20.35	127.66	1298.94
	18.76	117.84	1105.34
	19.08	119.90	1143.85

Appendix 14. Recorded puddling duration of lycaenid butterflies on different substratums.

Puddling substratum	Number of species	Individual number	Puddling duration (minutes)
Moist ground	10	31	1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 4, 4, 4, 5, 5, 5, 5, 6, 6, 6, 7, 7, 8, 8, 8, 8, 9, 9, 10, 10, 11, 11, 12
Mud	3	10	1, 1, 1, 1, 2, 2, 2, 3, 3, 3, 4, 5, 5
Moist pitch	2	8	2, 2, 2, 3, 3, 3, 5, 6, 8, 10, 11, 11
Wet sand	5	21	1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 4, 4, 4, 5, 5, 6, 6, 7, 7, 7, 8, 9, 9, 11
Debris	7	18	1, 1, 2, 2, 2, 2, 3, 3, 3, 4, 4, 5, 5, 5, 6, 7, 7, 7, 8, 8, 9, 9, 10, 10, 11
Decaying materials	5	12	1, 1, 2, 2, 2, 3, 3, 3, 4, 4, 4, 5, 6, 6, 7, 7, 9,
Dung	3	7	2, 2, 3, 3, 3, 5, 5, 5, 6, 7, 7

Appendix 15. Recorded basking status with time budget (seconds) of examined lycaenid butterflies.

Scientific name	No of butterfly	Place, date and time	Temp. and RH	Basking duration in different wing posture*		
				Horizontal	Angled	Closed sun
Psedozizeeria maha	4	BRP 11/12/2015 10.30-11.00	26.6°C; 43%	3, 6, 8, 10, 11, 15, 17, 19, 20, 22, 23, 29, 31, 40, 48	2, 3, 5, 6, 9, 10, 12, 13, 16, 16, 19, 21, 26, 28, 33, 37, 43, 46, 52	5, 8, 13, 17, 18, 20, 20, 25, 28, 29, 33, 33, 35, 39, 47, 48, 50, 59, 61, 63
	2	BRP 11/11/2016 10.00-10.30	28.6°C; 37%	5, 6, 9, 12, 13, 18, 22, 33, 53	2, 3, 7, 11, 12, 16, 23, 25, 32, 38, 48	10, 15, 20, 24, 27, 28, 31, 37, 40, 45
	5	CH, DU 08/05/2017 8.30-9.00	29.2°C; 50%	2, 3, 7, 9, 11, 12, 15, 16, 17, 18, 23, 26, 28, 29, 34, 38, 43	3, 5, 6, 8, 9, 12, 13, 15, 16, 17, 17, 18, 22, 23, 27, 30, 31, 33, 37, 40, 41, 43, 51	5, 7, 11, 15, 16, 17, 18, 19, 22, 23, 25, 27, 32, 33, 36, 37, 41, 43, 47, 52, 53, 55
Zizina otis	6	BRP 04/12/2015 10.30-11.00	26.8°C; 48%	2, 3, 7, 8, 17, 20, 21, 36, 37	3, 5, 7, 9, 10, 15, 24, 25, 33, 35, 47	6, 8, 10, 12, 16, 19, 20, 23, 27, 45

	5	BRP 11/12/2015 10.30-11.00	26.6°C; 43%	5, 6, 13, 18, 22, 26, 33, 54	2, 3, 11, 16, 17, 20, 25, 27, 38	3, 7, 9, 10, 12, 24, 25, 37, 46
	4	BRP 07/04/2017 9.00-9.30	31.2°C; 72%	3, 4, 17, 20, 25, 43	2, 7, 15, 18, 19, 30, 49, 53	5, 9, 11, 16, 28, 33, 55
	6	CH, DU 08/05/2017 8.30-9.00	29.2°C; 50%	2, 5, 7, 16, 19, 21, 28, 29, 39, 45	9, 13, 17, 18, 20, 23, 24, 25, 27, 32, 36, 39	8, 9, 10, 18, 21, 29, 31, 38, 40, 52
	4	CH, DU 09/05/2017 8.00-8.30	29.1°C; 45%	6, 9, 15, 17, 19, 24, 30	3, 7, 13, 16, 17, 21, 23, 36, 44	7, 13, 15, 17, 19, 23, 27, 29
Chilades lajus	6	KBP 05/09/2015 9.00-9.30	31.3°C; 71%	3, 4, 6, 7, 9, 10, 12, 13, 19, 20, 23, 24, 29, 32, 35, 41, 44	3, 5, 7, 8, 9, 10, 11, 13, 13, 15, 16, 17, 18, 20, 21, 25, 26, 36, 39, 44, 47, 48	2, 4, 5, 8, 9, 12, 13, 15, 17, 19, 22, 24, 28, 30, 35, 36, 41, 45, 58, 62
	5	KBP 31/10/2015 9.30-10.00	30.6°C; 65%	4, 8, 9, 11, 15, 16, 18, 23, 27, 36, 40, 48	3, 5, 6, 7, 9, 13, 14, 17, 18, 20, 21, 25, 33, 41	3, 5, 7, 8, 10, 11, 12, 14, 15, 22, 27, 34, 37, 43, 50
	6	RKS 03/12/2016 10.30-11.00	26.2°C; 46%	2, 5, 8, 8, 10, 15, 16, 17, 17, 18, 20, 22, 23, 25, 28, 38, 47, 49, 54	6, 7, 9, 9, 12, 13, 15, 18, 23, 24, 25, 27, 30, 33, 35, 40, 44, 52, 53	3, 4, 5, 7, 9, 12, 13, 14, 16, 17, 20, 26, 27, 36, 39, 43, 47, 52, 53
	4	BRP 07/04/2017 9.00-9.30	31.2°C; 72%	6, 8, 9, 10, 12, 16, 18, 22, 25, 33	3, 5, 9, 10, 15, 16, 17, 20, 23, 27, 32	3, 5, 5, 6, 8, 10, 13, 21, 25, 26, 33, 34
C. pandava	3	BG, BAU 27/10/2015 3.30-4.00	31.7°C; 66%	3, 5, 6, 7, 10, 11, 17, 19, 27, 37, 41, 48, 53	3, 6, 7, 9, 13, 14, 23, 24, 31, 34, 48, 51	3, 5, 8, 9, 12, 13, 17, 21, 26, 30, 35, 38, 46, 49, 61
	6	BG, BAU 11/11/2016 12.30-1.00	31.9°C; 53%	2, 6, 7, 9, 10, 12, 15, 15, 20, 21, 25, 27, 28, 29, 33, 35	3, 5, 5, 7, 10, 11, 16, 17, 18, 19, 23, 26, 27, 28, 30, 35, 38, 41	5, 6, 8, 12, 13, 16, 17, 20, 22, 24, 27, 37, 40, 44, 48, 52, 53
	5	BG, BAU 18/11/2016 2.00-2.30	30.5°C; 51%	3, 7, 8, 8, 12, 13, 15, 16, 17, 19, 22, 24, 25, 30, 32, 36, 43, 44	3, 5, 6, 7, 9, 10, 12, 16, 17, 17, 21, 25, 27, 27, 37, 45, 52	2, 3, 5, 7, 9, 12, 14, 16, 16, 18, 19, 20, 23, 24, 27, 29, 33, 38, 41, 53, 61
Catochrysops strabo	2	CH, DU 16/03/2015 10.00-10.30	29.7°C; 64%	5, 6, 8, 9, 13, 15, 15, 19, 20, 22, 25, 29, 31, 32, 35, 36, 49, 50	3, 7, 8, 8, 9, 10, 13, 18, 19, 20, 22, 29, 30, 35, 36, 43, 44, 48, 50	8, 9, 10, 10, 17, 18, 19, 24, 25, 27, 28, 33, 33, 38, 39, 47, 48, 54, 63
	3	CH, DU 03/03/2016 10.30-11.00	30.8°C; 68%	3, 7, 8, 9, 10, 13, 17, 18, 18, 19, 27, 29, 31, 31, 32, 34, 47, 48, 52, 55, 57	5, 6, 8, 10, 10, 15, 16, 17, 18, 19, 19, 20, 23, 25, 27, 28, 30, 35, 38, 39, 42, 43, 46, 47, 54	8, 8, 10, 13, 16, 19, 20, 22, 24, 25, 26, 27, 28, 29, 33, 35, 37, 38, 40, 45, 48, 50, 52
	2	BRP 07/04/2017 9.00-9.30	31.2°C; 72%	8, 9, 10, 10, 15, 19, 20, 26, 27, 30, 31, 32, 33, 38, 45, 47, 49	5, 7, 8, 9, 16, 17, 17, 18, 19, 19, 20, 27, 28, 29, 31, 34, 37, 39, 43, 51	6, 8, 10, 15, 19, 19, 20, 23, 26, 26, 28, 30, 35, 38, 39, 48, 49, 50
Castalius rosimon	3	BRP 04/12/2015 10.30-11.00	26.8°C; 48%	5, 7, 9, 10, 15, 17, 18, 21, 22, 33, 34, 41, 43	6, 7, 9, 12, 16, 19, 20, 23, 25, 28, 29, 37, 45, 53	6, 7, 8, 9, 10, 12, 13, 15, 16, 17, 20, 22, 28, 34, 36, 44, 47, 57, 61
	2	BRP 29/01/2016 11.00-11.30	26.5°C; 47%	8, 9, 13, 16, 19, 21, 35, 37, 41, 52	5, 7, 10, 12, 23, 27, 28, 34, 44, 47	6, 7, 9, 10, 15, 17, 22, 26, 29, 38, 39, 52, 55
	3	RKS 02/12/2016 1.00-1.30	27.3°C; 46%	3, 7, 10, 12, 13, 17, 18, 22, 31, 38, 40	8, 9, 16, 17, 17, 22, 31, 34, 35, 37, 42, 55	5, 9, 12, 13, 15, 17, 19, 21, 23, 25, 26, 27, 30, 33, 38, 43,

						44, 53, 59, 62
	1	KBP 31/10/2015 9.30-10.00	30.6°C; 65%	8, 9, 11, 17, 21, 33	7, 10, 27, 38, 52	3, 7, 15, 19, 22, 36, 41, 50
Caleta decidia	3	BRP 04/12/2015 10.30-11.00	26.8°C; 48%	2, 3, 3, 4, 5, 7, 8, 15, 17, 17, 18, 18, 19, 20, 21, 21, 22, 24, 26, 32, 34, 38, 43	2, 3, 3, 4, 4, 5, 5, 6, 7, 7, 9, 10, 10, 12, 13, 13, 15, 15, 17, 19, 20, 21, 21, 22, 22, 23, 23, 32, 35, 36, 37, 39, 45, 48	2, 3, 5, 6, 9, 12, 13, 15, 15, 15, 16, 17, 18, 19, 20, 21, 22, 22, 23, 24, 25, 31, 33, 37, 42, 51
	2	BRP 11/11/2016 10.00-10.30	28.6°C; 37%	2, 3, 4, 5, 10, 14, 18, 19, 20, 21, 21, 22, 23, 34, 35, 41, 46	2, 2, 3, 4, 5, 5, 6, 9, 9, 10, 12, 13, 15, 17, 18, 19, 20, 21, 22, 22, 23, 27, 35, 37, 38, 51	2, 3, 5, 8, 10, 13, 15, 15, 16, 19, 20, 21, 22, 22, 22, 23, 33, 35, 44, 45, 52
Jamides celeno	3	ScNP 18/12/2016 2.30-3.00	28.8°C; 49%	3, 4, 5, 7, 7, 9, 10, 11, 12, 14, 15, 17, 17, 18, 21, 22, 25, 26, 29, 33, 35, 38, 43, 47, 54	3, 3, 7, 8, 10, 12, 14, 14, 15, 17, 17, 19, 20, 23, 24, 27, 32, 37, 40, 45, 48, 49, 51, 56	2, 3, 5, 7, 9, 9, 10, 12, 12, 12, 12, 16, 17, 17, 19, 20, 21, 25, 27, 28, 31, 34, 35, 45, 47, 49, 51, 58, 64, 67, 72
	2	RKS 03/12/2016 10.30-11.00	26.2°C; 46%	3, 5, 7, 8, 12, 14, 17, 18, 20, 21, 22, 26, 32, 35, 37, 40, 46, 52	3, 5, 7, 8, 10, 12, 14, 16, 17, 21, 23, 24, 25, 35, 37, 43, 49, 55	3, 3, 6, 7, 9, 10, 12, 15, 17, 19, 20, 21, 23, 27, 30, 31, 37, 39, 43, 47, 48, 54, 60
Lampides boeticus	6	CH, DU 16/03/2015 10.00-10.30	29.7°C; 64%	3, 5, 6, 8, 10, 12, 14, 15, 17, 17, 20, 21, 22, 24, 26, 28, 29, 29, 30, 32, 33, 35, 37, 43, 44, 48, 49, 51	2, 3, 4, 6, 8, 9, 11, 13, 15, 16, 16, 18, 19, 22, 24, 25, 27, 27, 29, 30, 33, 35, 36, 38, 39, 42, 44, 47, 51, 53, 58, 62	3, 4, 7, 8, 12, 12, 14, 15, 15, 17, 20, 21, 23, 23, 26, 28, 29, 33, 36, 38, 39, 45, 50
	5	CH, DU 03/03/2016 10.30-11.00	30.8°C; 68%	3, 4, 5, 8, 13, 15, 15, 17, 19, 20, 22, 24, 24, 26, 28, 30, 33, 35, 35, 39, 43, 46, 48, 51, 54	3, 5, 9, 10, 13, 14, 16, 18, 18, 19, 20, 22, 24, 25, 27, 29, 30, 31, 33, 36, 38, 40, 47, 48, 49, 55, 61	2, 3, 5, 7, 9, 12, 15, 18, 20, 24, 26, 28, 29, 33, 36, 38, 44, 47, 53
	1	BRP 07/04/2017 9.00-9.30	31.2°C; 72%	3, 9, 14, 20, 29, 37, 40	2, 6, 11, 15, 22, 25, 33, 44	4, 10, 14, 19, 23, 28, 36, 42
Euchrysops cnejus	4	CH, DU 16/03/2015 10.00-10.30	29.7°C; 64%	3, 5, 7, 8, 12, 16, 18, 19, 23, 25, 27, 29, 31, 33, 39, 43, 46, 48, 50, 52	2, 4, 6, 8, 9, 10, 13, 13, 15, 15, 17, 19, 22, 24, 26, 28, 30, 33, 36, 37, 42, 44, 45, 51	3, 5, 6, 10, 12, 14, 15, 17, 18, 19, 25, 26, 28, 29, 34, 36, 37, 56, 62
	5	CH, DU 03/03/2016 10.30-11.00	30.8°C; 68%	2, 5, 9, 11, 12, 14, 16, 18, 20, 22, 23, 23, 23, 25, 27, 28, 29, 31, 36, 37, 43, 46, 50, 51	4, 7, 7, 9, 11, 13, 15, 15, 16, 17, 18, 22, 22, 26, 27, 28, 30, 31, 35, 37, 37, 39, 44, 48, 49, 52	2, 3, 5, 8, 10, 12, 15, 16, 17, 18, 19, 21, 23, 23, 26, 28, 30, 33, 34, 37, 38, 39, 42, 45, 48, 52, 55
	2	BRP 07/04/2017 9.00-9.30	31.2°C; 72%	3, 7, 10, 12, 16, 20, 22, 27, 30, 31, 37, 39, 45	2, 4, 5, 11, 13, 15, 18, 24, 26, 28, 33, 40, 48, 52	3, 5, 8, 17, 18, 23, 26, 30, 34, 41, 42, 45
Arhopala pseudocentaurus	2	BRP 13/11/2015 9.30-10.00	26.9°C; 52%	3, 6, 10, 14, 19, 23, 25, 30, 36, 42, 47, 55, 58, 69, 72	2, 7, 9, 13, 17, 22, 27, 29, 34, 36, 38, 43, 48, 51, 57, 61	4, 8, 12, 17, 20, 23, 28, 34, 37, 40, 45, 50, 57, 66, 70
	2	BRP 11/12/2015 10.30-11.00	26.6°C; 43%	5, 8, 12, 16, 20, 27, 29, 31, 36, 39, 46, 49, 54, 59	4, 7, 10, 13, 16, 18, 22, 25, 28, 33, 37, 40, 42, 48, 55	3, 6, 13, 19, 23, 26, 29, 34, 39, 43, 48, 52, 59, 63
	3	BRP 19/02/2016	27.9°C; 44%	6, 9, 12, 14, 18, 23, 25, 27, 31, 33, 38,	5, 8, 13, 16, 18, 20, 20, 22, 25, 29, 34, 36,	4, 10, 15, 17, 19, 21, 26, 28, 32, 34, 35, 37,

		3.00-3.30		39, 45, 48, 54, 63, 65	38, 44, 45, 49, 51, 57, 58, 61	40, 43, 46, 52, 55, 60, 69, 72, 76
	2	BRP 29/01/2016 11.00-11.30	26.5°C; 47%	3, 8, 12, 15, 20, 25, 29, 34, 35, 38, 47, 51, 58	5, 9, 11, 17, 18, 24, 27, 30, 31, 37, 42, 45, 50, 54, 59	6, 10, 17, 21, 26, 29, 34, 39, 42, 46, 48, 49, 55, 63
	2	BRP 07/04/2017 9.00-9.30	31.2°C; 72%	7, 10, 11, 16, 18, 22, 28, 31, 34, 36, 39, 43, 48, 50, 60	3, 7, 15, 16, 19, 21, 25, 28, 29, 30, 36, 38, 43, 46, 50, 57	5, 12, 18, 19, 23, 26, 28, 30, 35, 37, 38, 39, 41, 46, 54
Loxura atymnus	3	BRP 11/12/2015 10.30-11.00	26.6°C; 43%	2, 5, 7, 10, 12, 18, 22, 28, 33	2, 2, 3, 5, 7, 8, 8, 13, 15, 15, 17, 19, 21, 23, 25, 27, 30, 32, 34, 37, 39, 45, 51	2, 5, 5, 5, 7, 9, 12, 13, 16, 17, 19, 21, 23, 27, 29, 31, 34, 38, 43, 47, 51
	4	BRP 11/11/2016 10.00-10.30	28.6°C; 37%	3, 4, 7, 8, 10, 13, 19, 21, 25, 29, 32, 37, 41	2, 2, 2, 5, 5, 5, 6, 7, 8, 10, 12, 13, 13, 15, 15, 17, 18, 20, 21, 22, 23, 24, 27, 28, 28, 31, 34, 37, 43, 48, 52	2, 3, 5, 5, 5, 7, 9, 10, 12, 12, 13, 14, 16, 16, 19, 22, 23, 25, 27, 30, 31, 32, 33, 37, 38, 42, 45, 50, 51, 61
Rapala manea	4	BRP 04/12/2015 10.30-11.00	26.8°C; 48%	2, 5, 8, 9, 14, 17, 20, 23, 25, 26, 29, 32, 35, 37, 39, 41, 43, 47, 48, 52, 55, 59, 65	2, 3, 5, 7, 10, 11, 14, 16, 20, 22, 23, 24, 27, 28, 31, 31, 36, 38, 42, 49, 51, 53	2, 3, 5, 6, 9, 10, 11, 14, 14, 15, 17, 18, 21, 22, 23, 25, 26, 30, 31, 33, 33, 34, 35, 36, 37, 38, 42, 45, 47, 49, 51, 53, 56, 62, 71, 74
	4	BRP 29/01/2016 11.00-11.30	26.5°C; 47%	3, 7, 10, 14, 18, 21, 23, 26, 27, 29, 32, 34, 37, 38, 40, 43, 46, 49, 53, 57, 63	2, 2, 5, 7, 8, 9, 14, 16, 18, 20, 22, 23, 25, 27, 31, 32, 33, 35, 38, 43, 51, 55	2, 3, 4, 6, 9, 11, 12, 14, 15, 18, 19, 20, 22, 23, 25, 26, 29, 31, 33, 33, 34, 35, 36, 37, 38, 42, 42, 46, 47, 50, 58, 62, 71
	3	BRP 20/01/2017 11.30-12.00	27.2°C; 49%	2, 5, 8, 11, 17, 21, 25, 29, 32, 34, 37, 38, 43, 49, 52, 62	3, 5, 5, 7, 12, 14, 19, 22, 25, 31, 33, 35, 40, 51, 53	3, 4, 7, 9, 11, 12, 14, 15, 17, 19, 19, 22, 23, 26, 27, 30, 33, 34, 36, 40, 42, 47, 51, 53
	2	BRP 19/02/2016 3.00-3.30	27.9°C; 44%	3, 5, 9, 12, 20, 23, 26, 32, 37, 41, 51	2, 5, 8, 11, 14, 16, 25, 29, 31, 32, 33, 43, 47	2, 3, 6, 8, 14, 17, 22, 26, 31, 36, 37, 42, 45, 49, 53
R. pheretima	2	BRP 04/12/2015 10.30-11.00	26.8°C; 48%	3, 6, 8, 10, 14, 16, 17, 20, 23, 25, 28, 31, 36, 39, 42, 48, 53, 57	2, 4, 7, 8, 11, 12, 15, 16, 18, 23, 24, 25, 29, 34, 38, 40, 45, 47, 52, 54	5, 8, 12, 14, 19, 21, 23, 25, 28, 32, 33, 34, 37, 39, 43, 45, 47, 48, 50, 52, 56, 59, 64
	2	BRP 29/01/2016 11.00-11.30	26.5°C; 47%	3, 7, 10, 13, 14, 17, 19, 22, 25, 29, 33, 37, 41, 48, 56	2, 4, 7, 7, 8, 11, 12, 16, 22, 23, 25, 27, 29, 34, 38, 45, 52, 57	4, 7, 10, 14, 16, 17, 20, 23, 26, 28, 30, 34, 34, 36, 41, 43, 45, 48, 52, 56, 61, 63
	2	BRP 20/01/2017 11.30-12.00	27.2°C; 49%	2, 5, 8, 13, 14, 17, 19, 20, 25, 28, 30, 36, 39, 42, 45, 52	2, 3, 5, 7, 8, 9, 12, 16, 18, 20, 23, 28, 33, 36, 39, 41, 47	3, 5, 8, 12, 14, 17, 20, 23, 25, 27, 28, 29, 32, 34, 39, 45, 45, 48, 52, 55, 61
Remelana jangala	3	BRP 13/11/2015 9.30-10.00	26.9°C; 52%	3, 5, 8, 9, 11, 13, 18, 20, 24, 25, 27, 29, 31, 33, 36, 37, 40, 42, 45, 47, 51, 53, 55, 58	2, 4, 6, 7, 9, 10, 11, 12, 13, 13, 15, 17, 19, 22, 24, 26, 28, 28, 30, 31, 33, 35, 36, 37, 42, 46, 51	2, 5, 7, 9, 11, 13, 13, 16, 16, 18, 19, 20, 22, 25, 28, 33, 36, 37, 40, 43, 45, 48, 50, 51, 51, 54, 56, 62, 66, 72
	2	BRP 04/12/2015 10.30-11.00	26.8°C; 48%	2, 5, 8, 13, 18, 22, 27, 31, 35, 38, 44, 51, 53	4, 7, 11, 13, 15, 17, 19, 22, 25, 26, 30, 33, 35, 42, 49	3, 7, 8, 10, 13, 16, 19, 22, 25, 28, 34, 39, 43, 46, 51, 55
	3	BRP 11/11/2016 10.00-10.30	28.6°C; 37%	3, 8, 10, 11, 13, 13, 15, 16, 18, 19, 24, 27, 29, 31, 33, 36, 38, 42, 47, 49, 51, 53	2, 4, 7, 8, 9, 11, 11, 12, 13, 15, 17, 17, 19, 20, 22, 22, 22, 24, 26, 28, 28, 33, 33,	2, 5, 7, 9, 11, 13, 14, 16, 16, 18, 19, 20, 22, 24, 25, 27, 31, 37, 42, 43, 45, 48, 48,

					35, 37, 37, 44, 51, 54	51, 54, 56, 57, 63, 67
Hypolycaena erylus	3	BRP 11/12/2015 10.30-11.00	26.6°C; 43%	3, 5, 6, 8, 12, 17, 22, 23, 26, 28, 30, 31, 34, 35, 37, 39, 40, 43, 46, 48, 49, 51, 54, 55, 60, 62, 64	5, 7, 9, 14, 16, 20, 21, 23, 24, 25, 27, 29, 32, 33, 34, 35, 36, 38, 39, 40, 41, 45, 47, 50, 53	6, 7, 9, 11, 14, 16, 18, 23, 23, 25, 27, 29, 31, 32, 34, 34, 36, 38, 42, 43, 43, 45, 47, 49, 51, 54, 61, 63
	2	BRP 29/01/2016 11.00-11.30	26.5°C; 47%	4, 8, 11, 15, 23, 26, 29, 31, 34, 37, 38, 42, 45, 48, 49, 51, 57, 62	3, 7, 10, 14, 18, 21, 25, 29, 34, 34, 36, 38, 42, 45, 49, 53	5, 8, 11, 14, 18, 22, 23, 27, 29, 31, 32, 34, 38, 40, 43, 45, 54
	2	BRP 20/01/2017 11.30-12.00	27.2°C; 49%	3, 6, 9, 12, 20, 23, 24, 29, 34, 35, 37, 38, 42, 46, 49, 55, 61	5, 8, 12, 17, 21, 23, 27, 29, 32, 34, 36, 40, 45, 47, 51	6, 7, 9, 13, 17, 20, 23, 25, 27, 31, 34, 37, 38, 42, 43, 47, 51, 55

***** Numerical data of basking duration has been sorting in ascending pattern.

Appendix 16. Duration of immature stages of examined lycaenid butterflies in laboratory.

Butterfly species	**N**	**IP**	**Larva**					**Pre-pupa**	**Pupa**
			1st instar	**2nd instar**	**3rd instar**	**4th instar**	**5th instar**		
Chilades lajus	1	2	2	3	2	4	-	2	6
	2	2	1	3	3	4	-	2	7
	3	3	2	2	3	4	-	1	7
	4	3	2	3	2	3	-	2	6
	5	2	1	3	3	4	-	2	7
	6	2	2	3	3	4	-	1	7
	7	3	2	3	2	3	-	1	6
	8	2	1	2	3	4	-	2	7
	9	3	2	3	3	3	-	2	6
	10	2	2	2	3	4	-	1	7
	11	2	2	2	3	3	-	2	8
	12	3	1	3	3	3	-	2	6
	13	3	2	2	2	4	-	1	7
	14	2	2	3	3	4	-	1	7
Chilades pandava	1	2	1	3	2	4	-	1	7
	2	1	2	3	2	3	-	2	6
	3	1	1	3	3	3	-	1	7
	4	2	1	2	2	3	-	2	7
	5	2	2	2	2	4	-	1	6
	6	2	2	3	2	3	-	2	7
	7	1	2	2	3	3	-	2	6
	8	2	1	2	2	4	-	1	7
	9	1	1	2	3	3	-	2	7
	10	2	1	2	3	4	-	2	6
	11	2	1	3	2	3	-	2	6
	12	2	2	3	2	3	-	2	7
	13	2	1	3	2	4	-	1	7
Catochrysops strabo	1	2	2	3	4	5	-	0.41	7
	2	2	3	2	4	5	-	0.50	7
	3	3	2	3	3	5	-	0.50	6
	4	2	3	3	3	5	-	0.41	7
	5	3	2	3	4	4	-	0.50	7
	6	3	2	3	4	5	-	0.50	8
	7	2	3	2	3	5	-	0.41	7
	8	2	2	3	4	4	-	0.41	6
	9	3	2	3	3	5	-	0.50	6
	10	2	3	2	4	5	-	0.50	7
	11	3	2	3	4	4	-	0.50	6

Remelana jangala	1	3	2	4	4	3	6	1	6
	2	2	2	3	4	4	6	2	7
	3	3	3	4	3	3	5	1	8
	4	2	3	3	3	4	6	2	8
	5	3	2	4	4	4	5	2	7
	6	3	2	4	3	3	6	2	7
	7	2	2	4	4	4	5	1	6
	8	3	3	3	3	4	5	1	7
	9	2	3	3	4	3	6	2	8
	10	2	3	4	4	3	5	2	7
	11	3	2	4	3	3	6	2	8
	12	3	2	3	4	4	6	2	7
	13	2	3	4	4	3	5	2	7
	14	3	3	4	3	4	5	1	6
	15	2	2	3	4	4	5	2	7
	16	3	2	3	4	3	6	1	8
	17	2	3	4	3	4	5	2	8
	18	3	3	3	3	4	6	1	8
	19	3	3	4	4	3	5	1	6
	20	3	2	4	3	4	6	2	7
	21	2	2	3	4	3	6	2	7
Rathinda amor	1	3	2	3	1	4	-	2	8
	2	2	2	3	2	4	-	1	9
	3	3	2	2	2	3	-	1	9
	4	3	3	2	2	3	-	2	8
	5	2	2	3	1	3	-	2	8
	6	2	2	3	2	4	-	1	9
	7	2	3	3	2	3	-	1	8
	8	2	3	2	2	3	-	2	9
	9	3	2	3	1	4	-	1	8
	10	2	3	3	2	3	-	1	8
	11	3	2	2	2	4	-	1	9

Appendix 17. Lengths of immature stages of examined lycaenid butterflies in laboratory.

Butterfly species	**N**	**Larva**					**Pre-pupa**	**Pupa**
		1st instar	**2nd instar**	**3rd instar**	**4th instar**	**5th instar**		
Chilades lajus	1	2.5	5.6	9	13	-	9.6	9
	2	2	5	9.4	13.5	-	10	9
	3	3	5.5	9.6	12.8	-	9.4	8
	4	2.2	5	9	12	-	9	8
	5	2	5.4	9	13	-	9	8
	6	3	6	10	14	-	9.8	9
	7	3	6	9	12	-	9	8
	8	2.3	5.3	9	13	-	10	9
	9	3	6	10	13	-	9.5	8
	10	2.5	5.7	9	12.4	-	9.2	8
	11	2.5	6	9.5	12.8	-	10	9
	12	2.7	5	9.5	12.5	-	9.5	8
	13	2.8	5	9	12	-	9	8
	14	2.5	6	10	14	-	10	9
Chilades pandava	1	1.5	3.8	6.2	12	-	11	10
	2	2	5	8	12	-	10	9
	3	1.7	3.1	6.5	11	-	10	9
	4	2	3.5	6.4	11	-	10	9
	5	1.8	4.7	7.5	11.4	-	11	10

	6	1.8	5	8	11.6	-	10.4	9
	7	1.5	3.5	7.2	11	-	10.2	9
	8	2	3.6	6.4	11.2	-	10	9
	9	1.7	3.1	6.6	11	-	10	9
	10	2	4.4	7.2	11.4	-	11	10
	11	1.5	3.8	6.2	12	-	11	10
	12	1.6	4.6	7.8	11.4	-	10.6	9
	13	1.7	4.2	6.6	11.6	-	10.8	10
Catochrysops strabo	1	3	6	11	16	-	11	11
	2	3.5	6	12	16	-	10.5	10.5
	3	3.5	6.5	11.5	15	-	10	10
	4	3	6	11	15	-	10	10
	5	4	7	11.5	15.5	-	10	10
	6	4	6.5	13	15.5	-	10.5	10.5
	7	3	7	11	15	-	10	10
	8	3	6	11	16	-	11	11
	9	3.5	6.5	11.5	15	-	10	10
	10	3	6	11	15.5	-	10.5	10.5
	11	3.5	6	11.5	15	-	10	10
Remelana jangala	1	2.5	6	11	15	22	13	12
	2	2.7	6.3	10.8	15.5	23.6	13	12
	3	3	7	11	16	23	14	13
	4	2.6	6.8	10.6	15.8	24	14	13
	5	3	7	11	15.5	23.4	15	14
	6	2.8	6.7	11	15	24	15	14
	7	2.5	6.5	10.8	15.5	22.4	13	12
	8	3	6.5	11	15	22.5	14	13
	9	2.8	7	11	16	24	15	14
	10	3	6.5	10.5	15.6	23.8	14	13
	11	3	7	11	15.8	24	15	14
	12	2.8	6.3	10	15.2	23.6	15	14
	13	2.7	6.2	10	15	22.8	14	13
	14	2.8	6	10	15	22	13	12
	15	2.6	6	10.2	15	22.4	13.5	12
	16	3	6.4	11	15.6	23.5	13.5	12
	17	2.7	7	10.5	15.5	23	14	13
	18	2.8	6.8	11	16	24	15	14
	19	2.5	6	10	15.5	22.5	13	12
	20	2.6	7	11	16	24	14.5	14
	21	2.6	6	10.6	15.5	23.5	13.5	13
Rathinda amor	1	1.8	5.4	7	13	-	11.2	9
	2	2.2	6	8.6	14	-	12	10
	3	2.5	5.2	8	13	-	11	10
	4	2.5	5.6	9	14	-	12	9
	5	2	4.3	7.8	12.7	-	10.5	8
	6	1.5	4.7	8.3	13.2	-	11.2	10
	7	1.8	6	9	12.4	-	10	9
	8	2.3	5.7	8.5	13.4	-	11.7	10
	9	2.2	6	8.2	12.5	-	10.2	9
	10	2.4	6	8.6	13	-	11	10
	11	2.2	4.8	7.4	12.8	-	11.2	10

Appendix 18. Proximate analysis of Rangan flowers.

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TEST REPORT

No. of Sample : 01(One)	**Ref No. :** 39.345.042.03.05.008.2016.Ad.470
Date of Receipt: 03/08/2016 Analytical Service Cell, BCSIR, Dhaka Sample No. F-1478, Dt: 03/08/2016	**Date :** 07/08/2016
Date of submission of Report: 08/09/2016	**Referred by :** Mosammat Sajeda Akond Ph D Researcher Reg. No. 25/2013-2014 Department of Zoology University of Dhaka, Dhaka-1000 Mobile no. 01712531627 **Ref. No.** : **Date :**
Particulars of Sample : Plant Parts (Rangan Flower)	

Results:

Table: Proximate composition

SL. No.	Parameters	Results
1.	Moisture (%)	11.20
2.	Ash (%)	3.31
3.	Protein (%)	7.75
4.	Fat (%)	0.79
5.	Carbohydrate (%)	76.95
6.	Energy (kcal.) g/100g	354.60

Remarks/Comments: The above results have been found in the supplied sample.

Signature of the Analyst
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Signature of the Supervisor
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Signature of the
Research Coordinator
Dr. Samina Ahmed
Research Co-ordinator
BCSIR, Dhaka.

Counter Signed by Director
Dr. Md. Zahurul Haque
Director (In-charge)
Institute of Food Science and Technology
BCSIR, Dhaka-1205.

Note:
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iv. This report is free from any legal litigation and IFST, BCSIR is not liable for any legal implication relating the report.

Appendix 19. Analysis of the amino acid contents of Lemon leaves and Rangan leaves.

জীবনের জন্য বিজ্ঞান

খাদ্য বিজ্ঞান ও প্রযুক্তি ইনস্টিটিউট
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TEST REPORT

No. of Samples : 02 (Two)	**Ref No. :** 39.345.042.03.05.022.2016.Ad.1286
Date of Receipt : 28.11.2016 Analytical Service Cell, BCSIR, Dhaka Sample No. F-2288, Date: 28.11.2016	**Date :** 30.11.2016
Date of submission of Report: 23/03/2017	**Referred by :** Mosammat Sajeda Akond, PhD Researcher Reg. No: 25/2013-2014 Department of Zoology, University of Dhaka Dhaka-1000, Bangladesh, Mobile: 01712-531627
	Ref No.
	Date :
Particulars of Samples: Amino acid contents of Lemon leaf & Rangan leaf	

Results:

Table: Amino acid contents

Sl. No.	Amino Acids	Results (%)	
		Lemon Leaf	Rangan Leaf
1.	Aspartic Acid	1.76	0.84
2.	Threonine	0.81	0.42
3.	Serine	1.18	0.49
4.	Glutamic Acid	1.65	0.68
5.	Glycine	1.82	0.79
6.	Alanine	0.98	0.52
7.	Valine	1.23	0.77
8.	Methionine	0.76	0.56
9.	Isoleucine	0.87	0.44
10.	Leucine	0.35	0.26
11.	Tyrosine	0.67	0.28
12.	Histidine	0.33	0.43
13.	Lysine	1.28	0.65
14.	Arginine	2.45	1.13

Remarks/Comments: The above results have been found in the supplied sample.

23.03.2017
Signature of the Analyst
ANJUM ZERIN RUPA
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23.03.17
Signature of the Supervisor
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23.3.17
Countersigned by Director
Dr. Md. Zahurul Haque
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Note:
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iv. This report is free from any legal litigation and IFST, BCSIR is not liable for any legal implication relating the report.

Appendix 20. Proximate analysis of Lemon leaves and Rangan leaves.

জীবনের জন্য বিজ্ঞান

খাদ্য বিজ্ঞান ও প্রযুক্তি ইনস্টিটিউট

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TEST REPORT

No. of Samples : 02 (Two)	**Ref No. :** 39.345.042.03.05.021.2016.Ad.1207
Date of Receipt : 15.11.2016 Analytical Service Cell, BCSIR, Dhaka Sample No. F-2211, Date: 15.11.2016	**Date :** 16.11.2016
Date of submission of Report: 23/03/2017	**Referred by :** Mosammat Sajeda Akond, PhD Researcher Reg. No: 25/2013-2014 Department of Zoology, University of Dhaka Dhaka-1000, Bangladesh. Mobile :01712-531627 **Ref No.** **Date :**
Particulars of Samples: Proximate composition of Lemon leaf & Rangan leaf	

Results:

Table: Proximate composition

SL. No.	Parameters	Results	
		Lemon Leaf	Rangan Leaf
1.	Moisture (%)	8.30	7.80
2.	Ash (%)	8.33	6.81
3.	Protein (%)	26.53	13.44
4.	Fat (%)	0.20	0.19
5.	Carbohydrate (%)	56.64	71.76
6.	Energy (kcal.) g/100g	285.20	288.52

Remarks/Comments: The above results have been found in the supplied sample.

Arupa 23.03.2017
Signature of the Analyst
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Mrahman 23.03.17
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23-3-17
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Dr. Md. Zahurul Haque
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Institute of Food Science and Technology
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Note:
The results reported above pertain only to the sample supplied in these laboratories.
i. This report or any part there of should not be published without prior permission of the issuing authority.
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Appendix 21. Analysis of the proximate composition and amino acid contents of Cycas leaves.

জীবনের জন্য বিজ্ঞান

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TEST REPORT

No. of Samples : 01 (One)	**Ref No. :** 39.345.042.03.05.021.2016.Ad.1196
Date of Receipt : 14.11.2016 Analytical Service Cell, BCSIR, Dhaka Sample No. F-2200, Date: 14.11.2016	**Date :** 16.11.2016
Date of submission of Report: 23/03/2017	**Referred by :** Mosammat Sajeda Akond, PhD Researcher Reg. No: 25/2013-2014 Department of Zoology, University of Dhaka Dhaka-1000, Bangladesh, Mobile: 01712-531627
	Ref No.
	Date :
Particulars of Samples: Proximate composition & Amino acid contents of Cycus leaf	

Results:

Table-1: Proximate composition

SL. No.	Parameters	Results, Cycus leaf
1.	Moisture (%)	9.10
2.	Ash (%)	4.54
3.	Protein (%)	24.06
4.	Fat (%)	0.24
5.	Carbohydrate (%)	62.06
6.	Energy (kcal.) g/100g	278.89

Table-2: Amino Acid contents

Sl. No.	Amino Acids	Results (%) , Cycus leaf
1.	Aspartic Acid	1.50
2.	Threonine	0.87
3.	Serine	0.98
4.	Glutamic Acid	1.37
5.	Glycine	1.69
6.	Alanine	1.44
7.	Valine	0.98
8.	Methionine	0.52
9.	Isoleucine	0.79
10.	Leucine	0.29
11.	Tyrosine	0.57
12.	Histidine	0.36
13.	Lysine	1.35
14.	Arginine	2.16

Remarks/Comments: The above results have been found in the supplied sample.

Rupa 23.03.2017
Signature of the Analyst
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Rahman 23.03.17
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Appendix 22. Analysis of the amino acid contents of Rangan flowers.

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TEST REPORT

No. of Samples : 01 (One)	**Ref No. :** 39.345.042.03.05.014.2016.Ad.798
Date of Receipt : 25.09.2016 Analytical Service Cell, BCSIR, Dhaka Sample No. F-1809, Date: 25.09.2016	**Date :** 27.09.2016
Date of submission of Report: 23/03/2017	**Referred by :** Mosammat Sajeda Akond, PhD Researcher Reg. No: 25/2013-2014 Department of Zoology, University of Dhaka Dhaka-1000, Bangladesh, Mobile: 01712-531627 **Ref No.** **Date :**
Particulars of Samples: Amino acid contents of Rangan Flower	

Results:

Table: Amino acid contents

Sl. No.	Amino Acids	Results (%)
		Rangan Flower
1.	Aspartic Acid	0.48
2.	Threonine	0.29
3.	Serine	0.25
4.	Glutamic Acid	0.46
5.	Glycine	0.42
6.	Alanine	0.27
7.	Valine	0.36
8.	Methionine	0.21
9.	Isoleucine	0.23
10.	Leucine	0.20
11.	Tyrosine	0.32
12.	Histidine	0.16
13.	Lysine	0.52
14.	Arginine	0.70

Remarks/Comments: The above results have been found in the supplied sample.

23.03.17
Signature of the Analyst
ANJUM ZERIN RUPA
Scientific Officer
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23.03.17
Signature of the Supervisor
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Dr. Md. Zahurul Haque
Director (In-charge)
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Note:
i. The results reported above pertain only to the sample supplied in these laboratories.
ii. This report or any part there of should not be published without prior permission of the issuing authority.
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v. This report is free from any legal litigation and IFST, BCSIR is not liable for any legal implication relating the report.

Appendix 23. Analysis of the proximate composition and amino acid contents of Arhor leaves.

জীবনের জন্য বিজ্ঞান

খাদ্য বিজ্ঞান ও প্রযুক্তি ইনস্টিটিউট

INSTITUTE OF FOOD SCIENCE & TECHNOLOGY (IFST)

BANGALDESH COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH (BCSIR)

Dr.Qudrat –I-Khuda Road, Dhanmondi, Dhaka-1205, Bangladesh

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TEST REPORT

No. of Samples : 01 (One)	**Ref No. :** 39.345.042.03.05.023.2016.Ad.1308
Date of Receipt : 30.11.2016 Analytical Service Cell, BCSIR, Dhaka Sample No. F-2308, Date: 30.11.2016	**Date :** 04.12.2016
Date of submission of Report: 23/03/2017	**Referred by :** Mosammat Sajeda Akond, PhD Researcher Reg. No: 25/2013-2014 Department of Zoology, University of Dhaka Dhaka-1000, Bangladesh, Mobile:01712-531627
	Ref No.
	Date :
Particulars of Samples: Proximate composition & Amino acid contents of Arhor leaf	

Results:

Table-1: Proximate composition

SL. No.	Parameters	Results, Arhor leaf
1.	Moisture (%)	10.10
2.	Ash (%)	4.55
3.	Protein (%)	18.53
4.	Fat (%)	0.18
5.	Carbohydrate (%)	66.64
6.	Energy (kcal.) g/100g	272.02

Table-2: Amino Acid contents

Sl. No.	Amino Acids	Results (%) , Arhor leaf
1.	Aspartic Acid	1.16
2.	Threonine	0.64
3.	Serine	0.78
4.	Glutamic Acid	0.96
5.	Glycine	1.08
6.	Alanine	0.95
7.	Valine	0.83
8.	Methionine	0.46
9.	Isoleucine	0.51
10.	Leucine	0.30
11.	Tyrosine	0.44
12.	Histidine	0.28
13.	Lysine	1.14
14.	Arginine	1.85

Remarks/Comments: The above results have been found in the supplied sample.

Rupa 23.03.2017
Signature of the Analyst
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LIST OF PUBLICATIONS

1 Md. Kowser Miah, **Sajeda Akand**, Nousheen Parven and M. A. Bashar. 2015. Developmental stages of *Lampides boeticus* (Lepidopter: Lycaenidae) and their association with the host plant *Lupinus nanus* (Fabaceae). *The Dhaka University Journal of Biological Sciences*. **24**(1): 43-52.

2 **Sajeda Akand**, M. A. Bashar and Humayun Reza Khan. 2015. Biology of gram blue butterfly, *Euchrysops cnejus* (Fabricius) (Lycaenidae: Lepidoptera) and its relationship with the phenology of host-plant (*Vignaun guiculata*: Fabaceae). *Journal of Bangladesh Academy of Sciences*. **39**(2): 241-248.

3 **Akand, S.**, S. Rahman, K. Chowdhury, M. M. Alam, G. Moula, H. R. Khan and M. A. Bashar. 2015. Behavioural activities of lycaenid butterflies and their significance with the related plants. *Journal of Biodiversity Conservation and Bioresource Management*. **1**(2): 57-66.

4 **Akand, S.**, M. A. Bashar, H. R. Khan and S. Rahman. 2016. Abundance and some behavioural aspects of lycaenid butterflies in the Butterfly Research Park at the Bhawal National Park, Gazipur. *Journal of Biodiversity Conservation and Bioresource Management*. **2**(2): 39-46.

5 Aich, U., S. Chowdhury, **S. Akand**, S. Rahman, K. Chowdhury, Z. Sultan and M. A. Bashar. 2016. Synchronization of coincidences between the life stages of *Pachliopta aristolochiae*and the phenological stages of its host plant *Aristolochia indica*. Journal of Biodiversity Conservation and Bioresource Management. **2**(2): 61-68.

6 **Akand, S.**, M. A. Bashar, S. Rahman and H. R. Khan. 2017. Morphometric variation in the species of two subfamilies of lycaenid butterflies (Lepidoptera: Lycaenidae) of Bangladesh. *Journal of Biodiversity Conservation and Bioresource Management*. **3**(1): 9-16.

7 Alam, S., M. A. Bashar, U. Aich, **S. Akand** and S. Rahman. 2017. Colonization and strategic stratification of butterfly *Pachliopta aristolochiae* (Lepidoptera: Papilionidae) and its relationship with the host plant *Aristolochia indica* (Piperales: Aristolochiaceae). *Journal of Biodiversity Conservation and Bioresource Management*. **3**(1): 45-54.

8 Sultana, S., S. Rahman, **S. Akand,** M. F. Hoque, M. S. Miah and M. A. Bashar. 2017. Butterfly probosces and their functional relations with the nectar plants in some selected forests. *Journal of Biodiversity Conservation and Bioresource Management*. **3**(1): 93-102.

9 Mumu, N. N., M. Sarker, M. R. Islam, **S. Akand** and M. A. Bashar. 2017. Some morphological aspects of Asian honey bee (*Apis cerana*) and isolation of its melittin content. *Journal of Biodiversity Conservation and Bioresource Management*. **3**(2): 77-83.

10 Kamrunnahar, **S. Akand**, S. Rahman, H. R. Khan and M. A. Bashar. 2018. Basking behaviour in some nymphalid butterflies of Bangladesh. *Journal of Biodiversity Conservation and Bioresource Management*. **4**(1): 63-72.