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Studies on biology and reproduction of butterflies (family: papilionidae) in Nilgiris Hills, Southern Western Ghats, India

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Abstract

A study was carried out to determine the development of larvae, pupae and adult of the swallowtail butterflies (Papilionidae) in captivity in Nilgiri hills. The eggs on the host plants were collected from the field and reared in the laboratory under optimum conditions of temperature and humidity. The larvae were reared in a temporary laboratory and fed on respective host plants (*Troides minos :Aristolochia indica*, *Pachliopta aristolochiae: Aristolochia indica*, *Pachliopta hector: Aristolochia indica*, *Pachliopta pandiyana: Thottea siliquosa*, *Graphium sarpedon*:*Cinnamomum camphora*, *Graphium agamemnon: Annona squamosa*, *Graphium doson: Polyalthia longifolia*, *Graphium nomius : Polyalthia longifolia*, . *Graphium antiphates: Annona zeylanica*, *Papilio demoleus: Glycosmis pentaphylla*, *Papilio polytes: Murraya koenigii*, *Papilio polymnestor: Citrus limon*, *Papilio Buddha: Clerodendrum paniculatum*, *Papilio clytia: Cinnamomum camphora*, *Papilio liomedon: Acronychia pedunculata*, *Papilio dravidarum: Glysosmis arborea*, *Papilio helenus: Glycosmis arborea*, *Papilio paris: Toddalia asiatica* and *Papilio crino: Chloroxylon swietenia).* The egg laying behaviour of the gravid female, hatching, feeding and moulting behaviour of the 5 larval instars were recorded on the respective host plants. The duration of the larval instars on the respective host plants were also recorded. The various stages of pupation up to the emergence of the adult from the chrysalis were recorded. The fecundity of individual butterflies also recorded.

Keywords: Biology, Development, Reproduction, Larva, Pupa, Adult, Eggs

Introduction

Butterflies are the most tantalizing and beautiful creatures. Among the insect group, they are often regarded as flagship species. These are perhaps the most studied and well-known insect groups. Butterflies along with moths belong to the order Lepidoptera. In terms of indicator organisms for biodiversity studies butterflies are an excellent choice as they are common almost everywhere, attractive and easy to observe. The butterfly diversity is high in the tropics compared to temperate regions of the world. Their habitat ranges from arctic to the great deserts of the world. The butterflies are divided in to two super families *viz*., Papilionoidea constitutes 11,100 species and Hesperioidea constitutes 3,650 species in the world (Scott, 1986).

Papilionidae is the smallest butterfly family with about 550 species, but has a worldwide distribution. India harbors 107 species and Peninsular India has only 19 species. Papilionidae are classified into only three sub-families, namely Baroniinae, Pamassinae and Papilioninae. Papilioninae alone occurs in peninsular

India. Members of this family have general body forms in spite of dissimilar habits and habitats. Their legs are long and slender; the head is round, narrower than the shoulders and their eyes are black. The labial palpi are small, therefore the coiled proboscis, which is long and is easily visible. The thorax is large and long, but the abdomen even longer. The body is often marked with thin longitudinal lines, which are of the contrasting colour to the body. The two sexes have similar markings with some subtle differences. All species are nectar-feeders. They are generally non-migrant species. However, two exceptions, the lime butterfly *{Papilio demoleus* L.) and crimson rose *(Pachlilopta aristolochia* F.) can occasionally form very large migratory swarms and travel long distances. Some are economically very significant species. The lime butterfly is a pest on lime. Others, for example, the Bird wings and the Peacocks (*Paris peacock)* are in trade as high-priced fancy items.

Within the Papilionidae, many families of larval host plants are utilized, although five families generally dominate the host records: Aristolochiaceae, Annonaceae, Lauraceae, Apiaceae, and Rutaceae. Notably, the swallowtail tribes Zerynthiini (Parnassiinae), Luehdorfiini (Parnassiinae) and Troidini (Papilioninae) are limited almost exclusively to feeding on Aristolochiaceae. It has been demonstrated in a number of *Aristolochia*-feeders that caterpillars are able to sequester aristolochic acids, causing both the larval and adult stages to be unpalatable to predators (von Euw *et al*., 1968).

Swallowtail suddenly disappeared from some areas in Nilgiri hills. This site appeared to be suitable habitat for the butterfly, but after several failed attempts to re-establish it, careful research showed that although Nilgiri hills itself had not been drained, the draining of the surrounding fens had led to a drop in the water table and a slow drying out of the peaty soil. This had prevented the milk parsley from growing tall - the female butterflies only chose the tallest plants to lay their eggs on. Woody plants began to invade the fen which reduced suitable swallowtail habitat. At the same time, the traditional practice of cutting the sedge (tall grasses) was being continued on the fen, but it was being cut in the summer instead of the autumn, as it used to be, and the milk parsley was being cut along with it before it could mature or set seed. Pupae were being destroyed in the cut too. So this overall reduction in the amount and suitability of the food plant had a devastating effect on the swallowtails.

While discussing the basic relationship between resource allocation during metamorphosis and mean adult nutrient intake and reproductive output in holometabolus insects; Boggs (1981) gave importance to life history studies on such insects. It is well known that butterflies feed both at adulthood and during larval life. Since, reproductive effort involves a combination of larvae-derived and adult-derived nutrients, or energy, the proportion of larvae-derived nutrients allocated to adults reproductive resources is determined during the metamorphosis.

Information on the life history of butterflies of different geographical regions of the world is to some extent available. Working with *Peiris rapae*, Petersen (1947; 1949) showed that the variations in number of generations between populations is in part inherited, and in part directly induced by differences in the environment. When specimens from different parts of Sweden were reared at a constant temperature, the frequency of bivoltinism was highest in those from the south and decreased in those from north. The frequency of bivoltinism was also higher when specimens from the same locality were reared in a high constant temperature than in a low one. Chermock and Chermock (1947) published notes on the life histories of three Floridian butterflies. Clark and Dickson (1952; 1971) detailed the life history of South African butterflies. Shirozu and Hara (1960-62) provided the coloured pictures of the early stages of Japanese butterflies. Malicky (1969) surveyed the larval morphology of Central European lycaenids based on the morphology, colouration and host plants. Information on the life histories and early stages of macrolepidoptera of the continental United States and Canada is available (Tietz, 1972).

Some observations of the life cycle *of Heliconius xanthocles* in the fields of Colombia were made. This species lays eggs in clumped pattern. Its larval host is *Passiflora praecutta* (Mallet and Jackson, 1980). The duration of basic life cycles of a butterfly from egg to adult varies from 3 weeks (Harvester) to 2 years (Macoun's Arctic) in the Eastern United States (Opler and Krizek, 1984). In the far North or Alpine zones the majority of species have a single brood armually. By contrast, majority of species in the tropical zones are multivoltine. Accordingly, there is a change in proportion of broods in a north-south sequence of localities in the United States. The number of generation increases as one goes to southward. Holdren and Ehrlich (1984) described the life stages of the Montane butterfly *Euphydryas gillettii.* This butterfly undergoes unusual developmental flexibility in that it can diapause at second, third or fourth instar, depending on the climatic conditions. *Euphydryas chalcedona* is univoltine (Murphy *et al*., 1984)

Scott (1986) produced the last instar larval key to the families, sub-families and some tribes of North American butterflies. The life history and early stages of double brooded *Colias blameyi* (Pieridae) are described by Shapiro (1989) in the introduction to the paper; Shapiro writes that published information on the life history and early stages is also available for *Colia lesbia.* Ballmer and Prati (1988) surveyed the biology and last instar larval morphology of 69 species of California lycaenids. The duration of life cycle (from egg to adult) of each species of *Philiris* is about one month; it is 54 days in *T. myops,* 60 days in *T. onolaus.* The butterflies *Ochlodes uenata, Pyronia tithonus, Maniola jurtina* and *Aphantopus hyperantus* are univoltine and their larvae feed on grasses. *Lycaena phlaeas* and *Polyommatus icarus* are usually bivoltine (Pollard, 1991).

Owen (1971) summarized the information on life history of butterflies inhabiting the tropical regions of the world, particularly of the African continent. He has recorded the differences in the generation time between the butterflies in the tropics and their counterparts in the temperate zones of the world. In the tropics, most butterflies complete their life cycle within a short duration and produce nearly 12 generations per year. By contrast, the temperate species breed once or in some cases twice a year. Thus, it appears that the tropical species are multivoltine whereas the temperate ones are mostly uni or bivoltine. Consequently, most of the common butterflies occur almost throughout the year in the tropics. *Danaus chrysippus* has the fastest generation time, and in tropical Africa its generation time (egg-to-egg) is slightly less than a month, producing about 12 overlapping generations a year with no diapause (Owen, 1971; Edmunds, 1976). In India, this species passes through 5 instars in 9 days at 32°C, with the final instar lasting for 2 - 3 days (Mathavan and Pandian, 1975). The duration and other morphological parameters of different life stages of the butterfly *Cethosia biblis* on its food plant *Passijlora racemosa* is given by Bhuyan *et al.* (2003). In winter months in Assam, its egg life lasts 12, total larval period 55, pupal period 18, and adult life 18 days respectively.

In India, Bell (1909 to 1927) in a series of papers describing the common butterflies of some plains of India, published notes on the egg, larva and pupa of 238 butterfly species. The work of Bell and others on the early stages of Indian butterflies was compiled by Pant and Chatterjee (1950). However, as many experts observed, little is known of early stages of Indian butterflies (Kunte, 2000).

Atluri *et al*, (2002; 2004) studied life history parameters and larval performance of some butterfly species at Visakhapatnam. They reported the complete details of some Papilionid butterflies. They documented that *Papilo polytes* is a multivoltine, and produces 11 to 12 generations in a year with better reproductive performance during the months of August and February. Venkata Ramana *et al.* (2004) provided the life cycle details of the Tailed jay butterfly, *Graphium agamemnon menides*, from their observation, they supported the involvement of butterfly in pollination.

Very little work on the biology and life history has been done in India on the three species of *Graphium* i.e., G. *agamemnon,* G. *doson* and G. *nomius.* Yet whatever information collected about their life stages are given here. Information on the biology and life history of a few other papilionid butterflies are also documented here. According to Davidson and Aitken (1890) the larva of G. *doson* resembles closely with that of G. *agamemnon* but the second pair of spines is lacking and the third pair, which in G. *agamemnon* is rather long, curved and sharp is reduced to mere knobs encircled with a black ring. The colour is generally black or smoky until the last molt when it becomes dull green, inclining to rusty brown on the sides, but some specimens remain quite black throughout. Further they observed that the distinguishing mark of the pupa was the frontal horn, which is straight as in G. *agamemnon,* but directed forward instead of being almost erect. Its colour is normally green, but varies with that of the object to which it remains attached.

Materials and Methods

Study area

The study was carried out in Nilgiri hills of Nilgiri Biosphere Reserve, Southern Western Ghats, Tamilnadu, India. Nilgiri are a range of mountains forming a part of Western Ghats which is located in the western part of Tamilnadu, state at the junction of Karnataka and Kerala in southern India. At least 24 of the Nilgiri Mountains's peak above 2000 mts, the highest peak being Doddabetta at 2637 mts. The hills are separated from the Karnataka plateau to the north by the Moyar River and from the Anaimalai Hills and Palni Hills to the south by the Palghat Gap. The Nilgiris District of Tamil Nadu lies within these mountains. Its latitudinal and longitudinal dimensions are 130 km (Latitude: 11° 08' to 11° 37' N) by 185 km (Longitude: 76° 27' E to 77° 4' E). Central location is: 11°22′30″N 76°45′30″E. It has an area of 2,479 square kilometres.

Life cycle of Butterflies

Based on the field observations as to the breeding season, fresh eggs were collected with the plant material on which they were deposited without causing any disturbance to them in order to study the different life stages .The eggs with the material bearing them were kept in the Petri dishes (9.5 cm) diameter, brought to the laboratory, and incubated at room temperature (28±2) irrespective of the number of eggs laid, only one leaf was kept in each Petri dish. To avoid drying of the feeding leaves, the inside of the Petri dish was lined with a moistened filter paper. The eggs thus kept in the Petri dishes was examined at 6 hour intervals daily to record the time of their hatching and hatching success, larval development, survival, pupal development and adult emergence.

The length of each life stage (egg, larva and pupa) and the associated characters were noted. These data were recorded through out the season of adult activity the feeding behavior of the newly hatched larvae, particularly their feeding on the emptied egg shell or other wise was noted the young larvae was subsequently fed with the leaves of the plants utilized by the corresponding adults females for laying eggs . Fresh and clean leaves, which were relatively young, given as food to the larvae. Food was changed daily and the Petri dishes were kept clean by removing the feed waste including the faecal matter of the larvae.

As the larvae grew they required more space, increased space was provided by transferring the larvae to Petri dishes of bigger diameter (15.5 cm). Transfer was carried with the help of a camel hair brush and by the casting of the skin, the number of instars was determined.

Results

Butterflies have complete metamorphosis and the life history strategy of each species tends to represent an optimum use of resources in climate which are seasonally variable and which may restrict periods of activity. Information on the biology of butterflies is essential in conservation programmes. Biology of 19 species of Swallowtails *viz., Troides minos, Pachliopta aristolochiae, Pachliopta hector, Pachliopta pandiyana, Graphium sarpedon, Graphium agamemnon, Graphium doson, Graphium nomius, Graphium antiphates, Papilio demoleus, Papilio polytes, Papilio polymnestor, Papilio Buddha, Papilio clytia, Papilio liomedon, Papilio dravidarum, Papilio helenus, Papilio paris* and *Papilio crino* has been worked out. Data pertaining to the duration of various larval instars, pupae, adult and number of eggs was recorded (Table 1 to 4).

Table 1 shows the larval growth and development of *Papilionidae* butterflies. There are five larval instars. The duration of various larval instars are presented in Table 1. The larval duration of I,II, III, IV and V instar larvae of *Troides minos* was 5.28, 5.46, 4.43, 4.82, 5.54 days, *Pachliopta aristolochiae* was 2.46, 3.85, 3.82, 3.45,4.15 days, *Pachliopta hector* was 4.62, 3.61, 3.58, 3.29, 4.85days, *Pachliopta pandiyana* was 4.21, 3.54, 4.13, 4.31, 4.89 days, *Graphium sarpedon* was 2.98, 2.34, 2.21, 3.95, 4.35 days, *Graphium agamemnon* was 3.10, 3.11, 3.32, 3.54, 4.92 days, and *Graphium doson* was 3.12, 2.35, 3.26, 4.15, 5.24 days respectively. The larval duration of I,II, III, IV and V instar larvae of *Graphium nomius* was 3.95, 4.12, 4.35, 4.78, 5.12 days, *Graphium antiphates* was 2.53, 2.52, 2.55, 3.08, 7.01 days, *Papilio demoleus* was 2.68, 2.01, 2.02, 2.51, 4.05 days, *Papilio polytes* was 1.62, 2.61, 2.65, 4.32, 3.21 days, *Papilio polymnestor* was 3.01, 3.04, 4.15, 4.13, 5.23days, *Papilio Buddha* was 3.85, 3.58, 4.12, 4.85, 5.21 days, *Papilio clytia* was 3.25, 2.05, 2.13, 3.15, 4.20days, *Papilio liomedon* was 5.25, 4.05, 5.13, 4.15, 3.20 days, *Papilio dravidarum* was 3.12, 3.25, 4.86, 4.06, 5.24 days, *Papilio helenus* was 4.12, 3.85, 4.14, 4.36, 5.04 days, and *Papilio paris* was 3.85, 3.98, 4.45, 4.56, 5.25 days, *Papilio crino* was 4.96, 3.10, 3.36, 4.56, 5.21days respectively.

Table 1. Larval duration of Papilionidae butterflies in the laboratory

Butterfly species	Rearing plants	Larval Stages (Instars)/Days				
		I	II	III	IV	V
Troides minos	*Aristolochia indica*	5.28	5.46	4.43	4.82	5.54
Pachliopta aristolochiae	*Aristolochia indica*	2.46	3.85	3.82	3.45	4.15
Pachliopta hector	*Aristolochia indica*	4.62	3.61	3.58	3.29	4.85
Pachliopta pandiyana	*Thottea siliquosa*	4.21	3.54	4.13	4.31	4.89
Graphium sarpedon	*Cinnamomum camphora*	2.98	2.34	2.21	3.95	4.35
Graphium agamemnon	*Annona squamosa*	3.10	3.11	3.32	3.54	4.92
Graphium doson	*Polyalthia longifolia.*	3.12	2.35	3.26	4.15	5.24
Graphium nomius	*Polyalthia longifolia.*	3.95	4.12	4.35	4.78	5.12
Graphium antiphates	*Annona zeylanica*	2.53	2.52	2.55	3.08	7.01
Papilio demoleus	*Glycosmis pentaphylla*	2.68	2.01	2.02	2.51	4.05
Papilio polytes	*Murraya koenigii*	1.62	2.61	2.65	4.32	3.21
Papilio polymnestor	*Citrus limon*	3.01	3.04	4.15	4.13	5.23
Papilio Buddha	*Clerodendrum paniculatum*	3.85	3.58	4.12	4.85	5.21
Papilio clytia	*Cinnamomum camphora*	3.25	2.05	2.13	3.15	4.20
Papilio liomedon	*Acronychia pedunculata*	5.25	4.05	5.13	4.15	3.20
Papilio dravidarum	*Glysosmis arborea*	3.12	3.25	4.86	4.06	5.24
Papilio helenus	*Glycosmis arborea*	4.12	3.85	4.14	4.36	5.04
Papilio paris	*Toddalia asiatica*	3.85	3.98	4.45	4.56	5.25
Papilio crino	*Chloroxylon swietenia*	4.96	3.10	3.36	4.56	5.21

The table 2 shows the duration of pupal stage of *Troides minos* in this study is 35.32 days, *Pachliopta aristolochiae* is 12.85 days, *Pachliopta hector* is 12.45 days, *Pachliopta hector* is 12.45 days, *Pachliopta pandiyana* is 10.32 days, *Graphium sarpedon* is 10.65 days, *Graphium agamemnon* is 13.25 days, *Graphium doson* is 9.24 days, *Graphium nomius* is 8.25 days, *Graphium antiphates* is 12.58 days, *Papilio demoleus* is 9.25 days, of *Papilio polytes* is 15.25 days, *Papilio polymnestor* is 20.12 days, *Papilio* is 13.45days, *Papilio clytia* is 12.34 days, *Papilio liomedon* is 15.21days, *Papilio dravidarum* is 18.23 days, *Papilio helenus* is 13.57 days, *Papilio* is 16.54 days and the pupal stage of *Papilio crino* in this study is 6.52 days.

Table 2. Pupal duration of Papilionidae butterflies in the laboratory

Butterfly species	Rearing plants	Pupal duration (days)
Troides minos	*Aristolochia indica*	35.32
Pachliopta aristolochiae	*Aristolochia indica*	12.85
Pachliopta hector	*Aristolochia indica*	12.45
Pachliopta pandiyana	*Thottea siliquosa*	10.32
Graphium sarpedon	*Cinnamomum camphora*	10.65
Graphium agamemnon	*Annona squamosa*	13.25
Graphium doson	*Polyalthia longifolia.*	9.24
Graphium nomius	*Polyalthia longifolia.*	8.25
Graphium antiphates	*Annona zeylanica*	12.58
Papilio demoleus	*Glycosmis pentaphylla*	9.25
Papilio polytes	*Murraya koenigii*	15.25
Papilio polymnestor	*Citrus limon*	20.12
Papilio Buddha	*Clerodendrum paniculatum*	13.45
Papilio clytia	*Cinnamomum camphora*	12.34
Papilio liomedon	*Acronychia pedunculata*	15.21
Papilio dravidarum	*Glysosmis arborea*	18.23
Papilio helenus	*Glycosmis arborea*	13.57
Papilio paris	*Toddalia asiatica*	16.54
Papilio crino	*Chloroxylon swietenia*	6.52

In the laboratory culture, the adults of both the sexes had emerged. The adults were observedto emerge from the chrysalis by splitting open the case vertically on the dorsal side. The time taken for emergence was recorded between 60-120 minutes. Although both the sexes were closely identical, the extended tail of the hind wings were observed to be comparatively pointed in females and more or less rounded in males. Adult duration of *Troides minos* extend upto 36.35 days of male and 92.52 days of female (Table 3), duration of *Pachliopta aristolochiae* extend upto 8.47 days of male and 12.32 days of female, *Pachliopta hector* extend upto 10.32 days of male and 15.45 days of female, *Pachliopta pandiyana* extend upto 6.23 days of male and 10.14 days of female, *Graphium sarpedon* extend upto 6.52 days of male and 10.25 days of female, *Graphium agamemnon* extend upto 6.45 days of male and 10.35 days of female, *Graphium doson* extend upto 7.45 days of male and 11.35 days of female, *Graphium nomius* extend upto 8.47 days of male and 10.58 days of female, *Graphium antiphates* extend upto 8.24 days of male and 12.35 days of female, *Papilio demoleus* extend upto 10.21 days of male and 14.52 days of female, *Papilio polytes* extend upto 4.24 days of male and 8.56 days of female, *Papilio polymnestor* extend upto 6.45 days of male and 10.25 days of female, *Papilio Buddha* extend upto 8.24 days of male and 12.45 days of female, *Papilio clytia* extend upto 7.21 days of male and 11.34 days of female, *Papilio liomedon* extend upto 8.25 days of male and 12.85 days of female, *Papilio dravidarum* extend upto 8.21 days of male and 12.25 days of female, *Papilio helenus* extend upto 10.41 days of male and 14.68 days of female, *Papilio paris* extend upto 12.47 days of male and 16.78 days of female andthe adult duration of *Papilio crino* extend upto 10.12 days of male and 14.25 days of female.

Table 3. Adult duration of Papilionidae butterflies in the laboratory

Butterfly species	Rearing plants	Adult duration (days)	
		Male	Female
Troides minos	*Aristolochia indica*	36.35	92.52
Pachliopta aristolochiae	*Aristolochia indica*	8.47	12.32
Pachliopta hector	*Aristolochia indica*	10.32	15.45
Pachliopta pandiyana	*Thottea siliquosa*	6.23	10.14
Graphium sarpedon	*Cinnamomum camphora*	6.52	10.25
Graphium agamemnon	*Annona squamosa*	6.45	10.35
Graphium doson	*Polyalthia longifolia*.	7.45	11.35
Graphium nomius	*Polyalthia longifolia*.	8.47	10.58
Graphium antiphates	*Annona zeylanica*	8.24	12.35
Papilio demoleus	*Glycosmis pentaphylla*	10.21	14.52
Papilio polytes	*Murraya koenigii*	4.24	8.56
Papilio polymnestor	*Citrus limon*	6.45	10.25
Papilio Buddha	*Clerodendrum paniculatum*	8.24	12.45
Papilio clytia	*Cinnamomum camphora*	7.21	11.34
Papilio liomedon	*Acronychia pedunculata*	8.25	12.85
Papilio dravidarum	*Glysosmis arborea*	8.21	12.25
Papilio helenus	*Glycosmis arborea*	10.41	14.68
Papilio paris	*Toddalia asiatica*	12.47	16.78
Papilio crino	*Chloroxylon swietenia*	10.12	14.25

In laboratory conditions it was observed that a gravid female of *Troides minos* laid 32 eggs, *Pachliopta aristolochiae* laid 118 eggs, *Pachliopta hector* laid 42 eggs, *Pachliopta pandiyana* laid 58 eggs, *Graphium sarpedon* laid 112 eggs, *Graphium agamemnon* laid 103 eggs, *Graphium doson* laid 115 eggs, *Graphium nomius* laid 85 eggs , *Graphium antiphates* laid 42 eggs, *Papilio demoleus* laid 48 eggs, *Papilio polytes* laid 185 eggs, *Papilio polymnestor* laid 36 eggs, *Papilio buddha* laid 32 eggs, *Papilio clytia* laid 98 eggs, *Papilio liomedon* laid 420 eggs, *Papilio dravidarum* laid 120 eggs, *Papilio helenus* laid 480 eggs, *Papilio paris* laid 88 eggs and *Papilio crino* laid 92 eggs (Table 4).

Table 4. Fecundity of Papilionidae butterflies in the laboratory

Butterfly species	Rearing plants	Fecundity (Nos. of Eggs)
Troides minos	*Aristolochia indica*	32
Pachliopta aristolochiae	*Aristolochia indica*	118
Pachliopta hector	*Aristolochia indica*	42
Pachliopta pandiyana	*Thottea siliquosa*	58
Graphium sarpedon	*Cinnamomum camphora*	112
Graphium agamemnon	*Annona squamosa*	103
Graphium doson	*Polyalthia longifolia.*	115
Graphium nomius	*Polyalthia longifolia.*	85
Graphium antiphates	*Annona zeylanica*	42
Papilio demoleus	*Glycosmis pentaphylla*	48
Papilio polytes	*Murraya koenigii*	185
Papilio polymnestor	*Citrus limon*	36
Papilio Buddha	*Clerodendrum paniculatum*	32
Papilio clytia	*Cinnamomum camphora*	98
Papilio liomedon	*Acronychia pedunculata*	420
Papilio dravidarum	*Glysosmis arborea*	120
Papilio helenus	*Glycosmis arborea*	480
Papilio paris	*Toddalia asiatica*	88
Papilio crino	*Chloroxylon swietenia*	92

Discussion

Investigations on the biology of 19 species of Papilionid butterflies in the laboratory have revealed that survival of butterflies in the wild depends on the availability of foraging area, freedom from natural enemies and availability of conducive environment for courtship. This highlights the significance of site amelioration programmes in enhancing butterfly population in specific habitats.

In the present study the total development time from egg laying to adult eclosion was determined. This behavior is in line with the expectation of tropical butterflies to have a short life cycle, and multiple broods over the year (Owen, 1971). Since temperature influences instar duration and the overall development time (Mathavan and Pandian, 1975; Palanichamy *et al*., 1982; Pathak and Pizvi, 2003; Braby, 2003), the brood number in other parts of *A. merione merione* distribution may vary from our records depending on the prevailing temperatures. As no temperature extremes occur at Jammu, especially at the Jammu University site, the duration of life cycle did not vary much over the overlapping seasons. Adult feeding on the damaged and ripened fruit helps them obtain proteins and carbon sources (Levey and Del Rio, 2001), with such nutrient uptake improving egg productivity (Fischer *et al*., 2004).

In the present study the hatchability of eggs is influenced by the tempereature. Certain factors seem to have effects on hatchability and hatching time of the eggs. According to Novak (2000), at a temperature of 25°C, butterfly eggs take two to three days to hatch, but at 10°C the time is considerably longer, up to a few weeks or months. Humidity also affects the hatching time where eggs take longer to hatch in high humidity conditions. The hatching time of about 3 days for eggs in this study shows similar values with hatching times in other studies elsewhere. For example, Atluri *et al*., (2002) reported a time of about 3 days for eggs 50 in India and Chen and Ouyang (2007) also reported a hatching time of around 3 days for eggs of this species in Taiwan.

In the present study the larval duration varies. This is slightly less than the larval period reported by Chen and Ouyang (2007) of 20.3 + 0.3 days in Taiwan. Munir (2004) reported that the duration of the larval stage up to the 5th instar for this species in Pakistan is in the range of 12.5 to 17.5 days. We attribute these discrepancies to different climatic conditions and mainly to diet differences. The larvae raised by Chen and Ouyang (2007) were fed with leaves of *Citrus sunki* only, those reared by Munir (2004) were given a combination of citrus and *Murraya* leaves, while our larvae fed on *Murraya* leaves only. It would be interesting to see what the duration of the larval period would be if Malaysian larvae were fed on different leaf diets. The duration of the pupal stage in this study's range from 6.52 to 35.32 days. This is also slightly different from those reported by Chen and Ouyang (2007) of 10.2 + 0.1 days, and Munir (2004) of 9.5 to 25 days range. Again we believe that these are regional differences brought about by the interplay of climate, weather and diets.

Eggs were mostly oviposited on the underside of host plant leaves, to protect from exposure to high rainfall and also as a precautionary measure from predators (Suwarno, 2010). Organisms that prey on eggs are spiders (*Oxyopes* spp.), red ant (*Seleonopsis* sp.) and parasitoid (*Ooencyrtus papilioni*) in the butterfly house. Freshly laid eggs are 1.056 mm in mean diameter and are lemon yellow in colour, whereas eggs 51 that failed to hatch will have a gray colouration. The eggs hatch in about three days' time and the newly hatched larva will consume the egg case to retain the nutrients and obtain nourishments from the case (Anon, 2011). The length of the larva at this stage (first instar) is about 3 mm. The larva will start eating the leaves immediately after that. They will usually eat up the shed skin a few minutes after each molting process.

Mature fifth instar larvae are ready to form the pupa. At this stage they usually excrete soft and watery stools as opposed to dry and grainy stools in the other stages. Then at the onset of pupation their body will be compressed and silk threads produced by the silk glands will extrude from the anus and be wound round the abdomen of the larvae. This is then followed by the production of more silk threads from the mouth to fasten and anchor itself to the stem. This is termed the pre-pupal stage. The larva will be in this fixed position for anything from 15 to 18 hours until its skin becomes dry. Then the pupa takes form in three minutes as it shed its dried outer skin.

The pupa of Papilionidae is torpedo-shaped as viewed from the lateral part. Two colour forms of pupa are present namely light green and light brown. This stage will last for about few days, wherein the pupal skin will turn slightly transparent and the dark wing colour can be ascertained through the semitransparent skin. At the end of metamorphosis, the adult butterfly will move and wiggle to break the cocoon and the adult form will slowly crawl out of the skin in about 10 to 15 minutes. After 1 or 2 hours, the adult butterfly will be able to fly and hunt for food.

The females were observed to repeatedly visit the host-plants and tried to probe the leaves for ascertaining their suitability for egg laying like the tender nature of the leaves and availability of shade. After repeatedly flying around the host – plant for about 5-8 minutes, a female was observed to lay eggs, one in each of the tender leaves. During egg laying, the forewings were observed to be continuously fluttering and it took about 5 seconds to lay a single egg. The female under observation laid only 2 eggs within a time span of 30 seconds. The female repeatedly tested similar-shaped leaves before finally selecting the underside of suitable tender leaves in a shady damp place for egg laying. This species was observed to lay the eggs singly as is the case with most papilionid butterfly species (Stamp, 1980). The single egg-laying habit has an advantage in that it averts the possibilities of larval saturation by resource exhaustion and enables effective utilization of isolated plants (Davies and Gilbert, 1985).

The Common Rose is of conservation interest because of its relatively short life cycle as is characteristic of the tropical butterfly species (Opler and Krizek, 1984, Owen, 1971). There was nearly 100% survival of the larvae on the host plant leaves in the laboratory and as a monophagous feeder it is easier to rear such species in the laboratory. As described in the earlier records of Evans (1932) the status of this species was 'Very Common'. However the present status is not known and one of the major threats has been habitat destruction caused by human activities like logging for firewood collection by the forest villagers, burning down of forests for shifting agriculture which is in fact one of the major threats to declining butterfly diversity in North east India and stone quarrying activities. Majority of the hill forests in Northeast India are under severe threat due to practice of shifting agriculture (Jhum cultivation). Activities of private collectors engaged in the illegal trade in butterflies from the Eastern Himalayan region is also posing a major threat to the decline in the Papilionidae diversity in Northeast India. The earlier records of Evans (1932) and Talbot (1939) had documented 65 species of Swallowtail butterflies in the Eastern Himalayas out of which the status of nearly 40 species was Common. However there is a lack of recent documentation of the local butterfly assemblage. Declining tropical forest cover in Southeast Asia including Northeast India could be an indication of the declining butterfly diversity in North-east India as particularly the swallowtail butterflies are predominantly forest dwelling (Collins and Morris, 1984) and the IUCN has identified the entire Northeastern region as a

"Swallowtail-rich Zone" under the "Swallowtail Conservation Action Plan, 1984 (New,1991).

The biology of this species with respect to egg-laying and larval development is dependant on the host-plants *Aristolochia indica* and *Aristolochia tagala* belonging to the plant family Aristolochiaceae. This weak creeper is found in both closed and scattered or open forests and is associated with both shrubs in scattered forests or open forest patches and tall trees in closed forests with canopy > 70%. This plant is an endemic species in tropical South east Asia. Although most of the red-bodied swallowtails are canopy species, *Pachliopta aristolochiae* is an under-storey species and the females prefer the tender leaves in the under-storey for egg laying. The abundance of this swallowtail species is therefore dependant on the distribution of *Aristolochia* species as well as on the availability of the adult nectar sources. Observations on the adult food-plant resources of *P. Aristolochiae aristolochiae* in the field showed that it utilized nearly 14 species of flowering shrubs and trees for harvesting nectar and species like *Lantana camara*, *Hibiscus rosa sinensis* and *Nerium indica* were observed in year long flowering condition.

Observations made on the behavioural aspects have shown that butterflies demonstrate complex behaviour of foraging, patrolling and oviposition. Oviposition behaviours involved the repeated visits of the females to the hostplants and probing the leaves for ascertaining conditions suitabile for egg laying like the tenderness of foliage and the availability of protected environment. In many cases, egg laying commences only after repeatedly flying around the host plants for about 5-8 minutes. During oviposition, the female continuously flutters its forewings and it takes only about 5 seconds to lay the egg. A complex sequence of behaviour, utilizing a range of stimuli, may be involved foe locating the right oviposition site (Courtney and Chew, 1987).

Considering the relative immobility of caterpillars, the selection of oviposition sites assumed to be the crucial process. Of the 19 species of Papilionids observed, all of them were found to lay their eggs singly. The single egg-laying habit has an advantage in that it averts the possibilities of larval saturation by resource exhaustion and enables effective utilization of isolated plants (Davies and Gilbert, 1985). Of the various types of behavior covered in this study, patrolling was noted to be very pronounced in Papilionidae which is an attempt to enforce monopoly over the area for mate and resources. The Southern Birdwing, Blue Mormon, Red Helen and Malabar Banded Peacock exhibited patrolling behaviour and they were found to chase away the rival males. Butterflies are known to make use of 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 (Dobson, 1994). In certain cases, flowers of particular plants are more preferred by particular butterfly species and flower constancy is sometimes prominent (Goulson *et al*., 1997). Most of the Swallowtails preferred the blossoms of *Pentas*, *Ixora*, *Clerodendrum paniculatum* L., *Marigold*, *Cuphea*, *Zinnia*, *Lantana camara* and *Mussaenda* for nectaring. Tt was also observed that most of the Swallowtails preferred red coloured flowers for nectaring. Flower constancy, which varies with both the species of butterfly and the species of plant, appears to be an outcome of learning through the recognition of rewarding flowers (Lewis and Lipani, 1990). Flight behaviour of Swallowtails was very interesting. Birdwings generally soar slowly and royally on the tops of trees, the Jays skip quickly and suddenly from flower to flower, the Peacocks fly swiftly in the canopy and others such as the Red Helen and Mormons have a lazy flight. However, all of them have the ability for rapid progression if any danger threatens them.

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