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LIFE HISTORY PARAMETERS AND LARVAL PERFORMANCE OF SOME SOUTH INDIAN BUTTERFLY SPECIES[1]

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Life history parameters, such as pattern of egg laying, hatching, larval and pupal period and the total period from egg to emergence of adult of 14 butterfly species, distributed at Visakhapatnam are described. Larval performance with respect to consumption index (CI) and growth rate (GR), and estimation of nutritional indices like approximate digestibility (AD), efficiency of conversion of digested food (ECD) and efficiency of conversion of ingested food (ECI) is presented.

Acraea terpsicore and *Anaphaeis aurota* lay eggs in clusters, and the other 12 species lay single eggs. The hatching, larval and pupal periods, and ultimately the total period for the development of egg to the emergence of adult are longer (40-48 days) in *Pachliopta hector* and *P. aristolochiae* than in other Papilionids, and taxonomic groups. The larvae of each of the 14 species pass through five instars, and the last two instars have a major share of the total food consumed over the entire larval period. The consumption index (CI) values of these two instars ranged from 0.60 to 3.50. Among the five instars, the first shows the highest CI in all the 14 species and the values tend to decrease progressively through the successive instars. The AD values and food consumption are inversely related. The AD value is highest in the first instar and lowest in the fifth instar, the values ranging from 86 to 99.5%. The ECD values show a general decrease from the early to the late instars. The ECI values range from 19-60% for *Anaphaeis aurota* and from 2-34% for others, with most falling between 10% and 20%.

Key words: Butterflies, life history, larval performance, nutritional indices, conservation

INTRODUCTION

Over billions of years, evolution has established a balance in the ecological functioning of various organisms. However, as human societies developed and flourished, considerable disturbance and destruction of habitats of various organisms, resulted in the decline and extinction of several species. Butterflies considered as beneficial insects are no exception to the adverse effects of human civilizations. They are important natural resources as they (1) help in pollination, a key process in natural propagation, (2) are important ecological indicators as they are closely associated with plants both as adults and as larvae, (3) have an important place in the web of life, and (4) enhance the aesthetic value of the environment by their exquisite wing colours. Hence, there is an increasing global interest in conserving and managing butterflies (New *et al.* 1995). A complete understanding of the requirements of butterflies is the key to their successful conservation and management, but such knowledge on Indian butterflies is woefully inadequate (Gay *et al.* 1992).

Butterflies are holometabolous, and their reproductive output depends on the combined effect of larvae and adult derived nutrients (Boggs 1981). Therefore, detailed life history studies to assess the performance of larvae with respect to food consumption, utilisation and growth are necessary. Here, we report the results from assays of pre-adult stages (egg, larva, pupa and egg to adult), and the food consumption, utilisation and growth indices of larvae of 14 butterfly species based on laboratory studies conducted in the Andhra University, Visakhapatnam.

METHODS

Study Locality:

The present study was carried out from 1996-1998 at Visakhapatnam, located on the east coast of India in the State of Andhra Pradesh between 17° 42' N and 82° 18' E. The climate is typically coastal, dominated by two monsoons, the southwest (June-September) and the northeast (December-February). The period from October through November is cyclone prone. Total annual rainfall ranges between 100-150 cm with most of the precipitation occurring during June-October. The maximum temperature varies between 35-40 °C experienced mostly in May-June, and the minimum between 18-20 °C experienced mostly in January-February. During the rainy season, many herbs and shrubs appear, and the suburban vegetation is mainly deciduous scrub jungle. The whole area is subject to human disturbance because of urban expansion.

Breeding season, oviposition and larval host plants of the butterflies were observed at two sites: (1) the Andhra University campus spread over 0.5 sq. km, it enjoys both wild and cultivated flora, and (2) the Indira Gandhi Zoological Park and its neighbourhood with semi-protected forest area, spread over one sq. km. Representative samples of butterflies were collected at 10 day intervals from both the sites, by stalking or chasing the fast flying species or by gently sweeping the low flying species. The specimens collected were identified from Wynter-Blyth (1957); Varshney (1980, 1985) was referred to for nomenclature. For each of the 14 butterflies species of the present study, ovipositing activity was observed and larval host plants recorded.

Laboratory study

Life History: The breeding females were watched during the breeding season, and the fresh eggs laid were collected in petri dishes (9.5 cm diameter) along with the plant material on which they were laid. These were incubated at room temperature (*c.* 28 °C) in the laboratory. Irrespective of the number of eggs laid, only one leaf was kept in each petri dish and watched at 6 hour intervals to record the hatching time. The intervals were shortened if necessary after preliminary observations. The larvae that hatched were also observed at fixed intervals for moulting until they pupated. Based on the number of moults, the number of instars for each species was determined. As the larvae completed their first or second instar stage, each was maintained in a larger petri dish (15.5 cm) to facilitate free movement. The egg, individual larval instar, pupal and egg to adult duration were recorded. Five replicates were maintained for each species.

Food consumption and utilisation: Food was changed daily and the petri dishes were kept clean by removing the food remains and faecal matter, which were later weighed and disposed of. For every instar, its initial and final weight was taken and the weight gain noted. After preliminary observations of food consumed by the larvae, 5-10 leaves were weighed and given to the larvae. The total food consumed by the larvae was calculated at the end of each instar period. Mean and standard deviations were estimated for food consumed, weight of faeces and weight gained by the larvae. The following parameters were estimated as in Waldbauer (1968).

$$\text{CI (Consumption index)} = \frac{\text{Wt. of food consumed}}{\text{Wt. of instar x Number of feeding days}}$$

$$\text{GR (Growth rate)} = \frac{\text{Wt. gain of instar}}{\text{Mean Wt. of instar x Number of feeding days}}$$

$$\text{AD (Approximate digestibility)} = \frac{\text{Wt. of food consumed - Wt. of faeces}}{\text{Wt. of food consumed}} \times 100$$

$$\text{ECD (Efficiency of conversion of digested food)} = \frac{\text{Wt. gain of instar}}{\text{Wt. of food consumed - Wt. of faeces}} \times 100$$

$$\text{ECI (Efficiency of conversion of ingested food)} = \frac{\text{Wt. gain of instar}}{\text{Wt. of food consumed}} \times 100$$

RESULTS AND DISCUSSION

In all, 14 butterfly species have been examined for their oviposition, plant species used for ovipositing, and pattern of egg laying (Table 1). Egg, larval and pupal duration, and total egg to adult development time are summarized in Table 2. Food consumption, growth and utilization indices are given Tables 3-8.

Egg laying pattern and hatching duration

Of the 14 species of butterflies studied, 12 species lay single eggs, and the other two in clusters. *Anaphaeis aurota* (Family Pieridae) and *Acraea terpsicore* (Family Acraeidae) are cluster layers. The nymphalid *Junonia lemonias*, the two danaids, the six papilionids and the other three pierids are all single egg layers. Single egg laying habit dominates over cluster laying habit among butterfly species of most geographical areas (Thompson and Pellmyr 1991). Though the number of species examined in the present study is low, this study suggests a similar tendency. Based on the information provided by Ford (1957), Stamp (1980) estimated that 2.5% of the butterfly species in India are cluster layers, while the others lay single eggs. However, some reports show the influence of ecological conditions on egg laying pattern (Larsen 1988; Davies and Gilbert 1985). As such, a closer study is required on the pattern of egg laying in different ecological situations.

Table 1: List of the 14 butterfly species studied, their oviposition plants and egg laying patterns

Butterfly species	Oviposition plants	Patterns of egg laying
ACRAEIDAE		
Acraea terpsicore	*Hybanthus ennaespermus*	Cluster (4-6)
DANAIDAE		
Danaus chrysippus	*Calotropis gigantea*	Single
Euploea core	*Nerium odorum*	Single
NYMPHALIDAE		
Junonia lemonias	*Asystasia gangetica*	Single
PAPILIONIDAE		
Graphium doson]	*Polyalthia longifolia*	Single
Graphium agamemnon]		
Pachliopta hector]	*Aristolochia indica*	Single
Pachliopta aristolochiae]	*Aristolochia bracteolata*	Single
Papilio polytes	*Murraya koenigii*	Single
Princeps demoleus	*Citrus limon*	Single
PIERIDAE		
Colotis danae	*Cadaba fruticosa*	Single
Anaphaeis aurota	*Capparis spinosa*	Cluster (15-55)
Catopsilia pyranthe	*Cassia siamea*	Single
Eurema hecabe	*Cassia tora*	Single

According to Chew and Robbins (1984), the species with a single egg laying habit generally use small plants as larval hosts, but this is not true in *Acraea terpsicore* which lays eggs in clusters of 4-6 on the herbaceous *Hybanthus ennaespermus*. While single egg laying habit is advantageous to exploit isolated plants, preventing the possibility of larval starvation, egg clustering improves larval host resource exploitation (Davies and Gilbert 1985).

The hatching or incubation period is 3-4 days in 9 of the 14 species, 4-5 in 3 species, and 6-7 days in 2 species. In temperate species, the hatching period is reported to differ between cluster and single egg layers, the former being longer (Stamp 1980). Such a difference is not apparent in these 14 tropical species. In fact, *Pachliopta hector* and *P. aristolochiae* that lay single eggs have a longer incubation period of 6-7 days than the cluster laying *Acraea terpsicore* (3-4 days) and *Anaphaeis aurota* (4-5 days). It thus appears that the incubation period may depend on the size of the egg rather than on the egg laying pattern, the bigger eggs taking a relatively longer period. This requires to be tested under similar conditions of incubation.

Larval and pupal duration, and total development time

The durations of the different instars of the 14 butterfly species appear to be similar. The duration of instar I varied between 2-3 days, of instar II and III each 2-4 days, of instar IV 2-5 days, and instar V 3-7 days. Only the fifth instar of two papilionids *Pachliopta hector* and *P. aristolochiae* have a relatively longer duration of 6-7 days. The total larval period ranged between 11-20 days. The pupal period of six species, namely *Acraea terpsicore*, *Danaus chrysippus*, *Junonia lemonias*, *Anaphaeis aurota*, *Catopsilia pyranthe* and *Eurema hecabe* was short ranging from 6-8 days, and the remaining eight species had a longer period of 9-16 days. The period of egg to adult development time also had two groups, one showing a shorter period of 20-30 days and the other a longer period of 25-48 days (Table 2). The longest period was for *Pachliopta aristolochiae* (40-48 days), and for *P. hector* (39-47 days), and the shortest period of 20-27 days was observed in *Junonia lemonias* and *Eurema hecabe*. In Papua New Guinea, the world's largest butterfly *Ornithoptera alexandrae* (Papilionidae) has an egg to adult development time spanning over 122 days (Parsons 1984c), the lycaenids *Philiris helena*, *P. agatha*, *P. intensa* and *P. zisk* have 30 days each (Parsons 1984a). The nymphalid *Taeniaris myops* has 54 days, and *T. arotaus* 60 days (Parsons 1984b). Relevant data from other regions in India are required for a meaningful comparison and interpretation. However, temperature influences instar duration

Table 2: Duration in days of different stages in the life history of the 14 butterfly species under study

Butterfly species	Hatching period	Instar duration					Larval duration	Pupal duration	Duration of egg to adult development
		I	II	III	IV	V			
ACRAEIDAE									
A. terpsicore	3-4	2-3	3-4	3-4	3-4	4-5	15-20	7-8	25-32
DANAIDAE									
D. chrysippus	4-5	2-3	2-3	2-3	2-3	3-4	11-16	6-7	21-28
E. core	4-5	2-3	3-4	3-4	3-4	3-4	14-19	10-11	28-35
NYMPHALIDAE									
J. lemonias	3-4	2-3	2-3	2-3	2-3	3-4	11-16	6-7	20-27
PAPILIONIDAE									
G. doson	3-4	2-3	2-4	3-4	3-4	4-5	14-20	13-14	30-39
G. agamemnon	3-4	2-3	3-4	3-4	3-4	4-5	15-20	10-11	28-35
P. polytes	3-4	2-3	3-4	3-4	3-4,	3-4	14-19	10-11	27-35
P. demoleus	3-4	2-3	3-4	3-4	3-4	3-4	14-19	10-12	27-35
P. hector	6-7	2-3	3-4	3-4	4-5	6-7	18-23	15-17	39-47
P. aristolochiae	6-7	2-3	3-4	3-4	4-5	6-7	18-23	16-18	40-48
PIERIDAE									
C. danae	3-4	2-3	2-3	2-3	2-3	3-4	11-16	9-10	23-30
A. aurota	4-5	2-3	2-3	2-3	2-3	3-4	12-16	6-7	21-28
C. pyranthe	3-4	2-3	2-3	2-3	2-3	3-4	12-16	7-8	21-29
E. hecabe	3-4	2-3	2-3	2-3	2-3	3-4	11-16	6-7	20-27

Table 3: Instarwise food consumption and growth of 14 butterfly species

Butterfly species	Instar number	wt. of food consumed (mg)	wt. of faeces (mg)	wt. gain of larva (mg)
Acraea terpsicore	I	17.0 ± 0.21	0.5 ± 0.01	1.2 ± 0.08
	II	138.0 ± 0.42	3.9 ± 0.12	15.5 ± 0.21
	III	563.0 ± 4.70	18.2 ± 0.25	68.0 ± 0.28
	IV	1068.5 ± 9.20	132.8 ± 0.91	152.5 ± 0.94
	V	2840.0 ± 16.70	408.0 ± 2.90	402.0 ± 3.10
Danaus chrysippus	I	18.0 ± 0.08	0.1 ± 0.4	0.6 ± 0.02
	II	54.0 ± 1.40	3.7 ± 0.32	7.0 ± 0.7
	III	382.5 ± 3.40	15.6 ± 0.97	53.0 ± 1.20
	IV	1210.0 ± 6.14	98.0 ± 1.90	208.0 ± 3.10
	V	2972.0 ± 14.2	458.0 ± 4.20	417.0 ± 3.90
Euploea core	I	34.0 ± 0.21	0.65 ± 0.04	3.40 ± 0.21
	II	208.0 ± 1.40	4.8 ± 0.37	23.2 ± 0.41
	III	585.5 ± 2.10	49.2 ± 0.61	121.0 ± 0.74
	IV	1377.5 ± 6.70	231.4 ± 1.91	471.3 ± 2.1
	V	4125.5 ± 13.20	612.5 ± 4.3	665.3 ± 4.8
Junonia lemonias	I	35.1 ± 0.41	0.31 ± 0.21	3.15 ± 0.18
	II	254.3 ± 0.74	3.80 ± 0.21	27.00 ± 0.30
	III	723.7 ± 6.30	4480 ± 0.41	351.0 ± 0.94
	IV	1759.0 ± 12.40	181.50 ± 0.72	600.40 ± 5.70
	V	4656.2 ± 20.20	594.40 ± 5.10	701.00 ± 6.40
Graphium doson	I	21.6 ± 0.34	0.15 ± 0.09	2.2 ± 0.10
	II	88.50 ± 0.84	3.42 ± 0.18	18.0 ± 0.21
	III	1397.5 ± 8.40	110.5 ± 0.19	222.6 ± 1.80
	IV	2371.6 ± 11.2	194.5 ± 1.90	321.3 ± 2.40
	V	3497.3 ± 16.40	528.2 ± 5.30	678.4 ± 3.80
Graphium agamemnon	I	26.5 ± 0.92	0.12 ± 0.04	2.36 ± 0.18
	II	78.3 ± 2.10	3.08 ± 0.24	13.5 ± 0.67
	III	1413.0 ± 7.20	109.50 ± 2.9	206. 3 ± 3.70
	IV	2390.5 ± 12.40	186.4 ± 3.2	267.4 ± 3.90
	V	2733.5 ± 13.60	486.5 ± 4.1	518.8 ± 4.50
Pachliopta hector	I	47.5 ± 0.12	0.30 ± 0.02	2.5 ± 0.06
	II	93.5 ± 0.19	4.21 ± 0.08	19.7 ± 0.12
	III	1426.3 ± 1.20	122.80 ± 0.20	71.0 ± 0.14
	IV	2189.7 ± 4.20	189.50 ± 0.23	453.1 ± 0.41
	V	4320.6 ± 12.40	540.10 ± 0.41	1232.0 ± 1.10
Pachliopta aristolochiae	I	26.2 ± 0.98	0.32 ± 0.02	2.2 ± 0.18
	II	159.1 ± 1.90	3.40 ± 0.31	16.0 ± 0.71
	III	394.3 ± 2.70	18.60 ± 0.92	68.6 ± 1.41
	IV	1003.2 ± 5.10	72.40 ± 1.21	319.09 ± 2.30
	V	4757.3 ± 21.20	882.20 ± 4.40	1425.8 ± 6.30
Papilio polytes	I	31.0 ± 0.92	0.21± 0.02	3.21 ± 0.19
	II	154.3 ± 2.70	3.90 ± 0.27	19.60 ± 0.31
	III	482.7 ± 3.90	61.40 ± 1.40	150.30 ± 2.90
	IV	1683.0 ± 6.10	126.20 ± 1.40	256.80 ± 3.10
	V	2714.2 ± 9.70	375.80 ± 3.90	452.90 ± 3.60

Table 3: Instarwise food consumption and growth of 14 butterfly species (*contd.*)

Butterfly species	Instar number	wt. of food consumed (mg)	wt. of faeces (mg)	wt. gain of larva (mg)
Princeps demoleus	I	40.3 ± 0.21	0.19 ± 0.02	3.87 ± 0.10
	II	113.0 ± 0.80	4.20 ± 0.19	22.80 ± 0.19
	III	1546.0 ± 2.90	119.80 ± 0.82	302.50 ± 1.70
	IV	2474.1 ± 6.10	322.40 ± 1.90	478.30 ± 2.10
	V	4524.2 ± 14.50	818.60 ± 4.80	840.70 ± 4.20
Colotis danae	I	4.2 ± 0.13	0.10 ± 0.01	0.19 ± 0.02
	II	10.2 ± 0.21	0.34 ± 0.04	1.52 ± 0.08
	III	29.6 ± 0.34	6.10 ± 0.18	3.70 ± 0.18
	IV	98.1 ± 0.84	12.60 ± 0.24	13.70 ± 0.34
	V	308.4 ± 3.20	74.60 ± 0.64	59.00 ± 0.51
Anaphaeis aurota	I	4.1 ± 0.12	0.12 ± 0.01	2.47 ± 0.08
	II	43.0 ± 0.21	2.10 ± 0.08	8.29 ± 0.17
	III	129.8 ± 1.02	18.20 ± 0.14	57.25 ± 0.29
	IV	254.5 ± 2.70	52.50 ± 0.31	120.70 ± 1.01
	V	346.5 ± 3.10	196.20 ± 1.90	301.00 ± 2.90
Catopsilia pyranthe	I	4.40 ± 0.12	0.09 ± 0.01	0.10 ± 0.3
	II	42.00 ± 0.18	1.20 ± 0.08	1.70 ± 0.09
	III	260.00 ± 2.40	21.50 ± 0.14	24.50 ± 0.16
	IV	350.00 ± 3.60	62.90 ± 0.22	32.50 ± 0.17
	V	1339.00± 7.40	421.00 ± 3.90	141.00 ± 0.38
Eurema hecabe	I	6.0 ± 0.08	0.04 ± 0.02	0.06 ± 0.01
	II	48.0 ± 0.02	1.20 ± 0.08	2.87 ± 0.06
	III	232.0 ± 0.24	12.90 ± 0.09	36.60 ± 0.11
	IV	251.5 ± 0.26	29.10 ± 0.10	37.70 ± 0.11
	V	313.0 ± 0.32	60.20 ± 0.17	56.50 ± 0.18

(Palanichamy *et al.* 1982) and the overall developmental time from egg to adult (Owen 1971). Hence, the larval and pupal duration, and egg to adult development time of these 14 butterfly species in other regions may vary according to the prevailing weather conditions. The present data, however, agrees with Owen (1971), who states that egg to adult development time is much shorter in the tropics.

Food consumption and utilization

The data on the proportion of food consumed by the five instars of each of the 14 butterfly species indicates that the fourth or fifth instar had a major share of the total amount of food consumed over the entire larval period. Similar findings have been reported for other species (David and Gardiner 1962; Waldbauer 1968; Mathavan and Pandian 1975; Scriber and Slansky 1981; Palanichamy *et al.* 1982; Selvasundaram 1992; Ghosh and Gonchaudhuri 1996). The increase in consumption might be a strategy to compensate for the energy requirement in the non-feeding pupal stage (Delvi and Pandian 1972; Pandian 1973). The consumption index (CI) of instar I is the highest in all the 14 species, and CI decreases progressively across the instars. CI depends on the conversion efficiency of the food consumed (ECI) (Slansky and Scriber 1985), and is inversely proportional to ECI. Thus, the high CI of instar I of all the 14 butterfly species may be because of low conversion efficiency (ECI) (Table 4). The values of consumption index (CI) of any instar of the 14 species are within the ranges reported for Lepidoptera in general (Slansky and Scriber 1985) and correspond well with the values of swallowtails (Scriber and Feeny 1979; Scriber 1986).

The value of GR of the 14 butterfly species decreased progressively in general and was highest in instar I, and lowest in instar V (Table 5). A similar trend has been recorded for the moth *Pericallia ricini* (Ghosh and Gonchaudhuri 1996). Penultimate instars had a higher growth rate than the final instars in some swallowtails and moths (Scriber and Feeny 1979). The GRs of penultimate and final instars now obtained are in line with the above decreasing trend. The larvae reared on tree foliage show higher growth rates than the larvae

Table 4: Values of Consumption Index (CI) for successive instars of 14 butterfly species

Butterfly Species	Instars	CI I	II	III	IV	V
ACRAEIDAE						
A. terpsicore		7.47	2.40	3.40	1.80	0.90
DANAIDAE						
D. chrysippus		10.50	2.50	3.70	1.40	0.60
E. core		8.60	2.20	1.90	1.70	0.70
NYMPHALIDAE						
J. lemonias		9.80	6.60	3.50	1.90	2.00
PAPILIONIDAE						
G. doson		9.30	3.50	3.50	1.80	1.30
G. agamemnon		10.00	2.40	2.80	1.40	1.10
P. polytes		18.70	5.00	4.00	3.40	2.00
P. demoleus		14.40	3.12	1.62	0.98	0.65
P. hector		22.00	7.60	2.06	1.70	2.07
P. aristolochiae		16.00	14.60	5.40	1.64	0.93
PIERIDAE						
C. danae		8.30	4.80	1.10	0.84	1.10
A. aurota		10.80	4.79	3.23	1.94	1.99
C. pyranthe		8.10	1.80	4.00	3.50	1.70
E. hecabe		8.70	4.40	2.10	1.10	1.40

Table 5: Values of Growth Rate (GR) for successive instars of 14 butterfly species

Butterfly Species	Instars	GR I	II	III	IV	V
ACRAEIDAE						
A. terpsicore		0.78	0.53	0.39	0.27	0.28
DANAIDAE						
D. chrysippus		0.27	0.24	0.56	0.48	0.23
E. core		0.87	0.49	0.40	0.39	0.22
NYMPHALIDAE						
J. lemonias		0.75	0.52	0.56	0.28	0.17
PAPILIONIDAE						
G. doson		0.57	0.49	0.55	0.25	0.18
G. agamemnon		0.93	0.43	0.55	0.16	0.12
P. hector		0.45	0.45	0.39	0.35	0.20
P. aristolochiae		0.70	0.66	0.62	0.60	0.60
P. polytes		0.96	0.45	0.48	0.27	0.21
P. demoleus		0.96	0.48	0.54	0.27	0.21
PIERIDAE						
C. danae		0.57	0.73	0.49	0.54	0.39
A. aurota		0.87	0.60	0.71	0.46	0.29
C. pyranthe		0.50	0.30	0.20	0.15	0.21
E. hecabe		0.80	0.87	0.81	0.30	0.17

maintained on herbaceous foliage (Scriber and Feeny 1979). The host plant *Polyalthia longifolia* utilised by *Graphium agamemnon* and *G. doson*, and *Citrus limon* utilised by *Papilio polytes* and *Princeps demoleus* are tree species, whereas *Aristolochia indica* and *A. bracteolata* used by *Pachliopta hector* and *P. aristolochiae*, and *Hybanthus ennaespermus* used by *Acraea terpsicore* are herbaceous. While the growth rates of *Pachliopta aristolochiae* larval instars II to V are greater than those of other tree foliage feeders, those of *Pachliopta hector* are not different from other tree foliage feeders, hence the data is considered inadequate to consider the issue of different growth rates on the two kinds of foliage.

The values of approximate digestibility (AD) of the 14 butterfly species declined as the larvae aged (Table 6). The larvae may have consumed a larger proportion of indigestible crude fibre as they grew older which caused AD values to decrease along the successive instars (see Slansky and Scriber 1985). This decrease could also be the reason of the decreased growth rate (GR) described earlier. The AD values are inversely related to the food consumed by different instars. It is highest in instar I, the corresponding percentages of each of the 14 species are: *Pachliopta aristolochiae* 0.41, 98; *P. hector* 0.59, 99; *Papilio polytes* 0.61, 99; *Princeps demoleus* 0.46, 99; *Graphium agamemnon* 0.40, 99; *G. doson* 0.29, 99; *Anaphaeis aurota* 0.53, 97; *Calotis danae* 0.93, 98; *Acraea terpsicore* 0.37, 97; *Catopsilia pyranthe* 0.23, 98; *Eurema hecabe* 0.72, 99; *Junonia lemonias* 0.47, 99; *Danaus chrysippus* 0.39, 97; and *Euploea core* 0.53, 98. The AD is lowest in instar V, the corresponding percentages are *Pachliopta aristolochiae* 75.03, 84; *P. hector* 53.49, 87; *Papilio polytes* 41.15, 86; *Princeps demoleus* 52.02, 82; *Graphium agamemnon* 41.15, 82; *G. doson* 47.41, 84; *Anaphaeis aurota* 44.5, 70; *Calotis danae* 68.5, 76; *Acraea terpsicore* 61.38, 86; *Catopsilia pyranthe* 67.10, 69; *Eurema hecabe* 36.80, 81; *Junonia lemonias* 62.68, 87; *Danaus chrysippus* 64.10, 84; *Euploea core* 65.16, 85. Such a relationship between approximate digestibility and food consumption is also evident from the data compiled by Waldbauer (1968). The AD values of the 14 species ranging between 86.0 to 99.5% appear to be higher than those reported for several lepidopteran larvae (see Pandian and Marian 1986; Ghosh and Gonchaudhuri 1996). The larvae were given tender leaves daily. Tender leaves are usually rich in nitrogen and the larvae may have assimilated them more efficiently resulting in high values of AD. The values of efficiency of conversion of digested food (ECD) showed a general increase from

Table 6: Values of Approximate Digestibility (AD) for successive instars of 14 butterfly species

Butterfly Species	Instars	AD (%) I	II	III	IV	V
ACRAEIDAE						
A. terpsicore		97	97	89	88	86
DANAIDAE						
D. chrysippus		97	93	96	93	84
E. core		98	97	91	83	85
NYMPHALIDAE						
J. lemonias		99	98	93	89	87
PAPILIONIDAE						
G. doson		99	95	92	91	84
G. agamemnon		99	96	92	92	82
P. hector		99	94	92	91	87
P. aristolochiae		98	97	95	92	81
P. polytes		99	97	94	92	86
P. demoleus		99	96	92	87	82
PIERIDAE						
C. danae		98	96	89	85	76
A. aurota		97	95	86	79	70
C. pyranthe		98	97	92	82	69
E. hecabe		99	98	94	86	81

Table 7: Values of Efficiency of conversion of digested food (ECD) for successive instars of 14 butterfly species

		ECD (%)				
Butterfly Species	Instars	I	II	III	IV	V
ACRAEIDAE						
A. terpsicore		8.0	12.0	12.0	16.0	17.0
DANAIDAE						
D. chrysippus		3.4	13.9	14.4	14.7	16.5
E. core		10.2	11.4	23.4	41.3	18.9
NYMPHALIDAE						
J. lemonias		9.0	11.0	6.0	38.0	17.0
PAPILIONIDAE						
G. doson		7.7	20.3	17.2	14.7	22.8
G. agamemnon		2.3	17.9	15.8	12.1	22.9
P. hector		18.8	21.9	5.4	22.6	32.5
P. aristolochiae		8.4	10.2	18.2	34.0	36.0
P. polytes		10.4	13.0	14.7	16.5	19.3
P. demoleus		9.6	20.9	21.2	22.1	22.6
PIERIDAE						
C. danae		3.0	15.0	15.0	18.0	25.0
A. aurota		62.0	20.0	52.0	60.0	64.0
C. pyranthe		2.0	4.0	10.0	11.0	15.0
E. hecabe		1.0	6.0	16.0	19.0	19.0

Table 8: Values of Efficiency of conversion of ingested food (ECI) for successive instars of 14 butterfly species

		ECI (%)				
Butterfly Species	Instars	I	II	III	IV	V
ACRAEIDAE						
A. terpsicore		7.0	11.0	12.0	14.0	14.0
DANAIDAE						
D. chrysippus		3.3	12.9	13.8	13.8	14.0
E. core		10.0	11.5	21.5	34.2	16.0
NYMPHALIDAE						
J. lemonias		9.0	11.0	6.0	34.0	15.0
PAPILIONIDAE						
G. doson		7.7	19.3	15.9	13.5	19.3
G. agamemnon		8.9	17.2	14.6	11.2	18.8
P. hector		5.2	20.9	14.9	20.6	28.5
P. aristolochiae		8.3	10.0	17.0	31.0	29.9
P. polytes		10.3	12.7	13.8	15.2	16.6
P. demoleus		9.6	20.1	19.5	19.2	18.5
PIERIDAE						
C. danae		3.0	14.0	15.0	15.0	19.0
A. aurota		60.0	19.0	44.0	47.0	45.0
C. pyranthe		2.0	4.0	9.0	9.0	11.0
E. hecabe		3.0	6.0	17.0	12.0	23.0

early to late instars, and the values are very low compared to AD values, indicating poor utilisation of the digested food (Table 7).

The values of efficiency of conversion of consumed food (ECI) of *Anaphaeis aurota* ranged between 19-60% and those of the other 13 species varied between 2-34%; most of these values fall between 10% and 20%. These values indicate low conversion efficiency, but are comparable with the ECI values reported for swallowtails (Scriber and Slansky 1981). Excised foliage was used for rearing the larvae, and such foliage is likely to be deficient in water. Since leaf water content is directly related to conversion efficiency (Muthukrishnan 1990) the larvae had to spend energy to produce metabolic water, which may have resulted in low conversion efficiency. While it is indicated that the ECI values across the instars show a decreasing trend, and follow the pattern of decline in AD (Waldbauer 1968), the ECI pattern of the 14 species does not conform to the above relation (Table 8). The ECIs showed definite trend of increase or decrease across the instars, thus supporting the predicted inconsistency in ECI pattern (Slansky and Scriber 1985) also recorded in the moth *Pericallia ricini* (Ghosh and Gonchaudhuri 1996). The various nutritional indices of the 14 butterfly species will enable a proper understanding of the trophic interactions of these species.

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