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RESEARCH ARTICLE

BIO-PATTERNS AND LARVAL ONTOGENY OF *PAPILIO POLYTES* (L.) ON SEVEN DIFFERENT HOST PLANTS OF RUTACEAE FAMILY

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ABSTRACT

The Papilionidae butterfly *Papilio polytes (L.)* (Common Mormon) it occurs throughout the year. The larval ontogeny and Bio-patterns of *Papilio polytes* was studied at Andhra University campus using the leaves of seven host plants of *M. koenigii, C. limettioides, C. aurantiifolia, C. aurantium, C. sinensis, C. limon* and *A. marmelos* (Rutaceae) the larval host, both in laboratory and in the natural conditions. They eggs lay on the main host plant of *Murrayya koenigii*. The behavior and morphological characters of eggs, caterpillars, pupae and adult emergence were observed in the laboratory at 28°-30°c. The life duration was completed in 26-34 days, with egg hatching 3 larvae 14-19, and pupae 9-12 days. The values of consumption index (CI), growth rate (GR), and approximate digestibility (AD) across the instars decreased as the larvae aged. The highest values of the CI and GR are 46.38, 0.50 respectively, and that of AD is 98.1. However, the values of both efficiency of conversion of digested food (ECD) and efficiency of conversion of ingested food (ECI) either increased or decreased from instar to instar.

INTRODUCTION

Insects are the world's most diverse group of animals representing over 50% of global terrestrial biodiversity, yet we have poor understanding of their diversity, conservation status, and ecologies (Thomas, 2005). Contrary to most other groups of insects, most butterflies are well-documented, relatively easy to recognize, and popular with the general public. In addition, they are highly sensitive to environmental changes, such as climate change, farmland intensification or abandonment, and habitat fragmentation. These factors, among others, make butterflies one of the best species groups for monitoring changes in biodiversity (Thomas, 2005). The lovely and graceful butterflies provide economic and ecological benefits to the human society. Having multihued colours on their wings, they enhance the earth's beauty incontestably, and add immense aesthetic value to the ambient environment. They accomplish pollination, a keystone ecological process in natural sustainability throughout the world. Being dependent on vegetation both adults and larvae, they involve themselves in complex feeding relationships with green plants. As adults, they require a succession of adequate nectar resources. Nectar provides energy for flight, which is vital to find mates and to disperse the species.

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As larvae, butterflies are typically host specific and often show a "botanical instinct", in that closely related butterfly species choose closely related plants. As such, butterflies provide the best rapid indicators of habitat quality, and also they are the sensitive indicators of climate change. The present study relates to the Common Mormon – Papilio polytes (L.) (Lepidoptera: Papilionidae) and describes its adult food resources, oviposition and larval host plants *Murrayya koenigii, Citrus limettioides, Citrus aurantiifolia, Citrus aurantium, Citrus sinensis, Citrus limon and A. marmelos* (Rutaceae) egg deposition pattern, life history including the duration of early life history stages and food consumption and utilization efficiencies.

MATERIAL AND METHODS

Study Region

The present study was carried-out at Visakhapatnam during 2014 and 2015. Visakhapatnam (17o 42' N latitude and 83 o 20' E longitude) is located on the east coast of India in the State of Andhra Pradesh. The climate of the area is tropical monsoon type. Most of the precipitation during the year is June to November, and the total rainfall, though varies from year to year, normally ranges between 1000 – 1500 mm. The mean temperature is at its maximum on some days (38 - 45°C) during May/June. Monsoon rains cool the tropical heat from June/July onwards, with the mean temperature remaining

relatively high through October and thereafter decreasing to a minimum (18–20°C) in January/February.

Study Site

The present study was conducted at Andhra University campus, which spreads over an area of 168 hectares and is in proximity to the coastline. The wilderness on the Andhra University Campus was searched for the reproductive activity of the butterflies. A large number of tree and herbaceous species occur on the Campus. Some of the plants occurring on the campus are heavily foraged by adult butterflies for nectar. Many herbaceous tax a serve as the larval hosts for the butterfly species distributed on the vast campus.

Field Study

Regular walks in different patches of the study site were undertaken at 10-day intervals or when required even at shorter intervals or even daily. Butterflies are day active mostly during 0830 – 1500 h. Hence, walks were made during these hours of the day to record the flight behaviour, foraging, and ovipositing activity of the *Papilio polytes* chosen for the present study. These activities were observed during the entire period of adults on wing. Nectar resource plants and oviposition plants used by this species were recorded.

Laboratory Study

Life History Study

After noting the period of breeding season and the oviposition plants close and prolonged observations were made of the breeding females laying eggs on its host plants. Freshly laid eggs were spotted, and the plant material (leaves/twigs) on which they were laid, was plucked without causing any damage. The date and time of day of collection were noted. Then the material was transferred to Petri dishes of 10 cm diameter and 1.5 cm depth. The inside of each of these Petri dishes was lined with moist blotting paper to provide moist conditions. They were brought to the Department and incubated in the laboratory having a temperature of 28 ± 2°C, and relative humidity of 80 ± 10%. The Petri plates were kept in a clean, roomy cage (60 x 50 x 30 cm) covered with wire gauge. The light condition was the normal indirect sunlight, but its duration was not uniform throughout the year. It varied from a low of about 11 h during November – February (winter months) to a high of about 13 h during May – June.

The eggs thus incubated in the laboratory were examined at 6-hour intervals daily for recording their incubation period and hatchability. The eggs were treated as hatched when the larvae came out from them. In order to assess the total larval period and the number of instars that may be produced, the newly hatched larvae were transferred individually into the Petri dishes with the help of a camel hairbrush. Fresh young leaves were offered as food to the growing larvae. Moulting was noted, and thus the number of instars produced was recorded. Observations as color, shape and size of each instar was maintained. As the larvae grew, they needed more space. Increased space was provided by transferring the growing larvae to bigger Petri dishes (15 cm diameter; 2.5 cm depth). The full grown larvae pupate, and particulars of pupae including color, shape, size, weight and duration were also recorded. Millimeter graph paper was used for taking measurements. Taking the number of eggs studied, their developmental success (%) was calculated. In describing the details of adult characters, the butterflies that have emerged from the pupae in the laboratory, and those caught in the wild were used.

Food Consumption and Utilisation

The larvae represent the main feeding stage. Quantitative data of food consumption and utilization were recorded for each instar of the butterfly species under study using the gravimetric method of Waldbauer (1968). The larvae and the host leaves were weighed separately and then placed in Petri dishes. The larvae were allowed to feed on the leaves for 24 h and then the weights of the larvae and the remaining leaf material, and faecal matter in the Petri dish were determined. Fresh food was supplied, and the related weights were also taken every 24 h. From these fresh weight measurements, growth and food utilization indices were calculated. These indices included Consumption Index (CI), Growth Rate (GR), Approximate Digestibility (also called Assimilation Efficiency) (AD), Efficiency of Conversion of Ingested Food (also called Gross Conversion Efficiency) (ECI), and Efficiency of Conversion of Digested Food (called Net Conversion Efficiency) (ECD). The formulae of Waldbauer (1968) used in the calculation of these indices are:

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

$$\text{GR (Growth rate)} = \frac{\text{Weight gained by the instar}}{\text{Mean weight of instar x Number of feeding days}}$$

$$\text{AD (Approximate digestibility)} = \frac{\text{Weight of food ingested} - \text{Weight of faeces}}{\text{Weight of food ingested}} \times 100$$

$$\text{ECD (Net conversion efficiency)} = \frac{\text{Weight gained by the instar}}{\text{Weight of food consumed} - \text{Weight of faeces}} \times 100$$

$$\text{ECI (Gross conversion efficiency)} = \frac{\text{Weight gained by the instar}}{\text{Weight of food ingested}} \times 100$$

The weights are expressed in units of milligrams (mg). The values are based on five different observations for each parameter; standard deviations were also calculated.

Statistical Analysis

The relation between the food consumed and the weight gained per instar by the larvae of each of the butterfly species under study was statistically analysed on the basis of Legenders principle by fitting a straight line. Larval weights are represented on Y- axis, and the food consumed on X-axis. Correlation coefficient was calculated in each case along with_t'value.

RESULTS

Field observations on adults, their habits, nectar resources or other foods, oviposition host plants, egg-laying pattern, abundance and distribution of different life stages, and the laboratory results on hatching eggs, instar wise larval characters, instar duration, pupal characters, pupal period and pupal weight, success rate of development of eggs, larvae and pupae, food consumption and utilization indices of each instar,

and the moisture content of host plants – are all described here under for each of the seven butterfly species under the present study.

Food Resources

In the study area its nectar host plants included *Antigonon leptopus* Hk. and A.*, Lantana camara* Linn.*, Santalum album* Linn.*,* and *Cestrum diurnum* Linn. It held its wings horizontal while foraging at flowers for nectar.

Table 1. Biological observations of early life stages of *Papilio polytes on Murraya koenigii*

Stage	Length(mm)			Width (mm)			Duration (days)	
	Min.	Max.	AV.±S.D.	Min.	Max	AV. ±S.D.	Range	AV.±S.D.
Egg	0.9	1.2	1.04±0.10	1.8	2.1	1.94±0.10	3	3.00±0.00
I	3.5	4	3.30±0.90	1	1.5	1.40±0.23	2-3	2.60±0.54
II	4.6	8.3	7.10±1.52	1.7	2	1.70±0.25	2-3	2.80±0.44
III	13	17.2	15.00±1.75	2.5	3	2.60±0.26	3-5	4.00±0.70
IV	25	32	29.20±4.18	4	5.6	4.90±0.66	3-4	3.80±0.44
V	41	45.5	41.30±5.21	6.6	8.4	7.56±0.62	4-5	4.60±0.54
Total larval Period							14-19	16.60±2.07
Pupa	24	30	28.00±2.44	8	9	8.60±0.41	9-12	10.80±1.30

Table 2. Food consumption, growth and food utilization efficiencies of *Papilio polytes* larva fed with *Murrayya koenigii*

Instar	Wt. of food ingested (mg)	Wt. of faeces (mg)	Wt. gained by larva (mg)	GR (mg/day)	CI (mg/day)	AD (%)	ECD (%)	ECI (%)
I	108.9±19.72	2.0±1.52	0.64±0.19	0.24	46.38	98.1	0.54	0.53
II	136.7±25.62	4.56±1.93	1.88±1.45	0.5	5.91	96.71	1.49	1.44
III	312.0±94.41	39.6±21.45	18.74±12.72	0.28	0.91	83.21	7.65	6.68
IV	822.5±199.16	196.1±120.2	138.66±68.92	0.4	0.46	75.53	24.81	16.82
V	1658.2±336.21	707.9±81.09	1508.38±215.01	0.2	0.54	55.77	69.26	37.67

Table 3. Duration of Life Cycle of *Papilio polytes* on Seven Different Host Plants of Rutaceae family

Sl.No	*Stage*	*M. koenigii*	*C. limettioides*	*C. aurantiifolia*	*C. aurantium*	*C. sinensis*	*C. limon*	*A.marmelos*
1	Egg	3	3-4	3	3	3	3-4	3-4
2	I (D)	2-3	2-3	1-3	2	2-3	3-4	2-3
3	II (D)	2-3	1-2	4-3	2-3	2-4	2-4	2-4
4	III (D)	3-5	1-3	2-3	3	2-4	2-3	2-4
5	IV (D)	3-4	1-2	2-3	4-5	2-5	2-4	3-4
6	V (D)	4-5	2-4	3-5	5-7	5-7	5-7	5-6
7	* wt.g. larva	1508.38	1054.56	1132.82	1546.42	1333.8	1654.61	1054.24
8	Pupal days	9-12	10-12	9-12	9-11	11-13	13-15	14-16
9	Total no. of days	26-34	22-27	27-31	28-36	29-36	32-40	33-40
10	Moisture content	69.80	72.11	72.10	57.70	61.35	63.10	57.89

*D – Days

Papilio polytes (L.) Adult Stage (plate.H)

Field characters

Wingspan ranges between 90 - 100 mm. In male above, black, tailed. Upper side forewing with terminal series of white spots, decreasing in size towards the apex. Upper side hind wing with complete discal band of elongate white spots. Red marginal crescents present or absent. Forewing with terminal series of white or yellow spots, decreasing in size towards the apex. Hind wing with complete discal band of elongate white spots, more prominent in female, ending in a red lunule in the tornal region and sub marginal series of crimson lunules in female. The female of this black bodies swallowtails occurs in three different colour forms: one resembling the male and the other two mimicking the 2 red-bodies swallowtails: the Common Rose, *P. arstgolochiae* and the Crimson Rose, *P. hector*.

Habit

Males have fast flight, visitor to gardens where he will be seen hovering over flowers whenever the sun is shining. While females fly slowly in a leisurely manner just like common rose and Crimson Rose whom they mimic. Fond of flowers, males visit damp patches and dung. The Common Mormon prefers lightly wooded country but will be met with throughout the year over most of the plains of India and up to a considerable height in the hills. Occurs on the hills up to 1,830m.

Oviposition Host Plants

The plant used for ovipositing by this butterfly in the study area was *Murrayya koenigii* (L.). The larval host plants of the butterfly belong to the family Rutaceae. The recorded oviposition host plants of this butterfly including *Aegle marmelos, Atlantia racemosa, Citrus sinensis, C. aurantiifolia, C. grandis, C. limettioides, C. limon, C. reticulate, Glycosmis pentaphylla, Murrayya koenigii*, *M. paniculata, Ruta graveolens, triphasis trifolia.* The present study was carried out on the leaves of *Murrayya koenigii* (L.)sprengel, *Citrus limettioides* Tanaka, *Citrus aurantiifolia* (Christm.)Swingle, *Citrus aurantium* (L.), *Citrus sinensis* (L.) osbeck, *Citrus limon (L.) Burm.f* and *Aegle marmelos* (L.) Correa (Rutaceae) (plates.A, B, C, D, E, F and G).

Murrayya koenigii (L.) Spreng (Rutaceae) (Plate A)

Aromatic, deciduous tree, up to 7m tall; bark dark brown; wood grayish-white, a close grained; branch lets green to grey, finely pubescent, but glabrate. Leaves imparipinnate, rachis ca. 17cm long, petiole to 4cm; leaflets 11-25, oblique, elliptic-ovate. 1.5-3.8x1.4-2cm, glabrous and dark green above, pubescent beneath with black dots, apex acute, or retuse, margin irregular crenate-dentate, base symmetrical; petiolule

3mm. Flowers white in may flowered. Fruit sub globose, 1cm cross, purplish black when ripe, pulp whitish.

Biological observations recorded (Table 1)

Egg Stage (Plate I)

The newly laid egg is round and light yellow in colour. Spherical shaped with creamy white. At deposition, they are white but change to light yellow in a day. The gravid female laid eggs singly on the under surface of the leaves of *Murrayya koenigii*. It laid about 1 or 2 eggs at a time but on different leaves, mostly during 0830 – 1200h. The egg measured 0.90-1.20 (1.04±0.10) mm in length and 1.80 – 2.10 (1.94±0.10) mm in width. They hatched in 3 (3.00±0.00) days of incubation. The larva immediately after emerging consumed its eggshell. It passed through five instars over a period of 26-34 (24.80 ± 0.83) days.

LARVAL STAGE on Murrayya koenigii (Plate.J, K, L, M and N)

Instar I: This stage lasted for 2 - 3 days. The first instar was 3.50 – 4.00 (3.30 ± 0.90) mm long, and 1.00 – 1.50 (1.40 ± 0.23) mm wide. The young larva is dark brown with white markings. Head was black in colour, 0.6-0.9 (0.8± 0.12) mm wide.

Instar II: This stage lasted for 2-3 days. The larva measured 4.60 – 8.30 (7.10 ± 1.52) mm in length and 1.70 – 2.00 (1.70 ± 0.25) mm-in width. The larva colured pale yellowish green dull yellowish brown in colur. Head having with pink 'Y' shaped osmeterium. Head size increased to 2.0-2.6 (2.34±0.21) mm.

Instar III: This stage lasted for 3-5 days. The larvae attained a length of 13.00 – 17.20 (15.00 ± 1.75) mm and a width of 2.50 – 3.00 (2.60 ± 0.26) mm. the larva was grayish green and yellow with scarlet osmeterium. Head measured 3.1 – 3.8 (3.34 ± 0.30) mm in size.

Instar IV: This stage lasted for 3-4 days. The larva reached a length of 25.00 – 32.00 (29.20 ± 4.18) mm and a width of 4.00-5.60 (4.90 ± 0.66) mm. the larval body with yellow sides, crest on segments 4 and 5, two tubercles on segments 2 and 13. In addition, white marking and bands on segements 7 and 10. Head was 4.10-4.80 (4.46 ± 0.28) mm. Segmentation was clear.

Instar V: This stage lasted for 4-5 days. The full-grown larva measured 41.00 – 45.50 (41.30 ± 5.21) mm in length and 6.60-8.40 (7.56 ± 0.62) mm-in width. In addition, head was measured 5.10-6.30 (5.80±0.48). It also as same as fourth instar.

Pupal Stage (Plate.O)

Prepupa: on the last day of the fifth instar, the body of the caterpillar shortens and dull-shade of pale green. Hence, the caterpillar spins a silk pad and a silk girdle.

Pupa: This stage lasted for 9-12 days. It was 24.00 – 30.00 (28.00 ±2.44) mm in length and 8.00 – 9.00 (8.60 ± 0.41) mm-in width at its broadest end. The pupa has a pointed head and greenish body as white lateral lines. Its weight was about 1176.6 mg.

***Duration of Life Cycle (Table 3)*:** It ranged between on Main host plant of *Murrayya koenigii* 26-34 days (egg 3; larva 14-19; and pupa 9-12). The larvae were also reared on six potential host plants including, *Citrus limettioides, Citrus aurantiifolia, Citrus aurantium, Citrus sinensis, Citrus limon and A. marmelos* (Rutaceae). There was no difference in the characters of the larvae nurtured on these host plants from those reared on the oviposition host plant Murrayya koenigii. However, there was difference in the number of instars, larval development time, and pupal period as shown.

Development Success of Eggs, Larvae and Pupae

The data obtained in the laboratory study on the development success of three life stages are set out in Table 4. The eggs of *Papilio polytes* could be spotted on *Murrayya koenigii* and collected in each month during the period from September – July. The month-to-month hatching success rate varied from a low of 33% in September to high of 87.5% in March. The success rate of larvae ranged between 33.3% (June) – 87.5% (March) and that of pupae between 40% (December) – 80% (February).

Population Index (Table 5)

Searching and enumeration of the three early stages were made on nine M. *koenigii* plants. The three early life stages were evident in natural conditions during May – January. The adults were found during October – January and April - June in the study area (Fig.2). The period during January, March and October, December recorded a higher frequency of all the four life stages in the field.

FUI observations recorded (Table 2)

Food Consumption and Growth

The data on the weight of food consumed and weight gained by the larvae on seven different hosts were incorporated in Tables 6. The amount of food consumed increased from instar to instar, the proportion of total food consumption of successive five instars were: 3.58, 4.49, 10.26, 27.07, and 54.57% on *Murrayya koenigii,* 1.37, 3.21, 9.79, 21.81, and 63.79%, On *Citrus limettioides*, 1.89, 4.28, 12.85, 25.7, and 55.18% on *Citrus aurantiifolia*, 2.34, 4.60, 8.16, 12.15, and 72.72% on *Citrus aurantium*, 1.67, 3.34, 8.13, 25.07, and 61.77% on *Citrus sinensis,* 2.49, 4.66, 10.62, 34.29, and 47.92% on *Citrus limon* and 2.67, 5.97, 10.83, 24.03, and 56.48% on *Aegle marmelos.* Thus, the final instar consumed a greater amount of food 47.9 – 72.7% on the seven hosts studied. Corresponding with the pattern of food consumption, there was increase in the weight of each instar: *on M. koenigii* 0.03, 0.11, 1,12, 8.31, 90.41%, on *C. limettioides* 0.67, 2.74, 14.08, 19.60, 62.88%, on *C. aurantiifolia* 0.35, 1.34, 5.02, 12.90, 80.36%, on *C. aurantium* 0.05, 0.33, 1.05, 13.78, 84.76%, on *C. sinensis* 0.23, 0.77, 3.44, 14.70, 80.84%, on *C. limon* 0.18, 1.36, 5.85, 10.19, 82.41% and on *A. marmelos* 0.27, 1.21, 4.14, 10.52, 83.83%. Thus in the final instar alone there was 62.8 – 90.4% of growth. The weight gain by different instars was plotted against the food consumption (Fig. 1). The figures indicated a direct relationship between

these two parameters. The values of growth rate (GR) on *M. koenigii increased from second instar and gradually decreased to remaining instars,* and consumption index (CI) increased from first instar and gradually decreased to remaining instars. The values of GR varied between 0.20 – 0.50 mg/day/mg and those of CI between 0.54 – 46.38 mg/day/mg.

On *C. limettioides* decreased from instar V, increased to I instar, and consumption index (CI) increased from first instar and decreased to remaining instars. The values of GR varied between 0.22 – 1.45 mg/day/mg and those of CI between 0.53 – 5.97 mg/day/mg. On *C. aurantiifolia* decreased from instar III to V, increased to remaining instars and consumption index (CI) increased from first instar and gradual decreased remaining instars.

Table 4. Development Success of Eggs, Larvae and Pupae of *Papilio Polytes* on Murrayya koenigii Leaves In the Laboratory

Calendar month	Number of eggs incubated	Number of larvae hatched	Number of pupae formed	Number of adults emerged
JUL	4	2	0	0
AUG	0	0	0	0
SEP	3	1	1	0
OCT	10	7	3	2
NOV	12	9	4	3
DEC	25	20	15	6
JAN	30	21	13	9
FEB	39	30	24	20
MAR	45	40	35	25
APR	59	40	31	21
MAY	22	11	7	4

Table 5. Population Index of Different Life Stages of Papilio Polytes on Murrayya koenigii Leaves In the Field

Calendar month	Adult abundance	Number of eggs	Number of larvae	Number of pupae
JUL	Absent	10	8	7
AUG	Common	36	18	4
SEP	Very Common	125	126	2
OCT	Very Common	204	222	7
NOV	Very Common	145	117	7
DEC	Very Common	175	124	7
JAN	Very Common	193	224	1
FEB	Common	33	6	0
MAR	Very Common	80	36	2
APR	Very Common	101	109	0
MAR	Very Common	115	118	6
JUN	Very Common	117	113	1

Table 6. Comparative statement of GR, CI, AD, ECD, ECI Values for successive instars of the *Papilio polytes* on different host plants of Rutaceae family

	IN STAR	*M. koenigii*	*C. lime ttioides*	*C. auran tiifolia*	*C. aura ntium*	*C. sine nsis*	*C. limon*	*A.mar melos*
GR	I	0.25	1.45	0.59	0.52	0.72	0.34	0.33
	II	0.5	1.09	0.37	0.41	0.32	0.32	0.23
	III	0.28	1.62	0.27	0.28	0.34	0.47	0.4
	IV	0.4	1.53	0.35	0.31	0.47	0.29	0.16
	V	0.2	0.22	0.13	0.24	0.17	0.21	0.5
CI	I	46.38	5.97	3.09	29.32	5.45	6.25	3.46
	II	5.91	3.23	0.94	9.84	1.98	1.48	1.87
	III	0.91	1.82	0.94	2.17	1.06	1.11	1.25
	IV	0.46	1.49	0.85	0.65	0.82	0.93	0.53
	V	0.54	0.53	0.43	0.24	0.12	0.11	0.35
AD	I	98.1	92.83	92.49	96.96	93.33	93.26	95
	II	96.71	74.35	86.01	94.6	87.47	90.2	93.15
	III	83.21	76.75	73.92	89.35	61.72	82.17	86.83
	IV	75.53	65.72	67.71	64.09	63.05	82.43	83.88
	V	55.77	50.73	50.65	31.07	48.16	55.47	57.11
ECD	I	0.54	25.59	17.06	2.04	13.59	5.32	5.65
	II	1.49	28.85	34.39	6.28	23.72	29.84	18.48
	III	7.65	51.72	45.05	53.99	81.63	47.19	38.85
	IV	24.81	51.99	37.44	149.95	108.58	62.5	39.02
	V	69.26	91.06	244.84	387.42	290.32	378.6	226.88
ECI	I	0.53	23.75	15.57	1.98	12.67	4.35	4.84
	II	1.44	43.39	26.06	5.91	18.68	26.5	17.09
	III	6.68	42.7	31.81	9.09	46.52	40.21	33.42
	IV	16.82	32.97	38.13	92.58	62.76	46.18	32.7
	V	37.67	43.88	68.02	133.42	140.03	208.41	126.21

FUI : Food Utilization Indices; GR: Growth Rate; CI: Consumption Index; AD: Approximate Digestibility; ECD: Efficiency of Conversion of Digested Food; ECI: Efficiency of Conversion of Ingested Food

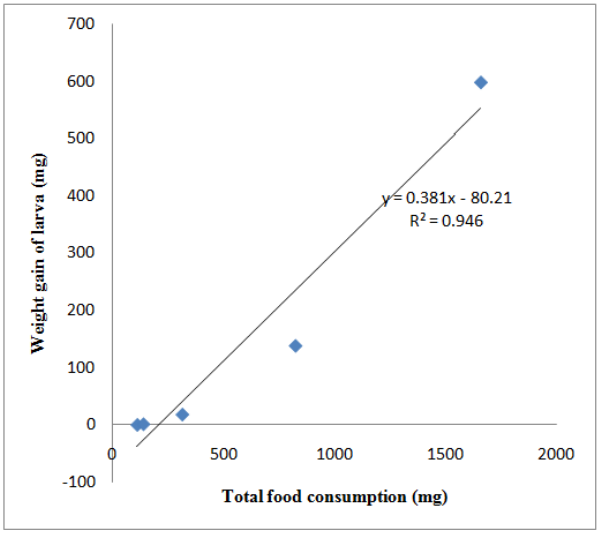

Figure 1. Relation between food consumption and growth in *Papilio polytes on Murrayya koenigii*

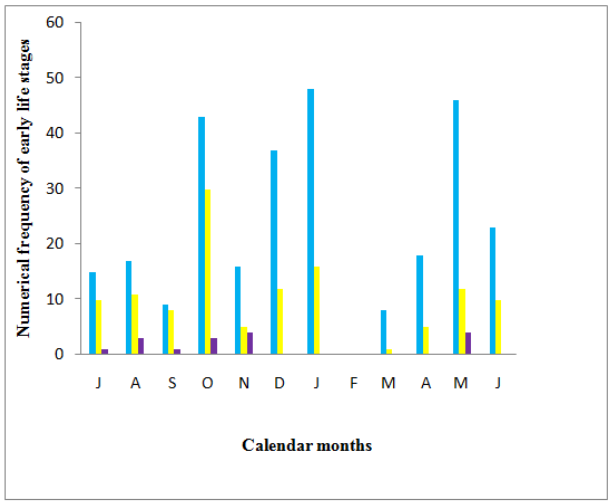

Figure 2. Population index of different life stages of *Papilio polytes* on *Murrayya koenigii* leaves in the field

The values of GR varied between 0.13 – 0.59 mg/day/mg and those of CI between 0.43 – 3.09 mg/day/mg. On *C. aurantium* decreased from instar III to V, increased to remaining instars and consumption index (CI) increased from first instar and decreased to remaining instars. The values of GR varied between 0.24 – 0.52 mg/day/mg and those of CI between 0.24 – 29.32 mg/day/mg. On *C. sinensis increased* to I instar, decreased to V instar, and consumption index (CI) increased from first instar and gradual decreased to remaining instars.

The values of GR varied between 0.17 – 0.72 mg/day/mg and those of CI between 0.12 – 5.45 mg/day/mg. On *C. limon* increased to instar III, decreased to V instar and consumption index (CI) increased from first instar and gradual decreased to remaining instars. The values of GR varied between 0.21 – 0.47 mg/day/mg and those of CI between 0.11 – 6.25 mg/day/mg. On *A. marmelos* increased III to V, decreased IV instar, and consumption index (CI) increased from first instar and gradually decreased to remaining instars. The values of GR varied between 0.16 – 0.50 mg/day/mg and those of CI between 0.35 – 3.46 mg/day/mg.

Indices of Food Utilization

Table.6 also included the indices of food utilization efficiencies AD, ECI, and ECD. The estimated values of AD were 55.77 – 98.10% on *M. koenigii*, 50.73 – 92.83% on C. limettioides, 50.65 – 91.49% on *C. aurantiifolia,* 31.07 – 96.96% on *C. aurantium*, 48.16 – 93.33% on *C. sinensis,* 55.47 – 93.26% on *C. limon* and 57.11 – 95.00%, on *A. marmelos.*

Plate A. *Murrayya koenigii* (L.)sprengel. host plant; B. *Citrus limettioides* Tanaka host plant; C. *Citrus aurantiifolia* (Christm.)Swingle. host plant; D. *Citrus aurantium* L. host plant; E. *Citrus sinensis* (L.) osbeck. host plant; F. *Citrus limon (L.) Burm.f.* host plant G. *Aegle marmelos* (L.)Correa host plant; H. *Papilio polytes* (L.) adult butterfly; I. Egg; J. First Instar (larva); K. Second Instar (larva); L. Third Instar (larva); M. Fourth Instar (larva); N. Fifth Instar (larva); O. Pupa

The values decreased on all the host plants as the instars progressed. On *A. marmelos, C. aurantiifolia, C. limettioides,* both ECI and ECD did not show any increase or decrease from first instar to final instar. The ECD values on *A. marmelos ranged* between 5.65 – 226.88%, the lowest value being associated with first instar, and the highest with fifth instar and those of ECI varied between 4.84 – 126.21%, the fifth instar having the highest value and the first instar showing the lowest value. On *C. aurantiifolia,* the ECD values ranged between 17.06 – 244.84%, the lowest value being associated with first instar, and the highest with fifth instar and those of ECI varied between 15.57 – 68.02%, the fifth instar having the highest value and first instar showing the lowest value. On *C. limettioides* the ECD values ranged between 25.59 – 91.06%, lowest value met with first instar, and the highest with fifth and those of ECI varied between 23.75 – 43.88%, lowest value met with first instar, and the highest with fifth instar. On *M. koenigii, C. limon*, *C. sinensis, C. aurantium*, both *ECD and ECI* values decreased with first instar, and gradual increased to remaining instars. The ECD values ranged between (0.54 –

69.26%, 5.32 – 378.66%, 13.59 – 290.32%, and 2.04 – 387.42%), the ECI values ranged between (0.53 – 37.67%, 4.35 – 208.41%, 12.67 – 140.03%, and 1.98 – 133.42%).

DISCUSSION

Data were obtained with reference to *Papilio polytes* on larval host plants, Population Index, egg-laying patterns, hatching period, the number of instars the larva passed through, their duration, and pupal period, and development success of eggs to adult in the laboratory. In addition, data were collected on larval performance on the basis of growth rate GR, food consumption index CI, approximate digestibility of food AD, efficiency of conversion of digested food ECD and efficiency of conversion of ingested food ECI. These different aspects of biology and food utilization are discussed below in the light of the relevant information available from temperate and tropical regions of the world. It is generally understood that the gravid females directly deposit their eggs on the plants on which their larvae later feed. The larval survival, growth rate, development time, pupal weight and the nutritional indices AD, ECI, and ECD have been estimated for *P.polytes* on its natural oviposition host plants and the effect of potential host plants on the offspring. The potential host plants chosen for this butterfly species was *Murrayya koneiggi*. In the present study though the developmental time is significantly less on *C.limmettoides,* the butterfly species preferred to lay eggs on *M.koenigii.* This could be due to the abundant presence of *C.aurantium* than C*.sinensis, C.limon, and C. aurantiifolia and. A. marmelos.*

The abundance of the host plants and the prevailing environmental factors may also determine the ecological adaptation of the respective butterfly species as expressed by Janz *et al*. (1994). Based on the spectrum of plant species utilized by the larvae for feeding, present report of the host plants of the butterfly species under study in the context of the above concept of food plant utilization indicated that, *Papilio polytes* could be treated as oligophagous and it has been shown wider range of potential host plants suitable for larval growth than the range of plants now used for oviposition. While Kitching (1981) recognized three categories of butterflies on the basis of their egg-laying habit, most authors considered only two categories: (1) the cluster or batch layers, and (2) those laying eggs singly. The species of the present study exhibited single-egg laying habit. The basic bio-patterns of butterfly from egg to adult vary from 3 weeks to 2 years (Opler and Krizek 1984). As is the case of *Papilio polytes*: average of 26-34days.

Food Consumption and Utilisation across the Instars

The larvae of *P.polytes* were found to eat firstly the shell, thus getting the valuable nutrients available immediately to them. After finishing the cell, the larvae continued to feed on young leaves of the host plant of *Murrayya koenigii, Citrus limettioides, Citrus aurantiifolia, Citrus aurantium, Citrus sinensis, Citrus limon and A. marmelos* (Rutaceae). Therefore, the larvae were reared in the laboratory feeding them with fresh young leaves of their natural host plants every day. The data obtained with respective to *P.polytes* on the quantity of food consumed and growth achieved in terms of larval body weight, and the values of consumption index (CI) and growth rate (GR) showed a definite trend of increasing absolute and declining relative rates of CI and GR with all the eight species of butterflies under study. There is a straight-line relationship between food consumption and growth (Fig.1). Of all instars, the penultimate and final instars together consumed a greater amount of food: *Murrayya koenigii 81.50, Citrus limettioides 85.61, Citrus aurantiifolia 81.0, Citrus aurantium 84.87, Citrus sinensis86.77, Citrus limon 82.24 and Aegle marmelos 80.54 %.* Food consumed over the entire larval period. The strategy of increased food consumption with the progression of larval age appears to be characteristic of all Lepidoptera and the same has been reported in other Lepidoptera in general (David and Gardiner 1962; Waldbauer 1968; Ghosh and Gonchaudhuri 1996; Atluri *et al.* 2004a; Samatha 2006).

Consumption index (CI) of instar I was the highest and the values decreased as the instars progressed (Table 6). This decline in CI as the larvae aged may be related to the increase in body size of the larvae or to the increase in conversion efficiency of ingested food to body mass (ECI). When the values of ECI increase, the values of CI decrease or the *vice versa* (Slansky and Scriber 1985). The values of CI obtained in the present study for early and late instars agree well with the values reported for some other butterfly species from the study area (Atluri *et al.* 2004a; Samatha 2006). Like food consumption, a larger proportion of total growth in terms of larval body weight took place during the last two instars. Thus as the instar larvae progressed there was a trend of increasing absolute weights, but the relative rates (values of GR) generally declined Probably GR is size dependant, and therefore its values declined as the instar larvae progressed gaining weight and size. A similar declining trend in GR has been reported in other butterfly species (Atluri *et al.* 2004a, Samatha 2006). The GRs of penultimate and final instars of the butterfly species of the present study is in line with the decreasing trend in growth rate from penultimate to final instars.

Like those of CI and GR, the values of assimilation efficiency or approximate digestibility (AD) also declined from early to late instars (Table.6). In the present study, the same expectation has been realized with AD value being at its highest in the first instar. The AD values of the present study ranged between *Murrayya koenigii 55.77-98.11, Citrus limettioides 50.73-92.83, Citrus aurantiifolia 50.65-91.49, Citrus aurantium 31.07-96.96, Citrus sinensis 48.16-93.33, Citrus limon 55.47-93.26 and Aegle marmelos* 57.11-*95.00 %.* These values appear to be on the higher side of the range 19 – 81% given for 60 species of lepidopteran larvae by Pandian and Marian (1986), and the range 28.7 - 84.6% for *Pericallia ricini* (Ghosh and Gonchaudhuri 1996). They are comparable to those (16-97% forb foliage; 12-98% tree) given by Slansky and Scriber (1985), those (72.0 - 98.0%) of Appala Naidu (2005) and those (39.40 – 97.25%) of Samatha (2006). The values of ECD across the instars showed no definite trend in the increase or decrease (Table 6) Slansky and Scriber (1985), remarked that it is rather difficult to determine the causes of such reduction in ECD. The ECI values in the present study varied between *Murrayya koenigii 0.53-37.67, Citrus limettioides 23.75-43.88, Citrus aurantiifolia 15.57-68.02, Citrus aurantium 1.98-133.42, Citrus sinensis12.67-140.03, Citrus limon 4.35-208.41 and A. marmelos 4.84-126.21%* (Table 6). This showed a continuous increase from first instar

to final instar. In line with the opinion of Slansky and Scriber (1985), it may be said that because both age and size of larvae are increasing during development, and because feeding habits may also be changing, it is frequently difficult to interpret the causes of the changes in performance values of the larvae.

REFERENCES

Appala Naidu, S. 2005. Ecobiology and food utilisation of some tropical butterfly species. Ph.D. Thesis, Andhra University, Visakhapatnam.

Atluri, J.B., Venkata Ramana, S.P. and Subba Reddi, C. 2002a. Autecology of the Common mormon butterfly *Papiliopolytes*(Lepidoptera: Rhopalocera :Papilionidae). *J. Environ. Biol.* 23(2): 199 - 204.

David, W.A.L. and Gardiner, B.O.C. 1962. Oviposition and hatching of the eggs of *Pierisbrassicae*in a laboratory culture. *Bull. Ent. Res.* 53: 91-109.

Ghosh, D. and Gonchaudhuri, S. 1996. Biology and food utilization efficiency of *Pericalliaricini*(Fab.) (Lepidoptera :Arctiidae) in Tripura. *Uttar Pradesh J. Zool*. 16(3): 109-112.

Janz, N., Nylin, S. and Wedell, N. 1994. Host plant utilization in the comma butterfly: sources of variation and evolutionary implications. *Oecologia 99:* 132-140.

Kitching, R.L. 1981. Egg clustering and the southern hemisphere lycaenids: comments on a paper by Stamp, N.E. *Amer. Nat. 118*: 423-425.

Opler, P.A. and Krizek, G.O. 1984. Butterflies: East of the Great Plains. The John Hopkins University Press, Baltimore, Maryland.

Pandian, T.J. and Marian, M.P. 1986. Prediction of assimilation efficiency of Lepidopterans, *Proc. Indian Acad. Sci.* (Anim. Sci.) 95: 641-665.

Samatha, B. 2006. Ecobiology and host plants utilization of some tropical butterfly species**.** Ph.D. Thesis, Andhra University, Visakhapatnam.

Slansky, F. and Scriber, J.M. 1985. Food consumption and utilization, pp. 85-163. In: Comprehensive Insect Physiology, Biochemistry and Pharmacology, Eds. Kerkuit, G.A. and Gilbert, L.I., Pergamon, Oxford.

Thomas, J.A. 2005. Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. Philosophical Transactions / Royal Society of London. *Biological Sciences*, 360 (1454), 339-357.

Waldbauer, G.P. 1968. The consumption and utilization of food by insects, pp. 229-288. In: Advances in insect physiology, Eds. Beament, Treherne, and Wiggles worth, Academic Press, London and New York.

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