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Biology and morphology of citrus butterfly *Papilio demoleus* Linnaeus (Lepidoptera: Papilionidae) on acid lime

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Abstract
Biology studies of citrus butterfly, *Papilio demoleus* L. were carried out on acid lime. Adult female laid eggs singly or in groups of two to five on the under surface of tender leaves and also on tender twigs. The mean duration of the different stages *viz.,* the egg period of 2.87 days, larval period of 17.53 days, pre-pupal period of 1.04 days, pupal period of 9.01 days, female adult longevity period of 6.75 days and male longevity period of 3.81 days respectively. The morphometric variations of different life stages of the citrus butterfly have been recorded.

Keywords: Morphometrics, citrus butterfly, *Papilio demoleus*, acid lime

Introduction
Citrus is one of the important fruit crops and is grown in more than 52 countries around the world. Citrus industry is the third largest, in the world after mango and banana. Citrus crop is being infested by around 165 species of economically important insect pests in India causing up to 30 per cent yield loss. [5] In India about 250 species of insects have been found attacking and spoiling various citrus species.[4] About 55 insect and mite species were recorded from Rayalaseema region.[6] Among various insects citrus butterfly, *Papilio demoleus* Linnaeus commonly known as the lime or citrus swallowtail, has a successful dispersal and becoming a major pest of citrus plants throughout Asia *P. demoleus* feeds on the foliage of citrus trees and is regarded as a major citrus pest especially in nurseries the larval forms cause serious damage to citrus family by devouring large quantity of foliage during the later stages of their development, particularly in Southern and Southeast Asia. The biology and developmental periods are mainly dependant on the climate, location and plant species on which it is feeding. 83 per cent defoliation were observed in sweet oranges grown in the Southern zone of Andhra Pradesh.[3] Severe infestation results in defoliation of the tree and leads to retarding of plant growth and decreases fruit yield. Information on the morphometric and biology of citrus butterfly on acid lime will be useful to evolve effective management strategy, against citrus butterfly.

Material and Methods
The larval population of citrus butterfly were collected on citrus trees from Chittoor, district and brought to Entomology laboratory, Institute of frontier technology, Regional Agricultural Research Station, Tirupati.

Egg Stage: Incubation period of the egg was recorded. The eggs were measured with the help of an occular micrometer. Egg colour were observed.

Larval stage: Data with regard to body length, width and head capsule width, spots on the larval body and colour of different instars were recorded. Body length, width and width of head capsule of first instar larvae were measured with the help of an occular micrometer. From second instar onwards the morphometric data was recorded by using a standard graph paper method.

Pupal Stage: The length and width of pre- pupa and pupa were recorded by using a standard graph paper method. Pupal projections, type of pupa and pupal colour were also observed.

Adult Stage: The body length, width, type of antennae, wing expanse, spots on the wing, tail on hind wing vein M3 and underside of hind wing colour in the discal and submarginal region, tornal spot pattern were recorded.

Results and Discussions

Egg: Fertilised adult female laid eggs singly, mostly on the under surface of tender leaves and also on tender twigs by curling its abdomen. Freshly laid eggs were creamy yellow, flattened at the base, smooth and spherical in outline. (plate 1) Before hatching the eggs turned to greyish colour with brown streaks all over the chorion. The eggs on an average measured 0.99 mm in diameter on host plant. Incubation period varied from 2.77-2.98 days with an average of 2.87 days on acid lime.

Larval stage

During the period of larval development, five instars were observed.

First instar larva: The newly hatched caterpillars were less spiny, cylindrical in shape, light brown to brownish black with dirty white marking on the dorsal side of the abdomen and resembled the bird droppings in appearance. Its thoracic region is broader than the rest of the body. The mean body length and width of newly hatched caterpillars were 2.30 and 0.40 mm respectively on acid lime. Mean body length, width and width of head capsule of first instar larvae were 4.9, 1.6 and 0.64 mm respectively on acid lime. The duration of first instar larvae lasted from 2.99-3.04 days with an average of 3.015 days on acid lime.

Second instar larva: The second instar larvae were less spiny and dark brown in colour with a dirty white line present obliquely along lateral sides of the abdomen with a break on the dorsal side. The mean body length, width and head capsule width of second instar larvae were 9.05, 2.6 and 0.85 mm respectively on acid lime. The duration of second instar larvae ranged from 3.06-3.18 days with an average of 3.12 days on acid lime.

Third instar larva: The third instar larvae resembled the second instar larvae in general appearance and colouration except in size. Mean body length, width and head capsule width of third instar larvae were 13.12, 3.7 and 1.54 mm respectively on acid lime. The duration of third instar larva varied from 3.98-4.02 days with an average of 4.00 days on acid lime.

Fourth instar larva: The fourth instar larvae were almost black in colour with a little greenish tinge. Whitish bands were seen on meso and meta thoracic segments laterally, anterior part of the abdomen and on the last anal segments. It had two red coloured sacs or osmeteria opening in the first thoracic segment dorsally at the anterior position. When disturbed, the osmotoria were pushed out from the anterior part of the prothorax that was bifid or forked in structure. It emits foul smelling material which is defensive in function.The mean body length, width and head capsule width of fourth instar larvae were 25.00, 5.6 and 2.50 mm respectively on acid lime. The duration of fourth instar larvae were 3.17-3.33 days with an average of 3.25 days on acidlime.

Fifth instar larva: Fifth instar larvae were entirely different from the previous four instars in all aspects, they were yellowish green or green in colour. The fifth instar larva had characteristic brownish stripes on each of the eighth and ninth sternites with two semi-circular yellowish bands on the elevated portion of the body. Head is pale green in colour. Two eye like spots were present on the second thoracic segment. A horn like structure was found on the dorsal side of the last body segment. The mean body length, width and head capsule width of fifth instar larvae were 40.76, 6.75, and 3.55 mm on acid lime. The duration of fifth instar larvae were 3.96-4.09 days with an average of 4.025 days. The prolegs will grasp onto the leaf and chew from the edge onwards with the help of its pairs of thoracic legs.(plate 2)

Body camouflage

The caterpillars of the lime butterfly resembled as bird droppings (1^{st} – 4^{th} instar) and green leaves like its host plant (5^{th} instar). (Plate 3) Its camouflage would trick potential predator into ignoring them as inanimate objects or hard to see.

Total larval period

The duration of total larval period varied from 17.16 to 17.66 days with an average of 17.53 days on acid lime. (Table 1)

The results of the present investigation are also comparable with Madansuri *et al.* [2] who recorded the mean head capsule width of first, second, third, fourth and fifth instars of *P. demoleus* as 0.61, 0.95, 1.49, 2.33 and 3.64 mm respectively and similarly, Sharif *et al.* [7] recorded the durations for egg, larva and pupal stages as 3.24, 18.24 and 11.7 days respectively and the butterfly had four generations in a year with a life cycle of 33.19 days.

Pre pupal stage: The mean length and width of pre pupa were 27 and 7.625 mm and duration of pre pupa varied from 1.02 to 1.06 days with an average of 1.04 days on acid lime.

Pupa: When the caterpillar is ready to pupate, it would orient itself to the wall with its head facing upwards and expelling its waste from the system. A network of silk pad span onto the surface and attached its body to the silk girdle for extra support. Then the body of the caterpillar became shorten in length gradually forming a hunch. After a day, the body gets hardened into a chrysalis, forming a hard pupa with a pair of anterior horns and bent away from the support. (Plate 4)

The pupa was variable in colour from green, straw to brown. There were numerous small black markings on the body. The pupa was initially green in colour and at the time of adult emergence it turns to brown colour. At the end, the pupal stage case was clearly seen. After the pupal stage, the butterfly underwent eclosion or emerged from its pupa. A slit was opened at the anterior portion of the chrysalis. The butterfly wiggled from the chrysalis and pushed itself away from the wall to free its 2 front legs. After achieving that, it climbed out onto the silk pad or branch to dry its wings. It slowly expands and to dry its wings before fluttering off to feed. The mean length and width of pupa were 29.75 and 9.05 mm and duration of pupa varied from 8.82 to 9.20 days with an average of 9.01 days on acid lime. (Plate 5)

Total life cycle: The total life cycle of citrus butterfly, *Papilio demoleus* L. i.e from egg to adult ranged from 29.77 to 30.9 days with average periods of 30.33 days on acid lime.

Adult: The fully developed butterfly inside the pupal case emerged out by splitting the case dorsally. Newly emerged adult butterflies were found to possess weak wings hence, were unable to fly in 1-3 h. Later they started to fly. Adult butterflies were large and beautiful with wide wing spread. Its head and thorax were black with creamy yellow streaks on each side. Antennae were dark reddish brown, touched with ochraceous on the inner side towards the club. (plate 6)

The legs and abdomen were dusky black, with creamy yellow colouration on the underside of the abdomen and the body was covered with black and yellow hairs. (plate 7) The wings were dull black, ornamented with yellow markings. Upperside of wings had the ground colour black. (Plate 8)

The fore wings were black. At the outer edge there was a chain of yellow spots. Next to the body there were four chains of little yellow spots. There were some other yellow spots at the rest of the wing. Post-discal mark were absent on the upperside cell M1 of forewing. The underside of *P. demoleus* was very similar to the upper side. Next to the body there were four yellow lines. (plate 9)

The hind wings of *P. demoleus* were black. The edge was wavy. Next to the body the wing was spotted by yellow scales. The wing was dominated by a broad, yellow band. At the outer edge there were five yellow spots. The underside was similar to the upperside. But all yellow marks were bigger than the marks on the upper side. Next to the body there was an yellow area with black lines. Hind wings had a black costal eyespot near apex that gradually spreads over the blue scales and shaped as crescent. Tornal spot on upper hind wing were orange with little blue scale in male and partial orange with more blue scale in female. Tail on hind wing vein M3 was rudimentary or very short, less than twice as long as those of neighbouring veins. The terminal abdomen segment shape was sharper in male and rounded in female. (Plate 10)

The mean body length from head to tip of abdomen, width and wing expanse of male butterfly were 27, 5.875 and 89.65mm, and average body length from head to tip of abdomen, width and wing expanse of female butterfly were 28.00, 6.25 and 90.75mm on acid lime. (table 2)

Adult longevity

The female adults lived longer than the male ones. Longevity of female varied from 6.65 to 6.85 days with an average of 6.75 days on acid lime. In male butterfly, the longevity ranged from 3.70 to 3.92 days with an average of 3.81 days on acid lime.

The results of the present investigation are also comparable with the results of Lewis [1] who observed external morphology of *P. demoleus* in citrus at different development stages. The results revealed that the first instar larvae were black and with two sub-dorsal rows of short fleshy spines. While second, third, and fourth instars had a dark brown and glossy head capsule. The anterior, middle, and posterior parts had broad transverse off-white bands, giving the larvae bird dropping camouflage pattern and an additional row of paired fleshy spines were present in the thorax. Pupae were green in the form and marked dorsally with yellow and attached to the thicker stems of the host plant, or to adjacent sticks and rocks. In adult the upper portion of the forewing was largely black and the outer wing margin had a series of irregular yellow spots and also a red tornal spot and discal black band dusted with yellow scales. Similarly, Smith *et al*. [8] studied the taxonomy and morphological characters of 5 species of *P. demoleus*, *P. demodocus*, *P. erithonioides*, *P. grosesmithi*, and *P. morondavana* based on features of the wings, male and female genitalia.The results revealed that the tail on hindwing vein M3 is rudimentary or very short, less than twice as long as those of neighbouring veins in *P. demoleus*.

Plate 1: Eggs of *Papilio demoleus* L.

First instar larva	Second instar larva	Third instar larva	Fourth instar larva	Fifth instar larva

Plate 2: Different larval instars of *Papilio demoleus* L.

Plate 3: Larva of the citrus butterfly, *Papilio demoleus* L.with the osmeterium exposed

Plate 4: Pre-pupa of *Papilio demoleus* L.

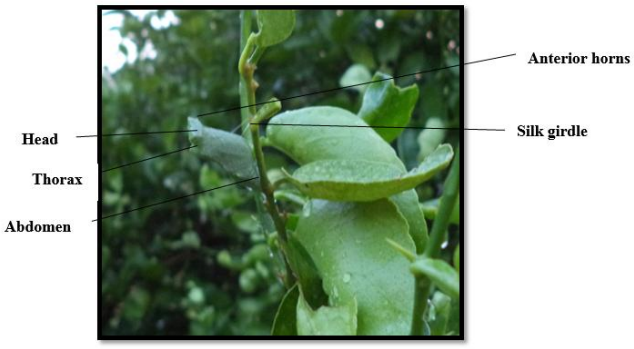

Plate 5: Chrysalis pupa

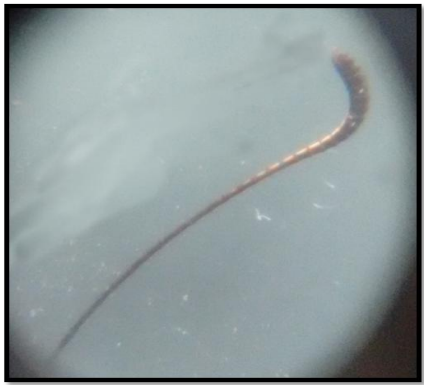

Plate 6: Antennae of *Papilio demoleus* L

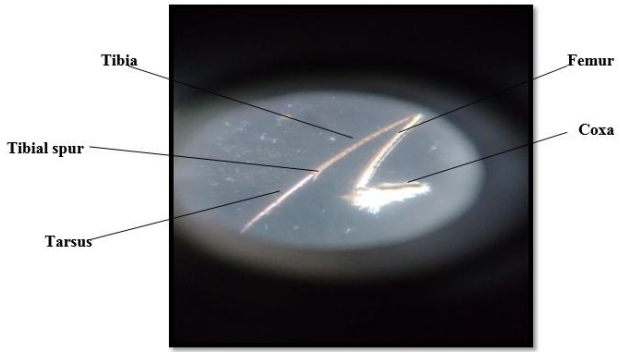

Plate 7: Leg of *Papilio demoleus* L.

Male **Female**

Plate 8: Adult butterfly of *Papilio demoleus* L.

Plate 9: Forewing upperside cell M1 with post-discal mark is absent

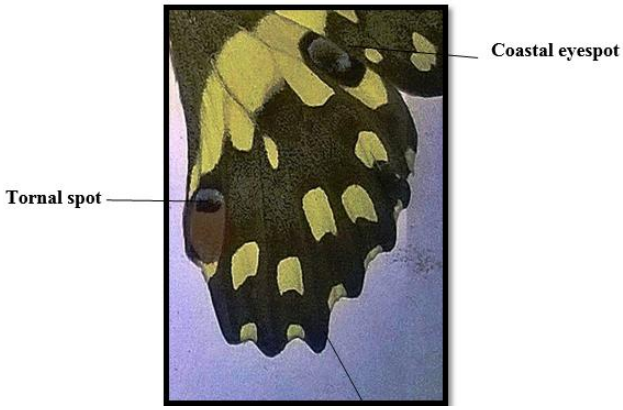

Plate 10: Hind wing vein M3 less than 2 times as long as the neighbouring vein

Table 1: Duration of different stages of life cycle of *Papilio demoleus* L. on Balaji acid lime

S. No.	Particulars/stage	Duration (days)			S.D	SEM
		Minimum	Maximum	Mean		
1.	Incubation period	2.77	2.98	2.87	0.106	0.033
2.	Larval periods					
	a. First instar	2.99	3.04	3.015	0.02	0.006
	b. Second instar	3.06	3.18	3.12	0.04	0.012
	c. Third instar	3.98	4.02	4.00	0.02	0.008
	d. Fourth instar	3.17	3.33	3.25	0.06	0.021
	e. Fifth instar	3.96	4.09	4.025	0.03	0.049
3.	Total larval period	17.16	17.66	17.53	0.17	0.096
4.	Pre pupa	1.02	1.06	1.04	0.01	0.003
5.	Pupa	8.82	9.20	9.01	0.19	0.061
6.	Longevity of adults (with 10% sugar solution)					
	a. Male	3.70	3.92	3.81	0.06	0.018
	b. Female	6.65	6.85	6.75	0.06	0.019
7.	Total life cycle (egg-adult)	29.77	30.9	30.33	0.476	0.193

SD=Standard deviation
SEM=Standard error mean

Table 2: Morphometric data of *Papilio demoleus* L. on Balaji acid lime

S. No	Particulars/stage	Morphometric measurements (mm)			S.D	SEM
		Minimum	Maximum	Mean		
1.	**Egg**					
	Diameter	0.91	1.08	0.99	0.071	0.022
2.	**Newly hatched caterpillar**					
	Length	2.05	2.55	2.30	0.222	0.070
	Width	0.30	0.50	0.40	0.076	0.024
3.	**First instar larva**					
	Length	4.45	5.35	4.9	0.24	0.076
	Width	1.50	1.70	1.6	0.073	0.023
	Width of head capsule	0.50	0.79	0.64	0.10	0.032
4.	**Second instar larva**					
	Length	8.80	9.30	9.05	0.225	0.071
	Width	2.35	2.85	2.6	0.18	0.057
	Width of head capsule	0.70	1.00	0.85	0.124	0.039
5.	**Third instar larva**					
	Length	12.00	14.25	13.12	0.62	0.196
	Width	3.40	4.00	3.7	0.273	0.086
	Width of head capsule	1.40	1.68	1.54	0.09	0.028
6.	**Fourth instar larva**					
	Length	22.00	28.00	25.00	2.22	0.767
	Width	5.30	5.90	5.6	0.27	0.085
	Width of head capsule	2.30	2.70	2.50	0.170	0.054
7.	**Fifth instar larva**					
	Length	38.02	43.50	40.76	1.61	0.509
	Width	6.40	7.10	6.75	0.281	0.089
	Width of head capsule	3.300	3.80	3.55	0.15	0.047
8.	**Pre-pupa**					
	Length	26.00	28.00	27	1.044	0.330
	Width	7.40	7.85	7.625	0.13	0.041
9.	**Pupa**					
	Length	28.00	31.50	29.75	1.291	0.408
	Width	8.65	9.45	9.05	0.16	0.051
10.	**Adult**					
	Male					
	Length	25.00	29.00	27	1.657	0.524
	(head to tip of abdomen) Width	5.7	6.05	5.875	0.09	0.028
	Wing expanse	87.00	92.30	89.65	2057	0.650
	Female					
	Length	26.00	30.00	28.00	1.506	0.476
	(head to tip of abdomen) Width	6.00	6.50	6.25	0.215	0.068
	Wing expanse	87.50	94.00	90.75	2.646	0.837

Mean values of 10 samples
SD= Standard deviation
SEM= Standard error of mean

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