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The efficiency of food utilization by the small orange tip butterfly *Colotis etrida* (Boisduval, 1836) (Lepidoptera: Rhopalocera: Pieridae) in the Eastern Ghats of Southern Andhra Pradesh-India

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Abstract
In the study was described the life history of the small orange tip butterfly, *Colotis etrida* (Boisduval, 1836), monthly occurrence and seasonality of early stages and larval performance in terms of food consumption and utilization, and the length of the life cycle. Field study indicated that *Colotis etrida* was in continuous flight and reproduction, with highest densities of early and adult stages occurring during June-September, the time of the entire South-West monsoon. The occurrence of the early stages was positive, but non-significantly correlated with rainfall, relative humidity, temperature and day length.
Field data on the numerical occurrence of eggs, larvae and pupae on the larval host plant *Cadaba fruiticosa* (L.), Druce (Brassicales: Caparidaceae) and the laboratory study on the successful development of eggs, larvae and pupae leading to the emergence of adult butterflies. The eggs are laid singly on the foliage. They hatch after 3-4 days. The larva passes through five instars and attains full growth over a period of 11-16 days. The pupal stage lasts 9-10 days. Assuming that the adult's life for 7-12 days, the length of generation time was estimated to span over 23-30 days, and accordingly the number of broods expected are estimated to be 6-7. The fifth instar larva has a greater share of the total food consumed over the entire larval period and growth was directly related to food consumption. While growth rate, fluctuated, consumption index showed a continuous decrease with the advancing age of the larvae, and their average values are 6.6 mm; and 5.4 mg; respectively. While the efficiency of conversion of ingested food and efficiency of conversion of digested FV Decreased as the larvae aged, with the average values coming to 15.32% and 13.44%, 88.8% respectively. *Colotis etrida* – *Cadaba fruiticosa* system presents an interesting situation of the same plant serving as larval and adult host, and the butterfly serving as is an exclusive pollinator.

Keywords: Andhra Pradesh, *Cadaba fruiticosa*, *Colotis etrida*, Eastern Ghats, Life history

Introduction
Of the estimated 20,000–30,000 species of butterflies occurring globally, at least 1,501 species occur in India. Several field guides for the identification of the Indian butterflies are available [1, 2, 3]. A list of the works, giving the descriptions of the life histories was given by [4]. of which those of [5]. are important.
Among insects butterflies are a fascinating group and are regarded as typical organisms in studies of evolution, behavior, ecology, and biogeography. Host selection for several development and reproduction in majority of insects often very in space and time [6] which in turn depends on the availability (minimum density per unit area) a closely related host plant species [4] and tradeoff between host preference by females for oviposition and larval performance of insects however adult butterflies and their caterpillars show preference for certain host plants for tender shoots, pollen, and nectar as food source. Thus butterfly diversity of particular habitat. Due to worldwide pressures on natural biomes, butterflies have already been shown to be highly delicate indicators of climate change [7, 8, 9] biotope destruction [10] and urbanization [11, 12]. The biodiversity crisis currently seems to appear more critical among butterfly species than other species [13, 14]. Butterflies are highly diversified in their habits require specific ecological conditions for their survival. Awareness of butterfly habitat [15, 16] and larval host plants was a prerequisite for any butterfly conservation program. Therefore, it was necessary to know the exact needs of the immature stages to make conservation successful. It was often suggested that captive rearing and releasing of species in the wild will

Threatened populations and serve as a means of protection [17, 18, 19, 20]. Butterflies are an essential component of any natural ecosystem. Their value indicators of biotope quality are being recognized because of their sensitivity to minor changes in microhabitat, climate conditions as well as seasonal changes [6]. Global interest in butterfly conservation was increasing since butterflies are valuable pollinators of wild plants and thus contributing to the world's natural sustainability. Also, the butterflies are increasingly attested as an indicator of environmental quality [4].

Successful planning and implementation of a conservation program require complete knowledge of biology and life history, larval food plants for oviposition, nectar resources for energy for adult flight, and the microclimatic needs of butterflies [21]. This knowledge of Indian butterfly species remains poorly known [2, 22, 4]. Such information was also necessary for rearing the species and releasing the adults into the wild – a strategy often suggested as a part of conservation measure. We describe here the related information for the small orange tip butterfly *Colotis etrida* of Pieridae. This butterfly species was distributed mostly in south India, and together with *C. eucharis* a species often associated with *Colotis etrida*, it was indispensable for the pollination of *Cadaba fruticosa* (Caparidaceae) of scrub jungles [23].

2. Materials and Methods

Our study was conducted during 2015 in the Sri Lankamalleswara wildlife sanctuary at Kadapa (14°47' N, 78°71' E), from Southern Andhra Pradesh, India. (Figure: 1) The natural plant community of the campus was searched for the distribution and reproductive activity of the small orange tip butterfly, *Colotis etrida*. Adult butterflies were seen mostly near the larval host plant *Cadaba fruticosa* (L.) Druce. Once located detailed observations were made at 10 sites in order to observe the flight activity and abundance of adults, the period of copulation and oviposition, following which we collected fresh eggs to study the life history and the duration of early stages. We noticed the *Colotis etrida* to lay eggs on the foliage of the bushy *Cadaba frulticosa* and forage on the floral nectar of the same plant. After plucking the leaves bearing the eggs, and brought the same in Petri dishes to the butterfly biology laboratory (about 27 ºC) at the Yogi Vemana University and incubated the same, and followed regularly to study the hatching time and success rate, larval development and survival, pupal development and adult emergence. We made these observations throughout the flying season of *C. etrida* activity.

Also searched at random and enumerated the eggs, larvae and pupae on 5 bushes of *Cadaba fruiticosa* in the scrub jungle to prepare the population index over the season. Tender leaves were supplied daily, for the larvae and studied instar wise performance in terms of growth rate (GR), consumption index, (CI), approximate digestibility (AD), the efficiency of conversion of ingested food to body tissue, (ECI), and efficiency of conversion of digested food to the body tissue (ECD); later computed theses performance traits using the formulae of Waldbauer (1968) as it was shown in the below. Fresh weights were taken in all the computations. Each parameter we maintained five replications and applied Karl Peterson's formula to find outs the correlation between food consumption and weight gain by larvae. The flower foraging activity also recorded at 15-day intervals and noted the floral species being utilized as nectar resource, their flowering periods, and nectar particulars and foraging speed. *Colotis etrida* frequently collecting nectar from *C. fruticosa* and described the diurnal foraging activity on the same plant.

The formulae of Waldbauer (1968)

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

$$\text{GR (Growth rate)} = \frac{\text{Weight gain of instar}}{\text{Mean weight of instar} \times \text{Number of feeding days}} \times 100$$

$$\text{AD (Approximate Digestibility)} = \frac{\text{Weight of food consumed} - \text{weight of feces}}{\text{Weight of food consumed}} \times 100$$

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

The study area

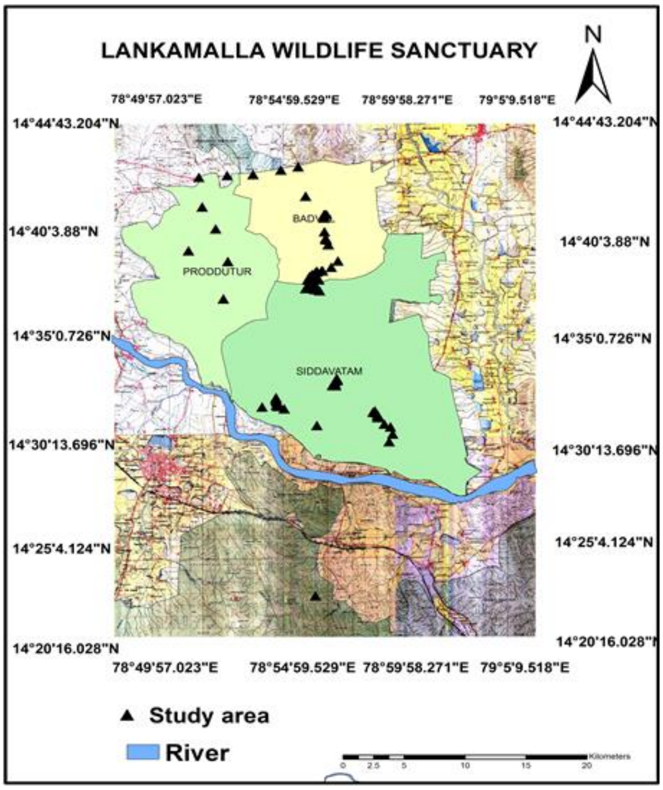


Fig 1: The Study area Sri Lankamalleswara wildlife sanctuary, Kadapa-A.P (cited by: Department of Geology, Yogi Vemana University, Kadapa)

Sri Lankamalleswara Wildlife Sanctuary was a wildlife sanctuary headquartered in Kadapa, Andhra Pradesh, India. It was the only habitat in the world which provides home for the Jerdon's courser, a highly endangered bird species. In addition to that it was also a home to nearly 176 families of vegetation and living organisms. The Sanctuary provides a home to nearly 76 butterfly species and 1400 plant species and nearly 176 families of vegetation and living organisms. It has dry deciduous mixed thorn forests with deep gorges and steep slopes. Red Sanders, an endemic species, can be found here.

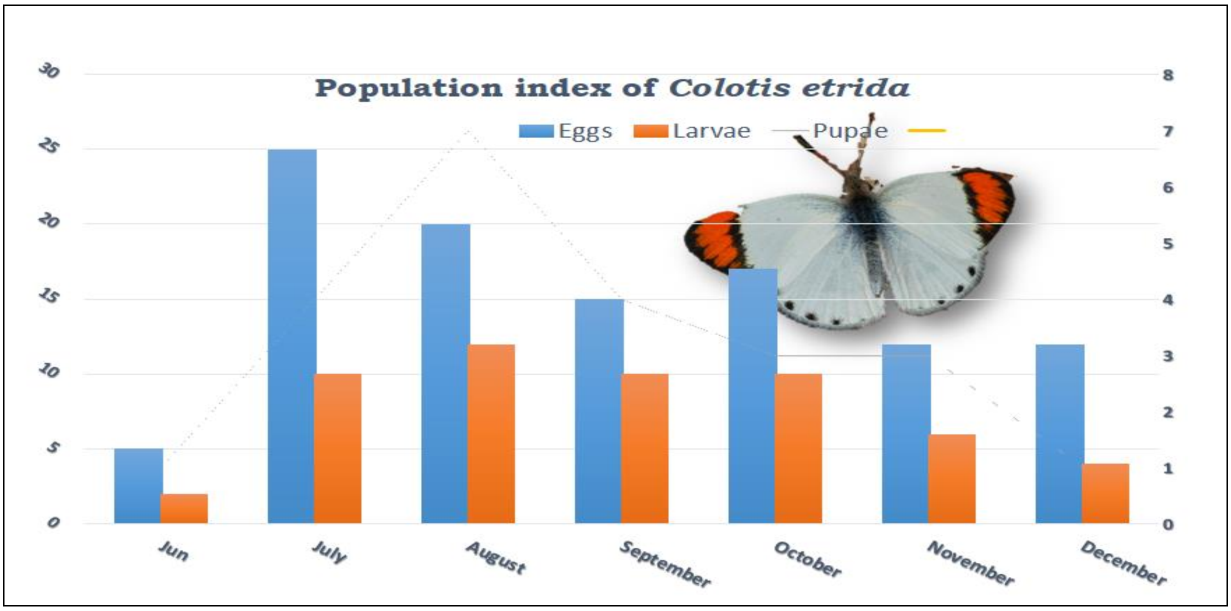
3. Results and Discussions

Seasonal distribution:

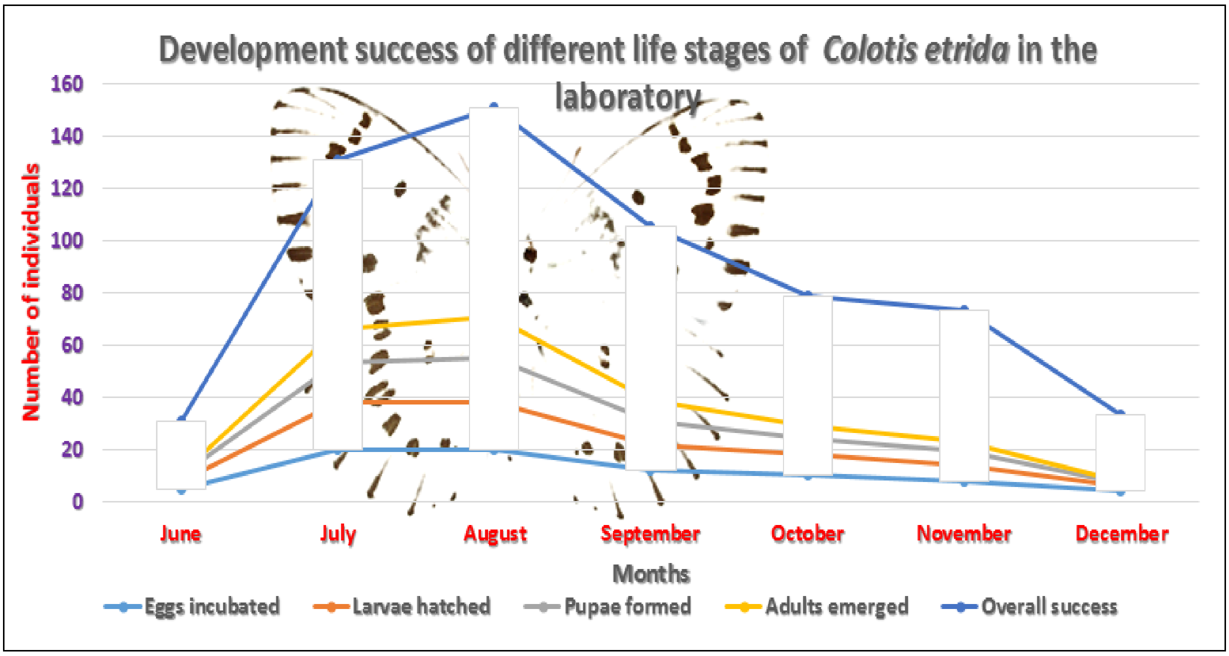
Month wise data on the frequency of eggs, larvae and pupae on the host plants indicated a distinct seasonality in the temporal distribution of *Colotis etrida* (Table -1) (Graph-1). This season of distribution from June to December, with a higher frequency of the three life stages occurring during July-October, correspond with the rainy season of this locality. This observation agrees with Wynter–Blyth (1957) who wrote that the distribution of butterflies at a locality mainly depends on the rainfall conditions of that locality and in south India the rainy season may vary from region to region and accordingly the exact period of *Colotis etrida* distribution may vary from region to region. The period from July to October was the better time for *C. danae* reproduction was also attested by the higher development success of the different life history stages in the laboratory; eggs 80-90%, larvae 75-94%, and pupae 83-94% (Table- 2).

Table 1: Population index of *Colotis etrida* in *Cadaba fruiticosa* in the wild number of individuals

Life cycles stage	June	July	August	September	October	November	December
Eggs	5	25	20	15	17	12	12
Larvae	2	10	12	10	10	6	04
Papae	1	4	7	4	3	3	1



Graph 1: Population index of different life stages of *Colotis etrida* in *Cadaba fruiticosa*



Graph 2: Growth success of different life stages of *Colitis etrida* in the laboratory

Table 2: Development success of different life stages of *Colotis etrida* in the laboratory

Life cycles stage	June	July	August	September	October	November	December
Eggs incubated	5	20	20	12	10	08	04
Larvae hatched	3	18	17	10	06	08	06
Papae formed	2	15	17	9	6	5	1
Adults emerged	1	13	16	8	5	4	1

Overall success	20	65	80	66.7	50	50	25

Life history and voltinism: (Figure: 2)

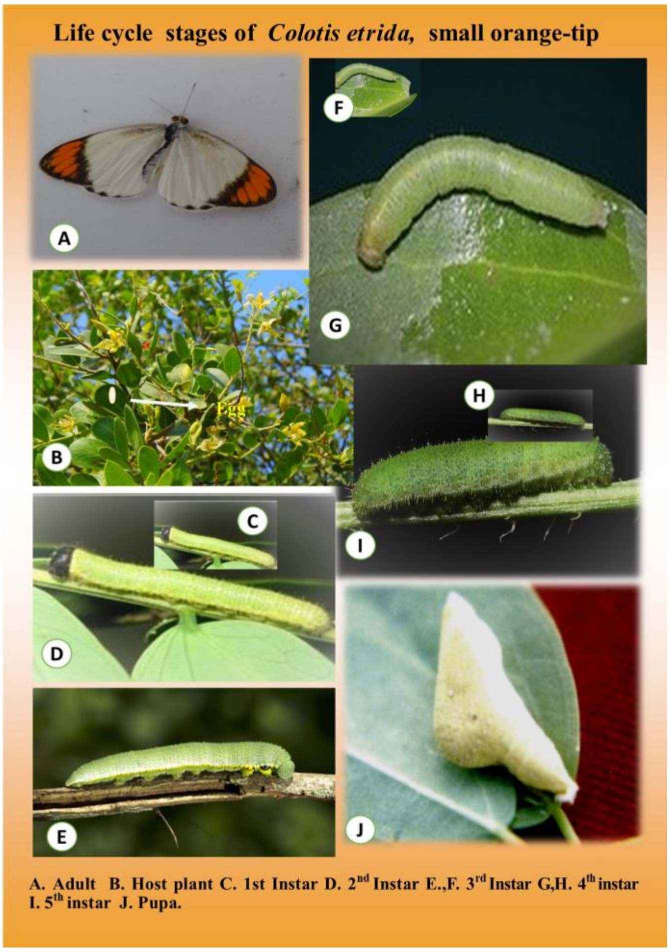


Fig 2: Life cycle of *Colotis etrida*

The eggs hatched 3-4 days after being laid; they are laid singly on both surfaces of young leaves of *Cadaba fruiticosa* in the study area, sometimes on twigs, and floral parts too. They are smooth with orange color, and longitudinal ridges extending from apex to base. They measured 1.5-2.1 (1.8 ± 0.23) mm in length, and 0.9-1.2 (1.0 ± 0.03) mm in diameter. The color has become dull by the day of hatching.

The length of the larval period varied from 11-16 days. During this period, each larva underwent four molts and had five instars. The first instar lasts 2-3 days. The first day it was 1.3-1.5 (1.4 ± 0.08) mm long. The second day it was 2-3 (2.6 ± 0.22) mm in length. Its head was round and 0.2-0.3 (0.25 ± 0.11) mm in diameter. Its body was green and bears small hairy structures. The second instar lasts 2-3 days and grows up to 4-5 (4.8 ± 0.09) mm in length. Its head was 0.3 – 0.35 (0.32 ± 0.01) mm in diameter. The body was green. The head was covered with small hairs. The third instar last 2-3 days grow up to 8-10 (9.1 ± 0.11) mm in length. Its head was 0.5 to 0.6 (0.55 ± 0.22) mm in diameter. The mid-dorsal line begins to appear; body becomes rough, hairy and green. The fourth instar lasts 2-3 days, attains a length of 12-15 (13.3 ± 0.09) mm and a width of 1.5-2 (1.8 ± 0.01) mm. Its head was 0.6-0.8 (0.69 ± 0.02) mm wide and 1.5 to 2 (1.7 ± 0.03) mm long. While the ventral profile of the body was pale green, the dorsal profile turns into dark green with lateral sides showing whitish- green patches. The lateral side of each leg bears a black spot. Hairy tips are shiny and slightly orange colored. Segmentation was clear. The fifth instar last 3-4 days. The fully grown larva measures 20-22 (21.0 ± 0.12) mm in length and 2.5-3.0 (2.7 ± 0.07) mm in width. Its head was dark green, 1.0-1.2 (1.1 ± 0.02) mm in width and 1.8-2.0 (1.9 ± 0.04) mm in length. The remaining characters are similar to those of the fourth instar. The pre-pupal process takes place for a day. The body of the fifth instar larva becomes short by contraction. It was 20-21 (20.6 ± 0.14) mm long it attaches to the substratum over its entire body. The pupae are brown in color. The pupal period lasts for 9-10 days the fully formed pupa measures 15-16 (15.7 ± 0.18) mm in length and 7-8 (7.6 ± 0.18) mm in width at the broader region. The anterior end of the pupa was pointed.

Colotis etrida [25, 26] commonly called small/little orange tip. The ground colour on the upperside of the males was white, sparsely irrorated at base of fore and hind wings with black scales. Fore wing has a small black spot on the discocellulars; apex broadly black, with an enclosed oval, curved, rich orange patch placed obliquely and traversed by the veins, which there are black; inner edge of black area diffuse. Hind wing was uniform, except for a preapical short diffuse black streak from the costa, sometimes absent, and a series of terminal black spots that in specimens from moist localities are very large.

Based on the length of the incubation period of eggs, the length of larval and pupal periods, it was estimated that the time required from the laying of eggs to emergence of adults was about 23-30 days. This length of life history was relatively short and was in line with the reported life history duration for tropical butterflies [27, 28]. Butterflies, with this kind of short generation time, distributed in regions of decreasing latitudes, are expected to have more than one generation [28]. Thus, *C. etrida* distributed was southern India located between latitudes 8º 10' N and 22º 24' N may have more than one brood. Assuming 7-12 days of lifespan for the adults [28] of *C. etrida*, the generation time would be at the maximum 23-30days. Thus over the period of 210 days of its flying season from June to December, *C. etrida* may yield 6-7 generations.

Food consumption and utilization efficiencies of larvae

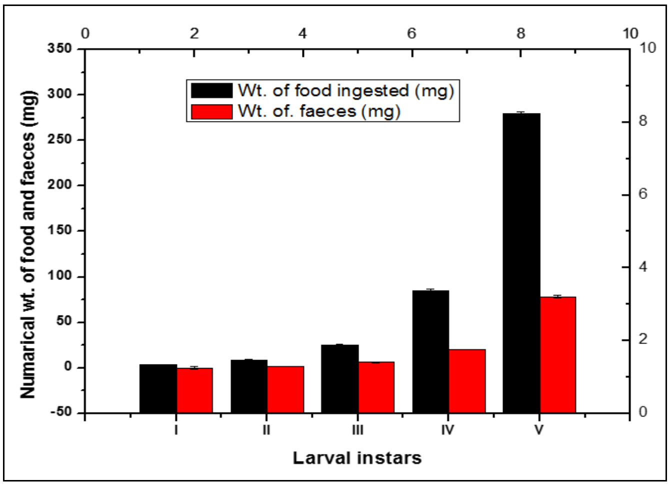
The data relating to the weight of food consumed, weight gained and indices of food utilization like GR, CI, AD, ECI and ECD obtained for each of five instars are included in Table - 3. The regression of weight gained by larvae on the food consumed by them was studied by applying the regression equation and the equation obtained was Y= 0.89X – 80.93 and, the correlation coefficient value obtained was r = 0.89 which greater than table‘t’ value (t =0.780 at 1% level). Thus, both food consumption and weight gained by the larvae show a linear relationship. Food consumption increased from instar to instar, the increasing being high from third instar to fourth instar, and very high from fourth to fifth instar larvae (Table- 3, Graph - 3), the last instar alone consumed 68.5% of the total food consumption of the entire larval period. This behavior of increased consumption of food by the penultimate and or final instar has been reported in several lepidopterous larvae in general [24, 29, 30] and was often interpreted as a strategy to provide sufficient energy for the metamorphic process in the non-feeding pupal stage [31].

While consumption index (CI) showed a continuous decrease in its value from instar I to instar V, growth rate (GR) had alternateiy, rises and falls (Graph 5). The average value of CI was 0.54 mg. The first two instars had a value higher than the average. The average value of GR was 6.6 mg; the value of the first instar only exceeded this average. The AD percentages decreased continuously through the successive instars and averaged to 88.8% the first two instars had a higher value than the average. The declining trend in AD through successive instars was often related to the ingestion of increased proportions of the indigestible crude fiber of the leaf material as the larvae grew older [32]. The AD values are comparable with the literary data: 19 – 81% for 60 species of Lepidoptera [6], 28.7-84.6% in *Pericallia ricine* [34]. 85.1-98.0% in *Euploea core* [35], 84-99% in *Graphium doson* [22, 38]. Being a foliage chewer, *C. danae* was expected to attain high AD values [37], and the foliage of *Cadabe fruiticosa* must be rich in nitrogen and water to promote high AD [6]. The values of both ECI and ECD increased as the larvae grew older. The increase is very steep from first instar to second instar. In spite of a very high value of CI of first instar, its conversion efficiency was rather low. Conversion efficiency was very much improved with all other instars, and was at its highest at fifth instar larvae. This increased efficiency was in line with the increased gain in body weight of instar V. continuous rise of ECI and ECD was also reported in *Phaeoba infunata* and *Pachliopta hector* [36]. The values of ECI ranged between 3.1-25.2% (avg. 15.32) and of ECD between 3.0-19.0% (avg 13.44). These are comparable with the range of values reported for foliage chewers in general [37].

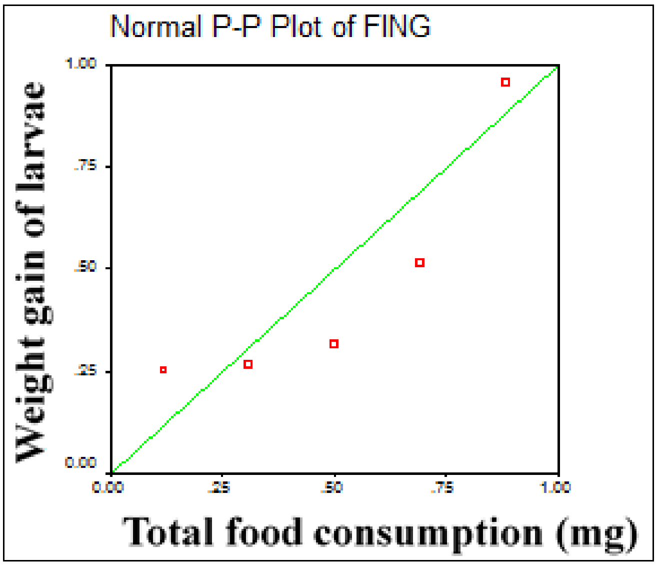
Table 3: Food Consumption and utilization efficiencies of *Colotis etrida* larvae on *Cadaba fruiticosa*.

Instar number	Wt. of food ingested (mg)	Wt. of. feces (mg)	Wt. gain by larva (mg)	GR	CI	AD	ECI (%)	ECD (%)
I	3.5 ± 0.30	0.12 ± 01	0.18 ± 0.03	1	17.77	96.25	3.1	3.0
II	8.5 ± 0.62	1.32 ± 0.11	1.62 ± 0.12	0.36	2.05	85.33	14.8	14.3
III	25.5 ± 0.81	6.05 ± 0.34	5.80 ± 0.32	0.45	2.07	77.16	15.4	15.3
IV	85.2 ± 1.71	20.40 ± 0.40	19.60 ±0.58	0.52	2.26	76.05	18.1	15.6
V	279.4 ± 2.12	78.50 ± 1.24	50.00 ±1.10	0.32	1.83	72	25.1	19.0

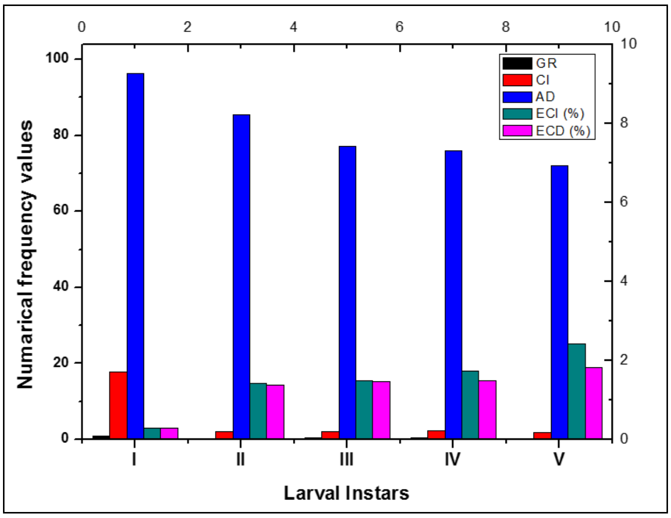
Growth rate (GR), Consumption index (CI), Approximate digestibility (AD), Efficiency of conversion of digested food (ECD), Efficiency of conversion of ingested food (ECI)



Graph 3: Relationship between food consumption and growth in *Colotis etrida* larvae on *Cadaba fruiticosa*



Graph 4: Relationship between food consumption and growth in *Colotis etrida* larvae on *Cadaba fruiticosa* Leaves



Graph 5: Food consumption, growth and food utilization efficiency of *Colotis etrida* larvae on *Cadaba fruiticosa*.

Nectar resources

In the study area, the adults of *Colotis etrida* collected the nectar of 9 floral species included *Cadabe fruticosa* (major part of the year), *Cleome viscoca* (June –Feb), *Xeromphis spinosa* (June- Aug), *Tridax procumbens* (yearlong), *Carissa spinarum* (April -July), *Lantana camara* (yearlong), *Stachytarpheta indica* (June – Sept), *Oscimum basilicum* (June – Sept), and *Antigonon leptopus* (Major part of year). Nectar volumes varied between 0.10 – 2.60 µl; *C. fruiticosa* contained a larger quantity than other species. Nectar sugar concentration varied from 16 to 58% (Table: 4) and was comparable with the reported range in psychophilic flowers (15 – 50%) [21]. The corolla depth of these flower species varied from 3-23 (X = 8.0) mm and the same could be conveniently probed by the 17 mm long proboscis of *Colotis etrida*. In *Cadaba fruiticosa*, nectar was located in a specialized tube to be manipulated by butterflies only. On *C. fruiticosa* was used as a major source of foraging activity occurring between 1000-1600 hr, and peaking at 1400-1500 hr; foraging speed per adult included 16 flowers per minute, spending 2.0 seconds per flower. The nectar thus collected, provided energy for flight, and flight was vital to find mates, oviposition plants and to disperse the species. Nectar intake may also increase adult longevity, and egg production, and improve egg maturation. While nectar at the floral species, *Colotis etrida* received pollen mostly on its proboscis (8 species), head (4), antennae, legs and wings each one species, and the same was transferred to the stigmas in the subsequent floral probes. Pollen deposition on proboscis and head was an important character of butterfly pollination [32]. But in *Cadaba fruilticosa* with relatively long exserted stamens, pollen deposition on wings constitutes pterigotribic pollination which is on par efficiency with nototribic pollination.

Table 4: Nectar characteristics of the floral species and foraging speed of *Colotis etrida*

Name of plant species	Nectar volume (µl) 10.00 h	1700 h	Nectar conc. (%) 10.00h	1700h	Sugars present	flower Visits/ min	Time spent (sec)
Cadaba Fruiticosa	2.70	1.60	18.00	20.00	gSf	16	2.0
Antigonon leptopus	0.04	0.30	58.00	52.00	Gsf	6	1.0
Octomum basilicum	0.02	0.01	18.00	15.00	Gsf	05	1.3
Stachytarpheta indica	0.80	1.00	27.00	26.00	gSf	11	1.0
Lantana camara	0.06	0.04	18.00	23.00	gSf	9	1.4
Xeromphis spinos	0.30	0.10	31.00	21.00	Gsf	7	1.1

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