

The efficiency of food utilization by the Plain orange-tip butterfly *Colotis aurora* (Cramer, 1780) (Lepidoptera: Rhopalocera: Pieridae) in the Eastern Ghats of Andhra Pradesh – India

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Abstract

Butterflies were fascinating creatures known for their colorful wings and graceful flight³. Butterflies can be found on every continent except Antarctica, and they play a crucial role in pollination and as indicators of environmental health⁷. The butterfly fauna of India was rich with over 1500 species which is close to 9% of the total butterfly species of the world¹⁶. The Western Ghats region in southern India is known for its high butterfly diversity, with over 330 species found in the region alone¹⁸. *Colotis aurora*, commonly known as the plain orange-tip butterfly, was a beautiful butterfly species belonging to the family Pieridae found in Africa and South-Western Asia¹⁰. The nominate subspecies, *Colotis aurora aurora* was found in India and Sri Lanka⁹. The larvae of allThe study detailed the life cycle, monthly occurrence, seasonality, and larval performance of the plain orange-tip butterfly, *Colotis aurora*, in terms of food consumption and utilization. Field research indicates that *Colotis aurora* reproduces and flies continuously, with maximum densities of early and adult stages occurring during the South-West monsoon period from June to September. The study found a positive correlation between early-stage occurrence and temperature, day duration, relative humidity, and rainfall, but not statistically significant. The laboratory study examined the number of eggs, larvae, and pupae on the larval host plant *Cadaba fruticosa* (L.) Druce and their development into adult butterflies. Eggs lie singly on leaves, hatch in 3–4 days, and go through five instars before growing to 14 - 16 days in size. 9–10 days pass during the pupal stage. It was multivoltine, breeds also throughout the year and with high frequency during the periods from June to October. The life cycle from egg to adult

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emergence was relatively short, spanning 26–30 days. Growth was directly correlated with food consumption, with the fifth instar larva consuming a larger portion of the total food consumed during the larval phase. The average values of the consumption index and growth rate are 0.32mg and 2.63mg, respectively, and they both varied as the larvae grew older. As the larvae grew older, the average values of the conversion rates of swallowed food and digested food increased to 20.94%, 24.93%, and 81.06%, respectively. The *Colotis aurora* – *Cadaba fruticosa* system was a fascinating system where the same plant serves as both larval and adult nectar, while the butterfly was the sole pollinator.

Key words : *Colotis aurora*, *Cadaba fruticosa*, Life history and Eastern Ghats.

Colotis species specialize on plants in the family *Capparaceae*. In Andhra Pradesh, *Colotis aurora* can be found in diverse habitats such as grasslands, scrublands, and forest fringes. They were often seen fluttering around flowering plants and bushes, feeding on nectar and soaking up the sunlight.

The adult *Colotis aurora* butterfly had striking orange-yellow wings with black spots and markings, which make them a visually appealing, sight in the natural surroundings. Their wingspan ranges from 3 to 4 cm, making them relatively small-sized butterflies. During the breeding season, female *Colotis aurora* butterflies lay their eggs on host plants like *Capparis*, *Maerua*, and *Capparaceae* species. The caterpillars of this species feed on these host plants before pupating and emerging as adult butterflies²³. *Colotis aurora* was adding to the diversity and beauty of the region's butterfly fauna. They play a crucial role in pollination and ecosystem maintenance, making them a valuable part of the local biodiversity⁹. Any natural ecosystem must have butterflies as a necessary component. Their sensitivity to minute changes in

microhabitat, climatic circumstances, and seasonal variations had led to the recognition of their potential indicators of biotope quality⁶. Due to butterfly's important role as pollinators of wild plants, which supports the survival of the natural world, interest in butterfly conservation had grown on a global scale. Butterflies were also becoming more and more recognized as a sign of a healthy environment²⁹.

Comprehensive understanding of biology and life history, larval food plants for oviposition, nectar supplies for energy for adult flight, and the microclimatic requirements of butterflies were necessary for the effective development and execution of a conservation programme¹³. There was still much to learn about Indian butterfly species^{5,25,29}. Such knowledge was also required for growing the species and releasing the individuals into the wild, a practice that was frequently recommended as a component of conservation measures. The relevant details regarding the Pieridae family's plain orange-tip butterfly, *Colotis aurora*, are discussed here. This species of butterfly was mostly found in south India, and it was essential for pollinating the *Cadaba*

fruticosa (Caparidaceae) of scrub jungles, along with *C. etrida* and *C. danae*, a species that was frequently linked to *Colotis aurora*²¹.

Our study was conducted during 2023 in the Nigidi forest at Anantapuram (12° and 41'19.07° N, 77° and 84°40' E), from Southern Andhra Pradesh, India (Figure: 1). The larval host plant, *Cadaba fruticosa* (L.) Druce was the main focus of the study, which looked at the distribution and reproductive practices of the orange-tip butterfly, *Colotis aurora*, in the Nigidi forest. Following their discovery, we collected fresh eggs to study their life cycle and the length of the early stages. We also conducted thorough observations at ten sites to monitor adult flying activity and abundance, as well as the timing of copulation and oviposition. We saw that the *Colotis aurora* feeds on the flower nectar of the bushy *Cadaba fruticosa* and lays its eggs on its leaf. Once the egg-bearing leaves were picked, the eggs were transferred in Petri dishes to the butterfly biology lab at Yogi Vemana University, where they were incubated at a temperature of roughly 27°C. The eggs were then monitored

closely to track the development of the larvae and their survival, their pupal stage, and their adult emergence. Throughout the *C. aurora* active flying season, we recorded these observations.

In order to prepare the population index for the year, five bushes of *Cadaba fruticosa* in the scrub jungle were randomly inspected and the eggs, larvae, and pupae counted. The larvae were given tender leaves every day, and their performance was examined 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) at each instar. These performance traits were then computed using Waldbauer's (1968) formulas, as the following illustrates. New weights were used in each calculation. Karl Pearson's formula was used to determine the relationship between food consumption and larval weight gain for each parameter, and five replications were kept.

The formulae of Waldbauer's³ :

$$\text{CI (Consumption index)} = \frac{\text{Wt of food consumed}}{\text{Wt of instar} \times \text{number of feeding days}}$$

$$\text{GR (Growth Rate)} = \frac{\text{Wt gain of instar}}{\text{Mean wt of instar} \times \text{number of feeding days}}$$

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

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

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

The Study area :

Fig. 1. The Study area Nigidi forest Ananthapuramu – Andhra Pradesh

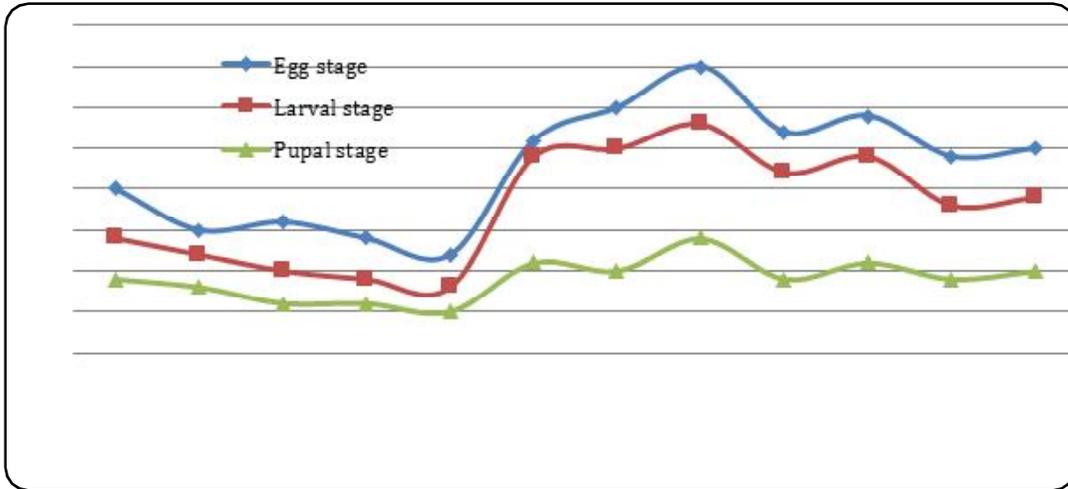
Seasonal distribution :

Colotis aurora temporal distribution exhibited a clear seasonality, according to month-by-month data on the frequency of eggs, larvae, and pupae on the host plants (Table-1) (Graph-1). Rainy season in this locality coincides with this season of distribution, which runs from June to December. During this time, there was a higher frequency of the three life phases. This observation supports the findings of Wynter-Blyth (1957), who

stated that the distribution of butterflies at a location primarily depends on the rainfall conditions of that location. In south India, the exact timing of the *Colotis aurora* distribution varies depending on the region because the rainy season varies geographically. The increased development success of the various life cycle stages in the laboratory eggs 80–90%, larvae 75–94%, and pupae 83–94% also attested to the fact that June to October were the best time for *Colotis aurora* reproduction (Table-2).

Table-1. Population index of *Colotis aurora* in *Cadaba fruticosa* in the wild number of individuals in the study area –

Life cycles stage	J	F	M	A	M	J	J	A	S	O	N	D
Eggs	15	10	11	9	7	21	25	30	22	24	19	20
Larvae	9	7	5	4	3	19	20	23	17	19	13	14
Pupae	4	3	1	1	0	6	5	9	4	6	4	5



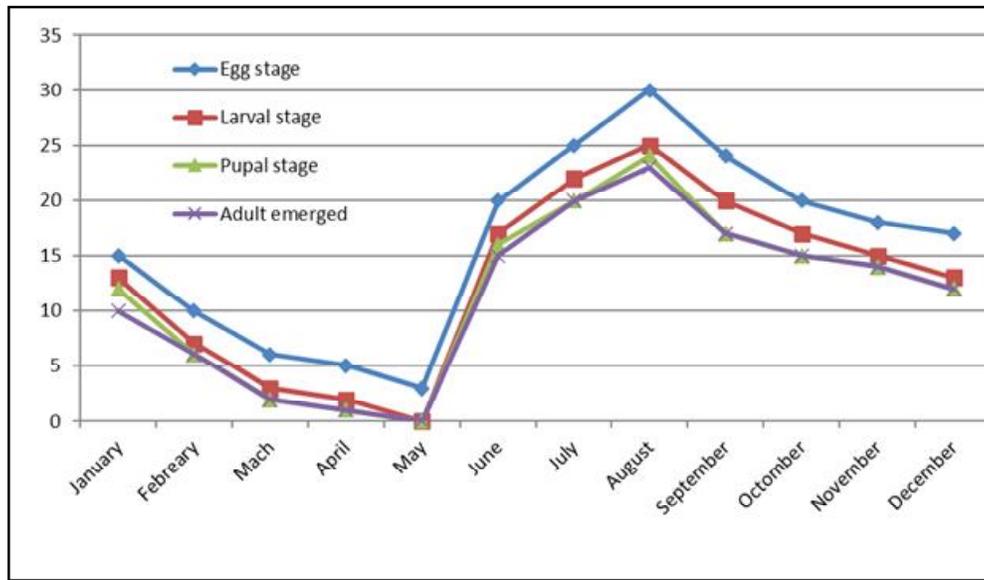
Graph 1. Population index of different life stages of *Colotis aurora* in *Cadaba fruticosa* in the study area

Table-2. Development success of different life stages of *Colotis aurora* in the laboratory

Life cycles stage	J	F	M	A	M	J	J	A	S	O	N	D
Eggs incubated	15	10	6	5	3	20	25	30	24	20	18	17
Larvae hatched	13	7	3	2	0	17	22	25	20	17	15	13
Pupae formed	12	6	2	1	0	16	20	24	17	15	14	12
Adult emerged	10	6	2	1	0	15	20	23	17	15	14	12

The eggs were laid singly on both surfaces of the young leaves of *Cadaba fruticosa* in the research area; occasionally, they were laid on twigs and floral portions as well. The eggs hatch 3–4 days after being laid. They have longitudinal ridges that run from the apex to the base, and they were smooth and orange in color, 0.37 - 0.39 (0.38 ± 0.03) mm width and their length ranged from 0.63 -

0.66 (0.64 ± 0.03) mm. By the day of hatching, the color was no longer vibrant. The larval phase lasted anywhere from 13 to 17 days. Every larva experienced four molts and five instars during this time. A first instar lasts two to three days. The length of the first instar was 2.82 – 6.12 (6.04 ± 0.08) mm and 0.80 – 1.04 (0.82 ± 0.22) mm width. The larva's head turns black after emergence and then turns



Graph 2. Growth success of different life stages of *Colotis aurora* in the laboratory

green. The circular head measured 0.82–1.05 (0.94 ± 0.11) mm in diameter. Its green body had little hairy features on it. The second instar lasts for 2 - 3 days and reaches a length of 6.13 – 9.23 (9.14 ± 0.09) mm and 1.05 – 1.46 (1.25 ± 0.21) mm width. The diameter of its head measured between 1.06 – 1.47 (1.43 ± 0.04) mm. The body had a green color. Tiny hairs were all over the head. The mid-dorsal line starts to show; the body turns green, hairy, and rough. During the third instar, the length can reach up to 9.24 – 14.25 (14.14 ± 0.11) mm and 1.46 – 1.48 (1.43 ± 0.05) mm width. The diameter of its head measured 1.46 – 1.47 (1.45 ± 0.02) mm. After two to three days, the fourth instar reaches a length of 14.26 – 18.25 (18.16 ± 0.09) mm and a width of 1.48 – 2.56 (2.55 ± 0.01) mm. The diameter of its head measured between 1.48 – 1.49 (1.46 ± 0.03) mm. The body's dorsal and ventral profile changes to a dark green color with patches of

whitish-yellow visible on the lateral sides. On each leg, there was a black spot on the side. The glossy, somewhat orange hairy tips were hairy. Segmentation was evident. The fifth instar lasts for three to four days. When completely developed, the larva's length and width measure 18.26 – 20.42 (20.3 ± 0.12) mm and 2.56 – 3.12 (3.05 ± 0.07) mm, respectively. Dark green in color, its head measured 1.48 – 1.49 (1.47 ± 0.02) mm in diameter. Comparable to the fourth instar were the remaining characters. Pre-pupal activity lasts for one day. The fifth instar larva's body contracts, making it shorter and its whole body were attached to the substratum. The pupae have a brown hue. The pupal stage lasts for 6 – 8 days. When fully developed, the pupa was 15.02 – 15.05 (15.01 ± 0.04) mm long and 5.69 – 5.71 (5.68 ± 0.03) mm wide in the wider area. The pupa had a pointed anterior end.

The male's upper sides were a clear

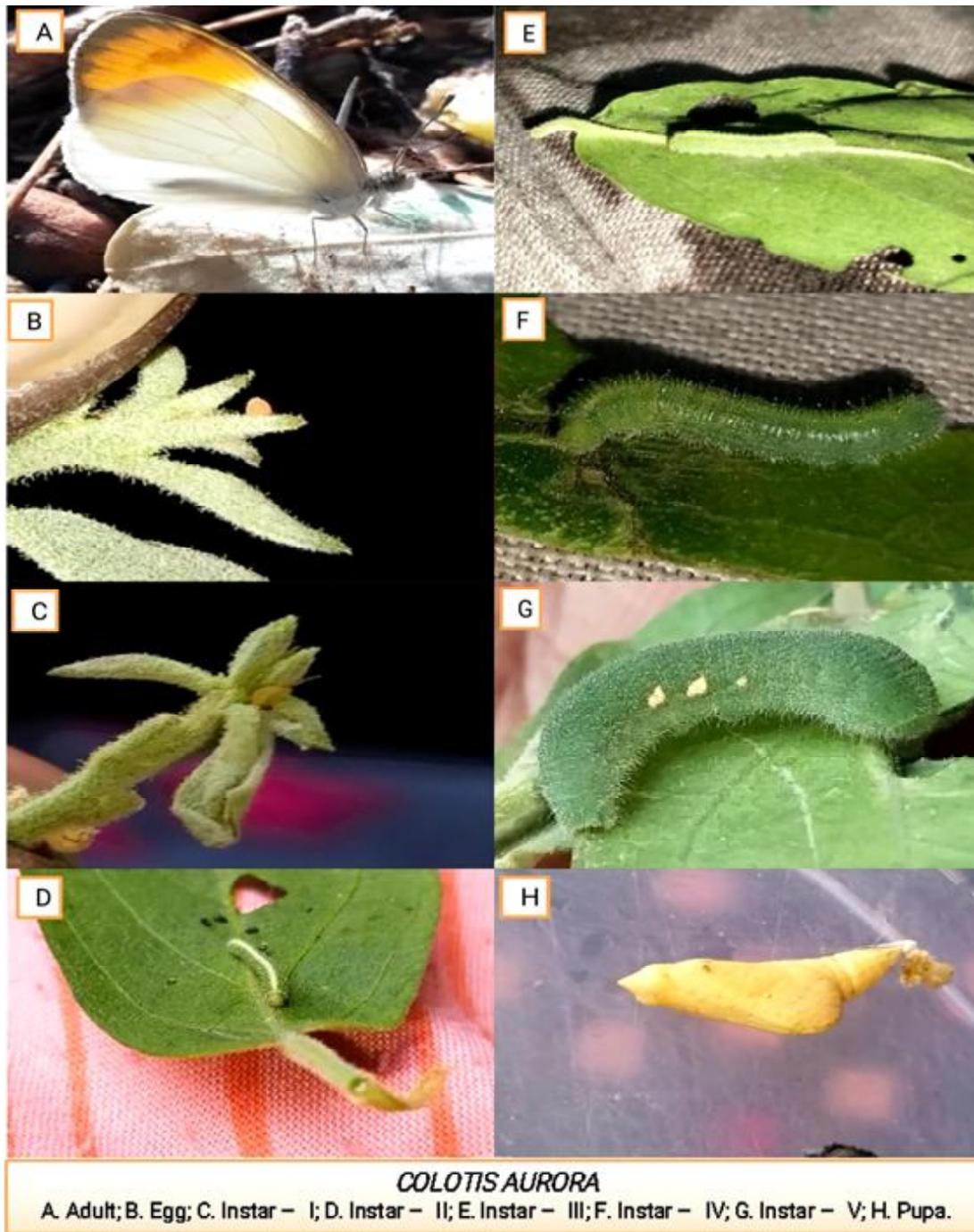


Fig. 2. Life cycle of *Colotis aurora*

white background hue. The forewing features a large orange-yellow patch at the apical region, with a straight inner edge and gamboge's yellow margins. The base and costa of the forewing were speckled with black scales near the base. On the male hindwing, there were black patches that vary in size at the vein apices and stop on the termen. Additionally, there was a diffuse pre-apical black spot on the costa^{1,2,12,24}.

The female was similar to the male in terms of ground color. Upper side, forewing: disco-cellular spot larger; base and costa more strongly irrorated with grayish-black scales; apical region black with three contained, elongate orange dots. Grayish-black scales on the hind wing's base were more sparsely irradiated than on the forewing; the pre-apical spot on the costa and terminal spots were significantly larger; there was an indistinct transverse posterior discal fascia in a few instances. Underside: markings resemble those of the male but were significantly larger, more densely marked, and more conspicuous; there are also more transverse fuscous dots and streaks. Head, thorax, abdomen, and antennae were the same as in the male^{1,2,12,22,24}.

It was calculated that the time needed from the laying of eggs to the emergence of adults was roughly 26–30 days based on the length of the egg incubation period and the duration of the larval and pupal stages. This life history was in keeping with the average amount of time that tropical butterflies have been known to have^{14,15}. Butterflies should have multiple generations given their short generation period and distribution across latitudes that were decreasing¹⁴. Southern

India was home to the species *C. aurora*, which has several broods between latitudes 8°10' N and 22°24' N. The generation time would be at most 28–30 days if adults of *C. aurora* survive¹⁴ for 7–12 days. *C. aurora* can therefore generate 6-7 generations over its 210-day flying season, which spans from June to December.

Food consumption and utilization efficiencies of larvae :

Table-3 provides data on food consumption, weight gain, and utilization indicators for each of the five instars, including GR, CI, AD, ECI, and ECD. The larval phase showed a significant increase in food intake from third to fourth and fourth to fifth instars (Table-3, Graph 3), with the final instar alone consuming 69.3% of the total food. The regression of weight gained by larvae on the food consumed by them was studied by applying the regression equation and, the correlation coefficient value obtained was $r = 0.99$ which greater than table 't' value ($t = 0.870$ at 1% level). Thus, both food consumption and weight gained by the larvae show a linear relationship. Penultimate or final instar larvae in various lepidopterous larvae consume more food to provide energy for metamorphic processes during the non-feeding pupal stage^{11,17,19}. The growth rate and consumption index showed a steady decline from instar I to instar V (Graph 4), with an average of GR 0.32 mg, with the first three instars exceeding the mean. The first instar exceeded the mean, with an average of CI 2.63mg, but successive instars had decreasing AD percentages, averaging 81.06%.

As larvae grew older, they devoured more indigestible leaf fiber, which was frequently associated with a decrease in AD throughout

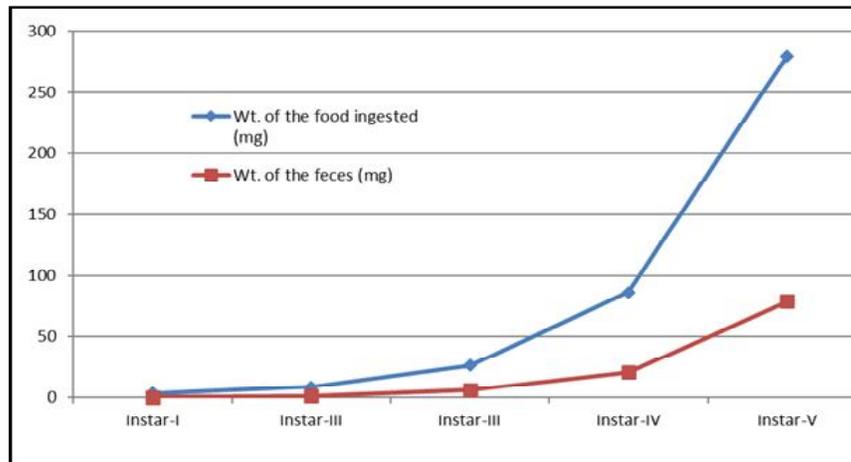
successive instars⁸. AD values were consistent with the literature, ranging from 19–81% for 60 Lepidoptera species⁶ and 28–84.6% for *Pericallia ricine*⁴. 1–98.0% in *Euploea core*²⁶ and 84–99% in *Graphium doson*^{25,28}. *C. Danae*, a foliage chewer, is likely to have high AD values²⁰. *Cadaba fruticosa* foliage, which was rich in nitrogen and water, also promotes high AD⁶. ECI had alternate rises and falls (Graph 4), and ECD levels grew with larval age. The increase was significant from first to second instar. Despite a high CI value

for the initial instar, conversion efficiency was low. Conversion efficiency increased with each subsequent instar, peaking at the fifth instar larvae. Increased efficiency coincided with increased body weight in Instar V. Similar increases in ECI and ECD were observed in *Phaeoba infunata* and *Pachliopta hector*²⁷. ECI ranged from 4.84 to 17.93% (avg. 20.94), whereas ECD ranged from 4.7 to 24.93% (avg. 18.78). These results are comparable to those observed for foliage chewers in general²⁰.

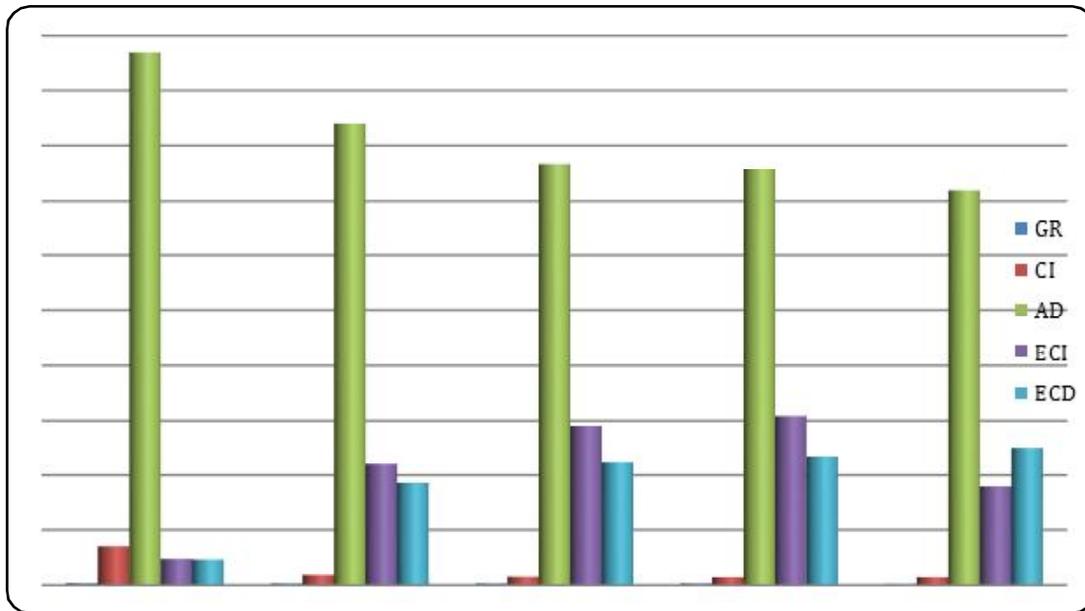
Table-3. Food Consumption and utilization efficiencies of *Colotis aurora* larvae on *Cadaba fruticosa* in the laboratory

Instar No	Wt. of the food ingested (mg)	Wt. of the feces (mg)	Wt. gain by the larvae (mg)	GR	CI	AD %	ECI %	ECD %
I	3.4±0.25	0.1±0.1	0.16±0.03	0.36	7.08	97.05	4.84	4.7
II	8.6±0.6	1.33±0.1	1.6±0.11	0.34	1.79	84	22	18.6
III	26.2±0.8	6.1±0.32	5.85±0.3	0.33	1.49	76.71	29.1	22.32
IV	85.79±1.5	20.89±0.6	20.04±0.6	0.32	1.42	75.64	30.87	23.35
V	279.9±2.09	78.6±1.2	50.2±1.12	0.25	1.39	71.91	17.93	24.93

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 aurora* larvae on *Cadaba fruticosa* in the laboratory



Graph 4. Food consumption, growth and food utilization efficiency of *Colotis aurora* larvae on *Cadaba fruiticosa* in the laboratory

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