development of universal formulations to increase inoculant survival during seed coating and storage. In addition, marketing of bioinoculant product as environmentally friendly alternatives to chemical fungicides will depend on the generation of essential biosafety data required for the registration of biocontrol agents in general.23.


9. Shani Noam, 2,4-diacylphloroglucinol (DAPG) producers in the rhizosphere of wheat; development of probes and primers to assess their presence and abundance in Indian rice–wheat crop rotations. MSc thesis, University of Neuchatel, Switzerland, 2002.


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Ecobiology of the tropical pierid butterfly Catopsilia pyranthe

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Successful and effective conservation management of butterflies depends on sound knowledge of their life history and host plant requirements in the wild. As part of an effort in this context of South Indian butterflies, the life history and the length of each life stage (egg, larva and pupa) of the pierid butterfly Catopsilia pyranthe (Linnae), which is a strong migrant, were studied. The development period from egg to adult emergence spanned over 22–29 days, thus opening up a possibility of at least 11–12 breeding genera.

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tions yearly. The larvae were reared in the laboratory (around 28°C), providing them daily fresh leaves of *Cassia siamea*, and quantitative data on food consumption, growth and efficiency of food utilization of different instars were obtained using the gravimetric method. Final (fifth) instar consumed more food, excreted more faeces and gained more weight than the other instars. The development success of eggs, larvae and pupae was recorded each month. The number of eggs, larvae and pupae occurring on 20 small plants of *C. siamea* was scored each month and also the abundance of adults in arbitrary units. All life stages occurred over the entire year with a higher frequency during July–September, a period falling within the southwest or summer monsoon season. Flower visitation of adults was examined and their foraging speed was measured. Nectar sugar concentration and type of dominant sugar present were determined and also pollen deposition on various body parts. The butterfly foraged on nectars varying in sugar concentration between 16 and 58%, and received pollen mostly on the head and proboscis while nectaring, thus complying with the important trait of psychophily.

The genus *Catopsilia* is a member of the subfamily Coliadinae, family Pieridae (Lepidoptera: Rhopalocera). It is a tropical genus, commonly found in India. Although Beeson\(^1\) mentioned four species of the genus: *C. pomona*, *C. pyranthe*, *C. florella* and *C. crocale*, Varshney\(^2\) recognized only two species as *C. crocale* (Cramer), with two separate subspecies *C. pomona* and *C. crocale*, and *C. pyranthe* (Linnaeus), with *florella* (Fabricius) as the dry-season form. Both species are characteristic of secondary vegetation and feed freely upon *Cassia* species (Caesalpiniaceae). They are common throughout the year\(^3\), the monsoon promoting higher frequency of population\(^4\). In southern India at Madurai (78°10'E–9°58'N), Christopher and Mathavan\(^5\) found a quiescent period in the reproduction of *C. crocale* during summer months, only the southwest and northeast monsoons promoting reproductive activity. At Visakhapatnam (82°18'E–17°42'N), also in southern India, we found no quiescent period in reproduction with *C. pyranthe*. Assuming that the two species, *C. crocale* and *C. pyranthe*, differ in their lifestyle adaptations, we studied in detail (i) life history sequence and length, (ii) development success of egg, larva and pupa, (iii) larval performance in terms of food consumption, growth and food utilization efficiency, (iv) population (eggs, larvae, pupae) index, (v) nectar resources of adults and the pollination efficiency of *C. pyranthe*. This knowledge is useful in the conservation management of the butterfly.

Adults of *C. pyranthe* breed throughout the year. Figure 1 gives the breeding pair and other life stages. Oviposition host plants included *Cassia siamea*, *C. fistula*, *C. occidentalis*, *C. auriculata*, *C. tora* and *C. alata* in the study area. Among these, *C. siamea* (a tree species used in social forestry) is most frequently used for ovipositing. Eggs are laid singly on the upper (48%) and lower (30%) surface of tender, pale-green leaves, and on their margins (22%). Fresh eggs along with the leaf placed in petri dishes of 15 cm diameter, were brought to the laboratory at the Andhra University and incubated at laboratory temperature at about 28°C, to study the life-history sequence and length of each stage through daily observations\(^6\). The larvae were provided fresh leaves daily. Based on skin casting, the different instars were identified. Instar particulars were recorded under a hand lens. Instar measurements were taken using centimetre graph paper.

The eggs (Figure 1 b) were erect, fusiform, 2.0–3.0 (2.5 ± 0.18) mm in height, 1.0–1.5 (1.2 ± 0.01) mm in diameter at the broadest region. White when oviposited, becoming creamy white within a day. Incubation period is 3–4 days. Freshly hatched-out larva ate its own eggshell. The larva passed through five instars over a period of 12–17 days.

The first instar (Figure 1 c) grows to a length of 4.5–5.5 (5.0 ± 0.2) mm. Body cylindrical, pale green, with head, thorax, anal region and abdominal legs yellow. Head round, plain, 0.3–0.6 (0.5 ± 0.12) mm in diameter. Length of instar period is 2–3 days.

![Figure 1](image-url)  
**Figure 1.** Life stages of *Catopsilia pyranthe*.  
* a. Adult;  
b. Egg;  
c. Instar I;  
d. Instar II;  
e. Instar III;  
f. Instar IV;  
g. Instar V;  
h. Pupa.
The second instar (Figure 1d) grows to a length of 8.5–10.0 (9.2 ± 0.6) mm. Body pale green, lateral sides yellow, head pale yellow. Head 0.9–1.3 (1.1 ± 0.14) mm in diameter. Length of instar period is 2–3 days.

The third instar (Figure 1e) grows to a length of 11–13 (12.2 ± 0.04) mm. Head 1.3–1.7 (1.5 ± 0.14) mm in diameter. Remaining characters as in second instar. Duration of instar is 2–3 days.

The fourth instar (Figure 1f) grows to a length of 19.0–20.5 (20.0 ± 0.12) mm. Body colour green, lateral sides yellow. Head 1.5–2.2 (2.0 ± 0.06) mm in diameter. Duration of instar is 2–3 days.

The fifth instar (Figure 1g) grows to a length of 29–36 (30 ± 0.1) mm. Body colour green, segmentation clearly visible, lateral side yellow with black band. Head creamy white, hairy, anal region pale green. Duration of instar is 3–4 days.

During the prepupa and pupa stages (Figure 1h), the body of the mature larva becomes thick and short by contraction, 23–28 (26 ± 0.11) mm in length. Attaches to the substratum over its entire body; duration being one day. Pupal body length 19–21 (20.0 ± 0.06) mm. Appears like a shell. Duration is 7–8 days.

Table 1 gives the quantitative data on food consumption, weight gain and values of growth rate (GR), consumption index (CI), approximate digestibility (AD), efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food to body tissue (ECM) for each of the five instars, calculated using the formulae of Waldbauer. Food consumption and weight gain profiles ran on similar lines, both showing an increase as the larvae aged. Out of the total food consumed over the entire larval period, 67% was shared by instar V alone, getting a weight gain of 70%. Such increased consumption of food and consequent increase in growth appear to be common with Lepidoptera. Statistical analysis of the relation between food consumption and weight gain gave a regression equation Y = 0.92 X – 83.24, with a value of correlation coefficient r = 0.89 exceeding Table 'r' value (0.780) at 1% level, thereby indicating a linear relationship between the two variables. A similar relationship was reported in Melanoplus bivittatus and M. femurrubrum. The values of GR and CI declined from instar I up to instar IV, but again showed a slight increase at instar V, the former with a high of 0.50 in instar I and a low of 0.15 at instar IV, the average being 0.27; the latter from a high of 22.0 at instar I and a low of 1.70 at instar IV, the average being 7.08. This tendency in GR and CI is in conformity with the findings of Mohanty and Mitrar in Antheraea mylitta, and those of Gosh and Gonchadurn in Pericallia ricini. AD is inversely related to food consumption. Its values declined from a high at instar I (98%) to a low at instar V (68.8%). Similar reports appear in the literature, and the tendency of AD to decline as the larvae aged is often attributed to the increased consumption of indigestible fibre by the ageing larvae. However, in this case it is likely that the growing larvae consumed food indiscriminately to meet the demand for energy and nitrogen. Accordingly, a larger portion of the ingested food is lost in the form of faeces. There was an increase in faeces egestion corresponding to the increase in food consumption and in body weight (Table 1). For foliage chewers, high AD values are expected, the present values (98.0–68.8%) are in line with this prediction. The profiles of both ECI and ECM are in inverse relationship with AD; the values of both indices showing up a progressive increase from instar I to instar V. The values of ECI ranged between 2.20 and 10.5% (av. 6.93%) and those of ECM between 2.30 and 15.30% (av. 8.64%); these values agree with those (ECI = 2–31 (av. 13); ECM = 2–93 (av. 37)) reported for tree foliage-chewing Lepidoptera in general. It is in the fifth instar that maximum food consumption and growth took place and also ECI and ECM attained the highest value among the different instars, thereby indicating that the food consumed was properly used for tissue growth of the larvae.

Assessment of adult population distribution and abundance using arbitrary criteria such as less common, common and abundant indicated that the adults of C. pyrantha are rather abundant during July–September, common during October–March, and rare during April–May. Enumeration of eggs, larvae and pupae once each month on 20 small host plants, repeated a similar trend in the seasonality of C. pyrantha. All the life stages are evident during the entire calendar year, with higher frequency during July–September (Table 2). The development success of these life stages leading to the emergence of adults as studied in the laboratory is also in support of the kind of annual distribution, with a seasonal high (Table 3). The success rate is high during July–September (81–86%) and it gradually declined to reach a low (33.3%) in the month of May. The year-round occurrence of C. pyrantha with higher frequency at a certain time of the year is in line with the behaviour of many species.

<table>
<thead>
<tr>
<th>Instar</th>
<th>Wt of food ingested (mg)</th>
<th>Wt of faeces (mg)</th>
<th>Wt gain (mg)</th>
<th>GR</th>
<th>CI</th>
<th>AD (%)</th>
<th>ECD (%)</th>
<th>ECI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4.40 ± 0.12</td>
<td>0.09 ± 0.01</td>
<td>0.10 ± 0.03</td>
<td>0.50</td>
<td>22.0</td>
<td>98%</td>
<td>2.20</td>
<td>2.30</td>
</tr>
<tr>
<td>II</td>
<td>42.00 ± 0.18</td>
<td>1.20 ± 0.08</td>
<td>1.70 ± 0.09</td>
<td>0.30</td>
<td>7.60</td>
<td>97.0</td>
<td>4.00</td>
<td>4.10</td>
</tr>
<tr>
<td>III</td>
<td>260.00 ± 2.40</td>
<td>21.50 ± 0.14</td>
<td>24.50 ± 0.16</td>
<td>0.20</td>
<td>2.05</td>
<td>91.7</td>
<td>8.75</td>
<td>10.20</td>
</tr>
<tr>
<td>IV</td>
<td>350.00 ± 3.60</td>
<td>62.90 ± 0.22</td>
<td>32.50 ± 0.17</td>
<td>0.15</td>
<td>1.70</td>
<td>82.0</td>
<td>9.20</td>
<td>11.30</td>
</tr>
<tr>
<td>V</td>
<td>339.00 ± 7.40</td>
<td>421.00 ± 3.90</td>
<td>141.00 ± 0.38</td>
<td>0.21</td>
<td>2.07</td>
<td>88.8</td>
<td>10.50</td>
<td>15.30</td>
</tr>
</tbody>
</table>
butterfly species in the tropics, where the climatic seasons are overlapping, and the temperatures remain relatively high throughout the year20.

The period July–September of higher density of all stages of C. pyranthe quite closely corresponded with the southwest or summer monsoon (June–September) in the study region. In a detailed study on C. crocale at Madurai, Christopher and Mathavan21 found a relation between adult abundance and its reproductive activity with the rainfall received in the southwest (April–August) as well as northeast (September–December) monsoons, the latter season promoting a high reproductive activity. Although there were enough rains during the northeast monsoon (October–December) at Visakhapatnam, the different kinds of data, either separately or collectively, revealed better performance of C. pyranthe during the southwest monsoon (June–September). Further, research on C. crocale reported a quiescent period in the reproductive activity of adults during the dry months. But such arrested reproductive activity is not seen with C. pyranthe adults. The kind of annual distribution of C. pyranthe with peak falling in the rainy season agrees with the observation of Wynter-Blyth4, who wrote that the distribution of butterflies at a locality mostly depends on the rainfall conditions. He also remarked that in southern India rainfall conditions are complicated and differ from region to region, thus causing differences in the behaviour of butterflies. These remarks are justified by the differences in the behaviour between the two species of Catopsilia, C. crocale at Madurai and C. pyranthe at Visakhapatnam, both places located in southern India. Or, the two species are adapted to different lifestyles.

C. pyranthe was on wings throughout the year and visited 44 out of 68 plant species kept under observation and collected nectar. The most frequently utilized species are included in Table 4 along with their nectar characteristics. The butterfly is a relatively strong flier and must be requiring adequate energy for flight, which is vital to find mates and food plants on which to lay eggs. Intake of nectar which contains sugars and amino acids22,23 provided the necessary energy22,23 and also might have contributed to egg production and egg maturation24,25. Graduated micropipette determinations of nectar volumes of the floral species of C. pyranthe varied from traces as in Santalum album, Cleome viscosa and Sida cordifolia to 1.8 μl in Jatropha podagrica, and sugar concentration determined using a refractometer from 16 to 58%, with either sucrose or glucose dominance as revealed by paper chromatography. Some researchers maintained that sugar concentrations in the range of 20–25% with sucrose dominance are characteristic of butterfly nectars27. Such nectars are met with the floral species having tubular

### Table 2. Population index of C. pyranthe during 1994–95

<table>
<thead>
<tr>
<th>Life stage</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of adults</td>
<td>CO</td>
<td>CO</td>
<td>CO</td>
<td>LC</td>
<td>LC</td>
<td>CO</td>
<td>AB</td>
<td>AB</td>
<td>AB</td>
<td>CO</td>
<td>CO</td>
<td>CO</td>
</tr>
<tr>
<td>No. of larvae</td>
<td>18</td>
<td>15</td>
<td>16</td>
<td>16</td>
<td>18</td>
<td>40</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>36</td>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>No. of pupae</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>10</td>
<td>12</td>
<td>33</td>
<td>27</td>
<td>21</td>
<td>16</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>No. of pupae</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>16</td>
<td>12</td>
<td>10</td>
<td>5</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

LC, Less common; CO, Common; AB, Abundant.

### Table 3. Development success of life stages of C. pyranthe in the laboratory

<table>
<thead>
<tr>
<th>Life stage</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of eggs incubated</td>
<td>22</td>
<td>12</td>
<td>10</td>
<td>14</td>
<td>18</td>
<td>20</td>
<td>48</td>
<td>48</td>
<td>37</td>
<td>30</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>No. of larvae hatched</td>
<td>16</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>15</td>
<td>66</td>
<td>45</td>
<td>36</td>
<td>28</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>No. of pupae formed</td>
<td>15</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>44</td>
<td>42</td>
<td>32</td>
<td>27</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>No. of adults emerged</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>12</td>
<td>43</td>
<td>41</td>
<td>30</td>
<td>22</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>

### Table 4. Nectar characteristics of floral hosts of C. pyranthe

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Volume (μl)</th>
<th>Concentration (%)</th>
<th>Sugars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albizia lebbeck</td>
<td>0.4–0.7</td>
<td>17–19</td>
<td>Gsf</td>
</tr>
<tr>
<td>Anacardium occidentale</td>
<td>0.6–1.3</td>
<td>26–31</td>
<td>Gsf</td>
</tr>
<tr>
<td>Antigonon leptopus</td>
<td>0.02–0.4</td>
<td>54–58</td>
<td>Gsf</td>
</tr>
<tr>
<td>Berberis hispida</td>
<td>0.02–0.02</td>
<td>28–32</td>
<td>Gsf</td>
</tr>
<tr>
<td>Caesalpinia coriaria</td>
<td>0.02–0.06</td>
<td>26–48</td>
<td>Gsf</td>
</tr>
<tr>
<td>Caesalpinia pulcherrima</td>
<td>0.68–1.22</td>
<td>18–29</td>
<td>gSf</td>
</tr>
<tr>
<td>Cleome viscosa</td>
<td>Traces</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Derris indica</td>
<td>Traces</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Duranta repens</td>
<td>0.6–1.0</td>
<td>19–24</td>
<td>gSf</td>
</tr>
<tr>
<td>Enterolobium saman</td>
<td>Traces</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Eupatorium triplinerve</td>
<td>0.4–0.8</td>
<td>23–28</td>
<td>Gsf</td>
</tr>
<tr>
<td>Homelia patens</td>
<td>0.9–1.3</td>
<td>21–26</td>
<td>Gsf</td>
</tr>
<tr>
<td>Jasminum angustifolium</td>
<td>0.5–0.61</td>
<td>16–28</td>
<td>gSf</td>
</tr>
<tr>
<td>Jatropha podagrica</td>
<td>1.4–1.8</td>
<td>53–56</td>
<td>Gsf</td>
</tr>
<tr>
<td>Justicia procumbens</td>
<td>0.01–0.04</td>
<td>18–21</td>
<td>Gsf</td>
</tr>
<tr>
<td>Murraya koenigii</td>
<td>0.01–0.06</td>
<td>16–23</td>
<td>Gsf</td>
</tr>
<tr>
<td>Santalum album</td>
<td>Traces</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sida cordifolia</td>
<td>Traces</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Stachydatum indica</td>
<td>0.9–1.0</td>
<td>33–36</td>
<td>Gsf</td>
</tr>
<tr>
<td>Tridax procumbens</td>
<td>0.5–0.9</td>
<td>25–29</td>
<td>Gsf</td>
</tr>
</tbody>
</table>

Sugars (glucose, sucrose, fructose): Dominance is indicated by capital letter.
flowers: *Duranta repens* with nectarial tube 19–24%, *Jasminum angustifolium* 16–28%, and *Caesalpinia pulcherrima* 18–29%. But in species having bowl-shaped flowers, nectar sugar concentrations are high with glucose dominance. Earlier studies showed that nectar with higher sugar concentration (30–65%) are also intensively foraged by butterflies, and the optimum concentration is approximately 40% (refs 28, 30). Nectar concentrations of *C. pyranthe* flowers (16–58%) stand close to the reported range of 15–50% in psychophilous flowers. Flower visiting rate and flower handling time of *C. pyranthe* are comparable with those reported for pierid butterflies. Although the pollination potentiality of a flower visitor is dependent on floral architecture, deposition of pollen on mouthparts is considered to be important in psychophily. Out of the 15 floral species tested in this context, *C. pyranthe* received pollen on the head in 14 species, proboscis 11, legs nine, antennae and wings six species each, thus qualifying itself as a pollinator of its floral species. It may be noted that a small proportion of butterfly pollination contributes to gene flow over relatively long distances. This butterfly is an established migrant in India, and migrant pollinators are receiving priority in the global conservation agenda. Although Williams indicated some directions in the movement of butterflies in India, there is an urgent need to trace the migratory corridor of *C. pyranthe* and identify ‘flowering waves’ along the corridor and determine the butterfly’s dependency on such ‘flowering waves’.

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**Phytochemical variability in commercial herbal products and preparations of Withania somnifera (Ashwagandha)**

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**Withania somnifera** (Hindi – Ashwagandha, English – winter cherry) is used in Ayurvedic formulations for a variety of health-promoting effects. Several mono- and poly-herbal products commercially available in the Indian market were quantitatively analysed for a number of chemical constituents. The results revealed wide variations in the content of all seven constituents tested. More than 70-fold variation in the daily intake of withaferin A (the main active constituent of Ashwagandha) was found in the products. The study thus emphasizes the need for stringent phytochemical standardization of herbal products.

**Therapeutic** properties of food and medicinal plants stem from the characteristic bioactive phytochemicals (mainly secondary metabolites) synthesized and amassed by them.

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