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Host-based life cycle traits of polyphagous defoliator *Cricula trifenestrata* Helfer (Lepidoptera: Saturniidae) from Terai region of West Bengal, India

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Abstract
Host-based life cycle traits of polyphagous defoliator *Cricula trifenestrata* Helfer (Lepidoptera: Saturniidae) was studied on *Mangifera indica* L., *Persia bombycina* King, *Anacardium occidentale* L. and *Cinnamomum cassia* in Terai region of West Bengal. The larvae were heavier when developed on *P. bombycina* particularly from October-January generation. The amount of consumed (5.204-6.896 gm) and utilized (1.701-2.356 gm) food as well as AD% (24.663-40.1157%) and RCR (0.608-0.669) were lowest in the larvae reared on *C. cassia* and as such the larvae were lightest (2.801-3.757gm) and needed a longer development period (85.95-149.38 days) than other hosts. The development of *C. trifenestrata* was faster during March-May due to higher level of food utilization (2.356-2.830 gm), AD% (35.429-41.802%) and RCR (0.669-0.864). Higher quantities of protein and lipid were found in the haemolymph on *P. bombycina* (121.72-167.24 mg/g and 14.01-32.00%) fed one. The larvae could utilize food resources of both *M. indica* and *A. occidentale* equally.

Keywords: Host plants, life cycle, nutrition, *Cricula*

1. Introduction

Cricula trifenestrata Helfer (Lepidoptera: Saturniidae) is polyphagous in nature and cause serious damage to the host plants. Some information on host range expansion of the defoliator is available from the recent literature. It is reported to be the major pest of mango [5, 9]. It is reported to thrive on cashew *Anacardium occidentale*; Daruchini plant, *Cinnamomum zeylanicum*, Cardamom (*Elettaria cardamomum*), Som (*Persia bombycina*), litchi (*Litchi chinensis* Sonn.), ber (*Zizyphus jujuba* Mill.) and pepper (*Litsea cubeba* Pers.) and Bakul (*Mimusops elengi*) and tea plantations [3, 4, 6, 12, 14, 25, 26, 28, 30, 36, 39].

The links between food quality, food consumption and utilization, and subsequent insect performance are a primary focus of insect nutritional ecology. For polyphagous insects, the availability of different host plants plays an important role in triggering population outbreaks [33]. Study of the effects of host plants on the biology of insect is important in understanding host suitability of plant infesting insect species [20].

Metabolic efficiency of insect, feeding on plant varieties [38] and the effect of plant on insect metabolism and interactions between insects and their food sources are shown by using feeding indices [10]. It is well known fact that the degree of food utilization depends on the digestibility of food and the efficiency with which digested food is converted into biomass [8]. The reduction in dietary utilization suggests that reduction in nutritional values may be resulted from both behavioral and physiological effects [27]. Low nutrient content of the food reduce digestibility of the insect to that food [34]. Larval feeding in non-feeding adult insects is an active and dynamic process and so the amount, rate and quality of food consumed by the larva have an immense effect on growth, development, survival and reproductive potential [33].

Like other lepidopteron insect *C. trifenestrata* is highly specialized for rapid growth, primarily achieved by the higher rate of food acquisition. Availability of literature is inadequate on relationship/interaction of the pest, *C. trifenestrata* with its hosts from North Bengal region of eastern India. The present study on food preference and life cycle performance of the defoliator on the host plants Mango, *Mangifera indica* L., Cinnamon, *Cinnamomum cassia*, Cashew, *Anacardium occidentale* L. and Som, *Persia bombycina* were undertaken to get an insight into the season–host plant–defoliator caterpillar relationship.

2. Materials and Methods
The experiment was carried out in the Instructional Farm and Laboratory, Department of Agricultural Entomology, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India during 2013 to 2015. The experimental domain is situated between $26^0 19'86''$N latitude and $89^0 23'53''$E longitude at an elevation of 43.0 m above mean sea level.

2.1 Host Plant materials
For the experiment, the four (4) different plant materials of the family Anacardiaceae namely *Mangifera indica* L. (Mango) and *Anacardium occidentale* L. (Cashew) and of the family Lauraceae, *Cinnamomum cassia* (Cinnamon) and *Persia bombycina* King (Som) were collected from the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, located under Terai region of West Bengal, India. The host plants selected for the study were of fifteen (15) years old.

2.2 Specimen collection and rearing of insects
Pupae of *C. trifenestrata* were collected in nature and brought to the laboratory, Department of Agricultural Entomology. They were kept in rearing cages 2ft (height) x 1.5ft (width) x 2ft (depth) for adult emergence. Upon emergence of the adults, the male and female moths were identified using spots on wings and size, and finally they were placed couple wise in the separate cages. Twigs of four host plants (*M. indica, C. cassia, A. occidentale and P. bombycina*) in a 150 ml water filled conical flask were placed in the cages to carry out their normal life. Once laid, batches of eggs were transferred to petridish carefully for hatching. Neonates hatching in mass were then transferred to culture containers. Twigs of host plants were provided as food, with their cut ends immersed in water-filled 150 ml conical flask so that neonates could obtain ready food immediately after hatching. Twigs of leaves were arranged in such a way that enough space in between leaves was present for free movement of the tiny caterpillars. Side by side mass cultures on different hosts were maintained under the laboratory conditions.

2.3 Life cycle parameters
Life cycle traits, *i.e*., duration of last developmental stage of the caterpillar and the total development period from egg to adult, were recorded on different hosts. Body weight was recorded for the freshly molted caterpillars. Weight of female and male pupae and adults were recorded. A fine electronic balance (BT 124 S, d = 0.1 mg, Sartorius) was used. Host-based life cycle parameters were studied throughout the year on different host plants during 2013 to 2015.

2.4 Food consumption and utilization
The larvae of *C. trifenestrata* were obtained from the stock culture. One-day-old final instar larvae (6th instar) were used after 3 h of starvation for the food consumption and utilization study. 20 larvae were kept individually and thus each individual served as a replicate. Any larva died during the experimental period was replaced from the stock.

Fresh and washed leaves (viz., mango, cinnamon, cashew and som) were supplied to the larvae daily as their food. The leaves were wrapped in water soaked cloth to maintain freshness. Each leaf divided into two identical portions, by removing their midrib, out of which one portion was given as food while the other served as an aliquot [12]. The aliquot was dried in an oven at 60^0C for determining the weight of food given. The food was changed after every 12 hours. Each day before providing fresh food, the leftover of food and faeces were collected and dried in an oven to calculate the amount of food ingested. In this study natural losses including biomass changes in substances, other than water were not measured.

Nutritional indices were evaluated on the basis of dry weight [38, 11]. Mean body weight was determined according to Gordon [17].

Approximate digestibility (AD %) = $\{(E-F)/E\}*100$;

Relative consumption rate (RCR) = $E/(A \times T)$;

Where, A = mean dry weight of insect over unit time, E = dry weight of food consumed, F = dry weight of faeces produced and T = duration of larval period.

Estimation of nutrients in haemolymph

For estimation of different nutrients the 6th instar larvae was starved for 8 hours. After that the larvae was surface sterilized with 70% alcohol and incision was made on the 1st abdominal leg to collect the haemolymph. 0.01ml of haemolymph was collected in a sterilized centrifuged tube and proceeds for estimation of different nutrients as described by the earlier scientists. The protein was estimated following Lowry method [24]. The total free amino acid was estimated following Sadasivam and Manickam [31]. The total carbohydrate concentration was estimated by Anthrone method [29]. The concentration of total lipid was estimated by following the Bligh and Dyer method [19].

2.5 Statistical analysis
The lipid percentage of haemolymph of *C. trifenestrata* was arcsine transformed before analysis. Pooled mean data of two years study for duration of 6th larval stage, weight of larva, pupa and adult, developmental time from egg to adult, food consumed, food utilized, approximate digestibility, relative consumption rate and the nutrient contents of haemolymph of *C. trifenestrata* were subjected to two-way analysis of variance (ANOVA) using the PROC GLM in SAS (Ver. 9.2).

3. Results
3.1 Host based life cycle parameters
Cricula trifenestrata completes four (4) generations in a year in terai region of West Bengal. It was observed that the larvae of *Cricula trifenestrata* passed six instars with five moults. Host-based difference in traits was noticed in the last instar larva, pupa and adult. The duration of 6th larval instar was significantly long when the food was *C. cassia* (8.85-10.50 days). The duration was shortest on *P. bombycina* (8.13-9.30 days) during October-March and on *A. occidentale* (8.38-8.80 days) in March-October. Development periods (egg– adult) were the shortest in March-May (82.82 days) and longest in May-October (146.56 days), followed by October-January (113.91 days). The duration was similar on *A. occidentale* (106.30 days), *P. bombycina* (106.34 days) and *M. indica* (106.41 days) but the period was approximately 3 days longer on C. cassia (109.45 days). Body weights of these stages were significantly higher when reared on *P. bombycina* and lowest on *C. cassia*. However, very less difference in weights of the life stages, i.e., larva, pupa and adult, was evident when reared on *A. occidentale* and *M. indica*. So, both the hosts equally supported growth and development of *C trifenestrata*. In response to season the weight of the larvae, pupae and adult was significantly more during May to January (Table I).

3.2 Food consumption and utilization
Food consumption and utilization studies (Table II) indicated that last instar caterpillars of *C. trifenestrata*, consumed and utilized significantly higher and smaller amounts of leaves when reared on *P. bombycina* (5.731-6.770 gm and 1.717-

2.761 gm) and *C. cassia* (5.204-6.896 gm and 1.701-2.356 gm) respectively in the year round. However, no significant difference in consumed and utilized food was evident when reared on *A. occidentale* and *M. indica*. The amount of consumed leaves was higher during October-January (6.462-6.896 gm) and significantly lowest during May-October (5.204-5.731 gm). The food utilization of the defoliator was highest during March-May (2.356-2.830 gm) and lowest during January-March (1.670-1.913 gm). The relative consumption rate (RCR) was higher in *A. occidentale* leaf fed caterpillar (0.864) and approximate digestibility (AD %) was higher in the *M. indica* leaf fed one (41.802%) particularly during March-May. The RCR was lowest for the caterpillar in October-January generation (0.565-0.608) and the AD% in January-March (27.400-33.654%). It proves that the caterpillar fed higher amount of *P. bombycina* leaves during October-January due to lower RCR and higher rate of AD%. The higher level of food utilization, AD% and RCR resulted in faster rate of growth of *C. trifenestrata* mainly during March-May on *P. bombycina*. *C. cassia* found to be the least preferred host among the host plants taken in the experiment with prolonged development period of the caterpillar due to inadequacy of the availability of food. The higher amount of consumed leaves, balanced food after digestion and AD coupled with higher RCR of the caterpillar prolonged the larval development to achieve optimum growth during March-May.

3.3 Quantification of nutrient contents in the haemolymph

In the larvae significantly higher amount of protein and lipid in the haemolymph was observed when the caterpillar reared on *P. bombycina* (121.72-167.24 mg/g and 14.01-32.00%) leaves than on other hosts. The carbohydrate level was higher in the haemolymph of the caterpillar fed on *C. cassia* (12.51-33.44 mg/g). The FAA level was higher in the same caterpillar on *A. occidentale* (14.00-76.90 mg/g). There present no significant difference in haemolymph carbohydrate and lipid level in *M. indica* and *A. occidentale* one. The caterpillar reared on C. cassia had significantly lower amount of protein (40.87-70.48 mg/g), FAA (13.99-53.57 mg/g) and lipid (11.15-20.99%) in the haemolymph. In response to seasonal influence the quantity of protein, carbohydrate and FAA in the haemolymph was lowest during October-January. The higher content was obtained during January-May. The lipid level was highest during May-October and lowest in caterpillar of March-May generation (Figure I).

4. Discussion

Many morphological parameters due to their contribution to the reproductive success of a species are considered as life history traits of the insects [1, 2]. One of the important fitness indicators in insect population dynamics is the body weight [23]. Morphological parameters like weight of the caterpillar during final instar, pupae and adult were significantly higher in *P. bombycina* reared *C. trifenestrata* than in the other host. The values were recorded as significant and minimum in *C. cassia* reared one. This is supported by the fact that the relative growth rate of the larvae was lowest when the food was *C. cassia* [15]. As the pupae and adult stages of the lepidopteran are non-feeding one therefore, egg production is usually maintained by nutrients acquired in the larval phase [35]. Therefore, for reproductive success of the insects, gain in weight of the larval stage is important. Pupal weight also regarded as an indirect but easily measurable indicator for lepidopteran fitness [22]. The findings of the present experiment indicated that *P. bombycina* leaves were better utilized by the caterpillar giving rise to heavier final instar caterpillars, pupae and adults. *C. trifenestrata* utilized both *A. occidentale* and *M. indica* almost equally, as evident from similar growth in terms of body weight and life traits when raised on both the host species. Variation in climatic condition also played significant role in life history traits. The heavier larva, pupa and adult as found during May-January might be to overcome the summer and winter diapause in pupal stage and also to maintain the population [16].

In order to understand the phenomenon of host range evolution it is necessary to have knowledge of preference-performance hypothesis [18]. According to this hypothesis, females select such plants for oviposition, on which survival of the offspring will be high *ie*., to maximize their fitness. Therefore, host plant selection by the gravid females is the determinant for the immatures' survival and performance in case of Lepidoptera [7, 37]. This conjecture is supported by the fact that the female of *C. trifenestrata* produced higher number of eggs when the larvae fed on *P. bombycina* in all the season closely followed by M. indica and it was least when the food was C. cassia [15] that supports the fact of preference of *P. bombycina* leaves by the caterpillar among the other hosts.

It is well known that the degree of food utilization depends on the digestibility of food and the efficiency with which digested food is converted into biomass [8]. The reduction in dietary utilization suggests that reduction in nutritional values may be resulted from both behavioural and physiological effects [27]. In the food consumption and utilization parameters, *C. trifenestrata* displayed better adaptation to *P. bombycina* and during October-January, possibly due to enhanced metabolism of plant nutrients that resulted in higher quantities of protein, FAA and lipid in the haemolymph. The larvae could utilize food resources of both *M. indica* and *A. occidentale* equally, as evident from the almost similar development parameters and nutrient level in the haemolymph particularly carbohydrate, FAA and lipid. Difference in value of AD shows differences in factors such as food shortages, lack of balance and higher levels of crude fiber and water shortages [13]. The higher values of AD% and RCR were observed on larvae fed by *P. bombycina* leaves and during March-May. It is generally accepted that low dietary protein can cause an understanding of the behavioural and physiological basis of insect response to host plants [21]. Lower fitness of *C. trifenestrata* on some host plants may be due to the presence of some secondary phytochemicals in the host plants, or absence of primary nutrients necessary for growth and development [12]. This might be the fact of least preference of *C. cassia* leaves by the caterpillar. *C. trifenestrata* reported to undergo pupal diapause both in summer and winter extending from May to January [15, 16] for such they store higher percent of lipid during May-January. Among the foods the higher ratio of carbohydrate-protein, carbohydrate-FAA, carbohydrate-lipid and lower protein-lipid ratio was observed on *P. bombycina* followed by *A. occidentale* and *M. indica* [15] might be the fact for better adaptation of *C. trifenestrata* on *P. bombycina* followed by *A. occidentale, M. indica*.

In spite of some variations, *C. trifenestrata* utilize the host resources of Mango (*Mangifera indica* L.), Cashew (*Anacardium occidentale* L.), Cinnamon (*Cinnamomum cassia*) and Som (*Persia bombycina* King) successfully to complete their life cycles. Feeding preference restricts the insect to some host plant due to the biochemical constituents of the leaves and that affect the larval feeding and thereby the storage of the nutrients in the insect tissues for maintenance of homeostasis. Occurrence of *C. trifenestrata* in a higher level during January to May on different host plants making the management of the pest more complicated and difficult due to environment and health issues.

Table I: Host based life cycle parameters of *C. trifenestrata* as influenced by seasons and host plants

Host	Season	6th larval instar duration (days)	Weight (gm)					Development period (egg-adult) (days)
			6th instar larva	Pupa male	Pupa female	Adult male	Adult female	
M. indica	January-March	8.20	3.178	0.881	1.591	0.289	0.721	84.72
	March-May	10.00	3.023	0.835	1.572	0.278	0.705	82.73
	May-October	8.58	3.394	0.897	1.643	0.329	0.753	144.60
	October-January	9.41	4.016	1.020	1.641	0.312	0.777	113.60
C. cassia	January-March	9.63	2.917	0.849	1.475	0.258	0.630	86.71
	March-May	10.50	2.801	0.815	1.451	0.248	0.603	85.95
	May-October	8.85	3.181	0.795	1.512	0.292	0.695	149.38
	October-January	9.99	3.757	0.934	1.589	0.278	0.659	115.76
A. occidentale	January-March	8.29	3.149	0.861	1.598	0.284	0.695	84.40
	March-May	8.80	2.976	0.846	1.584	0.284	0.700	81.01
	May-October	8.38	3.392	0.909	1.686	0.338	0.760	146.43
	October-January	9.50	3.972	1.021	1.660	0.315	0.775	113.35
P. bombycina	January-March	8.13	3.191	0.920	1.602	0.298	0.761	84.99
	March-May	9.20	3.062	0.861	1.586	0.293	0.721	81.60
	May-October	8.63	3.476	0.922	1.672	0.337	0.794	145.82
	October-January	9.30	4.029	1.024	1.673	0.316	0.787	112.93
Mean of seasons	January-March	8.56	3.11	0.88	1.57	0.28	0.70	85.21
	March-May	9.63	2.97	0.84	1.55	0.28	0.68	82.82
	May-October	8.61	3.36	0.88	1.63	0.32	0.75	146.56
	October-January	9.55	3.94	1.00	1.64	0.31	0.75	113.91
Mean of host plants	*M. indica*	9.05	3.40	0.91	1.61	0.30	0.74	106.41
	C. cassia	9.74	3.16	0.85	1.51	0.27	0.65	109.45
	A. occidentale	8.74	3.37	0.91	1.63	0.31	0.73	106.30
	P. bombycina	8.82	3.44	0.93	1.63	0.31	0.77	106.34
Seasons df=3	*Mean Square*	2.496	0.183	0.015	0.044	0.004	0.003	28.889
	F Value	26.150	110.970	65.435	0.688	54.411	235.332	172.007
	Pr > F	0.0000*	0.0000*	0.0000*	0.0466*	0.0000*	0.0000*	0.0000*
Host plants df=3	*Mean Square*	4.026	2.233	0.058	0.125	0.006	0.014	10686.224
	F Value	42.196	1353.621	247.283	3.791	74.348	104.934	63639.301
	Pr > F	0.0000*	0.0000*	0.0000*	0.0146*	0.0000*	0.0000*	0.0000*
Seasons X Host plants df=9	*Mean Square*	0.398	0.205	0.002	0.001	0.001	0.001	2.009
	F Value	4.172	1.505	6.484	0.018	0.619	4.610	11.961
	Pr > F	0.0012*	0.0497*	0.0003*	0.8596	0.7715	0.0006*	0.0000*

*Significant

Table II: Food consumption and utilization of 6th instar larvae

Host	Seasons	Food Consumed (gm)	Food Utilized (gm)	Approximate Digestibility %	Relative Consumption Rate
M. indica	January-March	6.236	1.913	30.682	0.751
	March-May	6.770	2.830	41.802	0.743
	May-October	5.454	1.942	35.606	0.612
	October-January	6.698	1.987	29.673	0.592
C. cassia	January-March	5.656	1.903	33.654	0.635
	March-May	5.866	2.356	40.157	0.669
	May-October	5.204	1.913	36.763	0.617
	October-January	6.896	1.701	24.663	0.608
A. occidentale	January-March	6.095	1.670	27.400	0.723
	March-May	6.787	2.405	35.429	0.864
	May-October	5.659	2.223	39.286	0.643
	October-January	6.462	2.368	36.645	0.565
P. bombycina	January-March	6.225	1.717	27.585	0.732
	March-May	6.770	2.761	40.782	0.786
	May-October	5.731	2.374	41.415	0.629
	October-January	6.713	2.634	39.247	0.595
Mean of seasons	January-March	6.053	1.801	29.830	0.710
	March-May	6.548	2.588	39.543	0.766
	May-October	5.512	2.113	38.268	0.625
	October-January	6.692	2.173	32.557	0.590
Mean of host plants	*M. indica*	6.290	2.168	34.441	0.675
	C. cassia	5.906	1.968	33.809	0.632
	A. occidentale	6.251	2.167	34.690	0.699

	P. bombycina	6.360	2.372	37.257	0.686
Seasons df=3	*Mean Square*	0.491	0.325	27.649	0.010
	F Value	52.272	446.316	193.285	60.258
	Pr > F	0.0000*	0.0000*	0.0000*	0.0000*
Host plants df=3	*Mean Square*	0.434	1.257	255.983	0.076
	F Value	365.362	1725.235	1789.508	464.039
	Pr > F	0.0000*	0.0000*	0.0000*	0.0000*
Seasons X Host plants df=9	*Mean Square*	0.205	0.185	58.326	0.007
	F Value	21.801	253.907	407.739	39.500
	Pr > F	0.0000*	0.0000*	0.0000*	0.0000*

*****Significant

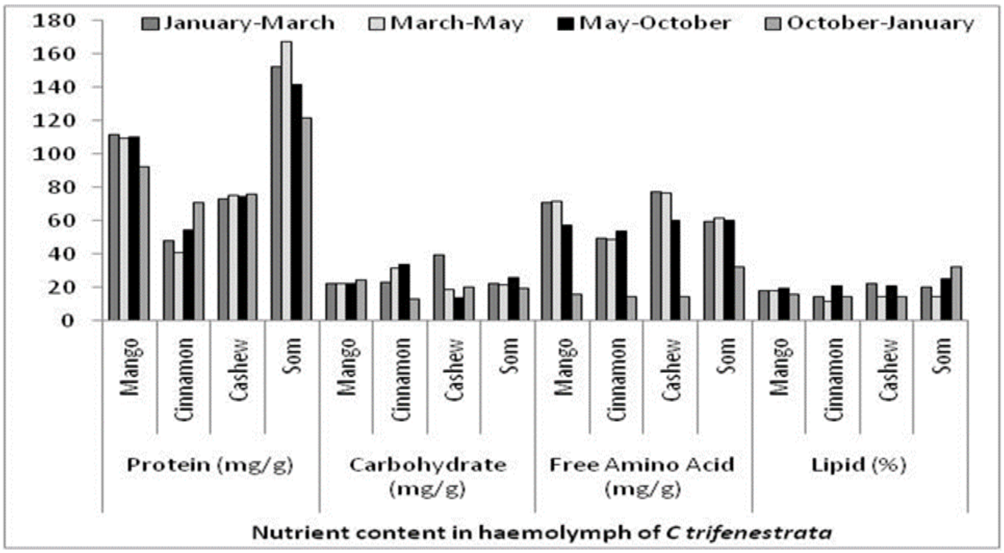

Fig I: Nutrient content of haemolymph of *C. trifenestrata* in different seasons and host plants

		Protein (mg/g)	**Carbohydrate (mg/g)**	**Free Amino Acid (mg/g)**	**Lipid (%)**
Seasons df=3	*Mean Square*	136.889	118.055	157.735	107.456
	F Value	588.023	711.577	354.317	466.275
	Pr > F	0.0000*	0.0000*	0.0000*	0.0000*
Host plants df=3	*Mean Square*	19414.526	20.877	685.634	124.530
	F Value	83402.461	125.836	1540.124	540.361
	Pr > F	0.0000*	0.0000*	0.0000*	0.0000*
Seasons X Host plants df=9	*Mean Square*	563.766	185.835	93.533	60.457
	F Value	2421.873	1120.119	210.101	262.339
	Pr > F	0.0000*	0.0000*	0.0000*	0.0000*

*Significant

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