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Eco-biology of Common Emigrant *Catopsilia pomona* Fabricius (Lepidoptera: Pieridae) with special reference to its life table attributes in Tripura, India

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ABSTRACT:

Butterflies of the family Pieridae are common in tropical parts of the world. They are considered as major pollinators as well as pests of economically important plants. *Catopsilia pomona* is a dominant pierid butterfly found in association with wild plants of Tripura, northeast India. It is abundant throughout the year. Present study was conducted to document the eco-biology of *Catopsilia pomona* with special reference to its life table attributes in the state of Tripura. Survival rates of life cycle stages in the semi-natural as well as in the field were the maximum during the wet and hot season. Mortality (k value) of different life cycle stages as a proportion of individuals dying during development varied from 0.16 to 0.46 in different seasons. Results suggested that abiotic factors and mortality factors of egg significantly influenced the survival rate of *C. pomona* population. This butterfly depends on three species of *Cassia* plants, all shrubs, for their oviposition and larval development in the environment of Tripura.

Keywords:

Catopsilia pomona butterfly, Pieridae, eco-biology, life table, Tripura, north east India.

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INTRODUCTION

Host selection for survival, development and reproduction in majority of insects often vary in space and time (van Nouhuys *et al*., 2003; Nylin *et al*., 2009) which, in turn, depends on the availability (minimum density per unit area) of closely related host plant species (Thorsteinson, 1960), and trade off between host preference by females for oviposition and larval performance of insects (van Nouhuys *et al*., 2003). 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 a particular habitat generally reflects the overall plant diversity of that habitat. Butterflies are essential component of any natural ecosystem. Their value as indicators of biotope quality is being recognized because of their sensitivity to minor changes in micro-habitat, climatic conditions as well as seasonal changes (Kremen, 1992; Murugesan and Muthusamy, 2011). They are considered as ideal subject for ecological studies of terrestrial landscapes (Thomas and Malorie, 1985).

North eastern region of India is blessed with vegetation rich landscapes that support diverse butterfly fauna and other insects (Alfred *et al*., 2002). The state of Tripura, being a part of this region, also contains large number of butterfly species which is evident from infrequent records of these taxa (Mandal *et al*., 2002; Agarwala *et al*., 2010; Majumder *et al*., 2011; Roy Choudhury *et al*., 2011). Butterflies of the family Pieridae are common in tropical parts of the world and are considered as major pollinators of crop plants (Borges *et al*., 2003), and a few of them are also considered as pests of economically important plants (Anonymous, 2007; Capinera, 2008). Despite their common occurrence, there is a lack of substantial study on the ecology, seasonal abundance, host preference and life history of the most common pierid species *Catopsilia pomona* F. found in association with wild plants of north east India, including Tripura. However, information on life table and host selections are available on other pierid species that feed and oviposit on crop plants (Chew, 1995). *C. pomona*, a dominant pierid butterfly, is found throughout the year in the state of Tripura (Agarwala *et al*., 2010; Majumder *et al*., 2011; Roy Choudhury *et al*., 2011). It prefers green and moist lands, pasture lands, farms, and edge of drains, moist deciduous forests, hillocks, and semi-arid areas with high abundance of grasses, small herbs and shrubs i.e. secondary type of vegetation (Atluri *et al.,* 2004). Reported larval host plants of common emigrant comprise of *Cassia fistula* L., *C. sophera* L., *C. occidentalis* L., *C. tora* L., *C. siamea* (Lam.) Irwin et Barneby, *Butea frondosa,* and *Bauhinia racemosa* L. (Kunte, 2000; Atluri *et al*., 2004). Among these plants *C. fistula, C. tora, C. occidentalis, C. sophera,* and *B. racemosa* are important as medicinal plants (Anonymous, 2004; Danish *et al*., 2011; Harshal *et al*., 2011; Singh and Dubey, 2012), and *C. siamea* is used in social forestry (Atluri *et al*., 2004, Borikar *et al.,* 2009). Hence, it is very important to document the seasonal occurrence and its host plant preference for oviposition and larval development of *C. Pomona*. With this view, the present study was conducted to know the eco-biology of *Catopsilia pomona* with special reference to its life history attributes in the state of Tripura.

Study site

Present study was conducted in Trishna Wildlife Sanctuary of south Tripura district (23°26.137' N, 91°28.184' E: 51-82 m asl), having an area of about 194.7 sq. km. Study location is characterized by patches of secondary moist deciduous forests and surrounded by swamp areas. Forest patches are rich in sal trees, garjan trees, bamboo bushes, herbs, shrubs and climbers. Trishna sanctuary is known by 230 tree species, 110 species of shrubs, 400 species of herbs, and 150 species of climbers (Economic review of Tripura, 2008-2009). Among the known host plants of *C. pomona*, the study area contains three species of *Cassia* only *viz. Cassia sophera, C. tora and C. occidentalis* which are considered to be the preferred hosts of larvae. Some part of the study area is used for rubber cultivation and paddy cultivation (Figure 1). The area has a tropical climate, with cold weather from November to February. Average daily temperature varies from the minimum of 6.8°C in January to the maximum of 37.7°C in June. The area receives, on an average, 3353.4 mm rainfall annually.

MATERIALS AND METHODS

Field census of eggs, larvae and oviposition preference of *C. pomona*

Prior to the study a reconnaissance survey was made in the Trishna study area to locate the available host plants distribution of *C. pomona*. Walk census for leaves of host plants containing eggs and larvae were held at an interval of 7-days from March 2007 to February 2008. For this, two line transects (approx. 1 km long and 5 m wide) were set up in the study area. Thirty host plants, 10 plants each of *C. sophera, C. tora* and *C. occidentalis*, were randomly selected for the study along the length of transects and were marked with plastic tags. Thus, sixty plants from three species were selected from transects. Ovipositing females were followed in the selected host plants for recording number of eggs laid per female per leaf. Binoculars were used to observe the females from a distance (about 2 m) without disturbing them. The same host plant was also observed for presence of larvae. All the females seen ovipositing on the selected host plants was recorded during the transect walk. Two transects were walked in two consecutive days in a week. Ten apical leaves were observed within a selected plant for egg and larval counts which were made between 8.00 AM to 12.00 noon local time. When a female was found to either laying eggs or seen perching near a host plant, halt was made for approx. 8 to10 minutes, and then move to the subsequent host plants along the transect. Different host plants selected by females for oviposition were recorded, photographed, collected and later identified by comparing with the herbarium deposited in the gallery of Plant Taxonomy and Biodiversity Laboratories, Department of Botany, Tripura University.

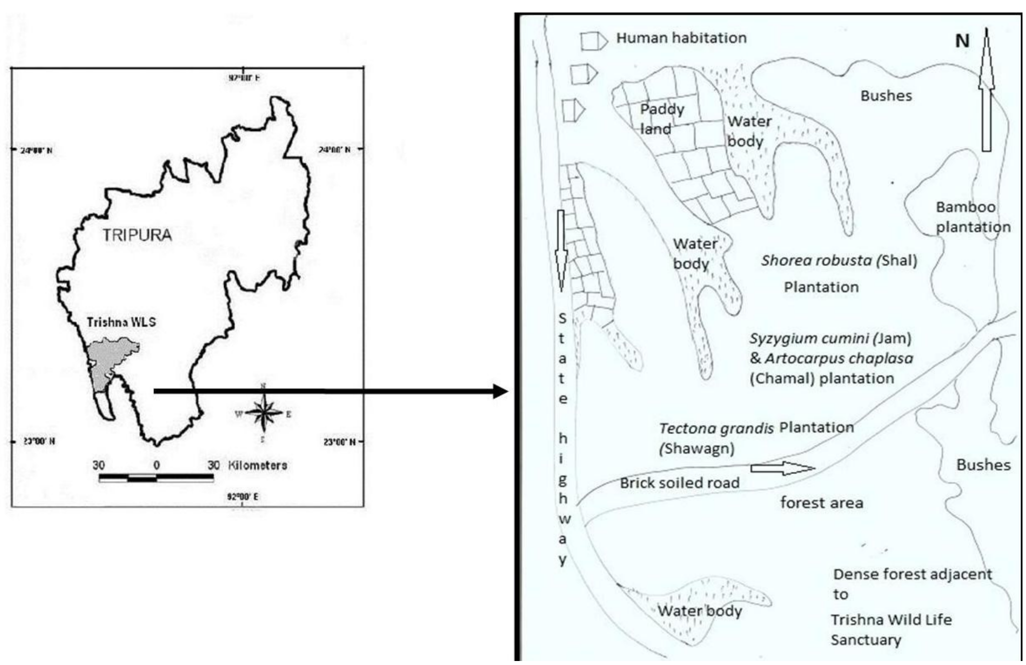

Figure 1. Geographical map of Trishna and landscape of the Study area.

Larval host range and seasonal variation in development

Leaves of the host plant species found to contain freshly laid eggs of *C. pomona* in field were brought to the field station (3 km from the study area), and transferred individually to 10 cm diameter paired Petri dishes lined with corrugated papers. These were fed with surplus quantity of tender leaves of respective host plants from which they were actually collected. Twenty replicates were used for each host plant species. Food was changed every 24 hrs intervals. Petri dishes were cleaned at the time of food change. These were observed twice in a day at 11 am and again at 5 pm to record the incubation period of eggs, developmental time of larvae, and pupae. Mortality in development, if any, was also recorded. This was simultaneously done on each host plant, once in five different seasons to record the seasonal variation, if any. Experiments were set up at the field station (Temp: 18°C ~ 27°C, RH: 45~75%, and L: D: 16:8h) i.e. in the controlled environment.

Larval development in field

Selected plants with freshly laid eggs and subsequent developmental stages were provided with coloured tags and these were numbered for easy identification. Individual eggs, larvae and pupae were followed daily, and the disappearance of individuals or those that failed to develop in to the next stage at different life stages were recorded. Larvae were found to be slightly sluggish and females laid solitary eggs, usually one on each leaf. The study was repeated once in different seasons.

Survival rate and K-factor analysis

An age-specific life table was constructed following the method of Stiling (2002). To prepare the life table, records were made on the larval durations and survival rate at each developmental stage i.e. eggs to emergence of adults from pupae. For this purpose, 409 eggs and 317 eggs of *C. pomona* were studied in natural (in field) and in controlled conditions (ambient condition of field station), respectively. Meteorological data of Trishna study area were collected from the records maintained by the Department of Agriculture, Govt. of Tripura at Arundhuti Nagar, Agartala.

Data analysis

Field data on proportion of host plants used by *C. pomona* for laying of eggs and distribution of eggs per leaf of the different host species during a year were used to draw population curves. For this purpose, weekly data were pooled on monthly basis. Developmental time from egg to the eclosion of pupae on different host plants and between different seasons was subjected to one-way analysis of variation (ANOVA). Mean values of development time on different host plant species and between different seasons were compared by Tukey's multiple comparison test. Differences in development time recorded in field and in field station were compared by Students *t*-test. A significance level of 0.05 was used to reject the null hypothesis. Field data on distribution of eggs on different host plant species were subjected to regression analysis to reveal the relationship between oviposition preference and host utilization. Based on the life table data, survival rate and K factor value that closely mirrors the overall population mortality was

Table 1. Oviposition preference of *C. pomona* females on different host plants in the study area

Host plant	No. of leaves observed	No. of larvae counted	Mean (±SEM) no of larvae/ leaf	ANOVA	No. of eggs counted	Mean (±SEM) no of eggs/ leaf	ANOVA
C. sophera	4800	984	0.21 ± 0.01	F = 6.909, df = 2,14397, P = 0.0001	1237	0.26±0.02	F = 5.26, df = 2,14397, P = 0.006
C.occidentalis	4800	563	0.12 ± 0. 02		899	0.19±0.03	
C. tora	4800	647	0.13 ± 0.01		816	0.17±0.02	

Table 2. Development time (in days) of *C. pomona* on different host plant species

Month	N	Mean ± SEM value (days)		
		C. sophera	*C. occidentalis*	*C. tora*
March	36	24.50 ± 0.26 ^{1} a	24.75 ± 0.25 ^{1} a	24.74 ± 0.33 ^{1} a
May	36	20.67 ± 0.31 ^{2} a	20.92 ± 0.42 ^{2} a	20.92 ± 0.42 ^{2} a
August	36	18.92 ± 0.23 ^{3} a	19.42 ± 0.63 ^{3} a	19.00 ± 0.28 ^{3} a
October	36	21.17 ± 0.24 ^{2} a	21.33 ± 0.28 ^{2} a	21.25 ± 0.25 ^{2} a
December	36	30.67 ± 0.47 ^{4} a	30.83 ± 0.41 ^{4} a	31.00 ± 0.41 ^{4} a

Dissimilar numbers following means in a column denote significant difference and similar letters accompanying means show no difference between them by Tukey's multiple comparison range test at 5% significant level.

determined. At each life stage, number of deaths (k value) was calculated as under: $k = \log N_t - \log N_{t+1}$, where N_t is the density of the population before it is subjected to the mortality and N_{t+1} is the density afterward. Total generational mortality factor K is determined as the sum of the individual mortality factors k at egg, larval and pupal stage of the *C. pomona* species (Stilling, 2002). For interpretation of colleted data, the year was divided in to five seasons: spring (March, April), summer (May, June), rain (July, September), autumn (October, November), and winter (December-February). To determine the relationship between successful development (%) of *C. pomona* eggs and climatic factors in the study area regression analysis was carried out. Origin 7 software (www.originlab.com) was used for the analysis of data.

RESULTS

Egg abundance and oviposition preference

Females of *C. pomona* laid solitary eggs at edges and on undersides of tender or young leaves (one egg/ leaf/female) of *C. sophera, C. occidentalis* and *C. tora* plants throughout the year (Table 1, Figure. 2). In the year-round census of 10000 m^2 (1000 m long x 5 m wide x 2 transects @ 1 ha) which represents less than 0.5% of the study area (19.47 ha), 52.54% to 85.07% of *C. sophera* plants, 21.31% to 69.47% of *C. occidentalis* plants and 23.88% to 56.52% of *C. tora* plants were found with one or more eggs. Between the three host plant species, common emigrant females selected the highest proportion of *C. sophera* for oviposition during hot and wet months, and the maximum was recorded in the month of August (Figure 2). In comparison, distribution pattern of eggs on *C. occidentalis* plants showed marked difference from the distribution of eggs on *C. sophera.* Higher proportion of this host plant species was recorded during dry and cooler months, and the maximum was recorded in the month of January (69.47%) (Figure. 2). In case of *C. tora,* the trend of egg distribution was found to be nearly similar to that of *C. sophera* but the proportion of host use was found to be much lower than *C. sophera* (Figure. 2). Occurrence of eggs showed that 4800 leaves each of *C. sophera, C. occidentalis* and *C. tora* that were surveyed during the year, contained 1237, 899 and 816 eggs, respectively (mean ± SEM: *C. sophera*: 0.26±0.02 eggs per leaf, *C. occidentalis:* 0.19±0. 03 eggs per leaf and *C. tora:* 0.17±0.02 eggs per leaf, ANOVA: $F = 5.26$, $df = 2, 14397$, $P = 0.006$) (Table 1).

Larval host range

Larvae of *C. pomona* were found to feed on tender leaves of the three host plant species, viz. *C. sophera, C. occidentalis and C. tora.* Higher proportion of *C. sophera* plants were used as food and maximum was recorded in the hot and wet month of August (26.70%). Incidence of larvae on *C. occidentalis*

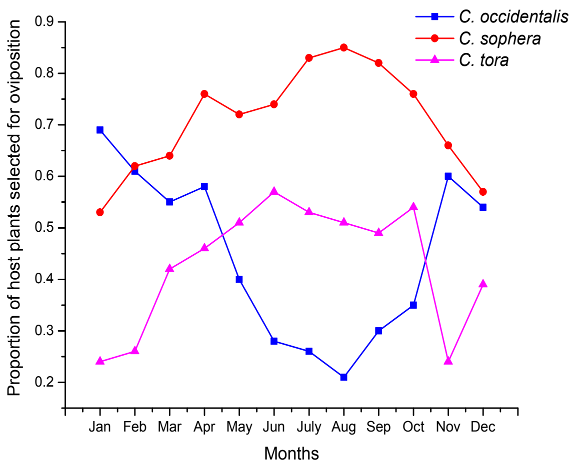

Figure 2. Proportion of host plants of three *Cassia* species recorded with eggs of *C. pomona* in different months of the year in the study area.

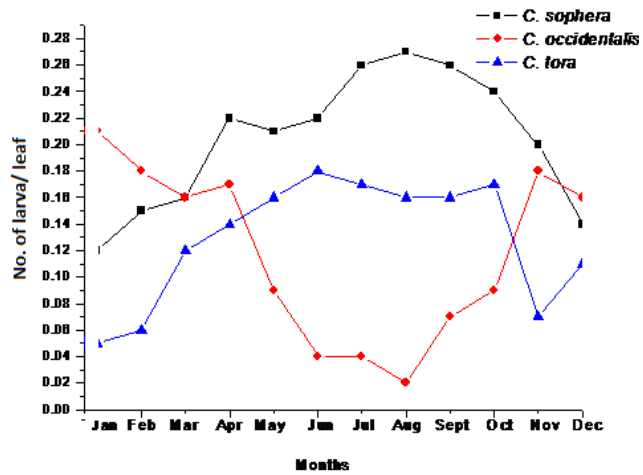

Figure 3: Mean number of larvae of *C. pomona* recorded on different host plants.

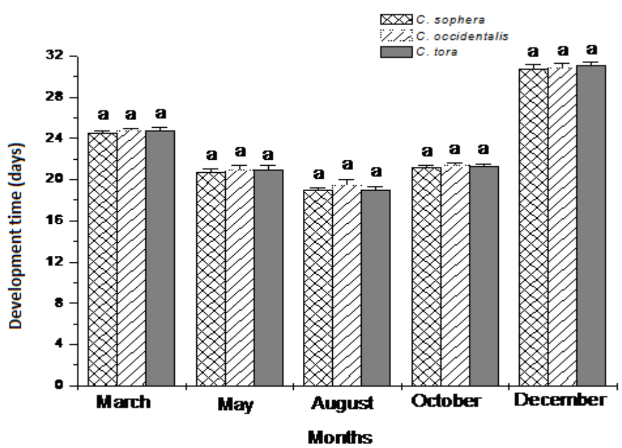

Figure 4. Development time (in days) of *C. pomona* on different larval host plants in different months of a year. Similar alphabets accompanying bars denote no significant difference between the mean values in that month.

plants was recorded to be the highest in January (20.61%) and lowest in August (1.64%), respectively. In case of *C. tora* host, the highest proportion was recorded in the month of June (17.24%) and the lowest in the month of January (5.33%) (Figure. 3). Occurrence of larvae showed that 4800 leaves each of *C. sophera, C. occidentalis* and *C. tora* that were surveyed during the year, contained 984, 563 and 647 larvae, respectively (mean $\pm$ SEM: *C. sophera*: 0.21 $\pm$ 0.01 larva per leaf, *C. occidentalis:* 0.12 $\pm$ 0. 02 larva per leaf and *C. tora:* 0.13 $\pm$ 0.01 larva per leaf, ANOVA: F = 6.909, df = 2,14397, P = 0.0001) (Table 1).

Developmental time and seasonal variation

Developmental time of different immature stages (egg to pupae) of *C. pomona* was found to vary in different seasons but did not show difference in any one season between different host species (Figure 4). Development time was recorded to be the longest at lower temperature and lower relative humidity corresponding to the month of December (controlled condition: average temperature=18°C, average relative humidity=51.33%) and shortest at higher temperature and higher relative humidity in August (average temperature=27.91°C, average relative humidity =77.07%) (Table 2).

Survival rate and K factor analysis

Results showed that in field about 30% of the eggs deposited by *C. pomona* developed in to pupae during the months of July and August (average temperature 31.09°C, average humidity 70%, mean rainfall 7.45 cm). Developmental success was limited to 13.04% in the month of December (average temperature 19.33^{0}C, average humidity 51%, rainfall 0 cm). Regression analysis of survival rate showed positive correlations with average temperature (y =1.08 + 0.87x,

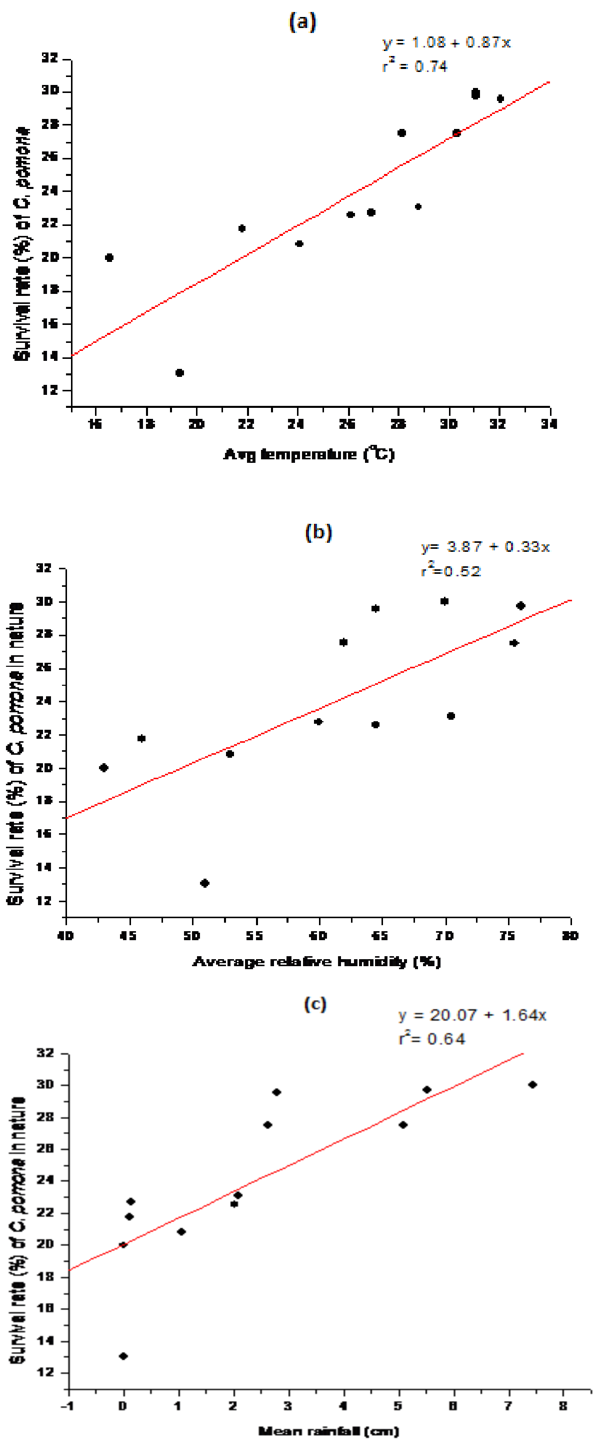

Figure 5. Regression analysis between successful development (%) of C. pomona eggs and climatic factors: (a) average temperature (°C), (b) average relative humidity (%), and (c) mean rainfall (cm).

r^2=0.74) (Figure 5a), average relative humidity (y = 3.87 + 0.33x, r^2= 0.52) (Figure 5b), and with mean rainfall (y =20.07 + 1.64x, r^2 = 0.64) (Figure 4c). Number of eggs that developed successfully in fields (24.03±1.46; n=240) and in semi natural condition (76.36±0.90; n=240) showed significant difference (t =30.54, df =478, P =0.000).

K-value analysis showed maximum mortality in development (0.46) in the month of December and minimum (0.16) in the month of September. K - values of the eggs recorded in different seasons were found to be very high (0.21) and very low (0.09), respectively, during these two months. Analyses showed that mortality in the egg stage influenced the total K value the most (Figures. 6a, b).

DISCUSSION

Natural populations of phytophagous insects including butterflies frequently encounter wide choice of host plants of differing suitability (Badeness *et al*., 2004; Dennis *et al*., 2006). The dominant strategy among herbivorous insects involves specialization on a set of closely related plants that will maximize offspring survival and fitness (Ward and Spalding, 1993; Gibbs *et al*., 2006), and also to the phenological characteristics of host plants. It is evident from the present study that *C. pomona* butterflies utilize three species of *Cassia* for oviposition and larval development in Trishna study area. Among these host plants, maximum number of *C. pomona* eggs were found in *C. sophera* with higher proportion recorded during hot and wet months, and lowest in dry and cooler months of the year. During dry and cool months, females choose *C. occidentalis* in higher proportion for oviposition followed by *C. tora*. This might be due to the availability of more young leaves in *C. occidentalis* and *C. tora* compared to *C. sophera* in dry and cooler months of the year. Results indicated that common emigrants preferred *C. sophera* than the two other host plants but utilized three hosts throughout the year depending on the host plant phenology, and made the larval host range wider. Patterns of host use have several effects on butterfly

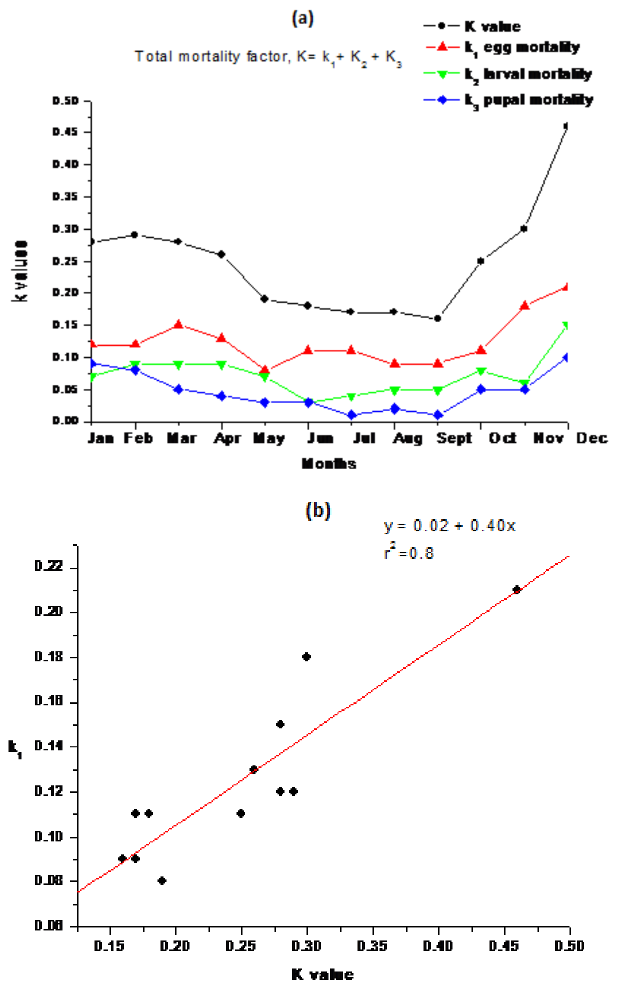

Figure 6. Key- factor analysis of development of *C. Pomona*: (a) mortality in developmental stages expressed as k values, (b) regression fit of mortality in egg stage (k_1) to the total K value.

population dynamics (Hanski and Singer, 2001). Food plant-insect herbivore association is based on resource size and optimal synchronization of their respective life-cycles. If resource size in time and given space is large, insects will show monophagism. In comparison, if resource size is short and patchy, then insect herbivores are generally polyphagous or oligophagous (Price, 1997; Dixon, 1998; Nylin *et al*., 2009). In this study, availability of taxonomically closely related *Cassia* plants in time and given area under study on which *C. pomona* successfully completed their life history attributes might widen their host range. This finding is in conformity with the optimisation theory of species in relation to host plants in time and space (Begon *et al*., 1996; Scheirs and Bryn, 2002).

Population of *C. pomona* showed strong relationships with climatic factors. They took longer time for development in the dry and cooler months when the suitable habitat for oviposition and larval development were minimum than in wet and hot months. But, developmental time on the different host plants did not differ during a particular season that suggested possible qualitative similarity between host plants. However, several studies showed that ovipositing females of phytophagous butterflies typically show a preference for host plants that are capable of supporting fast larval growth (Thompson, 1988a, b, c; Janz *et al.,* 1994).

Climatic factors are well known for their significant influence on population dynamics of animal communities (Leonard *et al.* 1998). Analysis of K-value in this study has revealed that the average temperature, the average relative humidity and the mean rainfall showed strong positive relationships with survival rate of *C. pomona*. In the present study no biotic factors such as parasites, predators were noticed which can also influence the population dynamics of *C. pomona* butterfly.

CONCLUSION

Results revealed that *C. pomona* females occurred and laid eggs throughout the year on three host plant species of *Cassia*. It preferred *C. sophera* host over *C. occidentalis* and *C. tora* for oviposition and larval development. Pattern of egg distribution i.e. oviposition was found to be linked with host plant phenology. Egg mortality was the major influencing factor in determination of survival rate. The k-value of egg mortality (k_1) and total mortality factor (K) showed strong positive relationship.

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REFERENCES

Anonymous. 2004. Ethnomedical Information on Fedegoso (*Cassia occidentalis*). Raintree Nutrition, Inc. Carson City, Nevada 89701.

Anonymous. 2007 *Overview of forest pests – Thailand*, 43.

Agarwala BK, Roy Choudhury S and Raychaudhuri P. 2010. Species richness and diversity of butterflies in urban and rural locations of north-east India. *Entomon.* 35:87-91.

Alfred JRB, Sinha N K and Chakraborty S. 2002. Checklist of Mammals of India, *Records of Zoological Survey of India,* Kolkata, Occ. Paper No. 199: 1-289.

Atluri JB, Venkata Ramana SP and Reddi CS. 2004. Ecobiology of the tropical pierid butterfly *Catopsilia pyranthe*. *Current Science,* 86(3): 457-461.

Badeness F, Shelton A and Nault B. 2004. Evaluating trap crops for diamond back moth, *Plutella xylostella* (Lepidoptera: Plutellidae). *Journal of Ecological Entomologia.* 97(4): 1365-1372.

Begon M, Harper JL and Townsend CR. 1996. *Ecology: Individuals, populations and communities*. Blackwell Science Ltd., London.

Borges RM, Gowda V and Zacharias M. 2003. Butterfly pollination and high contrast visual signals in a low-density distylous plant. *Oecologia*, 136(4): 571-573.

Borikar VI, Jangde CR, Philip P and Rekhe DS . 2009. Study of Antiulcer Activity of *Bauhinia racemosa* Lam in rats. *Veterinary World*, 2(6): 217-218.

Capinera JL. 2008. *Encyclopedia of Entomology*, 2nd Edition. Spinger.

Chew FS. 1995. From weeds to crops: Changing habitats of Pierid butterflies (Lepidoptera: Pieridae). *Journal of the Lepidopterists' Society.* 49: 285-303.

Danish M, Singh P, Mishra G, Srivastava S, Jha KK and Khosa RL 2011 . *Cassia fistula Linn. (Amulthus)-* An Important Medicinal Plant: A Review of Its Traditional Uses, Phytochemistry and Pharmacological Properties. *Journal of Natural Product Plant Resources***.** 1(1): 101-118**.**

Dennis RLH, Shreeve TG and Van Dyck H. 2006. Habitats and resources: the need for a resource-based definition to conserve butterflies. *Biodiversity and Conservation*. 15(6): 1943-1966.

Dixon AFG. 1998. *Aphid Ecology*, 2 nd edn. Chapman and Hall, London.

Economic review of Tripura. 2008-2009. Directorate of Economics & Statistics Planning (Statistics) Department Government of Tripura, Agartala.

Gibbs MLA Lace, Jones MJ and Moore AJ. 2006. Multiple host-plant use may arise from gender-specific fitness effects. *Journal of Insect Science*. 6: 04, available online: insect science. Org/6.04

Hanski I, Singer MC. 2001. Extinction-colonisation dynamics and host-plant choice in butterfly metapopulations. *American Naturalist.* 158: 341-353.

Harshal A. Pawar I and Priscilla M. D'mello. 2011. *Cassia tora Linn.: An overview. International Journal of Pharmaceutical Science*, 2: 2286-2291**.**

Janz NS, Nylin N, Wedell. 1994. Host plant utilization in the comma butterfly: sources of variation and evolutionary implications. *Oecologia* 99(1-2): 132-40.

Kremen C. 1992. Assessing the indicator properties of species assemblages for natural areas monitoring. *Ecological Applications.* 2(2): 203-217.

Kunte K. 2000. *Butterflies of peninsular India*, Universities Press (India) Ltd, Hyederabad.

Leonard G, Levine JM, Schmidt P, Bertness MD. 1998. Flow-generated bottom-up forcing of intertidal community structure in a Maine estuary. *Ecology* 79: 1395-1411.

Majumder J, Lodh R and Agarwala BK. 2011. Butterfly fauna of Rowa wildlife sanctuary, Tripura, North-East India. Proceedings of National Conference on water, energy and biodiversity with special reference to North-East region. Excel India Publishers, New Delhi, 1: 266-271.

Mandal DK, Ghosh SK and Majumdar M. 2002.

Zoological Survey of India, State Fauna Series 7: Fauna of Tripura. 3: 283-334.

Murugesan S and Muthusamy M. 2011. Patterns of butterfly biodiversity in three tropical habitats of the eastern part of Western Ghats. *Journal of Research in Biology* 1(3): 217-222.

Nylin S, Nygren GH, Soderlind L and Stefanescu C. 2009. Geographical variation in host plant utilisation in the comma butterfly: the roles of time constraints and plant phenology. *Evolutionary Ecology.* 23(5): 807-825.

Price PP. 1997. *Insect Ecology*, Third ed. Wiley.

Roy Choudhury S, Ray Choudhury P and Agarwala BK. 2011. Butterflies of Trishna wildlife sanctuary of north-east India with a note on their diversity and seasonality. Proceedings of National Conference on water, energy and biodiversity with special reference to North-East region. Excel India Publishers, New Delhi, pp. 261-265.

Scheirs J and Bryn LC. 2002. Integrating optimal foraging and optimal oviposition theory in plant-insect research. *Oikos* 96(1): 187-191.

Singh A and Dubey NK. 2012. An ethnobotanical study of medicinal plants in Sonebhadra District of Uttar Pradesh, India with reference to their infection by foliar fungi. *Journal of Medicinal Plants Research.* 6(14): 2727-2746.

Stiling P. 2002. *Ecology Theories and Applications*. Prentice Hall of India Pvt Ltd (4th Edition).

Thomas CD and Malorie HC. 1985. Rarity, species richness, and conservation: Butterflies of the atlas mountains in Morocco. *Biological Conservation* 33: 95-117.

Thompson JN. 1988a. Variation in preference and specificity in monophagous and oligophagous swallowtail butterflies. *Evolution* 42:118-28.

Thompson JN. 1988b. Evolutionary genetics of oviposition preference in swallowtail butterflies. *Evolution* 42(1): 1223-34.

Thompson JN. 1988c. Evolutionary ecology of the relationship between oviposition preference and performance of offspring in phytophagous insects. *Entomologia Experimentalis et Applicata.* 47(1): 3-14.

Thorsteinson AJ. 1960. Host selection in phytophagous insects. *Annual Review of Entomology* 5: 193-218.

van Nouhuys S, Singer MC, Nieminen M. 2003. Spatial and temporal patterns of caterpillar performance and the suitability of two host plant species. *Ecological Entomology*, 28(2): 193-202.

Ward LK and Spalding DF. 1993. Phytophagous British insects and mites and their food-plant families: total numbers and polyphagy. *Biological Journal of the Linnean Society* 49(3): 257-276.