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Flower visitation and preferences of *Danaus chrysippus* L. (Lepidoptera: Nymphalidae)

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Abstract
Nutritional worthiness of resources depend on various benefits and cost assessments for butterflies. Visitation time of *Danaus chrysippus* was observed on four different local variety of flowering plants, *viz*. *Pentas*, *Helianthus*, *Catharanthus* and *Petunia*, to deduce preference based on the worthiness of foraging resources. The relationship between the visitation time and time of the day was also investigated. Longest visitation time was observed on *Catharanthus* sp. (157.06 sec) followed by *Helianthus* sp. (113.40 sec), *Pentas* sp. (111.10 sec) and *Petunia* sp. (43.90 sec). Statistically significant differences were observed between the mean time spent in morning, afternoon and evening, on *Pentas* ($F_{2,12}$= 7.043, p<.05), *Catharanthus* ($F_{2,12}$= 12.93, p<.05) and *Petunia* ($F_{2,12}$= 52.01, p<.001), but not on *Helianthus* ($F_{2,12}$= 1.908, p=.191). Longest visitation times were observed on *Catharanthus* in morning (14.27±1.82, p<.001) and afternoon (11.14±0.74, p<.001), but in the evening it was highest on *Helianthus* (9.12±1.49, p<.05). Longer visitation time corresponded to more rewarding foraging resources such as nectar and its accessibility; while shorter time corresponded to longer corolla tube, as in *Petunia*, and lower nectar content. These aspects of local butterflies give vital inputs for their conservation by promoting local flowering plants as a strategy.

Keywords: *Visitation time*, *Foraging*, danaus chrysippus, *Nectar*, *endangered*

Introduction
Foraging success depends on the ability to judge the quality and availability of feeding resources. Animals have evolved efficient mechanisms to maximize this success [1]. Insects have to face a "exploitation vs. exploration" trade-off, as they have to judge the worthiness of foraging resources and choose whether to return or to quit for search of new resource [2]. Unlike caterpillars, adult butterflies can roam about and look for suitable food over a much broader territory. They mostly feed only on various liquids through a tube-like organ called a proboscis, which uncoils to sip liquid food and then coils up again into a spiral when the butterfly is not feeding [3].

Foraging behavior of butterflies and the choice of plants as nectar sources by them depends on different factors, like color and pattern preferences. Though, the foraging behavior of butterflies has been widely studied, their food preferences and the range of plant species chosen as a source of nutrition are still poorly understood [4]. *Danaus chrysippus* is a wide-ranging species belonging to Danainae, a subfamily of Nymphalidae. The Plain Tiger, *D. chrysippus chrysippus* (L., 1758) (Lepidoptera: Nymphalidae), along with the other subspecies, is one of the most widely distributed butterfly taxa in the world [5]. It is distributed throughout India, Indonesia, China, Hong Kong, Japan, Malaysia, Myanmar, Pakistan, the Philippines, Sri Lanka, Sumatra, Vietnam, Arabia, Africa (Egypt, Sudan, Ethiopia, Kenya, Uganda, Tanzania) as well as Pakistan, Palestine, Lebanon, Turkey, Cyprus, Malta, Greece, Italy etc. [5,6,7,8]. It prefers bushy, rocky places usually near gardens and cultivated areas. It is a medium-sized butterfly with a wingspan of about 7–8 cm (2.8–3.1 inch). The body is black with many white spots. The wings are orange, the upper side brighter and richer than the underside. The apical half of the forewing is black and the hind wing has three black spots in the center. The wings are bordered in black and outlined with semi-circular white spots. Adults feed on nectar from a variety of tropical and subtropical flowering plants and have also been seen feeding on withering stems and leaves at the tops of some non-flowering plants [6]. They have comparatively much longer proboscis and feeding duration, among other local butterflies, and shows positive correlation to corolla tube length [9].

D. chrysippus chrysippus is a common butterfly subspecies in this region, generally seen in gardens during flowering seasons. The present study aims to determine the flower preference through time spent by these butterflies on it for the collection of nectar. Since there are no previous reports in this regard from this region of Uttar Pradesh, in India, this study tries to unravel some aspects of the foraging behavior of the butterfly concerned.

Material and Methods
An insect trapping net, perforated container, and stopwatch were used for the experiment. For studying the visitation time, a closed chamber (46 x 48 x 70 cm) was constructed using polystyrene pieces joined together as a framework covered with transparent plastic sheets from all sides except the base. Specimens of *D. chrysippus* were trapped and collected during the month of March at the garden site in Gorakhpur (26.758°N, 83.369°E), eastern Uttar Pradesh, India. They were trapped one by one using the insect trapping net and used immediately for the determination of visitation time. *Pentas* sp., *Helianthus* sp. (local sunflower),

Petunia sp. and *Catharanthus* sp. (Sadabahar) flowering plants were used. During the experiment, the approximate temperature range was also noted. The flowering plant was kept inside the chamber and then the specimen of *D. chrysippus* was set free into the chamber to record the visitation time. After the experiment, the specimens were set free in the environment. The experiment was conducted in 3 shifts of 30 min each. Morning shift (8:00 - 8:30 a.m.), afternoon shift (1:00 - 1:30 p.m.) and evening shift (4:30 - 5:00 p.m.). The weather was completely dry, sunny and the daytime temperatures were around 18±4ºC, 30±4ºC and 24±4ºC, for each respective shift, along with humidity around 55±10 %. The collected data was assessed by analysis of variance (One Way ANOVA) for differences among visitation times on each flower type and to compare differences between the time spent in each shift. The significance threshold was set at p=.05 and mean separation tests were conducted, to find any statistically significant relationships, with Tukey's HSD post hoc test using SPSS Statistics version 20.0 (SPSS Inc., Chicago, IL, USA) statistical analysis software [2].

Observations

A total of 60 readings of visitation time of *D. chrysippus* were recorded in three shifts on the four flower types. During the experiment longest visitation time was observed on *Catharanthus* sp. (157.06 sec) followed by *Helianthus* sp. (113.40 sec), *Pentas* sp. (111.10 sec) and lowest on *Petunia* sp. (43.90 sec) (Fig 1.).

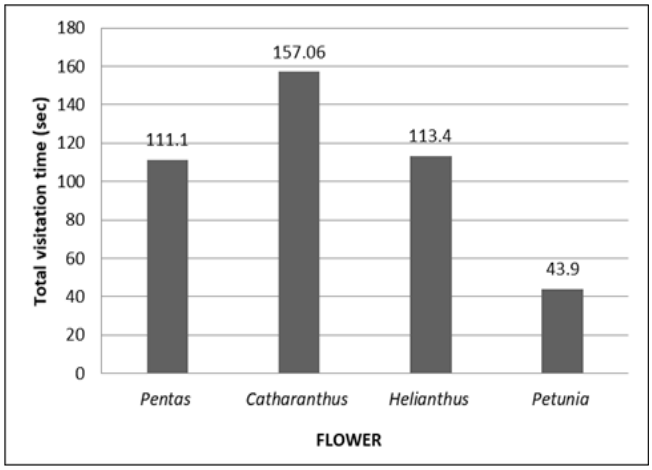

Fig 1: Total visitation time of *Danaus chrysippus* on the flowers

One- way ANOVA yielded statistically significant difference between the mean time spent in morning, afternoon and evening, on *Pentas* ($F_{2,12}$= 7.043, p<.05), *Catharanthus* ($F_{2,12}$= 12.93, p<.05) and *Petunia* ($F_{2,12}$= 52.01, p<.001). However, no significant difference was observed on *Helianthus* ($F_{2,12}$= 1.908, p=.191) (Table 1.). A Tukey Post Hoc Test revealed that the visitation time in the evening was significantly lower on *Pentas* (3.82±0.73, p<.05) and *Catharanthus* (6.00±0.41, p<.05); whereas significantly higher with *Petunia* (5.32±0.36, p<.001). However,

there was no significant difference between the visitation time on *Helianthus*. Longest visitation times were seen on *Catharanthus*, followed by *Pentas* and *Helianthus*. Whereas, shortest visitation times were observed mostly on *Petunia*.

Table 1: Visitation time of *Danaus chrysippus* on the flowers

S.No.	Flower	Mean visitation time (sec)			Visitation time in all shifts		
		Morning	Afternoon	Evening	Mean Total (sec)	$F_{(2,12)}$	Significance (p=.05)
1.	*Pentas* sp.	8.50±1.04Bb	9.90±1.64Bb	3.82±0.73Aa	7.41±0.95	7.04	.009
2.	*Catharanthus* sp.	14.27±1.82Cb	11.14±0.74Bb	6.00±0.41ABa	10.47±1.10	12.93	.001
3.	*Helianthus* sp	7.72±1.37Ba	5.84±0.41Aa	9.12±1.49Ba	7.56±0.73	1.91	.191
4.	*Petunia* sp.	1.20±0.25Aa	2.26±0.27Aa	5.32±0.36Ab	2.93±0.49	52.01	.000
Mean total in all flowers (sec)		7.92±1.21	7.29±0.91	6.07±0.60			
$F_{(3,16)}$		18.04	18.70	6.53			
Significance (p=.05)		.000	.000	.004			

Means and Standard error followed by different lowercase letters in the same row, and uppercase letters in the same column are significantly different (P<0.05) using Tukey's test.

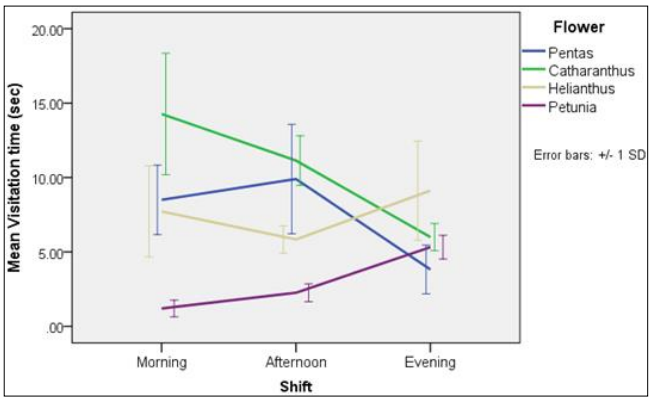

Fig 2: Mean visitation time of *Danaus chrysippus* on the flowers

Analysis by ANOVA also showed significant differences between the visitation times on flowers in all three shifts (p<.05) to a large extent. It was significantly highest on *Catharanthus* (14.27±1.82, p<.001) and lowest on *Petunia* (1.20±0.25, p<.001) in the morning shift. However, it was not significantly different between *Helianthus* (7.72±1.37, p<.001) and *Pentas* (8.50±1.04, p<.001). Visitation times during afternoon also varied significantly (p<.001) between flowers. It was significantly high on *Catharanthus* (11.14±0.74, p<.001), and *Pentas* (9.90±1.64, p<.001) than *Helianthus* (5.84±0.41, p<.001) and *Petunia* (2.26±0.27, p<.001). Visitation times also varied significantly (p<.01) between flowers during evening.

It was significantly high on *Helianthus* (9.12±1.49, p<.05), when compared to *Pentas* (3.82±0.73, p<.05) and *Petunia* (5.84±0.36, p<.05), but not with *Catharanthus* (6.00±0.41, p=.093). Visitation time was generally found to increase by evening on *Helianthus and Petunia,* and decrease on *Pentas* and *Catharanthus* (Fig 2.)

Results and Discussion

Butterflies do not select the nectar plant randomly rather; they exhibit distinct preferences that may vary among species [10,11,12]. The choice of nectar plant by butterfly is correlated with flower structure and their proboscis size and adaptability [13]. It has also been observed that, among suitable flowers, butterfly exhibits no specific flower preference and their feeding behavior is governed by the distribution and abundance of available nectar of flower [14,15]. *D. chrysippus* was found to spend significantly more time on *Catharanthus* sp. followed by *Helianthus* sp., *Pentas* sp. and then *Petunia* sp.. In a natural environment the reasons behind differences in the visitation times and preferences may be varied. Some of them may be size and age of butterfly, sex, proboscis length, the concentration of nectar, corolla tube depth, flower color, scent, predators, avoidance of larger other resident butterflies, other pollinators, and even plant phenomorphology etc. [16]. With all other factors excluded in the experiment, the flowers with long visitation time must therefore be the most rewarding in terms of foraging resources such as nectar.

Nectar is the main floral food-reward for pollinators. Floral nectar is highly variable because different plant species produce different quantities and qualities of nectar [17]. Also, factors like weather conditions, seasons, time of the day and extent of exploitation also cause variations in nectar concentrations [12,18,19]. Increase in visitation time by evening on *Helianthus* and *Petunia*, and decrease on *Pentas* and *Catharanthus* seems to be due to the interplay of ambient temperature and nectar availability. Although *D. chrysippus* has comparatively much longer proboscis and feeding duration, among other local butterflies, it shows positive correlation to corolla tube length [9]. However, the much longer corolla tube of *Petunia* and to some extent, nectar-poor small florets of *Helianthus* might have caused shorter visitation times on them. These observations will lead to further studies and deeper insights into the foraging preferences and behavior of butterflies.

Conclusions

For many holometabolous insects the quality and availability of nutrient resources during the adult stage correlation with fecundity, egg weight and longevity, as reported by O'Brien *et al*. [20]. Nectar feeding mechanism could play a significant role in the reproductive success and longevity for adult butterfly. Studying the preference and feeding behavior of local butterflies is very important because it can help save them from extinction. The reason behind the apocalypse of butterflies is the destruction of their habitats to a large extent. Local flowering plants like *Catharanthus*, *Helianthus*, *Petunia* and *Pentas* sp. should be promoted in home gardens and localities. Plants mostly preferred for nutrition by local butterflies not only help save them but also attract them to home gardens and urban areas.

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