Indian Journal of Ecology (2022) 49(3): 703-710
DOI: https://doi.org/10.55362/IJE/2022/3582

Manuscript Number: 3582
NAAS Rating: 5.79

Flower-Pollinator Interactions in Liana (*Caesalpinia cucullata* Roxb.) in a Tropical Rain Forest of Mizoram

Kewat Sanjay Kumar, Vinod Prasad Khanduri[1], Nagaraj Hegde, Saroj Ahirwar[2] and Puyam Devanda Singh

Department of Forestry, Mizoram University, Aizawl, Mizoram -796 004, India
[1]Department of Forestry, College of Forestry, VCSG Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal- 249 199, India
[2]Department of Industrial Microbiology, Jacob Institute of Biotechnology and Bioengineering (JIBB), Sam Higginbottom Institute of Agriculture, Technology and Sciences (SHUATS), Prayagraj-211 007, India
E-mail: kewatsanjay@gmail.com

***Abstract*:** Lianas (woody climbers) are relatively underexplored life forms of many forests, which predominantly forms tropical forests and provide food and shelter to a variety of animals. A study on flower-pollinator interactions in *Caesalpinia cucullata* Roxb. was conducted in the tropical rain forest of Indo-Burma hot spot at Tanhril area of Aizawl district of Mizoram. Floral visitors of *C. cucullata* were monitored and recorded during 24 field days, four to six hour per day with a total of about one hundred hours during the flowering season of November–December, 2016. The flowers of *C. cucullata* were found to be visited by three insect species belonging three families; nine passeriformes birds belonging eight families and one Hoary-bellied Himalayan squirrel (Irrawaddy squirrel) belonging family Scuiridae. Birds and squirrel mainly visited the flowers in morning hours while butterflies and bees exhibited diurnal pattern of foraging. The results revealed that the bird pollination is supported by butterflies in *C. cucullata*. The flowers of *C. cucullata* would be excellent food resource to the dependent animal species during dry cold period in the extreme tropical sloppy mountain forest site when availability of floral resource is very scarce. Therefore, *C. cucullata* could be a valuable liana species for the conservation of valuable species of insects, birds and squirrels.

***Keywords*:** Liana, Birds, Insects, Pollination, Tropical forest and conservation

Tropical forest community contains enormous diversity of flora and fauna with their ecological interactions. One of the peculiar and mesmerizing life forms found in tropical rain forest is woody climbers, i.e., liana, which remained a relatively underexplored plant life forms compared to that of tree species (Rice et al 2004). In the last two decades there is a pulsating trend in liana research owing to their growing significance in tropical forest dynamics due to global change (Ledo and Schnitzer 2014). Liana competes with trees for above and belowground resources, leading to decrease in recruitment, regeneration, growth, fecundity and survival of trees especially in disturbed forest sites (Phillips et al 2002, Schnitzer and Bongers 2011). Conversely, lianas act as an important resource to the forest functioning like stabilizing microclimatic conditions of under canopy, trail for arboreal animals to crossways the tree tops, acts as foliar, floral, fruit and nesting resources to a diverse group of vertebrate and invertebrate fauna (Emmons and Gentry 1983, Yanoviak and Schnitzer 2013). Birds are reported to depend on lianas for a variety of direct resources such as fruit (many lianas produce fleshy fruits which are frequently consumed by birds) and nectar. -Indirect resources like sheltering, nesting sites, perching space, insects and their larvae for feeding (Kominami et al 2003, Sankamethawee et al 2011). Nectar of lianas act as floral rewards to the diverse array of birds such as humming birds, honeyeaters, warblers, parrots, blackbirds, cardinals and orioles (Stein 1992, Peres 2000, Fleming et al 2005). Many liana-harboring insects (mainly Hymenopterans, Dipterans and Hemipterans) extract floral nectar as their feed, such insects turn act as a food resource to insectivorous birds (Gryj et al 1990). Lianas are also reported to be harbouring large number of endophytic fungi (Biplab 2018). Lianas and their tangles offer either obligate and facultative nesting and/or roosting niche for a spectrum of bird species (Mack and Wright 1996, Michel et al 2015). Intense liana entangles offer excellent habitat for birds to hide and protect from predators (Boinski et al 2003), song and display perches (Durães 2009). In turn, lianas get benefited from a range of services by birds in pollination, seed dispersal and protection from insects in herbivory (Gryj et al 1990, Stein 1992, Lenz et al 2011, Michel et al 2015), while some birds used to rob nectar and predate seeds of liana, thus affecting it negatively (Lara and Ornelas 2001).

The trend of bird population and their species diversity are declining globally (Sekercio˘glu et al 2004) and presently, 21% of bird species are measured to be extinction-prone and 13-39% of bird species are speculated to be extinct by 2100 (Sekercio˘glu et al 2004). Specialized fruit and nectar eating

bird species are more vulnerable to extinction than other functional groups. Therefore, the decline in population of specialist bird species involved in pollination and seed dispersal of liana are going to impact the liana and other key plant groups (Ansell et al 2011). Contrary to this, the generalist bird species are reported to increase with increasing liana abundance and diversity in logged rain forest site (Biamonte et al 2011). Therefore, it is utmost important to understand the nature and degree of liana-animal interaction for the sustainable conservation of lianas, mammals, birds, insects and tropical forest communities.

Caesalpinia cucullata Roxb. (Syn. *Mezoneuron cucullatum* (Roxb.) Wight and Arn.) commonly known as hooded-flowered brasiletto, Sahyadri thorn, (Locally known as Hling-Khang in Mizo) is a large climbing shrub with thorns and is reported to be an armed straggler (Muthumperumal and Parthasarathy 2009). It bears fragrant flowers in terminal and axillary racemes of 20-40cm in length. Yellow flowers appeared like hoods with long stamen filament and protruding red anthers. *C. cucullata* is distributed throughout the north eastern hilly states of India (Barik et al 2015), and sparsely found in evergreen forests of Sahyadri hills and its presence is also recorded from North Andaman in Semi evergreen and littoral forests (Ghosh 2013). It is closely related to *Caesalpinia decapetala* (Deshmukh et al 2013). Its beans are locally consumed by the tribals of Koraput, Orissa (Mishra and Padhan 2011) and roots are used in curing sprains (Bandopadhya and Mukherjee 2010). In Chinese traditional medicines it is reported to be an effective anti-abortion agent (Xiaoping and Shaanxi, 2003). A variety of active phytochemicals was isolated and characterized from the different parts of *C. cucullata* (Cheng-yu et al 2013). There is no scientific report on flower-animal interaction (floral visitors) of *C. cucullata* so far and this study is the first report on the flower visitors and their role in pollination and resource utilization for sustainability and conservation of dependent pollinators as well as the liana species.

MATERIAL AND METHODS

Five individuals of *C. cucullata* were identified along deep mountain slopes inside the Mizoram University campus, Tanhril, Aizawl (latitude 23°.43'53. 19" N to 24°.35' N and longitude 92°.39'44.21" E to 93°.29' E and altitude 832 m). A reconnaissance survey was also made all across the campus to locate other individuals of *C. cucullata* but other individuals were not found which might be due to highly dense and close forest canopy cover, inaccessible steep forest mountain slopes in the study area. Hence, recording of phenological events (for two seasonal calendars i.e., 2016-17 and 2017-18) and pollinator floral visitors (in 2016) were done on five individuals located nearby to each other with the help of binocular and camera. Floral visitors of *C. cucullata* were monitored and recorded during 24 field days, four to six hours per day with a total of about one hundred hours during the flowering season of November-December 2016. Five branches per individuals were chosen randomly and the observations were recorded over the course of whole day length between 0600 h morning to the 1700 h dusk in five blocks (0601-0800; 0801-1000; 1001-1200; 1201-1400 and 1401-1700). The visitation rate of the floral visitors was assessed in terms of visits per branch per day (visits/branch/day) and the pollinators were classified as regular and occasional visitors on the basis of their frequency. Floral visitors included insects, birds and squirrels. Floral visitors were monitored with the help of binocular, camera, and also directly when they visited the flower. Bird's mode of approach, landing, probing behaviour with bill while perched, floral resource used by the flower visitors, contact with reproductive organs which can potentially promote pollination were recorded. The allocation of each monitoring time block was done in such a way that all the selected individuals of lianas in a group was monitored in each observation block during field visit. Floral visitors were identified with the help of standard handbooks and manuals (Ali 1943, Richard et al 2011). The structure and brief tree floristic diversity of the forest and climatic features of the study site were described by Kumar and Khanduri (2016).

RESULTS AND DISCUSSION

Caesalpinia cucullata flowered during cool dry period from mid of November to first week of January with peak flowering (i.e. blooming) recorded during second to third week of December in 2016 (Fig. 1A-B). Early fruiting started in first week of January which coincided with late flowering phase. Both fruits and flowers can be observed simultaneously in the same branch of *C. Cucullata* (Fig. 1C). Fruiting phase was extended from first week of January-2017 to last week of April-2017. Fruit maturity took place in February-2017 and dispersal was recorded in March and April-2017 (Fig. 1D and Fig. 4). In 2017, floral budding was initiated in the third week of November-2017 and just before the anthesis and blooming phase a brief period of atypical intense rainfall occurred during 9-11 December-2017 (Fig. 3) which disrupted the whole flowering phase, pollination and fertilization and all unopened floral buds from the branches fell down within a week (Fig. 1E). Consequently, no animal foraging and fruit set were recorded during the season 2017-2018 (Fig. 4).

Three insect's species belonging to three families; nine

passeriformes birds belonging to eight families and one Hoary-bellied Himalayan squirrel (Irrawaddy squirrel) belonging to family Scuiridae were found visiting the flowers of *C. cucullata* during the flowering phase of December-2016. *Vindula erota erota* (butterfly) is one of most prolific floral visitor recorded exhibiting peculiar sexual dimorphism in morphology (colour) between male and female individuals (Fig. 1 H-I). Diurnal foraging activity for *V. erota erota* was

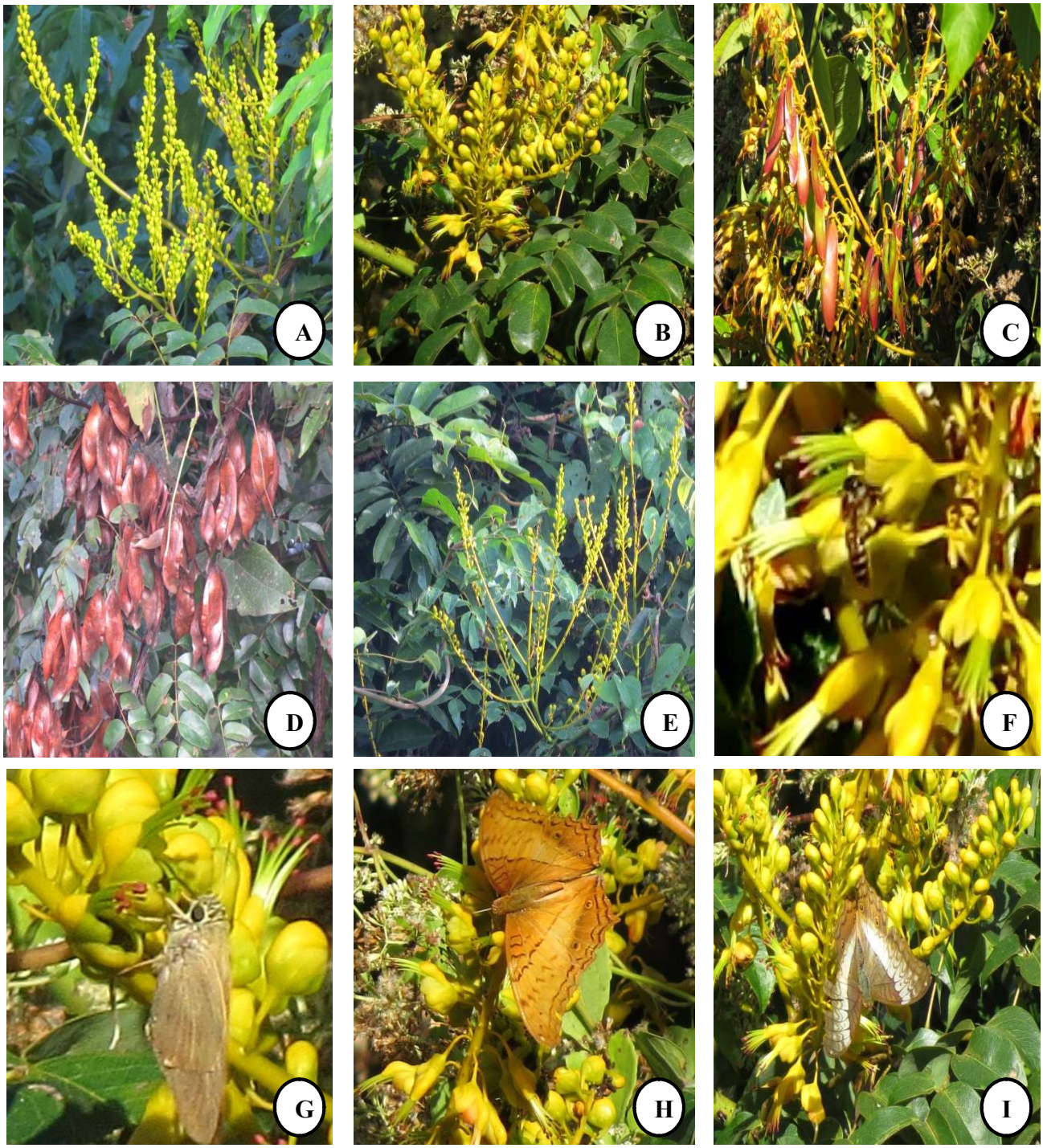

Fig. 1. Phenological phases and insects floral visitors of *C. cucullata* : (A) Early unopened floral bud-2016 (B) Flower in blooming phase-2016 (C) Early fruiting phase coincide late flowering phase-2016 (D) Mature fruiting stage-2016 (E) Detrimental impact of unusual out of season rainfall on flowering phase (all floral buds before anthesis fell down)-December 2017 (F) *Apis cerena* (G) *Badamia exclamationis* (H) *Vindula erota erota* (male) (I) *Vindula erota erota* (female)

observed with the peak foraging activity during morning and afternoon hours, however, inter flower movement was slow (Table 1). *Badamia exclamationis* (butterfly) occasionally visited the flower with peak visitation during 0801-1000 hours. Both species of butterfly exhibited hovering and sitting activity on flowers. During foraging, they make definite contact with stamens and stigma of *C. cucullata* and the nectar and pollen were harvested as their food resource (Fig. 1G-I). *Apis cerena* (bee) was recorded foraging the flowers of *C. cucullata* diurnally with peak visits during morning and afternoon. *A. cerena* makes inter flower movement and in one bout it visited 2-6 flowers in a branch. *A. cerena* extracts floral nectar without making regular contacts with protruding red-coloured stamens (Fig. 1F). While foraging, *A. cerena* very occasionally contacted the stamen of the flower for pollen resource and therefore they mainly visited for nectar of the flower.

C. cucullata offered some of distinguishing features for bird pollination (ornithophily) such as; (i) upright branches facilitating bird perching, (ii) large number of red colour protruding stamens in flowers can be easily sighted from distance, (iii) production of nectar in protected cup like yellow flower, (iv) corolla colors range from yellow to yellowish orange and (v) prolonged anthers seems to be important feature for pollen transfer. As bird forages for deep seated nectar, a definite contact with anthers to beak, head and neck region of birds was observed (Fig. 2 A-H).

Table 1. Butterflies, bee, passerine birds and squirrel visitors to the flowers of *C. cucullata*

Animal species	Common name	No. of visits/ branch/day (n=10 d) (Mean ±SD)	Frequency	Peak time of visitation	Floral resource sought	IUCN Status
Insects (Lepidoptera & Hymenoptera) Family : Nymphalidae *Vindula erota erota* Fabricius	Common cruiser	30.9±10.72	Regular	0801-1200; 1401-1700	Nectar, Pollen	NA
Family: Hesperiidae *Badamia exclamationis* Fabricius	Brown awl	3.5±1.77	Occasional	0801-1000	Nectar, Pollen	NA
Family: Apidae *Apis cerena* Fabricius	Asiatic honey bee	55.2±12.7	Regular	0801-1200;1401-1700	Nectar Pollen	NA
Birds (Passeriformes) Family: Chloropsidae *Chloropsis aurifrons* Temminck	Golden-fronted leaf bird	8.3±2.86	Regular	0601-1000	Nectar	LC,⇌
Chloropsis cochinchinensis Gmelin	Blue winged leaf bird	3.3±2.62	Occasional	0601-0800	Nectar	NT, ↓
Family: Pycnonotidae *Pycnonotus cafer* Linnaeus	Red vented bulbul	5.6±2.59	Regular	0801-1000	Nectar	LC, ↑
Family: Nectariniidae *Arachnothera longirostra* Latham	Little spider hunter	2.6±1.77	Occasional	0801-1000	Nectar	LC,⇌
Family: Cisticolidae *Orthotomus sutorius* Pennant	Common tailor bird	3.1±2.18	Occasional	0801-1000	Nectar	LC,⇌
Family: Zosteropidae *Zosterops palpebrosus* Temminck	Oriental white eye	5.3±2.35	Regular	0601-1000	Nectar	LC, ↓
Family: Tamaliidae *Mixornis gularis* Horsfield	Pin-striped tit-babbler	1.8±1.75	Occasional	0801-1000	Nectar	LC,⇌
Family: Phylloscopidae *Phylloscopus* sp.	Leaf warbler	1.4±1.5	Occasional	0801-1100	Nectar	
Family: Dicruridae *Dicrurus macrocercus* Vieillot	Black drongo	0.9±0.73	Occasional	0801-1000	Nectar	LC,?
Squirrel (Rodentia) Family: Sciuridae *Callosciurus pygerthus* I. Geoffroy Saint Hilaire	Hoary-bellied Himalayan squirrel	2.1±1.28	Occasional	0801-1000	Flower, Nectar	LC,⇌

NA (Not Available); LC (Least Concern); NT (Near Threatened); ⇌ (Stable); ↑ (Increasing); ↓ (Decreasing) ;?(Unknown)

Chloropsis aurifrons was recorded to be the regular visitor to the flower of *C. cucullata* during early morning hours (0601-1000; Table 1); it first perched on the branch of liana then try extracting nectar from more than one flowers in one sitting and spared about 15-35 seconds in a branch and 4-6 seconds per flower. On an average it pokes and extracts nectar from 5-15 flowers in one bout and makes definite contact with stamens through its neck, head and beak (Fig. 2D). *Chloropsis cochinchinensis* was foraging mostly during early morning hours and its behaviour was almost similar with

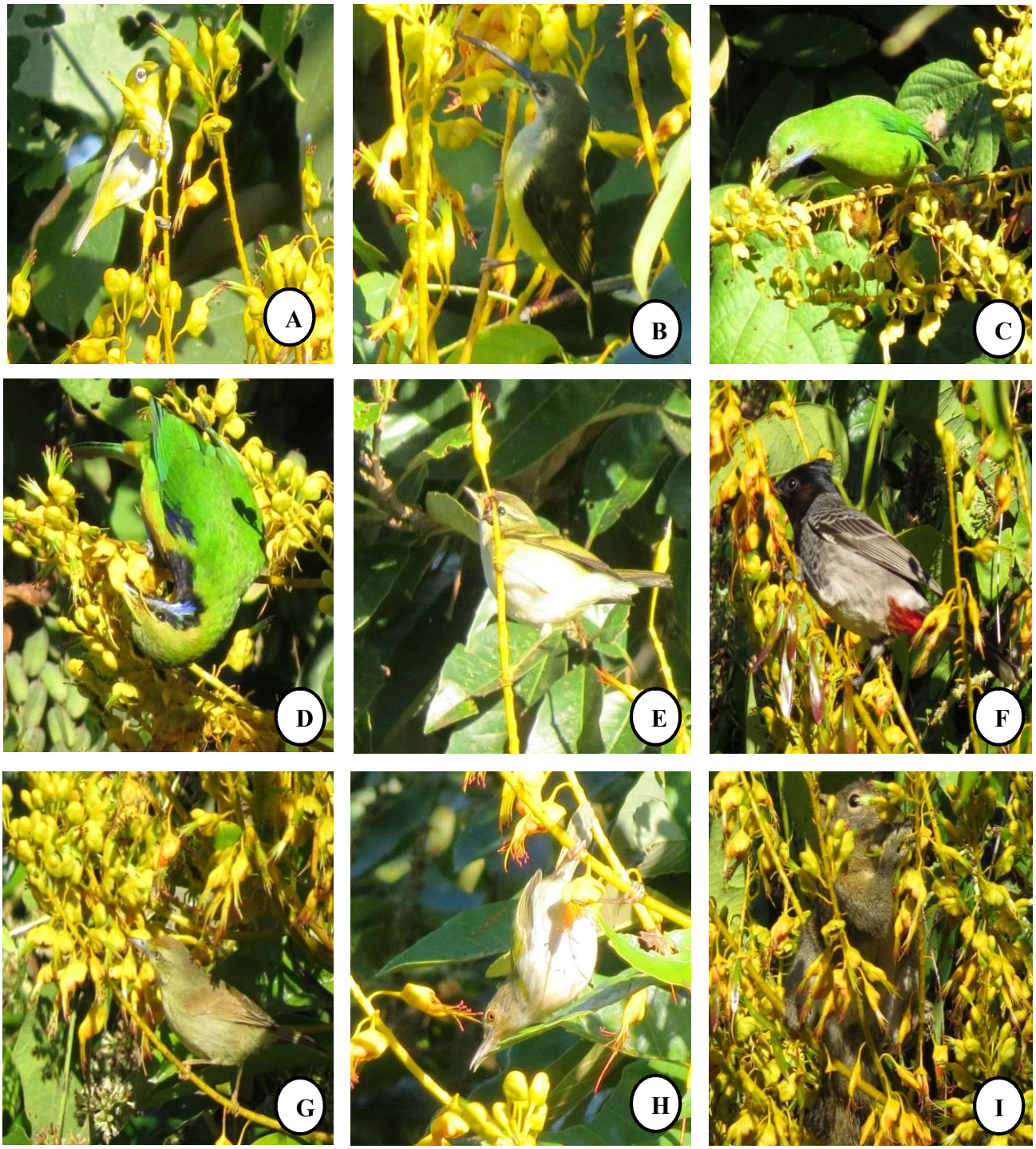

Fig. 2. Floral visitors (birds & squirrel) showing interactions with reproductive floral parts of *C. cucullata* (A) *Zosterops palpebrosus* (B) *Arachnothora longirostra* (C) *Chloropsis cochinchinensis* (D) *Chloropsis aurifrons* (E) *Phylloscopus* sp. (F) *Pycnonotus cafer* (G) *Mixornis gularis* (H) *Orthotomus sutorius* (I) *Callosciurus pygerthus*

C. aurifrons but it occasionally visited the flower for nectars (Fig. 2C, Table 1).

Pycnonotus cafer was observed as a regular visitor to flower with the average visit of 1-3 flowers per visit and was found to be very alert while foraging. It sensed small movement and fly away from the source. It extracted nectar during foraging and spared about 10-15 seconds per flower and simultaneously made precise contact with reproductive parts of flower (Fig. 2F). Oriental white eye (*Zosterops palpebrosus*) visited the flower both singly and in small flocks (Fig. 2A). The peak visitation was recorded during 0600-1000 h. The flower handling time was very less (~3-5 seconds). After harvesting nectar, it rubbed its beak on branches after nectar drinking. Little spider hunter (*Arachnothera longirostra*) occasionally visited the flower. It produced typical noise before and after foraging the flower and rubbed its beak on branches after nectar harvest. It legitimately foraged the flower with long curved beak. The beak and head of *A. longirostra* make precise contact with reproductive parts of flower (Fig 2B) . It spent around 3-5 seconds per flower. *Orthotomus sutorius*, *Mixornis gularis* and *Phylloscopus* sp. were found occasional visitors to flowers of *C. cucullata* and were observed visiting during morning hours (0800-1000) (Fig. 2F, G and H). They make firm perched on the branch and then precisely foraged flower for nectar. At one perch they poked 1-3 flowers. *Dicrurus macrocercus* was found to be very occasional visitor to flower, it perched on branch and try to harvest nectar from flower; while foraging it damages the flowers too. *Callosciurus pygerthus* (Irrawaddy squirrel) to the visited singly flowers of *C. cucullata*, during visits it makes extensive noise, while harvesting nectar, damaged the flower and also did florivory. The prehensile tail of *C. pygerthus* acts as balancer while moving from flower to flower, it spent good amount of time per visit.

Insects mostly exhibited bimodal pattern of regular foraging visit while bird visited mostly in the morning hours with unimodal pattern. *C. aurifrons, P. cafer* and *Z. palpebrosus* were recorded most regular visitors to the flowers of *C. cucullata* while others foraged occasionally for nectar. After web search on IUCN red list to assess the conservation status of floral visitor species, except blue winged leaf bird (*C. cochinchinensis*) which is found to be near threatened (NT), all other birds were found to be in least concern (LC) category. Population trend found be variable with stable population trend for *C. aurifrons, A. longirostra, O. sutorius, Mixornis gularis,* increasing trend for *P. cafer* while decreasing trend for *C. cochinchinensis* and *Z. palpebrosus. Callosciurus pygerthus* was enlisted in LC with stable population trend.

The majority of perennial plant species found in tropics exhibit some degree of seasonality in growth and reproduction to climatic factors (van Schaik et al 1993, Aide 1993). Such a periodicity in tropical long-lived plants is tightly coupled with activities of dependant animal species for plant resources such as emerging leaves, nectar, pollen, fruits and seeds. In turn, animals render their valuable services as pollinators, seed dispersers and protecting from herbivory from other animals. Thus, uneven patterns of climatic factors may have profound impact on such plant-animal interactions which may lead loss of biodiversity and associated ecological functions (Butt et al 2015). In present study erratic intense brief rainfall during 9-11 December, 2017 (Fig. 3) leads reproductive failure of *C. cucullata* in the season. The month of December in general considered as a dry month in present study site, as there were only two episodes of rainfall i.e. 56 mm and 37.6 mm in December-2010 and December-2017, respectively has been recorded during the past decade since 2005. Such atypical climatic events not only affected the liana flowering and reproduction but also influenced the dependent animal species (recorded three species of insects; nine species of birds and one squirrel in the study) for their food resources. Changes in temperature and intense erratic rainfall are reported to be most important factors affecting phenology (flowering and fruit drop) in tropics (Wright and Calderón 2006, Gunarathne and Perera 2014) and in turn has cascading effects on dependent vertebrate fauna.

C. cucullata might be a critical food resource during dry cold period, when moisture availability for plant growth and development is limited for deciduous trees and annual herbaceous community in the present tropical sloppy

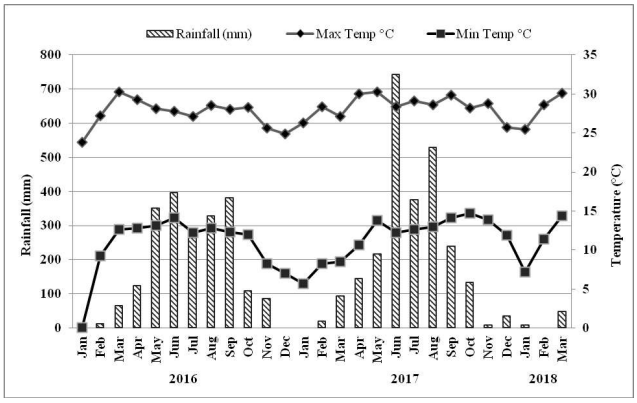

Fig. 3. Mean monthly rainfall, minimum and maximum temperature distribution in study area during study period 2016-18 (Source: ENVIS Centre, Mizoram). Atypical rainfall (35.6 mm) in the month of December-2017 on dated 9, December (5mm), 10 December (19mm) & 11 December (11.6 mm)

	2016						2017												2018					
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Flowering phase					**	****	* *										*	**						
Fruiting phase							ψψψ ψ	**ψψψ ψ**	**ψψψ ψ**	**ψψψ ψ**														

Fig. 4. Phenogram of *C. cucullata* for reproductive stages (*-Flowering; **ψ**-early fruiting; ψ-mature fruits) in two annual seasons (i.e. 2016-17 & 2017-2018); atypical rainfall during second week of December, 2017 negatively affected flowering phase, pollination and fruiting, hence no fruit set was recorded in 2017-18

mountain forest site. The floral resource availability to the dependent animals is very scarce in the months of November and December as compared to spring and rainy seasons. Other tree species which were overlapping with *C. cucullata* flowerings in December in the study site were *Bombax insigne*, *Parkia roxburghii*, *Neolamarckia cadamba* and *Prunus cerasoides* (Khanduri and Kumar 2017). Floral nectars are rich source of sugars, amino and organic acids which are a suitable source of food to a broad spectrum of animals (Koptur 1992). Floral nectars of liana were reported to serve as an important food resource to birds and around 94 bird species belonging 22 families mainly humming birds, honey eaters and warblers were reported so far (Michel et al 2015). Passerine birds have been recorded as major floral nectar feeders in tropical dry deciduous forest during low food availability in other species of liana *e.g., Combretum fruticosum* (Gryj et al 1990). The bird's acoustic activity and patterns were more complex in liana rich forest site as compared to low liana abundance site in tropical deciduous forests of Costa Rica, thus, indicating importance of liana as direct and indirect resource to floral bird communities (Hilje et al 2017).

CONCLUSIONS

On the basis of visitation frequency, time, and behaviour of observed animal visitors in *C. cucullata*, it is ample clear that the birds are main potential pollinators in *C. cucullata* duly assisted by butterflies (*Vindula erota erota* and *Badamia exclamationis*). However, diversity of floral visitors reveals that *C. cucullata* is a valuable liana species in the moist tropical forest for conservation of animal visitors, as it flowers during low resource availability. Moreover, the impact of atypical climatic rain exposed its vulnerability to reproductive success that also may influence the dependent animal species for food resources. *C. cucullata* could be a valuable liana species in green urban landscaping for their aesthetic as well conservation value for the dependent animal community.

REFERENCES

Aide TM 1993. Patterns of leaf development and herbivory in a tropical understory community. *Ecology* **74**(2): 455-466.

Ali S 1943. *The Book of Indian Birds*. The Bombay Natural History Society, Mumbai.

Ansell FA, Edwards DP and Hamer KC 2011. Rehabilitation of logged rain forests: Avifaunal composition, habitat structure, and implications for biodiversity-friendly REDD+. *Biotropica* **43**(4): 504-511.

Bandopadhya S and Mukherjee SK 2010. Diversity of climbing plants in Koch Bihar district of west Bengal, India. *Pleione* **4**(1): 82-89.

Barik S, Adhikari D, Chettri A and Singh P 2015. Diversity of Lianas in Eastern Himalayas and North-Eastern India, in Parthasarathy N., ed., *Biodiversity of Lianas, Sustainable Development and Biodiversity* **5:** 99-121.

Biamonte E, Sandoval L, Chaco´n E and Barrantes G 2011. Effect of urbanization on the avifauna in a tropical metropolitan area. *Landscape Ecology* **26**(2): 183-194.

Biplab B 2018. Diversity of endophytic fungi in few lianas of West Medinipur, South-West, India. *Indian Journal of Ecology* **45**(3): 499-504.

Boinski S, Kauffman L, Westoll A, Stickler CM, Cropp S and Ehmke E 2003. Are vigilance, risk from avian predators and group size consequences of habitat structure? A comparison of three species of squirrel monkey (*Saimiri oerstedii, S. boliviensis* and *S. sciureus*). *Behaviour* **140**: 1421-1467.

Butt N, Seabrook L, Maron M, Law BS, Dawson TP, Syktus J and McAlpine CA 2015. Cascading effects of climate extremes on vertebrate fauna through changes to low-latitude tree flowering and fruiting phenology. *Global Change Biology* **21**(9): 3267-3277.

Cheng-yu K, Li-hui J, Shuang-ting D and Sheng-lai L 2013. Study on chemical constituents of *Caesalpinia cucullata* Roxb. *Food and Drug* **2**: 15.

Deshmukh SA, Labhane NM, Waghmare MB, Chavan SR and Gaikwad DK 2013. Morphometric studies in the genus *Caesalpinia* L. from Kolhapur district. *Research and Reviews: Journal of Botany* **2**(1): 25-28.

Durães R 2009. Lek structure and male display repertoire of blue-crowned manakins in eastern Ecuador. *The Condor* **111**(3): 453-461.

Emmons LH and Gentry AH 1983. Tropical forest structure and the distribution of gliding and prehensile-tailed vertebrates. *The American Naturalist* **121**(4): 513-524.

Fleming TH, Muchhala N and Ornelas JF 2005. New World nectar-feeding vertebrates: Community patterns and processes, in *Contribuciones mastozoológicas en homenaje a Bernardo Villa* (eds V. Sanchez-Cordero and R.A. Medellin), Institutos de Biologia y Ecologia, UNAM, and CONABIO, Mexico, pp. 163-186.

Ghosh A 2013. Taxonomic diversity of climbing plants of North Andaman forest. India. - *Indian Journal of Plant Sciences* **2**(4): 20-43.

Gryj E, del Rio CM and Baker I 1990. Avian pollination and nectar use in *Combretum fruticosum* (Loefl.). *Biotropica* 266-271.

Gunarathne RMUK and Perera GAD 2014. Climatic factors responsible for triggering phenological events in *Manilkara hexandra* (Roxb.) Dubard., a canopy tree in tropical semi-

deciduous forest of Sri Lanka. *Tropical Ecology* **55**(1): 63-73.

Hilje B, Stack S and Sánchez-Azofeifa A 2017. Lianas abundance is positively related with the avian acoustic community in tropical dry forests. *Forests* **8**(9): 311.

Khanduri VP and Kumar KS 2017. Reproductive effort and success in Bombax ceiba L. in a tropical forest of Mizoram, Indo-Burma region of North-East India. *Brazilian Journal of Botany* **40**(1): 157-166.

Kominami Y, Sato T, Takeshita K, Manabe T, Endo A and Noma N 2003. Classification of bird-dispersed plants by fruiting phenology, fruit size, and growth form in a primary lucidophyllous forest: an analysis, with implications for the conservation of fruit-bird interactions. *Ornithological Science* **2**(1): 3-23.

Koptur S 1992. Plants with extra floral nectaries and ants in Everglades habitats. *Florida Entomologist* **21**: 38-50.

Kumar K S and Khanduri V P 2016. Flower pollinator interactions within two tropical tree species of Mizoram, North East India. *Notulae Scientia Biologicae* **8**(2): 256-262.

Lara C and Ornelas J 2001. Preferential nectar robbing of flowers with long corollas: experimental studies of two hummingbird species visiting three plant species. *Oecologia* **128**(2): 263-273.

Ledo A and Schnitzer SA 2014. Disturbance and clonal reproduction determine liana distribution and maintain liana diversity in a tropical forest. *Ecology* **95**(8): 2169-2178.

Lenz J, Fiedler W, Caprano T, Friedrichs W, Gaese B H, Wikelski M and Böhning-Gaese K 2011. Seed-dispersal distributions by trumpeter hornbills in fragmented landscapes. *Proceedings of the Royal Society B: Biological Sciences* **278**(1716): 2257-2264.

Mack AL and Wright DD 1996. Notes on occurrence and feeding of birds at Crater Mountain biological research station, Papua New Guinea. *Emu* **96**(2): 89-101.

Michel NL, Douglas Robinson W and Sherry TW 2015. Liana–bird relationships: a review. *Ecology of Lianas* 362-397.

Mishra S and Padhan S 2011. Traditionally and Culturally Indispensable Food Consumed by Adivasi women of Kalahandi and Koraput district, Odisha: A descriptive study. *International Journal of Science and Emerging Technology* **1**(1): 17.

Muthumperumal C and Parthasarathy N 2009. Angiosperms, climbing plants in tropical forests of southern Eastern Ghats, Tamil Nadu, India. *Check List* **5**(1), 092-111.

Peres CA 2000. Identifying keystone plant resources in tropical forests: the case of gums from Parkia pods. *Journal of Tropical Ecology* **16**(2): 287-317.

Phillips OL, Martínez RV, Arroyo L, Baker TR, Killeen T, Lewis SL and Alexiades M 2002. Increasing dominance of large lianas in Amazonian forests. *Nature* **418**(6899): 770.

Rice K, Brokaw N and Thompson J 2004. Liana abundance in a Puerto Rican forest. *Forest Ecology and Management* **190**(1): 33-41.

Richard G, Carol I and Tim I 2011. *Birds of Indian Subcontinent*. Christopher Helm Publishing Company, London.

Sankamethawee W, Pierce AJ, Gale GA and Hardesty BD 2011. Plant-frugivore interactions in an intact tropical forest in north-east Thailand. *Integrative Zoology* **6**(3): 195-212.

Schnitzer SA and Bongers F 2011. Increasing liana abundance and biomass in tropical forests: emerging patterns and putative mechanisms. *Ecology Letters* **14**(4), 397-406.

Şekercioğlu ÇH, Daily GC and Ehrlich PR 2004. Ecosystem consequences of bird declines. *Proceedings of the National Academy of Sciences* **101**(52): 18042-18047.

Stein BA 1992. Sicklebill hummingbirds, ants, and flowers. *BioScience* **42**(1): 27-34.

van Schaik CP, Terborgh JW and Wright SJ 1993. The phenology of tropical forests: adaptive significance and consequences for primary consumers. *Annual Review of Ecology and Systematics* **24**(1): 353-377.

Wright SJ and Calderón O 2006. Seasonal, El Nino and longer-term changes in flower and seed production in a moist tropical forest. *Ecology Letters* **9**(1): 35-44.

Xiaoping C and Shaanxi TCM 2003. Treatment of threatened abortion with anti-abortion granule: experimental researches on its hemostasis. *Journal of Shaanxi College of Traditional Chinese Medicine* **3**: 20.

Yanoviak SP and Schnitzer SA 2013. Functional roles of lianas for forest canopy animals, in *Treetops at Risk* (eds M Lowman, S Devy and T Ganesh), Springer Verlag, New York.

Received 06 December, 2021; Accepted 22 April, 2022