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RESEARCH ARTICLE

Foraging Behaviour of *Apis (Megapis) dorsata* on Two Mangrove Plant Species

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Key words: *Apis dorsata*, Handling Time, Mangrove, Visitation Rate, Pollen carrying capacity

Study area: Sunderban, West Bengal
Coordinate: Various

Introduction:

Mangrove is one of the most ecologically and economically important ecosystem, situated at the convergence of land and sea specially dominated with halophytes and characterized as a fragile but diversified ecosystem; in respect of forest architecture, this ecosystem is quite simpler than rain forest but highly productive (Alongi, 2002; Giri *et al.*, 2010; Mitra *et al.*, 2015; Therttil & Olakkengil, 2011). Sunderban is the largest mangrove forest around the world. This forest is divided in between two countries; Bangladesh and India. Bangladesh possesses 60% of mangrove forest of Sudarban where India held the rest.

Foraging activities of flower visitors *e.g.* visitation rate, handling time, pollen carrying capacity are essential for cross-pollinated plant regarding their reproductive success. With the view of plant reproduction for various angiosperm flowers, plant-pollinator interaction plays a very important role. The diversity and activity of pollinator species mostly depended on various parameters such as flower size, colour, scent, nectar, pollen and many others (Dupont & Olesen, 2009). Pollination ecology enlightens various aspects of information about the floral structure, the behavioral pattern of interactive animal, the structure

Abstract

Foraging activities of insect is one of the important phenomena for the reproductive system of the cross-pollinated plant. The present study was conducted during the year 2016 to 2018, to explore foraging activities of *Apis (Megapis) dorsata* on *Aegialitis rotundifolia* (AR) and *Aegiceras corniculatum* (AC) mangrove plants from Indian Sundarban. For both the plants, number of *A. dorsata* was showcasing a positive relationship with bloomed flowers. *A. dorsata* touched more flowers in one minute (VR) (12.1 ± 0.74 flowers/minute) on AC plant than on AR, while, the honey bee spent higher time for handling of a single flower (HT) (8.4 ± 0.88 second/flower) in case of AR than AC. This honey bee species also spent more time to fly in between two consecutive flowers for the plant AR (4.3 ± 0.56 Seconds) than AC. Furthermore, the pollen-carrying capacity of *A. dorsata* was higher for the plant AR than the plant AC. This study may indicate that *A. dorsata* may have an important role as a flower visitor for the reproductive success in both *Aegialitis rotundifolia* (AR) and *Aegiceras corniculatum* (AC) in Indian Sundarban.

of plant community, adaptability of visitor and especially the mechanism of pollination (Silberbauer-Gottsberger & Gottsberger, 1988; Gottsberger, 2012). Mangrove preferably selected with generalize the type of pollination system and this phenomena may happen due to the remote location, less availability pollination recourses and of harsh environmental conditions (Pandit & Choudhury, 2001). Pandit & Choudhury (2001) also reported that most of the mangrove plants are not dependent on a particular pollinator type where in some cases, mangroves may be dependent upon some class of pollinators. All the visitors of the angiosperm plant may not be beneficiary regarding the pollination of the plant, such as ant; though they are abundant visitors for some plants, ants are traditionally marked as a poor pollinator (Rostas *et al.*, 2018).

The present communication is conducted in the mangroves of Indian Sundarbans, to study the foraging activities of *Apis (Megapis) dorsata* Fabricious, 1793 on *Aegiceras corniculatum* (L.) Blanco (Family: Myrsinaceae) and *Aegialitis rotundifolia* Roxb. (Family: Plumbaginaceae) plant. Both of the plant genera are showing the characteristic of "Crypto-viviparous" situation (Soloman Raju *et al.*, 2012). *A. dorsata* was previously reported as a major flower visitor for both the plants (Pandey & Pandey,

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2014; Solomon Raju & Karyamsetty, 2018). Therefore, the study of various foraging activities of this honey bee species on these plants may indicate its' potentiality as a flower visitor as well as a pollinator.

Materials and methods:

Studied Plant: the present study was conducted on two ecologically important true mangroves viz. *Aegiceras corniculatum* (AC) and *Aegialitis rotundifolia* (AR) to determine the ecological role of *A.dorsata* in their pollination. Very few works have been conducted till now regarding the insect pollination of these plant species from Sundarban mangrove, among them Chakrabarti (1985), Naskar & Mandal (1999), Bhattacharya *et al.* (2006) & Mitra *et al.* (2015) was notable (Table-1).

Table-1 Morphology of studied mangrove plants

***Aegialitis rotundifolia*:** Small Tree, ~ 3 m ht.; **Leaf** structure- Round, broadly ovate or sub orbicular, size- 2.5 to 9 cm × 3 to 9 cm; **Flower** Colour- White, size- 18 mm long 11 mm diameter, 5 sepals, flowering period - Late February to Early April

***Aegiceras corniculatum*:** Small Tree, ~ 6 m ht.; **Leaf** structure- Ovate oblong, size- 4 to 8 cm × 2 to 4 cm; **Flower** Colour- White, size- 17 mm long 10 mm diameter, 5 sepals, flowering period - Late February to Early April

Reference: Aluri, 1990a; Aluri, 2013; Aluri & Karyamsetty, 2018, http://www.bsienviis.nic.in/Database/IndianMangroves_3941.aspx

Study area: the study was performed in the mangrove ecosystem of Sundarban Biosphere Reserve of the district South 24 Paraganas from the state West Bengal, India. Total numbers of five islands namely Gosaba, Satjelia, Bali, Bakkhali and Sagar Island have been selected for performing the study. From these five islands, on the basis of the availability and accessibility of the studied plants, three study areas have been selected from each island for further work (Map). Map is constructed by using QGIS 3.4 Madeira software (<http://qgis.osgeo.org>).

Sampling technique: three individuals of each plant species have been selected randomly from a marked area of 500 m² (10m width × 50m length) in each study area. The study was performed in the time of the flowering period of respective plants during the year 2016 to 2018. Each plant individual was monitored for the time period of 6 am to 6 pm with 2 hours of intervals, thrice in a week. The collection procedure, preservation procedure, setting and pinning procedure was followed by the manual of Zoological Survey of India (Jonathan & Kulkarni, 1986). For the identification of flower visitors, the specimens were taken to the Zoological Survey of India, Kolkata.

Foraging efficiency of flower visitors: for the maximum time of one minute, an individual flower visitor was monitored continuously for respective plant species. Each observation period was included with, total time spend on flower or flowers by an insect individual (TF; touching or landing on the flower to departure from the flower), total

observation time (TT; the time is consisting with the total time spent on flower/flowers and total time of flight between two consecutive flowers of the same plant species) was taken with the help of separate stopwatches. The total number of flowers visited by an insect (here *A.dorsata*) individual during an observation period was also recorded (NF). Three parameters were analyzed from these data; A) visitation rate (VR; flowers/minute)- average number of flowers visited by an insect individual per unit of time (NF/TT), B) handling time (HT; sec./flower)- average time spending by an insect on a single flower (TF/NF) and C) flight time (FT; sec.)- average Time spent in between the flight of two consecutive flowers while foraging [FT= (TT-TF)/NF] (Herrera, 1989; Meerabai, 2012; Bhowmik *et al.*, 2018).

Correlation analysis: to analyze the relationship between *A.dorsata* and bloomed flowers of AC and AR plants, correlation analysis was performed. The number of *A.dorsata* was counted in one minute of time along with the number of bloomed flowers on a randomly selected branch or inflorescence (as preferable) of the respective plant. A total number of 30 observations have been taken for each plant species for the calculation. Microcal Origin (version 6.0) software and Microsoft Excel 2007 software was used to calculated correlation analysis. The value of r indicates the potentiality of the relationship whether it is strong or weak, r value nearer to 1 leads stronger relationship among *A.dorsata* and the bloomed flowers of the plant.

Pollen collection and Pollen carrying capacity: for the estimation of pollen carrying capacity, *A.dorsata* was captured from 8 am to 11 am of the time interval and the pollen was separated by smooth brushing and washing technique. The pollen of corbiculae was separated in the beginning, only the loose pollen attached to the different body parts of *A.dorsata* was taken for estimation. A total number of 10 individuals were taken for pollen carrying capacity estimation. For the reference of pollen of respective plant species, pollen was directly collected by smashing the mature anthers of the plant on a glass slide and prepared a temporary slide. The pollen was then photographed with the help of phase contrast microscope (Olympus CKX53 microscope, Magcam MU2A camera) with desirable magnification.

Statistical analysis: BOX plot analysis was performed by using. Microcal Origin (version 6.0) software for exploring the range of VR, HT, FT and pollen carrying capacity of *A.dorsata* in the studied plants. Chi-square test was performed ($p < 0.05$) to indicate variation in the pattern of VR and HT of *A.dorsata* in different time intervals on an average of three years data.

Results:

Correlation analysis among *A.dorsata* with bloomed flowers: in the present study, data reveals that the number

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of *A.dorsata* showed a positive relationship with the bloomed flowers of AC and AR plants. More specifically, AC showed stronger relation with *A.dorsata* than AR ($r=0.68$, $n=30$, $p<0.05$ for AC & $r=0.54$, $n=30$, $p<0.05$ for AR) (Fig.-1a,b).

Figure-1: Correlation analysis in between *A.dorsata* & bloomed flowers [a] *Aegiceras corniculatum* [b] *Aegialitis rotundifolia*

Different foraging activities of *A.dorsata* on AC and AR plants: VR is one of the most important parameters to determine the efficiency of flower visitor regarding the plant-pollinator relationship. The present study revealed that *A.dorsata* was showing higher VR in case of AC (12.1 ± 0.74 flowers/minute) than AR (5.9 ± 0.59 flowers/minute) on an average. The estimation of HT is important for the determination of foraging efficiency. On an average, *A.dorsata* was with higher HT for AR plant (8.4 ± 0.88 sec./flower) than AC (5.05 ± 0.31 sec./flower).

FT is also an essential parameter to denote the pattern of the visit of different insect flower visitor; here, *A.dorsata* was showing very short FT, for the plant AC (0.42 ± 0.04 sec.) whereas, for plant AR, *A.dorsata* was showing a comparatively higher in range of FT (4.3 ± 0.56 sec.).

Visitation Rate pattern of *A.dorsata* on AC and AR plants: for both of the plants, the pattern of VR was almost the same among the three years. In both cases, *A.dorsata* showed peak VR in the time interval of 8 am to 10 am (VR= 16.9 ± 0.56 flowers/min. for AC & VR= 10.9 ± 0.81 flowers/min. for AR; Average of three years data) and the least VR showed by *A.dorsata* in the time interval of 2 pm to 4 pm (VR= 4.1 ± 0.20 flowers/min. for AC & VR= 2.4 ± 0.23 flowers/min. for AR; Average of three years data) (Fig.-2a & 3a). Chi-square analysis is showcasing that there was significant variation in VR of *A.dorsata* among the six-time intervals for both of the plants (Table-2)

Figure 2: Line graph of foraging activities pattern of *A.dorsata* on *Aegiceras corniculatum* [a] Visitation Rate; [b] Handling Time

Table-2 : Chi-square analysis of Visitation rate & Handling time of *A. dorsatai* among different time intervals. “**” marked value indicates significant variation ($p<0.05$)

χ^2 value	Degree of freedom (df)	p value
11.8	<i>Aegiceras corniculatum</i> Visitation Rate (5)	$<0.03^*$
2.8	<i>Aegiceras corniculatum</i> Handling Time (5)	>0.71
13.9	<i>Aegialitis rotundifolia</i> Visitation Rate (5)	$<0.01^*$
1.8	<i>Aegialitis rotundifolia</i> Handling Time (5)	>0.87

Figure-3: Line graph of foraging activities pattern of *A.dorsata* on *Aegialitis rotundifolia* [a] Visitation Rate; [b] Handling Time

Handling Time pattern of *A.dorsata* on AC and AR plants: for both of the plants, the pattern of HT was almost the same throughout the three years. In both cases, *A.dorsata* showed the highest HT in the time interval of 8 am to 10 am (HT= 6.4 ± 0.14 sec./flower for AC & HT= 9.9 ± 0.60 sec./flower for AR; Average of three years data) whereas the lowest HT showed in the time interval of 2 pm to 4 pm (HT= 2.3 ± 0.17 sec./flower for AC & HT= 5.9 ± 0.21 sec./flower for AR; Average of three years data) (Fig.-2b & 3b). Chi-square analysis demonstrated no significant variation among the HT of *A.dorsata* in different time intervals for both plants (Table-2).

The pollen-carrying capacity of *A.dorsata* on AC and AR plants: the analysis of pollen carrying capacity is an essential parameter to determine the plant-insect interaction regarding the pollination of plant and pollinator efficiency. *A.dorsata* showed higher average pollen carrying capacity for the plant AR (594.1 ± 89.7 pollen/individual, $n=10$) than AC plant (509 ± 79 pollen/individual, $n=10$) (Plate-1a & b).

Discussion:

Plant and flower visitor relationship is an essential phenomenon with respect to the reproduction in the plant. Insects play an important role as pollinators for various cross-pollinated plants. The interaction between plant and their pollinator are often considered as mutualistic and tightly coevolved relationship (Huang & Giray, 2012).

In a plant-pollinator relationship, the foraging parameters like VR, HT, and visitation frequency, of pollinators show an important role regarding the plant reproductive success for the cross-pollinated plants (Artz & Nault, 2011; Ne’eman *et al.*, 2010). VR of flower visitor depends on various parameters, such as flower structure, colour, size, flower design, the temporal and spatial

Plate-1: Phase contrast microscopic photograph of pollen [a] *A. corniculatum* (40X); [b] *A. rotundifolia* (10X)

Plate-2: Photograph of *A. dorsata* on flower [a] *Aegialitis rotundifolia*; [b] *Aegiceras corniculatum*

structure of floral display and nectar production. In this present communication, analyses of different foraging activities of *A. dorsata* help to predict its' importance as an essential flower visitor of studied mangroves. *A. dorsata* showed higher VR (6.4 to 20 flowers/min.) and lower FT (0.12 to 1.16 seconds) in AC than AR (VR range = 2 to 15 flowers/min.; FT range=0.6 to 13 seconds). This phenomenon may happen due to the completely different floral structure of both the plants (Plate-2). AC offers more flowers in a single inflorescence than AR and the distance between two consecutive flowers AC are far closer than the distance of two consecutive flowers of AR. For each of the plants, *A. dorsata* showed the same VR and HT pattern among the three years. In which, the time interval of 8 am to 10 am held the peak VR and 2 pm to 4 pm showed the least for both the plants. In the time interval of 8 am to 10 am, *A. dorsata* spent the highest HT, while the lowest for the time interval of 2 pm to 4 pm on both plants. Chi-square analysis shows significant variation in VR among different time intervals for both plants but not in HT for both cases.

Anthesis of AC was reported during 0500 hrs to 1900 hrs and maximum completion occurs during the forenoon period and the stigma receptivity is high during the morning and evening time period. It was also reported that the nectar of this plant is composed of different sugars such as fructose, galactose etc. also with amino acids such as, butyric acid and aspartic acid. The availability of nectar of this plant is high during the morning and evening period while in the noon period the nectar availability is lower in range (Pandey & Pandey, 2014). AR was reported with anthesis in the morning and the odourless flower denotes that this plant is meant to be pollinated in the daytime. In the nectar of this plant, both essential and non essential

amino acids such as lysine, tryptophan, phenylalanine, valine, threonine, and histidine is present and some of them are required for honey bees, because of that reason this plant may be better inclined for bee pollination or they show better melittophilous pollination (Solomon Raju & Karyametty, 2018; DeGroot, 1953). *A. dorsata* was showing significantly positive relation with the bloomed flowers of each of the plants where it showed a stronger relation with AC than AR. On the basis of pollen carrying capacity, *A. dorsata* clearly carrying a higher range of pollen (119 to 937 pollen/individuals) for AR plant, while the range was slightly lower in case of AC (117 to 866 pollen/individuals). All these analyses are likely to be indicating that the foraging pattern and foraging activities of this honey bee has an important role in the pollination of AC and AR (Fig.-6). All over the world Mangrove ecosystem is considered as a threatened one (Alongi, 2002). Sundarban Mangrove forest of Sundarban is also troubled with a lot of natural catastrophes and various anthropogenic threats (Mahadevia & Vikas, 2012). It was reported that seven mangroves are threatened and need to be conserved among the common mangroves of Sundarban and *A. corniculatum* (AC) is one of them. Barik & Chowdhury (2014) reported that *A. rotundifolia* (AR) is a near threatened species in the mangrove ecosystem.

Conclusively, qualitative and quantitative analyses may indicate that various foraging activities such as VR, HT, FT and Pollen carrying capacity of *A. dorsata* serves an essential role in the reproduction of both the plants. The present study also demonstrates that foraging pattern of *A. dorsata* may have a prominent positive relationship with the reproductive activities of these two mangroves, which indicates that, *A. dorsata* may have an ability for being a potential flower visitor for pollination of these two mangroves. Therefore, conservation of *A. dorsata* is highly recommended for ensuring the cross-pollination reproductive success of *A. corniculatum* (AC) and *A. rotundifolia* (AR) plant.

Figure-6: Box plot analysis of different foraging activities of *A. dorsata* on *A. corniculatum* & *A. rotundifolia*

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