Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.3, No.15, 2013

Implications of flower developmental stage, plant isolation and microclimatic condition on a hemiparasitic plant–avian pollinator interaction

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The research is financed by the Leventis Conservation Foundation

Abstract

The pollination success of bird pollinated plants is determined by avian visits and duration of foraging which in turn have been shown to be regulated by several plant features. However, very few of these factors have been demonstrated on hemiparasitic plants under tropical African climate. This study, determined how three flower developmental stages (ripe, unripe and open flowers), plant isolation and microclimatic conditions (temperature and wind speed) influenced frequency of visits and duration of foraging by avian pollinators on the Loranthaceae mistletoe *T. sessilifolius* in a tropical savanna habitat in Nigeria, West Africa. One hour focal observations across 40 individuals of the study plant species was used to collect information on avian visits and duration of foraging. While numbers of flowers for the three flower developmental stages were obtained through direct counts. Results showed that increased number of closed ripe flowers on the study plant significantly attracted avian pollinators. This relationship between avian visitors and ripe flowers may be connected with the high nectar content of such flowers as reported in previous studies. Increased intensity of microclimatic factors; temperature (°C) and wind speed (m/s) however, negatively affected avian pollinators. This could be linked to their established effects of increasing avian thermoregulatory costs and mechanical inhibition of flight. These observations could potentially limit pollen deposition at stigma with consequences on plant fitness as shown in previous studies. The observations also give a picture of the potential effects of increasing temperatures in the face of global warming.

Keywords: flower, avian, plant-isolation, microclimate, hemiparasitic-plant, interaction

1. Introduction

Inter-specific interactions such as between plants and animals are the central point of many population interactions in the ecosystem (Krebs, 2001). This is of significance in the tropics where about 90 % of plants rely on animal mutualists for a range of services including pollination (Kelly *et al*., 2004; Voigt *et al*., 2005). The ability to fly and the need to obtain energy has resulted in birds accessing different habitat types and a variety of plants, thereby, becoming good pollination agents (Segun, 1998; Valido *et al*., 2004). Consequently, about 50 bird families are reported as flower visitors (Valido *et al*., 2004). Some of these families include Trochilidae, and Nectariniidae (Schuchmann, 1999; Valido *et al*., 2004). Among several plant flowers visited and pollinated by birds, are those of the xylem-parasitic mistletoe family, Loranthaceae (Ladley *et al*., 1997; Norton *et al*., 1997) which grows on a variety of host plant species; the plants photosynthesize on their own but derive water and nutrient from their hosts (Barlow, 1983; Boussim *et al*., 2004). Mistletoes posses obligate explosive flowers, where only ripe flowers (often with dark terminal bud) open up upon tweaking by birds or strong mandibled insects when foraging for nectar and in the process, releasing pollen which may result in pollination (Ladley *et al*., 1997; Watson, 2001). Other flower developmental stages of the mistletoe are the closed unripe flowers (often with pink to yellow terminal bud which does not contain nectar and both stigma and pollen are not yet matured within the flower) and open flowers (often opened by the activity of birds/insects with the stigma sticking out within the flower tube ready for pollination). These two may co-occur with the ripe flowers on the same plant (Ladley & Kelly, 1995; Ladley *et al*., 1997; Watson, 2001). The pollination success of ornithophilous plants (i.e. bird pollinated plants) such as the Mistletoe might depend on avian visitors since increased frequency of avian visits and duration of foraging could enhance the chances of pollen deposition at stigma of flowers with consequences on seed/fruit set for the individual plant (Klinkhamer & de Jong, 1990; Ågren, 1996; Ladley *et al*., 1997; Kwak *et al*., 1998; Bosch & Waser, 1999; Ashmann *et al*., 2004). Both avian visits and duration of foraging may in turn be determined by: density of flowering plants in a patch (Ashmann *et al*., 2004), plant size, floral size, density of flowers on a plant (Klinkhamer & de Jong, 1990), density of pollinator birds (Kelly *et al*., 1996) and nectar quantity in flowers (Ladley *et al*., 1997). Similarly, Physical environmental factors such as wind, temperature, humidity and light could cause changes in pollinator abundance or foraging behaviour, leading to temporal variation in pollen limitation (Ramsey, 1995). For example, wind speed may mechanically inhibit flight by pollinators and increase energy expenditure during flight (Brantjes, 1981). Extreme temperatures could also induce a reduction in foraging activity in birds as most energy during such period is channelled into thermoregulation (Kersten & Piĕrsma, 1986; Tieleman & Williams, 2002). Although several of these factors have been studied under temperate climatic conditions and in the tropics outside of Africa, very little has been done under tropical African climate (Watson, 2001; Valido *et al*., 2004) despite the potential of such studies in unravelling individual specific traits that influence both plant and animal reproduction and survival. Similarly, studies that demonstrate how microclimatic factors specifically alter interaction between a plant and its avian mutualists are not common despite rapidly changing global climatic conditions. Therefore, this study is aimed at exploring how floral status (three flower developmental stages), plant isolation and microclimatic conditions (temperature and wind speed) influence interactions between avian pollinators and a hemiparasitic plant; the mistletoe *Tapinanthus sessilifolius* (P.Beauv.) Tiegh. under tropical West African climate.

2. Materials and methods

2.1 Study area

The study was conducted during mid wet season between June – July 2005 within the Amurum Forest Reserve (9^0 53'N, 8^0 59'E) located 15 km, northeast of Jos, Plateau State, North-Central Nigeria. The area spans 300 ha and is characterized by various habitat types, which include patches of gallery forest, scrub savannah, rocky outcrops and grassland. Temperatures may reach an average of 26 °C during the rainy season. The forest has been identified as an Important Bird Area (Ezealor, 2002).

2.2 Selection of focal plants, avian sampling and measurement of microclimatic conditions

Forty individual plants of the Mistletoe, *T. sessilifolius* were selected based on stratified random sampling; each selected plant was at least a 100 m from the other. To avoid re-sampling of the same plant, the position of any observed plant was taken using a Global Positioning satellite System (GPS; Garmin eTrex®, version 3.10) these were marked MD 1 – 40 (Fig. 1). Three plants were observed per day between 0700 – 1200 hrs. Each plant was observed once for a period of 1-hour divided into 10 min intervals using a digital stopwatch (Extech®, model 365510). At the beginning of each 10 min. interval, temperature (°C) and wind speed (m/s) were noted using a digital field thermometer/anemometer (Silva, Windwatch®) from these, hourly average temperature (°C) and wind speed (m/s) were then calculated. Using Kowa TSN-1, 20× wide telescope, positioned at varying observer distances of between 10-20 m due to variation in habitat vegetation characteristics, frequency of avian visits as well as time spent per foraging bout per bird species was observed (c.f. Ladley *et al*., 1997).

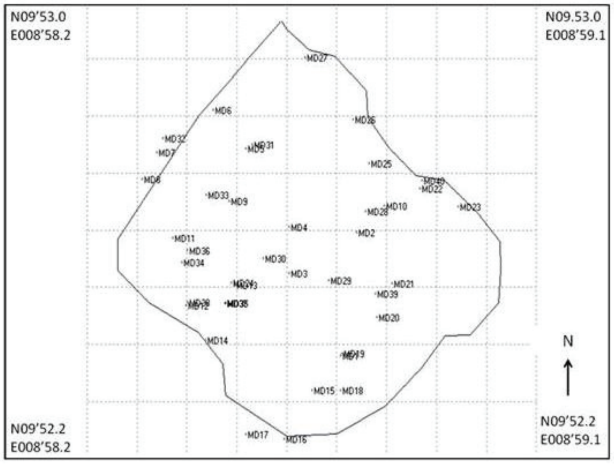

Figure 1: Distribution of individual *T. sesselifolius* studied in the
Amurum Forest Reserve, Nigeria

2.3 Flower developmental stages and plant isolation

T. sessilifolius is known to have three flower developmental stages as earlier described namely closed-unripe, closed-ripe and open flowers. On each of the 40 selected individual plants where focal observation was conducted, direct count of the three flower developmental stages was done on five randomly selected branches and averages taken. On the other hand, plant isolation was measured as the distance (m) of the focal *T. sessilifolius* to its nearest conspecific. These were related to both frequency of avian visits and duration of foraging.

2.4 Data analysis

All statistics was done using the software package SPSS (version 17.0, 2011). G.P.S.Utility® 4.10.9 was in addition used for some graphical plots. Data were statistically explored for normality and equality of variance using the 1-Sample Kolmogorov Smirnov test and Levene statistic; non parametric tests were used where assumptions of parametric tests were not satisfied. Only sunbirds data (a group of pollinator birds of the family Nectariniidae that feed on nectar) was statistically analysed because of small un-analysable sample size for other bird species recorded and due to foraging behaviours exhibited by these bird species such as nectar feeding which were regarded, as important to *T. sessilifolius* reproduction. General Linear Model (GLM) was used to check for the effects of the independent variables; flower developmental stages (closed-unripe, closed ripe and open flowers), plant isolation (m) and weather parameters (temperature and wind speed) on frequency of sunbird visits and duration of foraging (dependent variables). Each independent variable was assessed in separate models in order to eliminate the confounding effects of multi-colinearity (Gerard, 2001) as most of the independent variables were correlated.

3. Results

3.1 Bird species recorded and their activities

A total of 45 avian visits to *T. sessilifolius* were recorded during this particular study, this included, twenty three of 45 (51.1 %) visits by the variable sunbird *Cinnyris venustus*, sixteen (35.6 %) by the scarlet-chested sunbird *Chalcomitra senegalensis*, three (6.7 %) by the village weaver *Ploceous cucullatus*, one (2.2 %) each by yellow fronted tinkerbird *Pogoniulus chrysoconus*, senegal eremomela *Eremomela pusila* and rock loving cisticola *Cisticola aberrans*. Mean frequency of visits per *T. sessilifolius* shoot per hour was not significant between the two nectarivorous birds recorded (scarlet-chested and variable sunbird) (Mann-Whitney U-test, $z < 0.001$, $P = 1.000$).

3.2 Relationship of flower developmental stage, plant isolation with avian visits and duration of foraging

There was no effect of closed unripe flowers on both frequency of avian visits and duration of foraging even when each pollinator bird was considered separately ($P > 0.05$). However, pollinator birds responded positively in visits towards *T. sessilifolius* with higher numbers of closed ripe flowers (GLM, $F_{1, 28} = 12.074$, $P = 0.002$, $r^2 = 0.367$; Fig. 2). Though, closed ripe flowers had no effect on duration of foraging by such birds. Both open flowers and plant isolation distance (m) did not have effect on avian visits and duration of foraging ($P > 0.05$).

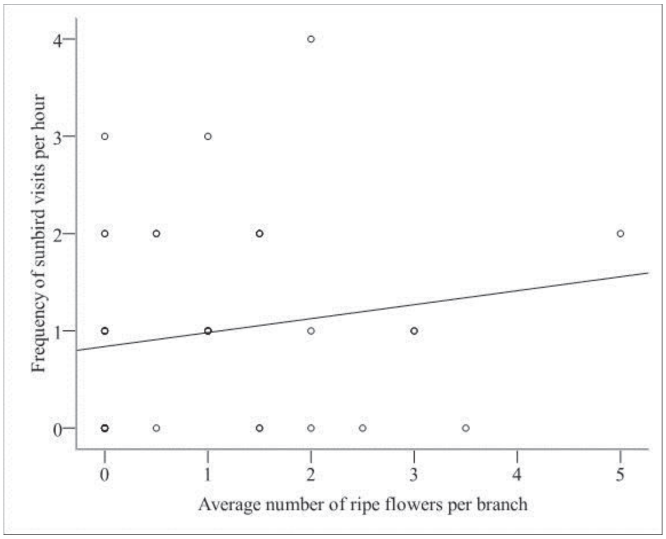

Figure 2: Frequency of avian visits with number
of ripe flowers on *T. sessilifolius*

3.3 Effect of Temperature (^0C) on avian visits and duration of foraging

There was a significant decrease in avian visits to *T. Sessilifolius* at higher temperatures (GLM, $F_{1, 38} = 5.021$, $P = 0.031$, $r^2 = 0.093$; Fig. 3). However, there was no significant effect of temperature on duration of foraging by avian nectarivores (GLM, $F_{1, 34} = 0.000$, $P = 0.992$, $r^2 = 0.029$).

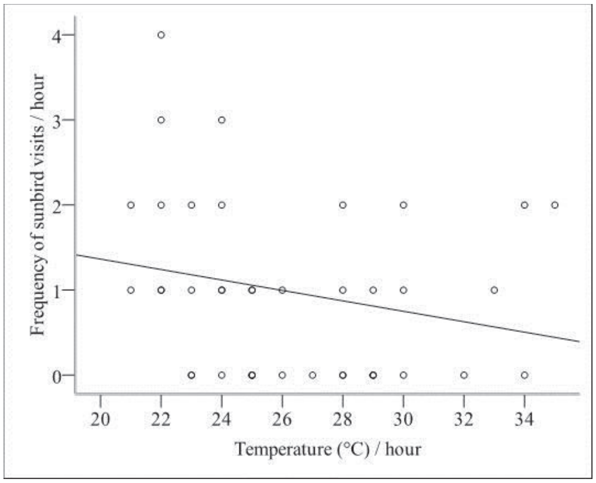

Figure 3: Relationship of avian visits to *T. sesselifolius*
with temperature (°C) during the study period.

3.4 Effect of wind speed (m/s) on avian visits and duration of foraging

Frequency of visits by nectarivorous birds decreased significantly with increase in wind speed (GLM $F_{1, 38}$ = 9.513, P = 0.004, r^2 = 0.179; Fig. 4). But wind speed had no significant effect on duration of foraging by birds (GLM, $F_{1, 34}$ = 0.181, P = 0.673, r^2 = 0.024).

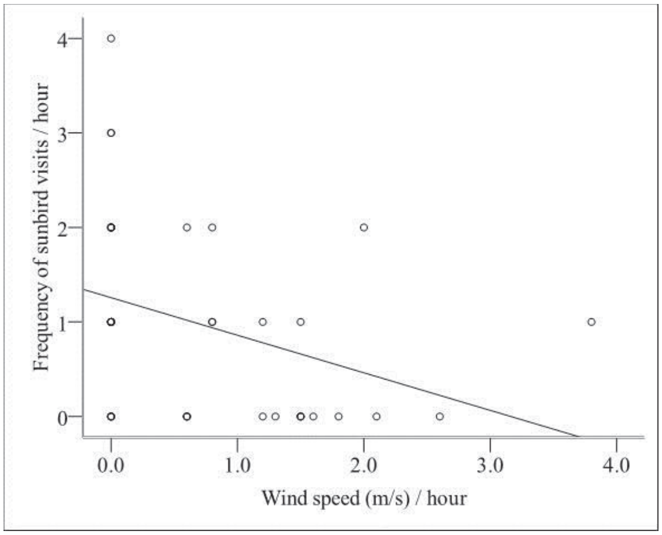

Figure 4: Effect of wind speed (m/s) on frequency of avian visits to *T. sessilifolius*

4. Discussion

Interactions of avian pollinators with their food plants have been widely reported to be regulated by plant structures. This study reaffirms earlier contributions in this regard and also enlightens on the effects of weather variables to the interaction; the major predictors of avian visits to the Mistletoe *T. Sesselifolius* in this study were number of ripe flowers on the plant as well as temperature and wind speed. Avian nectarivores were attracted more towards *T. Sesselifolius* with high ripe flower density. However, their visits to the study plant were limited at high temperatures and wind speed.

The attraction to forage at patches with high ripe flower density may not be unconnected with the high nectar content of such flowers as reported in previous studies (Gill and Wolf, 1975; Ladley *et al*., 1997). The tamper proof nature of such flowers also act as an assurance for energetic benefit to birds since mistletoes have obligate explosive flowers which do not open on their own unless tweaked by birds or strong mandibled insects (Ladley *et al*., 1997; Watson, 2001). Failure of closed-unripe and already opened flowers to influence number of avian visitors reaffirms the nectar assurance hypothesis above since such flowers are regarded to be in development or have their nectar already sipped; previous studies suggest that plants may reabsorb nectar after achieving pollination (Baker & Baker, 1975) however it is not yet clear whether this is the case for already opened flowers on the study plant.

On the other hand, high temperatures have been reported to carry along some thermoregulatory costs (Kersten & Piersma, 1986; Tieleman & Williams, 2002), which include loss of water in order to reduce body heat (Taylor *et al*., 1998). Under such conditions, birds are reported to reduce their activity by retreating to shady habitats or burrows and some take refuge in nests (Tieleman & Williams, 2002; Molokwu *et al*., 2007). This perhaps explains why frequency of avian pollinator visits decreased significantly at high temperatures. The negative effects of wind speed on frequency of avian visits might not be unconnected with its ability to mechanically inhibit avian flight as well as increase flight energy expenditure (Brantjes, 1981). In this case, both of these factors are suspected to have resulted in low frequency of visits to *T. sessilifolius* during periods of high wind speed. The observed effects of both temperature and wind speed on avian visitors have been suggested as capable of reducing plant reproductive potential (Robertson *et al*., 1999) e.g. low fruit set as shown in the loranthaceae mistletoe *Peraxilla tetrapetala* (Montgomery *et al*., 2003). This is because increased frequency of avian visits enhances the potential of pollen deposition on stigma of flowers and consequently fruit development as have been widely reported (Klinkhamer and de Jong, 1990; Ågren, 1996; Ladley *et al*., 1997; Kwak *et al*., 1998; Bosch and Waser, 1999; Ashmann *et al*., 2004). Thus, these observations particularly of weather parameters inhibiting pollinator visits might be a glimpse of the possible effects of global warming on some biological interactions which therefore should necessitate extensive research.

5. Conclusion

The observed effects of ripe (or matured) flowers on avian visits may not be unconnected with the high nectar content of such flowers as previously reported which could therefore induce positive response by birds to such perceived patches of high food availability as observed. Also, effects of temperature and wind speed may be linked to their established effects of increasing avian thermoregulatory costs and mechanical inhibition of flight. These observations could potentially limit pollen deposition at stigma with consequences on plant fitness as shown in previous studies. The observations also give a picture of the potential effects of increasing temperatures in the face of global warming.

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