Adamawa State University Journal of Scientific Research
(ADSUJSR)
Volume 11 Issue 1, 2023
ISSN: 2705-1900 (Online); ISSN: 2251-0702 (Print)
http://www.adsu.edu.ng

# Avian mediated Seed Dispersal of Two Hemi-parasitic Mistletoe Species *Agelanthus brunneus* (Engl.) Balle & Hallé and *Globimetula braunii* (Engl.) Danser - Interaction between host-parasite pair and disperser abundance at Ngel Nyaki Forest Reserve

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*(Received in July 2023; Accepted in August 2023)*

**Abstract**
Montane habitats are generally rare and disproportionately distributed around the world; and are rich in biodiversity with a high concentration of endemic species of conservative interest. These rare forests are highly threatened and their remnants are often surrounded by deforested landscapes typically dominated by high human population. These high concentrations of humans within and around these unique landscapes often exert undue pressures on the fragile ecosystem leading to habitat degradation and species loss. Restoration through dispersal actions by some vertebrates is therefore crucial to the survival of these threatened landscapes. Individuals each of *Agelanthus brunneus* and *Globimetula braunii* were monitored on different host tree species at both forest edge and fragments to record various avian dispersers. A total of 13 bird species, from 11 genera and 10 families were recorded, with only four species (African thrush, African green pigeon, Yellow rumped tinker bird, and Western green tinker bird) identified as mistletoe dispersers. Yellow rumped tinker bird was the most dominant disperser and moved the highest number (70) of seeds. Avian species abundance in concert with host-mistletoe pair combinations partially predicted species' relative contributions to fruit dispersal of the two mistletoe species.

**Keywords:** Dispersal, Mistletoe, Montane Forest, Avian, Abundance

## Introduction

In mutualistic interactions, different species live together in close association, with benefits ranging from reproductive support to protection from predators etc. Deforestation is rapidly removing large tracts of tropical forest around the world (Archard *et al.*, 2002; Hansen and Defries 2004). It reduces once continuous forests into isolated patches with negative consequences for the persistence of mutualistic networks such as dispersal and the survival of many plant and animal species in ecosystem. Natural regeneration through dispersal of fruits and seeds plays a vital role in the restoration of threatened forest landscapes. Studies have shown that Afro-tropical montane forests are one of the most threatened landscapes due to their uniqueness and rarity (Geist and Lambin, 2002; Barnes and Chapman, 2014).

Montane habitats are generally rare and disproportionately distributed around the world and are rich in plant and animal diversity with a high concentration of endemic species of conservation interest. These rare forests are highly threatened and their remnants are usually surrounded by deforested landscapes typically dominated by high human population (Chapman and Chapman, 1999). The high concentrations of humans within and around these unique landscapes often exert undue pressures on the fragile ecosystem leading to habitat degradation and species loss. Restoration through dispersal actions of some vertebrates is therefore crucial to the survival of these threatened landscapes

Forest regeneration is a multi-staged process that involves several ecological interactions (Muller-Ladau *et al*., 2008; Karen, 1999; Toledo-Aceves and Swaine, 2008; Chapman, 2001; Wright *et al*, 2007). These interactions influence forest regeneration by determining the quantity, location and germination of dispersed seeds and the resulting survival of seedlings (Toledo-Aceves and Swaine, 2008; Wright *et al*., 2007).

Seed dispersal is the movement of seeds away from the parent plant (Aliyu et al., 2014). Movement away from parent plant may occur via abiotic mechanism such as wind and water, plant mechanisms such as dehiscent pod that release pod upon maturity or through biotic means-the actions of animals (Aliyu *et al*., 2014).

Seed dispersal by animals provides a wide range of benefits to the tree whose seeds they disperse. A plant may benefit from dispersal in one or more ways (Barnes and Chapman, 2014). Un-dispersed seeds typically fall beneath the parent and for many species the probability of survival beneath the parent is low due to density and distance dependent mortality (Chapman and Chapman 1999; Barnes and Chapman, 2014; Aliyu *et al*., 2014). Seed dispersal may benefit whole plant communities by promoting species diversity and the formation of diverse local seedling assemblages, which may reduce competition, increase seedling survival through diversity dependent effects (Aliyu et al., 2014; Barnes and Chapman, 2014).

*Agelanthus brannues* and *Globimetula braunii* are hemi parasitic plants commonly known as Mistletoes. At Ngel Nyaki Forest Reserve, they grow on the trunks and branches of some trees species such as; *Ficus sur, Bridelia sp., Jansmin, sp., Allophylus africanus* and many others elsewhere, leading to the gradual destruction and elimination of these unfortunate host trees. Most times the loss of one of these species may trigger a cascade of other negative outcomes such as secondary extinction of obligate dependants of the destroyed host. For instance, most species of fig are known to have obligate host specific mutualistic relationships with wasp, who are the only pollinators of their respective fig host species (Chapman and Chapman 1999). Such pair wise interactions will suffer grave consequences if one partner is lost as a result of parasitism. Broadly speaking, hemi-parasites are detrimental to the persistence and survival of genetic and biological diversity in any given ecological community.

However, though it is pertinent to curb the excesses of antagonistic behaviors, ecological communities need these interactions for the maintenance of biological equilibrium. It is therefore crucial to identify the various actors or agents in these intricately connected networks of multi-host and multi-level interactions.

The cardinal objectives were to identify the various avian dispersers of the two focal mistletoe species in Ngel Nyaki Forest Reserve. Other goals were; Investigate the relative contribution of each avian species to the dispersal of mistletoe fruits; determine whether avian visitors were host specific; generate a checklist or network motif of avian dispersers in the study area; and identify possible limitations to seed dispersal in the study area.

***Study Site***

Ngel Nyaki forest Reserve ($7^{0}$30 N, $11^{0}$30E) lies on the western escarpment of the Mambilla plateau, Taraba State - Nigeria (Chapman *et al.*, 2001). Within the 46 km² reserve, 7.2 km² of the forest remains in two fragments; Ngel - Nyaki forest and the Kurmin Danko forest (Beck and Chapman 2008). The main forest is surrounded by a matrix of riparian forest fragments in a mosaic of sporobilus dominated grassland that has been modified by annual indiscriminate burning and unregulated cattle grazing (Chapman *et al.*2004). The 5.3 km² sub-montane Ngel Nyaki forest ranges between 1400 -1600m elevation. The forest is a dry type (Chapman *et al.*, 2001). The forest is one of the rarest of its kind in Nigeria and is home to several floral and faunal species of conservation interest. The reserve is a Bird Life International IBA (Important Bird Area) and EBA (Endemic Bird Area). It is the home of several primates including the endangered chimpanzee, *Pan troglodytes vellerosus* (Beck and Chapman, 2008); others include the Tantalus monkey (*Chlorocebus tantalus*), Olive Baboon (*Papio anubis*) etc. The forest has a rich flora of endemic and International Union for Conservation of Nature (IUCN) red data listed species such as *Entandrophragma angolense*, and species relatively new to Nigeria such as *Nuxia congesta* (Chapman *et al*., 2001).

***Study Species and Host Pairing***

Four individuals each of two species of mistletoes (*Agelanthus brunneus* and *Globimetula braunii*) were observed on various host tree species at the forest edge and fragment, at different times during the day. For each mistletoe species, four unique pair-wise combinations (mistletoe/host tree interactions) were monitored in the forest fragment (FF) and forest edge (FE) habitats. The mistletoe species and the host tree species at the forest fragment were *Agelanthus brunneus* 1FF (Forest Fragment) found on *Allophylus africanus* (P. Beauv.) at 07$^{o}$05.028'N, 011$^{o}$04.186'E and altitude 1662 m a s l and *Agelanthus brunneus* 2FF found on host plant *Ficus sur* (07$^{o}$04.026'N, 011$^{o}$03.182'E at altitude of 1690 m a s l), while those at the forest edge were *A. bruneus* 1FE (Forest Edge) found on an unknown host plant at 07$^{o}$04.755'N, 011$^{o}$03.390'E and altitude 1694 m a s l and *A.brunneus* 2FE found on *Jansmin* sp. at 07$^{o}$06.758'N, 011$^{o}$05.481'E and altitude 1717 m a s l. *G.braunii* 1FE was found on *Bridelia* (07$^{o}$05.036'N, 011$^{o}$04.022'E altitude of 1687 m a s l) and *G.*braunii 2FE on *Ficus* sp (07$^{o}$05.032'N, 011$^{o}$04.019'E and altitude 1700 m a s l). *G. braunii* 1FF was found on Ficus sur (07$^{o}$05.036'N, 011$^{o}$04.037'E) and *G.braunii* 2FF on Ficus sp (07$^{o}$05.036'N, 011$^{o}$04.029'E).

Before each observation, we estimated the total number of mistletoe species fruits (mature and immature) on a host tree. During each session of observation, we recorded the identity and number of individuals of each avian species seen, number of fruits removed by avian species per visit; the duration of visit of each avian species (i.e., time of arrival minus time of departure). Other activities and interactions such as perch, call or antagonism were recorded. The sum total of individuals of each avian species was calculated to determine species overall contribution to their respective host plant species.

***Data collection protocol and analysis***

The data was collected between the months of May to September, 2015 during peak periods of mistletoe species fruit abundance. The observation was carried out in two sessions; morning (6:00 am to 8:00 am) and evening sessions (4:00 pm to 6:00 pm). We alternated the observation periods to remove any possible biases associated with time of day. The observation of every single individual species pair (mistletoe/host combination) lasted for 20 minutes with 5 minutes break between species pair during each observation session using a pair of Nikon binoculars with 8 X 42 magnifications. Each individual host-mistletoe species pair was observed for four days with 40 minutes each day (20 mins. morning, 20 mins. evening) making a total of 160 minutes per individual. All the bird species found on focal tree species combinations (Host/mistletoe pair) were recorded. Only those found feeding on the fruits of each host plant species were recorded as dispersers while those found perched or engaged in non-foraging activities were considered as visitors. The number of fruits accidentally dislodged by visitor species while interacting with the mistletoe species was recorded. The data was analyzed using R statistical software (R Development Core Team, 2013). Data was explored and tested for normality to avoid violation of specific assumptions for parametric test.

**Results**

A total of 212 fruits of the two focal mistletoes species were move by 79 individuals of 13 bird species drawn from 11 genera and 10 families. Results indicate that the most dominant species was the Yellow rump tinker bird, dispersing a total of 72 fruits (Table 2). Of the 13 bird species only five were recorded in numbers greater than four individuals and in the range of (5 to 13 individuals), while the remaining eight species were sighted only once during the 160 minutes observation period for each individual tree/mistletoe species pair (Table 2).

Results also indicated that of the 212 fruits moved by dispersers and visitors, only183 were actually dispersed as they were moved away from parent plant or eaten by bird species. However, 29 of the 212 fruits moved were dislodged accidentally and fell underneath the parent tree species, and were considered as moved but not dispersed. Dispersers accounted for 86.32 % of moved fruits while visitors accounted for 13.68 % of fruits moved or dislodged.

Seven (*Agelanthus brunneus, Allophylus africanus, Ficus sur, Jansmin* sp *Bridelia species, G.braunii* and *Ficus sp*) and three (3) avian species were exclusive in their interactions with *A. brunneus* and *G. braunii* respectively, while the remaining three species (*P. bilineatus*, *P. coryphaeus*, *Colius striatus*) visited both mistletoe species at different times during the observation period. However, the fruits of *G. braunii* were dispersed more than those of *A. brunneus* on average (Figure 1). While 12 bird species were observed to interact with fruits, only 4 species were dispersers while 8 species were visitors, however, one species *Colius striatus* was both i.e., visitor on *A. brunneus /A. africannus* and disperser on *Ficus* sp. */ G. braunii* combined. *Ficus sur* interacted with both mistletoe species, while *Allophylus africannus* and *Bridelia* sp. were exclusive to *A. brunneus* and *G. braunii* respectively (Table 1).

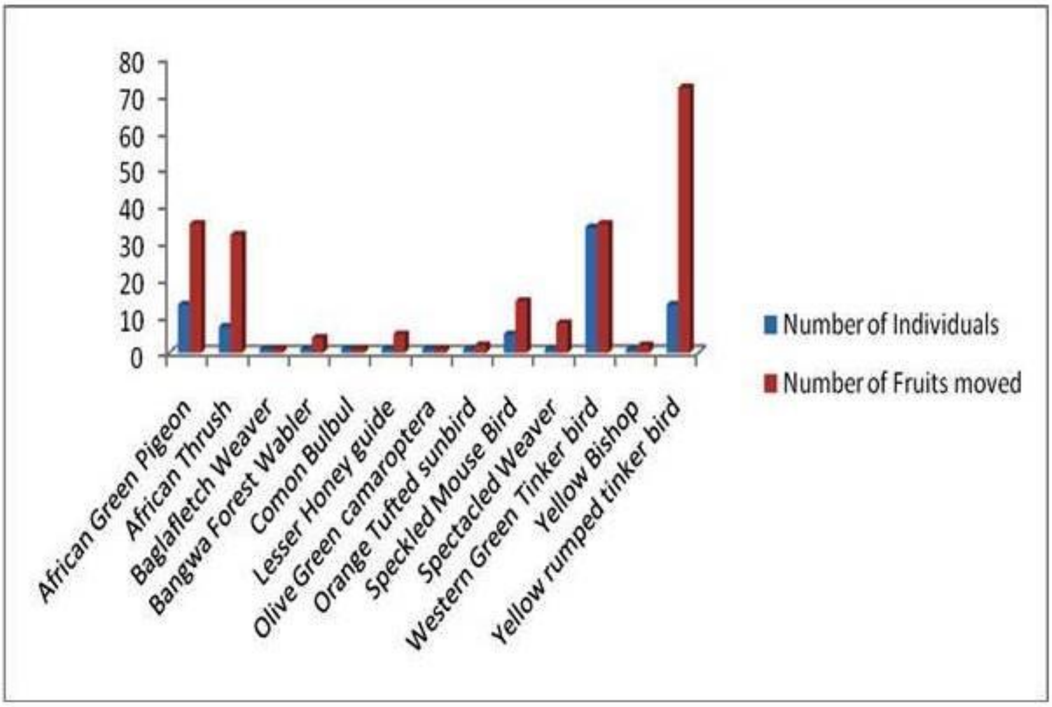


**Figure 1:** Histogram showing the relationship between avian species number (blue bars) and their relative contributions to fruit dispersal (red bar).

**Table 1:** Pair-wise interactions between mistletoe species and their various hosts plant species. FF = Forest Fragment, FE = Forest Edge. Altitudinal range (1662-1717m asl)

| S/N | Mistletoe Species | Habitat | Habitat/parasite code | Host species |
|---|---|---|---|---|
| 1 | *Agelanthus brunneus* | Forest Fragment | AG1FF | *Allophylus africanus* |
| 2 | *Agelanthus brunneus* | Forest Fragment | AG2FF | *Ficus sur* |
| 3 | *Agelanthus brunneus* | Forest Edge | AG1FE | Unknown |
| 4 | *Agelanthus brunneus* | Forest Edge | AG2FE | *Ficus sur* |
| 5 | *G. braunii* | Forest Fragment | GB1FF | *Ficus sur* |
| 6 | *G. braunii* | Forest Fragment | GB2FF | *Ficus sp.* |
| 7 | *G. braunii* | Forest Edge | GB1FE | *Bridelia* |
| 8 | *G. braunii* | Forest Edge | GB2FE | *Ficus* sp. |

**Table 2:** Checklist of Avian Species, their dispersal contributions/status and relative abundances

| S/n | Avian Species | Scientific name | Mistletoe | No | Fruits | Status |
|---|---|---|---|---|---|---|
| 1 | African Thrush | *Turdus pelios* | *brunneus* | 7 | 32 | D |
| 2 | Yellow Rumped Tinkerbird | *Pogoniulus bilineatus* | Both | 13 | 72 | D |
| 3 | Western Green Tinkerbird | *Pogoniulus coryphaeus* | Both | 34 | 35 | D |
| 4 | Speckled Mousebird | *Colius striatus* | Both | 5 | 14 | V/D |
| 5 | African Green Pigeon | *Treron calvus* | *G. braunii* | 13 | 35 | D |
| 6 | Common bulbul | *Pycnonotus barbatus* | *A. brunneus* | 1 | 1 | V |
| 7 | Baglafletch Weaver | *Ploceus baglafecht* | *G. braunii* | 1 | 1 | V |
| 8 | Bangwa Forest Warbler | *Bradypterus(lopezi) bangwaensis* | *A. brunneus* | 1 | 4 | V |
| 9 | Lesser Honey Guide | *Indicator minor* | *A. brunneus* | 1 | 5 | V |
| 10 | Olive Green Camaroptera | *Camaroptera Chloronota* | *A. brunneus* | 1 | 1 | V |
| 11 | Orange Tufted Sunbird | *Cinnyris bouvieri* | *A. brunneus* | 1 | 1 | V |
| 12 | Spectacled Weaver | *Ploceus ocularis* | *G. braunii* | 1 | 8 | V |
| 13 | Yellow Bishop | *Euplectes capensis* | *A. brunneus* | 1 | 2 | V |

Key: D = Dispersers, V/D = Visitors/Dispersers, V = Visitors

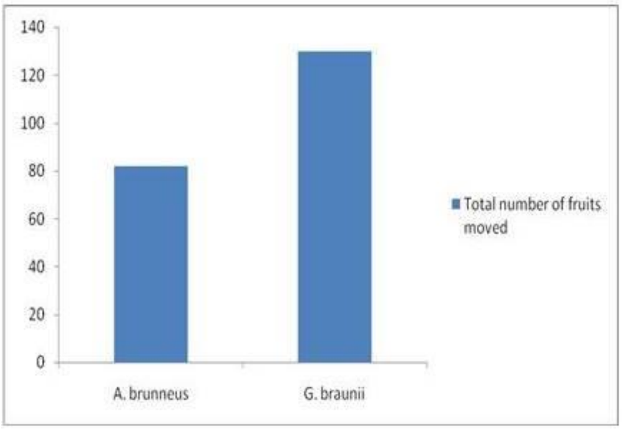


**Figure 2:** Fruit dispersal frequency between the two mistletoe species.

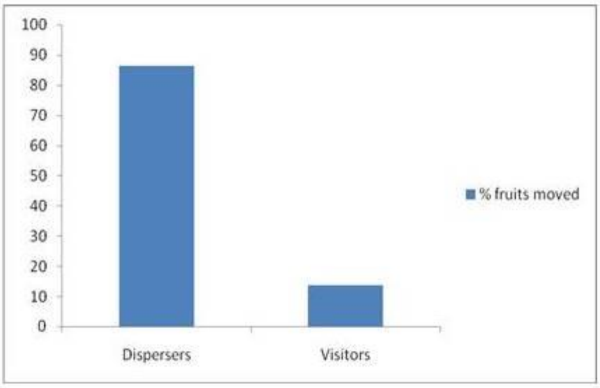


**Figure 3:** Percentage amount of fruits moved by dispersers and visitors


**Plate 1:** Western green tinker bird feeding on *Agelanthus brunneus*

**Discussion**

It is a well-established fact that dispersal increases the population of plants by enhancing and facilitating plant growth and ultimately forest regeneration (Holl, 2012). However, how this is achieved and the relative contributions of each player often need careful examination; this is necessary considering the fact that species conservation requires prioritization. Knowing which species are crucial for forest regeneration will place more emphasis on their protection during conservation actions (Jordano *et al*., 2007). This study ascertains the relative importance of dispersers to two host mistletoe species in a very poorly studied and highly threatened Afro-montane landscape.

Results revealed that Western green tinker birds and yellow rumped tinker birds of the genus *Pogoniulus* dispersed the fruits of both mistletoe species and were among the most dominant biotic agents of dispersal of *Agelanthus brunneus* and *Globimetula braunii* in the study area. However, African green pigeon and African Thrush were more specific in their interactions and dispersed exclusively the fruits of *G. braunii* and *A. brunneus* respectively. These two bird species made significant contributions to the dispersal of their respective host mistletoe species. Of the four-disperser species, the yellow rumped tinker bird dispersed the most fruits albeit from two of the mistletoe species. Its generalistic approach to dispersal is crucial for the reproductive success of most plant species in the study area.

Our study was limited in scope and sampling intensity making it difficult for us to draw conclusions with regards to the contributions and dispersal status of avian species. For instance, most of the birds were sighted once, throughout the entire observation period making any conclusions as to their fruit preferences and status hasty and bias. However, we are able to provide baseline information of their status and contributions to fruit dispersal with regards to host species wellbeing. Our findings reveal that these interactions were antagonistic in nature as they dislodged fruits, such that the fruits fell beneath the parent trees. These dislodged fruits would perhaps have fared better if they were to be ingested by more efficient disperser species. This antagonistic behavior on the part of the avian *visitors* is detrimental to the wellbeing and fortunes of both parent and fruit by subjecting the seed to a competitive disadvantage of density-dependent inhibitions in growth and reproductive success (Barnes and Chapman, 2014, Aliyu *et al*, 2014)

The role of Gape size as a determinant of diet preference or fruit selection was muted by the similarities in gape size of almost all disperser species. For instance, among the four dispersers were two closely related species of the *Pogoniulus* genera. However, despite these morphological similarities most avian species were preferential in their interactions; especially with the African

Thrush and African Green pigeon. This suggests that either palatability (Nyiramana *et al*., 2011; Aliyu *et al*., 2014) or some undisclosed factor(s) could be responsible for the selective nature exhibited by some of the avian visitors and dispersers with regards to food/host preferences.

With regards to dependability, the speckle mouse bird that dispersed the fruits of *G. braunii* irrespective of host/pair combination, was the most dependable disperser and may be pivotal to the success of *G. braunii* as well as other tree species in the forest reserve. It is not clear what could be the reason for this behavior considering the patchy nature of the distribution of this bird species in the reserve. More work is necessary to demystify this paradoxical behavior.

Although most studies on mutualism (pollination and dispersal) have shown that abundance is a good proxy for efficiency (Nsor *et al*., 2017). We could not justify this claim based on our result which suggests that abundance was a poor predictor of the relative dispersal contributions of avian species. For instance, the most abundant bird species western green tinker bird was not the most in terms of number of fruits dispersed. However, there was a partial or weak correlation between total number of fruits dispersed and the relative abundance of the avian species.

Some factors could mute the visitation pattern and fruit selection making certain birds seemingly more effective than others. For instance, vegetation is one of the proximate factors considered by birds in habitat selection (Colin and Chapman, 1996). Habitat selection is driven by factors acting singly or in combination such as food availability, roosting sites, cover away from predators etc. It is most likely that the interactions between host/mistletoe species pair did contribute to the pattern of selection and preference by avian species. This assertion is borne out of the fact that the host tree species differed in their distribution and structure for example tree height, canopy cover/spread, availability of own fruits etc. These structural differences accentuated by the verity that most birds have established flight routes, flight-height and distance away from cover (Nsor 2015); could have informed the choice of interaction partners for the avian dispersers. Avian species tended to interact with species found in forest patches that guaranteed a save cover away from exposure to predators.

The amounts of fruits moved by dispersers as opposed to those moved or dislodged by visitors suggest that the overall interactions between the avian species were mutualistic in nature. However, fruit dislodgement could post a major challenge to the reproductive wellbeing of mistletoe species as it appears to be limiting mistletoe fruit dispersal in the study area.

**Conclusion**

Dispersal of seeds of *G.braunii* and *A.brunneus* are basically avian mediated and may depend more on a few species than may be seen. The yellow rumped tinker bird may be crucial in the dispersal and sustenance of mistletoe host interactions in Ngel Nyaki Forest Reserve.

**Acknowledgment**

We are grateful to the Staff and Management of the Nigerian Montane Forest Project for logistic support and the Taraba State Government for the permit to work in the forest reserve.

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