Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2016) 40: 417-422

doi:10.3906/zoo-1407-42

Role of Indian flying fox *Pteropus giganteus* Brünnich, 1782 (Chiroptera: Pteropodidae) as a seed disperser in urban areas of Lahore, Pakistan

Tayiba Latif GULRAIZ[1], Arshad JAVID[1,*], Muhammad MAHMOOD-UL-HASSAN[2], Syed Makhdoom HUSSAIN[3], Hamda AZMAT[4], Sharoon DAUD[5]

[1]Department of Wildlife and Ecology, University of Veterinary and Animal Sciences, Lahore, Pakistan
[2]Department of Zoology and Fisheries, University of Agriculture, Faisalabad, Pakistan
[3]Department of Zoology, Government College University, Faisalabad, Pakistan
[4]Department of Fisheries and Aquaculture, University of Veterinary and Animal Sciences, Lahore, Pakistan
[5]Department of Chemistry, Forman Christian College, Lahore, Pakistan

Received: 19.07.2014 • **Accepted/Published Online:** 30.11.2015 • **Final Version:** 07.04.2016

Abstract: This 1-year study, extending from January to December 2011, was conducted to investigate the role of the Indian flying fox (*Pteropus giganteus*) as a seed disperser in Lahore, Pakistan. Ejecta of the species from two roosting sites, i.e. Jinnah garden and Lalazar garden, was collected and the plant seeds were extracted from bat boluses and guano. Various seeds of edible trees and forest plantation species extracted from ejecta of *P. giganteus* included areca palm (*Areca catechu*), coromandel ebony (*Diospyros melanoxylon*), Indian gaabh (*D. peregrina*), lemon-scented gum (*Eucalyptus citriodora*), Chinese fan palm (*Livistona chinensis*), sapodilla (*Manilkara zapota*), mahwa (*Madhuca longifolia*), Indian lilac (*Melia azedarach*), cajeput tree (*Melaleuca leucadendra*), rambutan (*Nephelium lappaceum*), guava (*Psidium guajava*), and janbolanum plum (*Syzygium jambolanum*). Measurements of the extracted seeds' length (mm), diameter (mm), and weight (g) were taken and the seeds of jack fruit (*Artocarpus heterophyllus*) were found the longest (40 mm) with the maximum average diameter (50 mm) while the rambutan (*N. lappaceum*) seeds were the heaviest (3.4 g). It can be concluded from the present study that *P. giganteus* is a seed disperser and transporter of heavier seeds as heavier seeds are mammal-dependent for their dispersal.

Key words: Heavy seeds, jack fruit, length of the seed, Lahore, *Pteropus giganteus*

1. Introduction

Frugivorous vertebrates and wind are two major factors that play a role in the dispersal of forests and woody plants. Among vertebrates, frugivorous bats participate more than birds in dispersing seeds and hence influence angiosperm diversity all over the tropics (Vander Pijl, 1957; Fleming, 1979; Marshall, 1983). Seeds themselves are immotile and depend on dispersal agents for transportation, and fruit bats, being the only mammals capable of true flight, are considered as major seed dispersal vectors as they can easily cross barriers that other frugivorous mammals cannot (Howe and Smallwood, 1982; Willson et al., 1989).

Bonaccorso (1998) documented that a relationship exists between specific bats and particular plant species and the extent of this relationship is dependent on the diversity of frugivorous bats and the physical properties of their food items. The distinctive morphological characters of tropical plant species such as color, strong odor, and exposed location attract the senses of bats (Vander Pijl, 1957; Fleming, 1979). The fruits have different shapes and sizes and a variety of morphological features; some are enclosed in a thin exocarp with soft flesh and some are harder, while others exhibit more durable coverings and relatively harder contents (Corlett, 1991). Some fruits contain many seeds while some contain one; seeds dispersed by vertebrates are much more variable and dependent not only on plant attributes but also on the behavior and distinctiveness of the disperser (Schupp, 1993; Holl, 1998; Martinez-Garza and Gonzalez-Montagut, 1999, 2002).

In the case of vertebrate-dependent seeds, the decrease in seed input is directly proportional to the increase in the distance from the source vegetation. In contrast, the seed input declines less when the disperser agents are fruit bats because frugivorous bats are more likely to defecate in flight rather than from perches (de Foresta et al., 1984; Gorchov et al., 1993). Seed dispersal among different habitats also depends on the size of the seed; smaller seeds are dispersed in the nearby successional areas of the forest

* Correspondence: arshadjavid@gmail.com

and are produced in larger amounts by parent plants. Large-sized seeds are produced in fewer numbers per plant with limited distributed, less likely to be dispersed across the habitat and colonize in successional habitats (Greene and Johnson, 1994; Wunderle, 1997; Duncan and Chapman, 1999; Harvey, 2000).

Frugivorous bats are considered primary dispersers and ecological counterparts of the early successional plant species (e.g., *Cecropias* spp., *Piper* spp., *Solanum* spp., and *Vismia* spp.) established in gaps and open areas in or adjacent to forests in moist Neotropic areas (Foster et al., 1986; Uhl, 1987; Gorchov et al., 1993; Medellin and Gaona, 1999). While conserving the abundance and diversity, the associations between seeds, seed dispersal, and dispersal agents must be well understood as the decline in abundance and biodiversity of dispersal agents will affect the diversity of their food plants (Fleming et al., 1987; Corlett, 1998).

Southeast Asian frugivorous bats are taxonomically different from those in the Neotropics but their role as seed dispersal agents has been the least studied in the region. The present study was therefore designed to study the characteristics of the seeds exploited by the Indian flying fox *Pteropus giganteus*, providing estimation of seed characters of the seeds dispersed by them that are dependent on these bats for their dispersal.

2. Materials and methods

2.1. Study area

Lahore is the second most populated city of Pakistan and is situated at an elevation of 208–213 m above mean sea level. The city experiences extreme climate; mean annual minimum and maximum summer temperatures range between 26.8 and 27.3 °C and between 35.0 and 40.4 °C, respectively, whereas the mean annual minimum and maximum winter temperatures range between 4 and 16 °C and between 6 and 18 °C, respectively. The average annual precipitation in Lahore is 629 mm with 34 (9.3%) rainy days in a year (NESPAK and LDA, 2004). Infrastructure development, recreational places, and construction of roads and overpasses have altered the native tropical flora that has been replaced by exotic and ornamental floral species (Joshua and Ali, 2008).

Roosting sites of *P. giganteus* were explored at Jinnah garden and Lalazar garden in Lahore and the ejecta (boluses and guano) of the species at both localities was collected and analyzed to extract plant seeds that can be transported by these bats for a period of 1 year, extending from January through December in 2011. The dominant vegetation of both gardens includes ashoka (*Saraca indica*) and buddha (*Chorisia insignis*), which grow well in tropical climates, and banyans (*Ficus* spp.), keekar (*Acacia* spp.), shisham (*Dalbergia sissoo*), and oak (*Quercus* sect. *Lepidobalanus*). The garden also harbors edible fruit trees like mango (*Mangifera indicia*), apple (*Malus sieversii*), guava (*Psidium guajava*), pear (*Pyrus pashia*), and jambolanum plum (*Syzygium jambolanum*).

2.2. Collection of ejecta and seed extraction

Bolus and guano samples of *P. giganteus* were collected by spreading 1-m^2 polythene sheets under the day roosts of these bats. These samples were air-dried and were placed separately in polythene bags (10 cm × 6 cm). Roost number, plot number, and site of collection were noted on each bag. Bolus and guano samples were transferred separately to 20 mL of distilled water and shaken well to separate the undigested food items. The separated seeds were counted and identified by comparison with reference seed collections from the Jinnah and Lalazar gardens (Vander Pijl, 1957; Mahmood-ul-Hassan et al., 2010).

2.3. Reference seed repository

A reference seed repository was also prepared by extracting the seeds from roosting trees and fruit trees in the nearby plots that can serve as potential food sources for the Indian flying fox. The plant seeds extracted from ejecta were considered as food species, seeds of the trees that served as roosting sites as roost species, and seeds collected from trees in the nearby plots as only reference seeds (Table). Fruits of the trees for the reference seed repository were collected during monthly surveys and seeds were then separated from the fruit pulp manually. The separated seeds were counted, air-dried at ambient temperature, and placed in polythene bags (10 cm × 6 cm) as reference seeds.

Seeds extracted from *P. giganteus* boluses and guano were identified by matching them with reference seeds. The unidentifiable seeds were grown in pots until they were identified (Whitmore, 1972, 1973; Ng, 1978, 1989).

2.4. Morphometrics of seeds collected from the study area and extracted from boluses and guano of *Pteropus giganteus*

The color of each extracted seed was observed and each seed was weighed using an electronic weighing balance (FES-600). Seeds were sorted into five seed weight classes (SWCs) as SWC-I (0.0 to 0.1 g), SWC-II (0.11 to 1.0 g), SWC-III (1.01 to 2.0 g), SWC-IV (2.01 to 3.0 g), and SWC-V (3.01 to 4.0 g) following Khurrana et al. (2006). Length and width of seeds was measured with a digital caliper.

Seed species and numbers in each weight class were noted and percentage of species in each seed weight class was calculated by using the following formula:

Percentage of species = 100 × (number of all species in that seed weight class divided by total number of all species in all the seed weight classes).

Table. Morphometrics of seeds extracted from bolus and guano of Indian flying fox (*Pteropus giganteus*) roosting at Jinnah and Lalazar gardens, Lahore.

Family	Species	Common name	Fruiting season, (native/exotic)	Average seed length, mm (n = 10)	Average seed diameter, mm (n = 10)	Average seed weight, g (n = 10)	Seed weight class
Food species							
Arecaceae	*Areca catechu*	Areca palm	Summer, winter (E)	13.5	7.5	1.1	III
	Livistona chinensis	Chinese fan palm	Autumn (E)	9.8	4	0.3	II
Ebenaceae	*Diospyros melanoxylon*	Coromandel ebony	Autumn (E)	26	13	1.6	III
	D. peregrina	Indian gaabh	Summer (N)	25	15	2.4	IV
Meliaceae	*Melia azedarach*	Indian lilac	Summer (N)	18	11	0.3	II
Myrtaceae	*Eucalyptus citriodora*	Lemon-scented eucalyptus	Autumn (E)	10.3	7	0.5	II
	Melaleuca leucadendra	Cajeput tree	Autumn (E)	1.2	0.2	0.07	I
	Psidium guajava	Guava	Summer, winter (E)	0.1	0.1	0.001	I
Sapindaceae	*Nephelium lappaceum*	Rambutan	Summer (E)	23	13	3.4	IV
Sapotaceae	*Manilkara zapota*	Sapodilla	Autumn (E)	18	11	0.3	II
	Madhuca longifolia	Mahwa	Summer (E)	10	1.3	0.004	I
Roost species							
Combretaceae	*Terminalia arjuna*	Arjun	Summer (N)	33.3	26	2.2	IV
Putranjivaceae	*Putranjiva roxburghii*	Drypetes	Autumn (E)	14	10	0.3	II
Rutaceae	*Aegle marmelos*	Apple wood	Summer (N)	7.21	19.6	0.1	I
Sapotaceae	*Manilkara hexandra*	Milky	Summer (N)	7.5	4.1	0.1	I
Food and roost species							
Myrtaceae	*Syzygium jambolanum*	Jambolanum plum	Summer (N)	33	26	0.9	II
Only reference seeds (neither food nor roost species)							
Anacardiaceae	*Spondias mangifera*	Hog plum	Summer, winter (N)	14.3	13.3	1.2	III
Ebenaceae	*Diospyros ebenum*	Ebony tree	Summer (N)	18.8	9.5	0.9	II
Euphorbiaceae	*Jatropha curcas*	Physic nut	Summer, winter (E)	14.5	7.8	0.3	II
Fabaceae	*Acacia catechu*	Mimosa catechu	Autumn (N)	17	6	0.04	I
	A. nilotica	Arabic gum tree	Summer (N)	13	11	0.06	I
	Albizia lebbek	Lebbek tree	Summer (N)	9.3	8	0.1	1
	Delonix regia	Flame tree	Summer (E)	8	6.6	0.1	I
	Pongamia glabra	Indian beach tree	Summer (N)	19	18.3	1.4	III
	Sophora chrysophylla	Mamane	Spring, summer (E)	10.3	10	0.8	II
	Tamarindus indica	Indian date	Autumn (E)	9.3	1	0.5	II
Malvaceae	*Brachychiton acerifolius*	Illawarra flame tree	Summer (E)	15.7	5.7	0.2	II
	Firmiana simplex	Chinese parasol tree	Autumn (N)	7	6	0.1	I
Meliaceae	*Chukrasia tabularis*	Chittagong wood	Summer, autumn (N)	7.7	5	0.02	I
Moraceae	*Artocarpus lakoocha*	Monkey fruit	Autumn (E)	12	11	0.2	II
	A. heterophyllus	Jack fruit	Autumn (E)	40	50	0.3	II
	Ficus infectoria	White fig	Summer (N)	15.6	9.5	0.1	I
Moringaceae	*Moringa oleifera*	Moringa	Autumn (E)	8	5.3	0.1	I
Myrtaceae	*Eucalyptus maculata*	Spotted gum	Autumn (E)	13.8	11	0.7	II
Phoenix	*Phoenix dactylifera*	Date palm	Autumn (E)	25.4	28.1	0.06	I
Rubiaceae	*Gardenia lucida*	Cambi resin tree	Spring (N)	6.3	5.7	0.3	II
Sapindaceae	*Schleichera oleosa*	Ceylon oak	Summer, autumn (E)	7	7	0.9	II

3. Results and discussion

During the present study a total of 170 seeds belonging to 12 species, 11 genera, and 6 families were extracted from boluses and guano of the Indian flying fox, *P. giganteus*, roosting at Jinnah and Lalazar gardens, Lahore (Table).

Most of the plant seeds extracted during the present study belonged to the family Myrtaceae (represented by four species, *Eucalyptus citriodora*, *Melaleuca leucadendra*, *Psidium guajava*, and *Syzygium jambolanum*), while the families Arecaceae (*Areca catechu* and *Livistona chinensis*), Ebenaceae (*Diospyros melanoxylon* and *D. peregrina*), and Sapotaceae (*Manilkara zapota* and *Madhuca longifolia*) were represented by two species each. *Melia azedarach* and *Nephelium lappaceum* were the only species of families Meliaceae and Sapindaceae, respectively. *Areca catechu* was the only plant species whose seeds were extracted only from bat guano; seeds of *D. melanoxylon*, *D. peregrina*, *E. citriodora*, *L. chinensis*, *Melaleuca leucadendra*, *Manilkara zapota*, *Madhuca longifolia*, *N. lappaceum*, and *Syzygium jambolanum* were extracted from boluses; and seeds of *M. azedarach* and *P. guajava* were extracted from both boluses and guano (Table). Pteropodid fruit bats show highly interspecific variations regarding timing, amount of food production, and seasonal availability of fruits (McKenzie et al., 1995). The diet of these phytophagous bats includes several floral resources ranging from leaves, nectar, and pollen to petals and fruits and often the seeds themselves (Marshall, 1985). It is reported that bolus has higher nitrogen, phosphorous, and potassium content than guano (3.3 : 4.3 : 0.7 vs. 2.6 : 4.2 : 0.6) of *P. giganteus* and the phosphorous concentration in *P. giganteus* excreta is higher than that in cow and sheep manure, indicating its value as natural manure to meet phosphorus requirements of plants (Goveas et al., 2006).

It was noted during the present study that out of the total 12 plant species whose seeds were extracted from the ejecta of Indian flying fox, three species, Indian gaabh (*D. peregrina*), Indian lilac (*Melia azedarach*), and Jambolanum plum (*Syzygium jambolanum*), were native in their origin, while the remaining nine were exotic plants. Additionally, *S. jambolanum* was the only tree species that served as both food and roost for these bats. Most of the tree species, including *Eucalyptus citriodora*, *Diospyros melanoxylon*, *Livistona chinensis*, *Manilkara zapota*, and *Melaleuca leucadendra*, produced fruits in autumn. Four of the plant species, i.e. *D. peregrina*, *Madhuca longifolia*, *Melia azedarach*, and *N. lappaceum*, produced fruits in summer, while the fruits of *A. catechu* and *P. guajava* were observed in summer and winter (Table). Our findings are in line with those of Mishra et al. (2009), who studied seed characteristics of *Albizia lebbek* (siris), *Bauhinia purpurea* (orchid tree), *B. variegata* (camel's foot tree), *Dalbergia sissoo* (Indian rosewood), *Grewia optiva* (dhaman), *Kydia calycina* (pula), *Melia azedarach* (Persian lilac), *Ougeinia oojeinensis* (sandan), *Terminalia bellerica* (bastard myrobalan), *T. chebula* (black myrobalan), *T. tomentosa* (crocodile bark), and *Toona ciliata* (Indian mahogany) in India. Similarly, Jeevan et al. (2013) recorded 10 roosting and more than 20 types of fruit trees of fruit-eating *P. giganteus* in Shivamogga, India, and documented that these bats play an important role in seed dispersal of fruit plants. The fruits are chewed to obtain juice and fruit pulp and the seeds are spit out. The bats travel 40 to 50 km per day around their nesting sites and find foraging sites far away from their resting places, especially during evening hours.

The extracted seeds from the ejecta of *P. giganteus* were classified into five weight categories, i.e. SWC-I, SWC-II, SWC-III, SWC-IV, and SWC-V, ranging in weight from 0.001 g to 3.4 g. It was observed that the majority of extracted seeds (41.6%) were from the SWC-II category, 25% from SWC-I, 16.67% from SWC-III, and 8.33% from SWC-IV and SWC-V each. Seeds of *Psidium guajava* were the lightest (0.001 g) in weight while the seeds of *Nephelium lappaceum* were heaviest (3.4 g). Lobova et al. (2003) documented bats as important seed dispersers, particularly in dispersing large seeds of primary forest plant species into secondary plant species. For example, *Artibeus lituratus* (great fruit-eating bat) was reported to transport fruits and seeds almost of its own size. The species is also known to disperse small and large seeds and fruits of primary and secondary forest plant species as *Bocoa prouacensis*, *Caryocar glabrum*, *Cecropia obtusa*, *Dipteryx odorata*, *Licania spp.*, *Swartzia panacoco*, *Symphonia globulifera*, and *Parinari spp.* (de Foresta et al., 1984; Charles-Dominique and Cooper, 1986). Izhaki et al. (1995) reported that *Rousettus aegyptiacus* consumes a number of cultivated and wild fruits in Israel. The roosts of bats were located about 30 m away from their feeding trees, indicating seed dispersal by *R. aegyptiacus* away from roosting trees. Most of the seeds, especially the larger ones, are spit out, while only 2% may pass through the digestive tract. It was concluded from their studies that the bolus and guano of *R. aegyptiacus* help in enhancement of plant fitness by dispersal of the seeds, especially in habitats where patterns of rainfall are not predictable.

Out of a total of 12 extracted plant species' seeds, seeds of five species fell into the SWC-II (0.01–1.0 g) category, three species into SWC-I (0–0.1 g), and two species each into SWC-III (1.01–2.0 g) and SWC-IV (2.0-3.0 g) (Table). Khurana et al. (2006) reported that the medium-weight seeds have more abundance than smaller seeds. According to Grubb (1998) and Putz and Appanah (1987), the seeds of successional plants species (*Alphitonia* spp., *Clerodendrum* spp., *Euphorbia* spp., etc.) in Southeast Asia are larger in size and length, are heavier, and are probably dispersed by bats.

Among the extracted seeds, seeds of *Psidium guajava* were the smallest and thinnest (0.1 mm) while the *Syzygium jambolanum* seeds were longest (33 mm) and thickest (26 mm). The length and diameter of seeds of food tree species ranged from 0.1 mm to 33 mm and from 0.1 mm to 26 mm, respectively. Seeds of *Madhuca longifolia* showed remarkable variation in length (10 mm) to diameter (1.3 mm) proportions as compared to all the other food species. Of all the extracted seeds, *Artocarpus heterophyllus* seeds were found longest with the maximum diameter (Table). Hodgkison et al. (2003) worked on the distribution of seeds by fruit bats in a lowland Malaysian rain forest and documented that the fruit bats are responsible for the dispersal of 12 plant species with smaller seeds and 20 plant species with larger seeds. The smaller seeds are dependent on wind for their dispersal while the larger and heavier seeds are mammal-dependent for their dispersal; the dispersal ability of seeds in tropical dry forests is therefore linked with seed mass (Guo et al., 2000).

Out of a total of 37 tree species whose seeds were measured, 12 species served as food, 5 as roost, and 1 as food and roost, while the remaining 21 species were only reference plant species (Table). Reginald et al. (2008) listed *Ficus religiosa*, *Tamarindus indica*, *Albizia lebbeck*, *Delonix regia*, *Polyalthia longifolia*, *Acacia* spp., *Azadirachta indica*, and *Samanea saman* as roosting tree species for *P. giganteus* in Tamil Nadu, India. Vendan and Kaleeswaran (2011) documented that *P. giganteus* plays an important role in the dispersal of a variety of seeds of different plants species, especially *Borassus flabellifer*, *Anacardium occidentale*, *Nerium indicum*, *Phoenix dactylifera*, *Prosopis juliflora*, and *Madhuca indica*. It was clearly described that *P. giganteus* helps in seed dispersal to maintain heterogeneity in the Madurai region. During the present study, the seeds of *Areca catechu*, *Livistona chinensis*, *Diospyros melanoxylon*, *D. peregrina*, *Melia azedarach*, *Eucalyptus citriodora*, *Melaleuca leucadendra*, *Psidium guajava*, *Nephelium lappaceum*, *M. zapota*, *Madhuca longifolia*, and *Syzygium jambolanum* were identified from excreta of *P. giganteus*.

In any ecosystem there is a strong association between the vegetation cover and the native herbivores. The herbivores are dependent on plants for their survival, whereas the plants are dependent on herbivores for effective pollination and seed dispersal. Seeds are quite stable organs, and the apparent features of the seeds like weight, shape, size, and color differ strikingly within the same species, genera, and family and can be strong tools for identification of particular seeds. The bolus and guano analysis of *P. giganteus* during the present study revealed that this species is an effective seed disperser and can disperse seeds weighing from 0.001 g to 3.4 g.

The role of seed size in germination, growth, and survival of seedlings is well documented. Variations in the size of seeds influence the fitness of the seedlings. Larger seeds showed greater germination percentage as compared to medium and small-sized seeds, as stated by Shaukat et al. (1999).

References

Bonaccorso FJ (1998). Bats of Papua New Guinea. Washington, DC, USA: Conservation International.

Charles-Dominique P, Cooper HM (1986). Frugivorie et transport des graines de Cecropia par les chauves-souris en Guyane. Memoir Mus Natl Hist 132: 145–157 (in French).

Corlett RT (1991). Plant succession on degraded land in Singapore. Annu Rev Ecol 4: 151–161.

Corlett RT (1998). Frugivory and seed dispersal by vertebrates in the Oriental (Indomalayan) region. Bio Rev 73: 413–448.

de Foresta H, Charles-Dominique P, Erard C, Prevost MF (1984). Zoochorie et premiers stades de la regeneration naturelle après coupe en forest Guyanaise. Annu Rev Ecol 39: 369–400 (in French).

Duncan RS, Chapman CA (1999). Seed dispersal and potential forest succession in abandoned agriculture in tropical Africa. Ecol Appl 9: 998–1008.

Fleming TH (1979). Do tropical frugivores compete for food? Am Zool 19: 1157–1172.

Fleming TH, Breitwisch R, Whitesides GH (1987). Patterns of tropical frugivore diversity. Annu Rev Ecol Evol Syst 18: 91–109.

Foster RB, Arce J, Wachter TS (1986). Dispersal and the sequential plant communities in Amazonian Peru floodplain. In: Estrada A, Fleming TH, editors. Frugivores and Seed Dispersal. Dordrecht, the Netherlands: Springer, pp. 357–370.

Gorchov DL, Cornejo F, Ascorra C, Jaramillo M (1993). The role of seed dispersal in the natural regeneration of rain forest after strip-cutting in the Peruvian Amazon. Vegetation 107: 339–349.

Goveas SW, Eldrich CM, Sahadevan S, Kandikere RS (2006). Observations on guano and bolus of Indian flying fox, *Pteropus giganteus*. Current Sci 90: 160–162.

Greene DF, Johnson EA (1994). Estimating the mean annual seed production of trees. Ecology 75: 642–647.

Grubb PJ (1998). Seeds and fruits of tropical rainforest plants: interpretation of the range in seed size, degree of defence and flesh/seed quotients. In: Newbery DM, Prins HHT, Brown ND, editors. Dynamics of Tropical Communities. London, UK: Blackwell, pp. 1–24.

Guo Q, Brown JH, Valone TJ, Kachman SP (2000). Constraints of seed size on plant distribution and abundance. Ecology 81: 2149–2155.

Harvey CA (2000). Windbreaks enhance seed dispersal into agricultural landscapes in Monteverde, Costa Rica. Ecol Appl 10: 155–173.

Hodgkison R, Balding ST, Zubaid A, Kunz TH (2003). Fruit bats (Chiroptera: Pteropodidae) as seed dispersers and pollinators in a lowland Malaysian rain forest. Biotropica 35: 491–502.

Holl KD (1998). Do bird perching structures elevate seed rain and seedling establishment in abandoned tropical pasture? Restor Ecol 6: 253–261.

Howe HF, Smallwood J (1982). Ecology of seed dispersal. Annu Rev Ecol Syst 13: 201–228.

Izhaki I, Korine C, Arad Z (1995). The effect of bat (*Rousettus aegyptiacus*) dispersal on seed germination in eastern Mediterranean habitats. Oecologia 101: 335–342.

Jeevan EN, Naik KL, Sayeswara HA, Hosetti BB (2013). Studies on feeding activity of fruit eating bat (*Pteropus giganteus*) in Shivamogga area, Karnataka, India. Asian Journal of Microbiology, Biotechnology & Environmental Sciences 15: 551–554.

Joshua G, Ali Z (2008). Avian diversity with the varying urban congestion of Lahore. J Anim Plant Sci 21: 421–428.

Khurana E, Sagar R, Singh JS (2006). Seed size: a key trait determining species distribution and diversity of dry tropical forest in northern India. Acta Oecol 29: 196–204**.**

Lobova TA, Mori SA, Blanchard F, Peckham H, Charles-Dominique P (2003). *Cecropia* as a food resource for bats in French Guiana and the significance of fruit structure in seed dispersal and longevity. Am J Bot 90: 388–403.

Mahmood-ul-Hassan M, Tayiba LG, Shehnaz AR, Arshad J (2010). Feeding niche of the Indian flying fox (*Pteropus giganteus*): first report from Pakistan. Acta Chiropterol 12: 341–347.

Marshall AG (1983). Bats, flowers and fruit: evolutionary relationships in the Old World. Biol J Linn Soc 20: 115–135.

Marshall AG (1985). Old world phytophagous bats (Megachiroptera) and their food plants: a survey. Zool J Linn Soc 83: 351–369.

Martinez-Garza C, Gonzalez-Montagut R (1999). Seed rain from forest fragments into tropical pastures in Los Tuxtlas, Mexico. Plant Ecol 145: 255–265.

Martinez-Garza C, Gonzalez-Montagut R (2002). Contribution of bats and birds to the seed rain of forest species in tropical pastures in Los Tuxtlas, Mexico. J Trop Ecol 18: 457–462.

McKenzie NL, Gunnell AC, Yani M, Williams MR (1995). Correspondence between flight morphology and foraging ecology in some Paleotropical bats. Aust J Zool 43: 241–157.

Medellin RA, Gaona O (1999). Seed dispersal by bats and birds in forest and disturbed habitats of Chiapas, Mexico. Biotropica 31: 478–485.

Mishra A, Nautiyal S, Nautiyal DP (2009). Growth characteristics of some indigenous fuelwood and fodder tree species of sub-tropical Garhwal Himalayas. The Indian Forester 135: 373–380.

NESPAK and LDA (2004). Integrated Master Plan for Lahore 2000-2021, Vol. 3. Lahore, Pakistan: LDA.

Ng FSP (1978). Tree Flora of Malaya, Volume 3. London, UK: Longman.

Ng FSP (1989). Tree Flora of Malaya, Volume 4. London, UK: Longman.

Putz FE, Appanah S (1987). Buried seeds, newly dispersed seeds, and the dynamics of a lowland forest in Malaysia. Biotropica 19: 326–333.

Reginald JL, Prasath PM, Mahendran C, Venkatasan A, Prabhu K, Ravichandran B, Molur S (2008). A survey on roosting sites of Indian flying fox *Pteropus giganteus* Brünnich, 1782 in and around Coimbatore and Palakkad district, India. Chiroptera Conservation and Information Network of South Asia 9: 11–12.

Schupp EW (1993). Quantity, quality and the effectiveness of seed dispersal by animals. Vegetation 107: 15–29.

Shaukat SS, Zamin SS, Seemi A (1999). Seed size variation and its effects on germination, growth and seedling survival in *Acacia nilotica* subsp. *indica* (Benth.) Brenan. Pak J Bot 31: 253–263.

Uhl C (1987). Factors controlling succession following slash-and-burn agriculture in Amazonia. J Ecol 75: 377–408.

Vander Pijl L (1957). The dispersal of plants by bats (chiropterochory). Acta Bot Neerl 6: 219–315.

Vendan SE, Kaleeswaran B (2011). Plant dispersal by Indian flying fox *Pteropus giganteus* in Madurai region, India. Bio-Diversity 30: 1810–1813.

Whitmore TC (1972). Tree Flora of Malaya, Volume 1. Kuala Lumpur, Malaysia: Longman.

Whitmore TC (1973). Tree Flora of Malaya, Volume 2. Kuala Lumpur, Malaysia: Longman.

Willson MF, Irvine AK, Walsh NG (1989). Vertebrate dispersal syndromes in some Australian and New Zealand plant communities, with geographic comparisons. Biotropica 21: 133–147.

Wunderle JM Jr (1997). The role of animal seed dispersal in accelerating native forest regeneration on degraded tropical lands. Forest Ecol Manag 99: 223–235.