ROOST CHARACTERISTICS, FOOD AND FEEDING HABITS
OF THE INDIAN FLYING FOX (Pteropus giganteus) IN
LAHORE

BY

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I would like to dedicate this scientific work/thesis

To my beloved

PARENTS

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For their prayers, patience, support and love,
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Bats belong to the Order Chiroptera, making up almost a quarter of all known mammal species and are divided into two suborders, the Megachiroptera and the Microchiroptera. The Megachiroptera (consisting of a single family, the Pteropodidae or Old World fruit bats) are found throughout the Old World tropics and sub-tropics from Africa through southern Asia to Australia and on islands in the Indian and western Pacific Oceans (Simmons 2005). The single Megachiropteran family, the Pteropodidae, ranges from Africa, the eastern Mediterranean, Madagascar and the Indian Ocean islands in the west, across mainland southern Asia, throughout the islands of the western Pacific from the Ryukyu Archipelago and Ogasawara-shoto in the north, to coastal eastern Australia, New Caledonia and the Loyalty Islands in the south, and east to Fiji, Tonga, Samoa and the Cook Islands (Pierson and Rainey 1992; Mahmood-ul-Hassan and Nameer 2006). There are 41 genera containing a total of 161 species, the largest and best known genus, *Pteropus*, with 57 species, is primarily an island taxon, with 55 species (96.5%) having some or all of their distribution on islands. In this genus levels of endemism are extremely high, with 35 species (61.4%) confined to single islands or small island groups. Only nine species are found in continental areas (five in Asia and four in Australia), and only two are restricted to continents (Mickleburgh et al. 1992; Simmons 2005).

Bats constitute 28% of the mammalian fauna of Pakistan (Roberts 1997) but the exact number of chiropteran species within territorial limits of the country is still debatable (Roberts 1997; Bates and Harrison 1997; Walker and Molur 2003; Wilson and Reeder 2005). Upper Indus plains of the country are colonized by bat fauna of Oriental region, north and west mountains are rich in Palaearctic bat diversity while the chiropteran species of Ethiopian
region probably reached country from south west through Makran coastal belt (Roberts 1997; Mahmood-ul-Hassan et al. 2009). Family Pteropodidae is represented by three genera and four species in Pakistan, these include the short-nosed fruit bat (*Cynopterus sphinx*), the Indian flying fox (*Pteropus giganteus*), the Egyptian fruit bat (*Rosuettus aegyptiacus*) and the fulvous fruit bat (*R. leschenaulti*) (Roberts 1997; Walker and Molur 2003; Mahmood-ul-Hassan and Nameer 2006). There have been few attempts to estimate population; available data on the status of many fruit bats suggest serious population declines throughout the range, due principally to habitat loss, overhunting, and tropical storms (Pierson and Rainey 1992). Reports by early explorers and scientists suggested that population of fruit bats were once high throughout the Old World tropics. In Australia in 1930, Ratcliffe (1932) reported *Pteropus* 'camps' of up to 10 km long and 1.3 km wide, with estimated numbers of up to 30 million. Now many colonies had disappeared entirely, and only a few were reported to contain more than 100,000 individuals (Pierson 1984). However such population counts of fruit bats never been made in Pakistan

*P. giganteus* is well adapted to live in vicinity of human habitations such as public parks, village surroundings, towns, home gardens, temples, roadside plantations, agricultural fields and factory campuses (Roberts 1997; Louis et al. 2008). *P. giganteus* is a colonial species and lives in large diurnal roosts which may comprise hundreds to thousands of individuals (Bates and Harrison 1997). However, the colony size varies seasonally (Bastawade and Mahabal 1976). In general, the colony size diminishes during summer, increases during rainy season and remains constant during winter. It was observed that the number of bats increases during summers in forested land having relatively cool temperatures suggesting local migrations (Bates and Harrison 1997). In northern Punjab, Pakistan, *P. giganteus* vacate their roosts during mid winters (Roberts 1997) while the species is autumn
migrant in Kathmandu valley, Nepal Scully (1887). The number of bats in a roosting site at Poona ranged from 274 during April to 1087 in January.

*Pteropus giganteus* prefers open day roosting in large groups called ‘camps’. Colonies are typically cited near human population in villages and cities. Large colonies of *P. giganteus* were recorded in Pakistan from Sialkot (USNM), Lahore, Maralla, Renala Khurd and Said Pur in Punjab, and Jacobabad, Shahpur and Karachi in Sindh (Roberts 1997). The species prefers to roost on *Albizia* species, paper mulberry (*Broussonetia papyrifera*) and banyan tree (*Ficus bengalensis*) (Roberts 1977). In Bihar, tree species favoured for roosting includes the semal (*Bombax malabaricus*), sheesam (*Dalbergia sissoo*), peepal (*Ficus bengalensis*), mango (*Mangifera indica*) and tamarind (*Tamarindus indica*) (Sinha 1980; Bates and Harrison 1997). The roosts of *P. giganteus* in Lahore were reported from Bagh-i-Jinnah, Governor of the Punjab House and Mohalandar Mango garden in Lahore. A large colony of the species was observed in Changa Manga forest. The colony at Renala Khurd comes in March during each year, remaining until end of monsoon (Roberts 1997). Knowledge of roosting sites and behaviour is fragmentary however it had been documented that roost site fidelity is generally high in those *Pteropus* genera that roost communally (Pierson and Rainey 1992).

This study on roost characteristics, food and feeding habits of the Indian flying fox (*Pteropus giganteus*) was conducted in two public parks i.e. Jinnah garden and Lalazar garden, Lahore, Pakistan. Lahore is the second most populated city of the country, capital of the most populated province, Punjab and is located in the upper Indus plain on the river Ravi bank. Other rivers that irrigate Punjab plains include Jhelum, Chenab, Sutlej and Beas, however, irrigation is also supplemented by rains. The city experiences two rainy seasons in a year, the monsoon in the late summer and winter rains during December and January.
The Jinnah garden (35°55' north latitude and 74°33' east longitudes) covers an area of 140 acres, was originally built as botanical garden modeled on Kew Gardens, London in England and was initially named as Lawrence garden after the name of former Viceroy of India but latterly renamed after the founder of Pakistan, Quaid-e-Azam Muhammad Ali Jinnah. The Garden now has 3 nurseries, 4 hillocks, a ladies club, tennis clubs, two libraries, manmade free fall, manmade lake and stream, Quaid-e-azam library and a Darussalam in it. The Lalazar garden (31°28' north latitude and 74°14' east longitudes) is extended over 4 acres, was built as a recreational garden and is under the control of Parks and Horticulture Authority (PHA). The garden was initially a private property and named after the owner. It is located at the proximity of the city, fringed by the BRB-canal and motor way flyover.

The habitat type of both gardens is managed and modified ecosystem comprising of rich collection of rare plantations, both indigenous and exotic. In recent years the Parks and Horticulture Authority (PHA) replaced many of the garden trees succumbed to old age with new varieties, such as the Ashoka (Saraca indica) and the Buddha (Chorisia insignis) which grow well in tropical climate. The banyan (Ficus spp.), the Keekar (Acacia spp.), the shisham (Dalbergia sissoo), the oak (Quercus lepidobalanus) and the camphor (Cinnamomum camphora) constitute the universe of the garden. The garden also harbors edible fruit trees like mango (Mangifera indica), guava (Psidium guajava), apple (Malus sieversii), and pear (Pyrus pashia) etc. Little is known about P. giganteus colonial organization though each male member has specific rank and particular resting place within a colony. Separate colonies of young males and maternal colonies had been observed from March to October (Neuweiler 1969). Self grooming, common behavior observed among colonial members includes licking, scratching and the cleaning of the ears and teeth with the claws of the feet whereas no social grooming between adults had been documented. P. giganteus likes position in dense foliage of the canopy by using their claws to transverse along a branch or to crawl in a half lying
position. Fanning with wings and moistened their bodies with saliva usually observed during summer in attempt to reduce body temperature. The species sleeps with wrapped wings, hanging downwards by one or both feet (Phillips 1980).

Indian flying foxes had been observed to leave their roosts 20 minutes after sunset (Brosset 1962a), all following one another in same direction. However, Phillips (1980) reported that the individuals take little notice of each other while flying. In Rajasthan, roosts are vacated about 30 minutes after sunset and revisited about 45 minutes prior to sunrise. Bats in North Male Atoll, Maldives are rather more diurnal and are often seen feeding long before sunset (Hill 1958). In a flight, in search of food the flying foxes may cover a distance from 2 to 20 km (Bates and Harrison 1997).

The distribution of bats is largely dependent on the spatial and temporal variation of their food resources. In equatorial regions food may be available within a small area throughout the year, whereas in more seasonal regions food may be relatively scarce for months. Some bat species may roost singly close to their food, whereas others may roost in great colonies (camps) from which they must fly long distances to feed. For example, McWilliam (1985-86) found that the feeding behaviour of three highly colonial species of Pteropus in Australia was dominated by the establishment and subsequent defence of long-term feeding territories. The food of megachiropteran bats tends to be conspicuous, often clumped, and generally abundant and easily harvested within the clumps. Interspecific competition may be limited by spatial and temporal separation. Flying foxes primarily feed on flowers and fruits which are bitten off and chewed, the solid are discarded and the soft pulp and juices swallowed. Food plants of P. g. ariel in the Maldives include Zizyphus, Terminalia, Calophyllum, banyan, bread-fruit and Pandanus (Anderson 1912). In India and Sri Lanka, P. g. giganteus feeds on flowers and flower buds of the silk cotton tree (Gossamipinus malabaricus), tulip tree (Spathodea campunulata), red gum (Eucalyptus
robusta), albizzia (A. falcata), dadap (Erythrina lithosperma) rubber (Heavea braziliensis) and coconut palms. Fruit species include mango (Mangifera indica), the jack (Artocarpus integr), soursop (Annona muricata), guavas (Psidium guajava), plantain, banana (Musa paradisiaca), papaws (Carica papaya), Indian blackberry (Syzygium cumini). Ficus (Prakash 1961), teak, custard apple, palm (Borassus flabelifer), date (Phoenix silvestrus), mahua (Bassia latifolia) and wood apple (Feronia species), together with many fruit and flowers of jungle trees (Phillips 1980; Sinha 1986a; Bates and Harrison 1997). P. giganteus avoid citrus fruits and during non fruiting season feed on soft leaves and twigs of semal and tamarind trees and flowers of muhua (Sinha 1986a). Prior to feeding, often they visit a water body to quench their thirst (Phillips 1980). The species does not feed on fish (McCann 1934). Despite damaging some fruit crops, the flying fox is also an invaluable pollinator of plant (Bates and Harrison 1997; Mahmood-ul-Hassan et al. 2010). The species is considered as an agricultural pest and the measures to control them are threatening the survival of this species (Bates and Harrison 1997).

The guano or faeces of P. giganteus is blackish grey in colour while bolus or spits are thick blackish with strong pungent odour in wet condition, that become odourless on drying containing the residual fruit pulp of fibrous fruits and seeds as they fed upon soft fruits or extract juice and spit out the remains known as bolus (Goveas et al. 2006). Bat guano forms the basis of food web consisting of bacteria, fungi, protozoans, nematodes and arthropods. The nutrient rich bat guano significantly alters the community structure of different microorganisms by enhancing algal growth and settlement of invertebrates in dense algal mats (Lane and Diver 2000). Such consumer-driven nutrients recycling via fecal decomposition by bats also affects community structure in guano-based ecosystem (Harris 1970; Fenolio et al. 2006). Another important component of nutrient rich bat guano had large variety of microorganisms that worked as decomposers and activators designated it as natural
farm yard manure (FYM). Primarily they function to accelerate the process of breaking down organic matter in the guano. These beneficial bacteria populations increase the guano’s wealth of essential nutrients, and provide benefit as soil inoculants. Bat guano beneficial microbes perform bioremediation that clean up toxic chemicals in the soil, control nematode infestation and composting activator as these nutrients and microbes speed up decomposition (Sridhar et al. 2006). Analysis of bat guano aid in understanding the habitat preference (Zielinski 1999), bat diets and food habits (Korine et al. 1999), seed dispersal, nitrogen and mineral budgets (Studier et al. 1991), and also in developing strategies to conserve bat habitats (Bhat and Sreenivasa 1990).

In Southeast Asia, where half (83/166) the world’s flying fox species are found, flying foxes remain virtually unstudied (Mildenstein 2002). This is a region with widespread fruit bat hunting, the world’s highest amount of natural habitat loss, and where there is, effectively, no formal bat conservation commitment from governments (Mickleburgh et al. 1992; Whitmore 1997). A daunting three quarters (20/27) of Southeast Asia’s endemic large flying foxes are threatened and endangered and habita use is an effective place to start conservation ecological research in Southeast Asia (Mildenstein, 2002). Roost disturbance is the major factor of species decline in Pakistan and the species is much rarer than twenty or ten years back. It is a common belief in Pakistan that the species’ fat can be used as cure for rheumatism and used by local medical practitioners. In 1972, one specimen of the species was saleable for five rupees in Lahore. Where numerous, the flying foxes can cause considerable damage to orchards and fruit trees however they are too limited in number in Pakistan to be of any economic significance (Roberts 1997). In recent years, disturbances in the foraging habitats have seriously affected bat populations and led to the gradual decrease in their number (Racey and Entwistle 2003; Vaughan et al. 1996). According to the International Union for the Conservation of Natural Resources (IUCN) reports the bats all
over the world are facing considerable local or global threats from habitat loss and fragmentation, destruction of, or disturbances to, roost sites is particularly problematic (Jones et al. 2009).

In Pakistan, the bats are considered fearsome and loathsome creatures and due to this mindset, the bats in Pakistan remained unexplored. Recently, some data on micro bats have been published (Mahmood-ul-Hassan et al. 2009; Javid et al. 2012a, b, 2014) however, there is extreme shortage of knowledge about fruit bats in Pakistan. Due to this reason the bats in Pakistan bats are amongst the least studied taxa and this bat species is considered as pest for poaching fruits and hunted by hakims or practitioner to fetch their body fats for the treatment of rheumatic fever. Pakistan exempts bats from the regulation of international trade, while the Punjab area of Pakistan specifically excludes *Pteropus giganteus* from protection (Mickelburg et al. 1992). According to IUCN action plan, 1992, an up to date chiropteran survey was recommended particularly *P. giganteus* in Punjab but so far neither a fruit bat survey nor any kind of their habitat study was conducted. IUCN had placed *P. giganteus* at priority grade 11 that is, there was lack of information on species status and had recommended surveys to assess species account, general education and research projects in Pakistan. This study was designed to assess the current roosts of the *P. giganteus*, their roost characters, food and feeding habits and also provide the baseline information in area. The species is assumed to be locally threatened due to cutting down of roosting trees because of road expansion, for medicines or other rationales (Roberts 1997). Webb et al. (2000) emphasized long duration study on the diet and roost preference of the *P. giganteus* in different regions of the world to conserve the survival of this locally threatened and environmental friendly species. As human population getting increase in number, thus more rapidly the forests are converted to agriculture there is urgent requirement to study the living
conditions, roost characteristics and preferences of the species in order to provide protection (Marshall 1983; Nelson et al. 2000).
CHAPTER 2

REVIEW OF LITERATURE

2.1 Order Chiroptera

Order Chiroptera (bats) is the second most diverse group of small mammals after rodentia and constitutes 20% of all known mammalian species (Neuweiler 2000; Hutson et al. 2001). The order is represented by two sub-orders i.e. Microchiroptera which is represented by 782 species and the Microchiroptera represented by 175 species. The Microchiropterans are represented by seventeen families viz., Carseonycteridae, Emballonuridae, Furipteridae, Hipposideridae, Megadermatidae, Molossidae, Mormoopidae, Mystacinidae, Myzopodidae, Natilidae, Noctilionidae, Nycteridae, Phyllostomidae, Rhinolophidae, Rhinopomatidae, Thyropteridae and Vespertilionidae while the Megachiropterans by a single family i.e. Pteropodidae. Family Pteropodidae is comprised of 42 genera (Simmons 2005; Mahmood-ul-Hassan and Nameer 2006).

Bats evolved during early Tertiary period, more than 60 million years back and microchiropterans were separated from megachiropterans some 50.2 million years ago. The microchiropterans are cosmopolitan in distribution and are present everywhere except Arctic, Antarctica and some isolated oceanic islands (Nowak and Walker 1994; Bastian et al. 2001). The megachiropterans or the Old World fruit bats are limited to Paleotropics and their distribution ranges from Africa, eastern Mediterranean, Madagascar and the Indian Ocean islands in the west, across mainland southern Asia, throughout the islands of the western Pacific from the Ryukyu Archipelago and Ogasawara-Shato in the north, to coastal eastern Australia, New Caledonia and the Loyalty Islands in the south, and east to Fiji, Tonga, Samoa and the Cook Islands.
Genus *Pteropus* predominantly an island dweller taxon with extremely high endemism rate, 55 species are distributed on islands, 35 species are limited to single islands or island groups, nine species are found in continental areas four in Australia, five in Asia and four species found in Pakistan (Mickleburgh et al. 1992; Pierson and Rainey 1992; Mahmood-ul-Hassan and Nameer 2006).

2.1.1 Chiropteran status in the Indian Subcontinent

The most recent and obsolete review of the Chiroptera in the Indian subcontinent, has procured with 119 species of bats belonging to eight families and 37 genera (Bates and Harrison 1997). As far as their status in the region is concerned, one bat species has gone Extinct, 43 are Threatened, six are Critically Endangered, nine are Endangered and 28 are Vulnerable. A total of 189 species are listed in Lower Risk categories, 62 are Near Threatened and 128 are Least Concerned. A further, 29 species are listed as Data Deficient (Hutson et al. 2001). In Pakistan, one species of bat is Endangered, four are Vulnerable, nine are Near Threatened, eighteen are Least Concerned, seven are Data Deficient and one is Not Evaluated (Walker and Molur 2003; Mahmood-ul-Hassan and Nameer 2006). Pakistan has distinctive zoogeographic location hence having rich and diverse bat fauna consisting of 50 species of bats representing 23 genera and 8 families. In the eastern part of the country Indo-Malayan forms are predominant, while the mountains in the north and west hold the Palaearctic forms and linked to the Ethiopian region through land stacks. The Palaearctic species include a mixture of those common to a large part of Eurasia, along with resemblances to the Middle East, West Asia (Afghanistan and Iran), Central Asia and Tibet. The unification elements from different origins ensure a unique and diverse mixture of fauna and flora (Horacek et al. 2000; Roberts 1997).

2.1.2 Representative Megachiroptera in Pakistan
The short-nosed fruit bat (*Cynopterus sphinx*), the Indian flying fox (*Pteropus giganteus*), the Egyptian fruit bat (*Rosuettes aegyptiacus*) and the fulvus fruit bat (*Rosuettes leschenaultii*) are symbolic species belonging to three genera of Pteropodidea, Megachiroptera in Pakistan (Roberts 1997; Walker and Molur 2003). Species of the genus *Pteropus* are the world’s largest bats, ranging in adult weight from 250 to 1000 g and have a wingspan up to 1.7 meters (Mickleburgh et al. 1992). *P. giganteus* is the largest fruit bat in the Pakistan and easily recognized of its brightly colored rufous brown body fur with an obvious band of orange or honey colored fur on the upper back while the fur of lower back is dark brown or almost black in color. The weight of an adult Indian flying fox ranged 1.3 to 1.6 kg and has a wingspan up to 1.17 to 1.32 meters (Roberts 1997). Wings being the most apparent characters in the bats and hence remarked them as the only known flying mammals achieved power of sustaining true flight along with the pterosaurs and birds. Wings consist of skin membrane (patagia) supported by specialized forelimbs with greatly elongated manual digits and generally broad in outline, designed for flight rather than speed (Bernard and Davison 1996). Hind limb is laterally orientated enables 180° rotation in bats; facilitate steering during flight and upside-down roosting posture. Wing shape and flight speed vary among the chiropterans and are highly correlated with diet and foraging behavior (Papadimitriou et al. 1996). In comparison with other mammals bats are also characterized by a complex series of structural changes in the axial skeleton and pectoral girdle (Hill and Smith 1984; Simmons 1994, 1995). The echolocating bats are further characterized by a series of specialization of the middle and inner ear (Novacek 1985, 1987) and by the presence of neomorphic calcar, a cartilaginous or bony element that extend from proximal calcaneum and supports the trailing edge of the tail membrane (Schutt and Simmons 1998; Simmons and Geisler 1998). However, Indian flying fox lacks the power of echolocation and relies on the usage of well developed sense of smell and memory in locating and discriminating different
ripe fruits, same feeding spots for many consecutive nights and locating a suitable roost tree even though it may be many miles far from the feeding grounds (Frahm and Bhatnagar 1980; Schmidt 1985; Oldfield et al. 1992; Johnson et al. 1994; Barton et al. 1995).

2.2 Habitats of Pteropodidae

Eleven out of 42 genera of family Pteropodidae habitats in colonial roosting, four genera in trees and seven in caves, including the largest genus in the family, Pteropus. Seven of these genera roost in caves or rock shelters colonies, and the rest off 16 either roost singly or in small scattered groups in tree (Marshall 1983). 26 Pteropus species, about half of the genus are known to roost colonially but all species does not exhibits the same degree of colonialism and these colonial sites are maintained over long periods of time (Mickleburgh et al. 1992; Pierson and Rainey 1992). Habitat chosen by Pteropus species for roosting varies greatly ecologically and geographically. There is also evidence that Pteropus species choose sites near riparian zones because they utilize rivers as landmarks for navigation and there is evidence of long-term roost fidelity when habitat remain undisturbed by humans (Pierson and Rainey 1992; Mildenstein et al. 2005) however there was lack of studies on habitat used by fruit bats when they are not roosting. Pteropus livingstonei restricted to the altitudes in the Islands of Comoro and P. leucopterus of Philippines are found only in native montane forest (Cheke and Dahl 1981; Heaney et al. 1987), whereas P. rufus in Madagascar (Anderson 1912), P. griseus griseus on Timor inhabits coastal forests (Goodwin 1979). P. phaeocephalus from the Mortlock Islands in Chuuk and P. howensis from Ontong Java live on scarcely developing coral atolls (Sanborn and Nicholson 1950). Many species roost mainly in primary forest, such as P. niger on Mauritius (Cheke and Dahl, 1981), P. ornatus in New Caledonia (Sanborn and Nicholson 1950), P. pumilis in the Philippines (Heaney et al. 1987), P. samoensis in Samoa (Cox 1983), and P. tonganus on Niue (Wodzicki and Felten 1975). Philippine P.vampyrus and the four Australian species (alecto, conspicillatus,
poliocephalus, and scapulatus), found in an array of anthropogenic habitat and Philippines P. hypomelanus is common in disturbed, agricultural plots (Heideman and Heaney 1992). P. giganteus is found in a mixed landscape of natural, disturbed, and agriculturally altered forest (Neuweiler 1969; Kummer 1991) and in certain towns and villages in southern India and Pakistan (Cox 1983; Marimuthu 1988; Roberts 1997).

2.2.1 Roost of Pteropus

Roosts provide sites for mating, hibernation, and rearing young; they promote social interactions and the digestion of food; and they offer protection from adverse weather and predators. The roosting habits of bats may be influenced by roost abundance and availability, risks of predation, the distribution and abundance of food resources, social organization, and an energy economy imposed by body size and the physical environment. For many bats the availability and physical capacity of roosts can set limits on the number and dispersion of roosting bats, and this in turn can influence the type of social organization and foraging strategy employed. Pteropus giganteus a social, colonial species and tend to aggregate in large colonies on the open branches of huge tree tops. The large colonies of these fruit bats are also referred as camps, diurnal roost which often comprised of thousands of individuals. The canopies of large fig tree like the banyan (Ficus prolixa) and the she-oak, Casuarina spp., are frequently used as roost by these fruit bats: for example, P. mariannus on Guam (Wiles 1987), P. giganteus in India (Marimuthu 1988), P. melanotus natalis on Christmas Island (Tidemann 1985), P. ornatus in New Caledonia (Sanborn and Nicholson 1950), and P. tonganus in Samoa and Vanuatu (Chambers and Esrom 1988). However, the canopy and sub-canopy of other trees are used roosted by flying foxes include; Indian walnut (Aleurites moluccana), Ylang-ylang (Cananga odorata), Sea Mango (Cerbera manghas), beach gardenia (Guettarda speciosa), Cook Islands Homalium (Homalium acuminatum), chopak (Mammea odorata) and the, catchbird trees (Pisonia species) (Sanborn and Nicholson 1950;
Tidemann 1985; Wiles 1987; Wodzicki and Feiten 1980). Mangrove swamps served as significant seasonal roosting habitat for species like *P. molossinus* on *Pohnpei* (Coultas 1931). The landscape aspect of all different type of roosts are naturally designed to provide protection from strong winds and uncomplicated approach for flight and thus selectively chosen by flying foxes as habitat (Cheke and Dahl 1981; Nicoll and Racey 1981). Despite the ecological, economic, and public health significance of flying foxes, little is known about their habitat requirements, particularly in Southeast Asia (Mildenstein et al. 2005). Understanding their habitat selection and roost requirements can provide information for the design of forest management strategies that preserve roosting and foraging landscape (Crampton and Barclay 1998; Mildenstein et al. 2005). Furthermore, preventing viral spillover from bats to humans requires understanding the ecological narrative linking bat habitat with human and livestock activity and explains when, where, and why a virus emerges (Halpin et al. 2007).

### 2.2.2 Roost observations of *Pteropus giganteus* (Indian flying fox)

The hypothesis regarding *Pteropus* selection to roost upon the branches of tall tree may be due their large size and necessity for "free-fall take off" flight (Kingdon 1974) and thick foliage of these preferred roosting of *P. giganteus* also protect them from weather extremities (Advani 1982; Roberts 1997). The roost characteristics of the Indian flying fox have been extensively studied elsewhere in the world but little is known about their roosts in Pakistan. A total of 14 roosting locations of *P. giganteus* were identified in and around Coimbatore and Palakkad districts of India (Louis et al. 2008). Of the 14 roost, five were home garden, two were temples and roadside plantations and one was an urban park, an agriculture field and a factory campus. Bat populations of three of the roosting places in the home gardens had shifted their roosting places in the last five years. The other two colonies that were monitored for a year indicated high population fluctuation between two to five thousand individuals.
The threats included netting, shooting for meat and chopping of roost trees. The both populations in the temples and park were conserved both due to the religious beliefs and law respectively.

Studies of roost site selection within the home range have found preferences for particular tree species and degree of canopy cover (Gumal 2004). At the finest scale, studies have assessed food resource use and observed selection based on fruit preference, availability, and nutritional value (Banack 1998) as well as in relation to configuration of food resources within the landscape (Walton and Trowbridge 1983). The idea that landscape heterogeneity affects ecological processes over a variety of scales is well established (Wiens 1989; Levin 1992; Turner 2005) and other 88 studies of resource selection have stressed the importance of multiscale analyses for habitat selection models (Estes et al. 2008; Razgour et al. 2011).

Chakravarthy et al. 2008 studied the roost characteristics of the Indian flying fox in Karnataka, South India at the roosting site Gidadapalya - a village 15 km north of Kunigal town. The roosting site extended to about one acre (10000 m²) and the village was surrounded by forest plantations of oaks (Casurina species), thorn trees (Acacia species) and indigenous tree species like figs (Ficus species), orchid tree (Bauhinia species) Rain tree (Samanea saman), Indian date (Tamarindus indica) and other species. The Indian flying fox had been residing in that village from the past 75 years was the third place that the bats had changed due to chopping of trees at the first and second roosts that were located in a private property. Later the bats shifted to the present place, Kungial town where there were 30 banyan (Ficus bengalensis) trees and bamboo clumps (Poaceae species) (Chakravarthy et al. 2008).

Opportunistic surveys of Indian fruit bat roosts in eleven districts of Karnataka by Chakravarthy and Yeshwanth (2008) revealed that large roosts were generally 30 % more secure than the smaller sized roost as these were more amenable to disturbance. The small
roosts were generally displaced and disturbed more quickly resulting in the fragmentation of the original population. The roost trees of Indian flying foxes in urban areas generally included *Ficus* species, Royal Poinciana (*Delonix regia*), gum tree (*Eucalyptus* species), *Acacia* species, Leadwood tree (*Terminalia* species), *Casuarina* spp. Indian date (*Tamarindus indica*), Mango (*Mangifera indica*) and Jackfruit (*Artocarpus heterophyllus*). In all, of the 22 roost of South Karnataka, 22 % of the roosts were traditional with the population varying from 1000 – 3000 individuals. The population of seven roosts varied from 500 – 1000 bats while those of another four roosts varied from 100 to 500 bats. There were six roosts having less than 100 bats. This study indicated that the numbers of smaller roosts were increasing due to different pressures while the number of large and traditional roosts in the area was decreasing. In the studies of Pierson and Rainey 1992; Brooke 2001 there was remarkable difference of habitat use between endemics and non-endemic fruit bats. In American Samoa, the local endemic, *P. samoensis*, characteristically inhabitant in large tracts of native, inaccessible forest, while *P. tonganus* capable of using both disturbed and undisturbed forest. This same pattern appears to exist with the endemic *P. livingstonii* and the non-endemic *P. seychellensis* in Comoros (Cheke and Dahl 1981).

### 2.3 Colonial ranking among *Pteropus* roosts

The existing information regarding the roosts of *Pteropus* species is insufficient to propose any extensive pattern pertaining social and colonial system among huge colonies of *Pteropus* species. Even though, at present there are no confirmed records of such behavior for flying foxes, but some *Pteropus* species show remarkable seasonal change in roost composition relating to population density and food availability, flying foxes provides an ideal models for studying spatial and temporal variation in safety among groups (Baker and Baker 1936; Nelson 1965). Roosting associations of fruit bats involved groups of females that can range from a few to dozens, along with a single male that either defends the females or the roost
Among the colonial species of *Pteropus*, harem construction is practically widespread and has been documented for *P. seychellensis comorensis* (Cheke and Dahl 1981), while in a study of Neuweiler (1969), *P. giganteus* in India, did not indicate any harem formation though he observed a vertical rank order for males within a colony, with the more dominant males defending positions near the top of the tree. Individuals that reside in center of the colonies have higher breeding fitness than the individuals residing at the margins of the colony (Krause and Ruxton 2002), centrally positioned animal in the colony gain number of mutual advantages like increased reproductive success, strong defense, lower rates of offspring loss, and experience less adverse environmental conditions as compared to animals positioned on peripheries (Cameron and Toit 2005; Hovi et al. 1994; Rattenborg et al. 1999). Whereas, the peripheral individuals have an important role in maintaining the safety of the colony since they are most probably the first to spot predators, the member of *P. poliocephalus*, the grey-headed flying-fox, situated at the margins of the colonies generate true acoustic "alarm calls", specific high-pitched calls to alert others members of the colony when a potential threat is detected (Nelson 1965; Wilkinson 1995). Group stability can be defined by the fidelity of individuals to the same group in which they were found at the beginning of the study, and the durability of the association (Lewis 1995; Entwistle et al. 2000). This kind of stable association can be observed when group members share some resource i.e foraging territory or information about food sources and can also be related to specific characteristics of the roost (Wilkinson 1987; Kunz and Lumsden 2003). Bats roosting groups inside caves or tree cavities tend to be most stable owing to the more permanent nature of these roosts (Bradbury 1977; Kunz et al. 1983; Lewis 1995; Ortega and Arita 1999; Kunz and Lumsden 2003). It has been postulated that roost characteristics are important factors influencing the social biology and mating
systems in bats, although our knowledge on this aspect of roosting ecology is deficient (Kunz and Lumsden 2003).

2.3.1 Maternal colonies of Pteropus species

In many colonial species, females usually choose socially dominant or centrally ranked males and passionate competition has been observed among males for central location in colonies (Balmford et al. 1992; Bart and Earnst 1999; Roithmair 1994). The young males of Pteropus species roost on a separate tree in the mating season, and the females gather together in the upper branches with the centrally positioned dominant males. When a single male defends a group of females independent of the roost, this type of polygynous mating system is referred to as female defense polygyny and conversely when a single male defends a roost independent of the presence of females, the mating system is referred to as resource-defense polygyny. However in either case, a dominant male is often capable of physically excluding other males that may attempt to enter an occupied roost to gain access to females (Emlen and Oring 1977; Clutton-Brock 1989; McCracken and Wilkinson 2000). On contrary microchiropterans tend to roost under structures, natural or man-made, that offer protection from predators and can accommodate maternal colonies that vary in size depending on the species. The colony size of little brown bat (Myotis lucifugus) often depends on the size of the structure that these bats settle inn; in dark attics, barns and under bridges consisting of several dozen to over 1,000 members (Pearl et al. 1996). Infants of Pteropus are scarcely haired clinging to mother's body using special hook-like growths on the inside curve of the claw and probably the hook-like milk teeth to hold on to the mother's fur (Nelson 1965). Such observation was also noted by Roberts (1997) in the colony of P. giganteus at Bag-i-jinnah, Pakistan. The newborns are dependent on their mothers to maintain their body temperature and are carried for many weeks (Nelson 1965; Neuweiler 1969; Roberts 1997). For P. giganteus and grey-headed flying fox (P. poliocephalus), the young are carried until
they became capable to fly till they are 3 months old, but at the age of three weeks, the
mothers left them behind and went for feeding (Nelson 1965; Roberts 1997). The rate of
infant mortality is highest at this stage as the young are more at the risk of predation and have
maximum chances of falling from the canopy (Wiles 1987). Although the young ones are
nursed by their mothers till the age of 4-6 months, and stay associated with their mothers
until they become a year old. Evidences of the weaning period in captive Guam Mariana fruit
bat (*P. m. mariannus*) and rodrigues flying fox (*P. rodricensis*) showed that the mothers feed
the young mouth to mouth (Pook 1977).

2.4 Feeding adaptations in frugivorous bats

The Indian flying foxes roosting in huge colonies had been observed to feed on fruits,
flowers, leaves, shoots, buds, nectar and pollen of tropical forest trees and shrubs (Banack
1996; Bonaccorso 1998; Tan et al. 1998). These fruits contain a significant amount of
indigestible fiber in the form of pulp and seeds that are not digested at all and form a bulk of
guano. The frugivorous bats only consume the juices rather than swallowing as a whole and
for this they had developed large heads with elongated muzzles and simple flat crowned teeth
that allow them to grab and tear pieces of fruits though the teeth are not meant for grinding
but for extracting juice. Their palate is often prominently grooved that helps in squeezing out
fruit juices as an adaptation to this mode of feeding (Roberts 1997). The digestive anatomy of
the frugivores bats extremely adapted to significant amount of high seedy nature of their diet.
The gut of Indian flying fox, therefore, depends heavily on enzymatic pathways and
metabolism in their nutrients assimilation and energy resource (Ratclift 1932; Rio et al.
1993). Whereas their stomach has primitive nature having small size of intestine and gut as
compared to other fruit-eaters which is probably an adaptation to aid in their flying ability.
Thus, these bats consume only juices that can pass quickly through their gut and do not
attempt to digest the fibrous content (Ratclift 1932). The ingested liquid portion of the fruits
and leaves travels through gut in only 20 minutes that decreases the massive wing load and energy cost travelling to and from foraging areas to roosts (Kunz and Ingalls 1994; Tedman and Hall 1985).

### 2.4.1 Staple food of Pteropodids

Figs - a favorite food of many flying foxes contains a significant amount of seeds and indigestible pulp. Other than figs their diets includes fruits like Guava (*Psidium guajava*), Sapota (*Achrus zapota*), Banana (*Musa paradisiaca*), Litchi (*Litchi chinensis*), Jack (*Artocarpus indica*), Mango (*Mangifera indica*), and peaches (*Prunus persica*), and other commercial plants. Besides commercial fruits, favorite pollen of the flying fox includes the pollens of Gum trees, *Eucalyptus* species (Chakravarthy and Girish 2003). Brooke (1998) describes that the tongan fruit bats (*P. tonganus*) forage in native forests, agricultural and residential areas and seems to favoring agricultural area but the usage of each habitat type is unknown. Pacific flying fox (*P. tonganus*) is phytophagus a highly plastic forager consume fruit, nectar, pollen and leaves of 42 plants species in American Samoay (Elmqvist et al. 1992; Banack 1998). Heideman and Haeney (1989) documented multiple habitats of the Malayan flying fox (*P. vampyrus*) including primary forest, mangrove forests, mixed fruit orchards and coconut grooves. These flying foxes can travel up to 50 km to reach their feeding grounds and shift their feeding sites in response to food availability (Medway 1969). In addition to fruits such as mangoes (*Mangifera indica*), bananas (*Musa paradisiaca*), rambutan (*Nephelium lappaceun*), figs (*Ficus* species) and langast (*Lansium domesticum*) the pollen, nectar and flowers of coconut (*Cocos nucifera*) and durian tres (*Durio zizebethinus*), were not only preferred but strongly defended by Malayan flying foxes (Gould 1977; Kunz and Jones 2000). Likewise other flying foxes figs are the chief food item of these bats while other dietary items are consumed on sequential basis throughout the year (Stier and Mildenstein 2001).
Mahmood-ul-Hassan et al. (2010) studies showed that, the *P. giganteus* (Indian flying fox) in Pakistan feed upon twenty plant species belonging to eleven families. Fruit bats encounter nutrient requirements needs by harvesting a wide variety of native fruits in bulk which tends to be conspicuous, abundant and easily obtainable in bunches (Dempsey 1999; Mickleburgh et al. 1992). Hundreds of bats may tumble down locally and temporarily abundant seasonal food source and thus these bats are often regarded as “sequential specialist” (Marshall 1983, 1985; Piesrson and Rainey 1992; Banack 1998).

Food choice of fruit bats subjected to numerous factors, including energy and nutrients needs, reproductive status, limitation of the digestive system, abundance, diversity, seasonality of different food items, competition and predation (Fleming 1988; Oftedal 1991). One explanation for *P. giganteus* roosting preference in forests near areas of high human density is that homestead gardens provide a diversity of food resources and protection from predators that may not be present in natural forests. In Bangladesh, about 70% roosts of *P. giganteus* were found in human colonized areas because more than 20 million households maintained a home garden, an average of 34 plant species per garden (Kabir and Webb 2008). Gorresen and Willig (2004) observed that the abundance of generalist frugivorous bats was positively associated with fragmentation of the landscape and proposed that their ability to feed on a variety of plant species allowed them to utilize heterogeneous landscapes. In a review of the genus *Pteropus*, Pierson and Rainey (1992), found that *P. giganteus* was one of the species that has been documented in forest remnants in populated areas as opposed to only in undisturbed natural forests, roosts were often near water, which may be used as a drinking source. One possibility is that in addition to selecting roost sites based on the roost tree, *P. giganteus* also choose sites near food resources but keep their roosting and feeding sites separate, a behavior that has been noted for other *Pteropus* bats. Fruit bats preferred to roost thick dense foliage trees, such trees likely provide cryptic roosts beneath multiple
overlapping crowns, with sufficient shelter from predators and the elements. Fruit bats, particularly on islands, have few natural predators. A variety of birds of prey, both Falconiformes and Strigiformes, various reptiles including snakes, large lizards, and some carnivorous mammals prey upon them (Nelson 1965a; McClure et al. 1967; Kingdon 1974; Wolf 1984; Heideman et al. 1987; White et al. 1988; Pierson and Rainey, 1992). Though predators may influence both feeding and roosting behaviour, they seldom cause serious loss to populations, unfortunately information on natural predators is limited, but there do not appear to be any that would constitute a serious threat. (Marshall 1983; Seehausen 1990).

Besides fruits and pollens folivory, leaf-eating are also documented in the fruit bats as consistent food item of their diet the leaves are chewed and juice swallowed whereas, the fibrous portion of the leaves are ejected as a small compressed pellet (Lowry 1989; Marshall 1985; Kunz and Diaz 1995). Leaves are important source of minerals, carbohydrates, proteins and are especially rich in calcium (Nelson et al. 2000; Ruby et al. 2000; Tan et al., 1998). Folivory was once assumed to be exceptional among fruit bats, with leaves taken only when other food sources were meager. However, recent studies showed that leaf-eating is both common and widespread among Old World flying foxes and has been reported in at least 17 species of Old World Megachiroptera. The leaves eaten by these bats include 44 species of plants represented by twenty three families for example, Lesser short-nosed fruit bat (C. brachyotis) fed regularly on the leaves of 14 plant species in southern India and Ryukyu flying fox (P. dasymallus) on 9 plant species in Taiwan (Kunz and Diaz 1995; Tan at al. 1998).

2.5 Bats as pollinators and seed dispersers
The Indian flying fox aids in the distribution of plants (and therefore, forests) by carrying the fruits with them and spitting the seeds or eliminating elsewhere. They also pollinate the plants they visit; this ecological relationship between plants and bats forms a mutualistic
relationship known as chiropterophily, because direct positive gain in fitness yielded to both counterparts (Fujita and Tuttle, 1991). Bats obtain a source of nutrition from plants and in turn transport pollens and disperse seeds of these plants included many economically important and edible commercial tree species such as the banana (Musa paradisiaca), the avocado (Persea americana), the date palm (Phoenix dactylifera), the fig (Ficus carica), the peach (Prunus persica) and the mango (Mangifera indica). Large Pteropus species commute distances up to 50 km (vander 1957) during their nightly searches for food patches at speeds of 40 km/h, frugivorous bats defecate during flight and this behaviour has been observed in Cynopectus species, Geoffroy’s rousette (Rousettus amplexicaudatus), Malaysian flying fox (Pteropus vampyrus) in Indonesia, and grey headed flying fox (Pteropus poliocephalus) in Australia (Richards, 1990). On many oceanic islands, fruit bats are the only animals capable of carrying large seeded fruits and are the single most important pollinators and seed dispersers (Cox et al. 1991). In spite of their important ecological, economic roles in regenerating forest the fruit bats are in the region are facing threats as they are regarded to be vermin that cause economic losses while feeding (Verghese 1998; Sirinivasulu and Sirinivasulu 2001).

2.5.1 Conflict with fruit growers
Large scale commercial fruit growing led to conflicts between fruit growers and bats in some areas of the world for example. Australia, Israel and South Africa (JacobsOn and Duplessis 1976; Loebel and Sanewski 1987). Many cultivars had developed from wild species that are dependent upon bats for pollination or seed dispersal, or for both (van der Pijl 1957; Marshall 1983). The same characteristics of fruit colour, smell, taste that attract bats to wild species may also attract them to cultivated ones, although in the latter case they can rarely be beneficial as pollinators or seed-dispersers as this role has largely been supplanted by the fruit grower. One exception to this was the durian, which still relies heavily on bats for its
pollination. The most serious conflicts may occur where the supply of native fruits had reduced through forest loss (Fleming and Robinson 1987; Tidemann and Nelson 1987) or where there had mass failure of native plants to flower, as happened with *Eucalyptus* in Australia, whose blossom provide the predominant food for *Pteropus* species there (Ratcliffe 1932; Nelson 1965a). In most cases bats feed on too ripe fruit that to be marketable. Many fruits that picked by farmers in unripened state and allowed to ripen off the tree. The ripening of fruit was mediated by the action of ethylene), which produced naturally in the plant and produced in increasing quantities as ripening progresses (Burg and Burg 1965). Any trauma to the plant tissue (e.g. bites or scratches) can led to increased ethylene production and in some cases premature ripening. Thus damage can be caused indirectly by bats clambering over unripe fruit or through 'test bites'. The relative perceived scale of damage has also increased through increased market demands for unblemished fruit. The level of damage varies considerably with locality and is generally greatest in the summer when females are lactating and have greater energy requirements (Ratcliffe 1932; van der Pijl 1957). However these conflicts between bats and farmers can be resolved by taking crop protection measures which include (a) partially covering of vulnerable portions of canopy, illumination and scaring frugivorous bats, (b) buffering the orchards with other trees preferred by bats, such as weeping fig (*Ficus benjamina*) and *Ficus microcarpa* (*F. retusa*) and (c) by making block plantation i.e. the orchards may be divided into smaller plots that they may be covered with sprigs or foliage or thatch or nylon nets. It is noteworthy that the beneficial effects and the ecological services of bats outweigh harmful effects (Jacobson and Duplessis, 1976).

### 2.6 Bat guano

The fresh guano of fruit bats is dark in color and forms a flat, laminated mass and generally contains more than 60% organic matter mainly cellulose and some minerals. The clay is found in plenty among all the minerals in the fresh guano while others include quartz and
traces of dolomite and calcite that possibly gather from the dust either adhering to the eaten fruit or blown onto the guano shortly after the deposition. The most abundant elements in bat guano are nitrogen ranges between 8 – 12% and phosphorus P\(_2\)O\(_5\) ranges between 2 – 7% while others include calcium, magnesium, potassium, aluminum, iron and sulphur are present in quantities lower than 5% each (Ruth et al. 2004). Differences in community structure of the microbes inhabiting the guano may be due to differences in guano composition of frugivorous (Pteropus rodricensis), sanguivorous (Common vampire bat, Desmodus rotundus), and insectivorous (Mexican free-tailed bat, Tadarida brasiliensis) bats. Desmodus guano contained more carbon (C) than Pteropus guano. The latter contained less nitrogen (N), and the former contained less phosphorous (P) than guano of the other two species. Pteropus guano had a higher C to N ratio, and Desmodus guano had higher N to P and C to P ratios than the other two species. Interestingly the diversity of organisms living on or in the guano piles depends upon the diet of the bat excreting guano, Guano of sanguivorous bats typically inhabitant by fly larvae, nematodes, springtails and beetles. Insectivorous bats guano inhabited by mites, pseudoscorpions, beetles, thrips, moths and flies whereas guano of frugivorous bats inhabited by spiders, mites, isopods, millipedes, centipedes, springtails, barklice, true bugs and beetles. Though, several studies had been done on the impact of guano from different bat species on cave ecology but the composition of bats consuming different diets have received little attention (Ferreira and Martins 1998). Similarly, different types of mycoflora and mycoflora inhabit the bat guano and the higher number of fungal isolates documented in frugivorous bats compared to insectivorous bats also showed correlation on food sources and their roosting site with the number of fungus isolated (Saleen et al. 2008). These differences in guano composition suggest that guano from bats in different feeding niche may vibrantly alter the structure of ecosystem (Justin and Roark 2007). No specific studies of degradation of fruit bat guano are available; in general, the most abundant
organisms in soil that contribute to organic matter decomposition are bacteria and fungi (Ruth et al. 2004).

2.6.1 Importance of Bat guano

Bat guano contains beneficial fungi and bacteria, which act as a natural fungicide to protect plants from disease and are vital in maintenance of soil health and productivity. Bacteria are necessary for plant growth on specifically newly fresh sediments, fix atmospheric nitrogen and carbon, produce organic matter and provide nutrient for initiating nitrogen cycling process in the soil. Fungi enhance soil superiority by decomposing complex carbon compounds, improve the accumulation of organic matter, and retained nutrients in fungal hyphal strands reduce the leaching of nutrients out of the root zone (Takashi et al. 2005). Their hyphae physically bind soil particles, improve plant growth, are a food source for other microorganisms, compete with other plant pathogens and decompose certain types of pollutants. It is therefore, essential to feed the poor soil with guano and promote the growth of biological soil life for plant health. The nutrient rich bat guano considerably modifies the community structure of different microorganisms by enhancing algal growth and settlement of invertebrates in dense algal mats (Lane and Diver 2000). Such consumer-driven nutrients recycling via fecal decomposition by bats also affects community structure in guano-based ecosystem. Bat guano forms the basis of food web consisting of bacteria, fungi, protozoans, nematods and arthropods (Harris 1970; Fenolio et al. 2006). Flying foxes are somehow credited as pollinators, dispersers and aforestation agents yet the benefits gained from excrement as natural organic matter is yet to be fully explored and also helpful in developing conservation strategies to bat habitat (Goveas et al. 2006).

Besides, ecological importance and manure qualities of bat guano, it also had zoonotic values and had reported for both important residence and vectors of pathogens. With respect to fungal pathogens, insectivorous bats are known to be the prime contenders as reservoirs of
fungi such as *Histoplasma capsulatum*, *Coccidioides immitis*, *Cryptococcus laurentii* and *Blastomyces dermatitidis* (Yamamoto et al., 1995; Garcia-Hermoso et al. 1997; Mattsson et al. 1999; Bunnell et al., 2000). Some of the other pathogens to be associated with bats were *Candida krusei*, *Trichosporum* sp., *Scytalidium* sp., and one unidentified yeast-like fungus from liver, spleen and lungs of frugivorous bats (*Carollia perspicillata* and *Sturnira lilium*), *Glossophaga soricina* (nectarivorous bats) and *Desmodus rotundus* (hematophagous bat) respectively (Silva-Vergara et al. 2005). The high number of fungal isolates documented in frugivorous bats compared to insectivorous. Bats also does show some correlation on food sources and their roosting site, apart from that, fruits consumed by the frugivore bats are also important factor in understanding the ecology of bats. Sometimes the infected fruit may contain pathogenic microorganisms that present during the fruit decay process (Sepiah 1985). So, this would be a key factor how the fungi are transmitted to bats since frugivorous bats consume fruits as their main diet.

### 2.7 Perspicacity

The bats are well acknowledged for their ecological services throughout the Europe and America (Mickelburgh et al. 1992; Fujita and Tuttle 1991). However, the importance of the positive role of bats in the ecosystem in Southeast Asia was recognized in 1998 when the Malaysian government passed a wildlife protection ordinance which included protection of all species of bats (Gumal and Racey 1999). In India, two species of bats viz., the Wroughten’s free-tailed bat (*Otomops wroughtonii*) and Salim Ali’s fruit bat (*Latidens salimalii*) are highly protected and are on schedule 1 of wildlife (protection) act 1972. The realization of the role of bats in agricultural economy of India can be documented from the fact owing to its feeding habits in Bihar, the Indian false vampire (*Megaderma lyra*) considered as a good friend of farmers who reward it by food in bad weather and call it goddess Laxmi (Sinha 1986). Bats are given no protection by law in Pakistan and many
species are hunted for their body fat to be used by local health practitioners to cure rheumatic pains and often viewed with fear and superstitious in many cultures (Roberts 1997). The negative perception of human towards bats is principally due to ignorance about their services offered to human beings and ecosystem. Such awareness educational campaigns should be initiated to storm the brains with the positive roles of bats in an ecosystem. The stability of Critically Endangered endemic *Pteropus livingstonei* population in Comoros is a successful example of local surveys and educational programs. Apart from general, public educational campaigns should also address the related groups such as archaeologists, farmers, forestry, fruit growers, speleologists and tourism (Action Comores 1997).

Fruit bats have received little attention of policy makers, ecologists and biologists of Pakistan and their services have never been acknowledged in Pakistan. Fruit bats have acquired the status of key stone species in the lives of many plants that are crucial to entire ecosystem. At least 443 plant products useful to man derived from 163 plant species rely to wholly or partly on bats for pollination and seed dispersal (Fujita and Tuttle 1991). Seed dispersal and pollination activities of fruit and nectar-eating bats are vital to the survival of forest and fruit orchards (Mickleburgh et al. 1992).

**2.8 The major threats to bats.**

Apart from their number of services to mankind, fruit bats are facing threats due to loss of habitat, hunting for food, medicine, primary and secondary poisoning throughout the world. The continuing deforestation, habitat alteration, industrialization and expansion of agricultural activities have threatened the survival of bats in many parts of Asia. In recent decades, bat populations have experienced global declines, a trend linked to extensive, recent habitat loss (Mickleburgh et al. 2002). In Southeast Asia, 20% of the bat species are predicted to become extinct by 2100 (Lane et al. 2006). This pressure is especially
acute in tropical countries where a large proportion of the population may live in rural 
areas and have relatively low incomes (Mikelburgh et al. 2002).

2.8.1 Urbanization

Wodzicki and Felton (1980), human activities constitute the greatest threat to fruit bat 
population. The increasing human population directly threatens to the bats with growing land 
need, food and other resources in the loosening or damaging their habitats, these demands are 
particularly highly acute in tropical countries where larger families are relying on low 
incomes (Verboom 1998). Tree lines, hedgerows, canals and other linear countryside 
elements are important for bats as they used during flight and possibly serve as essential 
linkage between roosts and feeding areas, the permanent loss of these topographic features 
due to extensive farming are extremely unfavorable for the existence of some bat species 
(Mickleburgh et al. 2002). Urbanization involves road building that had made easier access to 
remote roosting areas (Falanruw 1988a). This means it has been easier to hunt animals at 
their roosts. Such disturbance can cause animals to abandon roost sites with serious 
consequences, particularly during the maternity season (Wiles 1987b).

Worldwide, agriculture expansion had a major impact on many bat habitats. The negative 
effects of ‘slash and burn’ agriculture on bat populations recently been seen in Laos, where 
the nomadic peoples of the Nam Et Highlands burn primary forest to plant crops. Slash and 
burn destroys vegetation cover and may also kill individual bats that use tree crevices as 
roosts, affecting many of the threatened species of bats. Furthermore pesticide usage in 
agriculture with reduced mammalian toxicity, but highly toxic alternatives such as DDT are 
still used in developing countries (Fenton & Rautenbach 1998). DDT has been widely used in 
Africa as a way of controlling the *Anopheles* mosquito, which spreads malaria. Safer 
pyrethroid alternatives are now being used, although the use of DDT had been reintroduced 
in areas where resistance to pyrethroids has developed (McGinn 2001). Such pesticides had
been implicated in the decline of bat populations in the USA and Australia (Clark 1981) and McWilliam (1994) showed that spraying with DDT increased the mortality of some bat species in Zimbabwe. Clearly, the threat to bat populations from DDT needs to be weighed against the threat to humans from malaria. Fruit bats are also harmed by hunting the locally commercial level and have long been consumed by local people. Hunting continues at both the local and commercial level often as a part of luxury food trade or by commercial; fruit growing operations, where fruit bats are considered as pest (Loebel and Sanewski 1987; Fujita and Tutle 1991).

2.8.2 Deforestation

Cheke and Dahl (1981); Pierson and Rainey (1992) mentioned that habitat loss and forest destruction are now considered the major factor contributing to decline the fruit bat population. Loss of forest result in loss of both critical food and roosting resources for the fruit bats as the native forest is logged to make way for residential and commercial development and agriculture (Mickleburgh et al. 1992). Many fruit bat species roost deep in native forest and disturbance to the roost either accidental or intentional can result in abandonment that can have population effects during the maternity season. Rainey et al. (1995) the fate of the native forest and fruit bat population that reside within them are interconnected. Native forest provides fruits and roosts to fruit bats, and fruit bats are crucial to the maintenance and integrity of native forests. Due to paucity of alternative vertebrate pollinators and seed dispersers on isolated oceanic islands, fruit bat species are often considered as keystone species. The decline or extinctions among fruit populations may hence long-term impacts on forest regeneration and cascade effects on other species that reside in native forests (Bonaccorso and Humphery 1978). A loss or significant decline in bat population may ultimately affect community structure, biodiversity and ecosystem function (Rainey 1998).
Deforestation, widespread in almost all tropical areas of the world, has had several identifiable consequences for fruit bat populations. Many species, particularly those inhabiting mangrove swamps (e.g. *Pteropus vampyrus* in Malaysia and Indonesia) and lowland forest, had lost critical roosting areas. Mangrove swamps are being destroyed by the woodchipping industry, for mariculture, firewood, and coastal development, and lowland forest is felled for agriculture and timber (US Fish and Wildlife Service and National Environmental Protection Board 1989). Loss of forest results in the loss of critical food resources for many species. The loss of tamarind trees (Leguminosae: *Tamarindus indica*), a favourite food of *Pteropus rodricensis*, had been identified as one factor in the decline of this species. Even *Pteropus tonganus*, which appears adaptable to agricultural conversion, greatly preferred native to cultivated fruits in a recent feeding trial (Cheke and Dahl 1981).

The elevated extinction rate of so many local and regional species is the product of swift alteration of tropical rain forest into meadows and farming lands and needs to preserve the leftover mammalian fauna (Estrada et al. 1993; Myers 1988). Furthermore, the disintegration of these forests is the temporary phase in the process of destruction causing spatial and temporal segregation among flora and fauna hence providing worst ecological conditions which are insufficient for the survival of species (Lovejoy et al. 1984, 1986; Saunders et al. 1991).

Natural catastrophes also lead to dramatic decline in fruit bat population especially on small islands in Indian and Pacific oceans that repeatedly faced tropical storms (Brooke 1998; Craig et al. 1994). Then after, bats feed upon fallen trees and fruits from storm are at the peak risk of predated by domestic cats, dogs and pigs as they were unable to take ground flights (Pierson & Rainey 1992). Hence defoliation after storm increases the visibility to locate the animal and reduced food supply force the bats for day foraging hence increases predation and hunt. The effects of the typhoon that hit Western Samoa and American Samoa
in February, 1990 on *Pteropus tonganus* and *P. samoensis* are still being evaluated. After the typhoon the bats were foraging for fruit on the ground or at fallen trees in villages, not always at night. Since they were often unable to take flight from the ground they were extremely vulnerable to predation. Domestic animals (dogs, cats and pigs) were reported to have killed large numbers of *P. tonganus*. Since cats and pigs also forage extensively in agroforest, the mortality was probably greater than that directly observed (Mickleburgh et al. 2002). Hence, bats are also threatened by natural factors like tropical storms are an ever present hazard and can have devastating effects, particularly where populations are already under pressure from human activities.

2.9 Approbation

Presently, a lot of resources are being employed in Southeast Asia in bat research with the recognition of their endangerment (Chakravarthy 2007; Acharya 2008; Korad and Gaikwad 2008; Louis et al. 2008). Several international conservation organizations (e.g., Bat Conservation International, Wildlife Conservation Society, World Wildlife Fund, Lubee Foundation, etc.) are promoting conservation of Southeast Asian large Flying-foxes through awareness, educational and research projects (Mildenstein et al. 2005). However, the biology and ecology of almost all four species of fruit bats viz., the short-nosed fruit bat (*Cynopterus sphinx*), the Indian flying fox (*Pteropus giganteus*), the fulvus fruit bat (*Rosuetteleschenaultii*) and the Egyptian fruit bat (*R. aegyptiacus*), is poorly known on national and local scale in Pakistan (Mahmood-ul-Hassan and Nameer, 2006). There is no specialized bat biologist in the country. There are only a few who are either interested or poorly equipped to undertake such work. Similarly, bats are rarely considered either in environmental policies or educational projects. Therefore, they are facing considerable threats and higher probability of endangerment in our country (Mahmood-ul-Hassan and Nameer 2006). Lack of information
makes assessing the status of populations difficult, this in turn hampers the development of appropriate conservation measures.

There has been a remarkable decline in the population of Indian flying fox due to habitat destruction, hunting for food, medicine and conflict between bats and fruit growers over the past few decades (Roberts 1997; Walker and Molur 2003). Fruit bats are thus placed under the least conserved and the most endangered small mammal species in South Asia. Conservation Assessment and Management Plan (CAMP) Workshop for chiropterans of South Asia organized by IUCN in 1998 has emphasized on an urgent and up-to-date chiropteran survey in Pakistan. Chiropterans are exclusively vital, as they comprised 40 – 50% of mammal species and have a great impact on richness and diversity of other species by consuming plants and animals thus rigorously involved in recycling nutrients and energy in the ecosystem (Fleming et al. 1972). The members of order chiroptera are not only forest regenerators, pollen and seed dispersers but also important for plant population structure, abundance and reproductive phenology (Heithaus 1982; Charles-Dominique 1986; Fleming 1988) Such an ecological survey is necessary for better understanding on the taxonomic status, life histories, hunting, viability analysis and economic value of these species (Molur and Walker 1998). Since there has been no long or short term study on Indian flying fox, and bats in general are rarely considered either in environmental policies or educational projects, Pakistan is unable to meet its commitment to the Convention on Biological Diversity of which it is a signatory.

**Statement of Problem**

1. To find out roost preferences of the Indian flying fox in Lahore
2. To assess temporal and spatial variation in the diet of the Indian flying fox.
3. To make an inventory of the food plant species of the Indian flying fox and morphological characterization of remnants (seed, fruit, petals) of the bolus and guano of the fruit bats to aid future scientists.
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CHAPTER 3

EXPERIMENT NO. 1

Title: To find out roost preferences of the Indian flying fox in Lahore

Publications

3.1 Roost characteristics and habitat preferences of Indian flying fox (*Pteropus giganteus*) in urban areas of Lahore, Pakistan.
Roost characteristics and habitat preferences of Indian flying fox (Pteropus giganteus) in urban areas of Lahore, Pakistan.

Abstract

Indian flying fox, *Pteropus giganteus*, (Pteropodidae: Chiroptera) is native to Pakistan with the estimated population of less than 1200 flying foxes in Lahore. They had major role in maintenance of healthy ecosystem are are choosy in selecting roosting sites, yet the habitat characteristics of these giant fruit bats, or flying foxes, are not known in the region. 2 populations of Indian flying fox *Pteropus giganteus* roosting at Jinnah garden (n = 1052) and Lalazar garden (n = 40) in Lahore city were observed from May 2009 through April 2010 to find out their roost characteristics and habitat preferences. Total number of trees at Jinnah garden were 4119, belonging to 46 families, 103 genera and 132 species (45 native + 87 exotic); out of which 44 trees belonging to 17 families, 19 genera and 21 species (11 native + 10 exotic) served as bat roosts. The roosting trees harbor 5 acres out of total 140 acres land of the park. The height of roosting tree varied from 7.5 m (*Dendrocalamus hamiltonii*) to 19.8 m (*Celtis australis*) and dbh from 0.10 m (*Putranjiva roxburghii*) to 0.89 m (*Kigelia pinnata*). Maximum average bats (n = 88) were roosting at *Putranjiva roxburghii* with total height of 13.4 m and dbh 0.1 m. At Lalazar garden, out of total 90 trees belonging to 7 families, 9 genera and 9 species, bat roosts were observed at 6 trees belonging to 2 families, 2 genera and 2 species. Maximum average bats (n = 23) were counted on *Syzygium jambolanum* with tree height of 15.13 m (tallest roost tree) and average dbh 0.50 m whereas minimum average bats (n = 18.71) were observed on *Mangifera indica* having height 13.10 m and dbh 0.55 m (maximum dbh). It can be
concluded from present study that *P. giganteus* prefers to roost near water body, on tall trees with smaller diameter.

Keywords: Tree height, dbh, bat roost, Jinnah garden, Mangifera indica

**Introduction**

Pteropodidae (Order Chiroptera) is represented by only 1 genus *Pteropus*. The members of this genus are old World fruit and nectar eating bat species characterised by extensive series of geographic and ecological habitat characteristics (Pierson and Rainey 1992; Palmer and Woinarski 1999). Most of the *Pteropus* species are likely to roost in the landscape with emergent trees providing shelter from strong winds, regulate temperature, gives easy exit for upward flight and moreover a food resource to the species (Cheke and Dahl 1981; Kunz 1982; Pierson and Rainey 1992; Richmond et al. 1998). Many foliage roosting bats roost solitary or may form relatively small groups without transforming the plant while 2 pteropodid species, lesser short nosed fruit bat *Cynopterus brachyotis* and short nosed fruit bat *C. Sphinx* were observed to transform roost leaves and stems into tents to attain protection against predation, weather, for mating and rearing young sites (Balasingh et al. 1995; Bhatt 1995). The foliage roosting behaviour of the bats may be dependent on the factors like local climate of the foliage, dispersion of food and socialism. Some pteropodids roost in gregarious phase during 1 season may be roosting alone or in small groups in other season which may be a direct response against climate or availability of food (Kunz 1982; Law 1993; Perry-jones and Augee 1991).

Louis et al. (2008) identified 14 roosting sites 5 from home gardens and 2 from each, temples, roadside plantations, urban park, agriculture field and a factory campus in and around Coimbatore and Palakkad district, India. Roosts of Indian flying fox were observed
in forest plantations of Casurina species, Acacia species and indigenous tree species like Ficus species, Bahunia species, rain tree (Samanea saman) and Indian date (Tamarindus indica) Chakravarthy et al. (2008).

According to Chakravarthy and Yeshwanth (2008) roost trees in urban areas generally include Ficus spp., royal poinciana (Delonix regia), Eucalyptus spp., Acacia spp., Terminalia spp., Casuarinas spp., Indian date (Tamarindus indica), mango (Mangifera Indica) and jackfruit (Artocarpus Heterophyllus). Their studies conclude the numbers of smaller roost were increasing due to different pressures while the numbers of established roost of Indian flying foxes were continually decreasing in the area. Pteropus giganteus in Pakistan is reported from Sialkot, Lahore, Marala, Renala Khurd, Said Pur (Punjab), Jacobabad, Shahpur, Karachi (Sindh) and Islamabad (Roberts 1997). In Pakistan, Pteropus giganteus is included in the 4th schedule of the Punjab Wildlife (Protection, Preservation, Conservation and Management) Act 1974 section 2 (v), which lists the species among those that are given no legal protection and can be hunted (Mahmood-ul-Hassan et al. 2010). The species is hunted for its body fat to be used as potions and as putative cures for rheumatic pains, by local medical practitioners (Roberts 1997). In addition, extensive roost tree cutting for urbanisation threaten survival of the species and their role as seed dispersers, forest pollinator and regenerator is ignored. Therefore there is dire need to know the habitat requirements of P. giganteus for conservation of these environment friendly creatures.

**Materials and Methods**

Lahore is the second most populated city of Pakistan, covers an area of 1,775 km² and lies between 31°15’ and 31°42’ north latitude 74°01’ and 74°39’ east longitude, at an altitude of 208 to 213 meters above sea level. The Badian Ravi Bombanwala (BRB) canal is another
important physiographic and ecological feature that runs across the district. The city experiences extreme weather, summer season starts in April and continues till September. May and June are very hot and dry months which end up by heavy downpour and humid sultry monsoon season. The winter season lasts from November to March with minimum temperature reaching freezing points in the months of December and January. The average annual precipitation in Lahore is 629 mm with 34 (9.3%) rainy days in a year, the mean annual minimum and maximum summer temperature ranges between 26.8 °C to 27.3 °C and 35.0 °C to 40.4 °C, respectively whereas the mean annual minimum and maximum winter temperature ranges between 6 °C to 18 °C and 4 °C to 16 °C, respectively (NESPAK and LDA 2004).

Roosts of Indian flying fox, *Pteropus giganteus* in Lahore was reported from Bagh-e-Jinnah, Governor of the Punjab residence, Mohalandar Mango garden (Roberts 1997). Lahore city and nearby areas were thoroughly searched to re-locate and to find new roosting sites (if any). 2 bat populations 1 at Jinnah garden (35°55' north latitude and 74°33' east longitudes) and other at Lalazar garden (31°28' north latitude and 74°14' east longitudes) was inhabitant by Indian flying foxes, roosting on 50 trees. GPS location of each roost was recorded using a Garmin extra H Global Positioning System (GPS) to prepare digitized maps through Arc GIS software (Figure 1 & 2). All the roosting sites were visited monthly throughout the year from May 2009 to April 2010. Data regarding roost tree species, roost tree origin (native or exotic tree species), diameter of roost at breast height (dbh), height of the roost and flowering season of the roost were recorded.

Bats were counted in each roost through direct roost count method following Kunz et al. 1996. Tree height was estimated by taking a consensus of 2 or 3 observer estimates and
circumference of the tree trunk was measured at breast height by using a measuring tape and the diameter (dbh) was calculated following Granek 2002. The flowering and fruiting of roosting trees were observed during monthly visits.

**Results and Discussion**

Fruit bats play key role in forest pollination and seed dispersal, especially in tropical, rain and cloud forests and got international conservation attention for nearly 2 decades but their populations are still declining (Fujita 1988a, 1991b; Power et al. 1996; Wiles et al. 1997). Indian flying fox, *Pteropus giganteus* in Lahore was reported from Bagh-e-Jinnah, Governor of the Punjab residence and Mohalandar Mango garden (Roberts 1997) but during present survey the bats were recorded from Jinnah garden (Bagh-e-Jinnah) and Lalazar garden (newly reported roost). Fruit bats categorize their roosts by preferring specific biotic, abiotic, and geographic factors for roosting and sturdily associated with flora and other habitat variables (Kalko 1997). The roosting sites at both localities were located near water bodies and were well surrounded by dense vegetation, sheltering the bats from wind, cold climate and sun at warmer hours of the day. *P. giganteus* prefers to roost in areas which are in close proximity of water body and are therefore more humid, as the taxon is sensitive to temperatures. Similar observations have been noted for *P. alecto* (Palmer and Woinarski, 1999) and *P. livingstonii* (Granek 2002).

In Southeast Asia, where half the world’s flying fox species are found these environment friendly creatures remained unstudied. In addition there is extensive fruit bat hunting, natural habitat loss and no official bat conservation assurance from governments (Whitmore 1997). In Pakistan, *Pteropus giganteus* is given no protection by law and are hunted by local medical practitioners for its body fats to be used as potions for rheumatic
pains (Roberts 1997). The largest south Indian fruit bat, Indian flying fox (*Pteropus giganteus*) is known to live in close proximity of humans and was observed roosting in botanical gardens, cities and villages (Krystufek 2009; Chakravarthy et al. 2008). In Pakistan, bats are considered loathsome and fearful creatures that’s why remained unexplored. During present study, the roost characteristics of *P. giganteus* in urban areas of Lahore were explored which is the first step towards ecological conservation at local level as it provides information contributing to local management. Average bat number throughout the year at Jinnah garden and Lalazar garden was 1052 and 40, respectively. At Jinnah garden, which is administratively divided into 47 plots, the roosting trees of the bats were observed in 4 plots only i.e. plot no. 4, 5, 6 and 7. These plots are located near main entry gate of the garden, covered 8.5% of the total garden area and harbored 12.3% of total trees present there in the garden territory. The bats continued to roost in these plots throughout the study period and never found roosting on any other tree outside these plots. Chakravarthy et al. (2008) reported a roosting site of *Pteropus giganteus* extending on 1 acre in Tumakooru, India. The roosting site had 50% vegetation cover of forest plantation and the roosting trees included indigenous tree species like *Acacia*, *Casurina*, *Bahunia*, *Ficus*, *Sananea* and *Tamarindus*.

Total trees at Jinnah garden were 4119, belonging to 46 families, 103 genera and 132 species while 44 trees belonging to 17 families, 19 genera and 21 species were serving as bat roost. The roosting trees include white siris, *Albizia procera* (n = 1), wood apple, *Aegle marmelos* (n = 1), Indian devil tree, *Alstonia scholaris* (n = 1), cotton tree, *Bombax cebia* (n = 2), cedrus, *Cedrela toona* (n = 1), European nettle tree, *Celtis australis* (n = 1), camphor tree, *Cinnamomum camphora* (n = 1), Indian rosewood, *Dalbergia sissoo* (n = 1), iron
bamboo, *Dendrocalamus hamiltonii* (n = 2), Indian gaabh, *Diospyros peregrina* (n = 1), rubber plant, *Ficus elastica* (n = 2), cluster fig tree, *F. glomerata* (n = 4), ficus microcarpa, *F. retusa* (n = 2), sausage tree, *Kigelia pinnata* (n = 1), mango tree, *Mangifera indica* (n = 4), rayan, *Manilkara hexandra* (n = 6), dinner plate tree, *Pterospermum acerifolium* (n = 1), drypetes, *Putranjiva roxburghii* (n = 1) jambolan plum, *Syzygium Jambolanum* (n = 9), sabino, *Taxodium mucronatum* (n = 1) and arjun, *Terminalia arjuna* (n = 1) (Table). These 21 roosting tree species belongs to 17 families viz., *Anacardiaceae*, *Apocynaceae*, *Bignoniacaeae*, *Cannabaceae*, *Combretaceae*, *Cuperssaceae*, *Ebanaceae*, *Fabaceae*, *Lauraceae*, *Malvaceae*, *Meliaceae*, *Moraceae*, *Myrtaceae*, *Poaceae*, *Putranjivaceae*, *Rutaceae* and *Sapotaceae*. Among these families 3 species (n = 3) of *Moraceae* served as roosting tree (n = 8) and maximum number of roost trees are jambolan plum (n = 9) belongs to family *Myrtaceae*. Ali (2010) documented *Caesalpinia inermis*, *Ficus bengalensis*, *Ficus religiosa*, *Ficus glomerata*, *Eugenia jambolana*, *Alstonia scholaris*, *Eucalyptus globossus*, *Polyalthiya longifolia*, *Mangifera indica* and *Artocarpus heterophyllus*, among these the major roosting tree species used by the *P. giganteus* were *C. inermis*, *F. bengalensis*, *F. religiosa* and *E. Jambolana* in western Assam.

11 native and 10 exotic tree species served as roosting trees (Table). Most of the roosts bloom in spring n = 8, Indian gaabh, jambolan plum and white sirsis showed summer blooming. Only Indian devil tree blossom in winter and rest off the roosts (n = 9) showed biannual flowering viz., camphor tree, dinner plate tree, drypetes tree, ficus microcarpa, giant bamboo, Indian rosewood tree, rayan tree, rubber plant and sausage tree. All the roosts are woody trees accept giant bamboo and rubber plant (Table). Our findings are inline with Reginald et al. (2008) who documented *Ficus religiosa*, *Tamarindus indica*,

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Albizia lebbeck, Delonix regia, Polyalthia longifolia, Acacia spp. Azadirachta indica and Samanea saman as roosting tree species for P. giganteus in a public park of Tamil Nadu, India.

The dbh of roosting trees ranges from 0.10 m (drypetes tree) to 0.89 m (sausage tree). The minimum roost tree height was recorded 7.56 m (giant bamboo) while the tallest roost tree was European nettle tree 19.8 m with diameter 0.25 m at breast height. Evelyn and David (2003) reported that the frugivorous bat species Sturnira lilium prefers to roost on tree with large diameter while Arbiteus intermedius on trees with smaller diameter.

Among total 21 roosting tree species, 5 tree species, D. peregrine, F. glomerata, K. pinnata, M. indica and S. jambolanum also served as food source for Indian flying foxes. Most of the roosting trees blossom in spring viz., A. marmelos, B. cebia, C. toona, C. australis, F. glomerata, M. hexandra, T. arjuna and T. mucronatum. Whereas, only F. retusa was biflorous and A. scholaris was hibernal species. A. procera, D. peregrina and S. jambolanum were observed as summer annual trees. C. camphora, D. sissoo and P. acerifolium showed flowering during spring and summer, D. hamiltonii and P. roxburghii blooms from winter to spring and F. elastica, K. pinnata in summer and winter. The maximum average numbers of bats 88.25 were counted on P. roxburghii and minimum numbers of bats 7.58 were recorded on M. hexandra in Jinnah garden (Table). Vendan and Kaleeswaran (2011) surveyed 4 roosting sites of Pteropus giganteus in Madurai district, India and observed that Albizia lebbek, Artocarpus integrifolia, Eucalyptus globules, Eugenia jambolana, Ficus benjamina, F. glomerata, Mangifera indica, Peltophorum ferrugineum, Tamarindus indica, Toona ciliate, Dilonex regia, Tamarindus indica, Azadiracta indica, Polyalthya longifolia, Terminalia cattapa, Millingtonia hortensis, Cocos
nucifera, F. religiosa, Tamarindus indica and Peltophorum ferrugineum trees serve as roost for Pteropus giganteus.

Lalazar is a small garden spaced on 4 acres and owns a total of 90 trees belonging to 7 families, 9 genera and 9 species while the Pteropus giganteus was roosting at 6 trees belonging to 2 families, 2 genera and 2 species. The roosting tree species include mango tree, Mangifera indica (n = 2) that blossoms in spring season and jambolan plum, Syzygium jambolanum (n = 4) that blooms in summer. Both species are native in origin (28.6%), belonging to families Anacardiaceae and Moraceae (28.6%), respectively. All roosting trees also served as food for the Indian flying foxes. According to Vendan et al. (2008) P. giganteus prefers to roost on Ficus species, E. globulus, M. indica and T. indica tree species.

The average dbh of roosting trees in lalazar garden ranged from 0.50 m to 0.55 m and the height from 13.10 m to 15.13 m. The maximum average numbers of bats 21.58 counted on S. jambolanum having minimum dbh 0.50 m and maximum height 15.18 m (tallest roosting tree observed at lalazar garden) while minimum number of average bats 18.71 were counted on M. indica with maximum dbh 0.55 m and minimum height 13.10 m (Table). According to Granek (2002), mean roost tree dbh for P. livingstonii is 0.103 m while average height is 24.35 m.

Altogether 50 roosting trees representing 21 species were serving as roost trees at both the localities. 40 trees belonging to 11 species were native viz; wood apple, Aegle marmelos (n = 1), cotton tree, Bombax cebia (n = 2), Indian rosewood, Dalbergia sissoo (n = 1), iron bamboo, Dendrocalamus hamiltonii (n = 2), Indian gaabh, Diospyros peregrina (n = 1), cluster fig tree, Ficus glomerata (n = 4), ficus microcarpa, F. retusa (n =2), mango tree,
Mangifera indica (n = 6), Rayan, Manilkara hexandra (n = 6), jambolan plum, Syzygium Jambolanum (n = 13), and arjun Terminalia arjuna (n = 1). Vendan (2003) observed that P. giganteus in Madurai region preferred Ficus species, blue gum tree, Eucalyptus globules, M. indica and T. indica for roosting. A dependence on native trees was an indication of roost characteristic preference specific to Pteropus (Nelson et al. 2000).

Seasonal shifting pattern from 1 roosting tree to another and increase and/or decrease in bats were observed at both sites. In winter fruits bats were observed roosting with closed wings at the edge of naked branches of roosting tress notably Manilkara haxandra, in summer they were observed underneath the thick foliage cover in the middle of the tree canopy flapping their 1 wing and mostly populated at Aegle mermelos, dendrocalamus hamiltonii and Ficus species. In spring and autumn the roosting trees were observed noisy almost evenly distributed bat population, whereas Diospyros peregina were observed heavily populated throughout the year and bats were usually observed walking on the branches. The roosting trees of plot no. 4 and 5 were also observed as maternal colonies with pups clinging with the mother bodies in May and June. Throughout the year maximum total number of fruit bats (n = 1059) were counted on Putranjiva roxburghii, whereas the minimum number of bats (n = 71) were counted on Manilkara hexandra. At Lalazar garden, maximum number of bats (n = 323) were counted on Syzygium jambolanum while minimum number of bats (n = 229) were observed on Mangifera indica throughout the study period (Table). Pteropus species display remarkable seasonal changes in roost composition and colony size (Mickleburgh et al. 1992; Pierson and Rainey 1992; Wiles et al. 1997) and P. giganteus with no exception, showed variation in roost sizes and roost occupancy observed during monthly surveys in spring, summer, autumn and winter seasons.
(Granek 2002). This behavior pattern was also observed in other species of the genus *Pteropus* (Mickleburgh et al. 1992).

**References**


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Table. Roost details of Indian flying fox (*Pteropus giganteus*) at Jinnah garden and Lalazar garden, Lahore.

<table>
<thead>
<tr>
<th>Family</th>
<th>Roost species</th>
<th>Common names</th>
<th>Quantity (N/E)</th>
<th>Flowering season (Type: Tree/Shrub)</th>
<th>dbh (m)</th>
<th>Height (m)</th>
<th>Roost trees serve as food</th>
<th>Average Bat Count /year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jinnah Garden</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Anacardiaceae</td>
<td>Mangifera indica</td>
<td>Mango</td>
<td>4 (N)</td>
<td>Spring (T)</td>
<td>0.17</td>
<td>13.30</td>
<td>+</td>
<td>22.58</td>
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<tr>
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<td>Indian devil</td>
<td>1 (E)</td>
<td>Winter (T)</td>
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<td>19.2</td>
<td>-</td>
<td>59.42</td>
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<td>Kigelia pinnata</td>
<td>Sausage</td>
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<td>European nettle</td>
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<td>-</td>
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<td>Arjun</td>
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<td>Spring (T)</td>
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<td>18.3</td>
<td>-</td>
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<td>Sabino</td>
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<td>Spring (T)</td>
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<td>17.4</td>
<td>-</td>
<td>30.00</td>
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<td>Ebaneeceae</td>
<td>Diospyros peregrine</td>
<td>Gaabh</td>
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<td>Summer (T)</td>
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<td>16.8</td>
<td>+</td>
<td>75.08</td>
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<td>White siris</td>
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<td>14.3</td>
<td>-</td>
<td>52.58</td>
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<tr>
<td>Dalbergia sissoo</td>
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<td>Camphor</td>
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<td>-</td>
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<td>18.2</td>
<td>-</td>
<td>63.83</td>
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<td>Ficus elastica</td>
<td>Rubber</td>
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<td>0.34</td>
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<td>-</td>
<td>29.92</td>
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<td>Clusters fig</td>
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<td>0.17</td>
<td>15.63</td>
<td>+</td>
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<td>Jambolan plum</td>
<td>9 (N)</td>
<td>Summer (T)</td>
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<td>15.11</td>
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<td>7.56</td>
<td>-</td>
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<td>Drypetes</td>
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<td>Aegle marmelos</td>
<td>Giant bamboo</td>
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<td>17.5</td>
<td>-</td>
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<td>Species Name</td>
<td>Common Name</td>
<td>symbols</td>
<td>season &amp; temperature</td>
<td>Height</td>
<td>Width</td>
<td>Shape</td>
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<td>Sapotaceae</td>
<td><em>Manilkara hexandra</em></td>
<td>Drypetes</td>
<td>1 (E)</td>
<td>Spring &amp; Winter (T)</td>
<td>0.25</td>
<td>14.47</td>
<td>-</td>
<td>7.58</td>
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<tr>
<td>Lalazar Garden</td>
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<tr>
<td>Anacardiaceae</td>
<td><em>Mangifera indica</em></td>
<td>Mango</td>
<td>4 (N)</td>
<td>Spring (T)</td>
<td>0.55</td>
<td>13.10</td>
<td>+</td>
<td>18.71</td>
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<tr>
<td>Myrtaceae</td>
<td><em>Syzygium Jambolanum</em></td>
<td>Jambolan plum</td>
<td>4 (N)</td>
<td>Summer (T)</td>
<td>0.50</td>
<td>15.13</td>
<td>+</td>
<td>21.58</td>
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</table>
Figure 1. GIS based map of Jinnah Garden showing roosts of Indian flying fox populations.
Figure 2. GIS based map of Lalazar Garden showing its boundary and roosts of the Indian flying fox populations.
EXPERIMENT NO. 2

Title: To assess temporal and spatial variation in the diet of the Indian flying fox.

Publications

3.2.1 Microbial analysis of Indian flying fox (*pteropus giganteus*) ejecta collected from two public parks in Lahore, Pakistan.

3.2.2 Proximate analysis of Indian flying fox (*Pteropus giganteus*) natural food with a note on their roost count variations in urban areas of Lahore, Pakistan.
Microbial analysis of Indian flying fox (*Pteropus giganteus*) ejecta collected from two public parks in Lahore, Pakistan.

Abstract

Chiropterans (bats) ejecta was known important for having economic, ecological and zoonotic values. The aim of this study was to document variety of fungal and bacterial genera and NPK values from Indian flying fox, *Pteropus giganteus* ejecta. The microbes isolated from ejecta were subjected to both macroscopic and microscopic observations to characterize their morphology. Microbial analysis of the *P. giganteus* ejecta roosting at Jinnah and Lalazar garden, Lahore was carried out from January, 2011 through December, 2011 and a total of twelve fungal and twelve bacterial genera were isolated. Four fungal (*Candida, Fusarium, Penicillium* and *Saccharomyces*) and two bacterial genera (*Klebsiella* and *Nocardia*) were isolated from bolus only, three fungal (*Cryptococcus, Histoplasma* and *Trichophoton*) and six bacterial (*Acaligens, Azotobacter, Bartonella, Nitrosomonas, Paeudomonas* and *Salmonella*) genera were isolated from guano while five fungal (*Alternaria, Aspergillus, Chrysosporium, Exophila* and *Scopulariopsis*) and four bacterial (*Bacillus, Corynebacterium, Listeria* and *Streptomycete*) genera were common in bolus and guano samples. Seasonal variations were recorded in occurrence of various fungal and bacterial genera. From bolus samples, two fungal *Aspergillus* and *Fusarium* and one bacterial *Bacillus* genera were recorded throughout the year while from guano *Bacillus* was the only genus with year round occurrence. Microbial analysis shows that Indian flying fox ejecta are an amalgam of beneficial and pathogenic microbes and its pH (6.7 to 7.4), high concentration of phosphorus (4.50% and 4.33%) and nitrogen (3.26% and 2.37%) favour seed germination, enhance root growth and soil fertility.

**Keywords:** Fruit bat, jinnah garden, pathogen, bolus, guano
Introduction

The fruit bats are important reservoirs of many pathogens, some of which have been reported to be associated with many diseases like rabies (Paez et al. 2003), European lyssavirus (Fooks et al. 2002), Hendra (Halpin et al. 2000) and Menangle (Bowden et al. 2001) in Australia, Nipah and Tioman viruses in Malaysia (Chua et al. 2002a, b) and hantaviruses in Korea (Kim et al. 1994; Chua et al. 2005). Ejecta of the fruit bats supports a great diversity of organisms including arthropods, fungi, bacteria and lichens (Ferreira & Martins 1998) and are most common sources of pathogenic and other mycofauna distribution. The differences in composition of bats’ ejecta suggest that bats in different feeding guilds may affect ecosystem structure and dynamics (Justin & Roark 2007).

Due to the close proximity of bats with humans and domestic animals, it is possible that they had important role in the epidemiology and zoonoses. The contact of bats with humans and domestic animals are either direct or indirect, for example through many hematophagus arthropods such as mosquitos, ticks, (Pavslovsky 1996) and cone-nosed bugs (Albuquerque and Barreto, 1968) feeds on bats, domestic animals and man. They are thought to be transferring half of the communicable diseases in man and act as a reservoir, intermediate host or vector of various pathogens (Freitas et al. 1960). The fungi related to bat excreta are mostly limited to the places where bat guano is frequently abundant (Darling 1906). The association between bats and pathogenic fungi was first reported by Emmons (1958) who isolated *Histoplasma capsulatum* from soil contaminated by bat guano in Maryland. Over the next two decades, approximately 30 chiropteran species were identified as hosts for pathogenic fungi (Ajello et al. 1977; Carvajal 1977; Reis and Mok 1979).
Bat guano had also reported to contain beneficial fungi and bacteria, which act as a natural fungicide to protect plants from disease. Bacteria and fungi play important role to maintain soil health. Bacteria are necessary for plant growth on new fresh sediments. Bacteria fix atmospheric nitrogen and carbon, produce organic matter and immobilize enough nitrogen and other nutrients to initiate nitrogen cycling process in the soil (Lane and Diver 2000). The clay is the most abundant of all the minerals in the fresh guano while others include quartz and traces of dolomite and calcite. The most abundant elements in bat guano are nitrogen and phosphorus. The total nitrogen ranges between 8 – 12 % and P2O5 ranges between 2 – 7 %. Other elements include calcium, magnesium, potassium, aluminum, iron and sulphur that are present in quantities lower than 5 % each (Ruth et al. 2004). Differences in community structure of the microbes inhabiting the guano may be due to differences in guano composition of frugivorous (Pteropus rodricensis), sanguivorous (Desmodus rotundus), and insectivorous (Tadarida brasiliensis) bats. Desmodus guano contained more carbon (C) than Pteropus guano. The latter contained less nitrogen (N), and the former contained less phosphorous (P) than guano of the other two species. Pteropus guano had a higher C to N ratio, and Desmodus guano had higher N to P and C to P ratios than the other two species. These differences in guano composition suggest that guano from bats in different feeding guilds may affect ecosystem structure and dynamics differently (Justin and Roark 2007).

There is a loophole of specific studies on degradation of species specific bat guano, in general the most abundant organisms in soil that contribute to organic matter decomposition are bacteria and fungi. Marinkelle and Grose (1972) documented infectious pathogenic micro-organisms isolated from bats that affected man or domestic animals these are Salmonella spp., Spirocheaeta spp. and Leptospira spp. Numerous micro-organism like Bartonella rochalima and Grahamella
spp. etc are also reported from the bats which are considered harmless to man and domestic animals or reported as doubtful pathogens due to the fact they are apparently not potential pathogens. There are number of medically significant fungal species isolated from the excreta of bats are Cryptococcus neoformans, C. laurentii, Histoplasma capsulatum and Sporothrix schenckii (Reis and Mok 1979; Takashi et al. 2005). Keeping in view the clinical, economical, and environmental significance of fungi, bacteria and minerals found in bat ejecta the present study was designed to ascertain microbial load and mineral composition in bolus and guano of Indian flying fox (Pteropus giganteus) roosting in urban areas of Lahore.

**Material and methods**

**Study area**

Present study, extending from January, 2011 to December, 2011 was conducted in two public parks i.e. Jinnah garden (31°33′3.56″N 74°19′7.74″E) and Lalazar garden (31°28′N 74°14′E) in Lahore, the second most populated city of Pakistan. The city experiences extreme summer and winter seasons, the summer season is followed by rainy and humid monsoons season. The Jinnah garden covers an area of 176 acres (0.71 km²) with Indian flying fox, Pteropus giganteus population ranging from 3000 to 4000 individuals while at Lalazar garden which is smaller in size and stretched over an area of 04 acres (0.02 km²), the populations ranges from 800 to 1000 individuals. Both the public parks are permanent open day roosts of the Indian flying foxes (Pteropus giganteus) and governed by Pakistan Horticulture Authority (PHA).

**Sampling strategy**

The ejecta (bolus and guano) of Indian flying foxes were collected by spreading a polythene sheet of 1 m × 1 m under the roosting of Indian flying fox, Pteropus giganteus. Out of total 47
plots at Jinnah garden, the *P. giganteus* was roosting in four plots. Four polythene sheets, one in each plot were placed at Jinnah garden while one polythene sheet was spread under the roosting canopies at Lalazar garden once a month for the whole year. Each sheet remained spread for ten hours i.e. from 2000h Pakistan Standard Time (PST) till 6000h PST and was removed on the subsequent day. The ejecta were randomly collected and were placed in polythene bags along with the tags indicating garden, roost number, plot number and date (Mahmood et al. 2010).

Twelve monthly samples of bolus and guano were lumped together into four seasonal samples. The February, March and April samples were named as spring sample. All the remaining monthly samples were also lumped together in the same way and designated as summer (May, June, July), autumn (August, September, October), and winter (November, December, January) samples, respectively. From each of the three monthly samples, 333.3 mg of bolus and guano was used for microbial analysis in such a way that the combined seasonal sample weighed 1 g. The pH of each seasonal sample was observed on pH meter (Mahmood et al. 2010).

**Fungal analysis**

Fumigated incubators, sterilized glass-wares and autoclaved apparatus were used to prevent environmental contamination. One gram of sample was transferred in 10 ml (v/w) normal saline solution to prepare five concentrations of serial dilution ranging from $10^{-1}$ up to $10^{-5}$ which were used for further identification of fungi present in the bolus and guano samples.

Sabouraud dextrose agar (16.25 g) and agar agar (5 g) media were diluted with 250 ml of distilled water, shaken, boiled, autoclaved for 45 minutes and poured in Petri dishes. 0.1ml of each dilution was spread on media in Petri dishes and left for incubation at room temperature for 72 hours. The fungal growth was then monitored and were counted manually, petri plate with more than or equal to four fugal colonies were processed further for purification and
identification while the others were neglected.

Fungal colonies were purified by picking the growth with platinum loop from each different type of colony and were placed in separate petri plates and again incubated for 72 hours. The slides were then prepared from each purified colony and stained with Congo red and sealed with DPX. These permanent fixed slides were then observed under microscope (ML 5100) for identification. Macroscopic and microscopic characters of colonies were observed and genera were identified following Emmons et al. (1977).

**Bacterial analysis**

Seven grams of nutrient agar and 0.25 g agar agar was diluted with 250 ml of distilled water and shaken well, autoclaved for 45 minutes and were poured in 8 Petri plates. 0.1 ml of each dilution of the bolus and guano was spread separately on media in Petri plates and were left for incubation for 24 hours at room temperature. The bacterial growth was then checked and bacterial colonies were counted on bacterial counter (Keunzahlgerat BZG 28). Those Petri plates in which bacterial colonies ranged from 30 to 300 were further processed for purification and identification while the remaining were neglected. Bacterial colonies were purified by picking the growth with platinum loop from each different type of colony and were three way streaked in separate Petri plates and again incubated for 24 hours. The slides were then prepared from each purified colony, stained by gram staining method and were observed under microscope (ML 5100) for identification (Aaronson 1970; Cruickshank 1975).

**Mineral composition**

Each lumped seasonal sample (10 g) of both guano and bolus was incubated at room temperature in a pan for 24 hours. The samples were analyzed after incubation to determine the level of different minerals present in them. The samples were weighed and dried in an oven at
105 °C for 24 hours and placed in separate plates. A small part of the dry matter (5 g) was ashed at 650 °C for 4 hours in respected crucibles (of each season) in an electric furnace. 10 ml of nitric acid was added in each of these 5 g ashed samples then the flasks were kept in water bath at 65°C for 15 minutes. Perchloric acid (HClO₄), (5 ml) was then added to the flask and kept in water bath at 75°C for 15 minutes. The samples were then dried on hot plate till the fluid reached to 0.5 ml. After proper filtration, the samples were raised to 50 ml solution by repeated washing (Elaroussi et al. 1994). The mineral composition was estimated using atomic absorption spectrophotometer.

**Results and discussion**

During present study, a total of twelve fungal genera representing nine families were isolated from bolus and guano samples of Indian flying fox, *Pteropus giganteus*. These genera included *Alternaria*, *Aspergillus*, *Candida*, *Chrysosporium*, *Cryptococcus*, *Exophiala*, *Fusarium*, *Histoplasma*, *Penicillium*, *Saccharomyces*, *Scopulariopsis* and *Trichophyton*. Nine fungal genera were isolated from bolus and eight from the guano of Indian flying fox. Genus *Aspergillus* (*n = 7*) was most recorded while *Histoplasma* (*n = 1*) and *Trichophyton* (*n = 1*) were least recorded genera. Four of the isolated genera viz. *Candida*, *Fusarium*, *Penicillium* and *Saccharomyces* were isolated only from bolus of the Indian flying foxes whereas *Cryptococcus*, *Histoplasma* and *Trichophyton* were observed from isolated from guano samples only (Table 1). Goveas et al. (2006) observed that *P. giganteus* bolus samples contain more fungi while the guano. Takashi et al. (2005) reported *Candida lusitaniae* and *Debaryomyces hansenii* from bat guano.

Seasonal variations had been observed among the nine fungal genera isolated from bolus samples of the Indian flying fox during all the four seasons viz. spring, summer, autumn and winter. *Alternaria* and *Chrysosporium* were the genera isolated only in spring, *Scopulariopsis*
was isolated only in autumn whereas rest of the genera were isolated in two seasons as *Candida* and *Fusarium* in spring and autumn, *Penicillium* in spring and winter, *Exophiala* in summer and autumn and *Saccharomyces* was isolated in summer and winter season. *Aspergillus* was the only genus recorded in all of the four seasons. Seelan et al. (2008) observed 23 species of bats out of which 13 (56.5%) species were found to contain 17 fungal isolates of the genus *Aspergillus*. Maximum numbers of fungal colonies ($6.0 \times 10^5$ cfu/gm) from bolus were counted in spring season while minimum number of colonies ($4.0 \times 10^3$ cfu/gm) was counted in summer season (Table 2). Goveas et al. (2006) documented *Fusarium* and *Penicillium* as common fungal genera in bolus and guano of Indian flying fox.

Seasonal variations were also noted regarding occurrence of fungal genera in guano samples of Indian flying fox, *Pteropus giganteus*. A total of eight genera were isolated from guano during all the four seasons. Out of these, *Exophiala* and *Histoplasma* were isolated during spring season only; *Scopulariopsis* was isolated during summer and *Trichophyton* during autumn only. *Chrysosporium* and *Cryptococcus* were isolated in summer and winter season while *Alternaria* and *Aspergillus* were recorded in spring, autumn and winter. No genus was recorded in all the four seasons. Maximum number of fungal colonies ($4.0 \times 10^4$ cfu/gm) from guano were counted in spring while minimum number of colonies ($3.0 \times 10^4$ cfu/gm) were counted in autumn season (Table 2). Seelan at al. (2008) documented the diversity of *Aspergillus* species by isolating six species of *Aspergillus* from 13 species of bats. The abundance and diversity of isolated fungal genera is also correlated with food sources and the roosting site of the bats. Yamamoto et al. (1995) investigated that the bat guano may mediate the exchange of pathogenic fungi just as pigeon excreta mediate the exchange of *Cryptococcus neoformans*, the causative agent of cryptococcosis. Apart from that, fruits consumed by these frugivore bats are also important
factor in understanding the ecology of bats. Sometimes the infected fruit may contain pathogenic micro-organisms that may be present during the fruit decay process (Sepiah, 1985). So, this would be a key factor how the fungi are transmitted to bats since frugivorous bats consume fruits as their main diet.

**Macroscopic and microscopic characters of all the twelve genera were described (Table 1).**

Twelve bacterial genera namely *Acaligens, Azotobacter, Bacillus, Bartonella, Corynebacterium, Klebsiella, Listeria, Nitrosomonas, Nocardia, Pseudomonas, Salmonella* and *Streptomyces* were isolated from ejecta of *Pteropus giganteus*. *Bacillus* was the only bacterial genus recorded in all the seasons from ejecta while *Azotobacter, Bartonella, Nitrosomonas* and *Salmonella* were recorded once a year. Six out of ten genera isolated from only guano included *Acaligens, Azotobacter, Bartonella, Nitrosomonas, Pseudomonas* and *Salmonella* whereas two genera *Klebsiella, and Nocardia* were isolated from bolus samples only. Four genera *Bacillus, Corynebacterium, Listeria* and *Streptomyces* were represented in both bolus and guano samples of Indian flying fox (Table 2). The bacteriological examination of bolus and guano of the Indian flying fox done by Goveas et al. (2006) revealed the presence of *Alcaligenes* and *Pseudomonas* in guano, and *Bacillus, Klebsiella* and *Proteus* in bolus. Among actinomycetes, *Streptomyces* were common in guano and *Micromonospora* in bolus.

Mineral composition of bolus of Indian flying fox was analyzed in four seasonal samples. The pH of fruit bat bolus is near acidic to neutral ranges between 6.7 and 7.4. The most abundant elements in bolus are phosphorus and nitrogen whereas potassium is less abundant. The total nitrogen ranges between 2.28 % and 4.10 % in bolus which are higher than that in guano. Total
phosphorus ranges between 3.50 % and 5.0 % and total potassium ranges between 0.6 % and 0.74 % (Table 2).

pH of bat guano varied from 7.1 to 7.4 with nitrogen and phosphorus contents ranging from 2 % to 3.30 % and 3.10 % to 5.20 % respectively (Table 2). The studies of Goveas et al. (2006) revealed higher nitrogen, phosphorus and potassium in the bolus than the guano (3.3:4.3:0.7 vs 2.6: 4.2:0.6) of the Indian flying fox (Pteropus giganteus). Ruth et al. (2004) documented that nitrogen and phosphorus were the most abundant elements in bat guano. The total nitrogen ranges between 8 – 12 % and P2O5 ranges between 2 – 7 %. Other elements include calcium, magnesium, potassium, aluminum, iron and sulphur that are present in quantities lower than 5 % each.

In this study, the NPK values, fungal and bacterial load in guano and bolus of the Indian flying foxes were analyzed. The result showed higher nitrogen percentage in bolus than guano whereas phosphorus and potassium percentages were higher in guano of these bats. Nitrogen in guano is known to enhance crop growth while phosphorus provokes root development, shoots, budding, multiple branches and flowering in plants. Like other bat guano studies the present study clearly indicated that ejecta of the Indian flying foxes could be significantly used with appropriate ratios with soil to increase the growth, dry matter and productivity of plant and crops.

The fungal and bacterial analyses brought forward the presence of some useful and some pathogenic genera in bolus and guano of the Indian flying fox. Among 12 fungal genera Aspergillus, Penicillium and Saccharomyces are used in drug production, food making and fermentation. The maximum species of Candida, Cryptococcus, Fusarium and Scopulariopsis are harmless and are useful soil microbes. While the genera Alternaria, Chrysosporium,
Exophila, Histoplasma and Trichophyton are infectious and pathogenic either to humans, animals or plants. Among bacterial genera, Alcaligenes, Azotobacter, Nitrosomonas and Corynebacterium have economical and industrial significance and are also important in Nitrogen-cycle and N₂ fixative bacteria in environment. Some members of Streptomyces are pathogens while two third of them are important in medicine production and also plays important role in decaying vegetation. Nocardia species constitute major useful oral micoflora while some are pathogens. Species of Bartonella, Klebsiella, Listeria and Salmonella are infectious and pathogens. The members of Pseudomonas are important bio-control and bioremediation agents whereas some species are pathogenic.

References


Marinkelle CJ and Grose ES. 1972. A review of bats as carrier of organisms which are capable of infecting man or domestic animals. Mitteilungen aus dem Institut Colombo-Aleman de Investigaciones Cientificas 6:31-51.


### Table 1. Macroscopic and microscopic characters of fungal genera extracted from ejecta of *Pteropus giganteus* roosting at Jinnah and Lalazar garden, Lahore.

<table>
<thead>
<tr>
<th>Genera</th>
<th>Macroscopic Features</th>
<th>Microscopic Features</th>
<th>Source</th>
<th>No. of Isolates</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alternaria</em></td>
<td>Grows rapidly and the colony size reaches a diameter of 3 to 9 cm. The colony was flat, downy to woolly and covered by grayish, short, aerial hyphae in time. The surface, greyish white at the beginning which later darkens and becomes greenish black or olive brown with a light border. The reverse side, typically brown to black due to pigment production.</td>
<td>Septate, brown hyphae. Conidiophores septate and brown in color, occasionally producing a zigzag appearance, bearing simple or branched large conidia (7-10 x 23-34 µm) which had both transverse and longitudinal septations. Conidia, ovoid to obclavate, darkly pigmented, muriform, and smooth or roughened. The end of the conidium nearest the conidiophore is round while it tapers towards the apex. This gives the typical beak or club-like appearance of the conidia.</td>
<td>Bolus and guano</td>
<td>4</td>
</tr>
<tr>
<td><em>Aspergillus</em></td>
<td>Colonies are downy to powdery in texture. The surface initially white, quickly becoming black with conidial production. Reverse is pale yellow and growth may produce radial fissures in the agar.</td>
<td>Hyphae septate and hyaline. Conidial heads radiate initially, splitting into columns at maturity. Conidia brown to black, very rough, globose, and measure 4-5 µm in diameter. Conidiophores are long (400-3000 µm), smooth, and hyaline, becoming darker at the apex and terminating in a globose vesicle (30-75 µm in diameter). Metulae and phialides cover the entire vesicle.</td>
<td>Bolus and guano</td>
<td>7</td>
</tr>
<tr>
<td><strong>Candida</strong></td>
<td>The colonies are cream colored, grow rapidly and mature in 3 days. The textures of the colonies are pasty and glistening.</td>
<td>Abundant, branched pseudohyphae and true hyphae with blastoconidia are present. The blastoconidia are formed in grape-like clusters along the length of the hyphae.</td>
<td>Bolus</td>
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<tr>
<td><strong>Chrysosporium</strong></td>
<td>Colonies grow moderately rapidly at 25°C. The morphology of the colonies was variable, granular, woolly, cottony and flat, or raised and folded in appearance. From the front, the color was white cream, yellow to tan to pale brown. The reverse color white to brown.</td>
<td>Hyphae septate while the conidia hyaline, broad-based, one-celled, and smooth- or rough-walled. Conidia are broader than the vegetative hyphae and occur terminally on pedicels, along the sides of the hyphae, or in intercalary positions. Arthroconidia, on the other hand, abundant and larger than their parent hyphae in diameter.</td>
<td>Bolus and guano</td>
<td>3</td>
</tr>
<tr>
<td><strong>Cryptococcus</strong></td>
<td>Colonies, fast growing, soft, glistening, usually mucoid, and cream to beige in color.</td>
<td>Produced round, budding yeast cells. No true hyphae and pseudo hyphae are absent.</td>
<td>Guano</td>
<td>2</td>
</tr>
<tr>
<td><strong>Exophiala</strong></td>
<td>Initially yeast-like, moist, and brownish to greenish black in color, becomes velvety due to development of short, aerial grayish hyphae. The front color, olivaceous-black and the reverse was black in mature colonies.</td>
<td>Septate hyphae which bear conidiogenous cells (annelides). The annelids, tubular and rocket-shaped and typically taper to form a narrow elongated tip. Ellipsoidal, conidia (1-3x3-6 µm) produced from the annelides.</td>
<td>Bolus and guano</td>
<td>3</td>
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<tr>
<td><strong>Fusarium</strong></td>
<td>Grow rapidly on Sabouraud dextrose agar at 25°C and produce woolly, cottony, flat, spreading colonies. The front color of the colony, cream to yellow orange. The reverse side colorless.</td>
<td>Hyphae are septate and hyaline. Conidiophores are simple, Macroconidia are moderately curved, stout, thick-walled, usually 3-5 septate and are borne on short conidiophores that soon form sporodochia. Microconidia are borne from long monophialides, are one to three-celled and occur in</td>
<td>Bolus</td>
<td>2</td>
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<tr>
<td><strong>Histoplasma</strong></td>
<td>Thermally dimorphic fungus, colony was creamy, slow growing moist and yeast-like. The color was white initially and became buff brown with age. From the reverse, a yellow to yellowish orange in color.</td>
<td>Narrow-based, ovoid, budding yeast cells were formed</td>
<td>Guano 1</td>
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<tr>
<td><strong>Penicillium</strong></td>
<td>The colonies of <em>Penicillium</em> are rapid growing, flat, filamentous and velvety in texture. The colonies were initially white and become blue green with time. The plate reverse, pale to yellowish</td>
<td>Septate hyaline hyphae, branched conidiophores, metulae, phialides, and conidia were observed. Phialides were typical, formed brush-like clusters. The conidia were round, unicellular, and visualized as unbranching chains at the tips of the phialides.</td>
<td>Bolus 2</td>
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<tr>
<td><strong>Saccharomyces</strong></td>
<td>Colonies grow rapidly flat, smooth, moist, glistening, and cream to tannish cream in color.</td>
<td>Blastoconidia was observed, unicellular, globose, and ellipsoid to elongate in shape. Multilateral (multipolar) budding is typical. Hyphae absent.</td>
<td>Bolus 2</td>
<td></td>
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<tr>
<td><strong>Scopulariopsis</strong></td>
<td>colonies grow moderately rapidly and matured within 5 days, granular in texture. The front color, white initially and became light brown tan with time. Reverse color, tan with brownish center.</td>
<td>Septate, hyphae, conidiophores, annelides, and conidia were observed. Conidiophores was hyphae-like and branched. Conidia are one-celled, globose to pyriform, smooth, but more commonly rough-walled, spiny, truncate, and forming basipetal chains.</td>
<td>Bolus and guano 2</td>
<td></td>
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<tr>
<td><strong>Trichophyton</strong></td>
<td>The growth rate was slow to moderately rapid. Texture</td>
<td>Septate, hyaline hyphae, conidiophores, microconidia,</td>
<td>Guano 1</td>
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was waxy, the front color was white to bright yellowish beige. Reverse was pale yellowish brown. macroconidia, and arthroconidia were observed. Conidiophores poorly differentiated from the hyphae. Miroconidia (microaleuriconidia), one-celled and round. Macroconidia (macroaleuriconidia), multicellular (2- or more-celled), smooth, thin- or thick-walled, cylindrical and clavate.
Table 2. Seasonal variations in occurrence of various fungal and bacterial genera from bolus and guano samples of Indian Flying fox (Pteropus giganteus) roosting at Jinnah and Lalazar garden, Lahore.

<table>
<thead>
<tr>
<th>Season</th>
<th>Fungal cfu/gm</th>
<th>Fungal Genera</th>
<th>Bacteria cfu/gm</th>
<th>Bacterial Genera</th>
<th>Mineral Composition</th>
<th>Fungal cfu/gm</th>
<th>Fungal Genera</th>
<th>Bacteria cfu/gm</th>
<th>Bacterial Genera</th>
<th>Mineral Composition</th>
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<td>BOLUS</td>
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<td>Spring</td>
<td>6.0×10⁵</td>
<td>Alternaria</td>
<td>7.6×10⁵</td>
<td>Bacillus</td>
<td>4.10 4.60 0.60</td>
<td>4.0×10⁴</td>
<td>Alternaria</td>
<td>6.7×10⁶</td>
<td>Alcaligenes</td>
<td>2.50 4.10 0.60</td>
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<td></td>
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<td>Aspergillus</td>
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<td>Corynebacterium</td>
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<td>Chrysosporium</td>
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<td>Penicillium</td>
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<tr>
<td>Summer</td>
<td>4.0×10³</td>
<td>Aspergillus</td>
<td>3.5×10⁵</td>
<td>Bacillus</td>
<td>3.36 3.50 0.66</td>
<td>3.0×10⁷</td>
<td>Chrysosporium</td>
<td>8.9×10⁴</td>
<td>Alcaligenes</td>
<td>3.10 3.10 0.56</td>
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<td>Saccharomyces</td>
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<td>Nocardia</td>
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<td>Autumn</td>
<td>5.0×10⁵</td>
<td>Aspergillus</td>
<td>8.0×10⁷</td>
<td>Bacillus</td>
<td>2.28 4.90 0.70</td>
<td>4.0×10⁴</td>
<td>Alternaria</td>
<td>4.0×10⁴</td>
<td>Bacillus</td>
<td>2.00 4.90 0.64</td>
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<td></td>
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<td>Corynebacterium</td>
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<th>Exophiala</th>
<th>Klebsiella</th>
<th>Trichophyton</th>
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<td></td>
<td>Fusarium</td>
<td>Listeria</td>
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<td>Streptomyces</td>
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<td>Scopulariopsis</td>
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<td>Streptomyces</td>
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<td>Winter</td>
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<td>Aspergillus</td>
<td>Alternaria</td>
<td>Alcaligenes</td>
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<td>4.0×10^4</td>
<td>7.6×10^5</td>
<td>2.28 4.90 0.70 3.0×10^7</td>
<td>5.6×10^6</td>
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<td></td>
<td>Penicillium</td>
<td>Corynebacterium</td>
<td>Aspergillus</td>
<td>Bacillus</td>
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<td></td>
<td>Saccharomyces</td>
<td>Klebsiella</td>
<td>Chrysosporium</td>
<td>Corynebacterium</td>
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<td>2.28 4.90 0.70 3.0×10^7</td>
<td>Cryptococcus</td>
<td>Pseudomonas</td>
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Proximate analysis of Indian flying fox (Pteropus giganteus) natural food with a note on their roost count variations in urban areas of Lahore, Pakistan.

Abstract

Food habits of Indian flying fox, Pteropus giganteus roosting at Jinnah and Lalazar gardens were assessed by their ejecta collected from two locations, Jinnah and Lalazar gardens in Lahore. Thirty two plant species belonging to 23 genera and 15 families served as food for Indian flying fox at Jinnah and Lalazar gardens, Lahore. Out of total 32 species (8 native and 24 exotic), six are edible, 13 commercially important while 19 species have no mercantile values. Seasonal variations were observed in the diet of P. giganteus and proximate analysis revealed that these bats consume fruits containing comparatively higher moisture content during summer; carbohydrates, fibers, protein, fats, phosphorous, iron and sodium during winter; fruits having relatively higher calcium and vitamin C are preferred during autumn and phosphorous rich diets during spring. The roosting trees (n = 50) representing 17 families, 19 genera and 21 species were monitored throughout the study period to record the abundance and roost fidelity of Indian flying fox. All trees served as permanent bat roosts however the number of bats varied from minimum (n = 111) on Manilkara hexandra to maximum (n = 1059) on Putranjiva roxburghii. Similarly, seasonal variations were observed regarding number of bats on different tree species. Mean maximum bats (n = 425) were recorded on Dalbergia sissoo during summer, on Kigelia pinnata (n = 270) in spring, Celtis australis (n = 374) in autumn and Cedrela toona (n = 330) in winter.

Key words: Roost. abundance. season. food species. ejecta.

Introduction

Pteropus giganteus (Indian flying fox) plays significant roles in ecosystem maintenance and in assemblage of local plant communities as strong mutualistic interaction exist between native mammals and vegetations. P. giganteus is one of the largest flying fox,
and forms large communal open day roosts on trees in public parks, village surroundings, towns, home gardens, temples, roadside plantations, agricultural fields and factory campuses (Digana et al. 2000; Louis et al. 2008; Yapa et al. 2000). In Pakistan, urban and rural roosting sites of *P. giganteus* were recorded from Sialkot (USNM), Lahore, Maralla, Renala Khurd and Said Pur in Punjab, and Jacobabad, Shahpur and Karachi in Sindh. Roosts comprised of hundreds of these flying foxes were observed on *Ficus* trees at Governor of the Punjab residence in Lahore, banyan trees (*Ficus bengalensis*) near Islamabad, paper mulberry grooves (*Broussonetia papyifera*) on the shores of Rawal Lake and *Albizia* trees near road to Lehtrar (Roberts 1977). *P. giganteus* is limited to the tropical regions and assumed to be locally threatened due to Urbanization resulted in deforestation (IUCN 2013). The limited data is available regarding roost variation, feeding habits and nutritional requirements of species in Pakistan and one of the most persecuted flying foxes species in South Asia (Molur et al. 2007). The *P. giganteus* enlisted on Appendix II of CITES and population monitoring needed to establish major threats and overall declines (Molur et al. 2002).

Previous nutritional studies on flying foxes identified the organic nutrient protein (nitrogen) was the major limiting nutrient in the diet as it was assumed that flying foxes consumed only fruits and did not supplement their diet with other foods (Thomas 1984; Herbst 1986; Steller 1986). However, later research showed that the diet of flying foxes includes much more than just fruit (Banack 1996; Courts 1998). Flying foxes had been reported as deliberately ingesting insects, pollen, and leaves, possibly to provide extra protein in the diet and limited record of seed predation was also reported in frugivores bats. A major biological advantage of seed predation that seeds contained developing embryo with nutriment. Compared to other plant tissues seeds had relatively little water with concentrated nutrients enclosed within, even on dry weight basis generally have higher nutrient contents then roots, stems and leaves and this may explain why granivory is more widespread (Drew
Food choice may be influenced by a myriad of factors, including energy needs, requirements for specific nutrients, reproductive status, constraints of the digestive system, abundance, diversity, and seasonality of different food items, and competition and predation (Fleming 1988; Oftedal 1991). In response to the loss of native fruit species, flying foxes are likely to be attracted by introduced fruit species, some of which are of commercial value (Charles-Dominique 1991). Flying foxes acquire shelter and energy from plants and in turn disperse pollen and seeds from plant; thus transported hundreds of economically important plant species (Ganesh & Davidar 2001). The pollination and seed dispersal roles inferred from the diet studies of *P. giganteus* in urban areas of Lahore concluded that the ecological services rendered by these bats outweigh the losses, such as damage to the ripe fruit (Mahmood-ul-Hassan et al. 2010). The loss of this important regulatory service performed by the *P. giganteus* may severely jolt the agricultural production, the conservation of this beneficial species should be ensured in government policies and private land management toward conservation of natural ecosystems (Kunz et al. 2011).

The decline in *P. giganteus* populations is a consequence of habitat destruction, deforestation, urbanization and conflict between bats and fruit growers due to crop damage over the past few decades (Roberts 1997; Walker & Molur 2003). Apart from their number of ecological services like food, fiber, fuel, fertilizer seed dispersal and pollination provided direct benefits to humans the *P. giganteus* considered as pest in Pakistan and had given no protection by law (Mahmood-ul-Hassan et al. 2009; Kunz et al. 2001). The first step to conservation of this species in Pakistan is to determine the population status of *Pteropus giganteus* in the country and understand the interaction of these species with local plant communities. The present study was therefore designed to assess the seasonal roost variations
and generates the base line data on number of bats present in Lahore and nutritive composition of food items of *P. giganteus* of their own choices in particular seasons will be helpful to meet the nutritional requirements for feeding flying foxes in captivity.

**Materials and methods**

**Study area**

This one year study extending from January, 2011 through December, 2011 was conducted in Lahore, second most populous city of Pakistan. The city lies at an altitude of 208-213 meters above mean sea level and experiences extreme summer and winter seasons and annual temperature fluctuates between 4 °C to 40.4 °C (NESPAK & LDA 2004). Annual rainfall is 629 mm but the rains are more frequent during Monsoon season (July-September). Two roosting sites of Indian flying fox (*Pteropus giganteus*) were recorded from Jinnah garden (35°55' north latitude and 74°33' east longitudes) and Lalazar garden (31°28' north latitude and 74°14' east longitudes), Lahore. Jinnah garden is rectangular in shape and covers an area of 140 acres, there are managerial divisions and the garden has been divided into 47 plots. Roosts of *P. giganteus* were observed on the trees in four plots i.e. plot number four, five, six and seven. All these plots are located near the entry gate. Lalazar is a small garden covering four acres of land and has no managerial divisions. Badian Ravi Bombanwala (BRB) canal is a common physiological feature that runs with the distance of few meters nearby both gardens.

**Food analysis**

Bolus and guano samples of Indian flying fox, *Pteropus giganteus* were collected from the study area on monthly basis for a period of one year. For collection of ejecta, a polythene sheet (1m×1m in size) was spread directly under the roosts overnight and the bolus and guano samples were collected randomly on subsequent day and processed further. The
seeds were separated from ejecta and were identified through visual inspection and comparing with reference seeds. The unidentified seeds were germinated and germination involved transferring the unidentified seeds to small plastic pots containing wet cotton under natural conditions of temperature and day length (Hodgkison et al. 2003). The seedlings were then transferred to pots containing soil and were allowed to grow for 3 to 4 weeks until identified (Mahmood-ul-Hassan et al. 2010).

**Proximate Analysis**

Seeds are valued for both nutritional and economic values and a rich source of proteins (Coudert, 1982). Fruit contains low protein contents, to obtain proteins flying foxes ingest small seeds of many plant species particularly figs that passed through their gut and expelled in feces (Janzen, 1978). Seeds, separated from ejecta were air dried in oven at 40ºC, crushed manually into fine powder and were kept at 5ºC in polyethylene bags before analysis. Seed moisture, crude protein, crude fibre and fats were determined following Pearson (1976), ash content was determined following Pomeranz et al. (1994) and total carbohydrate was determined by subtraction. Concentrations of Ca, Na, Fe, K and P were determined using atomic absorption spectrometer (Perkin Elmer AA Analyst 700) following Elaroussi et al. 1994.

**Roost count**

A total of fifty roosting trees of the Indian flying fox were traced at Jinnah (n = 42) and Lalazar garden (n = 8), Lahore. All these trees were numbered and bats on each tree were calculated initially at the start of experiment and thereafter variations in each roost were recorded on monthly basis by direct roost counts method during dawn and dusk hours following Kunz et al. (1996).

Seasonal roost (%) variations were calculated by the following formula.

\[
\text{Seasonal roost variations (\%) = \frac{\text{No. of bats on specific roost in specific season} \times 100}{\text{Total no. of bats on all the roosts in that season}}}
\]
Results and discussion

Day roosts of Indian flying fox, *Pteropus giganteus* were recorded at two public places i.e. Jinnah garden and Lalazar garden in Lahore and it was observed that out of total 5209 trees belonging to 46 families, 103 genera and 132 species; 50 trees belonging to 17 families, 19 genera and 21 species were serving as roost trees (Table 1). Preferred roosting tree species include *Syzygium Jambolanum* (n = 13), *Mangifera indica* (n = 6), *Manilkara hexandra* (n = 6), *Ficus glomerata* (n = 2), *F. elastic* (n = 2), *F. retusa* (n = 2), *Bombax ceiba* (n = 2) and *Dendrocalamus hamiltonii* (n = 2). Chakravarthy and Yeshwanth (2008) documented that roost trees of *P. giganteus* in urban areas generally include *Ficus* spp., Royal Poinciana (*Delonix regia*), *Eucalyptus* spp., *Acacia* spp., *Terminalia* spp., *Casuarina* spp., Indian date (*Tamarindus indica*), Mango (*Mangifera indica*) and Jackfruit (*Artocarpus heterophyllus*).

During present study, on average maximum number of bats (n = 1059) were observed on drypetes and minimum (n = 111) on rayan. Seasonal roost variations were observed and maximum number of bats (n = 270) were recorded on sausage tree during spring, on Indian rosewood (n = 425) during summer, on European nettle (374) during autumn and on cedrus tree (330) during winter (Table 1). Dey et al. (2013) conducted similar research on *P. giganteus* in Purulia district, India and documented seasonal variations. More bats were counted during colder months of the year (260 in November) as compared to hotter months (120 in May). During favourable conditions bats prefer to roost on *Eucalyptus* species, *Dalbergia latifolia*, *Tamarindus indica* and *Terminalia arjuna*. *P. giganteus* exhibit incredible seasonal change in roost composition, roost size and roost shifting, this behaviour pattern might be a response of weather change and food availability. Similar behaviour had been observed in other species of the genus *Pteropus* (Mickleburgh et al. 1992; Pierson and Rainey 1992; Roberts 1997; Wiles et al. 1997).
During present survey, *P. giganteus* populations were found year round residents of Jinnah and Lalazar gardens however they showed some local movements. Our findings are in line with Bell et al. (1986) and Kunz (1982) who reported that *P. giganteus* populations do not show distant migrations but local movements.

Fruit bats are highly efficient in extracting the liquid portion of chosen foods. They have fewer teeth and relatively flat for crushing fruits, allowing the bats to squeeze out and swallow the juices (Gardener 1977; Constantine 1986). The fibrous portion remaining is much reduced in moisture and spitted out in tightly compressed pellets (ejecta). Seeds also may be swallowed, but many of those from figs appear to pass whole into the faeces (Hill and Smith 1984) These large volumes of food are processed through the digestive tract rapidly, with transit times ranging from 15-100 min (Morrison 1980; Tedman and Hall 1985). In most studies it had been assumed (Kunz1974, Anthony and Kunz 1977) or verified (Buchler 1976) that the digestive tract of bats is void of food by the time they begin nightly feeding bouts. The present study was undertaken to evaluate *P. giganteus* ejecta quantitatively and qualitatively. Droppings were excreted by these bats all year and can be collected with no stress on the bat, often with little extra effort by the researcher, large samples are thus possible. Belwood and Fenton (1976) advocated faecal analysis method to investigate dietary habits of bats because this approach did not require the sacrifice of bats. However, killing specimens to look at stomach contents will be ruthless option for the studies of endangered species and often is undesirable in studies of species with unknown status though stomach contents have been the major source of dietary information (Prys-Jones et al. 1974; Radke and Frydendall 1974). Collecting or photographing food brought to nestlings may be possible, but only for a limited season and necessarily few individuals involved in it. Whereas ejecta collection involved many individuals with random sampling of droppings available throughout the year, in all seasons.
Nutritional value is important in food selection and fruit bats in nature appear to meet their nutrient needs by consuming large quantities of a mixture of fruits, with consumption of flower parts, pollen, leaves bark, seed pods, cones, twigs and insects (Mickleburgh et al. 1992; Ange et al. 2001; Long and Racey 2007). Two possible reasons for eating a variety of fruit species are (1) a preferred species, which could alone fulfill the bat’s nutritional needs, may not always be available; or (2) no one fruit species is sufficient to meet the bat’s nutritional needs (Fleming 1986). Record of seed predation had been reported by (Bonaccorso 1979; Thomas 1991; Nogueira & Peracchi 2003). Nutrient gained from seed predation reduced the number of figs ingested each night, which would limit the number of foraging trips and thus advantageous (Kalko et al. 1996; Morrison 1978). During present study, seasonal variations in the diet of *P. giganteus* were recorded and the proximate analysis of their natural diet (Table 2) showed that these flying foxes are highly remarkable in selecting food item in particular season. *P. giganteus* consumed fruits identified from the seeds isolated from ejecta, showing increased level of particular nutrient according to their body requirement in particular season (Table 3). The dietary item consumed in summer, having comparatively higher moisture content (53.49%) during summer, relatively higher protein (9.58%), fat (7.26%), fibre (12.20%), phosphorus (5.60%) and iron (4.07%) contents during winter, relatively higher vitamin C (9.26 %) during autumn and higher potassium (3.41) during spring (Table 3).

The flying foxes supplemented their food with variety of plant material to fulfill their protein requirements. Apart from extensive list of dietary items, flying foxes had been observed consuming seeds however few records of seed consumption in flying foxes are available. (Kunz & Diaz 1995; Ruby et al. 2000; Nogueira & Peracchi 2003). Flying foxes gained 25% to 33% of the total energy from the contents contained in the seeds, seeds also contain 30% of the proteins though fruit itself had low protein contents and rich in minerals.
and vitamins (Morrison 1980). Seeds were ingested by *P. giganteus* as total of 878 seeds were recovered from the guano sample showed 9.26 % intake of Vitamin C in autumn and 8.09 % in winter (Table 3). Vitamin C (ascorbic acid) plays important roles as an anti-oxidant and in collagen synthesis. These important roles, and the relatively large amounts of vitamin C required daily, likely explain why most vertebrate species are able to synthesize this compound, but two bat species, *Pteropus sp* and *Vesperugo abramus* from two different suborders (Megachiroptera and Microchiroptera, respectively) were unable to synthesize vitamin C, thus dependent upon the intake of fruit species to meet the daily requirement of vitamin C (Birney et al. 1980). The fruits of *Diospyros* and *Ficus* spp. are the vital food resources for *P. giganteus* in wild as these are continually consumed by these bats even in the period of inadequate food resource availability (Terborgh 1986; Lambert & Marshall 1991).

Seed predation can be considered an important way by which bats maximize nutritional intake, expanding our view of the trophic roles played by this group. To understand these factors responsible for the high bat diversity in tropical ecosystems as well as to protect such diversity rely greatly on the clarification of these trophic roles (Fenton et al. 2001; Kalko 1997).

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Table 1. Seasonal variations in the populations of Indian flying fox (*Pteropus giganteus*) at Jinnah and Lalazar garden, Lahore.

<table>
<thead>
<tr>
<th>Family</th>
<th>Roost species</th>
<th>Common names</th>
<th>No. of bats/year</th>
<th>Spring (%)</th>
<th>Summer (%)</th>
<th>Autumn (%)</th>
<th>Winter (%)</th>
</tr>
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<td><strong>Jinnah garden</strong></td>
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<tr>
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<td><em>Mangifera indica</em> (4)</td>
<td>Mango</td>
<td>272</td>
<td>81 (3.40)</td>
<td>129 (3.89)</td>
<td>47 (1.33)</td>
<td>15 (0.44)</td>
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<td>Apocynaceae</td>
<td><em>Alstonia scholaris</em></td>
<td>Indian devil</td>
<td>713</td>
<td>197 (8.26)</td>
<td>91 (2.74)</td>
<td>163 (4.63)</td>
<td>262 (7.68)</td>
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<td>Bignoniaceae</td>
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<td>Sausage</td>
<td>898</td>
<td>270 (11.33)</td>
<td>211 (6.36)</td>
<td>192 (5.45)</td>
<td>225 (6.59)</td>
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<tr>
<td>Cannabaceae</td>
<td><em>Celtis australis</em></td>
<td>European nettle</td>
<td>829</td>
<td>161 (6.75)</td>
<td>112 (3.38)</td>
<td>374 (10.62)</td>
<td>182 (5.33)</td>
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<tr>
<td>Combretaceae</td>
<td><em>Terminalia arjuna</em></td>
<td>Arjun</td>
<td>495</td>
<td>54 (2.27)</td>
<td>267 (8.05)</td>
<td>129 (3.66)</td>
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<td>Cuperssaceae</td>
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<td>* Diospyros peregrine*</td>
<td>Gaabh</td>
<td>901</td>
<td>134 (5.62)</td>
<td>243 (7.33)</td>
<td>286 (8.12)</td>
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<td><strong>Lalazar garden</strong></td>
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<td>95 (37.85)</td>
<td>60 (21.13)</td>
<td>72 (22.57)</td>
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<tr>
<td>Myrtaceae</td>
<td><em>Syzygium Jambolanum</em> (4)</td>
<td>Jambolan plum</td>
<td>862</td>
<td>235 (69.73)</td>
<td>156 (62.15)</td>
<td>224 (78.87)</td>
<td>247 (77.43)</td>
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<td></td>
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<td>3317</td>
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<td>3412</td>
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<td>12.93</td>
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<td>18-425</td>
<td>27-374</td>
<td>9-330</td>
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**Lalazar garden**

<table>
<thead>
<tr>
<th>Family</th>
<th>Roost species</th>
<th>Common names</th>
<th>No. of bats/year</th>
<th>Spring (%)</th>
<th>Summer (%)</th>
<th>Autumn (%)</th>
<th>Winter (%)</th>
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<tr>
<td>Anacardiaceae</td>
<td><em>Mangifera indica</em> (2)</td>
<td>Mango</td>
<td>329</td>
<td>102 (30.27)</td>
<td>95 (37.85)</td>
<td>60 (21.13)</td>
<td>72 (22.57)</td>
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<td>Jambolan plum</td>
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<td>235 (69.73)</td>
<td>156 (62.15)</td>
<td>224 (78.87)</td>
<td>247 (77.43)</td>
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<td></td>
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<td>251</td>
<td>284</td>
<td>319</td>
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<td>125.5</td>
<td>142</td>
<td>159.5</td>
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<tr>
<td><strong>Standard Deviation</strong></td>
<td></td>
<td></td>
<td></td>
<td>94.05</td>
<td>43.13</td>
<td>115.97</td>
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### Table 2. Proximate analysis of food tree species identified from ejecta of the Indian flying fox (*Pteropus giganteus*) from Jinnah and Lalazar garden, Lahore.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Season</th>
<th>Moisture Dry wt. %</th>
<th>Protein %</th>
<th>Fat %</th>
<th>Fiber %</th>
<th>Carbohydrate %</th>
<th>Ca %</th>
<th>P %</th>
<th>Fe %</th>
<th>Vit. C %</th>
<th>K %</th>
<th>Na %</th>
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<tr>
<td>Anacardiaceae</td>
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<td>Spring, Summer</td>
<td>86.10</td>
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<td>0.10</td>
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<td>0.01</td>
<td>0.02</td>
<td>0.30</td>
<td>13.00</td>
<td>1.43</td>
<td>0.01</td>
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<tr>
<td></td>
<td>Pistacia chinensis</td>
<td>Winter</td>
<td>4.36</td>
<td>20.61</td>
<td>51.78</td>
<td>3.99</td>
<td>25.97</td>
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<td>45</td>
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<td>37.18</td>
<td>1.94</td>
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<td>Arceaceae</td>
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<td>40.6</td>
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<td>12.12</td>
<td>20.13</td>
<td>1.54</td>
<td>1.8</td>
<td>1.62</td>
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<td>Livistonia chinensis</td>
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<td>3.14</td>
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<td>4</td>
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<td>56.0</td>
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<td>75.4</td>
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<td>0.9</td>
<td>4.3</td>
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<td>0.29</td>
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<td>3.13</td>
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<td>0.17</td>
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<td>5.5</td>
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<td>7.9</td>
<td>4.0</td>
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<td></td>
<td>Melaluca leucadenron</td>
<td>Spring, Summer, Winter</td>
<td>8.7</td>
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<td>1</td>
<td>10.7</td>
<td>0.3</td>
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<tr>
<td></td>
<td>Psidium guajava</td>
<td>All the four seasons</td>
<td>84</td>
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<td>4.99</td>
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<tr>
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<td>Spring</td>
<td>55</td>
<td>0.69</td>
<td>0.20</td>
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<td>16.98</td>
<td>0.03</td>
<td>0.05</td>
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<td>Anthocephalus cadamba</td>
<td>Spring</td>
<td>30</td>
<td>15.51</td>
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<td>Spring, Autumn</td>
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<td>6.00</td>
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<td>Sapotaceae</td>
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<td>Medhuca longifolia</td>
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<td>0.2</td>
<td>0.7</td>
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</table>

Chapter 3
Table 3. Nutrient profile (dry wt.%) of seeds identified from ejecta of the Indian flying fox (*Pteropus giganteus*) from Jinnah and Lalazar garden, Lahore.

<table>
<thead>
<tr>
<th>Seasons</th>
<th>Moisture</th>
<th>Protein</th>
<th>Fat</th>
<th>Fiber</th>
<th>Carbohydrate</th>
<th>Ca</th>
<th>P</th>
<th>Fe</th>
<th>Vit. C</th>
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<td>4.48</td>
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<td>8.32</td>
<td>29.31</td>
<td>1.89</td>
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<td>1.55</td>
<td>9.03</td>
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<tr>
<td>Summer</td>
<td>53.49</td>
<td>6.89</td>
<td>2.93</td>
<td>8.38</td>
<td>22.43</td>
<td>3.41</td>
<td>1.65</td>
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<tr>
<td>Autumn</td>
<td>41.94</td>
<td>5.24</td>
<td>3.90</td>
<td>11.22</td>
<td>24.39</td>
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<td>9.26</td>
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<td>Winter</td>
<td>30.36</td>
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<td>12.20</td>
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<td>4.07</td>
<td>8.09</td>
<td>2.44</td>
<td>2.53</td>
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</table>
EXPERIMENT NO. 3

Title: To make an inventory of the food plant species of the Indian flying fox and morphological characterization of remnants (seed, fruit, petals) of the bolus and guano of the fruit bats to aid future scientists.

Publications

3.3 Role of Indian flying fox *Pteropus giganteus* as seed dispersers in urban areas of Lahore.
Role of Indian flying fox *Pteropus giganteus* as seed dispersers in urban areas of Lahore.

Abstract

This one year study extending from January, 2011 through December, 2011 was conducted to investigate the role of Indian flying fox *Pteropus giganteus* as seed dispersers 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 bolus and guano. Various seeds of edible trees and forest plantation species extracted from ejecta of *P. giganteus* include areca palm (*Areca catechu*), coromandel ebony (*Diospyros melanoxylon*), Indian gaabh (*D. peregrine*), lemon scented gum (*Eucalyptus citrodora*), Chinese fan palm (*Livistona chinensis*), *Manilkara zapota* (sapodilla), mahwa (*Medhuca longifolia*), *Indian lilac* (*Melia azadrach*), cajeput tree (*Melaluca leucandendron*), rambutan (*Nephelium lappaceum*), guava (*Psidium guajava*) and janbolanum plum (*Syzygium jambolanum*). The measurements of the extracted seeds viz. length (mm), diameter (mm) and weight (g) were taken and the seeds of jack fruit (*Artocarpus heterophyllus*) were found the longest (40 mm) with maximum average diameter (50 mm) while the rambutan (*N. lappaceum*) seeds were the heaviest (3.4 g). It can be concluded from present study that *P. giganteus* are the seed dispersers 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

Introduction

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

Bonaccorso (1998) documented that a relationship exists between specific bat and particular plant species and the extent of this relationship is dependent on diversity of frugivores and the physical properties of their food item. The distinctive morphological characters of tropical plant species viz. color, strong odor and exposed location imitate the senses of bats (Fleming 1979, Vander Pijl 1957). The fruits have different shapes, sizes and a variety of morphological features; some are enclosed in 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 disperser (Schupp 1993; Holl 1998; Martinez-Garza and Gonzalez-Montagut 1999; 2002).

In case of vertebrate dependent seeds, the decrease in seed input is directly proportional to the increase in distance from the source vegetation. In contrast, the seed input declines less when the disperser agents are fruit bats because the frugivore bats are more likely to defecate in flight rather than from perches (Forester et al. 1984; Gorchov et al. 1993). Seed dispersal among different habitats also relies on the size of the seed, the smaller seeds are dispersed in the successional nearby areas of the forest and produced in larger amount by parent plant. The large sized seed produced fewer in number per unit plant with limited distributed, less likely to dispersed across the habitat and colonized in successional habitats (Duncan and Chapman 1999; Greene and Johnson 1994; Harvey 2000; Wunderle 1997).
Frugivore bats are considered primary dispersers and ecological counterparts of the early successional plant species (e.g. *Piper* spp., *Solanum* spp., *Vismia* spp. and *Cecropias* spp.) established in gaps and open areas in or adjacent to forests in the moist Neotropics (Foster et al. 1986; Gorchov et al. 1993; Medellin and Gaona 1999; Uhl 1987). While conserving the abundance and diversity, the associations between seeds, seed dispersal and their dispersal agents must be well understood as the decline in abundance and biodiversity in dispersal agents will affect the diversity of their food plants (Fleming et al. 1987; Corlett 1998).

The early successional floral species (e.g., *Piper* spp., *Solanum* spp., *Vismia* spp., and *Cecropias* spp.) establish in gaps and open areas in or adjacent to forests in the moist Neotropics are primarily dispersed by fruit bats, hence frugivores bats are considered as ecological counterparts (Foster et al. 1986; Gorchov et al. 1993; Medellin and Gaona 1999; Uhl 1987). Southeast Asian frugivorous bats are also taxonomically diverse from those in the Neotropics but their role as seed dispersal agents have been least attempted in the region. The present study was therefore focused to study the characteristics of the seeds exploited by the Indian flying foxes *P. giganteus* providing estimation of seed characters dispersed by them that are somehow dependent on these bat for their dispersal.

**Materials and Methods**

**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 temperature ranges between 26.8 °C to 27.3 °C and 35.0 °C to 40.4 °C, respectively whereas the mean annual minimum and maximum winter temperature ranges between 6 °C to 18 °C and 4 °C to 16 °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, construction of roads and flyovers have altered native tropical flora that has been replaced by exotic and ornamental floral species (Joshua and Ali 2008).

Roosting sites of *Pteropus giganteus* (Indian flying fox) were explored at Jinnah garden and Lalazar garden in Lahore and the ejecta (bolus and guano) of the species at both localities was collected and analyzed to extract plant seeds that can be transported by these bats. The dominant vegetation of both gardens includes Ashoka (*Saraca indica*) and the Buddha (*Chorisia insignis*) which grow well in tropical climate, banyans (*Ficus* spp.), kekar (*Acacia* spp.), shisham (*Dalbergia sissoo*) and the oak (*Quercus lepidobalanus*). The garden also harbors edible fruit trees like mango (*Mangifera indica*), apple (*Malus sieversii*), guava (*Psidium guajava*), pear (*Pyrus pashia*) and jambolanum plum (*Syzygium jambolanum*).

**Collection of ejecta and seed extraction**

Bolus and guano samples of *Pteropus giganteus* were collected by spreading 1m² 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 distilled water and shaken well to separate the undigested food items. The separated seeds were counted and identified by comparing with reference seeds collection from the Jinnah and Lalazar gardens following (vander Pijl 1957; Mahmood-ul-hassan et al. 2010).

**Reference seed repository**

A reference seeds repository was also prepared by extracting the seeds from roosting trees and fruit trees in the nearby plots that can serve as potential food source for Indian flying fox. The plant seeds extracted from eject were considered as food species, seeds of the trees that served as
roosting sites as roost species and the seeds collected from trees in the nearby plots were termed as only reference seeds (Table 1). Fruits of the trees for reference seed repository were collected during monthly surveys and seeds were then separated from the fruit pulp manually. The separated seed were counted; air dried at ambient temperature and was placed in the polythene bags (10 cm x 6 cm) as reference seeds.

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

**Morphometrics of seeds collected from study area and extracted from bolus and guano of *Pteropus giganteus***

Color of each extracted seed was observed, each seed was weighed using electronic weighing balance (FES-600). Seeds were placed into five seed weight classes (SWCs) and were classified 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 taken by a digital caliper.

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

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

**Results and Discussion**

During present study a total of 170 seeds belonging to 12 species, 11 genera and 6 families were extracted from bolus and guano of Indian flying fox, *Pteropus giganteus* roosting at Jinnah and Lalazar gardens, Lahore (Table 1). Most of the extracted plant seeds were belonging to family
Myrtaceae (represented by four species viz. *Eucalyptus citridora*, *Melaluca leucandendron*, *Psidium guajava* and *Syzygium jambolanum*) while family Arceacea (*Areca catechu* and *Livistonia chinensis*), Ebanaceae (*Diospyros melanoxylon* and *D. peregrine*) and Sapotaceae (*Manilkara zapota* and *Medhuca longifolia*) were represented by two species each. *Melia azadrach* and *Naphelium lappaceum* was the only species of family Meliaceae and Sapindiaceae, respectively. *Areca catechu* was the only plant species whose seeds were extracted only from bat guano, seeds of *D. melanoxylon*, *D. peregrine*, *E. citridora*, *L. chinensis*, *Melaluca leucandendroni*, *Manilkara zapota*, *Medhuca longifolia*, *N. lappaceum*, and *Syzygium jambolanum* were extracted from bolus while the seeds of *M. azadrach* and *P. guajava* were extracted from both bolus and guano (Table 1). Pteropodid, fruit bats show highly inter-specific 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 was noted during present study that out of total twelve plant species whose seeds were extracted from the ejecta of Indian flying fox, three species viz. Indian gaabh (*D. peregrine*), Indian lilac (*Melia azadrach*) 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 food and roost for these bats. Most of the tree species viz. *Eucalyptus citridora*, *Diospyros melanoxylon*, *Livistonia chinensis*, *Manilkara zapota* and *Melaluca leucandendron* produced fruits in autumn season. Four of the plant species i.e. *D. peregrine*, *Medhuca longifolia*, *Melia azadrach* and *N. lappaceum* produced fruits during summer season while the fruits of *A. catechu* and *P. guajava* were observed in summer and
winter season (Table 1). Our findings are in line with Mishra et al. (2009) who studied seeds characteristics of *Albizia lebbek* (Siris), *Bauhinia purpurea* (Orchid tree), *B. variegate* (Camel’s foot tree), *Dalbergia sisoo* (Indian rosewood), *Grewia optiva* (Dhaman), *Kydia calyciana* (Pula), *Melia azedrach* (Persian lilac), *Ougeinia oojeinensis* (Sandan), *Terminalia bellerica* (Bastard myrobalan), *T. chebula* (Black myrobalan), *T. tomentosa* (Crocodile bark) and *Toona ciliata* (Indiam mahogany) in India (Mishra et al. 2009).

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 0.001g to 3.4g. It was observed that majority of extracted seeds (41.6%) were from 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 *Naphelium 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. (Forester et al. 1984; Charles-Dominique and Cooper 1986).

Out of total twelve extracted plant species’ seeds, seeds of five species fell into SWC-II (0.01-1.0 g) category, three species into SWC-I (0-0.1 g) while two species in SWC-III (1.01-2.0 g) and SWC-IV (2.0-3.0 g) (Table 1). Khurana et al. (2006) reported that the medium weight seeds have more abundance than the smaller seeds. According to Grubb (1998), Putz and Appanah (1987) the seeds of successional plants species (*Alphitonia* spp., *Clerodendrum* spp., and
Euphorbiaceae, spp. etc) in Southeast Asia are larger in size, length and heavier and are probably dispersed by bats.

Amongst the extracted seeds, seeds of *Psidium guajava* were the smallest and thinnest (0.1mm) 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 0.1 mm to 26 mm, respectively. Seeds of *Medhuca 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 maximum diameter (Table 1).

Hodgkison et al. (2003) worked on distribution of seeds by fruit bats in 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 large 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 total 37 tree species whose seeds were measured, 12 species served as food, 5 as roost, 1 as food and roost while the remaining 21 species were the only reference plant species (Table 1). Reginald et al. (2008) listed *Ficus religiosa, Tamarindus indica, Albizia lebbeck, Delonix regia, Polyalthia longifolia, Acacia spp. Azadirachita indica* and *Samanea saman* as roosting tree species for *P. giganteus* in Tamil, Nadu, India.

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 weight differ
strikingly within same species, genera and family and can be a strong tool for identification of particular seed. The bolus and guano analysis of the *Pteropus giganteus* during present study revealed that this species are effective seed dispersers and can disperse seeds weighing from 0.001 g to 3.4 g.

References


Table 1. Morphometrics of seeds extracted from bolus and guano of Indian flying fox (*Pteropus giganteus*) roosting at Jinnah and Lalazar gardens, Lahore.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Common names</th>
<th>(Native/ exotic) fruiting season</th>
<th>Average seed length mm (n=10)</th>
<th>Average seed diameter mm (n=10)</th>
<th>Average seed weight g (n=10)</th>
<th>Seed weight class (SWC)</th>
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<td>Areca palm</td>
<td>Summer, Winter (E)</td>
<td>13.5</td>
<td>7.5</td>
<td>1.1</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td><em>Livistona chinensis</em></td>
<td>Chinese fan palm</td>
<td>Autumn (E)</td>
<td>9.8</td>
<td>4</td>
<td>0.3</td>
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<tr>
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<td>Caromandel ebony</td>
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<td>26</td>
<td>13</td>
<td>1.6</td>
<td>III</td>
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<tr>
<td></td>
<td><em>D. peregrine</em></td>
<td>Indian gaabh</td>
<td>Summer (N)</td>
<td>25</td>
<td>15</td>
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<td><em>Melia azadrach</em></td>
<td>Indian lilac</td>
<td>Summer (N)</td>
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<td>11</td>
<td>0.3</td>
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<td><em>Eucalyptus citrodora</em></td>
<td>Lemon scented eucalyptus</td>
<td>Autumn (E)</td>
<td>10.3</td>
<td>7</td>
<td>0.5</td>
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</tr>
<tr>
<td></td>
<td><em>Melaluca leucandendron</em></td>
<td>Cajeput tree</td>
<td>Autumn (E)</td>
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<td>0.07</td>
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<td>Guava</td>
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<td>0.1</td>
<td>0.001</td>
<td>I</td>
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<td>Rambutan</td>
<td>Summer (E)</td>
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<td>13</td>
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<td><em>M zapota</em></td>
<td>Sapodilla</td>
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<td>11</td>
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<td><em>Medhuca longifolia</em></td>
<td>Mahwa</td>
<td>Summer (E)</td>
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<td>Arjun</td>
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<td>26</td>
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<td>Rutiaceae</td>
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<td>I</td>
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<td>Sapotaceae</td>
<td><em>Manilkara hexandra</em></td>
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<td><strong>Food and roost species</strong></td>
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<td></td>
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<tr>
<td>Myrtaceae</td>
<td><em>Syzygium jambolanum</em></td>
<td>Jambolanum plum</td>
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<td>33</td>
<td>26</td>
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</tr>
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</table>
### Only reference seeds (neither food nor roost species)

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Common Name</th>
<th>Season</th>
<th>N</th>
<th>E</th>
<th>I</th>
<th>Stage</th>
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<td>Anacardiaceae</td>
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<td>13.3</td>
<td>1.2</td>
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<td>0.9</td>
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<tr>
<td>Euphorbiaceae</td>
<td>Jatropha curcus</td>
<td>Physic nut</td>
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<td>7.8</td>
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<td>Mimosa catechu</td>
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<td><em>A. nilotica</em></td>
<td>Arabic gum tree</td>
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<tr>
<td></td>
<td><em>Albizia lebbek</em></td>
<td>Lebbek tree</td>
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<tr>
<td></td>
<td><em>Delonix regia</em></td>
<td>Flame tree</td>
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<td>0.1</td>
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<td></td>
<td><em>Pongamia glabra</em></td>
<td>Indian beach tree</td>
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<td><em>Saphora chrysophylla</em></td>
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<td><em>Fimiana simplex</em></td>
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<td>Dhayu</td>
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<td><em>A. heterophyllus</em></td>
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<td><em>Ficus infectoria</em></td>
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<td>0.1</td>
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<tr>
<td>Moringaceae</td>
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<td>Moringa</td>
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</tr>
<tr>
<td>Myrtaceae</td>
<td><em>E. muclata</em></td>
<td>Spotted gum</td>
<td>Autumn (E)</td>
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<tr>
<td>Phoenix</td>
<td><em>Phoenix dactylifera</em></td>
<td>Date palm</td>
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<tr>
<td>Rubiaceae</td>
<td><em>Gardienia lucida</em></td>
<td>Cambus resin tree</td>
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<td>5.7</td>
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<td>II</td>
</tr>
<tr>
<td>Sapindaceae</td>
<td><em>Schleichea oleosa</em></td>
<td>Ceylon oak</td>
<td>Summer, autumn (E)</td>
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<td>7</td>
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</table>
CHAPTER 4
SUMMARY

*Pteropus giganteus* (Indian flying fox), Pteropodidae: Chiroptera, the largest fruit bat of Southeast Asia has been acknowledged for number of their ecological services, world widely. The positive roles of the Indian flying foxes and their services included bioindicators, pollinators, seed dispersers, forest generators and manure qualities. Investigatory surveys at Jinnah and Lalazar garden during March 2010 and subsequent visits in each successive month for the year provided new information regarding roost characteristics, food and feeding habits of the Indian flying fox (*Pteropus giganteus*) in Lahore.

(Jambolan plum) and six trees of both *Manifera indica* (Mango) and *Manilkara hexandra* (Rayan) were used as roost. The maximum number of bats were roosted at *Dalbergia sissoo* n = 425 (12.81%) in summer where as the minimum number of bats roosted at *Syzygium jambolanum* n = 9 (0.26%) in winter season. The maximum seasonal abundance of Indian flying foxes at Jinnah garden were observed in autumn season n = 3521 and minimum in spring season n = 2384. While maximum abundance at Lalazar garden were observed in spring season n = 337 and minimum in summer season n = 251. Throughout the year maximum total number of fruit bats (n = 1059) were counted on *Putranjiva roxburghii*, whereas the minimum number of bats (n = 71) were counted on *Manilkara hexandra*. At Lalazar garden, maximum number of bats (n = 323) were counted on *Syzygium jambolanum* while minimum number of bats (n = 229) were observed on *Mangifera indica*. The height of roosting tree at Jinnah garden varied from 7.5 m (*Dendrocalamus hamiltonii*) to 19.8 m (*Celtis australis*) and dbh from 0.10 m (*Putranjiva roxburghii*) to 0.89 m (*Kigelia pinnata*). The maximum height of roost tree at Lalazar garden was 15.13m (*Syzygium jambolanum*) and maximum dbh was 0.55m (*Mangifera indica*).

32 plant species consumed by the Indian flying fox belonging to 23 genera and 15 families species were identified from their bolus and guano. The Indian flying fox depends heavily on family Moraceae (49.2%), Ebenaceae (28.5%) and Myrtaceae (11.2%) that jointly formed 48.9% of its overall diet throughout the year. The fruits of family Moraceae formed the main staple of the bats diets during spring and winter (82.66%) and (56.78%) respectively. The fruits of the family Ebanaceae was recorded the main diet of in bats in summer (44.75%) and (64.30%) respectively. The fruits of family Araceae (0.58%) and Sapindaceae (1.95%) in spring and summer respectively were consumed by bats in ignorable quantity.
The fruit of six species formed the bulk of the diet of the bats. These species included, in order of their descending frequency of occurrence, *Diospyros peregrine* (23%), *Ficus retusa* (18.8%), *Psidium guajava* (11.2%), *F. religiosa* (9.8%), *F. glomerata* (8.8%) and *D. kaki* (5%). The seeds of *Morus nigra* had the highest percentage of carbohydrates, and *Pistachia chinensis* seeds had the highest percentage of fats, iron and phosphorus. The moisture, protein and fibre contents were higher in the seeds of *Ficus carica*, *Terminalia cattapa* and *Mallotus philipensis*. The essential analysed macrominerals in seeds indicated their higher levels of Ca, Na and K in *Diospyros kaki*, *D. melanoxylon* and *Manilkara zapota*, respectively while the higher contents of vitamin C was recorded in *L. chinensis*.

The seed of *Psidium guajava* (0.1mm) were thinnest and smallest while seeds of *Syzygium jambolanum* were the longest (33 mm) and thickest (26 mm). The seeds of *Areca catechu*, *Melia azadrach* and *Putranjiva roxburghii* had an average length whereas *Areca catechu* and *Melia azadrach* had average diameter. The seeds of *M. longifolia* had remarkable variation in length (10 mm) proportion to diameter (1.3 mm) comparatively to other seeds of food tree species. The seed weight of these food tree species shows that *Psidium guajava* (0.001 g) was the lightest and *Naphelium lappaceum* (3.4 g) was the heaviest.

Bat guano forms the basis of food web consisting of bacteria, fungi, protozoans, nematods and arthropods. Ten fungal genera were identified from bolus and eight fungal genera from guano the randomly collected samples of the Indian flying fox in different seasons at Jinnah Garden. *Alternaria, Aspergillus Candida, Chrysosporium Fusarium Penicillium* and *Saccharomyces* were observed in the bolus of the bat. The fungal genera observed in guano included *Alternaria, Aspergillus, Chrysosporium, Cryptococcus Exophiala Histoplasma Scopulariopsis* and *Trichophyton*. Six bacterial genera were identified from bolus and ten from the guano seasonal sampling at Jinnah Garden. These included *Acaligens, Azotobacter,*
Bacillus, Bartonella, Coryenbacteria, Klebsella, Listeria, Nitrsomonas, Nocardia, Salmonella and Stretomyces.

The fresh guano of fruit bats is dark in colour and forms a flat, laminated mass. It generally contains more than 60% organic matter. Mineral composition of bolus and guano of Indian flying fox at Jinnah Garden were analyzed in four seasonal samples throughout the year. The pH of fruit bat bolus near acidic to neutral ranges between 6.7 and 7.4 whereas pH of fruit bat is guano is near neutral to alkaline ranges between 7.1 and 7.4. The most abundant elements in bolus and guano are nitrogen and phosphorus whereas potassium is less abundant. The total nitrogen ranges between 2.28% and 4.10% the nitrogen values are higher in bolus than guano (2.0% and 3.30%) and the total phosphorus ranges between 3.10% and 5.20% which is slightly higher than the phosphorus range of bolus (3.50% and 5.0%).