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Observations on guano and bolus of Indian flying fox, *Pteropus giganteus*

Bats are cosmopolitan in distribution, except in the Arctic and Antarctic[1]. The Indian subcontinent harbours a variety of chiropterans, including frugivorus bats[2]. Over 200 species of flying foxes are distributed throughout the tropics and being frugivorous they play a major role in pollination and seed dispersal[3]. The Indian flying fox, *Pteropus giganteus* Brunnich commonly roosts on large trees (e.g. *Ficus*; Figure 1 *a*). They earned the name 'flying fox', as the head and fur resemble a fox (Figure 1 *a*, *b*). Their roosting results in the accumulation of substantial amount of guano on the floor (Figure 1 *c*). They swallow soft fruits (Figure 1 *b*) or extract juice and spit out the remains known as bolus (Figure 1 *d*), containing the residual fruit pulp of fibrous fruits and seeds. Besides fruits, they are also known to feed on juice and pollen of various tree flowers. Although flying foxes are widespread species, they are facing threats mainly due to loss of roost trees, hunting and pesticide use[3,4]. A dramatic decline in their population has been seen due to hunting for food and medicine and are thus placed under least conserved and endangered species in South Asia[3]. Investigations pertaining to ecological values and ecosystem services of flying foxes are warranted in biodiversity conservation measures. This study draws attention to the nutrients and microbial composition of guano and bolus of *P. giganteus* roosting in one of the locations in southwest Karnataka, India.

A huge banyan tree (*Ficus benghalensis*) located at Moodbidri, Dakshina Kannada has been a roosting site for a large number of flying foxes (about 400–500) over the past six years (Figure 1 *a*). Guano and bolus of flying foxes were observed in plenty under the canopy. Some sections of the floor under the canopy were cleared and polythene sheets were spread to collect bat excrement during September 2003. Replicate samples of guano and bolus were randomly collected, weighed and allowed to dry in a hot-air oven (100°C, 24 h) to determine moisture content. Additional samples collected aseptically were air-dried and used for nutrient and microbiological analyses. The pH (1 : 10 w/v in distilled water), total nitrogen, phosphorus and potassium were determined based on methods outlined by Jackson[5]. Bacteria (nutrient agar), actinomycetes (Kenknight's agar) and fungi (Martin's Rose Bengal–

Table 1. Nutrients and microbial composition of guano and bolus of flying fox, *Pteropus giganteus* (range in parenthesis)

Parameter	Guano	Bolus
Total nitrogen (%)	2.6 ± 0.5 (2–3.3)	3.3 ± 0.82 (2–4)
Total phosphorus (%)	4.2 ± 0.8 (3.1–5.2)	4.3 ± 0.6 (3.5–5)
Potassium (%)	0.6 ± 0.04 (0.6–0.7)	0.7 ± 0.04 (0.6–0.7)
pH	7.3 ± 0.1 (7.1–7.4)	7.1 ± 0.3 (6.7–7.4)
Bacteria (cfu/g dry wt)	$29 \times 10^4 \pm 50$ ($25–32 \times 10^4$)	$48 \times 10^4 \pm 28$ ($46–50 \times 10^4$)
Actinomycetes (cfu/g dry wt)	$5.55 \times 10^4 \pm 7.8$ ($5–6 \times 10^4$)	$4.1 \times 10^4 \pm 7.8$ ($3.5–4.6 \times 10^4$)
Fungi (cfu/g dry wt)	$2.9 \times 10^4 \pm 3.5$ ($3.1–4.3 \times 10^4$)	$4.6 \times 10^4 \pm 3.5$ ($4.3–4.8 \times 10^4$)

Figure 1. Flying foxes (*Pteropus giganteus*) roosting on a banyan tree (***a***), feeding on ripened banana fruit (***b***), faecal pellets or guano (***c***), bolus accumulated on banyan leaves (***d***), seedlings of banyan (***e***) and guava (***f***) from seeds in guano.

streptomycin agar) were isolated and enumerated[6,7]. Bacteria were identified up to genus level based on morphological characters and biochemical tests[8]. Seeds present in unit weight of air-dried guano were enumerated and tested for their germination. Replicates of air-dried guano weighing 25 g each were transferred to 100 ml distilled water and shaken to separate seeds from organic matter. Seeds in each sample were enumerated and transferred to petri dishes containing wet cotton for germination under sunlight. Later the seedlings were transferred to pots containing soil and allowed to grow for 3–4 weeks and plants were identified.

The guano consists of blackish-grey elongated pellets, measuring 1–2 × 0.5–0.8 cm (Figure 1 *c*). Bolus spits were thick blackish fluids (Figure 1 *d*) with strong pungent odour in wet condition, that become odourless on drying. Table 1 shows the result of assessment of bat excrements. The pH was close to neutral (7.1–7.3). Total nitrogen, total phosphorus and potassium were highest in bolus. Colony forming units (cfu) of bacteria and fungi were highest in bolus, while those of actinomycetes were high in guano. Bacteriological examination 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. *Fusarium* and *Penicillium* were the most common fungi in guano as well as bolus. An average of 23 seeds (range 20–30) per 25 g air-dried guano was recovered. Out of them, 31% (range, 10–55%) germinated. Seed germination was initiated within 5–6 days of incubation, and the first pair of leaves emerged after 2 weeks. Among seeds, 70% was banyan (*F. benghalensis*) (Figure 1 *e*), 20% guava (*Psidium guajava*) (Figure 1 *f*), and rest (10%) unidentified.

Analyses of bat guano aid in understanding the habitat preference[9], food habits[10–12], seed dispersal[11] and also in developing strategies to conserve bat habitats[11,13]. Our study revealed higher NPK in bolus than in guano (3.3 : 4.3 : 0.7 vs 2.6 : 4.2 : 0.6) of flying fox. As they are frugivorous, phosphorus is fairly high in their excrement. Phosphorus in guano and bolus is higher than in cow and sheep manure[14], indicating their value as natural manure to meet phosphorus requirements of plants. Phosphorus-rich guano is known to induce root growth, multiple branches in shoot and flowering in plants. As the pH of flying fox excrement was close to neutral range (7.1–7.3), its direct application or amendment with other organic manure may not drastically alter soil pH. Use of non-conventional organic manure in plant production is becoming more popular (e.g. vermicompost)[15]. Farmyard manure (FYM) is known to partially meet NPK requirement of plantation crops[16]. Thus, amending flying fox excrement with FYM in appropriate proportion may help overcome such deficiencies. This study revealed the occurrence of high proportion of bacteria and fungi in excrement, which may enhance decomposition of organic matter in soil on application.

Roosting sites of bats have great ecological significance in conservation of biodiversity[17]. In this study, flying fox guano with 70% banyan seeds, indicates their role in dissemination of an important keystone plant species in our ecosystem. As flying foxes are also dependent on juice and pollen of tree flowers, they play a crucial role in the pollination of tree species. Public awareness on the importance of flying foxes in pollination, seed dispersal[18] and the benefits of their excrement (as natural organic manures) may create better understanding to preserve their roosting habitats. Future studies need to address the efficiency of flying fox excrement amendment to soil or other organic manure in plant production. It will be interesting to assess flying fox guano for the presence of plant-promoting and plant-colonizing microbes for their application in agriculture.

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