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MANURE QUALITIES OF GUANO OF INSECTIVOROUS CAVE BAT *Hipposideros speoris*

[CALIDAD DEL GUANO PROVENIENTE DEL MURCIELAGO *Hipposideros speoris*]

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SUMMARY

This study aimed at assessing the physicochemical characteristics, microflora and manure quality of guano of an endemic insectivorous cave bat *Hipposideros speoris*. The impact of bat guano on crop growth was also assessed. Results indicated that organic matter, total carbon, total nitrogen and phosphate were high in faecal pellets. Calcium, magnesium, bacteria, actinomycetes and fungi were higher in humus-like guano than faecal pellets. Physicochemical features and microbial load between faecal pellets and humus-like guano significantly differed ($p<0.05$). One set control pots received red loamy soil; four sets of experimental pots received soil amended with different quantity of guano (w/w); one set each with guano + farm yard manure (FYM) and FYM. After three weeks (finger millet) and six weeks (black gram) of growth, crops were harvested and assessed various parameters. Both crops, in soil amended with guano at the ratio of 20:1 showed the highest shoot length, total dry matter, nitrogen content and nitrogen uptake. The shoot length, total dry matter, nitrogen content and nitrogen uptake in both crops were significantly differed between treatment 20:1 and control ($p<0.05$). The results clearly indicated that incorporation of low amount of bat guano into the soil enhances crop production. Importance of conservation of insectivorous bats in agricultural fields and their guano have been emphasized.

Key words: *Hipposideros speoris*, insectivorous cave bat, bat guano, organic manure, crop production.

RESUMEN

Se evaluaron las características físico-químicas, microflora y calidad del guano proveniente del murciélago insectívoro *Hipposideros speoris*. Se evaluó el efecto del guano en el crecimiento de cultivos. Los resultados indicaron que los pellets fecales contenían cantidades elevadas de material organica, carbono, nitrógeno y fosfato. Los contenidos de calcio, magnesio, bacterias, actinomicetos y hongos fueron mayores en el guano que en los pellets fecales. Las características físico químicas y la carga microbial del guano y los pellets fecales fueron significativamente diferentes ($P<0.05$). en una prueba con macetas estas recibieron suelo, suelo mezclado con diferentes cantidades de guano (w/w), guano + heces de granja (HG) y sólo HG. Después de tres o seis semanas de cultivo se evaluaron varios parámetros. Los cultivos mostraron mayores crecimientos, contenidos de materia seca y nitrógeno y captura de nitrógeno en los suelos con guano 20:1 y estos fueron significativamente diferentes del control ($P<0.05$). Los resultaron mostraron que la incorporación de pequeñas cantidades de guano de murciélago mejora la producción de cultivos. La importancia de conservar murciélagos insectívoros en campos agrícolas y su guano es enfatizada.

Palabras clave: murciélago insectívoro de caverna, guano de murciélago, fertilizante orgánico, producción de cultivos.

INTRODUCTION

Although agricultural chemicals drastically increase food production, it leads to impaired soil health, depletion of organic matter and microbes and persistence of heavy metals and pesticides. Organic farming has been promoted to restore soil health and fertility status. Application of farmyard manure (FYM), compost, green manure and bioinoculants are the most important management practices in organic farming (Thampan, 1993). Improvement of soil fertility through the application of vermicompost is becoming more popular. In contrast to chemical fertilizers, application of FYM meets one half of nitrogen, one sixth of phosphate and about one half of potassium requirements of crops during the first season. On equivalent nitrogen basis, FYM or compost is 40-60% efficient as chemical nitrogenous fertilizers to increase crop production. Even though long-term (>5 years) application of organic manure overcome such disparity, efficient application of organic matter for self-sustenance in agriculture has not reached the farming community. Several organic manures of animal origin are available for use (e.g. night soil, bovine dung and urine, sheep manure, poultry manure, bat guano, silkworm wastes and vermicompost). Availability of such manures for crop production is restricted due to many constraints such as geographical region, awareness of manure value, extent of manure production and management. There is ample scope to assess and utilize non-conventional organic manures in agriculture. Recently, the use of pill millipedes (*Arthrosphaera magna*) in composting organic matter has been proposed (Ashwini and Sridhar, 2002, 2006; Ashwini, 2003). Likewise, bat guano has been assessed to understand bat diets and food habits (Marais et al. 1980; Fenton *et al*., 1998; Korine *et al*., 1999), nitrogen and mineral budgets (Studier *et al*., 1991), seed dispersal (Korine *et al*., 1999), habitat preference, flight activity (Zielinski and Gellman, 1999), ecology and conservation strategies (Korine *et al*., 1999; Bhat and Sreenivasan, 1990). The specific objectives of our study were: 1) to assess the physicochemical characteristics and microflora of guano of an endemic cave bat (*Hipposideros speoris*); 2) to assess the feasibility of amending soil with bat guano to increase crop production.

MATERIALS AND METHODS

Study location

The study site is located at Assaigoli village (12°47' N, 74°52' E), 18 km away from Mangalore towards Mangalore University. At the cellar of a private residence exposed to mixed plantation and forest, a colony of an insectivorous cave bat, *Hipposideros speoris* (Figure 1. A, B, C) was traced in January 2003. This species is endemic and confined to India and Sri Lanka (Bates and Harrison, 1997). A huge cave at 50 m away from cellar was the day roosting site of these bats. About 400-500 bats regularly roost during night in the cellar ceiling measuring 36 m^2. Bats arrive after dusk, stay overnight and continuously move in and out for hunting. Sand has been spread on half of the floor area, while the rest consists of compact soil. Bat guano accumulated in the form of intact pellets on the sand (Fig. 1D), while on the soil floor, ants earthed the faecal pellets and transformed them into fine fluffy humus-like powder (Figure 1E).

Analysis of guano

The guano deposited on sand and soil surface was cleared to quantify the deposition in three months duration in unit area. The fresh weight, dry weight (dried at 80ºC for 24 hr), pH (1:20 dilution w/v with distilled water), electrical conductivity, organic matter, total carbon, total nitrogen, C/N ratio, phosphate, potassium, calcium, magnesium (Jackson, 1973), bacteria, actinomycetes and fungi (Aaranson, 1970) of faecal pellets and humus guano were determined. All parameters were assessed for five replicate samples.

Bioassay

Efficiency of humus-like bat guano in crop production was assessed based Neubauer technique on amending bat guano with soil and farmyard manure (FYM) (Tisdale and Nelson, 1975). Seven treatments (T1-T7) (5 replicates each) consisting of loamy soil (collected at 30 cm depth), bat guano and farm yard manure (FYM) (w/w) were assessed. Red loamy soil (150 g) was mixed with bat guano and FYM in different proportions in plastic pots. The treatments include: T1, soil (control); T2-T5, soil + bat guano (20:10, 20:5, 20:2.5, 20:1 respectively); T6, soil + bat guano + FYM (20:2.5:10); T7, soil + FYM (20:10). Finger millet (*Eleusine coracana*) and legume (*Phaseolus mungo*) were used as test crops to assess the efficiency of manure treatments. Seeds were soaked in tap water up to six hours. Water was drained and the seeds were allowed to germinate overnight on wet cloth. Fifty germinated finger millet seeds and five germinated black gram seeds were sown separately per treatment and allowed to grow in green house. The pots were watered twice a day until harvest (finger millet, 3 weeks; black gram, 6 weeks). On uprooting the seedlings, shoot and root lengths were determined. Plants were dried, ground and assessed for the total nitrogen, phosphorus and potassium (Jackson, 1973). Uptake of NPK by the crops was evaluated based on the dry mass and nutrient levels in plants (Shuxin *et al*., 1992).

Statistical analysis

Paired *t*-test was used to assess the difference in physicochemical characteristics and microbial load between faecal pellets and humus guano. So also the total dry matter, shoot length, NPK and uptake of NPK in crops grown with different treatments (Stat Soft Inc., 1995).

RESULTS

Properties of guano

Colour of bat faecal pellets were usually black and gray (rarely light pink). The average number of faecal pellets per gram was 322±35 (range, 256-352). Faecal pellets were elongated, usually segmented with tiny pits on the surface, tips blunt (rarely pointed), easily powdered on crushing and consisted of shiny bits of insect remains. Faecal pellets measured: 4.6±0.8 mm length (range, 3.5-6 mm) and 1.6±0.24 mm breadth (range, 1.25-2 mm). Ants were common in humus guano and they carry the faecal pellets deposited on the sand to soil. Larvae of ants and tiny insect larvae were common in humus guano (larvae per gram, 7.4±3.4; range, 5-14). Humus guano was black and powdery with brownish tinge. The guano possesses strong pungent smell during rainy season, but the smell was eliminated on drying.

Physicochemical features and microbial load of bat guano is presented in Table 1. Dry weight of humus guano was higher than faecal pellets (2.8 vs. 2.5 kg/m^2). Faecal pellets were alkaline, while humus guano was acidic (7.5 vs. 6.5). Organic matter, total carbon, total nitrogen and potassium were considerably higher in faecal pellets than in humus guano. Conductivity, bacteria, actinomycetes and fungi were substantially high in humus guano. Paired *t*-test revealed significant difference between physicochemical characteristics of faecal pellets and humus guano, so also microbial load ($p<0.05$).

Bioassay

Figures 1F and 1G show finger millet and black gram grown on soil and soil amended with guano and FYM respectively. Crop growth was better in T1, T5-T7 than in T2-T4. Details of crop parameters (shoot length, total dry matter, NPK and uptake of NPK) are shown in Figure 2 and Figure 3. Both crops, in T5 (soil + guano, 20:1) showed the highest shoot length, total dry matter, N content and N uptake. Paired *t*-test revealed significant difference ($p<0.05$) between T5 (20:1) and T1 (control) in shoot length, total dry matter, N and N uptake in both crops. In finger millet, the total dry matter ($p=0.0183$), nitrogen ($p=0.0001$) and phosphorus ($p=0.0061$) contents and nitrogen uptake ($p=0.0351$) were significantly differed between treatments T5 and T6. So also the shoot length ($p=0.0178$), phosphorus ($p=0.0149$) content and nitrogen uptake ($p=0.0477$) between T5 and T7. In black gram, the shoot length ($p=0.0006$), nitrogen ($p=0.0023$) content and potassium uptake ($p=0.0091$) were significantly differed between treatments T5 and T6. So also the shoot length ($p=0.0016$), nitrogen ($p=0.0009$), phosphorus ($p=0.0002$) content and potassium uptake ($p=0.0498$) between T5 and T7.

Table 1. Physicochemical and microbiological characteristics of bat guano (n=5; mean±SD; range in parentheses)

Characteristics	Faecal pellets	Humus guano
Fresh weight (kg/m^2)*	2.9±0.4 (2.5-3.5)	5.3±0.3 (4.9-5.5)
Dry weight (kg/m^2)*	2.5±0.4 (2-3)	2.8±0.8 (1.5-3.7)
pH	7.5±0.1 (7.4-7.6)	6.5±0.2 (6.2-6.8)
Conductivity (m mhos/cm)	2.8±0.4 (2.5-3.1)	3.8±0.9 (2.8-4.8)
Organic matter (%)	79.3±5.3 (70.2-86)	45.6±19.7 (24-61)
Total carbon (%)	46±3.1 (40.7-49.9)	26.4±11.4 (14.5-35.4)
Total nitrogen (%)	7.9±0.7 (7.7-8.5)	5.7±1.5 (3.5-7.7)
C/N ratio	5.9±0.6 (5-6.8)	4.6±1.6 (2.7-7.1)
Phosphate (%)	2.4±0.3 (2-3)	2.2±1.1 (0.8-3.7)
Potassium (%)	1.14±0.1 (1-1.2)	0.9±0.3 (0.4-1.3)
Calcium (%)	1.1±0.1 (1-1.3)	1.5±0.4 (1.3-2.2)
Magnesium (%)	2.8±0.1 (2.7-2.9)	3.1±0.6 (1.9-3.7)
Bacteria (cfu/g dry wt)	$0.43\pm0.3 \times 10^7$ (0.07-0.8)	$1.22\pm0.7 \times 10^7$ (0.64-2.6)
Actinomycetes (cfu/g dry wt)	$1.78\pm0.5 \times 10^3$ (1.2-2.4)	$9.94\pm5.9 \times 10^3$ (4.5-21)
Fungi (cfu /g dry wt)	$0.3\pm0.2 \times 10^5$ (0.1-0.7)	$3.1\pm1.4 \times 10^5$ (0.5-7.4)

*Accumulation in three months duration

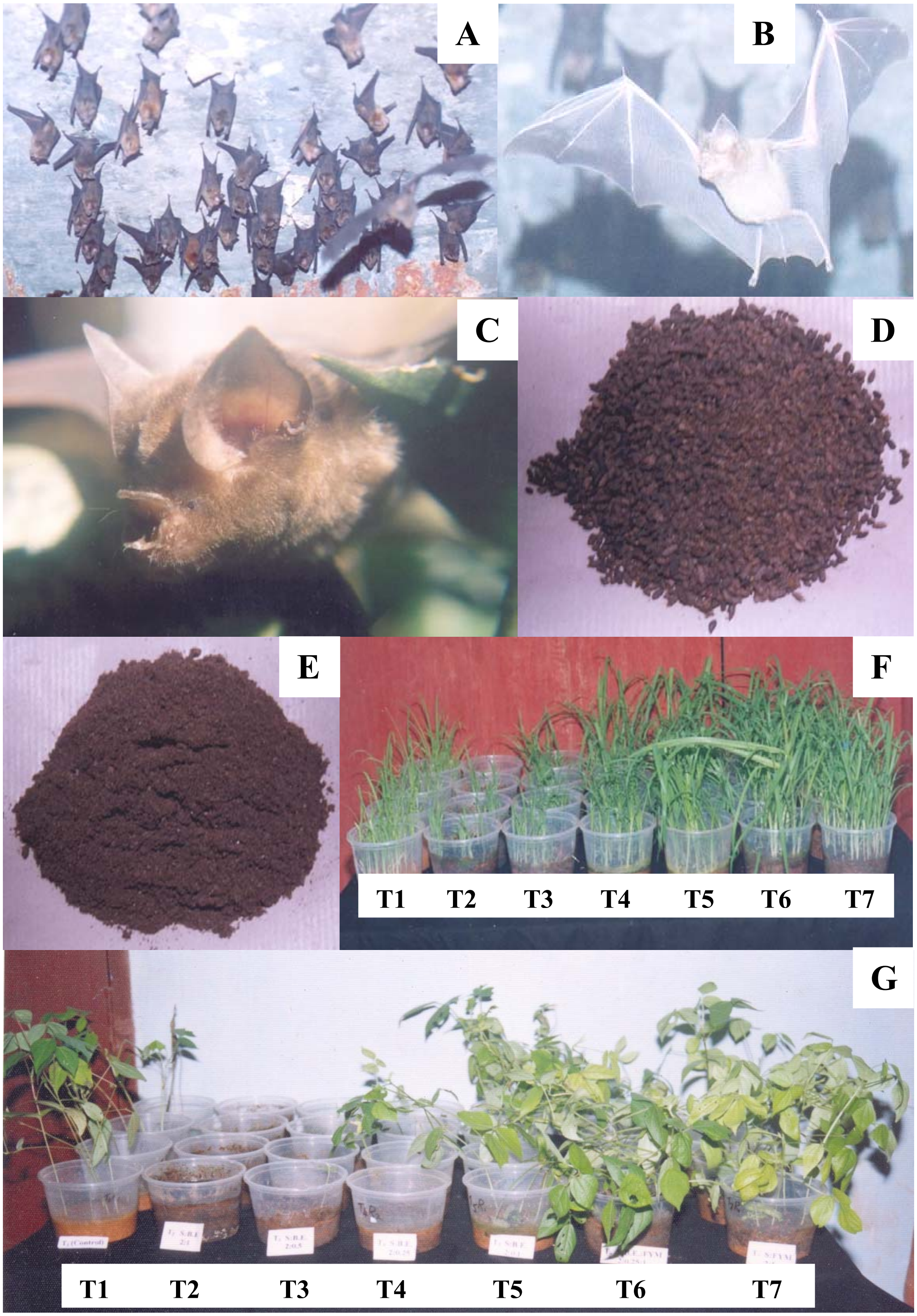

Figure 1. A B C, Night-roosting insectivorous cave bat *Hipposideros speoris*; D, heap of bat faecal pellets; E, heap of fluffy humus-like bat guano; F, growth performance of finger millet on different manure treatments (T1-T7); G, growth performance of black gram on different manure treatments (T1-T7) (T1, soil, 150 g - control; T2, soil + bat guano – 20:10; T3, soil + bat guano - 20:5, T4, soil + bat guano - 20:2.5, T5, soil + bat guano - 20:1; T6, soil + bat guano + FYM - 20:2.5:10; T7, soil + FYM - 20:10)

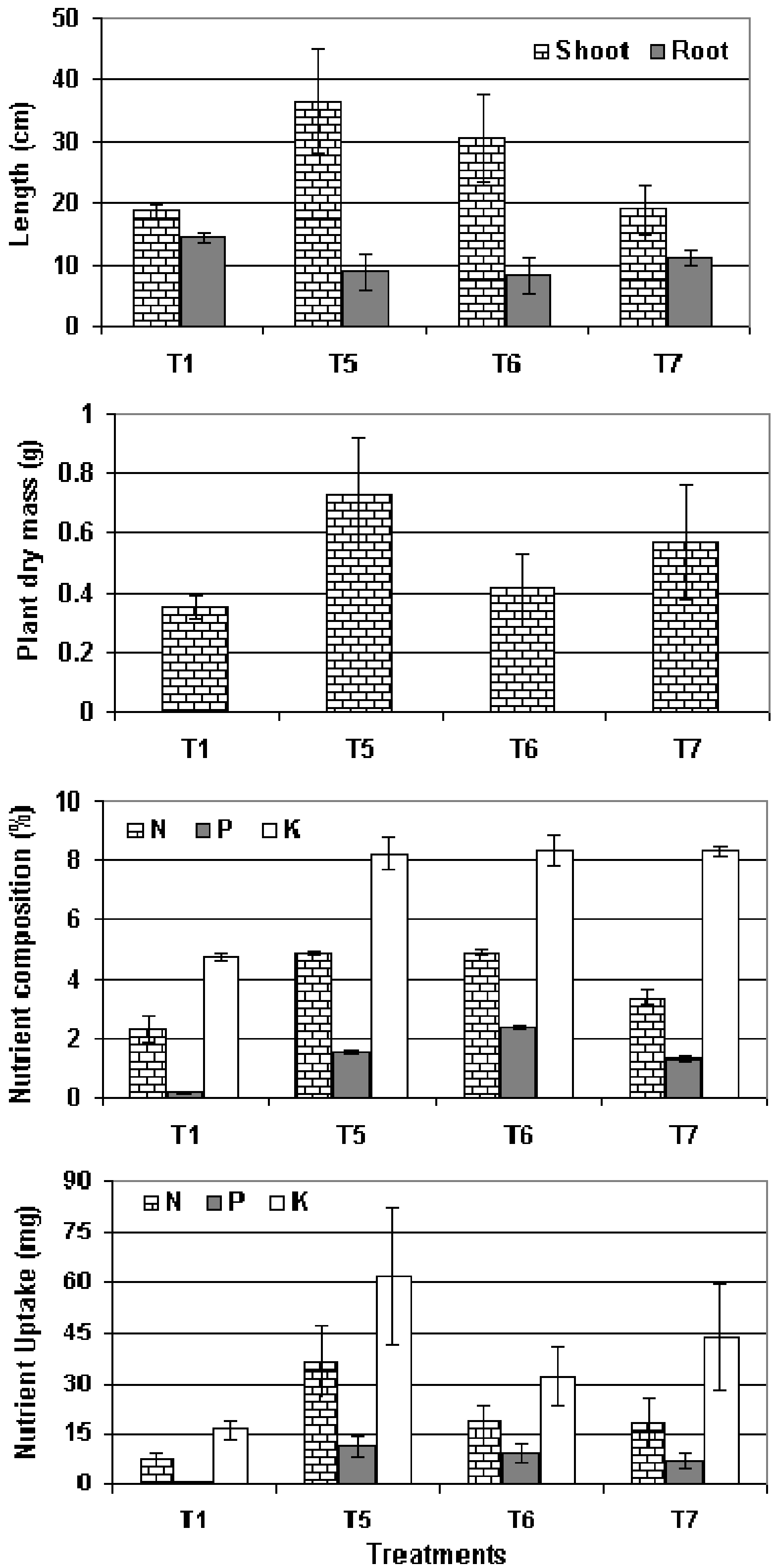

Figure 2. Crop length, total dry matter, NPK and uptake of NPK by finger millet on treatment T1, T5, T6 and T7 (T1, soil, 150 g - control; T5, soil + bat guano - 20:1; T6, soil + bat guano + FYM - 20:2.5:10; T7, soil + FYM - 20:10) (n=5; mean ± SD).

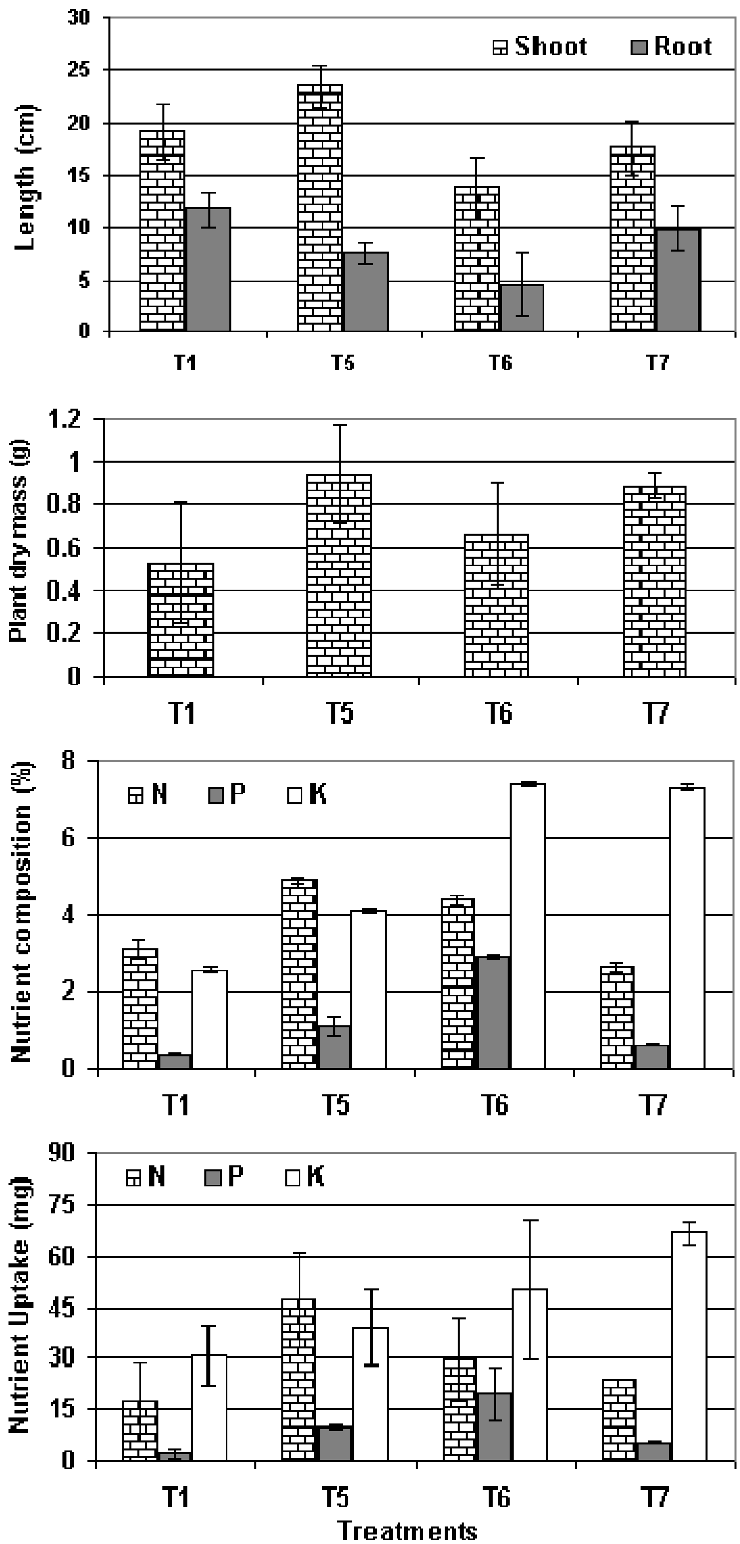

Figure 3. Crop length, total dry matter, NPK and uptake of NPK by black gram on treatment T1, T5, T6 and T7 (T1, soil, 150 g - control; T5, soil + bat guano - 20:1; T6, soil + bat guano + FYM - 20:2.5:10; T7, soil + FYM - 20:10) (n=5; mean ± SD).

DISCUSSION

Bat guano deposits have been found in several natural caves of the world and commercially exploited as natural manure (Bhat and Sreenivasan, 1990; Korine *et al*., 1999). Among the bat guano, two broad categories have been identified based on NPK ratios: high-phosphorus guano (3:13:4 – 4:30:4) from frugivorous bats and high-nitrogen guano (8:4:1 – 13:3:3) from insectivorous bats. *Hipposideros speoris* being insectivorous bats, the guano analyzed in this study showed higher nitrogen levels than phosphorus. The NPK was higher in faecal pellets than in humus guano (7.9:2.4:1.1 vs. 5.7:2.2:0.9). Comparing bat humus guano with other animal manures, nitrogen is higher and total carbon is lower than poultry, cow and sheep manures resulting in narrow C/N ratio, while phosphate is more than in cow and sheep manures (Mathur *et al*., 1990). Usually finished composts are known to be acidic and become even more acidic on nitrification during further maturation (Mathur *et al*., 1990). Due to humification, humus guano is acidic (6.48) than faecal pellets (7.5). Humus guano had lower total carbon (26.4 vs. 46%), nitrogen (5.7 vs. 7.9%) and C/N ratio (4.6 vs. 5.9) than the faecal pellets. Actinomycetes were higher than fungi and bacteria in humus guano indicating their importance in transformation of bat guano into valuable manure. Bat excrement produces unpleasant pungent odour and it attracts arthropod fauna. In our study, ants, ant larvae and unknown larvae were numerous in humus guano; thus indicating their role in humification of bat faecal pellets. The importance of saprophagous fauna in transformation of bat faecal pellets to humus needs to be investigated.

Nitrogen guano is known to enhance crop growth, while phosphorus guano induces root development, shoot budding, multiple branches and flowering. In this study, the uptake of N in finger millet and black gram in treatment T5 was significantly different than control plants (T1) ($p<0.05$) indicating the presence of N in available form and importance of bat guano in crop growth. The high N uptake in T5 treatment resulted in increased shoot length and total dry matter in crops. This indicates the soil amendment with humus guano at 20:1 ratio supplied adequate nutrients, which enhanced the dry matter of crops. Amending soil with high quantities of humus guano (in T2, 20:10; T3, 20:5; T4, 20:2.5) resulted in the wilting of seedlings possibly due to high concentration of nutrients and thus the dry matter of crops did not increase substantially (see Fig. 1F and G). The current study clearly demonstrated that humus guano of insectivorous bats could be successfully used in mixing with appropriate ratios with soil to increase the growth, dry matter yield, nitrogen content and nutrient uptake of crops. As the FYM partially meets the NPK requirements of plantation crops (Thampan, 1993), amending FYM with humus guano of insectivorous bats in appropriate ratios may help overcome the nutrient deficiencies to improve production.

CONCLUSIONS AND OUTLOOK

Tree canopies, dilapidated buildings amidst vegetation and caves are the ideal habitats of bats and such roosting or swarming sites are of great significance for bat diversity and conservation (Parsons *et al*., 2003). Considering bats as agricultural pests, their colonies were exterminated in 1950's through fumigating the caves in Israel resulted in drastic decline of insectivorous bat population that shared the roosts of frugivorous bats (Makin and Mendelssohn, 1987; Moran and Keidar, 1993; Korine *et al*., 1999). Later, it was realized that only four fruit species (15%) of the frugivorous bat's diet are commercially grown (Korine *et al*., 1999). Public awareness on the ecological services of bats is crucial at regional, national and global level for their conservation. Studies pertaining to ecological values of this least-conserved mammalian group are warranted in biodiversity conservation programme. The current study advocates conservation of bats in order to utilize their guano as organic manure in addition to their role in pollination, seed dispersal and insect pest control. Besides conserving natural habitats, creating appropriate shelters might support the activities of bats (commuting, roosting, foraging and swarming). Investigations on the possibilities of using non-conventional organic manures (e.g. vermicompost, millipede compost, bat guano) (Kale *et al*., 1992; Ashwini and Sridhar, 2002, 2006) in agriculture are becoming popular. Further studies are essential to investigate the occurrence of plant-promoting microbes in bat guano and their application in agriculture. Production of seedlings of plantations in nurseries with sufficient vigour is an essential prerequisite than mass propagation of seedlings in the field. If bat swarming and roosting sites are preserved, their guano may become low cost natural manure for pot mixtures, gardens, nurseries, green houses and landscapes. Studies on the efficiency of combinations of insectivorous and frugivorous bat guano in crop production need to be addressed as they are rich in nitrogen and phosphorus respectively.

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