Short communication

Effect of bat guano on the growth of five economically important plant species

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Abstract

Fertiliser applications are critical to crop production and food security in Cambodia. While inorganic forms are mostly used, livestock manure, compost and bat guano are also widely applied. As the efficacy of bat guano as a plant fertiliser is unknown in the country, this was tested in eight-week growth trials for five economically important species: horseradish tree *Moringa oleifera* Lam., jackfruit *Artocarpus heterophyllus* Lam., longan *Dimocarpus longan* Lour., eggplant *Solanum melongena* L. and papaya *Carica papaya* L. Three treatments were employed in the trial: a control, a chemical fertiliser treatment, and a bat guano treatment. Results indicate that bat guano applications enhance plant growth. Compared to controls, all plant species in the guano treatment exhibited greater growth rates, most of which were statistically significant. Compared with chemical fertiliser treatments, three species in the guano treatment also exhibited greater growth, though only two were significantly different. In the remaining two species, growth was less or similar although again not significantly different. Additional trials are recommended to elucidate any longer term and cumulative benefits that might accrue from the use of bat guano as a plant fertiliser.

Key words: Organic manuring; Plant growth

Agriculture remains the core source of income for most Cambodians, accounting for 34.7% of the country's GDP and 56.7% of national labour force work in 2012 (Save Cambodia's Wildlife, 2014). As much of Cambodia's arable land is nutrient deficient, access to and use of fertilisers is critical to agricultural productivity and national food security (Save Cambodia's Wildlife, 2014). Though inorganic (or synthetic) fertilisers are most commonly applied, organic forms such as livestock manure, compost and bat guano are also extensively used throughout the country. For instance, harvesting of bat guano for fertiliser has occurred for decades at sites inhabited by the cave-dwelling Asian wrinkle-lipped bat *Chaerephon plicatus* (Buchannan, 1800). In addition, creation of artificial roosts colonised by the foliage-dwelling lesser Asiatic yellow house bat *Scotophilus kuhlii* Leach, 1821 whose guano is collected for fertiliser is widespread in the Pursat, Kandal and Takeo provinces (CBNRMLI, 2009; Chhay, 2013). This intriguing practice of establishing free-ranging bat colonies for on-farm guano collection appears to be unique to Cambodia and small neighbouring areas of Vietnam (Furey, 2012).

Although bat guano is commonly traded and used as fertiliser in Cambodia, empirical studies

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Table 1: Summary attributes of plant species employed in the growth trials.

Species	Attributes
Horseradish tree *Moringa oleifera* Lam.	Shrub or small tree. Young leaves provide a good source of protein, vitamins A, B and C and minerals such as calcium and iron (Radovich, 2011; Orwa et al., 2009). Various parts are effective in treating dental conditions, digestive disorders, skin conditions, circulatory issues and parasitic growth (Agbogidi and Ilondu, 2012). Also used for fuel wood, living fences, animal fodder and soil stabilisation (HDRA, 2002) and leaf extractions can increase vegetable yields (Culver et al., 2012a, b).
Jackfruit *Artocarpus heterophyllus* Lam.	Large tree. Produces a fruit which can weigh >30 kg in cultivation. Fruit and seeds are edible, and timber is relatively high quality and used in the manufacture of furniture and music instruments (Dy Phon, 2000). Jackfruit also has anti-bacterial, anti-inflammatory, anti-diabetic, anti-oxidant and immune-modulatory properties which are used for medicinal purposes (Prakash et al., 2009).
Eggplant *Solanum melongena* L.	Annual herb. Widely cultivated for its edible fruit. Eggplant can be eaten raw or cooked and is a good source of vitamin B, C, calcium, iron phosphorus and potassium (Dy Phon, 2000). Various parts of the plant have also been found to provide benefits such as antioxidants, anti-fungal properties and increase cardiovascular health (Noda et al., 2000).
Papaya *Carica papaya* L.	Large herb. Widely cultivated for its large fruit which can weigh as much as 9 kg. The fruit is a good source of vitamin A, C, E and potassium and magnesium. Other parts of the plant can be used to treat numerous ailments associated with warts, corns, sinuses, eczema, cutaneous tubercles, glandular tumors, blood pressure, dyspepsia, constipation and amenorrhoea (Aravind et al., 2013).
Longan *Dimocarpus longan* Lour.	Tree or shrub. Widely cultivated for its sweet fruit. Once free from its kernel, the arillus can be candied in sugar, dried or eaten fresh. Fruit, seed and flowers are used in traditional medicine to relieve neural pain and swelling (Yang et al., 2011). Pharmacological activities including anti-tyrosinase, anti-glycated and anti-cancer activities, and memory-enhancing effects of the longan arillus, pericarp and seed extract have also been found (Yang et al., 2011; Huang et al., 2012).

of its efficacy have yet to be conducted. Consequently, the aim of the study was to test whether bat guano applications actually do improve plant growth, and should this prove the case, to determine how favourably this enhanced growth compares to that obtained using chemical fertilisers.

Five multi-purpose species were selected for the study (Table 1). These were selected based on their availability in Cambodia, local knowledge and markets or were species that have beneficial attributes related to nutrition, human health, the environment or a combination of these. The growth trial was undertaken at the biological field research laboratory of the Royal University of Phnom Penh from March to July 2013. Three treatments were adopted in the trial: i) a control, with no fertiliser applications; ii) a chemical fertiliser treatment; and, iii) a bat guano treatment. Each treatment consisted of 10 replicates per species which were grown for eight weeks under shade netting at the laboratory, providing a total sample of 30 individual plants for each species (or a study total of 150 plants).

All plants in the trial were grown from seed at the laboratory. Seeds were obtained for two species (*C. papaya* and *S. melongena*) from the Chua Yong Seng Seed Company in Phnom Penh, while seeds for *A. heterophyllus* and *D.*

longan were obtained from private growers in Phnom Penh, and for *M. oleifera* from private growers in Pursat province. Three seeds were germinated for each replicate which consisted of a plastic soil bag (measuring 8 cm in diameter x 20 cm in height) filled with alluvial soil obtained from the banks of the Mekong River. The most robust of the three germinating seeds was retained and each species was monitored daily to determine its time to germination. The growth trials began 1-2 weeks after germination in all five species and treatments for each species were undertaken concurrently.

In all treatments, replicates were watered twice a day for the entire study period (as well as the post-germination period prior to the trial) and checked daily for potential insect and/or disease damage, with removal and/or cleaning undertaken as needed. For the chemical fertiliser treatment, granular fertiliser produced by the Binh Dien Fertiliser Joint-Stock Company was obtained in Phnom Penh which consisted of 20% nitrogen (N), 20% phosphorus (P) and 15% potassium (K) (by weight). For the bat guano treatment, guano produced by *S. kuhlii* was obtained from farmers in Kandal province. This

Table 2: Variations in weekly growth of five plant species subjected to three treatments over eight weeks. Values are given in centimetres as mean, ± SD (minimum-maximum).

Species / Response variable	Treatment			***p***
	Control (*n*=10)	Chemical Fertiliser (*n*=10)	Bat Guano (*n*=10)	
Moringa oleifera				
stem circumference	1.72 ± 0.58 (0.80–3.10)	1.96 ± 0.69 (1.00–3.30)	1.93 ± 0.74 (0.90–3.50)	0.026
stem height	59.74 ± 32.35 (10.0–112.50)	66.21 ± 37.20 (12.00–145.00)	59.32 ± 34.57 (12.80–139.00)	0.125
Artocarpus heterophyllus				
stem circumference	1.62 ± 0.30 (1.10–2.40)	1.58 ± 0.28 (1.10–2.30)	1.78 ± 0.42 (1.00–2.90)	<0.001
stem height	33.27 ± 9.08 (16.00–55.20)	26.39 ± 9.00 (8.00–53.70)	35.60 ± 10.78 (13.00–62.50)	<0.001
Solanum melongena				
stem circumference	1.22 ± 0.32 (0.60–2.00)	1.30 ± 0.45 (0.50–2.20)	1.66 ± 0.51 (0.50–2.60)	<0.001
stem height	11.67 ± 7.41 (1.50–26.20)	13.76 ± 9.67 (1.50–40.20)	21.50 ± 13.26 (2.00–47.20)	<0.001
Carica papaya				
stem circumference	1.82 ± 0.80 (0.80–4.10)	2.99 ± 1.72 (0.80–10.00)	2.99 ± 1.19 (1.00–5.40)	<0.001
stem height	18.63 ± 11.68 (1.70–48.50)	34.26 ± 21.58 (4.50–106.00)	28.76 ± 14.49 (3.50–56.50)	<0.001
Dimocarpus longan				
stem circumference	0.92 ± 0.17 (0.40–1.50)	0.96 ± 0.14 (0.70–1.30)	1.06 ± 0.15 (0.80–1.40)	0.010
stem height	9.37 ± 3.58 (3.50–18.00)	8.15 ± 2.08 (3.30–12.50)	9.89 ± 2.47 (4.00–16.50)	0.297

was tested for macronutrient content in Phnom Penh and comprised 9.97% N, 3.4% P and 0.4% K (by weight). In each species treatment, one gram of chemical fertiliser / bat guano (as appropriate) was added to each replicate every seven days for eight weeks, the total application being comparable to similar studies (Sridhar et al., 2006; Shetty et al., 2013).

Two response variables reflecting plant growth were measured (in centimetres) during the trial: stem circumference (taken just above soil level) and stem height. Both were measured at seven day intervals for eight weeks, immediately prior to the weekly bat guano and chemical fertiliser applications. The mean weekly value arising from the eight weeks of measurement of the two variables for each replicate was employed in analysis. As these data were normally distributed (Kolmogorov-Smirnov tests, $p>0.05$) and had homogenous variances (Levene tests, $p>0.05$), ANOVA were employed for group comparisons and the Bonferroni method for pair-wise comparisons.

Bat guano applications enhance plant growth. Except for stem height in *M. oleifera*, all of the five plant species subjected to the bat guano treatment experienced greater weekly increments in stem circumference and height compared to the control (Table 2), and this difference was statistically significant ($p<0.05$) in six of the nine remaining pair-wise comparisons. Compared to the chemical fertiliser treatment, three of five plant species subjected to the bat guano treatment experienced greater increments in both response variables, namely *A. heterophyllus*, *S. melongena* and *D. longan*, although differences were not significant ($p>0.05$) in the latter species. In the remaining two species (*M. oleifera* and *C. papaya*), weekly increments were less or similar (in the case of stem circumferences of *C. papaya*) though once again these differences were not significant ($p>0.05$).

That three of the five species treated with bat guano experienced the greatest growth despite its lower N-P-K content (9.97-3.4-0.4%) compared to the chemical fertiliser (20-20-15%) is noteworthy. Though not yet tested for in guano produced by *S. kuhlii*, this is likely attributable to the presence of organic matter, carbon, important micronutrients (e.g. calcium, magnesium, iron, aluminium, iron) and a beneficial microflora which are typical of insectivorous bat guano (Sridhar et al., 2006; Shetty and Sreepada, 2013; Reichard, 2010), and their absence in the chemical fertiliser. This is supported by trials in India which suggest that only small amounts of bat guano are required to enhance the efficiency of plant growth (Sridhar et al., 2006; Shetty et al., 2013). Nonetheless, given the short duration of the present study it would be instructive to conduct additional trials to elucidate any longer term and possibly cumulative effects that may accrue from bat guano applications. Given the important role that *C. plicatus* plays in consuming major agricultural pests in Thailand (Leelapaibul et al., 2005), research to determine the significance of agro-ecosystem services provided by *S. kuhlii* is also recommended.

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