Original Research Article

Efficacy of bat guano as a plant fertiliser on growth of Fenugreek (*Trigonella foenum-graecum* L.) in sustainable agriculture

Abstract

Synthetic/chemical fertilizers has been rapidly increased due to extensive agricultural activities to meet the demand for food to sustain an ever-expanding global population which has become a pressing concern. There is a need for development of sustainable agricultural practices which promote the use of natural fertilizers to improve soil health and support high value crops for cultivation. Bat guano, an organic fertilizer composed of bat excrement, has gained attention as a promising substitute for synthetic fertilizers, offering numerous benefits to plants and soil health as it's highly rich in nutrient contents. Fenugreek (*Trigonella foenum-graecum*), a versatile annual herb, with multifarious uses can be used for exploring natural fertilizers for enhancing quality and crop productivity. Hence present study was under taken to examine the impact of bat guano application on the growth and productivity of fenugreek. Amongst all the treatments, the highest germination was recorded in 50% guano with soil amendments treatment resulting in 99% germination rate followed by 100% guano (96.3%). Least germination rate was observed in control with only 85.3%. Also, 50% was best treatment with maximum plant height of about 16.3 cm within 4 weeks period compared to vermicompost (15.9cm) and control (11.3cm). Similarly, leaves number per plant was also maximum in 50% guano (10.33 leaves/plant) followed by vermicompost (10 leaves/plant). NPK content of plant and soil were also analysed using standard techniques which provides valuable insights into the existing soil composition, enabling informed decisions on how to use bat guano effectively to correct nutrient deficiencies and support optimal crop growth. Further studies are recommended to assess the benefits from the use of Bat Guano as a plant fertilizer in sustainable agriculture.

Key Words: Fenugreek, fertilizers, bat guano, sustainable agriculture, soil fertility.

1.0 Introduction

Agriculture is the backbone of Indian economy and Indian agriculture used to depend on organic techniques for farming in ancient times, where the fertilizers, pesticides were obtained from plant and animal products such as bovine dung, sheep manure, poultry waste, composted agricultural wastes, bat guano, vermicompost etc. Around 70% population earns its livelihood from agriculture. Two most important challenges regarding global security are the continuously increasing human population which is expected to reach 9.7 billion in 2050 and 10.4 billion in 2100 and the impact of climate change on food, fibre, and other ecosystem products (Dimande et al., 2023, Kerr et al., 2022).

To ensure sustainability in food production for growing population and to enable adaptation to a changing climate, more lands were brought under cultivation, organic manure replaced by chemical fertilizers and locally made pesticides were replaced by chemical pesticides and the crop production increased. As time passed, extensive application of chemical fertilizers has led to the depletion of soil organic matter, adversely affecting soil health. Indiscriminate use of inorganic fertilizers has inflicted severe damage on both soil and the surrounding environment. In order to overcome the health menace created by chemical fertilizers and pesticides, organic farming is popularizing among farmers in modern India (Mehdi et al., 2012; Michael et al., 2102; Naseer et al., 2003; Reddy et al., 1998, Shetty et al, 2013). Application of vermicompost to improve soil fertility has become very popular but little is known about the application of bat guano as organic manure (Sridhar et al, 2006).

Bat guano is a multi-functional fertilizer that known to contain all the macro and micronutrients that plants require in a natural form and hence ably serve as soil conditioner, enriching the soil with NPK and trace minerals, improving soil texture. It also has fungicidal effect when applied to leaves, and a compost activator that speeds up the decomposition process of compost and can also control harmful nematodes in the soil. Moreover, the microbes in Guano fertilizer have been reported to aid with cleansing toxicities from the soil, improving the natural balance without increasing alkaline or acid levels, while providing the soil's biological system with fast and slow release nutrients. It also claimed that Guano positively enhances the taste of the produce by making the overall flavor sweeter, richer, and less watery (Abubaker et al., 2020). In ancient times it was used in agricultural practice as manure but with advent of synthetic/chemical fertilizers, its usage became less popular. Western countries such as Jamaica, Indonesia, Mexico promote and sale bat guano as manure. Inspire of so many

valuable properties, use of this rich manure has not gained any popularity among the farming community in India (Shetty et al, 2013).

Fenugreek (*Trigonella foenum-graecum* L.) is versatile annual crop belonging to the family Legume and is native to India, especially found in Kashmir, Punjab and Upper Gangetic planes. It is the oldest medicinal plant and commercially important spice crop due to its multifarious uses and is extensively grown in every part of the country for seeds, tender shoots and fresh leaves. Its production is concentrated mainly in the states of Rajasthan, MP, Gujarat, Haryana, West Bengal and Uttaranchal. A total of 1, 88,480ton of fenugreek seed was produced during the year 2019-2020 and 27,660 metric tonnes of fenugreek seed of worth Rs. 1638.36 million was exported from India to USA, UAE, South Africa, Korea, UK, Nepal, Bangladesh, Saudi Arabia, Egypt, Sri Lanka, Germany and Sudan (Kakani et al., 2009). Limited research work has been carried out on the Fenugreek in general, using Bat Guano in particular both at International and National level.

Hence the present study was under taken to find out the effects of Bat Guano on growth of Fenugreek, and also to find out the possibly of its application as economically sound, socially acceptable and environmentally friend organic fertilizer to boost crop productivity while minimizing adverse ecological effects and exponential raising prices of the chemical fertilizers.

2.0 Materials and Methods

2.1 Study site and collection

This study was under taken at the Institute of Wood Science and Technology (IWST), situated at 13.0113° N, 77.5704° E within Bengaluru, India (Fig 1) during the year 2024. The organic amendment named guano in this study is bat excrement, locally available from natural deposits in the 10 acres forest land maintained at IWST campus. Trowel was used to gently collect the bat guano which have accumulated over years of untouched forest land where predominant species is insectivorous bats. Vermicompost was procured from the SVA Biotek, Hebbal, Bengaluru.

Fig 1: Amendment (Bat Guano) collection site in forest area of Institute of Wood Science and Technology, Bangalore

2.2 Effect of bat guano concentrations on fenugreek seed germination and growth

To assess the impact of bat guano on fenugreek seed germination and seedling growth, seeds were pre-soaked overnight in water and sowed in different treatments for germination. Potting mixture consists of autoclaved red soil and river sand (1:1) was mixed with guano in different ratios in polybags. The treatments included: T1- autoclaved soil + 10% bat guano; T2- autoclaved soil + 20% bat guano; T3- autoclaved soil + 50% bat guano; T4- autoclaved soil+ 100% bat guano; T5- vermicompost; T6- autoclaved soil (control) respectively. All the treatments were taken in triplicates. The polybags were watered (sterile water) twice a day until harvest (4 weeks). Germination percentage was recorded at the end of four weeks period. On uprooting the seedlings shoot length and number of leaves were determined.

2.3 Soil sampling and analysis

At the end of pot experiment the soil was sampled for determination of general soil properties, and to obtain a biological index of soil nutrient availability. After harvesting the fenugreek crop, the soil samples were taken per treatment from the 0-0.20m layer. The soil was air dried and sieved (2mm mesh). Sieved soil was used for analysis as per standard soil testing techniques along with some specialized analyses tailored to assess specific parameters relevant to fenugreek growth and the effects of organic amendments such as pH (soil/solution, 1:2.5), Organic carbon (Wet oxidation method, Walkley and Black, 1934), Nitrogen-N (Alkaline potassium permanganate distillation method, Subbiah and Asija, 1956), Phosphorous-P (Olsen's extractant method, Jackson, 1973) and Potassium-K (Ammonium acetate extractable method, Jackson, 1973).

2.4 Plant sampling and analysis

The plant samples (whole) were collected from each treatment and washed with water. Oven-dried at 65°C until a constant weight was obtained, ground (1mm mesh) and analyzed for elemental composition. Elemental tissue analysis were performed by Kjeldahl digestion and distillation (N), Diacid digestion and colorimetry (P) and Flame photometry (K).

2.5 Experimental design, data collection and analysis

The experiments were performed in completely randomized design with six treatments. Each treatment consists of 3 replicates and each replicate has 50 seeds for germination studies. Observations were recorded every week for germination studies. To compare plant growth and productivity among the treatments and the control, plant height (cm) and total number of leaves were measured at the end of the experiment (4 weeks after transplanting). The experiment was repeated twice and the data was pooled together and variance (one way or single factor analysis) in treatment means and standard errors were determined, followed by the least significant difference (LSD) test at P 0.05 to compare means.

3.0 Results and Discussion

The obtained results casted light on studied plant *Trigonella foenum-graecum* (Indian Fenugreek) and how they were influenced by the application of different concentrations of bat guano. The results are presented in the following tables and figures followed by discussion in the respective headings.

3.1 Physical characteristics of Bat guano

The bat guano sample appears in the form of small blackish sticks. The bat guano granules are elongated, usually segmented with tiny perforations on the surface, blunt ends and made up of shiny fragments, whereas dry bat guano is very brittle and light. When damp, it has a strong pungent odour.

3.2 Effect of bat guano concentrations on fenugreek seed germination and plant growth

It was observed that the germination in *T. foenum* started from 2nd day. The highest germination was recorded in 50% guano with soil amendments treatment resulting in 99% germination rate followed by 100% guano (96.3%). Least germination rate was observed in control with only 85.3% (Table 1) (Fig 3A). The results of *T. foenum* plant growth showed that plant height was significantly increased due to application of different concentrations of guano and vermicompost, but it did not show any significant difference in the plant leaf number

because of application of either Guano or vermicompost. It was observed that Bat guano applications enhance overall plant growth even though the NPK content was low.

Amongst all the treatments, 50% was best treatment with maximum plant height of about 16.3 cm within 4 weeks period compared to vermicompost (15.9cm) and control (11.3cm). The plant height was almost similar in 100% guano and control. Similarly, leaves number per plant was also maximum in 50% guano (10.33 leaves/plant) followed by vermicompost (10 leaves/plant) (Fig 2). Shetty *et al.,* (2013) reported that lower quantities of soil: guano ratio (20:0.5) is better for crop production. It is also evident from the obtained results that, the bat guano in lower quantities increased the biomass significantly. Likewise amending the guano with farmyard manure in appropriate ratios may help overcome the nutrient deficiencies to improve crop production (Sridhar *et. al.,* 2006). Levina and Levinsh, (2015) reported that the addition of bat guano to vermicompost fertilizer enhanced its positive effect on plant growth, although high guano concentrations increased the proportion of potentially plant pathogenic fungi. Jumao-As *et al.,* (2022) identified a diverse bacterial community in bat guano, including plant-growth promoters and biodegraders of hazardous environmental contaminants, but also pathogenic species. Seena, (2006) demonstrated that the incorporation of low amounts of bat guano into soil significantly enhanced crop production.

3.3 Fresh and dry weight (g/plant) of *Trigonella foenum-graecum*

Among all treatments 100% guano recorded maximum fresh weight 21.24g/ plant followed by 50% guano (18.51g/plant) and maximum dry weight was 3.21g/ plant followed by 50% guano (2.80g/plant). Similarly, Singh *et al.,* (2023) reported that 100% RDF+FYM gave maximum fresh weight (83.43g/plant) in Indian mustard.

3.4 Plant and soil sample analysis

No significant interaction was found between macro elements and soil amendment treatments on the plant. It was found that soil amendment with bat guano experienced the greatest growth in *T. foenum* despite its lower N-P-K content (1.81-0.77-0.44%) compared to the vermicompost (2.03-0.49-0.52%) and control (1.87-0.48-0.46%) (Table 4). It was also observed that the guano analyzed in this study showed higher phosphorus levels in soils (34.42%) than nitrogen and potassium (Table 5). Palita *et. al.* (2021) also observed that the addition of bat guano to soil improved the growth parameters and photosynthetic response in finger millet and black gram seedlings. Similar findings were recorded (Sothearen *et al.,* 2014) in five economically important plants. The soil sample analysis also revealed that NPK and soil

properties such as pH, and EC did not show any significant relation with the soil amendment treatments (Table 6). Thus, it was noteworthy that, addition of guano to the soil has no negative effect on pH of the soil and is almost alkaline in nature which favors the maximum plant growth. Ernest *et. al.* (2021) has reported that guano contains high levels of NPK (nitrogen, phosphorus, potassium), which enhances soil quality and supplies essential nutrients for plant growth.

Nitrogen rich manure enhances crop growth and phosphorus rich manure induces root development, shoot budding, branching and flowering. Hence, bat guano can be mixed at various proportions with other high nitrogen organic manures for wholesome plant growth and soil fertility. Trials in India have suggested that, only small amounts of bat guano are required to enhance the efficiency of plant growth (Sridhar *et al.,* 2006; Shetty *et al.*, 2013). Reichard (2010) demonstrated that, moderate applications of guano in a controlled greenhouse experiment promoted growth in a grass species native to Texas (Indian grass, *Sorghastrum nutans*), but reduced root/stem ratio and had a neutral effect on two other native species: little bluestem, *Schizachyrium scoparium*, and prairie coneflowers, *Ratibida columnifera*, respectively. He further speculated that guano deposition may have species specific effects on plant communities (Reichard, 2010; Kunz *et al.*, 2011). Bafadhal *et al.*, (2023) found that bat guano increased the production of the Indole Acetic Acid hormone, improved soil properties, and increased bacterial diversity.

Table 1: Effect of different concentrations of bat guano on germination and plant growth

Sl.N	Treatments	Germination percentage	Plant height (cm) (Mean ± SE)			
			1st week	2nd week	3rd week	4th week
1	**10%**	85.7	3.2 ± 0.12	6.1 ± 0.12	9.3 ± 0.18	14.2 ± 0.27
2	**20%**	88	3.1 ± 0.06	6.1 ± 0.06	9.1 ± 0.07	13.9 ± 0.23
3	**50%**	**99**	**3.4 ± 0.03**	**6.7 ± 0.12**	**10.1± 0.07**	**16.3 ± 0.09**
4	**100%**	96.3	2.1 ± 0.07	4.4 ± 0.03	7.9 ± 0.15	11.7 ± 0.15
5	**Vermicompost**	95.3	3.4 ± 0.09	6.7 ± 0.15	9.9 ± 0.12	15.9 ± 0.09
6	**Control**	85.3	2.3 ± 0.15	4.9 ± 0.06	8.0 ± 0.09	11.3 ± 0.15
LSD (α at 5%)		**-**	**0.23**	**0.25**	**0.29**	**0.44**

Table 2: Effect of different concentrations of bat guano on number of leaves per plant

Sl.N	Treatments	Number of leaves per plant (Mean ± SE)			
		1st week	2nd week	3rd week	4th week
1	**10%**	2.33 ± 0.33	3.33 ± 0.33	9.0 ± 0	9.67 ± 0.33
2	**20%**	2.67 ± 0.33	3.67 ± 0.33	8.33 ± 0.33	9.0 ± 0.58
3	**50%**	**2.67 ± 0.33**	**4.0 ± 0**	**9.33 ± 0.33**	**10.33 ± 0.33**
4	**100%**	2.0 ± 0	3.33 ± 0.33	6.33 ± 0.33	7.0 ± 0.58
5	**Vermicompost**	2.33 ± 0.33	3.33 ± 0.33	9.0 ± 0	10.0 ± 0
6	**Control**	2.0 ± 0	3.33 ± 0.33	5.67 ± 0.33	7.67 ± 0.33
LSD (α at 5%)		**0.69**	**0.76**	**0.68**	**1.02**

Table 3: Effect of different concentrations of bat guano on fresh and dry weight of plant after germination.

Sl. No	Treatments	(Mean ± SE)	
		Fresh weight (g/plant)	Dry weight (g/plant)
1	**10%**	13.62 ± 1.61	2.52 ± 0.13
2	**20%**	13.48 ± 1.20	2.51 ± 0.08
3	**50%**	18.51 ± 1.41	2.80 ± 0.05
4	**100%**	21.24 ± 2.38	3.21 ± 0.17
5	**Vermicompost**	18.16 ± 2.21	2.81 ± 0.13
6	**Control**	19.73 ± 1.09	2.96 ± 0.11
LSD (α at 5%)		**4.17**	**0.29**

Table 4: Effect of different concentrations of bat guano on macro elements of plant after germination.

Sl.N	Treatments	Macro elements of plant (Mean ± SE)		
		N	P	K
1	**10%**	1.87 ± 0.10	0.48 ± 0.17	0.39 ± 0.04
2	**20%**	1.89 ± 0.17	0.44 ± 0.17	0.40 ± 0.02
3	**50%**	**1.98 ± 0.15**	**0.56 ± 0.15**	**0.41 ± 0.06**
4	**100%**	1.81 ± 0.11	0.77 ± 0.11	0.44 ± 0.03
5	**Vermicompost**	2.03 ± 0.09	0.49 ± 0.05	0.52 ± 0.04
6	**Control**	1.87 ± 0.09	0.48 ± 0.17	0.46 ± 0.04
LSD (α at 5%)		**0.296**	**0.356**	**0.099**

Table 5: Effect of different concentrations of bat guano on macro elements of soil.

Sl.N	Treatments	Macro elements of soil (Mean ± SE)		
		N	P	K
1	**10%**	233.75 ± 6.79	27.1 ± 2.23	250.88 ± 42.74
2	**20%**	263.11 ± 9.42	26.22 ± 2.43	226.24 ± 33.45
3	**50%**	234.2 ± 11.67	32.22 ± 5.99	206.62 ± 5.94
4	**100%**	253.81 ± 17.62	34.42 ± 5.89	201.56 ± 18.49
5	**Vermicompost**	262.59 ± 10.24	31.24 ± 1.72	236.54 ± 6.53
6	**Control**	163.11 ± 18.83	22.19 ± 2.24	265.26 ± 32.17
LSD (α at 5%)		**33.20**	**9.73**	**68.25**

Table 6: Effect of different concentrations of bat guano on soil properties of potting medium.

Sl.N	Treatments	Soil properties (Mean ± SE)		
		pH	EC	OC
1	**10%**	6.95 ± 0.22	0.58 ± 0.135	0.12 ± 0.006
2	**20%**	6.91 ± 0.18	0.35 ± 0.069	0.15 ± 0.009
3	**50%**	6.89 ± 0.10	0.46 ± 0.07	0.33 ± 0.064
4	**100%**	6.87 ± 0.18	0.54 ± 0.14	0.44 ± 0.018
5	**Vermicompost**	6.63 ± 0.03	0.22 ± 0.06	0.62 ± 0.062
6	**Control**	6.62 ± 0.11	0.15 ± 0.04	0.15 ± 0.015
LSD (α at 5%)		**0.38**	**0.23**	**0.10**

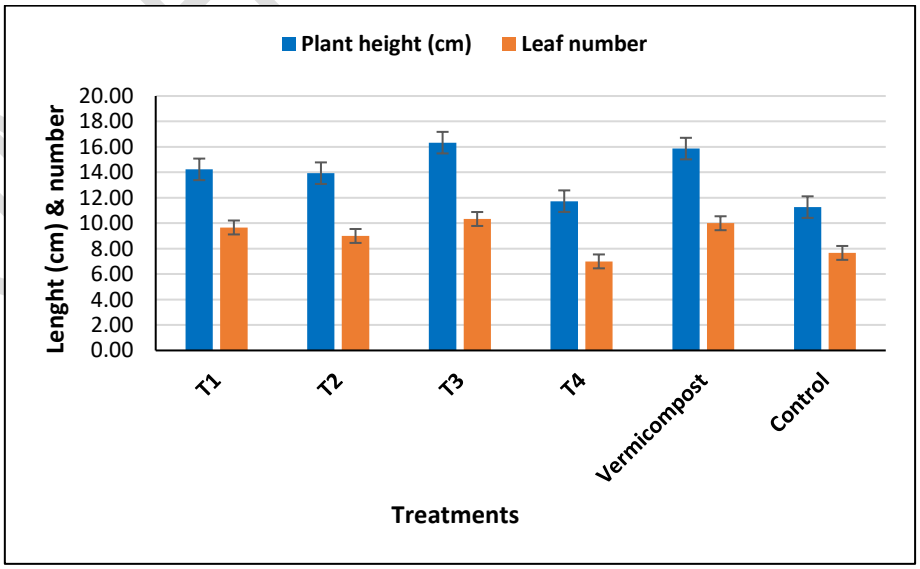

Fig 2: Effect of different concentrations of bat guano on plant height and leaf number after 4 weeks period.

Fig 3: A. Germinated *T. foenum* seedlings after 4 weeks period; B. Growth of *T. foenum* in different concentrations of bat guano after 4 weeks period; C. Soil sample analysis; D. *T. foenum* plant samples before NPK analysis

4.0 Conclusion

The findings of the study showed the presence of a wide range of elements in the guano of bats. Especially 5: 800 (5gm Gauno: 800 gm Soil) concentration showed good growth of fenugreek plant including the length and number of leaves. Nitrogen, potassium (K), and magnesium (Mg) in guano are adequate for crop production across various bat feeding habits. An analysis of bat guano revealed that it has higher nitrogen content compared to phosphorus. Additionally, in farming, Guano based fertilizers can improve availability of nutrients in the soil, increases growth and yield of vegetable crops. Further, studies are essential to investigate the occurrence of plant-promoting microbes in the bat guano and their applications. Also more in-depth assessments are necessary to tackle the associated health risk to the farmers for proper utilization of this organic fertilizer over chemical fertilizers.

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