Effect of Different Rate of Bat Guano on Growth and Yield of Tomatoes (*Lycopersicon esculentum* Mill) in Niamey, Niger

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**Authors’ contributions**

This work was carried out in collaboration among all authors. Authors AHK and GY designed the study, performed the experiment, wrote the protocol, drafted the manuscript and edited the manuscript. All authors read and approved the final manuscript.

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**ABSTRACT**

**Aims:** A field experiment was conducted at the Research Farm of Faculty of Agricultural Sciences, Abdou Moumouni University of Niamey - Niger, from November to March 2018 to determine the effects of different rate of bat guano fertilizers on growth and yield parameters of tomato (*Lycopersicon esculentum* Mill).

**Study Design:** The four treatments included no manure T0 as control, T1-500 kg/ha, T2-1000 kg/ha T3-1500 kg/ha of bat guano fertilizers was laid out in a Randomized Complete Block Design (RCBD) with four replications.

**Methodology:** The variables measured were plant height, number of branches, stem diameter and fruit yield obtained. Data collected were subjected to Analysis of Variance (ANOVA). The means were separated using LSD at five percent level of significance.

**Results:** The results showed that all levels of bat guano improve the growth and yield parameters of tomato compared to the control. Growth and yield parameters of tomato plants treated with 1500

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kg/ha and 500 kg/ha of bat guano were higher than the other treatments. The T3 (1500 kg/ha) and T1 (500 kg/ha) of bat guano are statistically homogenous and showed highest plant yield with 40.45 and 38.75 t/ha of tomato fruits respectively. **Conclusion:** Based on the findings of the experiments it could be deduced that bat guano seems to promote higher growth yield of tomato. Thus, it should be recommended 500 kg/ha of bat guano for growers of tomato crop in the study area.

**Keywords:** Bat guano; tomato; growth; yield; sandy loam; Niamey.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely grown vegetables in the world, with a global production of 182 301 395 tons in 2017, covering a total area of 4 848 384 hectares [1]. It occupies an important place in the human diet due to its low content of lipids, calories and free cholesterol as well as its high content of vitamins A, B and C, carotene and lycopene [2]. It is a lucrative activity for many producers in rural, urban and peri-urban areas [3].

In Niger, tomato is cultivated on 10 508 ha, thus occupying the third place among the most cultivated vegetables after the onion and the cabbage [4]. However, local tomato production did not meet the ever-increasing needs of the population. One of the major problems causing a decline in tomato production is the low soil fertility [3,5,6]. The use of fertilizers is necessary to improve the yield, quality and fertility of the soil because it corrects the nutrient deficiency quickly and efficiently [7]. However, excessive use of mineral fertilizers has an harmful effects on plants and soils. Also, the excessive leaching and drainage of the elements leads to the eutrophication of water and pollution of groundwater [8]. Given the negative effects of mineral fertilizers on agricultural land and environment, there is a need to explore other ways to improve soil fertility in order to increase crops production [9]. Over the years, researchers and farmers have turned to the use of organic fertilizers like compost, chicken droppings and guano [10].

Bat guano, essentially made up of bat feces, rich in carbon, nitrogen, essential minerals and beneficial microbes. The use of bat guano is a long-standing practice, it is generally accepted, commercially viable, relatively inexpensive and environmental friend. When applied to soil, bat guano can improve physical properties of the soil and microbial population and has little or no adverse effects on humans and the environment [11,12,13,14]. The chemical and microbial properties of bat guano help improving soil fertility, remove toxins, and help control fungi and nematodes in the soil [11]. The nutrients contained in organic fertilizers such as bat guano are released more slowly and are stored for a long time in the soil, thus ensuring residual effects on the following crops [15]. In contrast, guano is an organic fertilizer of immediate action because it contains organic matter at advanced stage of decomposition and thus, undergoes fast nitrification. Despite the fertilizing potential of this product, most studies have focused on the biological characterization of bat guano. However, unreasonable use of organic fertilizers such as bat guano can significantly reduce their effectiveness and negatively affect soil productivity [16,17]. In addition, to obtain maximum economic value from organic fertilizers, they should be applied in an optimal doses that meet the nutrient requirements of the crops in order to increase their yield [18]. This is the context for this study, which aims to determine the effect of different doses of bat guano on the growth and yield of tomatoes in the Niamey region of Niger.

2. MATERIALS AND METHODS

2.1 Study Site

The study was carried out in the experimental site of the Faculty of Agronomy of the Abdou Moumouni University of Niamey in Niger Fig. 1. This study area is located at 13°30'00.12 “ north latitude and 2°05’24.5.”

2.2 Experiment Design

The field experiment was installed during the dry season. The experimental design used was Randomized Complete Block Design (RCBD) with four treatments and replicated in four (blocks) Fig. 2. Each block was subdivided into four elementary plots with a dimension of 3 m x 1 m (3 m²) with a spacing of 1 m between the plots and 2 m between the blocks to facilitate movement during cultivation operations and phenological observations.
2.3 The Plant Material

The plant material used consists of tomato seeds variety Mongal F1 developed by the National Institute of Agronomic Research of France (INRA, France), sold and distributed by the company Technisem in Niger. The choice of this variety is justified by its availability and adaptability to any type of climate [19]. It is also resistant to nematodes as well as to bacterial and fungal diseases such as Ralstonia solanacearum, Stemphylium, tobacco mosaic. It is resistant to gall nematodes such as Meloidogyne spp [19].

Fig. 1. Geographical location of the experimentation site
Source: www.maplibrari.org/ IGN Niger

Fig. 2. Diagram of the experimental design for the study of the effect of guano on tomatoes
Rep: Replication
2.4 Organic Fertilizer Used: Guano

The fertilizer used in this study is the bat guano extracted from the caves of the hill of Magarawa located at 27 km from Gouré chief town of the department of the same name in the Zinder region of Niger. Fig. 3 shows the geographic location of Magarawa bat guano collection site.

2.5 Determination of the Physico-Chemical Parameters of the Soil

Before setting up the experiment, soil samples were first collected at 0-15 cm from the ground using an auger randomly on the experimental site. Then, they were mixed, dried in ambient air (25-30°C) and sieved using a 2 mm mesh sieve to eliminate coarse soil particles. The analyzes focused on soil moisture, pH, organic matter content, total nitrogen, available phosphorus and particle size.

Soil moisture was assessed by the method [20]. To do this, 2 g each of soil samples were put to dry in an oven at 105°C for 24 h. After cooling for 30 min in the open air, the soil moisture (TH) was evaluated as follows:

\[
\text{TH} = \left[ \frac{W1 - W2}{P1} \right] \times 100
\]

Where:

- **W1**: Weigh (g) of sample before drying;
- **W2**: Weigh (g) of sample after drying.

The soil pH was determined using a soil-water mixture in a ratio of 1:2.5 using the digital electronic pH meter according to AFNOR standards (1981). The international method, Robinson pipette was used for particle size (5 fractions) determination. The rate of organic matter is determined according to the method Walkey and Black: the organic carbon is oxidized in a sulfuric medium concentrated by the potassium dichromate in excess. The excess of the dichromate is then titrated with a Mohr salt solution in the presence of diphenylamine. The total organic matter, we use a multiplying coefficient 1.724 [21,22]. Total nitrogen N was determined by the method of Kjeldahl [23]. Available phosphorus was extracted using 0.5 M NaHCO3 solution and measured calorimetrically using ammonium molybdate procedure by spectrophotometer according to Olsen et al. [24,25].

![Fig. 3. Geographical location of the bat guano sampling site](image)
2.6 Determination of the Chemical Parameters of Guano

The chemical parameters measured for guano are pH, humidity, organic matter content, total nitrogen, available phosphorus, potassium, exchangeable bases. Potassium (K), Exchangeable calcium (Ca) and magnesium (Mg) were extracted using ammonium acetate. Thus, the potassium level was determined using a flame photometer; calcium and magnesium have been determined by titrimetry with EDTA normality [26].

2.7 Implementation of the Study

The technical work begins with the establishment of the nursery. Tomato seeds were sown in line on 1 m² nursery bed, then covered with foliage and watered daily with tap water using a watering can. Germination took place four days after sowing. Irrigation continued every morning to prevent the soil from drying out. Weeding was done by hand whenever necessary.

Cultivation operations such as soil preparation, transplanting, weeding / hoeing, harvesting and phytosanitary treatment were carried out in accordance with the variety instruction manual (INRA France technical sheet). The soil was plowed two weeks before plotting the plots for transplantation. Thirty (30) days after sowing in the nursery, the most vigorous plants with 5 leaves were selected and transplanted to the different plots. Transplanting was carried out in the evening with a spacing between the lines of 0.7 m and 0.5 m between the pockets, for a total of 28 570 plants / ha. The plants were watered immediately after transplanting, then regularly at an interval of two days with 40 liters of water per 3 m² (equivalent to four watering cans). The culture took place over three (3) months.

2.8 Application of Bat Guano to Tomato Plants

The effect of different rates of guano (treatments) namely 500 kg/ha, 1000 kg/ha and 1500 kg/ha was followed. These are: T0 control (no fertilizers); T1 (500 kg/ha of guano; with: N=49%; P₂O₅=2.5% and K₂O=3%); T2 (1000 kg/ha of guano with: N=98%; P₂O₅=5% and K₂O=6%) and T3 (1500 kg/ha of guano with: N=147%; P₂O₅=7.5% and K₂O=9%). The treatments were distributed randomly and repeated four times. Bat guano was incorporated into the soil at 10 cm depth and 5 cm from the plant (see Fig. 4) then covered with slightly soil to limit the entrainment by the wind of the particles of guano and volatilization of nitrogen. This incorporation technique has been preferred over spreading which is the peasant practice because it promotes mineralization and release of nutrients from fertilizers, facilitating nutrients availability for plant growth [27,28]. The contribution of the different doses of guano to the tomato plants at the level of the bags is illustrated in Fig. 4.

![Fig. 4. Local application of bat guano to the tomato plant](image)

2.9 Data Collection

Growth parameters (height of the plant, number of branches per plant, diameter of the collar) and yield (number of fruits; average diameter of the fruit; weight of the fruit) were collected on all the plant in each plot. Height of the plant, number of branches per plant, diameter of the collar was recorded every 30 days, the data on the fruit yield (number of fruits; average diameter of the fruits; weight of the fruits) were measured at each harvest. The total yield was obtained by combining the harvests. The height of the plants was measured using the measuring tape from the base of the plants to the end of the stem, the number of branches per plant by counting; the diameter of the collar per plant and the average diameter of the fruits using a caliper.

2.10 Statistical Analysis

Statistical analysis of the data was carried out using Genstat 9th Edition software. Fisher LSD
test was employed to test for significant differences between treatments at $p = 0.05$.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Physico-chemical parameters of the soil and bat guano

The results recorded in Table 1 show the soil physico-chemical characteristics of the experimental site as well as the chemical parameters of guano. Analysis of the table shows that the site soil has a high sandy fraction 77% with an average rate of fine particles which gives it a sandy loam texture. The soil is slightly acidic pH=6.26 with a very low content of organic carbon, total phosphorus nitrogen and available. Bat guano of Magarawa has an alkaline pH with high levels of nitrogen, total and assimilable phosphorus as well as exchangeable bases (Calcium, Magnesium and Potassium).

3.1.2 Physical characteristic of guano

The observation of the sample of bat guano shows that it is 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 (Fig. 5). The sizes of the measured fecal granules vary from 3.7 to 4.1 mm in length. The diameter varies between 1.1 to 1.8 mm. When dry, bat guano is very brittle and light. When damp, it has a strong pungent odor like that of urine.

3.1.3 Effects of guano on tomato growth

The results relating to the influence of bat guano on tomato growth are presented in Fig. 6. Statistical analyzes revealed that the application of guano had a significant influence on vegetative growth such as the height of the plant, the number of branches and the diameter of the collar.

<table>
<thead>
<tr>
<th>Soil property</th>
<th>Value</th>
<th>Guano property</th>
<th>Guano</th>
</tr>
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<tbody>
<tr>
<td>Sand (%)</td>
<td>76.97</td>
<td>pH (water)</td>
<td>8.87</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>8.73</td>
<td>Organic carbon (%)</td>
<td>46.6</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>14.30</td>
<td>Total N (%)</td>
<td>9.8</td>
</tr>
<tr>
<td>Textural class</td>
<td>Sandy loam</td>
<td>Available P (mg kg$^{-1}$)</td>
<td>5090</td>
</tr>
<tr>
<td>pH (water)</td>
<td>6.26</td>
<td>Calcium (mg kg$^{-1}$)</td>
<td>6571</td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>0.22</td>
<td>Potassium (mg kg$^{-1}$)</td>
<td>962</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.038</td>
<td>Magnesium (mg kg$^{-1}$)</td>
<td>3438</td>
</tr>
<tr>
<td>Available P (mg kg$^{-1}$)</td>
<td>9.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P total (ppm)</td>
<td>420.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Moisture content on oven dry weight basis

![Fig. 5. Physical characteristic of bat guano: (a): Sample of bat guano; (b): Pellet of bat guano](image-url)
3.1.3.1 Height of plants

The results show that the height of the tomato plants varied significantly with the addition of guano. However, the plots that received guano inputs were not significantly different from each other. The T1, T2 and T3 treatments are homogeneous and the highest height 49.17 ± 0.8 cm was recorded in the plots that received the high rate (1500 kg / ha) of guano. The unfertilized plots (control) recorded the lowest height 42.15 ± 4.59 cm.

3.1.3.2 Number of branches

Fig. 6B shows the variation in the number of branches on the tomato stems. The results from the analysis of variance show the existence of a significant difference between the different guano treatments (P = 0.02). The plots T3 treated with the rate (1500 kg / ha) of guano recorded the highest number of branches 9.38 ± 1.2. However, the mean comparison at the 5% threshold shows a homogeneous effect between the plots having received a contribution of guano (T1; T2 and T3). However, the results of the plots that received no guano input (control) are statistically different from those of the plots that received a bat guano input. The lowest branching was noted on the control with an average of 6.35 ± 0.61 per plant.

3.1.3.3 Stem diameter

The addition of guano to the plots allowed a significant variation in the stem diameters of the tomato P <0.0001 (Fig. 6C). These averages stem diameters varied from 9.3 to 12.18 mm. However, the LSD test shows that the plots fertilized with bat guano are statically identical to each other. The plot treated with 500 kg/ha of bat guano recorded the diameter of the largest collar in absolute value (12.18 ± 0.99 mm). Nevertheless, the stem diameters of the unfertilized (control) plots are different from the others having benefited from a contribution of bat guano. The lowest values in terms of the stem diameter were recorded at the control 9.3±0.83 mm.

3.1.3.4 Fruit diameter

The results of the analysis of variance at the 5% presented in Fig. 6D show, with regard to the fruits diameter, that statistically there is no significant difference between the doses of guano P = 0.327. However, in absolute value, the rates of guano largely influenced the size of the tomato fruits. The largest fruits were obtained in plots which received 1500 kg / ha of guano 53.5 ± 2.5mm.

3.1.4 Effect of bat guano on tomatoes yield

Fruits are the main parameters taken into account in the productivity and marketing of the tomato.

3.1.4.1 Number of fruits per plant

The results concerning the number of fruits per plant according to the rates of bat guano are presented in Fig. 7.

It appears from Fig. 7 that the intake of guano significantly influenced the number of fruits per tomato plant (P <0.0001). The number of fruits varies from 8.21 to 20.12 per tomato plant. These results are respectively obtained from plants that received T0 and T3. However, the plots having been treated with 1500 kg / ha of guano recorded the highest amount of fruit (20 ± 2 fruits). This result, is not statically different from the amount of fruit obtained with the dose of bat guano at 500 kg/ha. However, 18 ± 1 fruits/plant and 20±2 fruits / plant was collected on the plots treated with 500 and 1500 kg / ha and are statistically homogeneous. The control plots recorded the lowest number of fruits (8.21 ± 1.39 fruit/plant).

3.1.4.2 Tomato yield

Fig. 8 shows the variation in tomato production according to different harvest dates.

The peak production of the different doses is 67 days after transplanting (DAT). The plots having been treated with 1500 kg of guano recorded a higher yield than the other treatments while the production in the control plots remained lower than that of the other treatments. Tomato production on the 67th DAT in plots under treatment of 1,500 kg of guano (16.04 t / ha) is greater three times to the control plots (6.02 t / ha). After the peak, a decrease in production was observed, which will eventually stabilize at 2 t/ha at 84 DAT.

The results of the total yields of tomato harvested per ha presented in Fig. 8B show a trend similar to that of the number of fruits per plant (see Fig. 7). However, the contribution of guano induced a significant change compared to the yield compared to control. The highest yield was recorded at the plots which received 500 and 1500 kg / ha of guano (38.75±2.71 t / ha and
40.45 ± 4.19 t / ha respectively) which are statically identical. However, the lowest amount of tomato was harvested from the control plots 17.25±2.03 t/ha.

**Fig. 6.** Tomato growth parameters: A) height of the tomato stem; B) number of branches of the tomato; C) Stem Diameter of the tomato plants and D) Fruit Diameter of the tomato

Where: T0 = control; T1 = 500 kg/ha guano; T2 = 1000 kg/ha guano and T3 = 1500 kg/ha guano. Error bars indicate standard deviations. Means for each effect followed by similar letter are not significantly different at p = 0.05 according to Fischer’s LSD test.

**Fig. 7.** Effect of guano on the number of tomato fruit / plant

Where: T0 = no input; T1 = 500 kg / ha guano; T2 = 1000 kg / ha guano and T3 = 1500 kg / ha guano. Error bars indicate standard deviations. Means for each effect followed by similar letter are not significantly different at p = 0.05 according to Fischer’s LSD test.
results are corroborated by [31], who compared to the control in terms of plant height, allowed a significant improvement in plant growth rates of bat guano (500, 1000 and 1500 kg/ha) particularly on the height, number of branches and stem and fruit diameter. Applying different rates of bat guano (500, 1000 and 1500 kg/ha) allowed a significant improvement in plant growth compared to the control in terms of plant height, number of branches, the stem diameter. These results are corroborated by [31,32,33], who showed that the use of bat guano had a positive influence on plant growth. The highest tomato plant height was 49 cm which is similar to the result obtained by [34] who got a maximum height 41 cm of Mongal F1 tomato plant.

The application of 500, 1000 and 1500 kg/ha of bat guano brought 50, 100 and 150 kg/ha of nitrogen in soil while control plot didn’t receive nitrogen. These results showed that application of nitrogen to the soil increase tomato plant height. The stimulating effect of bat guano on these growth parameters could be attributed to its higher content in nutrients such as nitrogen and phosphorus [35,30]. These results are similar to [36] who find that application of organic fertilizers with Sida cordifolia increase nitrogen level in soil which help in improving tomato plant height. [37] and [38], showed a positive relation between plant height and soil nitrogen level. Nitrogen is an element which mainly influences vegetative growth while phosphorus promotes the root development of plants. This improvement in the growth of tomato plants may also be due to the diversity of microbial organisms living in bat guano which act on organic matter mineralization by converting the organic form into immediately available elements to the plant [30]. These results are similar to those of [39] who found that organic fertilizers contain macro- and micro-elements which improve soil fertility and the stem diameter of tomato. These results show that the addition of guano creates the optimal conditions for sustained plant growth.

3.2 Discussion

3.2.1 Physico-chemical parameters of soil and guano

The physico-chemical composition of the soil shows that the soil is very poor in nutrients although the texture is sandy loam with a slightly acidic and good drainage makes it suitable for tomato production. To improve the fertility of this type of soil, it is necessary to make amendments [29].

According to the chemical composition the used guano in this experiment it looks similar to that produced by the Hipposideros speoris species from India in term of nitrogen, phosphorus and potassium (7.7 to 8.5% nitrogen, 2.0 to 3.0% P2O5 and 0.4 to 1.2% K2O) [30]. According to this author, bat guano can be categorized in two types according to their chemical composition: Insectivorous rich in nitrogen and frugivorous low in nitrogen but rich in phosphorus and potassium. Thus, Magarawa bat guano belongs to the insectivorous type.

3.2.2 Effect of guano on growth parameters of tomatoes

The applications of bat guano induced changes in the growth parameters of the tomato, particularly on the height, number of branches and stem and fruit diameter. Applying different rates of bat guano (500, 1000 and 1500 kg/ha) allowed a significant improvement in plant growth compared to the control in terms of plant height, number of branches, the stem diameter. These results are corroborated by [31,32,33], who showed that the use of bat guano had a positive influence on plant growth. The highest tomato plant height was 49 cm which is similar to the result obtained by [34] who got a maximum height 41 cm of Mongal F1 tomato plant.

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It was found that increasing the rates of bat guano from 500 to 1000 and 1500 kg / ha did not
allow an increase in terms of plant height, number of branch/plant and stem diameter. This stabilization of growth when more than 500 kg/ha of guano was used could also be attributed to the variation of soil pH. The application of a high dose of more than 30 t/ha of chicken droppings lowers the pH to acidic level and increases the nitrogen content of the soil. This acidity and excess nitrogen affect the vegetative growth of the tomato by reducing the absorption of other nutrients from the soil [17,16].

However, the different rates of bat guano allowed better growth compared to the control plots. This lowest growth in control plot may be due to the soil condition. Thus, this can be explained by the fact that, none application of organic manure in control plots induce high loss of soil organic matter and nutrients which leads to lower phosphorus solubilization, microbial activities and plants growth [40]. Similar results are obtained by [36], who find that the lowest growth parameter of tomato plant such as height observed in control plot may be due to low pH of the soil. The use of organic fertilizers improve the growth of the tomato by modifying soil properties [41].

### 3.2.3 Effect of Guano on Tomato Yield

The result on tomato production indicates that significant differences were observed between treatment. The application of bat guano had a significant effect on the number of tomatoes fruits/plant (P < 0.0001) comparatively to the control plot. The lowest number fruit/plant (8 fruits/plant) was registered in control plot while in fertilized plot it varies from 16 to 20 fruit/plant. The increased in number of fruits could be attributed to the ability of bat guano to promote vigorous growth, increase meristematic and physiological activities in the plants due to supply of plant nutrient and improvement in the soil properties, thereby, resulting in the synthesis of more photo assimilates which is used in producing fruits. These results are superior to [42] and [43], who obtained respectively 4.95 and 8 fruits/plant of tomato with variety Mongal F1. These differences may be explained by the experimental condition the temperature and season.

In comparison with the control, the plots treated with bat guano had a significantly higher yield. The highest tomato yield 40.25 t/ha was obtained with the application of 1500 kg/ha of bat guano. This is superior with the results obtained by [42], who got a maximum tomato yield of 20.3 t/ha with the same variety Mongal F1. The yield obtained with T3 (1500 kg/ha) is three times higher than the control treatment T0. This showed that bat guano increased the tomato yield. This is similar with the conclusions of [41] who indicated that application of organic manure improved the yield and quality of tomato fruits. The significant performance of bat guano over the control in yield could also be due to the fact that, this organic fertilizer contained essential nutrient elements associate with high photosynthetic activities and thus promotes roots and vegetative growth [44]. Improvements in fruit yields may also be attributed in part to increases in soil microbial biomass after applications of organic fertilizers, which induce the production of hormones or humates that act as plant growth substances as found by [45]. The application of chicken droppings and guano has been found to improve the productivity of vegetables by increasing the activities of microorganisms in the soil [46,30,47].

The treatment 1500 kg/ha of bat guano that gave the highest yield remains statistically identical to that of the T1 treatment 500 kg/ha. Therefore, tripling the guano rate did not cause a significant increase in the yield of the tomato. This small variation may be due to the reduction in nutrients absorption by plants or modification of the soil properties [17]. [48] found that application of 40 t/ha of urban waste reduced the corn yield compared to 20 t/ha. This is in contradiction with the conclusions of [49,41] who found that fruit production increased with the increase in the amount of organic fertilizer applied. This difference can be explained by the difference in the quality and quantity of the substrate used. Following these observations, this stagnation in production can be attributed to the increasing amount of nitrogen which is found in excess in the soil. [50] found that application of large quantity of nitrogen in soil can leads to decrease of tomato yield. Similarly, [51] observed the reduction in tomato yield when large quantities of organic fertilizers are used and attributed it to the increase of soil acidity. According to the same authors and [17], an excess of nitrogen could lead to a drop soil pH (acidity) thus causing an imbalance in the absorption of nutrients in by tomato plants. The optimal dose for tomato production is 500 kg/ha of guano.

### 4. CONCLUSION

This study showed that bat guano is an organic fertilizer with a high content of carbon and
essential nutrients for the plant, including nitrogen, phosphorus and potassium. Fertilizer applications based on bat guano are essential to improve the availability of nutrients in the soil and increase growth and yield of vegetable crops. The plots treated with bat guano gave highest yields comparatively to the control plots. These results showed that the optimal yield of marketable tomatoes was obtained with the application of 500 kg / ha of bat guano. This yield equals the tomato yield held by Egypt 5th greatest producer of tomato in the world ranking and first in Africa.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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