Growth and Yield of Sweet Corn (*Zea mays* L) as Influenced by Guano Char in Degraded Upland Soils

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ABSTRACT *Biochar created from bat manure (guano) is a way to produce a value added soil amendment that is less expensive and rich in macro and micronutrients, however, limited published studies about its effects on nutrient availability to plants are available. Hence, a pot experiment was conducted at the experimental site of the Department of Agriculture and Related Programs, Northwest Samar State University, San Jorge Campus, San Jorge, Samar from June 2017 to February 2018. The study aimed to determine the effects of guano char (GC) on the growth and yield of sweet corn and properties of degraded upland soils, and to determine the optimum rate of GC influencing growth and yield of sweet corn. There were five treatments used: (T_1 - 0 g GC 15 kg^{-1} soil; T_2 - 75 g GC 15 kg^{-1} soil, T_3 - 150 g GC kg^{-1} soil, T_4 – 300 g GC kg $^{-1}$ soil and T_5 - 600 g GC 15 kg^{-1} soil) with three replication and arranged in Randomized Complete Block Design (RCBD). Transplanting of sweet corn was done after 10 days of soil incubation. Sweet corn were harvested 65 days after planting for soil and tissue analysis and data gathered were subjected to statistical analysis using SPSS version 17. Results revealed that addition of increasing rates of guano char resulted in consistent increase on weekly plant height (cm) and fruit yield (kg) of sweet corn. Statistically, results indicated that 75 g to 150 g of GC 15 kg $^{-1}$ soil found as optimum rate enhancing growth and yield of sweet corn. On the other hand, addition of guano char significantly increases the soil pH_{H2O}, % OM, total N, extractable P and exchangeable K after harvest. Likewise, plant tissue N and P concentration were also increased.*

Keywords: *Biochar, Guano, Sweet Corn, Degraded Upland Soil*

I. Introduction

Sweet corn is one of the high valued crops raised by farmers, ranking second to rice for human consumption in the Philippines. As human food, it contains high amount of carbohydrates, fats, and protein and used as feed grain for poultry and livestock and at the same time it serves as flour, starch, alcohol, syrup and many others (Cereligia, 1995). This crop is commonly planted in the uplands of San Jorge, Samar by different farmers for consumption and livelihood. However, these uplands are characterized to have dominant vegetation such as *Imperata cylindrica*, *Chromolaena odorata, Melastoma malabathricum and Saccharum spontaneum* which are indication of soil degradation.

In the country, soil degradation is identified as major threat to food security by the National Action Plan (NAP) for 2004 to 2010. It was reported that about 5.2 M hectares are seriously degraded resulting to 30 – 50 % reduction in soil productivity and water retention capacity (NAP, 2004). Due to this problem, PCARRD (2006), promotes the use of organic materials as alternative fertilizer that is affordable and environmentally friendly. One of the most abundant organic wastes is the animal manure, which has higher nutrient contents than crop residues. Application of this animal manure as organic fertilizer has been more popular, but very little is known about the application of bat manure (guano) as organic fertilizer.

Guano is feces of bats rich in carbon, nitrogen, vital minerals and of course beneficial microbes. The chemical properties of guano enrich soil fertility and texture at the same time soil detoxification, control fungal attack and nematodes as well (Shetty et al., 2013). In addition, guano contains all micro and macro nutrients that plants require in natural form which serve as plant fertilizer, soil builder and cleanser, and nematocide. However, the intensive use of animal manures like guano in crop production was an issue due to concerns about food safety and possibility of contaminating crops and water bodies.

Therefore, one of alternative practice could be conversion of animal manure to biochar (carbonized material) by pyrolysis. It is a carbon rich product produced by the slow thermo-chemical pyrolysis of biomass materials. It is a useful resource to improve the physico-chemical properties of soil, effectively maintain soil rrganic matter (SOM) levels, and increase fertilizer use efficiency and increase crop production, particularly for long cultivated soils in subtropical and tropical regions (Van Zwieten et al., 2010). This material is also higher in available P by up to 5 times compared to the original waste (Shinogi et al., 2003). Moreover, they reported that biochar produced from animal origin and feedstock have higher nutrient content due to the generally higher nutrient content of animal waste (Chan et al., 2007 & 2008).

Despite its benefits, little information is available on agricultural and ecological value of biochar from bat manure serves as baseline information in developing additional effective organic farming technology. Hence, this study was conducted to determine the optimum level of guano char addition that enhances growth and yield of sweet corn and evaluate its effect on the chemical properties of degraded upland soils.

II. Methods and Materials

A. Site Description

This study was conducted in Brgy. Erenas, Northwest Samar State University (NwSSU), San Jorge Campus, San Jorge Samar, Philippines. The site is located in the Northwestern part of Samar Island (Figure 1). It is surrounded by large areas of degraded upland soils predominantly vegetated with *Imperata cylindrica*, *Chromolaena odorata, Melastoma malabathricum, Saccharum spontaneum* and other crops.

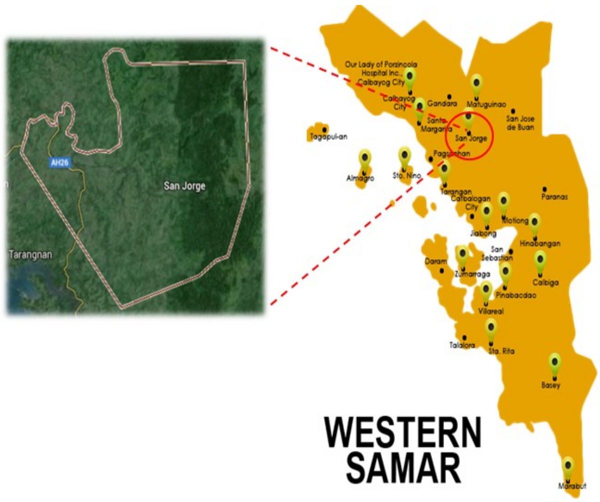

Fig. 1. Map shows the location of the study site.

B. Field and Laboratory activities

1) Soil collection, preparation and analysis:

Bulk samples of degraded upland soil from a depth of 0 - 20 cm were collected randomly from the degraded grassland areas of NwSSU, San Jorge Campus. The bulk samples were air-dried, pulverized and passed through a 4 mm sieve. Subsamples were then subsequently taken for initial analysis which passed through a 2 mm and 0.425 mm sieve and the rest were prepared for bagging. Samples were subjected to chemical analysis for soil pH (H_2O) by potentiometric method using 1:5 soil diluents ratio distilled water (PCARR, 1980); Organic Matter (%) using modified Walkey-Black method (Nelson and Sommers, 1982); Total Nitrogen (%) using a Kjeldahl method (Bremner and Mulvaney, 1982); Extractable P (mg kg^{-1}) through Olsen method extraction (Olsen and Sommers, 1982) and Exchangeable K (mg kg^{-1}) through 1N NH_4 OA_C (pH 7.0) methods (ISRIC, 1995).

2) Guano pyrolysis and processing: Guano charring was done following the Top Lift Updraft Double Barrel Method (Quayle, 2000). Subsamples of air dried guano were charred inside the carbonization chamber (40 cm height x 30 cm diameter) with three holes at its lowers side. The chamber was placed inside the drum (80 cm height x 50 cm diameter) with three small cans below to facilitate air flow. After which, filled with rice hull and wood chips at 3:1 ratio which acted as the combustion field to achieve an even burn. After a few minutes, a tin lid with a chimny (62 cm height x 8 cm diameter) was placed on top center of the drum to achieve a sufficient burn, during 3 to 4 hours period of charring, temperature of about (500 ^oC and above) was monitored every 10 minutes using a thermometer attached to the external wall of the combustion chamber. After charring, the combustion and carbonization chamber was allowed to cool and guano char was removed, weighed and placed in a polyethylene pots. Guano char (GC) was then grounded and passed through to a 2 mm sieve, and analysed for pH, % OM, % N, extractable P and exchangeable K.

3) Pot preparation and char application: Twenty five pots (12 x 14 inches) were used in the experiment. Each pot was filled with 15 kg soil in oven dry weight basis. Guano char was calculated and applied to the soil in each pot base on the treatment and incubated for 2 weeks before sowing.

4) Seed sowing and thinning: Seed sowing was done 2 weeks after soil incubation. Three seeds were sown per pot. Planting distance was 75 cm between rows and 50 cm between pots Thinning was also done 5 days after seedling emergence.
5) Care and management: Watering was done with the use of sprinkler every morning and afternoon. Hand weeding and cultivation was done every 2 weeks to prevent water, sunlight, space and nutrient competitions. Insect damage was also controlled by handpicking wherever necessary.
6) Harvesting: Harvesting of sweet corn was done 63 to 70 days after sowing. Harvesting was done by hand picking when the sweet corn plant changed its physical color from green to brown or their fruit hairs changed to brown as physical indices. Plant tissue samples were also collected, processed and subjected for total nitrogen (%) and total phosphorus (%) analysis.

C. Experimental design and lay out

Pot experiment was carried out in a modified shed house with plastic film roofing at the experimental area of NwSSU, San Jorge Campus. There were five treatments and three replications that were laid out in Randomize Complete Block Design (RCBD). The treatments used were as follows:T_1 = Control (0 g Guano char 15 kg^{-1} soil); T_2 = 75 g Guano char 15 kg^{-1} soil; T_3 = 150 g Guano char 15 kg^{-1} soil: T_4 = 300 g Guano char 15 kg^{-1} soil and T_5 = 600 g Guano char 15 kg^{-1} soil.

D. Data gathered

1) Plant height (cm): This was determined by measuring the height of sweet corn from the soil surface up to the tip of the longest leaf in a weekly basis.

2) Days from sowing to tasseling, fruiting and harvesting: This was obtained by counting the number of days from corn seed sowing to tasseling, fruiting and harvesting.

3) Weight (g) of sweet corn fruit with peel and without peel after harvest: This was obtained by weighing the sweet corn fruit with peel and without peel after harvest. Marketable and non- marketable corn fruits were also sorted according to consumer preference standard

4) Length (cm) of fruit ear: This was determined by measuring the fruit ear length of sweet corn after harvest.

E. Statistical Analysis

Statistical analysis was done using Statistical Tool for Agricultural Research (STAR). The effect of guano char on the growth and yield of sweet corn and on the chemical properties of degraded upland soil was analysed using the analysis of variance (ANOVA). The treatments were also compared using Least Significant Difference (LSD) at 5 % level of significance.

III. Results and Discussion

A. General Observations

The growth response of sweet corn to different levels of guano char was noted few weeks after emergence (Fig. 2). Three days after sowing, 100 % seed germination was observed. At one to four weeks after seedling emergence, plants applied with 75 to 600 g GC (T_2 to T_5) showed bigger stem, greener and taller and had faster normal growth than the control. It was clearly observed that plants without GC showed yellowing of leaves and stunted growth (T_1).

Figure 2. Photo shows the growth of sweet corn one month sfter sowing

B. Growth Performance of Sweet corn

1) Plant growth: Biochar is suggested that would be beneficial and potential for plant growth in acid soils where the elements becomes the limiting factor of plant growth (Van Zwieten et al., 2010). Their report suggest also that soil incorporated biochars can enhance plant growth (Asai et al. 2009). In the study, figure 3 shows the effects of guano char on the growth performance of sweet corn. Plant growth did not show any visible differences in all treatments (T_1 to T_5) at 1 week after sowing. However, after 2 - 7 weeks the plant height of sweet corn applied with levels of guano char (T_2 to T_5) were significantly increased 2 - 7 weeks at ($P<0.05$) compared to T_1 (control). Similarly, their study found that, the applications of biochar were significantly increased the plant height of corn by 64.4 % compared with the control (Uzoma et al., 2011). Statistically, a comparable effects of 75 g, 150 g, 300 g and 600 g GC (T_2 to T_5) in enhancing the growth performance of sweet corn was observed during the growing season of the crop. Thereby, it further recommend the application of 75 grams guano char per 15 kg soil in enhancing better growth of sweet corn.

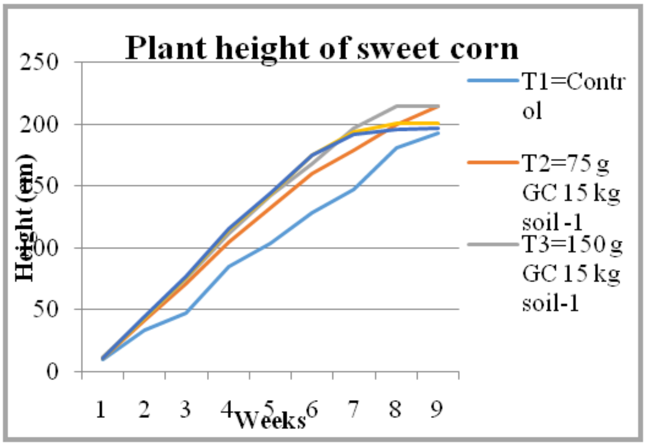

Figure 3. Plant height (cm) of sweet corn as influenced by different level of guano char

C. Days from sowing to tasseling, fruiting and harvesting

In the study, guano char application showed a significant effect on the number of days from sowing to tasseling, fruiting and harvesting at ($P<0.05$) among treatments except for control. It was observed that sweet corn plant with no applied fertilizer (T_1), tasseling, fruiting and harvesting was delayed. These results also confirmed the finding of Catingan (1982) that corn, in low fertility of the soil delay silking and maturity.

Table1. Days from sowing to tasseling, fruiting and harvesting of sweet corn.

Treatment	Days from Sowing to:		
	Tasseling	Fruiting	Harvesting
T1-Control	54.00a	61.00a	70.00b
T2-75 g GC $15kg^{-1}$ soil	48.00b	57.00b	63.00a
T3-150 g GC $15kg^{-1}$ soil	47.00b	50.00c	63.00a
T4-300 g GC $15kg^{-1}$ soil	47.00b	50.00c	63.00a
T5-600 g GC $15kg^{-1}$ soil	47.00b	50.00c	63.00a

Means not sharing letter in common differ significantly at 5% level by List Significant Different.

Moreover, guano char applications (T_2 to T_5) have a comparable effect on tasseling, fruiting and harvesting of sweet corn. The results explained that 75 g GC 15 kg^{-1} soil is the recommended rate to improve the early tasseling, fruiting and harvesting of sweet corn.

D. Yield and Yield Component

1) Marketable weight (g): Biochar as soil amendment improved soil fertility, retains and supplies plant nutrients more effectively and consequently increase crop yield (Lehmann et al., 2003). Result in figure 4 revealed that the weight of sweet corn with peel and without were significantly increased with addition of different levels of guano char at a rate of 150 – 600 g GC 15 kg^{-1} soil than control. Similarly, Uzoma et al. (2011) found that, maize grain yield was significantly increased by 150 and 98 % after the application of biochar at 15 and 20 t ha^{-1}, respectively compared to control. Moreover, their application (T_3 to T_5) showed a comparable effect on increasing the yield of sweet corn. Hence, T_3 is statistically the optimum recommended rate to improve the marketable yield of sweet corn.

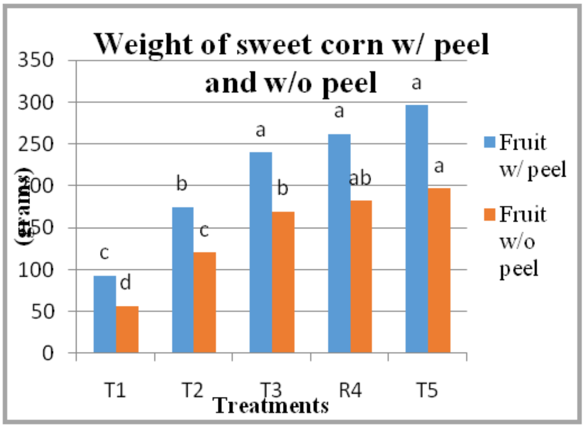

Figure 4. Weight of sweet corn with peel and without peel after harvest

2) Length of fruit ear: Results in figure 5 and 6, shows the length of fruit ear for each treatment. It was observed that there is no significant effect observed in T_1 and T_2. However, a significant increase of fruit ear was noted in T_3 – T_5. Moreoever, it was clearly compared statistically that they obtained similar significant results. Suggesting the application of 150 g GC (T3) on the degraded soil to increase the fruit ear length of sweet corn. The result agreed with their study that, maize grain yield was significantly increased by 150 and 98 % after the application of biochar at 15 and 20 t ha^{-1}, respectively compared to control (Uzoma et al., 2011).

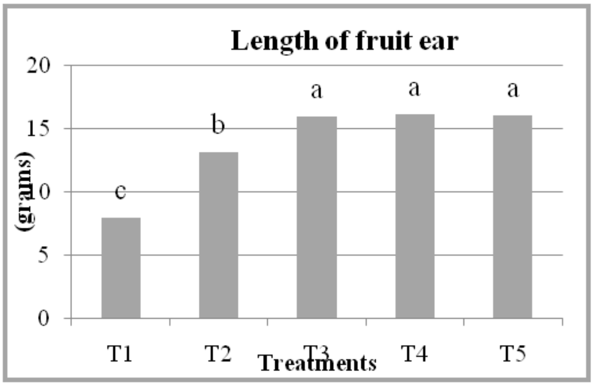

Figure 5. Length of fruit ear of sweet corn after harvest

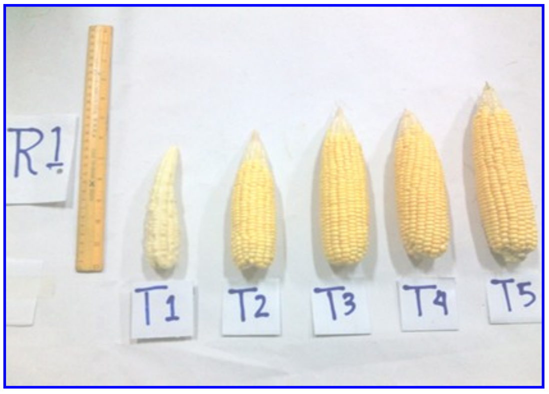

Figure 5. Length of fruit ear of sweet corn after harvest

E. Soil Characteristics

1) Initial Soil and Guano Char Analysis: The initial soil analysis in Table 2 shows that the soil used was moderately acidic, had low amount of organic matter, low amount of nitrogen, low amount of available phosphorus and exchangeable potassium. The low amount of nitrogen content, could partly explain the observed yellowish coloration of leaves in some plants particularly in pots without guano char amendment. In contrast, the initial analysis of guano char was analysed to be slightly alkaline pH, have high percent organic matter, very high percent nitrogen, high available phosphorus, and moderate exchangeable potassium. This result is attributed to the nutrient content of guano char which is a good source of nutrients available for growth and yield of sweet corn. Earlier studies had shown that poultry litter char has alkaline nature (pH 9-13) and high organic C content (15 -16%) (Chan et al., 2008). In addition, earlier research had also noted that nutrient content in biochar ranged from 2.7 to 480 g total P kg^{-1} soil and 172 and 905g total C kg^{-1} soil (Lehmann et al., 2003). This nutrient content of poultry litter char could be a good source enhances nutrient availability and plant growth.

Table 2. Initial soil and guano char analysis

Samples	Value
Soil	
pH (H_2O)	5.99
Organic Matter (%)	2.47
Total Nitrogen (%)	0.15
Available Phosphorus (mg kg^{-1})	2.00
Exchangeable Potassium (mg kg^{-1})	4.53
Guano char	
pH (H_2O)	7.68
Organic Matter (%)	15.08
Total Nitrogen (%)	6.93
Available Phosphorus (mg kg^{-1})	21.15
Exchangeable Potassium (mg kg^{-1})	61.93

2) *Chemical analysis of soil after harvest:* The result in Table 3 showed the final analysis of soil after addition of guano char. The results of soil analysis after harvest revealed that addition of guano char has a significant effect on the pH of the soil. Based on the pH level, the soil applied with guano char was significantly increased in all treatments. This result was the same to the finding of Dume et al. (2016) that application of biochar was relatively highest pH value in the soil treated with 15 t/ha biochar, while the lowest value were recorded in the control. In addition, biochar with an initial alkaline pH value is suitable as an amendment for acidic, degraded soil, it might lead to nutrient deficiencies in plant, when soil gets too alkaline (Xu et al., 2012).

In terms of the percent organic matter (OM) content of treated guano char, a significant difference were observed among treatments in which T_5 and T_4 has higher percent OM than T_3, T_2 and T_1 shown in Table 3. However, a slight difference from guano char after addition with soil was observed between T_3 and both T_2 and T_1. Therefore, the higher results of OM after addition of guano char was obtained from T_5 (600 g GC 15 kg^{-1} soil).

The total percent nitrogen (N) showed a significant difference among treatment (Table 3). The soil applied with higher rate of guano char which is T_4 and T_5 have better percent N level compared to the other treatment like T_3, T_2 and the T_1. However, T_4 and T_5 have the same level of

Treatments	Soil Analysis					Plant Tissue Analysis	
	pH (H_2O)	OM (%)	Total N (%)	Avail. P (mg/kg)	Exch. K (mg/kg)	Total N (%)	Total P (%)
T_1- Control	5.99b	2.74d	0.15b	2.00d	61.93b	0.15b	0.70c
T_2- 75 g GC 15 kg^{-1} soil	5.98b	2.94cd	0.20b	33.13c	56.85b	0.35a	0.71c
T_3- 150 g GC 15 kg^{-1} soil	6.03ab	3.12c	0.21b	65.18b	62.84b	0.37a	0.96bc
T_4- 300 g GC 15 kg^{-1} soil	6.08a	3.69b	0.32a	115.95a	69.4b	0.43a	1.06b
T_5- 600 g GC 15 kg^{-1} soil	5.97b	4.50a	0.37a	113.70a	156.02a	0.41a	1.72a

percent N of 0.32 and 0.37, and both T_3, T_2 and T_1 have also the same result in total percent N of 0.21 %, 0.20 %, and 0.15 %, respectively. This result was similar to the finding of (Abbsi and Anwar, 2015) that the total nitrogen content in the soil with biochar was on average 1.18 g kg^{-1} significantly higher than control from 0.73 g kg^{-1}.

The availability of Phosphorus (P) showed a significant difference from among treatments (Table 3). The soil applied with higher rate of guano char which is T_4 and T_5 obtained the higher result in availability of P compared to the T_2, T_3 and the T_1. Likewise, T_1 obtained the lowest result in availability of P than other treatment. The result revealed that soil applied guano char almost have 40 times higher available P than the control.

According to Shinogi et al. (2013), that carbonized material is higher in available P by up to 5 times compared to the original waste.

Meanwhile, Exchangeable K also shows a significant effect among treatment (Table 3).The result indicates that T_5 obtained the highest result in exchangeable potassium compared to T_1 and the rest of the treatment applied with guano char like T_2, T_3 and T_4 showed in table 3. The result was similar to the finding of Dume et al. (2016) that application of biochar increased the value of exchangeable K from 0.85 – 3.0 me 100 g^{-1} (an increment by 72.97 %). However, T_1, T_2, T_3, and T_4 have a comparable result in term of exchangeable potassium.

1) Total Nitrogen and Phosphorus of Sweet Corn Plant Tissue: The total percent of Phosphorus (P) showed a significant affect among treatments (Table 3). The results explained the plant tissue of sweet corn was significantly increased by guano char addition (T_2 – T_5). The highest available phosphorus was obtained by addition of 600 g 15 kg^{-1} soil. According to Rollon (2010), that PHC application was affected P uptake with the application of 10 and 20 g PHC kg^{-1} soil resulted in highest P uptake value than those without PHC application. Moreover, statistically the effect of guano char application (T_1-T_3) is comparable. Therefore, the optimum recommended rate to increase the available phosphorus of sweet corn plant tissue.

IV. Conclusion

Guano char application can increase the growth and yield of sweet corn in degraded upland soil. The result indicated that application of T_2 (75 g GC 15 kg $soil^{-1}$) is the optimum recommended rate to enhance the growth performance of sweet corn particularly plant height, number of days from sowing to tasseling, fruiting and harvesting. On the other hand, weight of fruit and the properties (pH, OM, N, P, and K) of degraded upland soil was increased with guano char addition at a rate of 150 g 15 kg $soil^{-1}$.

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