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Growth and Yield of Corn (*Zea mays* L.) and Physico-chemical properties of Degraded Upland Soils as Influenced by Poultry Litter Char

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ABSTRACT

Poultry litter char (PLC) is one of the high valued fertilizer rich in nutrients and locally available, however, limited published data are available on its effects on crops and soil properties. The study was conducted to determine the optimum rate of poultry litter char enhancing growth and yield of corn and evaluate its effect on the physico-chemical properties of degraded upland soil. Five treatments using 0, 2.5, 5, 10, 20 tons of PLC ha^{-1} were used in a randomized complete block design with three replications. The results showed that poultry litter char application significantly increased the plant height, resulted to earlier tasseling, fruiting and harvesting of corn and increased their yield particularly number of fruits, fruit yield, ear length, weight of 1000 seeds and stover yield as well. In addition, corn tissue was found to have a considerable amount of nitrogen and phosphorus. On the other hand, addition of PLC significantly improved the physico-chemical properties of degraded soil such as reduction of soil strength, increased soil porosity and soil water holding capacity and increased pH, % OC, total N, Extractable P, Exchangeable K and Ca. The study recommends an application rate of 20 t ha^{-1} of PLC to improve the growth and yield of corn and enhance the properties of highly degraded soil and 2.5 t ha^{-1} PLC to gain a higher return on investment.

KEYWORDS - Biochar, Corn, Degradation, Poultry Litter

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INTRODUCTION

Large areas of lands are planted to different agricultural crops such as cassava, sweet potato, corn, banana, coconut, rice, and other crops. However, unsuitable crop production and management of soil resources have resulted to widespread soil degradation and very low crop yield. It was reported that about 5.2 million hectares are seriously degraded resulting to 30 to 50% reduction in soil productivity and water retention capacity[1]. Moreover, the fast growing population in the country creates a tremendous imbalance on food supply and increased problems to food insecurity and global climate change. Hence, food security is an issue of great and growing concern.

Accordingly, corn is second to rice as the most important crop with one-third of Filipino farmers, or 1.8 million, depending on corn as their major source of livelihood[2]. Out of 1.6 million hectares planted to corn in the Philippines, 75% are in degraded soil. Total land area planted to corn was highest in 1990 at 3.8 million hectares, but declined at 1.9% per year from 1985 to 2001[3]. Corn is a staple food in periods of rice shortage, especially for people living in degraded areas and about 15% of the Filipinos living in rural areas of the Philippines. The grits obtained after milling the grains are boiled as a substitute for rice. Of all the cereal grains, corn is highly valued due to its multifarious uses, aside from having higher amount of vitamins, proteins, and carbohydrates[4].

Furthermore, the continued increase in human population led to the decrease in prime agricultural land areas for corn cultivation, which resulted in the decline in crop production and thus corn-supply shortage. With this problem, the primary goal of the government is to improve soil quality for better crop production. Fertilizer application is considered the most common and conventional farm practice in augmenting and overcoming the limitation of infertile soil to supply the adequate nutrients for better growth and higher yields of the crops[5].

Soil fertility can be maintained and improved by using either organic or inorganic fertilizers[6]. However, PCARRD[7] promotes the use of organic materials as alternative fertilizers that is affordable and environmentally friendly. Most of the commonly used organic fertilizers include the poultry litter because of each high nutrient content especially nitrogen. Poultry litter can be one of a valuable source of rich nutrients due to its considerable amount of organic matter[8]. Because of contaminant, waste disposal problems, food safety and environmental concerns resulted from application of animal manures in unmodified form. An alternative practice could be the conversion of animal manure to biochar by pyrolysis. Pyrolysis technology can potentially be used to convert poultry litter into value added products such as bio-oil, gas, and biochar[9,10]. Carbonized material is higher in available P by up to 5 times compared to the original waste[11]. Biochar can sequester around 50% of the initial C in the biomass, compared to the 30% from burning[12]. The inorganic component of poultry litter is also significantly concentrated in the biochar during pyrolysis and gives it potential value as a slow release nutrient source for crops[13]. Due relatively to the little information available on the agricultural and ecological value of biochar from poultry litter. Its application to the changes in soil fertility and productivity of degraded upland soil was evaluated. Hence, the study aimed to determine the optimum rate of poultry litter char enhancing growth and yield of corn, evaluate its effects on the physico-chemical properties of degraded upland soil and determine the economic analysis of applying poultry litter char to corn in degraded upland soil

MATERIALS AND METHODS

The study was conducted in a highly degraded soil of Brgy. Erenas, San Jorge, Samar. The site is located in the northwestern part of Samar Island as reflected in fig. 1. The site is planted to different kinds of crops by most of the farmers as alternative source of livelihood. However, low production is one of the problems encountered because of the decline of soils fertility level resulted to soil degradation.

Figure 1. Location of the Study Site

Biochar Production and Analysis

The collected poultry litters were air-dried at the modified screen-house of the Department of Agriculture, NwSSU, San Jorge Campus. After air-drying, subsamples of poultry litter and guano were taken for moisture content determination and the rest of each feedstock were charred using the modified Top Lit Updraft Barrel processing method[14]. After charring, poultry litter char (PLC) were ground and passed through 0.5mm sieve. The sieved PLC were subsequently be analyzed for pH, OC, total N, extractable P and CEC following the standard methods for soil chemical analyses. The total P, K, Ca, Mg, and Na were determined by dry ashing 0.5 g of PLC in a muffle furnace set at 550 ^{0}C and the ashes were soaked overnight in 3 ml concentrated HCl. The total P content of acid treated ash was quantified following the ascorbic acid method of Murphy and Riley[15] while total K, Ca, Mg and Na were quantified by atomic absorption spectrophotometry at Central Analytical Service Laboratory, PhilRootcrops, VSU, Baybay City, Leyte, Philippines.

Soil Analysis

Collected soil samples before and after harvest were analyzed for bulk density determination by core method. Soil porosity was calculated using the computed bulk density (BD) values and the constant particle density (PD) value of 2.65 g cm^{-3} using the standard formula. Water holding capacity was determined also at field capacity. Particle size distribution was determined by pipette method[16]. Soil separates were completely dispersed using the ultrasonic disintegrator (Hielscher UP100H) with 1N sodium hexametaphosphate as dispersing agent.

Soil pH was potentiometrically determined at 1:2.5 soil water ratio[16.] Total nitrogen was quantified by micro-kjeldahl method[17]. Organic matter content was determined using the Walkley-Black method[18]. The available phosphorus was extracted using the Bray-2 method and absorbance was read using spectrophotometer (Spectronic 20D)[15]. Exchangeable bases (K, Ca, Mg, and Na) were quantified using the atomic absorption spectrophotometer (Varian Spectra 220 FS).

Experimental Design and Layout

The study was carried out in the degraded grassland area of NwSSU, San Jorge Campus, Brgy. Erenas, San Jorge, Samar. There were 5 treatments and three replications, which were laid out in a Randomized Complete Block Design (RCBD). The treatments used were as follows: T_1= Control (0 t PLC ha^{-1}); T_2= 2.5 t Poultry Litter Char ha^{-1}; T_3= 5 t Poultry Litter Char ha^{-1}; T4= 10 t Poultry Litter Char ha^{-1} and T_5= 20 t Poultry Litter Char ha^{-1}.

Land Preparation, Planting, Management, Harvesting and Data Gathering

The experimental area was subjected to plowing and harrowing few weeks before seed sowing. One week before sowing, poultry litter char was applied base on the computed value per treatment at 10 tons per hectare basis. After a week, three to four seeds of corn were sown per hill with a distance of 50 cm between hills and 75 cm between furrows. One week after emergence, the seedlings were thinned one to two plants per hill. Plants were watered whenever necessary. Weeds were removed manually immediately after the emergence of weeds. Insects were also removed by manual method.

Corn were harvested at three to four months after sowing. Sample plant in each hill was cut close to the soil surface. The soils adhering to the roots were removed carefully. The shoot and roots were washed with tap water, rinsed with distilled water and blot-dried in the net bags. After obtaining the wet weight, the different plant parts were air-dried prior and then oven dried for three days in a forced draft oven set at 70^0 C for plant tissue analysis. Meanwhile, soil samples per treatment will be collected, processed and prepared for physical and chemical laboratory analysis stated above.

Furthermore, the parameters were gathered such as plant height (cm), number of days from sowing to tasseling, fruiting and harvesting, number of fruits per plant, length of ear (cm) weight of 1000 seeds (g), fruit yield (t), stover yield (t). In addition, the economic analysis was determined to gain insight what specific treatments will gave the highest return on investment.

STATISTICAL ANALYSIS

Statistical analysis was done using SPSS version 17.0. The main effects of poultry litter char on the physico-chemical properties of degraded soil and growth and yield of corn was determined using the Analysis of Variance (ANOVA). The treatment means were also compared using Duncan Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

General Observations

The response of corn to different rates of poultry litter char was noted one week after seed sowing. The emergence of corn seedlings in degraded soil were observed to be uniform in all treatments although differences in growth were noted one month later (Fig. 2). Plants without poultry litter char applied showed yellowing of leaves and stunted growth (T_1). Likewise, plants in control pots were observed to have inferior growth compared to those applied with organic fertilizer[2]. Moreover, corn applied with increasing rates of poultry litter char from 2.5-20 t ha^{-1} grew bigger, greener and had faster and normal growth. Early corn tasseling, fruiting and harvesting was also observed to those plants applied with biochar.

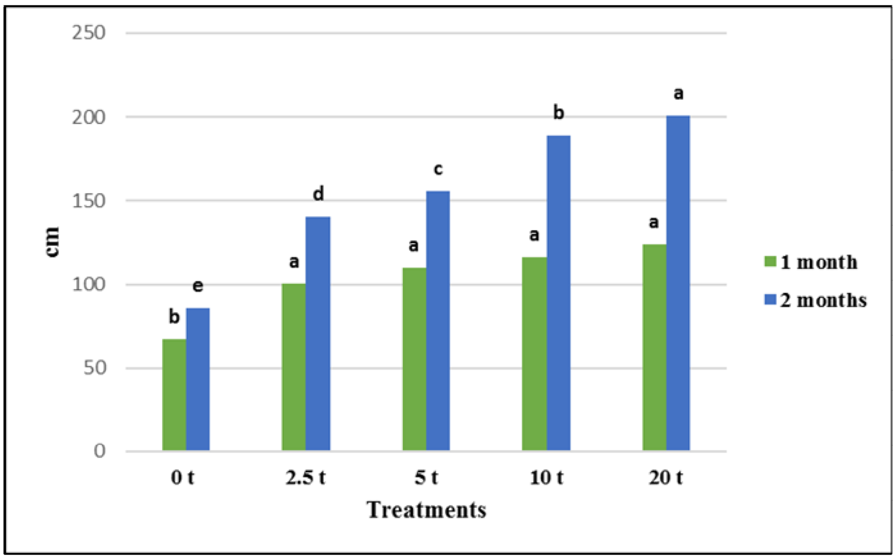
Growth Performance of corn

Several researches in clayey and acidic soils have reported positive effect of biochar application on crop growth and yield[19,20,21]. They observed positive plant responses in plant growth owing to biochar amendment[22]. In this study, growth responses of corn after addition of varying rates of poultry litter char were observed in all the treatments (T_1-T_5). The plant height of corn one month and two months after sowing were significantly increased when soil is added with increasing rates of biochar from 2.5-20 t ha^{-1} compared to control (Graph 1). The plant height of corn one month after sowing however, reflected comparable effects of using 2.5 t, 5 t, 10 t, 20 t ha^{-1} and observed to be not significantly different at ($P<0.05$). Moreover, at two months growth of corn after sowing, plant height was significantly greater with increasing rates most specially addition of 20 t biochar ha^{-1}(Graph 1).

These findings implied that poultry litter char application to degraded soil significantly enhanced growth of corn. Additionally, the positive response of corn from biochar addition could be attributed to the greater availability of available nutrients in poultry litter char (Table 3). Our result showed that the increase in plant productivity after biochar application is attributed to the soil able nutrients[21,23].

20 t PLC ha^{-1} No application

Figure 2. Growth performance of corn one month after sowing applied with 20 t PLC ha^{-1}



Graph 1. Plant height (cm) of corn one month and two months after sowing

Similarly, they found that cow manure biochar addition increased maize growth compared to the control in sandy soil condition[24]. There were significant positive effects of biochar rate on total height and number of leaves at different growth stages of maize using 15 t ha^{-1} and 20 t ha^{-1} than control. Different finding reported that guano char rates significantly improved plant height of sweet corn from 75 – 600 g kg^{-1} soil in degraded soil[25]. Van Zwieten et al[26] also found that 40% increases in wheat height when paper mill sludge biochar was applied to an acidic soil.

On the other hand, results in table 1 showed that the number of days from sowing to tasseling, fruiting and harvesting when soil is added with biochar rates were observed to be significantly affected ($P<0.05$) compared to control. Corn exhibited early tasseling, fruiting and maturity of corn after biochar addition. More importantly, early fruiting and maturity until corn harvest was observed to those soils applied with increasing rates of biochar (2.5 t – 20 t PLC ha^{-1}). In the same study, early tasseling, fruiting and harvesting was observed to sweet corn in degraded soil applied with increasing rates of guano char[25].

It was clearly observed also in the study that corn with no applied fertilizer (T_1), tasseling and fruiting were delayed (Table 1). The delayed tasseling and fruiting of corn may be due to the very low amount of available nutrients in degraded soil (Table 2). These result confirmed that corn, in low fertility of the soil delay silking and maturity due to nutrient deficiency.

Table 1. Number of days from sowing to tasseling, fruiting and harvesting of corn

Treatment	Days from Sowing to:		
	Tasseling	**Fruiting**	**Harvesting**
T_1 – Control (0 t PLC ha^{-1})	53.67.00^a	61.00^a	75.67^a
T_2 – 2.5 t Poultry Litter Char ha^{-1}	51.33^a	56.67.00^b	68.67^b
T_3 – 5 t Poultry Litter Char ha^{-1}	47.00^b	50.00^c	67.0^b
T_4 – 10 t Poultry Litter Char ha^{-1}	47.00^b	49.67.00^c	66.00^{bc}
T_5 – 20 t Poultry Litter Char ha^{-1}	46.00^b	50.00^c	65.67^c

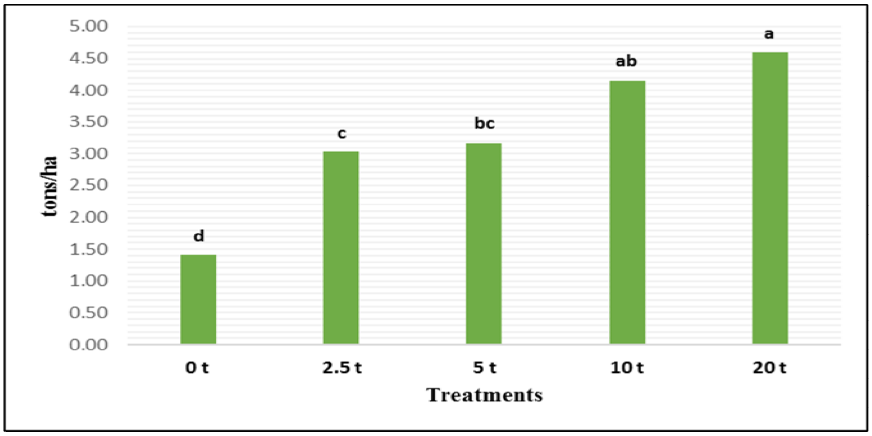
Means not sharing letter in common differ significantly at 5% level by Duncan Multiple Range Test.

Yield Performance of Corn

Biochar as soil amendment improved retention and supply of plant nutrients more effectively and consequently increase crop yield[23]. Their studies have already reported the agronomic effects of biochar on crop yield[21,27]. Results revealed that the soil treated with poultry litter char significantly improved and increased fruit yield of corn at $P<0.05$ than that of control (Graph 2).

The yield performance of corn presented in graph 2 is clearly showed that the increase of poultry litter char rates from 2.5-20 t ha^{-1} could greatly affect the fruit development of fruit grains from fruiting to maturity. Other agronomic parameters as reflected in Table 2 and Figure 3 such as number of fruits per plant, length of ears and weight of 1000 seeds were significantly improved by biochar addition. Moreover, their application showed a comparable effect on the yield of corn ($P<0.05$). The improved fruit yield performance of corn in degraded soil could be reflected and explained due to its better stover yield after biochar addition (Graph 3).

In similar study, they found that maize grain yield in sandy soil was significantly increased by 150 and 98 % after the application of biochar at 15 and 20 t ha^{-1}, respectively compared to control[24]. Sabijon and Gulla[25] reported that corn gave higher fruit yield of sweet corn particularly the weight of fruits and length of fruit ears support it. In addition, from a related study conducted, it was found that poultry litter biochars had similar effects on the dry matter yield of radishes with yield increases as compared to the unamended control of 42% at 10 Mg ha^{-1} ranging up to 96 % at 50 Mg ha^{-1} of poultry litter biochar application[28].



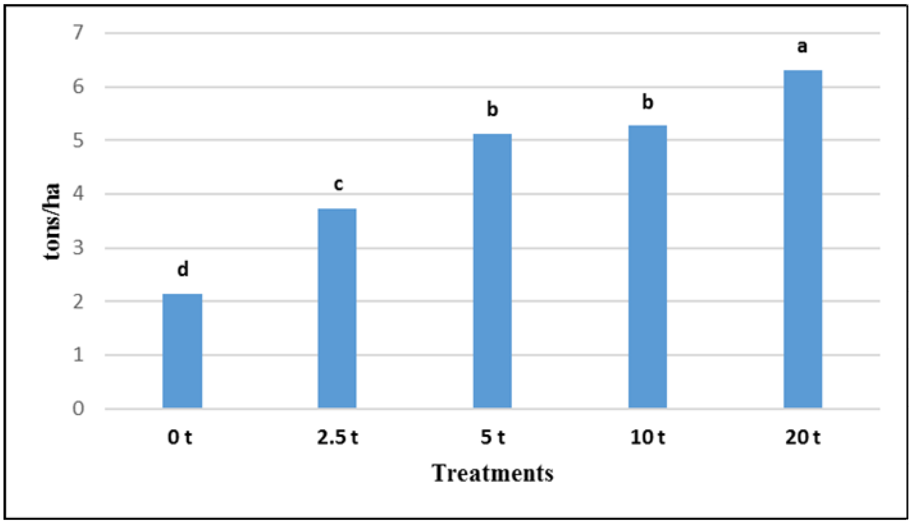
Graph 2. Fruit yield (t ha^{-1}) of corn as influenced by poultry litter char at harvest

Table 2. Number of fruits plant-1, length (cm) of ears and weight (g) of 1000 seeds of corn after harvest

Treatments	No. of fruits plant^{-1}	Length of ear (cm)	Weight of 1000 seeds (g)
T1 – Control (0 t PLC ha-1)	1.00bc	5.75b	94.87c
T_2 – 2.5 t Poultry Litter Char ha^{-1}	1.33^{bc}	9.67^{a}	105.15^{c}
T_3 – 5 t Poultry Litter Char ha^{-1}	1.67^{b}	9.75^{a}	161.67^{b}
T_4– 10 t Poultry Litter Char ha^{-1}	2.00^{ab}	10.79^{a}	216.67^{a}
T_5– 20 t Poultry Litter Char ha^{-1}	2.67^{a}	11.42^{a}	253.56^{a}

Means not sharing letter in common differ significantly at 5% level by Duncan Multiple Range Test.

Figure 3. Length (cm) of corn ears comparing the effect of increasing rates of poultry litter char



Graph 3. Stover yield (t ha^{-1}) of corn as influenced by poultry litter char at harvest

Soil and Biochar Characteristics

The initial soil analysis in Table 3 shows that the degraded soil used was physically denser and compact, slightly porous and retain considerable amount of water. Chemically, the soil is moderately acidic, had low amount of organic carbon, low amount of nitrogen, low available P, low exchangeable K and considerable amount of exchangeable Ca, Na and Mg. Likewise, the degraded soil was initially tested to have lower pH, lower organic carbon and nitrogen. It contained also lower amount of extractable P and exchangeable K. In our study, soil was found to have moderate amount of Fe that resulted to the acidity and insolubility of other essential macronutrients particularly phosphorus. On the other hand, the low N and P content, could partly explain the observed yellowish and purplish coloration of older leaves in corn particularly without biochar addition. The considerable amount of exchangeable bases in the soil may be also attributed originally to the traditional burning of grassland that resulted to the accumulation of plant ashes in the surface soil.

In contrast, poultry litter char was found to be very loose, permeable and consequently hold high amount of water. Biochar is alkaline in pH, high in organic carbon, inherently high nitrogen and available phosphorus, contained high amount of exchangeable potassium and calcium. It possessed also considerable amount of sodium and magnesium. The increased in exchangeable bases could be due to the formation of ashes during poultry litter pyrolysis. Earlier studies had shown that poultry litter char has alkaline nature (pH 9-13) and high organic C content (15 -16%)[27]. In addition, a research had also noted that nutrient content in biochar ranged from 2.7 to 480g total P kg^{-1} soil, 172, and 905g total C kg^{-1} soil[23]. These values were similar to those measured and reported total P of 31.1g kg^{-1}, total K of 47.1g kg^{-1} and total Ca 55.0 g kg^{-1} in poultry litter biochar[10]. The nutrient content of poultry litter char could be a good source enhances nutrient availability of the soil.

Physico-chemical characteristics of soil after harvest

Biochar is a porous material with high surface area that can significantly affect soil moisture and nutrient dynamics[23,29,30]. Effects of biochar on soil physico-chemical properties have been reported in many studies[21,27]. More importantly, these studies considered that high moisture contents and lower bulk densities are good soil characteristics for better and improved plant growth. Because, lowering the bulk density of agricultural soils is good for crop production due to an increase in pore space[31].

The results of the study revealed that the soil treated with biochar after harvest was analyzed physically to have clay loam texture, lowered soil strength (compaction), increased porosity and water holding capacity (Table 4). These physical properties were greatly changed and improved further when the rates of biochar were also increased from 2.5-20 t PLC ha^{-1}. This finding could be explained due to high organic matter, which can increase water holding capacity due to its positive effects on aggregation and pore space distribution and has the capacity to increase water retention.

In similar studies, Laird et al[32] found that biochar additions decreased bulk density. Moreover, water holding capacity increased linearly with the addition of biochar to degraded soils used because fine textured soils are known to have greater WHC than coarse textured soils[33]. They also found that a 10 % by weight application of hardwood derived biochar decreased the bulk density of a sandy clay loam by 29 percent[34]. It was also reported that a 10 Mg ha^{-1} application of poultry litter biochar reduced soil strength of a hard setting Alfisol by 30 percent[27]. Likewise, poultry manure, adds organic matter to the soil and has the ability to retain appreciable amounts of soil moisture, hence, probably moisture level will rise[35].

Meanwhile, previous studies have reported increased nutrient availability and improved cation exchange capacity after the addition of biochar to soils[26,27]. Soil pH dictates the availability of nutrients in various types of soil. Thus, increasing the pH level of soil is very important because a soil with a pH value of 5.5 significantly limit crop production in many developing countries where food production is critical. The results in table 5 presented the positive responses of nutrients from poultry litter char application to degraded soil. It was observed that from an acidic nature of the soil, it was significantly changed into a slightly alkaline in nature from a pH value 5.93 – 7.51. However, biochar with an initial alkaline pH value is suitable as an amendment for acidic, degraded soil, because it might lead to nutrient deficiencies in plant, when soil gets too alkaline[36].

The result indicated that among the rates of biochar, the greatest liming effect was obtained by addition of 20 t ha^{-1}. Such liming potential biochar could be attributed to its high pH (9.15), high Ca content and high percent organic carbon content. This result was the same to their studies: Dume et al[37] reported 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. Major et al[38] found that application of poultry litter biochar to acid soil will increased soil pH, and showed a decreasing trend of exchangeable acidity. Likewise, in other study of Uchimiya et al[39] they found out that pH increase of soil resulted from the application of broiler litter-derived biochar. In addition, poultry litter biochar with pH of 9.3 and guano char with pH 7.68 increased the pH of both sandy loam and silt loam and degraded soils respectively after application[25,28].

Because of its influence on physical, chemical and biological properties of soils, soil organic carbon (SOC) is crucial in sustaining agricultural productivity[40]. Biochar is known to have greater amount of organic carbon and nitrogen ratio depending on the type of organic materials. Increasing values of organic carbon together with nitrogen were clearly observed in the study (Table 5). There were linear increase of the carbon and nitrogen content with an increase of biochar rates from 2.5-20 t ha^{-1}. Biochar significantly increased total C and concentration increased with increasing biochar application[24]. Poultry litter char addition to soil significantly increased the carbon and nitrogen after corn harvest compared to control. This result was similar to the finding of Abbsi and Anwar[41] that the total nitrogen content in the soil with biochar was significantly higher than control. They also revealed that application of pouty litter biochars significantly changed the soil pH and consequently increased total C and N[27]. Although, an increased were observed, the value however, ranges to lower critical nutrient levels. This could be expected when increasing biochar application rate, increased of soil C is greater than the increase in soil N, thereby resulting in high C:N ratio, which consequently lowered N availability as a result of N immobilization[23, 27].

Moreover, the availability of Phosphorus (P) was significantly higher in the soil after harvest (Table 5). The soil applied with higher rate of poultry litter char at 20 t ha^{-1} obtained the higher value of 524.91 mg kg^{-1} compared to the other treatments especially control. The result revealed that soil applied increasing rates of biochar almost have 3 to 27 times higher available P than the control. This could be explain because it is well known that P in poultry litter is largely plant available[42]. In the presence of biochar, soil soluble P increased significantly and this could be attributed to the P contained in poultry litter char. The result is in accordance to the finding of Uzoma et al[24] in the sandy loam, the M1 P increased from 24±1 mg kg^{-1} in the control to 1600±70 mg kg^{-1} at the 5% biochar rate and from 260±4 mg kg^{-1} to 1480±17 mg kg^{-1} in the silt loam.

Furthermore, biochar has a higher capacity for cation adsorption per unit carbon than other soil organic matters[43] due to its greater surface area, greater negative surface charge, and greater charge density[29]. As a result, it can help to increase soil cation exchange capacity. Cation exchange capacity is very important to plant nutrient availability and retention in soil and therefore the possibility of increased CEC due to biochar additions is an important characteristic of biochar[44]. In terms of cation exchange capacity of degraded soil in the study after addition of poultry litter char, significant responses were observed. The exchangeable K and Ca were significantly increased after biochar addition (Table 5). Whereas, a slight increase on exchangeable sodium and magnesium were also observed. It was found that addition of biochar to degraded soil had significant effects to the exchangeable cations compared to control. The observed strong relationship between soil total C and exchangeable cations (K, Ca and Mg) and CEC also confirms that biochar improved exchangeable cation status of the soil[27,45]. Similarly, different studies conducted confirmed that exchangeable nutrients and CEC in postharvest soil were higher when biochar was applied[24]. An increased in exchangeable K was reported after addition of 600 g kg^{-1} guano char in degraded soil[25]. The study also found that the addition of increasing rates of poultry litter char significantly decreased the extractable Fe of degraded soil. In similar way, they found also a significant decreased in exchangeable Al after biochar addition[27]. The decreased in extractable Fe that could lead to the decline of soil pH and insolubility of other nutrients is vital and maybe due to the increased in pH and at the same time increased in organic carbon and exchangeable cations (Table 5).

Total Nitrogen and Phosphorus of Corn Plant Tissue

The results in graph 4 shows the total nitrogen and phosphorus taken up by corn with poultry litter char. Results revealed that nitrogen and phosphorus uptake exhibited by corn is significantly higher in the treatments where biochar were added. Compared to phosphorus, the total nitrogen taken up by plant is relatively lower. This result was reflected in Table 4 that nitrogen was found to be lower due to immobilization. Whereas, higher phosphorus uptake was expected due inherently to the higher amount of phosphorus available in poultry litter char. Generally, nitrogen and phosphorus uptake were greater when the greater rates of biochar were applied.

In other findings, Major et al[38] found very high nutrient uptakes by maize using biochar amendment under field condition. Revell et al[28] reported similar effect of biochar on N uptake that soil application of biochar significantly increased uptake of plant N. Similarly, Chan et al[46] who reported that N uptake of radish plants grown in biochar-amended with increasing biochar application rates. In addition, total nutrient uptake increased with application of poultry litter biochar in compared to the control[28].

Table 3. Initial chemical analysis of soil and poultry litter char before seed sowing

Sample	Bulk density (g cm^3)	Soil Porosity (%)	WHC_{FC} (%)	pH (H_2O)	OC (%)	Tot. N (%)	Avail. P (mg kg^{-1})	Exch. K (mg kg^{-1})	Exch. Ca (mg kg^{-1})	Exch. Na (mg kg^{-1})	Exch. Mg (mg kg^{-1})	Extr. Fe (mg kg^{-1})
Soil	1.59	0.4	28.10	5.64	1.39	0.13	6.87	124.55	1555	55.43	2075	73.26
Poultry Litter Char	0.63	0.76	65.42	9.15	10.35	0.89	303	204	2420.23	53.77	2250.55	n.d

Means not sharing letter in common differ significantly at 5% level by Duncan Multiple Range Test

Table 4. Physical properties of degraded soil as influenced by poultry litter char after harvest

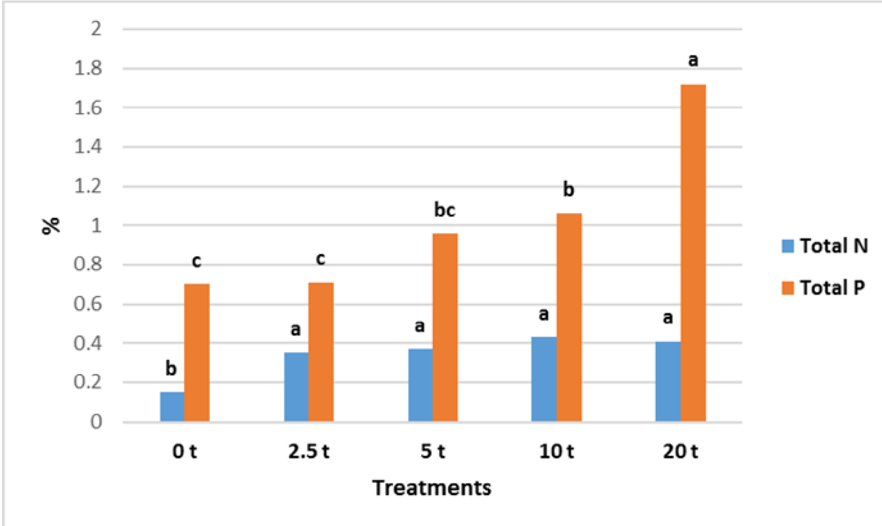
Treatments	Soil texture	Bulk density (g cm3)	Soil Porosity (%)	Water holding capacity at FC (%)
T1 – Control (0 t PLC ha-1)	Clay Loam	1.60a	0.40c	28.10d
T2 – 2.5 t Poultry Litter Char ha-1	Clay Loam	1.52b	0.42c	28.63d
T3 – 5 t Poultry Litter Char ha-1	Clay Loam	1.49b	0.43c	31.13c
T4 – 10 t Poultry Litter Char ha-1	Clay Loam	1.28c	0.52b	35.03b
T5 – 20 t Poultry Litter Char ha-1	Clay Loam	1.02d	0.60a	41.20a

Means not sharing letter in common differ significantly at 5% level by Duncan Multiple Range Test.

Table 5. Chemical properties of degraded soil as influenced by poultry litter char after harvest

Treatments	pH (H_2O)	OC (%)	Tot. N (%)	Avail. P (mg kg^{-1})	Exch. K (mg kg^{-1})	Exch. Ca (mg kg^{-1})	Exch. Na (mg kg^{-1})	Exch. Mg (mg kg^{-1})	Extr. Fe (mg kg^{-1})
T_1 – Control (0 t PLC ha^{-1})	5.93^{d}	2.27^{c}	0.09^{b}	18.83^{c}	74.55^{b}	1535.83^{b}	53.08^{a}	2095.42^{a}	63.6^{a}
T_2 – 2.5 t Poultry Litter Char ha^{-1}	6.16^{cd}	3.50^{c}	0.10^{b}	54.35^{c}	83.82^{b}	1620.83^{b}	51.15^{a}	2240.83^{a}	56.76^{a}
T_3 – 5 t Poultry Litter Char ha^{-1}	6.63^{bc}	3.80^{bc}	0.11^{ab}	134.29^{bc}	117.15^{b}	2225.00^{ab}	54.17^{a}	2251.67^{a}	54.57^{a}
T_4 – 10 t Poultry Litter Char ha^{-1}	7.11^{ab}	4.30^{ab}	0.13^{ab}	244.71^{b}	187.30^{b}	2691.25^{a}	57.17^{a}	2297.5^{a}	56.88^{a}
T_5 – 20 t Poultry Litter Char ha^{-1}	7.51^{a}	4.82^{a}	0.14^{a}	524.91^{a}	336.75^{a}	3144.17^{a}	53.27^{a}	2367.92^{a}	40.93^{b}

Means not sharing letter in common differ significantly at 5% level by Duncan Multiple Range Test.



Graph 4. Plant tissue N and P as influenced by poultry litter char after harvest

Return on investment

The results reflected in table 6 revealed a variation of the total cost, gross income, net income and the percent return on investment with increasing rates of poultry litter char application. In agronomic purposes, the application of increasing levels of poultry litter char increases the yield of corn grown in highly degraded soil. However, economically, an application of only 2.5 tons per hectare poultry litter char to corn has the highest return on investment. Increasing its rates up to 20 tons per hectare could result to a lowest return on investment and bigger inputs needed (Graph 5). In the case of the farmer's income, it is highly recommended that an application not greater than 20 t per hectare would result to a higher profit.

Table 6. Return on investment of corn as influenced by poultry litter char (t ha^{-1})

Treatments	Total cost (Php)	Gross income (PhP)*	Net Income (PhP)	ROI (%)
T1- 0 t PLC ha^{-1}	62,216	70,750	8,534	13.71
T2- 2.5 t PLC ha^{-1}	74,716	151,500	76,784	102.77
T3- 5 t PLC ha^{-1}	87,216	158,750	71,534	82.02
T4- 10 t PLC ha^{-1}	112,216	207,750	46,534	41.47
T5- 20 t PLC ha^{-1}	162,216	230,300	68,084	41.97

* Selling Price (50 PhP/kg)

Graph 5. Return on investment of using poultry litter char as fertilizer to corn

CONCLUSION

The utilization of biochar derived from poultry litter for agronomic and soil fertility improvement is a potential sustainable waste management option for the degraded land areas. Degraded soil amended with poultry litter char resulted in significant increased in growth and yield of corn. Improved soil physico-chemical properties of soil particularly pH, total C, total N, Olsen-P, exchangeable K, Ca, Na and Mg were found after addition of increasing rates of poultry litter char. The increase in maize growth and yield was mainly owing to the improvement in the available nutrients of the soil. Application at 20 t ha^{-1} gave the best growth and yield of corn under grown in degraded soil and 2.5 t ha^{-1} gave the highest return on investment.

However, it is highly recommend an additional field studies on the long-term effect of poultry litter char on degraded soil physicochemical properties and plant productivity that is needed to understand the sustainability of biochar as alternative fertilizer.

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