Asian Journal of Agriculture and Rural Development
Volume 13, Issue 3 (2023): 192-205.

http://www.aessweb.com/journals/5005

Productivity of inbred rice applied with biochar under different planting distances

Darwin M. Cacal[a] †
Angelo R. Santos[b]
Marilene C. Hipolito[c]
Sheila Rose F. Morales[d]

[a]*Isabela State University, Cabagan Campus, Philippines.*
[b,c,d]*Nueva Ecija University of Science and Technology, Philippines.*

† ✉ darwin.m.cacal@gmail.com *(Corresponding author)*

Article History
Received: 27 March 2022
Revised: 19 May 2023
Accepted: 23 June 2023
Published: 25 July 2023

Keywords
Biochar application
Inbred rice
Productivity
Return on investment
Rice farming
Sustainable agriculture
Yield.

ABSTRACT
This study explores the influence of varying biochar rates and planting distances on the growth and yield of inbred rice. The randomized complete block design (RCBD) implemented a two-factorial design with four biochar rates (none, 25 MT/ha, 20 MT/ha, 15 MT/ha) and three planting distances (20 cm x 20 cm, 20 cm x 25 cm, 20 cm x 30 cm). The 20 MT/ha biochar application (A3) manifested the highest mean outcomes for plant height, productive tillers, panicle length, weight of 1,000 grains, filled grains percentage, and estimated yield. However, the highest mean biomass yield was observed with 25 MT/ha biochar (A2). The 20 cm x 20 cm planting distance (B1) displayed the highest mean panicle length, while B2 (20 cm x 25 cm) produced the highest filled grains percentage and lowest unfilled grains percentage. B3 (20 cm x 30 cm) showed the highest mean values for plant height, productive tillers, biomass yield, estimated yield, and weight of 1,000 grains. The highest yield and return on investment (ROI) were seen in Treatment 6 (25 MT/ha of biochar at a 20 cm x 30 cm planting distance), revealing that increased biochar application results in higher yield at a 20 cm x 30 cm planting distance. The findings suggest that biochar application can augment the growth and yield of inbred rice across diverse planting distances.

Contribution/Originality: This study uniquely examines the effects of various biochar applications and planting distances on inbred rice yield. The methodology employs a two-factorial randomized complete block design (RCBD) for a comprehensive analysis.

DOI: 10.55493/5005.v13i3.4829
ISSN(P): 2304-1455/ ISSN(E): 2224-4433
How to cite: Cacal, D. M., Santos, A. R., Hipolito, M. C., & Morales, S. R. F. (2023). Productivity of inbred rice applied with biochar under different planting distances. *Asian Journal of Agriculture and Rural Development, 13*(3), 192–205. 10.55493/5005.v13i3.4829

1. INTRODUCTION
Agriculturists and farmers are facing the challenge of increasing food production, which has led to a surge of interest in climate-resilient agriculture. Effective collaboration and proficient management are crucial to achieving success in diverse fields such as agriculture, urban planning, and business. Particularly, success indicators related to purchasing decisions centre on factors such as supply conditions, competitive advancements, social responsibility, operational processes, organizational structures, product availability, special promotions, authority, status, empathy, persuasiveness, age, income level, and risk tolerance, as mentioned by Santos (2020). The recent surge of interest in

climate-resilient agriculture (Santos & Constantino, 2021) has led to biochar being explored as a potential solution to fight climate change and improve soil fertility. Biochar, which is produced by carbonizing organic materials in an oxygen-depleted atmosphere, has been steadily gaining research interest and is considered a suitable method for long-term carbon storage and soil improvement (Shackley & Sohi, 2010). To foster its success, governments and stakeholders must coordinate their efforts, and robust economies are crucial to agricultural success (Santos, 2023). Additionally, farmers' human resource management practices are essential to improving performance and achieving business success (Santos, 2023). Biochar derived from the partial combustion of rice hulls is recognized as a superior soil fertilizer and conditioner, rich in phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), and crucial micronutrients for crop growth. The loosely composed structure of biochar enhances clay soil porosity and fortifies the soil structure by augmenting bulk density, water-holding capacity, and aeration.

Filiberto and Gaunt (2013) demonstrated the diverse impacts of biochar on several crops: it enhanced corn yield by 140% and cowpea yield by 100%, and radishes grown with poultry litter biochar witnessed a 96% increase. The application of biochar leads to improved above-ground productivity, crop yield, soil microbial biomass, rhizobia nodulation, and plant potassium tissue concentration, in addition to enhancements in soil P, K, total N, and C levels compared to control conditions (Biederman & Harpole, 2013). Moreover, biochar from biosolids or sewage can elevate yields. For instance, applying 10 tons/ha of wastewater sludge biochar to cherry tomatoes led to a 64% yield increase compared to control soil conditions. Rawat, Saxena, and Sanwal (2019) recommended using biochar to remediate contaminated agricultural soil, enhance soil fertility by decreasing acidity, and increase nutrient availability. Biochar supplementation improves soil-plant-water interactions, resulting in superior photosynthetic performance and enhanced nitrogen and water use efficiency, thus remediating biotic stress and bolstering crop productivity. Consequently, biochar is suggested as a soil amendment for long-term carbon sink restoration. Inbred rice, which retains genetic consistency across generations, dominates farmers' fields. Agricultural researchers advocate for the use of improved inbred or open-pollinated rice varieties (OPVs), such as Rc 222, especially for farmers struggling with the cost of hybrid seeds.

The results of this study will be a great help to farmers in terms of increasing crop yield and net income (return on investment; ROI), lowering the cost of inputs, improving the tiller number and panicle length, improving soil properties, increasing the absorption of nutrients by plants in soils, and reducing soil compaction.

2. MATERIALS AND METHODS

2.1. Time and Place of the Study

The study was conducted in an area that has been cultivated for rice production for almost 50 years. It is a lowland irrigated area near the residential area of Zone 6 (Lungot), Barangay Bantug, Tumauini, Isabela. The study was conducted during the wet cropping season from August to November 2022.

2.2. Biochar Preparation

This study aimed to explore the effectiveness of using biochar as a soil amendment in improving soil fertility and crop productivity. To make biochar, rice hull was carbonized using an open type carbonizer made of galvanized iron sheet. Other materials used in the process included wood, used papers, a shovel, a weighing scale, and a knapsack sprayer for watering. The steps involved in the process included producing fire, covering it with the carbonizer, adding fresh rice hull, and moving the rice hull from the bottom to the top of the burning mound. After the rice hull was burned completely, it was sprinkled with water to extinguish the char, which was then allowed to cool before being placed in a clean and dry sack for storage. The study produced 6 sacks (150 kgs) of biochar from 12 sacks (300 kgs) of rice hull. Different amounts of biochar were applied in three different plots: A2 (25 MT of biochar per hectare) received 30 kgs of biochar per plot, A3 (20 MT of biochar per hectare) received 24 kgs of biochar per plot, and A4 (15 MT of biochar per hectare) received 18 kgs of biochar per plot. The use of personal protective equipment such as masks, boots, and jackets is recommended during the production of biochar.

2.3. Rice Seed Variety

The study utilized seeds of the variety National Seed Industry Council (NSIC) Rc 222, which is an International Rice Research Institute (IRRI)-bred variety also known as Tubigan 18. This variety is characterized as an early maturing one with a maturity period of 114 days when transplanted. It consistently shows good performance in both transplanted and direct seeded crops, with a high yield advantage during the wet season ranging from 12.1% to 13.2%. The yield potential of NSIC Rc 222 is about 6 MT/ha at 14% moisture content, according to IRRI in 2019.

2.4. Seedling Production

To break the dormancy of the NSIC Rc 222 seeds, they were dried in the sun for at least 3 hours and then soaked in running water for 24 hours. The seeds were then placed in an incubator for 24 hours until they germinated, with the seeds turned every 12 hours to ensure uniform germination. The pre-germinated seeds were spread on a wet seedbed at a rate of 50 grams per square meter, 18 days after seeding. The seedbed was prepared by ploughing once and harrowing twice to break up the soil and ensure good soil tilth. The seedbed measured 1 meter by 5 meters, with the surface levelled using a wooden plank to ensure even water distribution.

2.5. Care of Seedlings

After 7 days, the seedlings were irrigated at 2-3 centimetres depth. After 10 days, the seedlings were fertilized with urea (46-0-0) to produce vigorous seedlings. The presence of golden apple snail (GAS; *Pomaceae canaliculata*), was controlled by hand picking.

2.6. Land Preparation

1. The experimental area was initially ploughed and tilled in saturated or flooded conditions using a hand tractor.
2. The field was flooded with water for 1 week prior to ploughing in order to soften the clods and decompose the green manures, such as rice straw, rice stalks and weeds.
3. Dikes were constructed on every block to maintain the depth of water in every plot and minimize water losses through seepage.
4. The second ploughing and harrowing took place at a week's interval to produce puddled and levelled soil.
5. The field was levelled using an animal-drawn wooden harrow.

2.7. Biochar Analysis and Application

Analysis of the biochar performed at the Soils Laboratory of Cagayan Valley Research Center, City of Ilagan, revealed that it had a pH of 7.30 (neutral), which is an ideal pH for plant growth (See Appendix A Table) and contained 0.13% phosphorus and 0.85% potassium.

The biochar was broadcasted in each plot following the required quantity per treatment and was further incorporated through harrowing until no trace of biochar remained floating on the water surface.

2.8. Transplanting

The seedlings were transplanted 18 days after sowing (DAS) with 3 seedlings per hill. Replanting was carried out 7-10 days after transplanting (DAT) to replace the missing hills attacked/eaten by golden apple snails to complete the plant population per plot.

2.9. Soil Analysis and Fertilizer Application

Prior to land preparation, a one-kilogram sample of representative soil was randomly collected in the experimental area. It was pulverized, air-dried, properly packed and then brought to the Soils Laboratory of Cagayan Valley Research Center, City of Ilagan, for nutrient analysis. Adhering to the report on soil analysis, the fertilizer applied during basal was 16-20-0 and 46-0-0, while the 1st, 2nd and 3rd top dress was applied with 46-0-0 (see Appendix B Table).

2.10. Irrigation Management

After transplanting, irrigation was maintained to a depth of two to three (2-3 cm) centimetres and gradually increased by up to four to five (4-5) centimetres as the crop grew taller to prevent weed germination. The plots were irrigated twice a week or when cracks in the soil were visible, indicating a lack of moisture. The availability of water was ensured during the scheduled fertilizer application, panicle initiation, booting, heading, and flowering stages of the rice. Fields were drained two (2) weeks before harvesting.

2.11. Weed Management

Hand weeding was done every 15 days to ensure that the experimental area remained free from weeds and to minimize competition for light, moisture, and nutrients.

2.12. Pest Management

Golden apple snails (GAS) were controlled by hand picking before transplanting to avoid damage to seedlings. To further manage the GAS, the area was sprayed with molluscicide with an active ingredient of 300g/kg ten days after transplanting. The application of insecticides with an active ingredient of 500g/kg was used to control green leaf hoppers, stem borers, rice bugs and rice black bugs, following the recommended dosage.

2.13. Harvesting, Threshing, Drying and Cleaning

Manual harvesting took place 114 days after transplanting (DAT) using a scythe or sickle. The samples were threshed manually. Sun drying was done for two (2) days. Cleaning by winnowing and packing was carried out immediately.

2.14. Data Gathered

Ten (10) sample plants were selected randomly from every plot, and the following data were gathered:

1. Plant height at maturity (cm). Randomly selected plant height was measured from the base of the culm to the tip of the highest leaf at 90 DAT using a metre stick.
2. Number of productive tillers. The number of productive tillers was gathered at maturity of the plants (during harvesting).
3. Length of the panicle (cm). Ten panicle samples were randomly selected to measure their length. Measuring was done from the base or neck of the panicle up to the tip of the last spikelet.
4. Weight of 1,000 grains (g). The weight of 1000 seeds per treatment was recorded.

5. Percent filled and unfilled grains per panicle (%). After harvesting, the panicles of 10 sample plants per plot were counted for the productive and non-productive grains.
6. Computed yield (kg/ha). The yield of the rice grains per 1 square meter quadrant of different treatments was weighed and recorded after drying to 14% moisture content (MC). Yield per hectare was computed using the formula: Y= yield per $1m^2$ x 10,000.
7. Biomass yield (grams per plant). Biomass yield was measured by weighing the whole fresh uprooted rice plant sample with its panicles.
8. Cost and return analysis. The cost and return analysis was computed to determine the return on investment (%) obtained using the different treatments.

2.15. Statistical Analysis

The data were analysed using the Statistical Tool for Agricultural Research (STAR) software. Duncan's multiple range test (DMRT) was also used to further analyse the difference among the treatment means.

2.16. Experimental Design and Layout

The experimental field had an area of 705.0 square meters, which was divided into three blocks (4 m x 47 m). Each block was subdivided into 12 equal plots measuring 3m x 4m, with a 1.5-m alleyway between blocks and 1.0 m between plots.

The experimental area was laid out according to the randomized complete block design (RCBD) for a two-factor experiment and replicated three times with the treatments as follows:

Factor A	Factor B
A_1 - No biochar (Control)	B_1 - 20 cm x 20 cm planting distance
A_2 - 25 MT biochar per hectare	B_2 - 20 cm x 25 cm planting distance
A_3 - 20 MT biochar per hectare	B_3 - 20 cm x 30 cm planting distance
A_4 - 15 MT biochar per hectare	

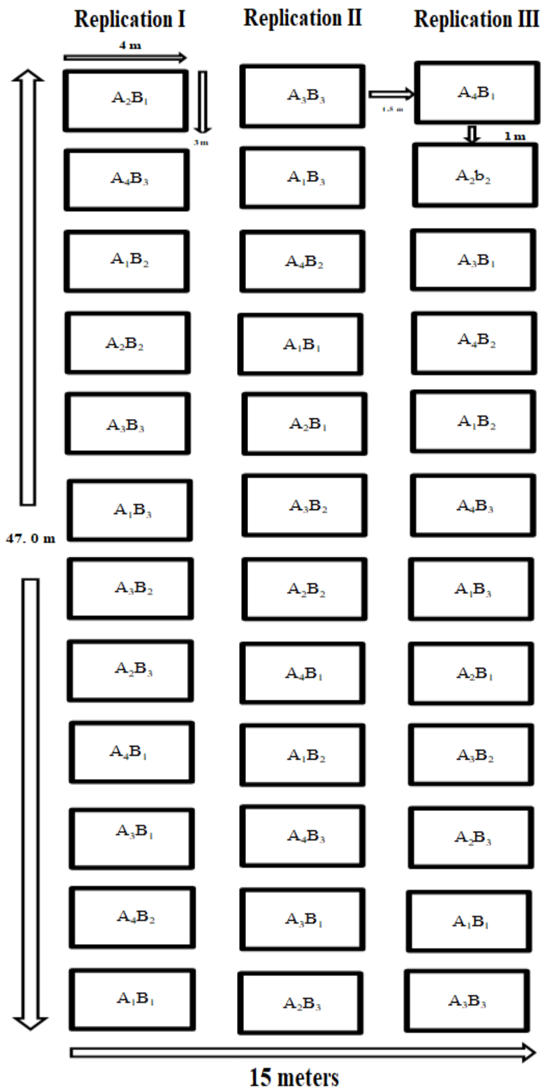

Figure 1. Experimental layout.

2.17. Treatment Combinations

T_1 - A_1B_1 - No biochar per hectare at 20 cm x 20 cm planting distance
T_2 - A_1B_2 - No biochar per hectare at 20 cm x 25 cm planting distance
T_3 - A_1B_3 - No biochar- per hectare at 20 cm x 30 cm planting distance
T_4 - A_2B_1 - 25 MT biochar per hectare at 20 cm x 20 cm planting distance
T_5 - A_2B_2 - 25 MT biochar- per hectare at 20 cm x 25 cm planting distance
T_6 - A_2B_3 - 25 MT biochar per hectare at 20 cm x 30 cm planting distance
T_7 - A_3B_1 - 20 MT biochar per hectare at 20 cm x 20 cm planting distance
T_8 - A_3B_2 - 20 MT biochar per hectare at 20 cm x 25 cm planting distance
T_9 - A_3B_3 - 20 MT biochar per hectare at 20 cm x 30 cm planting distance
T_{10} - A_4B_1 - 15 MT biochar per hectare at 20 cm x 20 cm planting distance
T_{11} - A_4B_2 - 15 MT biochar per hectare at 20 cm x 25 cm planting distance
T_{12} - A_4B_3 - 15 MT biochar per hectare at 20 cm x 30 cm planting distance

Figure 1 illustrates the layout of the experimental rice field, delineating the specific configurations of the study. The total area, measuring 47.0 meters by 15 meters, is divided into three replications: I, II, and III. Each replication occupies a space of 4m x 3m and represents a unique combination of the factors being investigated.

3. RESULTS AND DISCUSSION

3.1. Plant Height at Maturity (cm)

In Table 1, column 2 shows the effect of the different rates of biochar on plant height (PH) at maturity, which ranged from 109.82 cm to 118.54 cm. The analysis of variance (ANOVA) revealed that the application of biochar at different levels resulted in significantly different plant heights. Also, the test of comparison among the treatment means using Duncan's multiple range test (DMRT) revealed that A_3 (20 MT biochar per hectare) did not differ significantly from application A_2 (25 MT biochar per hectare) or A_4 (15 MT biochar per hectare) but did differ significantly from A_1 (no biochar). This result was consistent with the study of Roslan et al. (2017), who observed that biochar application in rice resulted in statistically higher plant heights than the control (no biochar).

The effect of different planting distances on plant height at maturity (cm) is shown in Table 2 column 2. The plant height (PH) ranged from 113.99 cm to 115.68 cm. The result of the ANOVA showed a non-significant effect of planting distance on plant height.

The combined effect of different levels of biochar and different planting distances on the mean plant height at maturity can be gleaned from Table 3 column 2. Statistical analysis revealed non-significant differences among the treatments.

3.2. Number of Productive Tillers per Hill at Maturity

Table 1 column 3 shows that the mean number of productive tillers (PT) at maturity ranged from 22.41 to 23.59 in response to the different levels of biochar application. Nevertheless, the result of the ANOVA revealed non-significant differences among the treatments.

The effect of different planting distances on the number of productive tillers at maturity is shown in Table 2 column 3 (PT). The result shows that the highest mean of productive tillers was observed in B_3 (20 cm x 30 cm), with 23.60, followed by B_2 (20 cm x 25 cm) with 22.63, and the lowest was B_1 (20 cm x 20 cm) with a mean of 22.29. However, the ANOVA revealed no significant differences among the treatments.

The interaction effect of different levels of biochar and different planting distances can be found in Table 3 column 3 (PT); it shows a mean range of 21.40 productive tillers at maturity to 25.53 counts. The ANOVA showed that the production of tillers was not significantly affected by the application of biochar at different levels together with the different planting distances.

3.3. Length of Panicle (cm)

Table 1 column 4 (LP) presents the length of panicles as affected by biochar application. Numerically, the application of 20 MT biochar per hectare (A_3) attained the longest panicle measure with a mean of 27.17 cm. The other treatments had means of 27.01 cm, 26.96 cm, and 26.27 cm. However, the ANOVA revealed no significantly different effect of the different levels of biochar application on panicle length.

Table 1. Effect of different biochar rates on different parameters.

Factor A	PH	PT	LP	FG	UFG	WG1000	BMY	CY
A_1	109.82^b	22.93	26.27	64.45	35.55	28.99	354.15	3684.44^b
A_2	116.00^a	22.42	26.96	67.87	32.13	28.23	439.00	4964.44^a
A_3	118.54^a	23.59	27.17	70.86	29.14	29.56	436.20	5208.89^a
A_4	114.51^a	22.41	27.01	67.22	32.78	29.29	388.60	4704.44^a

Note: PH - plant height at maturity; PT - productive tillers; LP - length of panicle; FG - filled grains; UFG - unfilled grains; WG1000 - weight of 1000 grains; BMY - biomass yield; CY - computed yield.
The lowercase letters (a, b) associated with the values in the 'PH' and 'CY' columns represent statistical groupings. If values have the same letter, they are not statistically significantly different. Conversely, if they have different letters (e.g., 'a' and 'b'), they are significantly different based on the results of statistical analysis.

Table 2 column 4 (LP) shows the length of panicles as affected by planting distances. It was observed that the panicle length ranged from 26.63 cm to 27.12 cm, and the ANOVA showed a non-significant effect of planting distance on panicle length.

Table 2. Effect of different planting distances on different parameters.

FACTOR B	PH	PT	LP	FG	UFG	WG1000	BMY	CY
B1	113.99	22.29	27.12	68.59	31.41	28.84ab	403.47	4406.67
B2	114.48	22.63	26.81	69.29	30.71	28.05b	395.58	4671.67
B3	115.68	23.60	26.63	64.93	35.07	30.16a	414.42	4843.33

Note: PH - plant height at maturity; PT - productive tillers; LP - length of panicle; FG - filled grains; UFG - unfilled grains; WG1000 - weight of 1000 grains; BMY - biomass yield; CY - computed yield.
Lowercase letters (a, b) next to the 'WG1000' column values represent statistical groupings. Values sharing the same letter do not significantly differ from each other statistically. However, values that do not share a common letter (e.g., 'a' and 'b') are significantly different from each other based on statistical analysis.

Table 3 column 4 (LP) shows the interaction effect of applied biochar and different planting distances on the length of panicles. The treatment means ranged from 25.95 cm to 27.78 cm. Statistical analysis revealed no significant difference among the treatments.

Table 3. Interaction effect of applied biochar and different planting distances for every parameter.

Treatments	PH	PT	LP	FG	UFG	WG1000	BMY	CY
T1	107.33	23.13	25.99	66.86	33.140	28.20	346.11	4413.33b
T2	109.70	21.90	26.38	64.51	35.490	28.63	344.28	3226.67c
T3	112.43	23.77	26.45	61.99	38.010	30.13	372.06	3413.33c
T4	114.10	22.00	27.78	66.35	33.650	28.80	452.61	3833.33bc
T5	117.83	22.53	27.15	71.82	28.180	25.23	437.61	4586.67b
T6	116.07	22.73	25.95	65.44	34.560	30.67	426.78	6473.33a
T7	119.07	21.40	27.18	71.25	28.750	29.13	403.28	4760.00ab
T8	118.87	23.83	27.53	72.19	27.810	29.23	434	6013.33a
T9	117.70	25.53	26.78	69.15	30.850	30.30	471.33	4853.33ab
T10	115.47	22.63	27.52	69.90	30.100	29.23	411.86	4620.00ab
T11	111.53	22.23	26.18	68.64	31.630	29.10	366.44	4860.00ab
T12	116.53	22.37	27.33	63.12	36.880	29.53	387.5	4633.33ab

Note: PH - plant height at maturity; PT - productive tillers; LP - length of panicle; FG - filled grains; UFG - unfilled grains; WG1000 - weight of 1000 grains; BMY - biomass yield; CY - computed yield.
The lowercase letters (a, b, c) next to the values in the 'CY' column represent statistical groupings, indicating significant differences (or lack thereof) among the treatments. Values sharing a common letter do not significantly differ from each other statistically.

3.4. Percentage of Filled and Unfilled Grains (%)

The data in Table 1 under the percentage of filled grains (FG) and unfilled grains (UFG) shows the effects of biochar application. Application of 20 MT of biochar per hectare (A_3) produced the highest percentage of filled grains (FG) with 70.86%, followed by A_2, A_4, and A_1 with means of 67.87%, 67.22% and 64.45%, respectively, while the result of unfilled grains (UFG) shows that A_1 attained the highest percentage of unfilled grains with 35.55% and A_3 the lowest with 29.14%; however, the ANOVA showed no significant differences among the treatments.

In Table 2, the columns filled grains (FG) and unfilled grains (UFG) show the effects of different planting distances. A planting distance of 20 cm x 25 cm recorded the highest percentage of filled grains with 69.29%, followed by 20 cm x 20 cm with 68.59% filled grains and 20 cm x 30 cm with 64.93% filled grains. B_3 obtained the highest percentage of unfilled grains with 35.07%, followed by B_1 (31.41%) and B_2 (30.71%). However, the ANOVA of filled and unfilled grains revealed no significant differences among the treatments.

Table 3 shows the percentage of filled (FG) and unfilled grains (UFG) as affected by the interaction effect of biochar application and different planting distances. The highest percentage of filled grain was observed in Treatment 8 with 72.19%. This was followed by T_5 and T_7 with 71.82 % and 71.25%, respectively, while the lowest result was obtained by T_3 with 61.99%. Concerning the percentage of unfilled grains, the highest mean was recorded in Treatment 3 with 38.01%, followed by T_{12} with 36.88%, and the lowest was obtained by T_8 with 27.81%. However, the ANOVA of filled and unfilled grains revealed no significant differences among the treatments.

3.5. Weight of 1000 Grains (g)

The weight of 1000 grains (g) of rice as affected by the different levels of biochar application can be seen in Table 1 (column WG1000). The heaviest mean weight was obtained by 20 MT biochar per hectare (A_3) with 29.56 grams, followed by 15 MT biochar per hectare (A_4), no biochar (A_1) applied, and 25 MT biochar per hectare (A_2), with means of 29.29 g, 28.99 g, and 28.23 g, respectively. However, the ANOVA did not show any significant effect of biochar levels on grain weight.

Table 2 (column WG1000) shows the effect of planting distance on grain weight. The heaviest 1000 grains of rice was obtained from the wider planting distance B_3 (20 cm x 30 cm) with a mean of 30.16 g (Figure 2) followed by the planting distance of 20 cm x 20 cm and 20 cm x 25 cm with means of 28.84 g and 28.05 g, respectively. However, the ANOVA revealed that the different planting distances did not significantly affect the weight of 1000 grains of rice. Nevertheless, the wider planting distance B_3 resulted in a heavier 1000-grain weight (30.16 g) than closer planting distances (B_1-20 cm x 20 cm and B_2-20 cm x 25 cm). This result was similar to that of Ali, Ali, Sattar, and Ali (2010) in their study on the improvement of rice yield by manipulating seed rate and row spacing, which reported that wider spacing resulted in a higher 1000-grain weight than narrow spacing.

The weight of 1000 grains of rice as affected by the interaction of biochar levels and different planting distances resulted in mean weights ranging from 25.23 g to 30.67 g, which can be found in Table 3 (column WG1000). The ANOVA revealed no significant difference in interaction effects.

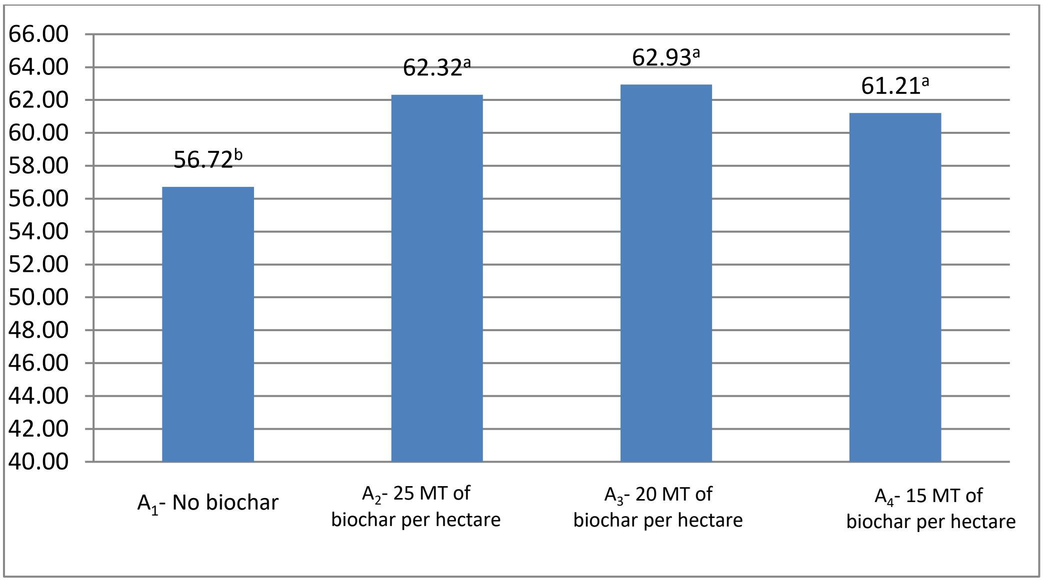

Figure 2. Plant height (cm) at 30 DAT as affected by biochar application.

Note: In this figure, the annotations "a" and "b" are used to denote groups for statistical comparison. The same letter indicates no significant difference between groups, while different letters suggest a significant difference.

3.6. Mean Biomass Yield (g) per Plant

The biomass yield obtained per plant with different levels of applied biochar is shown in Table 1 column 8 (BMY). A_2 (25 MT of biochar per hectare) gave the highest mean biomass of 439.00 g, followed by A_3 (436.20 g), A_4 (388.60 g) and A_1 (354.15 g), respectively. The ANOVA showed that biomass yield was not significantly affected by the application of different levels of biochar.

Table 2 (column BMY) shows that the weight of biomass as affected by planting distances ranged from 395.58 g to 414.12 g. Similarly, however, the ANOVA revealed no significant differences among treatments.

The interaction effect of the different levels of biochar application and planting distances is shown in Table 3. Biomass yield (BMY) had means ranging from 344.28 g to 471.33 g; however, the ANOVA again showed a non-significant effect on biomass yield per hectare.

3.7. Computed Yield (kg/ha)

Table 1 (column CY) shows the computed yield per hectare as affected by biochar. The highest grain yield was attained by A_3 (20 MT of biochar per hectare) with 5,208.89 kg followed by A_2 (25 MT of biochar per hectare) with 4,964.44 kg, while A_4 (15 MT of biochar per hectare) at 4,407.44 kg and A_1 (no biochar) at 3,684.44 kg were the lowest; however, the ANOVA revealed that A_3 was statistically the same as A_2 and A_4 but statistically different from A_1. This result aligns with the findings of Jeffery, Abalos, Spokas, and Verheijen (2015), who studied biochar effects on crop yield and reported that significantly higher grain yield was attained by crops with biochar application when compared to no biochar. Similarly, Huang, Fan, Chen, Jiang, and Zou (2018), in their study on "Continuous application of biochar into rice: Effect on nitrogen uptake and utilization", found a significantly better yield in areas where biochar was applied as compared to the control (no biochar). Table 2 (column CY) shows the effect of different planting distances on yield. B_3 (20 cm x 30 cm) obtained the highest yield of 4,843.33 kg per hectare, followed by B_2 (20 cm x 25 cm) and B_1 (20 cm x 20 cm) with weighted means of 4,671.67 kg and 4,406.67 kg per hectare, respectively. The ANOVA revealed no significant differences among the treatments. This result is the same as that of Haque, Razzaque, Haque, and Ullah (2015), who found that wider spacing resulted in better grain yields than closer spacing. Table 3 (column CY) showed the interaction effect of applied biochar and different planting distances on yield. The highest yield was attained by T_6 with 6,473.33 kg, followed by T_8 with 6,013.33 kg, while other treatments ranged from 3,226.67 kg to 4,860.00 kg. However, the ANOVA revealed that T_6 and T_8 were statistically the same as T_7, T_9, T_{10}, T_{11}, and T_{12}. Similarly, T_1 and T_5 differed statistically from T_3, T_4, and T_2 but were statistically the same as T_7, T_9, T_{10}, T_{11}, and T_{12}.

3.8. Cost and Return Analysis

The cost and return analysis of inbred rice production per hectare as affected by the different treatments is presented in Table 4. Remarkably, Treatment 6 (25 MT of biochar per hectare at 20 cm x 30 cm) gave the highest net income (Php 59,601.00) and return on investment (ROI) (118.15%), followed by Treatment 8 (20 MT of biochar per hectare at 20 cm x 25 cm) with a net income of Php 54,355.00 or 113.54% ROI. The lowest income and ROI were obtained from Treatment 4 (25 MT of biochar at 20 cm x 20 cm) at Php 15,144.00 or 30.27%.

3.9. General Appearance of the Plant

It was observed that the transplanted seedlings with biochar application recovered faster at 3 DAT than the control (no biochar), and their stand and vigour were improved as manifested by their light green leaf colour.

Some of the rice plants treated with biochar started to lodge due to continuous rainfall and because the panicles had more filled grains; however, this was immediately controlled by using bamboo to hold the plants upright to prevent the grains from being submerged in the water.

3.10. Pest Infestation

The occurrence of golden apple snails (*Pomaceae canaliculata*) during the seedling stage was strictly observed at 7 DAT and was immediately controlled by hand-picking.

The occurrence of rice bugs was observed during the flowering stage in all the treatments. During the vegetative stage, there was an occurrence of white stem borers (*Scirpophaga innonata*), which caused the central tiller to dry out and the panicles to turn white in colour and be unfilled/empty. This is known as deadheart. This was controlled by spraying with insecticide at the recommended dosage of 1 tbsp in 16L water at 1-week intervals.

A few cases of false smut disease appeared during the early maturity stage. False smut is slightly flattened, smooth and yellow in colour, but the immature spore balls appear orange and may cause chalkiness in the grains of rice.

Many different weeds were found in the experimental area, including flatsedge (*Cyperus iria*), purple nutsedge (*Cyperus rotundus*), fimbristylis (*Frimbistylis gaudich*), and barnyard grass (*Echinochloa glabrescens*), but these were controlled by manual weeding. Weeding of the experimental plot, including the dike, was carried out twice a month to remove insect pest hosts and prevent nutrient competition.

3.11. Summary

This study on the productivity of inbred rice with biochar applied under different planting distances was conducted to evaluate the growth and yield performance of an inbred rice variety with different rates of biochar application at different planting distances and to conduct a cost and return analysis of rice production per ha as affected by the different treatments. It was conducted in an irrigated farm area of Zone 6 (Lungot), Barangay Bantug, Tumauini, Isabela, during the wet cropping season from August to November 2019.

The experiment was laid out according to the principles of randomized complete block design (RCBD) with three replications per treatment in a two-factor experiment. The following treatments were used in the study: Factor A - different levels of biochar application, including A_1 - no biochar (control), A_2 - 25 MT of biochar per hectare, A_3 - 20 MT of biochar per hectare, and A_4 - 15 MT of biochar per hectare; Factor B – planting distance, which included B_1 - 20 cm x 20 cm, B_2 - 20 cm x 25 cm, and B_3 - 20 cm x 30 cm.

The results of the study showed that Factor A as a single factor had a highly significant effect on plant height at maturity (cm), as well as computed yield (kg/ha).

On the other hand, an insignificant effect was observed on the panicle length (cm), biomass yield (g), productive tillers at maturity, weight of 1,000 grains (g), and percentage of filled and unfilled grains (%).

Factor B as a single factor had a significant effect on the weight of 1000 rice grains, while the other parameters were not significantly affected; these were plant height at maturity (cm), panicle length (cm), biomass yield (g), productive tillers, computed yield, and percentage of filled and unfilled grains.

The interaction effects of varying applications of biochar (Factor A) and different planting distances (Factor B), resulted in a highly significant effect on computed yield (kg/ha). The highest yield was attained by Treatment 6 (25 MT biochar per hectare at 20 cm x 30 cm) with a mean yield of 6,473.33 kg per hectare and net income of Php 59,601.00, which was a 118.15% return on investment.

Table 4. Profitability analysis per hectare.

Particulars	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	A_1 - No biochar			A_2 - 25 MT of biochar per hectare			A_3 - 20 MT of biochar per hectare			A_4 - 15 MT of biochar per hectare		
A. Labour cost	B_1- 20 x 20 cm	B_2- 20 x 25 cm	B_3- 20 x 30 cm	B_1- 20 x 20 cm	B_2- 20 x 25 cm	B_3- 20 x 30 cm	B_1- 20 x 20 cm	B_2- 20 x 25 cm	B_3- 20 x 30 cm	B_1- 20 x 20 cm	B_2- 20 x 25 cm	B_3- 20 x 30 cm
Rotavator	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
Harrowing (2x) 3MAD @ 500/day	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Seedbed preparation 1MD @ 250/day	250	250	250	250	250	250	250	250	250	250	250	250
Seed Soaking/Incubation 1MD @ 250/day	250	250	250	250	250	250	250	250	250	250	250	250
Biochar application 4 MD @ 250/day				1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Pulling of seedlings 7 MD@250/day	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750
Transplanting 12MD @ 250/day	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Replanting 5MD @ 250/day	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Irrigation 2MD @250/day	500	500	500	500	500	500	500	500	500	500	500	500
Weeding 5MD @ 250/day	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Spraying 5 MD @ 250/day	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Harvesting 20MD @ 250/day	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000

Threshing 5 MMD@ 500/day	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
Hauling 10MAD @ 300/day	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Drying 5MD @300/day	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
Sub-total	27.000	27.000	27.000	28.000	28.000	28.000	28.000	28.000	28.000	28.000	28.000	28.000
Particulars	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	A_1- No biochar			A_2- 25 MT of biochar per hectare			A_3- 20 MT of biochar per hectare			A_4- 15 MT of biochar per hectare		
B. Material inputs	B_1- 20 x 20 cm	B_2- 20 x 25 cm	B_3- 20 x 30 cm	B_1- 20 x 20 cm	B_2- 20 x 25 cm	B_3- 20 x 30 cm	B_1- 20 x 20 cm	B_2- 20 x 25 cm	B_3- 20 x 30 cm	B_1- 20 x 20 cm	B_2- 20 x 25 cm	B_3- 20 x 30 cm
Seed (NSIC Rc 222) (1sacks)	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
Fertilizers												
Basal												
46-0-0/.6 bags @ 1.200	720	720	720	720	720	720	720	720	720	720	720	720
16-20-0/ 2bags @ 980	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960
Top dress (1st. 2nd and 3rd)												
46-0-0/ 2.9 bags @1.200	3.480	3.480	3.480	3.480	3.480	3.480	3.480	3.480	3.480	3.480	3.480	3.480
Biochar 500/tons				12.500	12.500	12.500	10.000	10.000	10.000	7.500	7.500	7.500
Pesticides												
Insecticide (a.i. 500 g/kg) 1pack @ 650/pack	650	650	650	650	650	650	650	650	650	650	650	650
Molluscicide (a.i. of 300g/kg) @800/pack	800	800	800	800	800	800	800	800	800	800	800	800
Sacks (50kls) @ P8/sacks	706	516	546	613	734	1.036	762	962	777	739	778	741

Sub total	9.616	9.426	9.456	22.023	22.144	22.446	19.672	19.872	19.687	17.149	17.188	17.151
C. Total cost of production	36.616	36.426	36.456	50.023	50.144	50.446	47.672	47.872	47.687	45.149	45.188	45.151
D. Yield (kg/ha)	4413.33	3226.67	3413.33	3833.33	4586.67	6473.33	4760.00	6013.33	4853.33	4620.00	4860.00	4633.33
E. Gross income @ 17/kilo	75.027	54.853	58.027	65.167	77.973	110.047	80.920	102.227	82.507	78.540	82.620	78.767
F. Net Income	38.411	18.427	21.571	15.144	27.829	59.601	33.248	54.355	34.820	33.391	37.432	33.616
G. Return on investment (ROI)	104.90	50.59	59.17	30.27	55.50	118.15	69.74	113.54	73.02	73.96	82.84	74.45

4. CONCLUSIONS

Based on the aforementioned results of the study, the following conclusions can be drawn:

1. Biochar application

a. Crops applied with 20 MT biochar per hectare performed significantly better in terms of the following parameters: plant height at maturity (cm), panicle length (cm), productive tillers, weight of 1000 rice grains(g), percentage of filled grains (%), and computed yield (kg/ha).

b. 25 MT biochar per hectare resulted in a significantly better biomass yield (g).

2. Different planting distances

a. 20 cm x 20 cm (B_1) produced the highest mean panicle length (cm).

b. 20 cm x 25 cm (B_2) performed significantly better in terms of the percentage of filled grains (%).

c. 20 cm x 30 cm plant spacing performed significantly better in terms of plant height at maturity (cm), productive tillers, biomass yield (g), computed yield (kg/ha), and weight of 1000 grains (g).

3. Interaction effect of biochar and planting distances

a. The interaction effect of different levels of biochar and planting distances had significant effects on plant height at maturity.

b. The effect of different levels of biochar and planting distances on the number of tillers was significant at 30 and 45 DAT.

c. 25 MT of biochar per hectare at a 20 cm x 30 cm planting distance (T_6) performed significantly better in terms of computed yield.

4. Cost and return analysis

a. Concerning the cost and return analysis, 25 MT biochar per hectare at 20 cm x 30 cm was found to be the most profitable treatment.

5. RECOMMENDATIONS

Based on the results of the study, the following recommendation are made:

1. Twenty-five (25) metric tons (MT) of biochar per hectare (with the recommended fertilization package technology based on soil analysis) is recommended for high-yield performance.
2. The planting distance of 20 cm x 30 cm is recommended in terms of yield per hectare.
3. A follow-up study should be conducted during the dry cropping season to validate the results of this study and arrive at more conclusive results.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Ali, M., Ali, L., Sattar, M., & Ali, M. (2010). Improvement in wheat (Triticum aestivum L.) yield by manipulating seed rate and row spacing in Vehari zone. *Journal of Animal and Plant Sciences, 20*(4), 225-230.

Biederman, L. A., & Harpole, W. S. (2013). Biochar and its effects on plant productivity and nutrient cycling: A meta-analysis. *GCB Bioenergy, 5*(2), 202-214. https://doi.org/10.1111/gcbb.12037

Filiberto, D. M., & Gaunt, J. L. (2013). Practicality of biochar additions to enhance soil and crop productivity. *Agriculture, 3*(4), 715-725. https://doi.org/10.3390/agriculture3040715

Haque, M. A., Razzaque, A. H. M., Haque, A. N. A., & Ullah, M. A. (2015). Effect of plant spacing and nitrogen on yield of transplant aman rice var. BRRI dhan52. *Journal of Bioscience and Agriculture Research, 4*(2), 52-59. https://doi.org/10.18801/jbar.040215.42

Huang, M., Fan, L., Chen, J., Jiang, L., & Zou, Y. (2018). Continuous applications of biochar to rice: Effects on nitrogen uptake and utilization. *Scientific Reports, 8*(1), 11461. https://doi.org/10.1038/s41598-018-29877-7

Jeffery, S., Abalos, D., Spokas, K. A., & Verheijen, F. G. (2015). Biochar effects on crop yield. In Biochar for environmental management. In (pp. 301-325). London: Routledge.

Rawat, J., Saxena, J., & Sanwal, P. (2019). Biochar: A sustainable approach for improving plant growth and soil properties. *Biochar-an Imperative Amendment for Soil and the Environment*, 1-17. https://doi.org/10.5772/intechopen.82151

Roslan, I., Noraini, J., Yusof, M., Muharam, F., Mohd, I., & Lai, L. (2017). Effects of rice straw biochar and nitrogen fertilizer on rice growth and yield. *Asian Journal of Crop Science, 9*(1), 159-166.

Santos, A. (2023). Human resource lens: Perceived performances of ISO 9001: 2015 certified service firms. *International Journal of Human Capital in Urban Management, 8*(2), 229-244.

Santos, A. R. (2020). Indicators of buying influence in business markets perceived by marketing students. *International Journal of English, Literature and Social Sciences, 5*(1), 325-329. https://doi.org/10.22161/ijels.51.53

Santos, A. R. (2023). Critical success factors toward a safe city as perceived by selected medium enterprises in the province of Nueva Ecija: A crafted business development policy model. *Asian Development Policy Review, 11*(1), 53-66. https://doi.org/10.55493/5008.v11i1.4750

Santos, A. R., & Constantino, J. A. (2021). Production practices and harvesting operations and problems of farmers in San Antonio, Nueva Ecija. *United International Journal for Research & Technology, 2*(8), 70-75.

Shackley, S., & Sohi, S. (2010). *An assessment of the benefits and issues associated with the application of biochar to soil.* Retrieved from A Report Commissioned by the UK Department for Environment, Food and Rural Affairs and Department of Energy and Climate Change.

Appendix A. Soil analysis.

Republic of the Philippines
DEPARTMENT OF AGRICULTURE - RFO 02
ILAGAN SOILS LABORATORY
DA-CVRC Cmpd, San Felipe, City of Ilagan, Isabela
Tel. No. 0917-115-2147, Email: ilagansoilslab@gmail.com
CERTIFIED: ISO 9001:2015

REPORT OF SOIL ANALYSIS

Test Report No.: ISL-2019 **154**
Name of Farmer : Noly Elefante
Location of Farm : Bantug, Tumauini, Isabela
Submitted/Date : Owner /June 04, 2019
Date Finished: June 13, 2019
Area (ha): 0.5
Crops: Rice

Lab # RSL 2019	Spl/ Field#	pH	O.M. % (N)	P, ppm	K, ppm	Zn, ppm	Texture	Lime Req't. tons/ha Kgs/tree	CROP Variety/Age	Nutrient Req't (kg/ha)		
										N	P	K
Rw- 154		4.96	1.48	8.7	137				Hybrid DS	140	20	0
									Hybrid WS	100	20	0
									Inbred DS	100	20	0
									Inbred WS	80	20	0

Note:

Method: *pH: Potentiometric;* ***N****: Walkley & Black Spectrophotometric;* ***P:*** *Olsen;* ***K:*** *Cold Sulfuric Extraction;*

FERTILIZER RECOMMENDATION

Hybrid Rice-DS — **140-20-0**
Basal App. — 2.0 bags/ha. 16-20-0 & 1.10 bags/ha. 46-0-0
10 bags/ha. Organic Fertilizer
1st Topdress — 1.0 bags/ha. 21-0-0, 7-10 days after transplanting
2nd Topdress — 2.5 bags/ha. 46-0-0, 20-25 days after transplanting
3rd Topdress — 1.1 bag/ha. 46-0-0 or based on leaf color chart, 35-40 days after transplanting.
1.0 bag/ha. 0-0-60 at booting stage.

Hybrid Rice-WS — **100-20-0**
Inbred Rice-DS — **100-20-0**
Basal App. — 2.0 bags/ha. 16-20-0 & 0.60 bags/ha. 46-0-0
10 bags/ha. Organic Fertilizer
1st Topdress — 1.0 bags/ha. 21-0-0, 7-10 days after transplanting
2nd Topdress — 1.7 bags/ha. 46-0-0, 20-25 days after transplanting
3rd Topdress — 0.9 bag/ha. 46-0-0 or based on leaf color chart, 35-40 days after transplanting.
1.0 bag/ha. 0-0-60 at booting stage.

Inbred Rice-WS — **80-20-0**
Basal App. — 2.0 bags/ha. 16-20-0 & 0.3 bags/ha. 46-0-0
10 bags/ha. Organic Fertilizer
1st Topdress — 0.8 bags/ha. 21-0-0, 7-10 days after transplanting
2nd Topdress — 1.4 bags/ha. 46-0-0, 20-25 days after transplanting
3rd Topdress — 0.7 bag/ha. 46-0-0 or based on leaf color chart, 35-40 days after transplanting.
1.0 bag/ha. 0-0-60 at booting stage.

Analyzed By:
Signature privacy
CLARITA J. DOMINGO
Agriculturist II
License No. 0006805

Recommended by:
Signature privacy
RO... ...USTIN
Science Reseach Specialist II

Certified by:
Signature privacy
SA... ...UINO, RCh
Chemist III / Laboratory In Charge
License No. 0010971

Disclamer: Results relate to air dried samples and shalll not be reproduced except in full written approval of the DA-RFO Integrated Laboratory Division. Any erasures thereon will invalidate the report.

DA-RFO 02-ILD-FORM 06
Revision Code: 03
Revision Date: January 22, 2018
Effectivity Date: February 1, 2018

Appendix B. Biochar analysis.

Republic of the Philippines
DEPARTMENT OF AGRICULTURE - RFO 02
INTEGRATED LABARATORY DIVISION
Ilagan Soils Labaratory
Cagayan Valley Integrated Agricultural Labaratory,
Regional Goverment Center, Carig Sur, Tuguegarao City
Tel. Nos. (078)377-0263, Email: ild.darfo2@gmail.com

DOCUMENT CODE:
DARF02.ILD.124-44.FORM06.04
Effectivity Date: June 17, 2019

REPORT OF FERTILIZER ANALYSIS

Test Report No.: ISL-2019 21
Name: Darwin M. Cacal
Address: Tumauini, Isabela
Submitted by: Owner

Date Submitted: 7/22/2019
Date Finished: 8/6/2019

Lab . No 2019	Code	KIND OF SAMPLE	pH	% Moisture	Nutrient Content						
					%Total Nitrogen	%Total Phosphorus	% Total Patassuim	Micronutrient Content (ppm)			
								Zinc (Zn)	Copper (Cu)	Manganese(Mn)	Iron(Fe)
SA0 - 055		Biochar 1	7.30			0.1375	0.853	-	-	-	-
SA0 - 056		Biochar 2	7.30			0.131	0.853				
								-	-	-	-
								-	-	-	-

***Method**: % **Moisture**: Gravimetric **% Total N**: Kjeldahl Jaudber-Gunning; **%Total P**: Vanadomolybdate; **%Total K**: Flame Atomic Emission;*
***%Total Micronutrients:** Atomic Absorption Spetrophotometric*

Analyzed By: Signature privacy
SARAH B. AQUINO, RCh
Chemist III / Laboratory In Charge
License No. 0010971

Certified By: Signature privacy
FEVIE RICA A. ANCHETA, RCh
Chemist III / OIC, Reg'l Soils Lab.
License No. 117965

Approved By: Signature privacy
GERLY T. ZULUETA, DVM
Vet, IV / OIC, Integrated Lab. Div.

DA-DOS, Matatag at Maayos

Disclamer: Results relate to air dried samples and shalll not be reproduced except in full written approval of the DA-RFO Integrated Laboratory Division.
Any erosures thereon will invalidate the report.

DA-RFO 02-ILD-FORM 06
Revision Code: 03
Revision Date: January 22, 2019
Effectivity Date: February 1, 2018