EFFECT OF NITRATE ENRICHED BIOCHAR ON CASSAVA (MANIHOTESCULENTACRANTZ.) GROWTH AND FERTILIZATION EFFICIENCY

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Abstract - Field experiment was carried out to study the effect of enriched biochar on cassava growth and soil qualities. The experiment was carried out on severely eroded soil at Batu, Malang, Indonesia. The treatments tested were: (i) control (without nitrogen without biochar), (ii) No biochar with nitrogen, Nitrogen; (iii) poultry litter biochar, PLbiochar; (iv) corncob biochar, Ccbiochar; (v) Nitrogen enriched poultry litter biochar, and (vi) Nitrogen enriched corncob biochar. These treatments were arranged in a Randomized Block Design with 4 replications. Biochar was enriched with Nitrate acid. To observe the efficiency of nitrogen fertilization, nitrogen content in aerial biomass and tuber was also measured. The experimental results showed that cassava planted on nitrogen enriched biochar soil grew faster and yielded a higher aerial biomass than that of planted on non biochar and biochar treated soil. They also produced a higher tuber yields compared to the cassava grown in non biochar and biochar treated soils. The highest yield (40.35/ha) was obtained by cassava grown in nitrogen enriched poultry biochar, but this was not significantly different with that of grown in nitrogen enriched corncob biochar (36.72). The yield of non biochar (control), poultry biochar and enriched biochar was 13.29, 32.42 ton/ha, and 40.35 ton/ha respectively. Biochar and enriched biochar application increased nitrogen fertilization efficiency. However, application of enriched biochar was much more efficient than when biochar and nitrogen were applied separately. This indicated that biochar, regardless of its feedstuffs, can be used as the carrier for nitrogen fertilizer.

Index terms - Nitrogen Carrier, Slow Release Fertilizer, Soil Amendment, Organic Farming

I. INTRODUCTION

As a soil amendment, biochar has been shown able to increase crop yield, especially on degraded and marginal soil conditions. The increase of cassava yield with biochar application has been shown for monoculture cassava [1], and cassava intercropped with maize [2]. The yield increase was attributed to the improvement of soil fertility status, either chemical, physical or biological fertility. The increase of soil organic matter and cation exchange capacity with biochar application had been shown by many workers [3]. In acid soil, biochar application has been shown able to increase soil pH [4], and hence it was suggested that this soil pH increase would reduce the toxic element, such as Aluminum. The improvement of soil physical qualities with biochar application has been shown previous researches [5-6]. The improvement includes a decrease in soil bulk density, which in turn would enhance the tuber development. The importance of mycorhiza for cassava has long time been understood [7]. Therefore, since biochar was a good medium for mycorhizal activity [8], it is reasonable to suggest that increasing cassava yield withbiochar application is a result of increasing mycorhizal population and activity [9].The increase of soil cation exchange capacity with biochar application will increased the efficiency of nitrogen utilization. With its high cation exchange capacity, biochar enhanced the nitrogen retention in the soil [10]. Other research showed that the loss of nitrogen in biochar applied soil was lower compared to that of non biochar treated soil [11]. Reference [12] and [13] showed that biochar application increased the efficiency of nitrogen fertilization. To attain the same yield, maize planted in biochar treated soil required less nitrogen fertilizer compared to that of planted in non biochar treated soil.

In this study, it was hypothesized that biochar can be used as the carrier of some elements of plant nutrition, especially nitrogen. This hypothesis was based on the study by Taghizadeh-Toosi, et al. [14] who showed that nitrogen in ammonium enriched biochar was bio-available. The study discussed here was aimed to investigate the effect of ammonium enriched biochar on the cassava growth and yield. The study also investigated the effect of nitrogen enriched biochar on nitrogen fertilizationefficiency.

II. MATERIALS AND METHOD

a. Location

The field experiment was carried out on severely eroded soil at Junrejo, Batu, East Java, Indonesia, and laboratory analysis was done at the Soil Science Department, University of Brawijaya, Malang. The field experiment was conducted from December 2016 to August 2017. The soil belongs to Entisol with silty texture and an effective depth of less than 30 cm.

b. Experimental Treatment

The treatments tested were: (i) No biochar no nitrogen as the control, (ii) No biochar with nitrogen, Nitrogen; (iii) poultry litter biochar PLbiochar; (iv) corncob

biochar, Ccbiochar; (v) Nitrogen enriched poultry litter biochar, Enriched PLbiochar; and (vi) Nitrogen enriched corncob biochar, Enriched CCbiochar. These treatments were arranged in a Randomized Block Design with 4 replications. The non biochar and biochar treatments were given with 300 kg Urea/ha.
Biochar was made from poultry litter and corncobwhich collected from the farmers filed at Junrejo, Batu. Biochar was made according to the method described by Masuliliet al. [15] at a temperature of 300^0 C. Biochar was enriched with ammonium sulfat as done by Wisnubroto et al. [16]. Some soil properties of soil and biochar used in this experiment was presented in Table 1.

Table 1.Some properties of soils and biochar used in the experiment

Soil	Soil properties					
	pH	Carbon (%)	Nitrogen (%)	CEC (cmol/kg)	Silt (%)	Clay (%)
Neutral	6.39	0.82	0.08	13.90	62.45	13.25
PLbiochar	7.95	28.45	0.02	15.50	-	-
Enriched PLbiochar	7.40	27.95	3.85	14.50	-	-
CCbiochar	8.14	47.06	0.00	14.75	-	-
Enriched CCbiochar	7.65	48.04	3.70	16.55	-	-

About 20 cm cassava cutting of Faroka variety was planted at plant distance of 1.0. X 1.0 m on a plot of 7.0 X 6.0 m. All treatments were given 150 kg Super Phosphate 36 and 100 kg KCL per ha; applied at planting date. Nitrogen fertilizer for non biochar and biochar treatments was applied 3 times: 1/3 rate at planting, 1/3 at 30 days after planting, and 1/3 at 90 days after planting

Measurements were done for plant height, dry aerial biomass and tuber yield. To measure dry aerial biomass and tuber yield, 2 plants/plot were harvested at 30 days, 60 days, 90 days, 180 days and 240 days after planting. Then the daily Relative Crop Growth Rate (CGR) [17] was calculated by the equations :

$$CGR = \frac{W2-W1}{T2-T1}$$

Here: W 2 and W 1 is the dry biomass at measurement day T2 and day T1.

Before experiment, oil samples to a depth of about 15 cm was taken for soil pH, organic carbon, nitrogen content and cation exchange capacity measurement. Soil pH (1:1 H_2O) was observed with a pH meter (Jenway 3305), soil organic carbon was determined with the Walkley and Black method [18], and total nitrogen was analysed with Kjeldahl method [19]. NH_4OAc I N pH 7 was used to extract and determined Cation exchange capacity.

To investigate the efficiency of nitrogen application, nitrogen in aerial biomass and tuber was determined with Kejldahl method, and then the efficiency of nitrogen fertilizer application was calculated by equation:

$$N\ eff = \frac{\text{total uptake of treated cassava} - \text{total uptake of control}}{\text{applied nitrogen}} X\ 100\%$$

III. RESULTS AND DISCUSSION

The effect of enriched biochar on growth pattern was presented in Figures 1 (plant height) and 2 (aerial biomass). At 15 days after planting, the application of enriched biochar did not significantly influence both plant height and aerial biomass. However, starting from 30 days after planting enriched biochar significantly improved cassava growth. Cassava applied with enriched biochar growth faster than the other treatment.

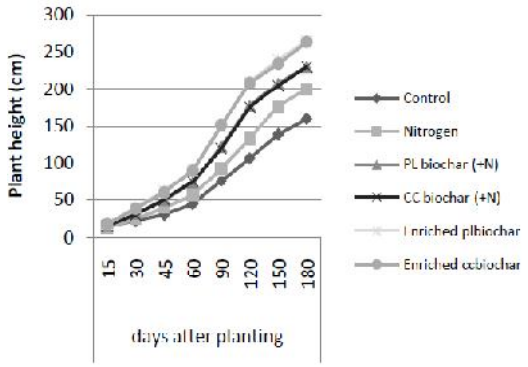


Figure 1. The development of plant height as influenced by enriched biochar application.

The application of biochar in nitrogen treatment improved the positive effect of nitrogen fertilization. The results in Figures 1 and 2 showed that cassava applied with biochar + N had a higher plant height and aerial biomass compared to the cassava that only received N. This result indicated that biochar increased the effectiveness of nitrogen fertilization. The high cation exchange capacity of biochar (Table 1) would increase cation exchange capacity of the soil (Table 5).The increase of nitrogen adsorbtion due to the high cation exchange capacity of biochar has been [10] and therefore it will decrease nitrogen loss.Widowatiet al. [11] had demonstratedthe decreased of nitrogen loss due to biochar application. The decrease in nitrogen loss would increase nitrogen fertilization efficiency as has been shown eleswhere [12]. The experimental results presented in Figure 1 and 2 shows that the incorporation of nitrogen into biochar (enriched biochar) yielded a higher plant height an aerial biomass than the other treatments. This result indicated that biochar was a good for nitrogen carrier. Furthermore, the results in Figures 1 and 2 also show that from point view of plant height

and aerial biomass there was no different effect of biochar type, both for enriched and non-enriched biochar.

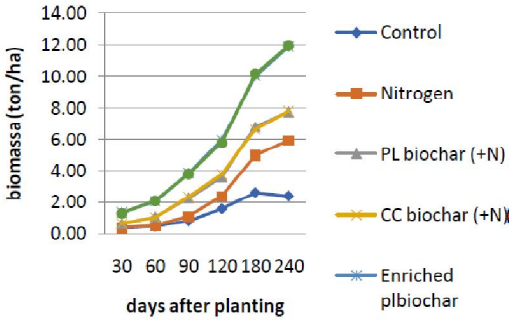


Figure 2. The development of aerial biomass as influenced by enriched biochar application.

The positive effect of enriched biochar on crop growth become more pronounce when viewed from Crop Growth Rate point of view (Table2).Since the early of growth phase the Crop Growth Rate of cassava applied with enriched biochar was much higher compared to the other treatment.

Table 2. Effect of enriched biochar application on daily Crop Growth Rate (CGR) of cassava

Treatment	Crop Growth Rate (kg/ha/day)at ..... to ..... days				
	30–60	60–90	90–120	120–180	180–240
Control	4.3a	11.6a	25.6a	17.3a	-3.30
Nitrogen	5.6a	18.6b	42.6b	43.8b	16.15
PL biochar (+N)	14.3b	39.6c	43.7b	52.8c	15.35
CC biochar (+N)	12.3b	43.6c	47.5b	48.5bc	18.66
Enriched PLbiochar	24.2c	58.8d	70.5c	68.5d	29.65
Enriched CCbiochar	26.3c	56.3d	66.3c	73.5d	29.50

*) mean followed by the same letters in the same column was not significantly different (p=0.05)

Furthermore, the experimental result presented in Table 2 show that, except the control treatment, cassava in all treatment showed the same phenomenon. Crop Growth Rate increase up to 180 days after planting, and then decreased as the crops older. For control cassava, at 120 days after planting Crop Growth rate already decreased, and after 180 days after planting there was a decrease in aerial biomass (figure 2), and therefore there was a negative Crop Growth Rate (Table 2). The decrease of aerial biomass in the control treatment because the old leaves senescence and falling. It seems that the faster leaf dying was due to the limited of nitrogen availability in the control treatment.

Number of roots was not significantly influenced by nitrogen, biochar and enriched biochar application (Table 3). Number of marketable roots (than called as "tuber") increased as cassava was given with nitrogen, biochar and enriched biochar. Furthermore, the results in Table 3 show that, mean tuber length, mean tuber diameter, mean tuber weight and tuber yield per plant was significantly influenced by biochar and enriched biochar application. The values of these parameters increased in order of control, nitrogen, nitrogen + biochar and enriched biochar. How these roots develop to be a tuber", however, is influenced by the availability of plant nutrient and soil properties. This suggestion was supported by the results which show the tuber in nitrogen treated soil was bigger and longer compared to that of the control treatment, and the tuber in biochar treated soil were longer and bigger than that of the control and nitrogen soil.

References [5] and [6] had shown that biochar application improved soil physical properties, include an increased soil aggregation and a decreased soil bulk density. These conditions would make root easier to develop to be a "tuber" and therefore, biochar treatment increased both tuber diameter and tuber length. There were no differences between biochar type, both for original biochar and enriched biochar. It seems that the number of rot is genetically properties of cassava.

The experimental results presented in Table 4 show that nitrogen, biochar, and enriched biochar application significantly increased aerial biomass, tuber yield and total yield. However, their application decreased harvest index. Application of nitrogen significantly increase both aerial biomass and tuber yield. Application of biochar in addition nitrogen on this eroded soil further increased aerial biomass and tuber yield. This phenomenon indicated that biochar increase the effectiveness of nitrogen fertilization.

Furthermore, the results in Table 4 show that aerial biomass and tuber yield of cassava applied with enriched biochar, regardless of biochar type, higher compared to that of other treatments. The highest yield (40.35/ha) was obtained by cassava grown in nitrogen enriched poultry litter biochar, but this was not significantly different with that of grown in nitrogen enriched corncob biochar (36.72 t/ha). The yield of non biochar, poultry biochar and enriched poultry biochar was 13.29, 32.42 ton/ha, and 40.35 ton/ha respectively.

Table 3. Effect of enriched biochar on yield component and tuber yield per plant

Treatment	Yield Component				
	No of total roots per plant	No of tubers per plant	Tuber diameter (cm)	Tuber length (cm)	Tuber yield (kg/plant)
Control	25.4a	8.4a	3.4a	34.4a	1.63a
Nitrogen	26.5a	14.6b	6.5b	44.3b	2.99b
PL biochar (+N)	28.9a	20.3c	10.2c	52.3c	3.66c
CC biochar (+N)	27.9a	19.7c	9.8c	50.6c	3.28bc
Enriched PLbiochar	28.7a	19.6c	10.2c	55.6c	4.84d
Enriched Ccbiochar	29.3a	19.4bc	10.4c	55.2c	4.51d

*) mean followed by the same letters in the same column was not significantly different (p=0.05)

Table 4. Effect of enriched biochar on aerial biomass, tuber yield and harvest index at 8 months old

Treatment	Fresh aerial biomass (t/ha)	Tuber yield (t/ha)	Total Yield (t/ha)	Harvest index
Control	10.05a	13.29a	23.34a	0.57c
Nitrogen	25.20b	29.80b	57.62b	0.52b
PL biochar (+N)	30.05bc	32.42b	62.72c	0.52b
CC biochar (+N)	31.22c	30.06b	61.28c	0.49ab
Enriched PLbiochar	44.81d	40.35c	85.16e	0.47a
Enriched Ccbiochar	40.39d	36.72c	77.11d	0.48a

*) mean followed by the same letters in the same column was not significantly different (p=0.05)

Looking from harvest index point of view, enriched biochar tend to decrease harvest index (0.47 in enriched poultry biochar, compared to 0.57 in the control treatment. This result indicated that the increase of aerial biomass much higher than the increase of tuber yield.

Although cassava did not show nitrogen deficiency symptom, the increase of cassava yield with nitrogen application indicated that the soil was deficient in nitrogen availability. As shown in Table 1, nitrogen content of the soil prior to the experiment was only 0.08%. Application of biochar in addition to nitrogen significantly improved crop growth (Figures 1 and 2), and tuber yield (Tables 3 and 4). This phenomenon indicated that biochar was able to decrease nitrogen lost. The ability of biochar to decrease nitrogen lost probably come from its negative charge, thus the increase nitrogen retention in the soil [10].

As a further positive impact of decreasing nitrogen lost, biochar and nitrogen enriched application increase the efficiency of nitrogen fertilization (Table 5).The results in Table 5 show, both enriched PLbiochar and enriched CCbiochar had the highest nitrogen fertilization compared to that of biochar and nitrogen applied separately. Again, this result proven that biochar is an excellent carrier for nitrogen plant nutrient. Therefore, it could be proposed to use biochar as "the slow release nitrogen fertilizer". Economic analysis, of course, should be done before producing these slow release nitrogen fertilizer commercially.

Table 5. Effect of enriched biochar application on nitrogen uptake and fertilization efficiency

Treatment	Nitrogen in aerial biomass (kg/ha)	Nitrogen in Tuber (kg/ha)	Total nitrogen in plant (t/ha)	Fertilization efficiency (%)
Control	25.38a	33.69a	59.07a	
Nitrogen	65.92b	53.32b	119.24b	44.57a
PL biochar (+N)	94.75c	60.96cd	154.81c	70.91b
CC biochar (+N)	97.81c	60.06c	157.87c	73.18b
Enriched PLbiochar	151.88c	77.96de	229.84d	88.37c
Enriched CCbiochar	148.93c	79.19e	228.12d	91.51c

*) mean followed by the same letters in the same column was not significantly different (p=0.05)

CONCLUSION

Cassava grown in nitrogen enriched biochar soil had a better growth compared to that of grown in nitrogen or the non enriched biochar soil.Cassava grown in enriched biochar soil grew faster and had a higher of plant height and dry matter yield. They also produced a higher tuber yields compared to the cassava grown in non biochar and natural biochar treated soils. The highest yield (40.35/ha) was obtained by cassava grown in nitrogen enriched poultry litter biochar, but this was not significantly different with that of grown in nitrogen enriched corncob biochar. The yield of non biochar (control), poultry litter biochar and enriched biochar was 23.29, 32.42 ton/ha, and 40.35 ton/ha respectively. Biochar and enriched biochar application increased nitrogen fertilization efficiency. However, application of enriched biochar was much more efficient than when biochar and nitrogen were applied separately. This indicated that biochar, regardless of its feedstocks, can be used as the carrier for nitrogen fertilizer. It had a good prospective to be used as a slow release nitrogen fertilizer.

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