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THE EFFECT OF CORNCOB BIOCHAR PLUS NITROGEN ON GROWTH, YIELD AND SOIL PROPERTIES IN INTERCROPPING SYSTEM APPLIED IN MAIZE (*Zea Mays L.)* AND CASSAVA (*Manihot Esculenta*)

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ABSTRACT

The field experiment was carried out to study the effect of biochar application on the growth and yield of maize planted on the intercropping system with cassava plants. This research has been done in agricultural land of Dampit, Malang, East Java. This study aims to improve soil fertility and health through the application of biochar to intercropping maize and cassava. This research is experimental research by using randomized Block Design with 4 replications. The treatment consisted of 2 cropping system (maize monoculture and maize intercropped with cassava), and 3 biochar application (without biochar without nitrogen as the control, Nitrogen; Biochar; Biochar plus Nitrogen). The results showed that application of nitrogen and biochar improved maize growth and yield both in maize monoculture and intercropping system. Maize grown in biochar treated soil was teller and grew faster than that of grown in non-biochar soil. This maize plant had a higher dry matter and grain yield. The yield of maize grown in the intercropping system in non-biochar treated soil was lower than that of grown in a monoculture system. The highest grain yield was obtained by maize monocrop grown in biochar treated soil (4.97 ton/ha) but did not significantly different from the intercropped maize treated biochar (4.85 ton/ha). The control maize yielded only (2.94 ton/ha) grain yield. After harvesting maize, the soil-applied with biochar possessed a higher soil pH, soil organic matter, soil cation exchange capacity, and soil nitrogen content. Biochar application increases the efficiency of nitrogen fertilization, both in maize monoculture and maize intercrop.

Keywords: The Effect, Corncob Biochar, Nitrogen, Growth, Yield, Soil, Properties, Intercropping, System, Applied, Maize, Cassava

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INTRODUCTION

Monoculture cultivation of cassava, production is generally low and decreases soil fertility, this is due to the smaller availability of nutrients in the soil and nutrient requirements for the high growth needs of cassava. Likewise for maize plants. this happens simultaneously on land, so that agricultural land is increasingly critical and decreases soil fertility [3] [2] Intercropped of maize in cassava-based cropping system is common practiced by cassava farmers. This practice is good to increase the farming efficiency and reduce the risk, but it will speed up the decrease of soil fertility status, especially the decrease of soil organic matter [3]. The conventional technique to overcome this problem is by applying organic biomass, such as green manure, compost, and manure. In the humid tropical condition such as Indonesia, however, these organic materials decompose rapidly. Hence, the addition of organic material should be repeated every year, or even every planting time [4] This practice makes farmers reluctant to practice organic materials application, because of difficulty for obtaining the materials and make the farming less efficient.

Lately, some workers [4] suggested using "biochar" instead of conventional organic materials. Biochar is a name given to the solid product obtained from thermochemical conversion of biomass in an oxygen-limited environment. Different from the conventional organic compound, most of the carbon compound in biochar is in the form of an aromatic compound, and hence resistant to decomposition. Therefore, in addition as a soil amendment, biochar can be used for a range of applications such as to improve resource use efficiency, protection or remediation against particular environmental pollution and as an avenue for greenhouse gas (GHG) mitigation. As a soil amendment, the long-life of carbon compound in biochar will make the addition of organic materials to soil much more efficient, because it did not necessary to be replicated each planting season.

Biochar has considered a very prospective soil amendment [6]. A lot of studies, at least in marginal or degraded soil, biochar application improve soil qualities and productivity. The increase of pH of acid soil has been shown by [4] [7][8] . With its carboxyl and phenolic compounds, biochar increases the negative charge of the soil [9] and hence improves soil exchangeable capacity [8]. [10] has shown that application of biochar increased nitrogen retention, and hence would reduce nitrogen loss caused by leaching [11][12]. The improvement of soil physical qualities with biochar application has been demonstrated by some workers. These include decreasing of soil bulk density [13]; the improvement of soil aggregation and increasing of soil water retention [14]. Showed the increase of soil microbial activity due to biochar application [15].

The researches of biochar application on maize yield have been done extensively [8][16] 17] [18]. [12] showed that application of biochar increase maize yield in acid soil, whereas [19] studied the effect of biochar application on sandy soil. [20] in their greenhouse experiment found that application of biochar increased nitrogen fertilization, and [17] demonstrated that in a soil that had been applied with biochar the nitrogen fertilizer requirement was less compared to the non-biochar soil.

It seems that there is no such study done for maize grown in intercropping system. Therefore, this experiment was aimed to study the effect of biochar application on the growth and yield of maize intercropped with cassava. The effect of biochar application on soil qualities will also be investigated.

MATERIALS AND METHOD

Location

The field experiment was conducted on farmers' field at Dampit, Malang, East Java, Indonesia, and laboratory analysis was done at Soil Science Laboratory, University of Brawijaya, Malang.

The soil is severely eroded and belongs to Inceptisol with an effective depth of about 30 cm. The field experiment was conducted from March 2018 to June 2018, and laboratory analysis was done during July 2018.

Experimental Treatment

The treatments tested consisted of two cropping system (maize monoculture and maize intercropped with cassava), and 3 biochar treatment (without nitrogen without biochar, as the control; applied with nitrogen; applied plus nitrogen and biochar). These eight treatments combinations were arranged in a Randomized Block Design with four replications.

Biochar was made from corn-cob which collected from farmer around filed experimental field. Biochar was made according to the method at a temperature of 300^0 C.[4] Biochar was ground pass through 2.0 mm sieve diameter, after which it was applied by mixing it with soil to a depth of about10-20 cm at a rate of 5 tones/ha. Some soil properties of soil and biochar used in this experiment were presented in Table 1.

Maize, Pioneer hybrid variety was planted at plant spacing of 1.0 x 0.3 m on a plot of 6.0 m x 6.0 m. In the intercropping system, maize was planted in between cassava row. With this system, there were 120 maize plant in monoculture system and 100 maize plant in the intercropping system. All treatments were given 100 kg Super Phosphate 36 and 100 kg KCl/ha. The nitrogen and biochar plus nitrogen treatments were given 300 kg N/ha. All Super Phosphate and KCl were given at planting time; and urea was given 3 times: 1/3 rate at planting time, 1/3 rate at 30 days after planting and 1/3 at 60 days after planting.

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Measurements were done for plant height, dry aerial biomass and grain yield. To measure dry aerial biomass, 2 plants/plot were harvested at 15 days, 30 days, 45days,60 days, 75 days after planting. Then the daily Relative Crop Growth Rate (CGR) was calculated by the equations (Ekanayake, 1996)

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

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

Soil data was collected before an after harvested maize. Two soil samples to a depth of about 15 cm were collected from each plot, mixed and processed for soil pH, organic carbon, nitrogen content and cation exchange capacity measurement. Soil pH in 1:1 H_2O water solution was measured with a pH meter (Jenway 3305), soil organic carbon was determined with the Walkley and Black method. Total soil nitrogen content was determined with the Kjeldahl method. Ammonium Acetate N, pH 7 was used to extract and determined Cation exchange capacity.

RESULTS AND DISCUSSION

There was no significant interaction effect of cropping system and biochar application on plant height and dry biomass yield (Tables 1 and 2). Plant height and dry biomass were only significantly influenced by biochar treatment.

The results in Table 1 show that at 15 days measurements, there was no significant difference for maize height. However, starting from 30 days measurement, application of nitrogen significantly improved maize growth. Application of biochar only decreased plant height at 30 days and 45 days after planting. Incorporation nitrogen in biochar treatment further increased plant height.

Nitrogen application increased dry biomass yield (Table 3). With its effect on plant height (Table 2) this phenomenon indicated that nitrogen in the soil was not enough for maize growth. Similar to its effects on plant height (Table 2) biochar application decreased plant height at 30 and 45 days after planting. [13] suggested that the application of biochar increased soil bacteria population and activity. The increase in bacteria population and activity would increase a nitrogen competition between maize and bacteria. Under limited soil nitrogen such as in the soil used for the experiment, this condition would have negative effect maize growth, especially at the early growth phase.

When there was enough soil nitrogen, the addition of biochar further increased the positive effect of nitrogen fertilization. This phenomenon indicated that the addition of biochar in nitrogen treatment proven that biochar increased the effectiveness of nitrogen fertilization. With its high cation exchange capacity, biochar would help nitrogen retention [10], and this would increase the

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possibility of applied nitrogen can be utilized by the maize plant. This phenomenon can be seen in the treatment plus nitrogen which yielded a higher plant height (table 2) and dry biomass (Table 3) compared to the nitrogen treatment only. Furthermore, the results in Tables 2 and 3 also show that the development of plant height and dry biomass in biochar plus nitrogen treated soil occurred much faster than the other treatment.

The effect of nitrogen, biochar, and biochar plus N application on maize growth was more pronounced if viewed from Crop Growth Rate (CGR) point of view (Table 4). All maize treatment showed a similar growth pattern, but with different magnitude. The speed of plant development increased up to 75 days after planting and then decreased as the maize going to be older. The highest dry biomass increment was obtained by maize applied with biochar plus nitrogen treatment at 45 to 60 days after planting (160.0 kg/ha/day), and the lowest was obtained by the control maize (90 g/ha/day

The effect of biochar application on grain yield and harvest index was presented in Table 5. As a result of better growth, maize applied with biochar plus nitrogen yielded a higher dry biomass and grain yield. However, different from plant height and dry biomass up to 75 days after planting, the interaction between cropping system and biochar application significantly influenced dry biomass at harvest and grain yield. If there was no biochar application (control and nitrogen treatment), intercropped maize decreased grain yield. The addition of biochar, especially in the maize applied with nitrogen, minimized this decrease.

The result presented in Table 5 also shows that biochar application improved the formation of grain yield, as shown by its higher harvest index. The harvest index of non-biochar treated maize varied from 0.41 to 0.45, whereas the harvest index of biochar maize was 0.48. The increase of grain yield with either nitrogen or biochar application is a consequence of better maize growth, The higher yield of nitrogen plus biochar maize, again demonstrated the significant effect of high cation exchange capacity as has been suggested by [13].

The experimental results presented in Table 6 show that after harvesting maize, biochar application improves the fertility status of the soil used for the experiment. Biochar application increased soil pH, soil organic matter, soil nitrogen, and cation exchange capacity.

The increase of organic C in biochar treated soil is a logic consequence of high organic carbon content in the biochar (Table 1). The same phenomenon occurred for soil pH and cation exchange capacity. The increase of cation exchange capacity with biochar application. [9] This high cation exchange capacity had resulted in a more efficient in nitrogen utilization, so that the maize in biochar treated soil grew better (Tables 2 and 3) and yielded a higher yield (Table 5).

CONCLUSION

The application of nitrogen and biochar improved maize growth and yield both in maize monoculture and intercropping system. Maize grown in biochar treated soil was taller than that of grown in non-biochar soil. This maize plant had a higher dry matter and grain yield. The yield of maize grown in the intercropping system in non-biochar treated soil was lower than that of grown in a monoculture system. Application of biochar could minimize this yield decrease. Maize monocrop grown in poultry litter biochar treated soil yielded the highest grain yield (5.02 ton/ha), and then followed by maize monocrop grown in corncob biochar treated soil (4.87 t/ha). After harvesting maize, the soil-applied with biochar possessed a higher soil pH, soil organic matter, soil cation exchange capacity, and soil nitrogen content. Biochar application increases the efficiency of nitrogen fertilization, both in maize monoculture and maize intercrop.

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APENDIX

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

Experimental	Soil properties					
Materials	pH	Carbon (%)	Nitrogen (%)	CEC (cmol/kg)	Sand (%)	Clay (%)
Soil	6.40	0.90	0.08	15.06	34.35	20.20
CCbiochar	8.14	47.06	0.00	19.75	-	-

Table 2: Effect of biochar application on plant height

Treatments	Plant height at some days after planting (cm)				
	15	30	45	60	75
Control	31.5 a	54.6 ab	118.4ab	145.2 a	163.2 a
Nitrogen	29.7 a	65.6 b	129.4 b	188.6 b	205.4 b
PL biochar plus Nitrogen	30.4 a	48.6 a	110.7 a	140.6 a	165.2 a
CC biochar plus Nitrogen	31.4 a	67.6 b	146.7 c	206.7 c	220.6 c

*) means folwed the same letter in the same column is not significantly different (p=0.05)

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Table 3: Effect of biochar application on dry biomass production

Treatments	Biomass production at some days after planting (cm)				
	15	30	45	60	75
Control	0.03 a	0.35 a	1.05 b	2.30 a	2.34 a
Nitrogen	0.05 a	0.54 b	1.46 c	3.46 b	3.96 b
PL biochar plus Nitrogen	0.03 a	0.28 a	0.90 a	2.35 a	2.40 a
CC biochar plus Nitrogen	0.04 a	0.58 b	1.58 d	3.70 c	4.85 c

*) means folwed the same letter in the same column is not significantly different (p=0.05)

Table 4: Effect of biochar application on Crop Growth Rate

Treatments	CGR (kg/ha/day			
	15 – 30	30 -45	45 -60	60-75
Control	21.3 b	40.0 b	90.0 a	2.7 a
Nitrogen	32.6 c	61.3 c	133.5 b	33.5 b
PL Biochar plus Nitrogen	16.6 a	9.3 a	96.7 a	3.3 a
CC Biochar plus Nitrogen	36.0 c	66.7 c	142.5 c	76.7 c

*) means folwed the same letter in the same column is not significantly different (p=0.05)

Table 5: Effect of biochar application on dry biomass at harvest, grain yield and harvest index

Treatments Cropping system	Biochar	Dry biomass (Stem, leaves and cobs) (ton/ha)	Grain yield (ton/ha)	Harvest Index
Maize	Control	3.34 a	2.76 b	0.45 ab
monoculture	Nitrogen	5.26 c	4.18 c	0.44 ab
	PL Biochar plus	3.40 a	2.87 b	0.46b

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	Nitrogen			
	CC Biochar plus Nitrogen	5.25 c	4.97 c	0.48 b
Maize intercrops	Nil	3.34 a	2.40 a	0.41 a
	Nitrogen	4.96 b	3.60 b	0.42 a
	PL Biochar plus Nitrogen	3.40 b	2.75 b	0.45 ab
	CC Biochar plus Nitrogen	5.22 c	4.85 c	0.48 b

*) means folwed the same letter in the same column is not significantly different (p=0.05)

Table 6: Effect of biochar application on some soil properties after harvesting maize

Treatments		Soil properties			
Cropping system	Biochar	pH	C-organic (%)	Nitrogen (%)	CEC (m mol)
Maize monoculture	Control	6.40 a	0.90 a	0.08 a	14.95 ab
	Nitrogen	6.36 a	0.89 a	0.11 b	14.85 ab
	PLbiochar plus Nitrogen	6.90 b	1.45 c	0.19 c	17.46 c
	Ccbiochar plus Nitrogen	6.84 b	1.46 c	0.18 c	17.80 c
Maize intercropping	Nil	6.45 b	0.95 a	0.09 ab	14.16 a
	Nitrogen	6.46 b	1.15 b	0.09 ab	15.80 b
	PLbiochar plus Nitrogen	6.83 b	1.56 c	0.18 c	18.45 c
	Ccbiochar plus Nitrogen	6.85 b	1.49 c	0.19 c	18.27 c

*) means folwed the same letter in the same column is not significantly different (p=0.05)

