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Research Article
Effect of Biochar Application on the Growth of Cassava and Maize, Maize Yield and Soil Erosion in Cassava+Maize Intercropping System

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Abstract
Background and Objective: In the tropical soil, soil organic matter is important not only to provide nutrients and improve soil fertility, but also enhance soil physical properties to reduce soil erosion. Biochar as a recalcitrant organic matter provides opportunity to improve soil physical, chemical and biology properties for a longer period compare to other organic matter. A field experiment was carried out to investigate the effect of biochar application in soil erosion, cassava growth and maize yield in cassava+maize intercropping system. **Materials and Methods:** The tested treatments consisted of two factors, i.e.,: biochar applications (no biochar, with biochar) and cropping system (cassava monoculture, maize monoculture and cassava+maize intercropping). There were two replications of each treatment. **Results:** The experimental result showed that the biochar application improved cassava growth both in the monoculture and the intercropping system. Maize yield was found to be increased with biochar application in both cropping systems, however there was no significant difference between cropping systems. The highest maize yield in this experiment (4.626 t ha^{-1}) was obtained by maize monoculture applied with biochar. The higher plant growth under biochar resulted in better land cover, thus reduce the surface runoff and subsequently soil erosion. **Conclusion:** Biochar used in this study showed improvements not only to increase maize yield, but also improve soil physical properties such as soil aggregate stability. Hence, due to better land cover and higher soil aggregate stability, the loss of soil from erosion was lower in biochar treatment compare to the no biochar treatment.

Key words: Soil productivity, carbon sequestration, soil organic amendment, cassava+maize intercropping system, monoculture

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cassava has been assumed as a crop which speeds up soil degradation. This assumption is based on the high plant nutrition removal with harvesting cassava[1,2]. In addition, a lot of experiments also show that soil erosion from cassava was higher compared to that from other crops[3-5]. Recent study showed that erosion from cassava planted on the Lesti Watershed, East Java Indonesia, could be more than[5] 90 t ha^{-1}. This is far higher than the acceptable limit erosion of soil in this watershed.

The assumption of planting cassava will degrade soil is not either wrong or entirely correct since soil degradation is not determined by the crop factor alone[6]. The soil degradation is also influenced by crop and soil management. The high erosion rate of cassava usually occurs at the early growth phase. Cassava is usually planted at wide spacing (1.0$\times$1.0 m). Since cassava has slow growth rate at the early growth phase, the land surface will open to rain drop impact. Ardjasa *et al.*[7] showed that the amount of eroded soil during the first 4 months was about 90% of the total erosion during cassava growth. Therefore, an easier method to decrease soil erosion rate from cassava field is by speeding up the land coverage, such as mulching[6], or planting others crops between cassava[2,7]. In addition to speeding up surface land coverage, planting short maturity crops can improve soil quality[8]. All these processes would decrease soil erosion rate. Yuniwati *et al.*[2] showed that erosion occurred from the monoculture cassava cropping system can be lowered by integrating cassava and maize in the intercropping system. The study showed that the erosion from maize monoculture was 65.4 t ha^{-1}, while the intercropping system showed a lower erosion[8] value of 32.1 t ha^{-1}.

Speeding up the crop growth can also be thought as one of methods to increase land coverage. This can be done by applying correct fertilizer or soil amendment[9,10]. The biochar is one of the very promising soil amendments, can improve cassava growth and therefore increase the cassava yield[10]. The improvement of maize growth and yield with biochar application has been shown by many researchers[11-13]. In addition, it has been shown that, as a soil amendment, biochar is also able to improve soil physical properties, especially soil aggregate stability[14]. It has been widely understood that soil aggregate stability influences soil erosion[15]. Therefore, it is expected that biochar application is expected to decrease soil erosion.

The study was aimed to investigate the effect of biochar application to the soil erosion from a cassava field. In addition, the effect of biochar application to the plants growth and yield was also investigated.

MATERIALS AND METHODS

Location: The field experiment was carried out in eroded soil at Junrejo, Batu, East Java, Indonesia. Laboratory analysis was done at the Soil Science Department, Brawijaya University, Malang. The field experiment was conducted from 12 January to 10 May, 2017.

Biochar was made from poultry litter collected from poultry farmers surrounding the field and done according to the method described by Masulili *et al.*[16] at the temperature of 300°C. Some properties of soil and biochar used for the experiment were presented in Table 1.

Experimental treatments and management: The tested treatments consisted of two factors, i.e.: biochar applications (no biochar, with biochar) and cropping system (cassava monoculture, maize monoculture and cassava+maize intercropping). These treatments were arranged in a randomized block design with 3 replications.

The experimental plot had a size of 2.0$\times$5.0 m with the land slope of 15%. To collect surface runoff and eroded soil, a collector from "unused petrol container/drum" was built at lower part of the experimental plot.

Cassava with Faroka variety, was planted at 1.0$\times$1.0 m and maize, Pioneer hybrid variety, was planted at 1.0$\times$0.3 m. In the intercropping treatment, maize was planted in between cassava row. The monoculture cassava was fertilized with 300 kg urea ha^{-1}, 100 kg super phosphate 36 ha and 100 kg KCl ha^{-1}. The monoculture maize was planted with 200 kg urea ha^{-1}, 100 kg super phosphate 36 ha and 50 kg KCl ha^{-1}. Intercropping cassava+maize was fertilized with 300 kg urea ha^{-1}, 100 kg super phosphate 36 ha and

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

	Chemical properties					
Experimental materials	pH	Carbon (%)	Nitrogen (%)	Cation exchange capacity (cmol kg^{-1})	Sand (%)	Clay (%)
Soil	6.34	0.91	0.10	14.96	24.35	34.20
Biochar	7.90	32.45	0.04	17.50	-	-

200 kg KCl ha^{-1}. All super phosphate and KCl fertilizers were given at planting date and urea was given 3 times: $^1/_3$ at planting date; $^1/_3$ at 45 days after planting and $^1/_3$ at 110 days after planting.

The data collected were surface runoff, soil erosion, infiltration, soil organic matter, soil nitrogen, soil stability, cassava growth and maize yield. The soil infiltration was measured on day 100 after planting and soil sample was collected before harvesting maize for soil organic matter, soil nitrogen, soil aggregate and stability determination.

The infiltration was determined by double ring infiltrometer[17]. The soil organic matter was measured with Walkley and Black method[18]. The Kjeldahl method was employed for soil nitrogen determination with the Kjeldahl method[19]. The soil aggregate water stability was determined by wet sieving method according to the description by Utomo and Dexter[20] and the results were expressed as the mean weight diameter (MWD) of stable aggregate with an equation of:

$$\text{MWD} = \sum_{i=1}^{n} \text{diwi}$$

where, di is the mean diameter of any size ranges of aggregates separated by sieving and iwi is the weight of aggregates in that size range as a fraction of the total dry weight of soil used.

Analysis of variance (ANOVA) with 95% degree of confidence was used for data analysis. If there was a significance, the least significant difference (LSD) test was employed to further analysis the significant difference between treatment.

RESULTS

Until 30 days of measurement, cassava plant height was not significantly influenced by both cropping system and biochar application as presented in Table 2. Starting form 60 days of measurement the intercropped of maize in cassava significantly decreased plant height. Biochar application increased cassava height in each cropping pattern. Therefore, biochar application lowered the negative effect of maize intercrop in cassava+maize intercropping pattern.

Similar to cassava, until 30 days of measurement, the maize height was not significantly influenced by both cropping system and biochar application (Table 3). Until 60 days of measurement, the maize height was not significantly influence by cropping system, but it was significantly influenced by biochar application. Thus, it could be concluded that intercropping cassava with maize did not influence the maize growth. Furthermore, the results in Table 3 showed that in maize monoculture, started from 45 days of measurement, biochar application significantly increased the maize height. The effect of biochar application in cassava+maize intercropping just appeared at 60 days of measurement.

The effect of biochar application on yield and yield component of maize in monoculture and intercropping system as presented in Table 4. The measured yield components were not significantly influenced by cropping system; they were only influenced by biochar application. Both in the monoculture and intercropping system, the biochar application improved cob length, number of grain cob^{-1} and 100 grain weight. As a result, the gained yield in biochar

Table 2: Cassava height as influenced by cropping system and biochar application

Treatments		Plant height at day after planting			
Cropping system	Biochar	15	30	60	90
Cassava	No biochar	13.66^a	24.65^a	56.66^b	92.57^c
	With biochar	13.16^a	26.17^a	61.45^c	112.45^d
Cassava+Maize	No biochar	14.07^a	25.65^a	40.56^a	67.26^a
	With biochar	13.95^a	26.17^a	42.37^a	73.25^b

Values followed by the same letters in the same column indicate that the differences are not significant (p>0.05)

Table 3: Maize height as influenced by cropping system and biochar application

Treatments		Plant height			
Cropping system	Biochar	15	30	45	60
Maize	No biochar	32.5^a	74.3^a	112.9^a	166.6^a
	With biochar	33.4^a	78.6^a	129.3^b	184.7^b
Cassava+Maize	No biochar	32.9^a	76.8^a	115.4^a	165.6^a
	With biochar	32.6^a	77.8^a	124.3^{ab}	182.4^b

Values followed by the same letters in the same column indicate that the differences are not significant (p>0.05)

Table 4: Maize yield and yield component as influenced by cropping system and biochar application

Treatments		Yield components					
Cropping system	Biochar	Cob length (cm)	Grain no. cob^{-1}	100 grain weight (g)	Grain yield (t ha^{-1})	Vegetative yield (t ha^{-1})	Harvest index
Cassava	No biochar	19.45^{a}	325.23^{a}	30.45^{a}	4.03^{a}	5.16^{a}	0.45^{ab}
	With biochar	24.50^{b}	344.60^{b}	33.45^{b}	4.66^{c}	5.20^{a}	0.47^{b}
Cassava+Maize	No biochar	20.45^{a}	327.43^{a}	30.90^{a}	4.10^{ab}	5.26^{a}	0.44^{a}
	With biochar	24.90^{a}	339.20^{b}	34.05^{b}	4.52^{bc}	5.19^{a}	0.47^{b}

Values followed by the same letters in the same column indicate that the differences are not significant (p>0.05)

Table 5: Effect of biochar application on surface runoff and soil erosion of cassava based on cropping system

Treatments		Surface runoff	Rain	Soil loss
Cropping system	Biochar	(m^{3} ha^{-1})	(%)	(t ha^{-1})
Cassava	No biochar	2670.9^{a}	20.80^{a}	57.51^{a}
	With biochar	2566.0^{ab}	19.98^{ab}	50.26^{bc}
Maize	No biochar	2526.0^{ab}	19.67^{ab}	51.55^{b}
	With biochar	2476.6^{b}	19.28^{ab}	47.31^{bc}
Cassava+Maize	No biochar	2291.6^{c}	17.84^{b}	45.69^{c}
	With biochar	2250.3^{c}	17.52^{b}	37.05^{d}

Value followed by the same letters in the same column indicate that the differences are not significant (p>0.05)

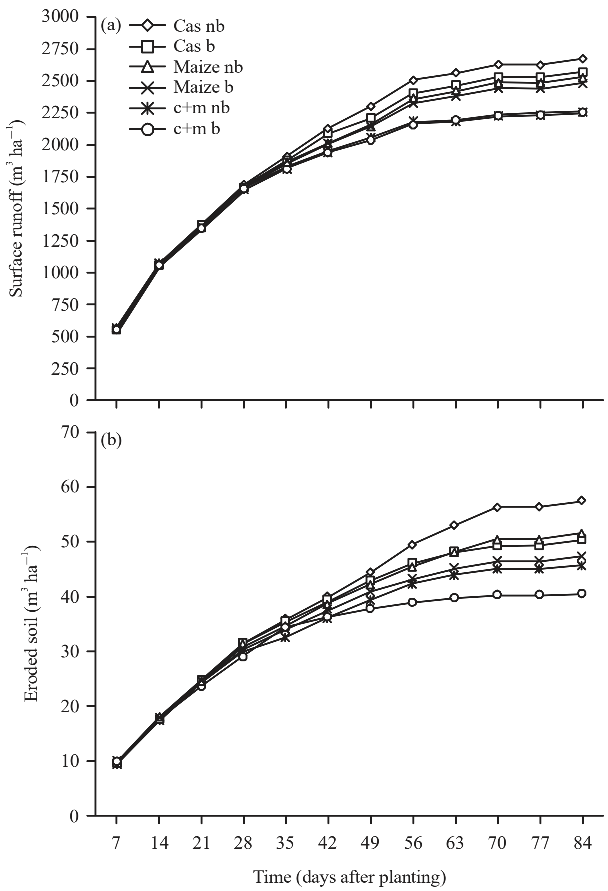

Fig. 1(a-b): (a) Surface runoff and (b) Soil loss from cassava (cas), maize and cassava+maize intercropping (c+m)
nb: No biochar, b: Biochar

applied soil was higher compared to that in non-biochar soil. The highest grain yield was obtained by maize monoculture applied with biochar (4.66 t ha^{-1}), but it was not significantly different from that of maize in intercropping pattern applied with biochar (4.52 t ha^{-1}).

The results presented in Table 4 also showed that biochar application tended to increase Harvest Index (HI). The lowest HI (0.44) was obtained by maize planted in cassava+maize intercropping without biochar and increased to 0.47 with biochar application. This phenomenon indicated that the improvement of generative past was higher than that of the vegetative part.

During the growth of maize there was 1355 mm rainfall. However, surface runoff and erosion were occurred until the 13th weeks with total rain 1284 mm. The results presented in Table 5 show that application of biochar and intercropped maize in between cassava significantly decreased surface runoff and soil erosion. Furthermore, the result in Table 5 showed that surface runoff and soil erosion from cassava+maize intercropping was significantly lower than those from cassava and maize monoculture. In all cropping patterns, biochar application decreased surface runoff, however this difference was not significant (p>0.05).

Regardless the difference in the cropping patterns, biochar application tended to decrease soil erosion as shown in Table 5. However, the biochar application was significantly (p<0.05) decreased soil erosion only in the cassava+maize intercropping system. In term of percentage, the decrease of soil loss due to biochar application from cassava+maize intercropping was higher as compared to that of cassava monoculture and maize monoculture. A higher decrease of soil erosion from cassava+maize intercropping was probably due to a better growing of both crops in this cropping pattern.

It was observed that until 30 days after planting, the surface runoff and soil erosion from all treatments were not different as shown in Fig. 1a-b. After 30 days of measurement, intercropping and biochar application gradually decreased the surface runoff and soil loss. This is reasonable, because until 30 days after planting the cover of land surface for all treatment was relatively not different as presented in Table 3 and 4.

DISCUSSION

The improvement of cassava and maize growth with biochar application could be thought as the result of plant nutrient efficiency usage. The data presented in Table 1 showed that biochar possessed high cation exchange capacity and the application of this material into soil has been proven to be able to increase cation exchange capacity of the soil[11,21]. As a result, there was a decrease in nutrient lost, especially in the form of cation, such as NH_4^+ and K^+. The increase of nitrogen fertilization efficiency with biochar application has been shown by Widowati *et al.*[22].

The decrease in soil erosion with biochar application is mainly attributes to the better coverage of land surface in the intercropping system. Results from this experiment also showed that the improvement of soil physical properties also contributed to the decrease in soil erosion. Biochar is considered as one of most promising soil amendments, which can be used to improve cassava growth and therefore increase the cassava yield[23]. The increase of soil aggregate stability due to biochar application also has been reported elsewhere in the tropical soil[24,25] and clays soil in the sub-tropical condition[26]. There are several theories to explain the better soil aggregate stability in the biochar treated soil, one of the theories is that biochar application to soil will increase the CEC thus could create cation bridge formation to increase soil structure stability[26].

It has been shown from this study that biochar application could improve soil aggregate formation and stabilization and therefore would decrease soil erodibility. The lower soil erodibility means that the soil would be more resistant to rainfall and surface runoff detachment, hence less soil erosion. Similar results of biochar application reducing soil erosion also reported by Doan *et al.*[25] and Li *et al.*[27] where the soil loss in the biochar treated soil was 20-40% lower than the soil loss in the non-biochar soil. However, Li *et al.*[27] suggest that application of biochar together with intensive tillage could increase the risk of higher surface runoff. Further studies are needed to find the appropriate combination of soil tillage management and biochar amendments in tropical soils to reduce the risk of higher soil loss by erosion.

CONCLUSION

The result showed that biochar application improves cassava growth both in monoculture and intercropping system. The cassava growth in intercropping system is lower than that in monoculture system. Maize yield, in both cropping systems, increases with biochar application, but is not significantly influenced by cropping system. The highest maize yield (4.66 t ha^{-1}) was obtained by maize monoculture applied with biochar. The lowest maize yield was obtained by maize monoculture without biochar (4.03 t ha^{-1}) but is not significant compared to intercropped maize without biochar (4.10 t ha^{-1}). As the effect of plant growth improvement, biochar application reduces the surface runoff and erosion rate. Intercropped of maize in cassava-based cropping system significantly lowers surface runoff and soil erosion. The decrease of soil erosion in intercropping system due to biochar application was higher than that in the monoculture system.

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SIGNIFICANCE STATEMENT

This study found that the biochar application in a tropical soil could improve maize and cassava growth and subsequently increase the land cover. Not only that biochar improves plant growth, but also enhance the soil physical properties such as soil aggregate stability. As a result, better land cover and soil physical properties, the surface runoff and soil erosion were found to be lower in biochar treated soil than non-biochar treated soil. This study provides another significant evidence that biochar is an important source of soil organic matter to improve soil sustainability in the tropical areas.

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