Residual Effect of Biochar on Growth and Yield of Red Chili (*Capsicum Annum* L.)

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***Abstract*—A field experiment was done to study the residual effect of biochar application on the growth and yield of red chili (*Capsicum annum* L.). The experiment was done at Wringinrejo Village, Blitar Regency of Indonesia. The biochar treatment was applied to cassava crops from 2009 until 2013. The subsequent soil then was used for chili planting in 2013 with the treatment of: (i) Biochar residue (with and without biochar), and (ii) fertilizer application (No fertilizer, Nitrogen, Farm Yard Manure (FYM), and combination of N+FYM). These treatments were arranged in a split plot design with biochar residue as the main factor, and fertilizer application as the sub factor; with 4 replications. The collected data were: (i) the growth and yield of chili, (ii) yield component, and (iii) soil quality. The results show that after4 year of application, biochar still had a significant effect on the growth and yield of red chili. In general, chili planted on plot that given biochar before, tend to be higher with more branches compared to the chili planted on non-biochar applied plot. Thus it can be concluded residual effect of biochar significantly influenced the growth and yield of red chili. Application of nitrogen fertilizer and farm yard manure increase the chili yield, both on non-biochar, and applied biochar plot. The highest fruit yield (14.6 t.ha^{-1}) was obtained by chili planted on biochar-treated plot applied with nitrogen and Farm yard manure.**

***Index Terms*—chili pepper, organic farming, farm yard manure, nitrogen fertilizer, sustainable agriculture**

I. INTRODUCTION

Since the discovery of terra preta in the Amazon valley, biochar has been believed as attracted an extraordinary attention. It is believed that biochar is the key of sustainable agriculture in the humid tropics [1]. This suggestion is based on the occurrence of recalcitrant organic-C compound in biochar. It is believed that the existence of recalcitrant organic-C compound in biochar will make biochar resistant to degradation, and hence lasting for a longer time than conventional soil organic amendment.

As a soil amendment, biochar has been proven to have many positive effects in improving soil quality [2]. Biochar application had been proven able to improve soil chemical fertility [3]-[5], physical fertility [6] and [7] as well as soil biological fertility [8] and [9] and increase crop yield [9] and [10]. The ability of biochar application to increase fertilization efficiency has been shown by Widowati *et al.* [11] and Utomo and Islami [12]. The increase of crop yield with biochar application has been reported elsewhere, such as for rice [5] and [13], maize [7] and [10], cassava [14], soybean [15] and cowpea [10].

Due to its resistant to decomposition, it is believed that the positive effect of biochar application will last for a long time similar to the terra preta soil. Although there is no evidence that the effect of man-made biochar is similar to the natural biochar in the terra preta soil, experiments had shown that the positive effect of biochar application was still persists after several years of application [16].

Chili is one of the important crops in Indonesian diet. Therefore chili is one the favored cash crop because it has a high potential returns per unit area per season. To obtain high yield, farmers should use a high dose of inorganic fertilizer. However, it has been shown that the use of inorganic fertilizers alone cause problems for human health and the environment. However, under Indonesian ecological condition, effect of compost or manure only persists in one season [16] so that the use of manure or compost should be repeated per planting season. This practice make farming is very expensive and beyond the economic ability of the farmers. Therefore, the use of biochar would be very prospective.

The use of biochar for chili production is limited, and mostly done in a greenhouse [17]. It seems there is no experiment to study the residual effect of biochar application on chili. Therefore, the experiment discussed

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here was aimed to study the residual effect of biochar application on the growth and yield of red chili (*Capsicum annum* L.). The information from this reported experiment will be very helpful to red chili farmers, because it will help them in soil organic management for their crops.

II. Materials and Method

A. Location

The experiment was carried out on an upland farmers' field at Wringinrejo, Blitar, Indonesia. The location has a distinct wet and dry season with an average annual rainfall of about 2000mm with the rainy season started in around November, and ended in March of the following year. Before used for this study, the soil was used for biochar experiment on cassava crops for 4 year [18].

B. Experimental Treatments

The experiment used a factorial split plot design with 4 replications. The main factor is biochar residue (no biochar and the soil had been applied with biochar). The sub-factor is fertilizer application, namely: (i) Control (no fertilizer); (ii) 135kg.ha^{-1} N fertilizer; (iii) 5 t.ha^{-1} Farm Yard Manure (FYM); (iv) the combination of N fertilizer and FYM. All treatments were given 100kg SP36 ha^{-1}, and 100kg KCl ha^{-1}.

In accordance with the numbers of sub-factor, 4 ridges of chili growth media was prepared on a 6 m width plot (a plot of the biochar cassava experiment) at about 40cm width and 30cm high were prepared for growth medium of red chili. Distance between ridges was about 1.5m. The ridge was covered with plastic mulch of about 0.03mm thick. About 15cm height seedling of red chili (Gada MK F1 variety) was transplanted in a single row ridge with 40cm plant spacing; thus there were 12 plants per treatment.

Data collected were plant height, plant biomass, yield and component yield. After harvesting the soil was sampled soil organic-C, soil Nitrogen, and Cation exchange capacity. Soil analysis was done with the method developed by Centre for Soil Research, Bogor - Indonesia [19].

C. Statistical Analysis

Analysis of variance (ANOVA) was performed for analyzing the data. If there was a significant difference, then LSD with the probability level of 5% was used to see the differences.

III. Results and Discussion

A. Chili Growth and Yield

It was observed that one month after planting, plant height and the number of branches did not significantly influenced by either biochar residue or fertilizer application. The mean height and number of branches at one month was 20.45cm and 2.35 branches per plant respectively. Interaction between biochar residue and fertilization significantly influenced plant height at 2 months after planting (Table I). However, the significant effect of interaction between biochar residue and fertilization occurred only after 3 months measurement.

The experimental results presented in Table I show that in general, the red chili planted on the plot given biochar before, tend to be higher and had more branches compared to the chili planted on non-applied biochar plot. These results indicated that the biochar residue (after 4 year of application) had a significant effect on the growth of red chili. The positive effect on chili growth had also found by Carpenter [17]. Biochar application increased plant height, and chlorophyll content of chili grown on Anthrosols.

TABLE I. Effect of Biochar Residue and Fertilization on Plant Height and the Number of Branches of Red Chili

Treatments		Plant height (cm)		Branch number/plant	
Biochar residue	Fertilizers	2 months	4 months	3 month	4 months
No biochar	0	25.12 a	48.75 a	2.25 a	5.45 a
	Nitrogen (N)	33.42 b	65.28 cd	2.86 ab	8.67 b
	Manure (FYM)	34.14 b	60.46 bc	2.46 ab	9.85 bc
	N + FYM	38.77c	75.60 e	3.04 b	12.25c
Biochar residue	0	27.48 a	55.67 b	2.35 ab	8.91 b
	Nitrogen (N)	38.75 c	69.30 de	4.14 c	11.34 c
	Manure (FYM)	38.44 c	64.25 cd	3.98 c	9.86 bc
	N + FYM	39.29 c	72.15 e	3.10 ab	12.45 c

*) Means followed by the same letters in the same column are not significantly different (P > 0.05)

The result presented in Table I also show that both on non-biochar and biochar plot, nitrogen and farm yard manure application improved red chili growth. The effect of fertilizer application on plant growth was more markedly on non-biohar plot. Khan *et al.* [20] studied the effect of N and K application on the growth and yield of chili. Their experimental result showed that nitrogen application significantly improved chili growth.

Similar to the N fertilizer application, farm yard manure application also improved the growth of chili. The effect of organic fertilizer on chili growth and yield had been studied by Narkhede *et al.* [21] who found that the effect of organic fertilizer was better than that of in-organic fertilizer. Furthermore, the result in Table I shows that in non-biochar plot, the growth parameter of the combination of farm yard manure and nitrogen fertilizer treatment was better than nitrogen or FYM alone. These phenomena indicated that biochar-treated soil had a better soil fertility status. Thus although had been applied 4 year before, the positive effect of biochar application was still persist.

The experimental result presented in Table II show the effect of biochar residue and fertilizer application and chili yield component performance. Similar to its effect on plant growth, the performance of yield component of red chili planted on biochar-treated plot was better than that of on non biochar plot. The chili was longer with a bigger fruit circumference. Again, this phenomenon

indicated that the biochar-treated soil had a better soil fertility status compared to that non-biochar treated soil.

TABLE II. EFFECT OF BIOCHAR RESIDUE AND FERTILIZATION ON YIELD COMPONENT OF RED CHILI

Treatments		Fruit length	Fruit circumference	Fruit weight
Biochar residue	Fertiilizer	(cm)	(cm)	(g per 10 fruit)
No biochar	0	9.36 a	2.33 a	45.55 a
	Nitrogen (N)	13.45 bc	3.68 ab	88.67 b
	Manure (FYM)	14,05 bc	3.52 ab	89.26 b
	N + FYM	16,76 c	4.32 b	118.69 c
Biochar residue	0	12,45 ab	3.08 ab	86.27 b
	Nitrogen (N)	15,75 bc	4.11 b	119.27 c
	Manure (FYM)	15,08 bc	3.85 ab	92.44 bc
	N + FYM	17,20 c	4.66 b	120.66 c

*) Means followed by the same letters in the same column are not significantly different (P > 0.05)

In both non-biochar and biochar-treated soil the performance of chili yield component improved with application of either inorganic fertilizer or farm yard manure. The fruit was longer, bigger and hence heavier. The best performance was obtained by a combination of N +FYM treatment, both on non-biochar and biochar-treated soil. The heaviest fruit (120.66 g per 10 fruit) was obtained by N + FYM planted on biochar-treated plot.

The experimental result presented in Table III showed that the interaction between biochar residue and fertilizer application significantly influenced dry biomass and fruit yield of red chili.

TABLE III. EFFECT OF BIOCHAR RESIDUE AND FERTILIZATION ON DRY BIOMASS AND FRUIT YIELD OF RED CHILI

Treatments		Dry biomass	Fruit yield
Biochar residue	Fertilizer	(g/plant)	(t/ha)
No biochar	0	58.78 a	6.05 a
	Nitrogen (N)	108.50 c	11.66 bc
	Manure (FYM)	118.45 cd	10.25 bc
	N + FYM	124.56 d	12.30 c
Biochar residue	0	76.45 b	8.30ab
	Nitrogen (N)	147.58 e	14.25 d
	Manure (FYM)	144.55 e	13.80 cd
	N + FYM	148.50 e	14.60 d

*) Means followed by the same letters in the same column are not significantly different (P > 0.05).

Although both, in non-treated and biochar-treated soil biomass and fruit yield increase with fertilizer application, in general the biomass and fruit yield of biochar-treated soil were higher. This indicated that biochar, although had been applied 4 year before, still had a positive effect on growth and yield of red chili. This result is different from that obtained by Carpenter *et al.* [17]. Carpenter *et al.* [17] found that biochar application on Anthrosol only significantly influenced the marketable chili fruit yield, but not influenced total fruit yield. This difference was probably due the different in soil fertility status. It seems that Anthrosol used for Carpenter *et al.* [17] experiment had a better soil fertility status.

B. Soil Quality

The soil quality data after planted with red chili was given in Table IV. Soil organic-C of biochar treated soil was higher compared to non-treated biochar soil. Compared to the condition before the experiment, there was an increase in soil organic content of biochar-treated soil; this occurred for the treatment of FYM and N + FYM treatments. Together with increasing soil organic-C content, there was an increase in Cation Exchange Capacity (CEC). This is a reasonable phenomenon, because soil organic material is one of the negative charge resources.

TABLE IV. EFFECT OF BIOCHAR RESIDUE AND FERTILIZATION ON SOIL ORGANIC-C, NITROGEN CONTENT AND CATION EXCHANGE CAPACITY

Treatments		Soil organic-C	Soil-N	CEC
Biochar residue	Fertilizer	(%)	(%)	cmol kg^{-1}
No biochar	0	0.95 a	0.09 a	10.55 a
	Nitrogen (N)	0.92 a	0.10 a	10.06 a
	Manure (FYM)	0.92 a	0.11 a	10.95 a
	N + FYM	0.93 a	0.16 b	11.05 a
	Before experiment	0.91	0.08 a	10.73
Biochar residue	0	2.15 b	0.10 a	14.85 b
	Nitrogen (N)	2.08 b	0.18 bc	14.66 b
	Manure (FYM)	2.36 b	0.20 bc	16.27 c
	N + FYM	2.40 b	0.21 c	15.40 bc
	Before experiment	2.12	0.09	14.12

*) Means followed by the same letters in the same column are not significantly different (P > 0.05)

IV. CONCLUSION

Until 4 years after application, the positive effect of biochar was still persisting. The red chili planted on biochar-treated had a better growth with a higher yield compared to the chili planted on non-biochar soil. Application of inorganic fertilizer and farm yard manure improved crop growth and fruit yield of the red chili planted both in non-biochar and biochar treated soil. The highest fruit yield (14.60 $t.ha^{-1}$) was obtained by chili planted on biochar plot applied with nitrogen and Farm yard manure. Soil organic-C content of biochar treated soil was still high, and even higher compared to the condition before experiment. Again, this phenomenon proven that biochar was resistant to decomposition.

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