Corn Growth and Yield on Suboptimal Upland Soil After Amended with Biochar and Low Levels of Fertilizer in West Kalimantan, Indonesia

Pertumbuhan dan Hasil Jagung pada Tanah Dataran Tinggi Suboptimal Setelah Diubah dengan Biochar dan Pupuk Kadar Rendah di Kalimantan Barat, Indonesia

Sutarman Gafur[1*], Saeri Sagiman[1], Tatang Abdurrahman[2]

[1] Department of Soil Science, Faculty of Agriculture, Universitas Tanjungpura
[2.] Department of Agrotechnology, Faculty of Agriculture, Universitas Tanjungpura

[*]*Email:sutarman.g@faperta.untan.ac.id*

Abstrak: Biochar sudah terkenal sebagai bahan amandemen tanah yang memiliki potensi besar untuk meningkatkan sifat tanah yang terdegradasi. Namun, untuk memaksimalkan perannya dalam meningkatkan karakteristik tanah yang penting untuk mendukung pertumbuhan tanaman, perlu dikombinasikan dengan bahan potensial lainnya. Dalam penelitian ini kami mencari paket perlakuan yang berpotensi bermanfaat dan terjangkau secara lokal. Eksperimen ini dirancang untuk mempelajari efek biochar dan input rendah dari paket perlakuan NPK pada pertumbuhan jagung dan hasil di tanah dataran tinggi suboptimal Kalimantan Barat, dan untuk mempelajari dampak dari perawatan ini pada beberapa karakteristik tanah yang penting. Empat tingkat perlakuan yang digunakan: T0 (kontrol), T1 (Biochar 5% (W / W), dan NPK 300kg / ha), T2 (Biochar 5%, dan NPK 600 kg / ha), T3 (Biochar 10% dan NPK300 kg / ha, dan T4 (Biochar 10% dan NPK 600 kg / ha). Setiap perlakuan memiliki empat ulangan. Hasilnya menunjukkan bahwa total berat kering tanaman meningkat dari 151 g / tanaman (T1) menjadi 237 g / tanaman (T4), sedangkan total produksi jagung meningkat dari 12,9 (T1) menjadi 15,7 ton / ha (T4). Selanjutnya, semua paket perlakuan juga secara signifikan meningkatkan pH tanah, kandungan C-organik, KTK, dan rasio C / N tanah. Selain itu, kandungan N, P, K, di tanah pada akhir percobaan juga meningkat rata-rata 163, 1143, dan 432%, masing-masing. Singkatnya, semua perawatan berbasis biochar secara signifikan meningkatkan pertumbuhan tanaman, hasil panen, dan beberapa karakteritik tanah yang penting. Kami sangat merekomendasikan T3, dengan kadar NPK lebih rendah dari biasanya, sebagai paket perawatan yang akan diuji lebih lanjut di lahan dataran tinggi suboptimal di Kalimantan Barat..

Kata kunci: Jagung (*Zea mays L.*), Lahan kering, Pertukaran kalium, Pupuk organik dan Anorganik

Abstract: Biochar is already well-known as a soil amendment material that has great potential to improve degraded soil properties. However, in order to maximize its role in improving important soil characteristics to support plant growth, it needs to be combined with other potential materials. In this study we are seeking a treatment package that is potentially useful and locally affordable. This experiment is designed to study the effects of biochar and low input of NPK treatment packages on corn growth and yield in suboptimal upland soil of West Kalimantan, and to study the impact of these treatments on some important soil characteristics. Four treatment levels were used: T0 (control), T1 (Biochar 5% (W/W), and NPK 300kg/ha), T2 (Biochar 5%, and NPK 600 kg/ha), T3 (Biochar 10% and NPK300 kg/ha, and T4 (Biochar 10% and NPK 600 kg/ha). Each treatment had four replications. The results show that total plant dry weight increased from 151 g/plant (T1) to 237 g/plant (T4), while total corn production increased from 12.9 (T1) to 15.7 ton/ha (T4). Furthermore, all treatment packages also significantly increased soil pH, C-organic content, CEC, and soil C/N ratios. Moreover, the content of N, P, K, in the soil by the end of the experiment also increased on average 163, 1143, and 432%, respectively. In short, all biochar based treatments significantly increased plant growth, yields, and some important soil charactersitics. We highly recommend T3, with lower NPK levels than normally recommended, as a treatment package to be further field tested in suboptimal upland soil in West Kalimantan.

Keywords: Biochar, Low inputs, Upland soil,Corn growth and Yield

PENDAHULUAN

The area of upland soil in West Kalimantan that is potentially used for upland rice and horticulture crops is about 233.946 hectars (BPS Kal Bar, 1992). Specifically, the land that is able to be used for upland rice is only about 138.723 ha. However, the total harvest of upland rice in 2013 as reported to be only 103.972 hectars (BPS Kal Bar, 2014). The potency of upland soil will be a very important and meaningfull resource for increasing the productivity and food self-sufficiency in this province.

The upland soil of West Kalimantan is already known as moderately old to severely degraded land. Moderately degraded upland soil is generally widespread in agricultural land areas, while severely degraded land is mostly found in illegal mine site areas. The impact of this low quality degraded land is its low productivity level. It is reported that the average upland rice productivity in West Kalimantan is only about 1900 kg per hectar (BPS Kal Bar, 2014). Therefore, in order to use upland soil in West Kalimantan for food crop development, there is a need to find specific local technology that is able not only to upgrade upland soil characteristics but also to improve plant growth and its yields.

Biochar research is already well-known worldwide, and it is also known for having great potentialities to improve some important soil characteristics (Zong et al. 2015; Yoo et al. 2013). Black biochar is known for having wide internal surface areas and high in micro pores so that it would be a high quality absorbent material (Downie et al. 2009). This absorbent function is highly expected in retaining soil nutrients and preventing their loss from the soil through the erosion process. It is also known that Some important impacts of biochar application were improving soil CEC, reusing plant residue, reducing surface run-off, decreasing water and fertilizers use, increasing crop yield, improve soil biodiversity, strengthening and building soil food-web, improving soil carbon storage, increasing soil pH, restructuring degraded land, and reducing methane and ammonia gases emisson from agricultural land (Ekebafe et al. 2015). However, biochar is not yet widely used as part of agricultural technology in West Kalimantan. Good impact of biochars could be a prospect to upgrade the characteristics of upland soil in West Kalimantan and to support the development of sustainable agriculture in this areas. However, biochar is not the only resource that could upgrade soil quality. Another suggestion is to combine biochar with other materials in order to maximize its role in improving soil characteristics (Wimmer, 2011).

Low input agricultural systems might be regarded as unacceptable or an impossible agricultural system to overcome the handicaps faced in upland agricultural systems in West Kalimantan. In fact, for the poor farmers in this province low input agricultural systems might be the only one they can apply, especially the one which use more local resources as it is believed able to increase land quality and productivity. Combining the use of biochar, compost, and low doses of inorganic fertilizers look promising in developing a simple and adoptable crop culture technology to support sustainable agricultural system in West Kalimantan. Biochar, that is having high water retention and absorption, and also slow in nutrient release, is regarded as an approriate choice to improve the quality of suboptimal upland soil properties. On the other hand, compost of empty bunch of oil palm fruits and cow manure are able to improve not only the soil physical properties but also to the nutrient storage to enrich the soil's chemical and biological properties. Specifically low input of NPK is expected to provide early need of the plants so that the plants

can grow as potentially expected. Eventually, collectively, effects of this combination of treatments will result in better soil quality and increasing crop productivity. Gradually, this low input system is believed to be able to improve physical, chemical, and biological soil properties. In turn, this system will slowly improve land productivity that benefit the farmers. Finally, this experiment was designed with as its main objectives to study the effects of biochar, compost, and low input of NPK treatment packages on corn growth and yields in suboptimal upland soil of West Kalimantan, and also to study the treatment impact on some important soil characteristics.

MATERIALS AND METHODS

Materials Preparation and Experimental Design

Soils used in this experiment were collected from the Village of Toho, Subdistrict of Toho, West Kalimantan, Indonesia, in April 2017. Its chemical and physical propoerties were analysed in Soil Chemical Laboratory, Faculty of Agriculture, Tanjungpura University, and prepared for growth media in polybag. Biochars were made from rice husk burnt in controlled burning called pyrolysis technique. Composts were made by mixing empty bunch of palm oil and cow manure by 50:50 percent for each composition and left for two weeks for its incubation process. Soils were mixed with biochars, and composts based on each treatment doses, while for NPK compound fertilizers were applied a day before planting. The corn seeds used were commercial hybrid corn type called as Pioneer.

The selected corn seeds were grown in the polybags arranged in a Completely Randomized Design. There were four levels treatment applied which were known as T0 as control, T1 (Biochar 5% (W/W), Compost 2.5% (W/W), and 300kg/ha NPK), T2 (Biochar 5%, Compost 2.5%, and 600 kg/ha NPK), T3 (Biochar 10%, Compost 2.5%, and 300 kg/ha NPK, and T4 (Biochar 10%, Compost 2.5%, and 600 kg/ha NPK). Each treatment has 4 replications.

In this experiment there were 2 group parameters to be observed. For plant growth parameters they were measured as plant height at 5, 6, and 7 weeks after planting, total biomas, and plant dry weight after harvesting. Plant productions were predicted from yield per plant and total plant population per hectar. Soil parameters observed were soil pH, total-N, total P, available P, exchangeable Al, Fe, K, Ca, Mg, and Na. They were twicely measured, before the treatment were applied and at the end of the research activities.

Statistical Analysis

Statistical analyses for mean of each variable were performed using the procedure according to Gomez and Gomez (2007). Firstly, all data were tabulated using Microsoft Excel 2007, and analyzed using One Way-ANOVA, and when there is a significant effect of the treatment, then continued with Duncan's Multiple Range Test at 5% significant level.

RESULTS AND DISCUSSION

Corn Growth and Yield

Corn Growth and Yield

Growth response of corn at each treatment package were presented at the following Figure 1.
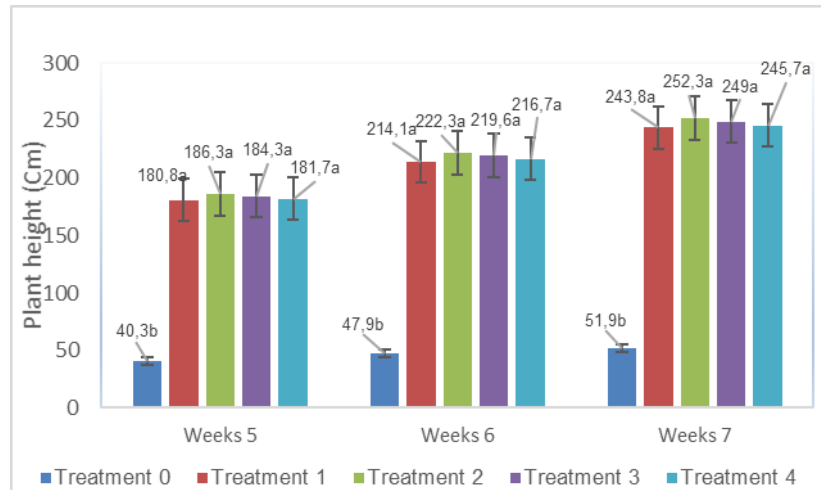

Figure 1. Corn growth responses at each treatment after 5, 6, and 7 weeks after planting.

Figure 1 shows that the corn were highly responsive to all biochar treatment packages, since plant height at all treatment package (T1 to T4) were significantly different compared to that of control treatment (T0). Eventhough, there is no significntly different in plant height response among biochar treatment package, the highest plant height was occured at treatment 2 at which 5% biochar and 600 kg NPK per hectar were applied.

Other growth response parameters were wet and dry weight of above ground plant parts as presented in Figure 2. They show similar trend that the highest weight was occured at treatment 4. It is mostly to occur because at treatment 4 were applied 10% biochar and 600 kg NPK per hectar. However, these responses were not statistically significantly different with that of in treatment 3 at which there were 10% biochar and only 300 kg NPK per hectar applied.
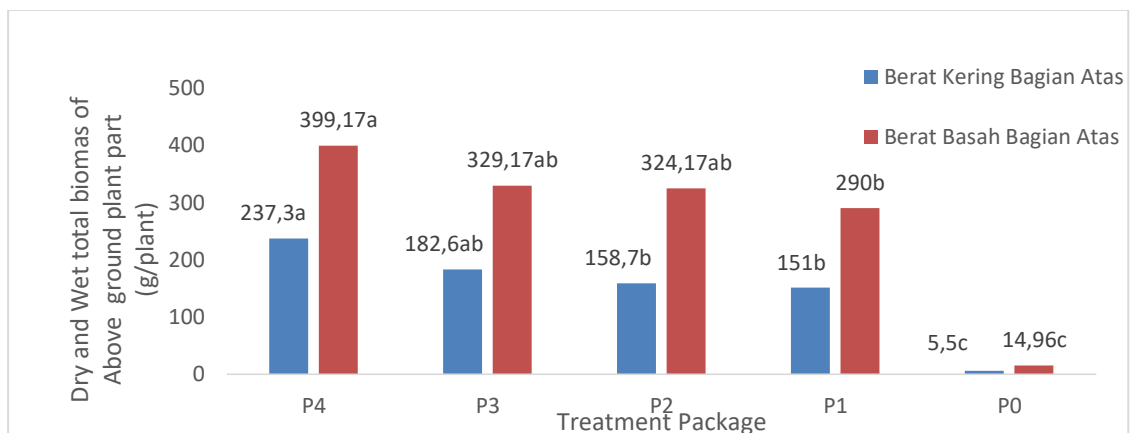

Figure 2. Total Biomas showed as Wet and Dry weight of above ground plant parts at harvest for each treatment package.

Corn yield per plant and total production per hectar were presented in the following table (Table 1).

Table 1. Corn Yield per plant (g), and Total Production Prediction per hectar (ton), the average length of corn knob per plant (cm), and average weight of 10 seeds (g) for each treatment.

Treatment Package	Corn Yield per plant (g)	Predicted Total Prodution per hectar (ton)	The length of corn knob (cm)	The average weight of 10 seeds (g)
Biochar 5% + Compost 2.5% +NPK 600kg/ha (T2)	209,74a	15,73a	16,25a	4,64a
Biochar 10% + Compost 2.5% +NPK 300kg/ha (T3)	207,58a	15,58a	15,79a	4,27a
Biochar 10% + Compost 2.5% +NPK 600kg/ha (T4)	184,55a	13,84a	15,62a	4,59a
Biochar 5% + Compost 2.5% +NPK 300kg/ha (T1)	171,39a	12,85a	14,67a	4,02a
Control (T0)	0,0b	0,0b	0,0b	0,0b

Note: Figures within the same colums followed by the same letters were not significantly different at 5% significant level.

Table 1 above shows that statistically there is not a significant different among all biochar base treatments for corn production level. However, it is interesting to be discussed that for treatment 2 and 3, at which they have two higher production levels, they were having different package proportion level. For treatment 2, it has highest production level, and it is believed due to its highest NPK level (600 kg NPK/ha) as it is recommended. This response was similar to that of growth response as it is presented in Figure 1, however, it is not similar to the response on wet and dry weight. Interestingly, at treatment 3 at which biochar dose increased to 10% and NPK dose was only 300 kg/ha, its production level was statistically similar to that of treatment 2 at which its NPK level was double. For its productivity and economic reasons that both tretament 2 and 3 are recommended for further field tests. The result also shows that the seed quality was relatively similar (Table 1), at which the average weight of 10 seeds were similar among the treatments. It means that the corn seed average size within each knob is realtively similar. More importantly that the treatments of biochar, compost, and both low input and recommended doses of NPK had successfully increased both the growth and yield of corn grown in suboptimal upland soil at Subdistrict of Toho, West Kalimantan. Furthermore, all the treatment packages had successfuly prevented them from the failure of growth and production as it was occured in the control treatment (T0).

Generally, above findings show a similar trend with the findings of Carter et al., (2013) that biochar application were able to increase total biomass, root biomass, and plant growth of *Lactuca sativa* and *Brassica chinensis*. It was also reported that rice husk biochars were able to increase the growth of mustard-greens (Suryana et al. 2016).

Soil N, P, and K Content at the end of the experiment.

The treatment package of biochar, compost, low input of NPK had greatly increased soil N, P, and K content by the end of the experiment (Table 2). Soil N and K content had significantly increased at all treatment package, it might be due to high

content of K found in rice husk biochar and high N content contributed from the compost compared to that of found in control treatment soil. Specifically for soil P, its content only significantly different from that content of in treatment 4 at which it has the highest of NPK compound applied. It could be concluded that low input of NPK applied together with rice husk biochar and compost had significantly increased the residue of N, P, and K within the soil. These increases were resulted from collective impact of biochar and compost applied. Biochar is known as better absorant for soil nutrients so that it will retain more soil nutrients, while compost will contribute for the availability of soil nutrients. These residue will be a prospective soil nutrient resources that might be available and ready for use in the next following planting period.

Table 2. Soil macro nurient content of N, P, and K by the end of the experiment.

Treatment Package	N (%)	P_2O_5 (ppm)	K-dd $(cmol(^+)(kg^{-1}))$
Biochar 10% + Compost 2.5% +NPK 600kg/ha (T4)	0,37a	121,07a	0,52a
Biochar 10% + Compost 2.5% +NPK 300kg/ha (T3)	0,345a	39,68b	0,51a
Biochar 5% + Compost 2.5% +NPK 600kg/ha (T2)	0,32ab	39,09b	0,39b
Biochar 5% + Compost 2.5% +NPK 300kg/ha (T1)	0,27b	33,73b	0,31b
Control (T0)	0,20c	5,11b	0,10c

Note: Figures within the same colums followed by the same letters were not significantly different at 5% significant level.

The effects of treatment packages on the soil base elements and soil base saturation levels by the end of experiment.

In general, all the treatment packages of biochar, compost, and low input of NPK had increased soil content of base elements mainly K, Ca, and Mg. On the other hand, no treatment packages were able to increase soil Na content. Eventhough soil Na content at treatment 4 was highest than that of other biochar treatments, it is still no significantly different than that of control treatment.

Table 3. Soil Base Saturation Levels and Soil Base elements content of each treatment package by the end of the experiment.

Treatment Pakacge	K-dd $(cmol(^+)(kg^{-1}))$	Ca-dd $(cmol(^+)(kg^{-1}))$	Mg-dd $(cmol(^+)(kg^{-1}))$	Na-dd $(cmol(^+)(kg^{-1}))$	KB (%)
Biochar 10% + Compost 2.5% +NPK 600kg/ha (T4)	0,52a	3,40a	2,05a	0,57a	37,39a
Biochar 10% + Compost 2.5% +NPK 300kg/ha (T3)	0,51a	2,76b	1,86ab	0,20b	35,23a
Biochar 5% + Compost 2.5% +NPK 600kg/ha (T2)	0,38b	2,59b	1,63b	0,26b	32,64ab
Biochar 5% + Compost 2.5% +NPK 300kg/ha (T1)	0,31b	1,56c	1,06c	0,28b	25,56bc
Control (T0)	0,10c	0,75d	0,36d	0,37ab	18,95c

Note: Figures within the same colums followed by the same letters were not significantly different at 5% significant level.

The increase in soil base element contents has resulted in significantly increase of percentage of soil base saturation. Soil base element content and soil base

saturation levels at the end of the experiment were presented in the following Table 3.

The effects of treatment packages of biochar, compost and low input of NPK to other important soil characteristics.

The results of this experiment also show that all the treatment packages of biochar, compost, and low input of NPK had significantly increased other important soil charactersistic such as soil pH, CEC, C-organic content, and C/N ratios, and it was also significantly decrease soil exchangeable content of H and Al.   The increases in the status of soil C-organic, K, Ca, Mg, and soil CEC were similar to the findings reported by Sukartono and Utomo (2012) and Carter et al, (2013). Furthermore, the effects of biochar treatments on the increases in soil pH, C-total, available P and K, and the decreases in soil exchangeable H and Al were similar to the findings reported by Zong et al. (2016).

Table 4. The characteristics of soil pH, CEC, C/N ratio, and C-Org content, exch-Al and exch-H for each treatment package by the end of the experiment.

Treatment Package	pH	C-Org (%)	CEC (cmol($^+$)(kg^{-1})	C/N Ratio	Exch-Al (cmol($^+$)(kg^{-1})	Exch-H (cmol($^+$)(kg^{-1})
Biochar 10% + Compost 2.5% +NPK 600kg/ha (T4)	5,58a	3,21a	17,70a	8,65a	0,07b	0,18ab
Biochar 10% + Compost 2.5% +NPK 300kg/ha (T3)	5,40ab	2,98a	16,46a	8,69a	0,12ab	0,17b
Biochar 5% + Compost 2.5% +NPK 600kg/ha (T2)	5,25bc	2,79ab	15,14ab	8,71a	0,10ab	0,23ab
Biochar 5% + Compost 2.5% +NPK 300kg/ha (T1)	5,00c	2,29b	12,64b	8,46a	0,13ab	0,24ab
Control (T0)	4,57dc	1,64c	9,01c	8,06b	0,16a	0,30a

Note: Figures within the same colums followed by the same letters were not significantly different at 5% significant level.

CONCLUSION

Results of the study indicated some findings as follows: All the treatment packages of rice husk biochar, compost and NPK compound had significantly increased not only the residue content of N, P, K nutrients within the soil, but also the content of element bases such as K, Ca, and Mg, and soil base saturation level. Furthermore, all the treatment package of rice husk biochar, compost and NPK compound also had increased the other soil characteistics such as soil pH, CEC, C-organic content, C/N ratio, and significantly decreased the content of soil exch-Al and soil exch-H by the end of the experiment.   Soil amendment with rice husk biochar, compost, and NPK compound as low input treatment package in thie experiment had significantly increased corn growth and yield at upland soil of District of Toho,

West Kalimantan. These results were paralel with the hyphotesis that the application of rice husk biochar, compost, and NPK compound in low inputs treatment package were able to increase corn growth and yield in suboptimal upland soil of West Kalimantan. The treatment package of 10 % Biochar, 2,5% Compost, and 300kg/ha NPK compound (T3) set up as low input treatment had succesfully increased both the growth and yield of corn more than that of in recommended treatment (T4). Therefore, that treatment (T3) is highly recommended for one of technology packages that will be field tested in suboptimal upland soil in West Kalimantan.

ACKNOWLEDGEMENTS

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