Soil Chemical Properties Improvement by Addition of an Enriched Biochar for Growth Promoting on Soybean

Sugeng Winarso(✉) and Rendy Anggriawan

Department of Soil Science, University of Jember, Jember, Indonesia
{winarsosugeng,anggriawan}@unej.ac.id

Abstract. Biochar is a carbon-rich material that has various functions in improving soil properties. This research aimed to determine the characteristics of improvement in soil chemical properties and soybean plant growth by adding biochar from various biomass sources. The design used was a factorial complete randomized design with two factors. The first factor is the source of biochar biomass which consists of four treatments, and the second factor is the dose level of enrichment fertilizer which consists of four doses. Nutrients used for enrichment were N, P, and K, with the ratio between NPK being 8:5:4 based on the total amount of nutrients in soybean crops and their level of biochar. Soil material Ultisols used for planting medium was taken from Jasinga, Bogor District, West Java. The results show that adding enriched biochar with NPK (8:5:4) improves acidic soil properties, pH, C-organic, C/N, CEC, and NPK availability. Meanwhile, adding biochar (without NPK enriched) also significantly increased soil pH, C/N, and C-organic. Increased soil chemical properties and improvement of NPK availability were also followed by enhancement of dry weight of plants, correlated positively with N ($r = 0.72^{**}$) uptake, P absorption ($r = 0.32$ ns), and K absorption ($r = 0.98^{**}$), but negatively correlated with the weight and number of roots nodule ($r = -–0.54^{*}$). A negative correlation between nutrient uptake, especially N, and the dry weight of the plant might have a particular effect on the falling activity of the root nodules, as indicated by the number and weight of the root nodules.

Keywords: Enriched Biochar · Soil Properties · Fertizer · Soybean

1 Introduction

Production and quality of soybean in Indonesia still need to be expected. Recently, the average national soybean production is 16.70 qu ha^{-1} [1]. This low production occurs due to unsuitable soil support for soybean growth. One of the factors causing low soybean production is the low quality of organic soils, such as the decline in overall soil properties, even their physics, chemistry, or biology, and ultimately leads to decreased soil fertility and health and buffer to change. Returning crop residues or harvesting, and giving compost material to the field, has been done to increase soil organic compounds. Most

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organic compounds administered are smaller than the decomposition process and have volatile levels in the form of CO_2 or CH_4. Because Indonesia is a humid tropical country (hot and high humidity), which is the main factor affecting the decomposition rate of organic material, thus making the decomposition process exceeds compost production. This situation is still going on to date, making soil organic matter as much as 73% of agricultural land in Indonesia only comprises less than 2% [2]. Instead, most agricultural experts said that the critical factor in ensuring soil health is the level of soil organic matter [3, 4].

Biochar is carbon-rich material which the potential to function as bioenergy, stable chemical characteristics, durable carbon even for thousands of years, distinctive properties distinct from its source, the ability to absorb toxic compounds or heavy metals, and the ability to store water [5–9]. Palansooriya [10] showed that amending the biochar to change microbial habitats directly or indirectly affected the activity of microbial metabolism and modified the soil microbial community in terms of diversity and abundance. The presence of organic matter derived from biochar is 10 to 1000 times longer than soil organic matter [11]. It has to investigate and used as an alternative to increasing soil fertility by consistently benefiting the environmental aspects, especially global warming [3, 12], so the use of biochar is also to exhibit distress (absorb and store) carbon [13]. The rate of biochar decomposition varies to a certain extent, depending on biomass sources, and the provision of small doses in the soil can cause it to decompose more rapidly than in large doses [14].

The tremendous potential possessed by biochar is that it can increase natural resources, including land, water, and air, and it becomes significant for the future [15]. Schahczenski [12] mentions that biochar also has the potential to produce better farming needed in the tropics. It can help accelerate decomposition and become a rectifier of land with valuable values for increasing soil productivity. Other research shows that biochar produced from meadow cuttings and applied at the 10 t/ha rate causes great impacts on soil biota abundance and plant communities over the 3-year. Therefore, this type of biochar could potentially be used for soil carbon sequestration, with minimal impacts on soil biota abundance or diversity, plant biodiversity, and productivity [16].

Referring to how biochar production requires a large amount of heat and a low oxygen state, known as pyrolysis, the process will lead to nutritional deficiencies, primarily N and S [17]. In addition, biochar triggers several other beneficial properties, such as the broad surface and the ability to increase the cation exchange capacity (CEC) in the soil [18]. The addition of other materials applied together with biochar also affects the characteristics of soil properties. Soil organic carbon, cation exchange capacity, dehydrogenase activity and metabolic quotient significantly increased in the amended plots. Inorganic NPK fertilizer + biochar with mixed bacterial cultures, enhanced organic C, dehydrogenase activity and metabolic quotient compared to NPK alone or NPK + biochar. Nitrogen, phosphorus and potassium uptake and the use efficiency and yield of maize, were superior in treatments that included mixed bacterial cultures compared to the addition of NPK alone or NPK + biochar [19]. This research aimed to determine the characteristics of improvement in soil chemical properties and soybean plant growth by adding enriched biochar from various biomass sources.

2 Materials and Methods

This research began by producing biochar from various sources so that the resulting product could be used in a variety of comprehensive land conditions involving the source of organic compounds with high C/N levels, i.e., wood. This was followed by C/N intermediate levels derived from low-level rice straw, and C/N derived from soybean straw. The principle of biochar production is to heat or burn plant material, keep it dry and minimize the amount of oxygen. Combustion results indicated that the biochar properties, based on the variables described in Table 1, consist of a low amount of macronutrients (mainly N and P), high amounts of alkali, a high number of C/N, and relatively high amounts of ash.

Based on the research at Indonesia Legumes and Tuber Crops Research Institue (ILETRI), Malang, Indonesa, it was stated that soybean's absorption reached 240 N kg ha^{-1}, 102 P_2O_5 kg ha^{-1}, dan 120 K_2O kg ha^{-1}. The extent of nutrient absorption was operationalized in calculating the need for NPK so as to enrich biochar, and the calculation result was presented in Table 2, resulting in biochar with NPK (8:5:4) to undergo a test on soybean growth in Ultisol.

The experiment was projected to discover nutrient-rich biochar's effectiveness in improving soil's properties, particularly Ultisol's chemical properties. Its effectiveness in improving the chemical properties depends on NPK nutrient, pH of soil's organic compound, and cation exchange capacity (CEC). Soybean growth was evaluated on the basis of agronomic aspects, nodules' growth, and NPK absorption. Ultisol was obtained from Bogor, West Java, with such distinctive properties, pointed out in Table 3.

The soil pH conditions were acidic, and referring to the difference in pH between H_2O and KCl, it has been found that the soil has a negative charge or in other words, the exchange process is still strongly dominated by CEC. As can be seen from the table, the level of soil organic compounds is relatively low. The ratio of C/N ratio on the ground was below ten or low. In addition to the low levels of organic compounds, the same thing was seen in NPKs, so it was important to ensure nutritional inputs for agricultural enterprises were biased favorably. In this case, substandard biochar inputs with the above-mentioned property could hardly support the growth and production of the plant. In addition, the exchange of small biochar to Ultisol requires the inclusion of other nutritional resources, and in this paper, the resources served as biochar enrichment before being applied in the agricultural business world.

The experiment was carried out in the Green House of the Faculty of Agriculture of Jember University by deploying a completely random design with factorial pattern of two factors. The first factor included various resources of biochar which was enriched with NPK 8:5:4 (8% N; 5% P_2O_5; 4% K_2O), encompassing 4 traits, i.e. b0: Biochar from wood without NPK, b1: Biochar from rice straw + NPK, b2: Biochar from soybean straw + NPK, and b3: Biochar from wood + NPK. The second factor were biochar concentrations (Mg ha^{-1}) comprising of 4 levels, including d1: 0,5 ton·ha^{-1}, d2: 2,5 ton·ha^{-1}, d3: 5,0 ton·ha^{-1}, and d4: 10 ton·ha^{-1}. In accordance with the standards of biochar products from the International Biochar Initiative that enrichment or additives in biochar of no more than 2% can still meet these standards [20]. Each experiment was repeated three times, yielding 48 treatment units. Soil nutrient and chemical analysis were carried out after harvest in a 6-week period.

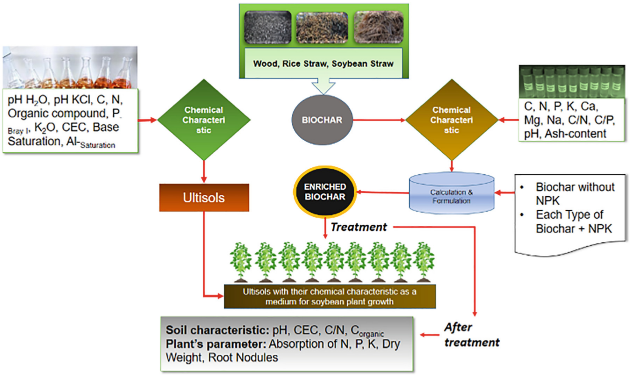

Fig. 1. Flowchart of Research method

Table 1. The Characteristics of Biochar from Various Sources

Characteristics	Wood	Rice straw	Soybean straw
C (mg kg^{-1})	704	634	657
N (mg kg^{-1})	1	1	1
P (mg kg^{-1})	3	4	4
K (mg kg^{-1})	301	170	176
Ca (mg kg^{-1})	254	212	209
Mg (mg kg^{-1})	70	183	181
Na (mg kg^{-1})	12.5	7.01	7.30
C/N	704	634	657
C/P	235	159	164
pH	7.35	8.21	8.00
Ash (x 10 g kg^{-1})	49.2	50.4	50.5

Fig. 2. Biochar from Various Sources (wood, rice straw, and soybean straw) as the treatment source

3 Results and Discussion

Analysis of variance (ANOVA) results show that the interaction between various resources of biochar which was enriched with NPK 8: 5: 4 and biochar concentrations,

Table 2. The Calculation Results of Biochar Enrichment

Variable	Wood	Wood + NPK	Rice Straw	Rice Straw + NPK	Soybean Straw	Soybean Straw + NPK
N mg kg^{-1}	1	749	1	749	1	749
P mg kg^{-1}	3	247	4	246	4	246
K mg kg^{-1}	301	199	170	330	176	324

Table 3. The Characteristics of Ultisol Obtained from Bogor, West Java

Variable	Unit	Ultisol
pH H_2O (1:5) pH KCl (1:5)		5.03 4.89
C Organic Compound N C/N	% % %	1.81 3.15 0.20 9.05
P_2O_5 Extract Bray 1	Mg kg^{-1}	10
K_2O (extract HCl 5%)	Cmol kg^{-1}	16
CEC (NH_4-Acetite 1 N pH 7)	$Cmol_{(+)}$ kg−1	23.40
Base Saturation	%	18
Al Saturation	%	65

significantly increased soil pH and availability of P and K in the soil; but not significantly for the N-total, C-organic, and CEC of soil. The combination of biochar treatment with NPK enrichment (8:5:4) ratio in soy planted Ultisols proved effective in improving soil chemical properties and nutrient NPK availability. As a result, this could increase the absorption of nutrients and promote plant growth.

A. Soil's Chemical Properties

Ultisol soil planted with soybeans had initial pH of 5.03. The addition of biochar (pH > 7) could increase the soil pH level as shown in Fig. 2. This effect ranges from 5.83 to 6.62. The tendency of improvement of soil pH was evident. This situation proved to be different when biochar was applied without NPK enrichment and the pH continued to increase with the addition of biochar concentration. The pH (y) elevation against the biochar dose, ton.ha^{-1} (x) was well aligned with the equation $y = -0.06x^2 + 1.08x + 5.71$ with $R^2 = 0.98$. Biochar might increase the pH of the Ultisol because of the existing conditions (K, Na, Ca and Mg) as illustrated in Table 1, while biochar enrichment with increased NPK levels along with increased biochar addition results in lower pH levels compared to biochar without NPK enrichments. The addition of NPK from urea (46% N) and SP36 (36% P_2O_5) during the disolving processes would release NO_3^- and $H_2PO_4^-$ and HPO_4^{2-} all of which were acidic. In a similar study, where Co-application

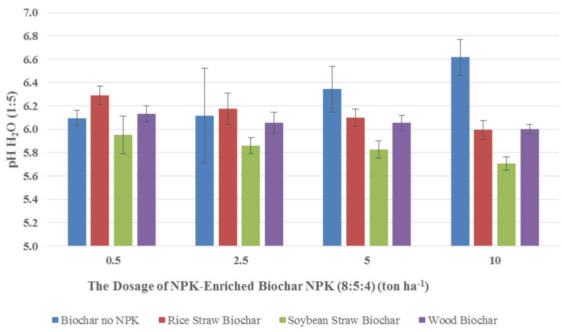

Fig. 3. The Change of Soil pH after Biochar Treatment and Soybean Planting

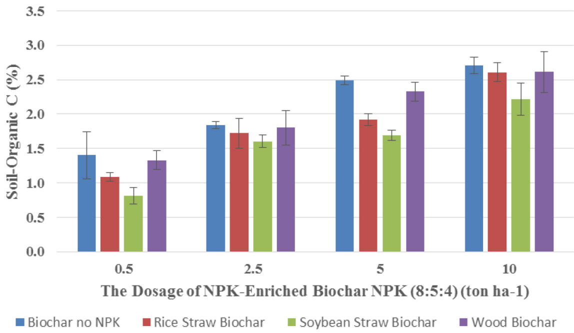

Fig. 4. The Change of Soil C-Organic After Biochar Treatment

of compost or inorganic NPK fertilizer with biochar can significantly increase soil pH values. The greatest increase in pH (14%) was observed in compost + biochar treated soil and this was followed by the NPK + biochar amended soil (7.5%). Compost alone increased soil pH by 2% and NPK, in contrast, decreased pH by 2% [21].

Biochar possessed high level of Carbon (which originated from rice straw containing 657 mg kg^{-1} of C, soybean straw containing 634 mg kg^{-1} of C, and wood containing 704 mg kg^{-1} of C) and high ratio of C/N was also proven to escalate the level of soil C-organic after incubation and soybean planting (approximately 2 months). The escalation of soil C-organic was essential to ensure the sustainability of agricultural activities and environmental health. Figure 3 indicated that the adding of biochar significantly had improved soil C-organic and this improvement kept abreast with the amount of addition concentration. The soil given the treatment with the highest addition of 10-ton ha^{-1} possessed the highest level of C-organic, which was evidenced by average of 2.71% or equal to 4.67% soil organic compound (medium status). As shown by the Fig. 3, the above-mentioned data were aligned with the previous elaboration on the fact that the highest pH level was evident on soil given biochar treatment with no NPKenrichment (8:5:4). However, after meticulous calculation or evaluation, the correlation between C-organic level and soil pH was found low, which was 0.17 with n = 48. This indicated that the level of soil pH was not dominantly under the influence of soil C-organic.

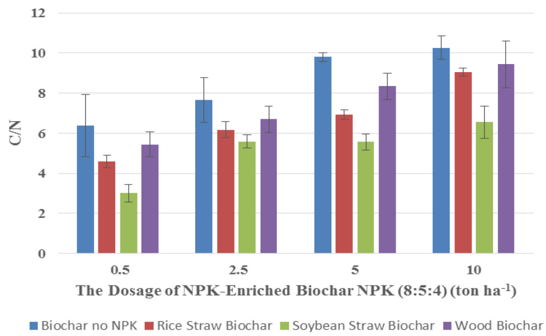

Fig. 5. The Change of Soil C/N Comparison after Biochar Treatment and Soybean Planting.

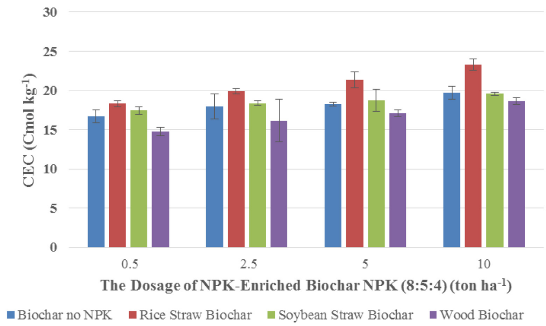

Fig. 6. The Change of Soil CEC After Biochar Treatment and Soybean Planting.

Referring to the biochar treatment with NPK enrichment, it appeared that the addition of biochar with no NPK enrichment would cause the C-organic in biochar or in the soil more stable, compared to the one with NPK enrichment. Consequently, soil C-organic given only biochar was found higher than that given NPK-enriched (8:5:4) biochar. The decrease of C-organic level in the soil given biochar treatment with NPK enrichment (8:5:4), compared to soil C-organic given biochar treatment without NPK enrichment was as follow: rice straw biochar (0.28%); soybean straw (0.53%); and wood (0.09%).

The value of C/N ratio in soil was found essential in evaluating the N availability or immobilization process. As shown by Fig. 4, it was clear that soil C/N ratio was so low that immobilization was not possible to take place, nor did it indicate the presence of nutrient, particularly N, which was highly available. Moreover, based on the level of N-total, the soil which varied from 0.21 (%) to 0.5% by SRC [22] belonged to medium.

The other soil chemical properties under evaluation to indicate the influence of enriched biochar treatment on acidic soil was the soil ability to exchange its cations or CEC. As shown by Fig. 5, it was obvious that the biochar addition, to significant extent, could escalate soil CEC, especially biochar originating from rice straw, which escalated as extrapolated by the equation $y = 1.63x + 16.63$ with $R^2 = 0.99^{**}$. This escalation of soil CEC was due to the addition of CEC originating from biochar. As a corollary, the escalation of soil CEC was aligned with the addition of biochar. The improved soil

CEC varied to some extent, ranging from 0.43 to 3.53 Cmol kg^{-1}. The value of soil CEC given biochar treatment from wood showed the smallest escalation of the other treatments. The description of the results of this study is also in accordance with the results of the research by Wang [5] showed that biochar used in soils could increase total carbon and nitrogen content, water holding capacity (WHC), exchangeable Ca^{2+}, K^+, Mg^{2+}, P-Bray I and radish dry matter.

The evaluation on the impact of biochar addition with NPK enrichment (8:5:4) was also operative on the availability of NPK nutrient after soybean planting and continued until vegetative phase. The availability of soil N-total would rise, due to adding biochar enriched with NPK, when compared to only biochar addition, which has improved by 0.04% on average and varied from 0.02% to 0.08% or indicated medium status of N availability in soil. The condition of soil P-available (P-Bray I extract) was also increased by NPK-enriched biochar addition, leading to an average increase of 5.75 mg kg^{-1} P_2O_5 and ranging from 2.2 mg kg^{-1} to 12.46 mg kg^{-1} P_2O_5, indicating low status. The availability of K nutrient in the form of soil K-available (K was susceptible to change, K_{exch}) also increased due to biochar addition with NPK enrichment, indicating an average increase of K_2O up to 0.32 Cmol kg^{-1} and ranging from 0.1 to 0.73 Cmol kg^{-1}, indicating medium status.

The escalated NPK nutrient availability in the soil was primarily due to the addition of biochar with NPK enrichment (8:5:4) or biochar possessing NPK by means of enrichment. However, referring to the measure of biochar availability at the end of planting, indicating low to medium status, biochar addition was supposed to increase or NPK-enriched biochar (8:5:4) needed to be made higher. The status of low soil P-available was worth particular concern in as much as it would dominantly constrain plant growth and production. This finding was obvious as the soil used in the research was Ultisol or acidic mineral soil.

The result of laboratory experiment, as corroborated by Barus [23], showed that the application of biochar and compost could improve soil fertility, which indicated that the escalation of soil pH and the availability of nutrient to plant, particularly P_2O_5 and K_2O. In addition, the mixture of rice straw biochar and compost was better than single application to improve soil fertility and soybean production. The combinatory application of 10 Mg ha^{-1} rice straw biochar and 10 Mg ha^{-1} hay compost increased the weight of grain rice by 41%, compared to control. It was also shown by Juriga [24], that the application of biochar and biochar combined with N fertilizer had a positive influence on soil organic matter and soil structure. It was also stated that based on the fractionation of soil organic matter there was a decrease in humic and fulvic acids of humic compounds when compared with controls.

B. The Growth of Soybean

The growth of soybean in acidic soil given the combinatory treatment of biochar and NPK was fathomed on the bases of plant height, wet weight, dry weight, the number, and weight of root pimple as well as NPK absorption, as presented in Table 4. The growth of plant, as measured from the dry weight, was found significant, resulting from the addition of biochar 5 and 10 ton. ha^{-1}. In addition, the growth inclined to rise especially due to NPK-enriched biochar from wood and rice straw. Respectively, dry weight of 5.10 and 5.66 g indicated wood and rice straw biochar with NPK enrichment (8:5:4), and 5.14 g

Table 4. Several Variables of Soybean Growth on Biochar Treatment

Treatments	Dose (ton.ha^{-1})	Absorption (%)			Efficiency			EDW[a]
		N	P	K	N	P	K	
Biochar without NPK	0.5	2.84	0.069	1.50				
	2.5	3.25	0.070	1.73				
	5	3.36	0.085	2.16				
	10	3.54	0.088	2.15				
Rice straw Biochar + NPK (8:5:4)	0.5	3.52	0.114	1.83	0.193	0.396	0.213	0.044
	2.5	3.41	0.142	2.03	0.048	0.507	0.121	0.031
	5	3.73	0.133	2.44	0.099	0.362	0.309	0.217
	10	3.87	0.103	2.66	0.086	0.142	0.412	0.272
Soybean straw Biochar + NPK (8:5:4)	0.5	3.39	0.083	1.78	0.162	0.167	0.175	0.026
	2.5	3.64	0.107	1.86	0.106	0.346	0.170	0.109
	5	3.76	0.110	2.33	0.106	0.230	0.243	0.182
	10	4.10	0.079	2.46	0.137	0.117	0.361	0.268
Wood Biochar + NPK (8:5:4)	0.5	3.84	0.101	1.79	0.261	0.318	0.190	0.033
	2.5	4.12	0.124	1.82	0.212	0.436	0.095	0.050
	5	4.13	0.129	2.41	0.186	0.340	0.294	0.212
	10	4.28	0.115	2.50	0.173	0.232	0.434	0.343
LSD5%		0.57	0.019	0.13	0.081	0.08	0.013	0.018
CV (%)		9.33	11.11	3.73	4.960	5.05	0.770	1.120

[a] Efficiency Dry Weight

and 5.11 g dry weight resulted from rice straw biochar + NPK (8:5:4). Different from biochar treatment without NPK, the plant growth was relatively similar or insignificantly different (varied between 3.55 g and 4.02 g) even though biochar increased to 10-ton ha^{-1}. The plant growth was strongly intertwined with or significantly related to the escalated absorption of NPK along with the increased biochar addition or, in other words, indicated positive correlation. The strong correlation of plant's dry weight with the absorption of N was positive and significant, indicating $r = 0.72$ **; and 0.32^{ns} with P absorption, as well as 0.98** K absorption.

Commonly, NPK absorption on soybean until vegetative phase was corresponding to particularly biochar treatment, as shown by the source of biochar, indicated that biochar originating from rice straw was higher than that from wood and soybean straw. The absorption was also affected by biochar dosage, it indicated increasing absorptions by escalation of biochar dosage as far as 5-ton ha^{-1}, but the absorption decreased when the dosage was elevated to 10 ton ha^{-1}. The fall of NPK absorption on the highest dosage, 10 ton·ha^{-1}, was due to the imbalance between C level in biochar and the added NPK, which led to the need for further research dealing with higher biochar

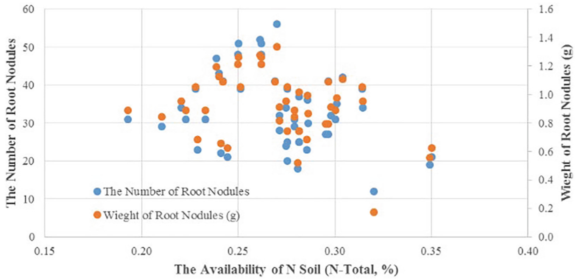

Fig. 7. The Correlation between the Availability of N Soil (N-Total) and The Number (left) and Weight (right) of Soybean Nodules.

addition leading to higher need for NPK addition as enrichment compound. Besides, the finding was assumed to have correlation with the rate of biochar decomposition. The presence different rate of biochar decomposition based on the source of biochar and its increased dosage into soil [14]. However, based on the results of research by Wang, several commercial biochar showed that the application of biochar can cause plant contamination with polycyclic aromatic hydrocarbon (PAH), which poses a risk to human health. Therefore, it is necessary to do processing before use, so that the level of PAH in biochar is small or even non-existent [5].

Different from the correlation between plant dry weight and NPK absorption, the correlation between dry weight and the number of nodule was negative. Negative and significant correlation indicated nodule' increased dry weight on plant's height, which was 0.54*. It was highly related to the condition or the availability of NPK nutrient in the soil. Soils with high amount of N availability even showed decreased number and activity of root nodules. The activity of root nodules was fixating N-atmosphere by rhizobium bacterium which had symbiotic relation with soybean in the nodules. Similar result was also informed that the use of biochar taken from rice straw and wood could improve the growth of water spinach as evidenced by the increased biomass production [14]. Such increased growth was also initiated by the improvement of soil properties, such as the comparison of Water Holding Capacity (WHC) of silt and organic compound (C-organic).

Soybean, during its growth, could associate with rhizobium bacterium in mutualism symbiosis by forming root nodules. The bacterium had the ability to fixate N-atmopshere (N_2) for its growth and even for the soybean (host plant), while the host plant contributed to the symbiosis by transferring its substrate (source of energy for its activity) [25]. In this research, root nodules indicated fine growth and development in that the number of plantings ranged from 0.17 g to 1.34 g plant^{-1} with an average of 0.9 g plant^{-1} (Table 4). The result of evaluation on soybean root nodules evinced that the growth and development were negatively correlated with N-total in the soil although it was statistically proven insignificant or low (the correlation between N-total and the number of nodules was −0.27; and with wet weight was −0.30). Most (91%) of the nodules or nodules formed in the root were proven effective due to their relatively big size and red tone inside. The relation among soil conditions, especially the level of N-total, showed

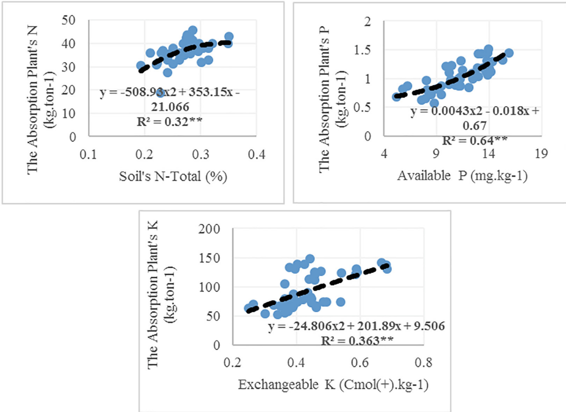

Fig. 8. The Correlation between NPK Availability in Soil and Absorption of Soybean

that the higher the level of N-total would result in lowered number and weight of root nodules, indicating negative correlation (Fig. 6).

C. Plant's Growth in Relation to Soil

The correlation between soil and plant is convincing in that every single nutrient element of plant comes from soil, either entirely or partially. As a corollary, attempts to improve soil in accordance with plant's need were essential to escalate plant growth and production. Combinatory treatment between biochar source and NPK enrichment (8:5:4) on various biochar dosages was found effective in increasing or improving soil acidic chemical properties, such as pH, C-organic, CEC, and the level of soil NPK. The improvement of soil chemical properties was followed by improved absorption of plant's N, P, and K, as presented by the following Fig. 7. Figure 7 indicated that the absorption of plant N rose significantly in accordance with the improvement of N-total level in the soil, following the equation $y = -508.93x2 + 353.15x - 21.07$ (y refers to the absorption of N, kg ton-1 and x refers to the level of N total soil, %); while the escalation of plant's absorption of P and K kept abreast with the availability of P and K in soil, which followed the equation $y = 0.0043x2 - 0.0183x + 0.67$ (for P) and $y = -24.81x2 + 201.89x + 9.51$ (for K).

The correlation was so significant that it indicated that the growth of soybean (Table 4) in acidic soil was influenced by the improved chemical properties of soil due to several combinatory treatments involving biochar source and dosage as well as NPK enrichment (8:5:4). The improvement of soil chemical properties, such as pH, C-organic, and CEC could also elevate the availability of plant macro nutrient (NPK), which consequently allowed plant to increase its absorption. The increase absorption of nutrient NPK by plant was found to affect plant's growth as indicated by its height, wet weight, and dry weight. Besides biochar can improve soil properties and plant growth, also according to the study results of Huang, biochar had great potential in the field of wastewater treatment, as an excellent adsorbent or catalyst for removing harmful organic contaminants in wastewater [26].

4 Conclusions

The addition of biochar either from rice straw, soybean straw, and wood enriched with NPK (8:5:4) possessed the ability to improve the chemical properties of soil such as pH, C-organic, C/N, CEC, and the availability of NPK. On the other hand, the addition of biochar (with or without NPK enrichment) only escalated pH, C-organic, C/N, and soil CEC. The improved chemical properties of soil and improved availability of NPK could increase the plant's NPK absorption. The use of organic waste from agricultural activities for producing biochar has been found promising for sustainable agriculture activities and C sequitration in soil. This research is the basis for land management with acid pH characters where their soil characteristics can be improved by applying nutrient-enriched biochar. The use of various other types of local agricultural biomass has the opportunity to be applied to agricultural land to support sustainable development goals. This research is limited to the application of nutrient-enriched biochar on lands with acidic pH characters, future research can be focused on contaminated lands to see how far the effect of biochar and its benefits for supporting plant productivity.

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