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Amelioration of Acid Upland to Increase Soil Productivity and Soybean Yield

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ABSTRACT

The space between young rubber plants can be utilized for growing soybean. The aim of this study was to quantify the effectiveness of some soil ameliorants applied in combination with a reduced dosage of NPK fertilizer on soil properties and soybean yield, in a young rubber and soybean intercropped system on acid upland soil. The study was conducted in East Lampung Indonesia from April to July 2013. The plots were designed in a split-plot with three replications. The main plots were the level of NPK fertilizer recommendation dosage (100% and 75%). The subplots were soil ameliorants. The results showed that a 25% reduction of NPK did not significantly affect the soil properties and soybean yield when applied with soil ameliorants. Application of dolomite 2 t/ha and Biochar SP50 2.5 t/ha reduced soil exchangeable Al content by 25.3% and 20.8% respectively. Dolomite was the most effective to increase soil pH, whilst Biochar SP50 provided the highest soil available water pores (15.25% vol.). Soybean gave better yield when the soil was treated with dolomite, Biochar SP50, and organic fertilizer plus. Reduction in soil acidity and improvement of soil available water pores most likely were responsible factors to give better yields of soybean planted on acid soil.

INTRODUCTION

Agriculture extensification in Indonesia will utilize more suboptimal land in the future with various physical and chemical limiting factors since the availability of fertile soils has been increasingly limited. Acid upland soil, available mainly in the Islands outside the Island of Java, is one of the potential suboptimal lands that can be used for agricultural development. Acid upland soil in Indonesia occupies around 107.36 million ha; 98.3 million ha of them are suitable for agriculture which consisted of 33.6 million ha suitable for seasonal crops and 53.59 million ha for perennial and plantation crops (BBSDLP, 2014).

The land-use competition between food and plantation crops, especially rubber plantation, on acid upland soil has been intensified recently. The farmer's selection of crops to be grown is determined by several factors including the difficulty on maintaining the crops, availability of market, price of the product and continuous cash income contribution to the farmer. Food crops that are commonly cultivated by farmers in the relatively flat and fertile soils tend to be replaced by rubber or palm oil because of those mentioned reasons. The continuous trends of active expansion of plantation crops such as rubber and palm oil to the area where annual crops used to grow threaten the production of food crops locally and nationally in the long run. The foods availability for the community in acid upland soil was constrained by the rapid conversion of fertile land into rubber plantations, so that the utilization of acid upland soil for food crops among immature rubber plantation was highly recommended. Moreover, the time lag between planting and tapping for latex poses major problems to smallholder farmers as no income can be generated from the rubber during this period, which lasts anywhere between 4 to 5 years. One solution is to intercrop the young rubber plants with annual crops or cash crops which can be harvested 3 to 4 months to not only provide direct cash to the farmer before the rubber get mature but also to improve soil productivity. Previous studies indicated that

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intercropping food crops with young rubber plants increased farmers' income, soil organic matter, soil fertility both physically and chemically, better growth of rubber trees (Langenberger, Cadisch, Martin, Min, & Waibel, 2017; Pansak, 2015; Tetteh et al., 2019; Xianhai, Mingdao, & Weifu, 2012), and promote vigorous growth of rubber, thereby reducing the length of the immature period (Tetteh et al., 2019). Rodrigo, Stirling, Silva, & Pathirana (2005) and Rodrigo, Stirling, Naranpanawa, & Herath (2001) also reported that the productivity of land and income of smallholder rubber farmers increased through the cultivation of land space between the young rubber trees by seasonal cash crops such as soybean and banana.

The acid upland soil is categorized as infertile soil, the nutrients content of N, P_2O_5, K_2O, cation exchange capacity (CEC) and C-organic are low (Cornelissen et al., 2018; Martinsen et al., 2015). High soil acidity (low pH) causes high aluminium content in the soil and high soil P fixation (Ch'ng, Ahmed, Majid, & Jalloh, 2017; Hale et al., 2013). This situation results in the lack of P nutrient availability for optimal growth and development of cultivated crops (Mbene, SuhTening, Suh, Fomenky, & Che, 2017). In addition to nutrient deficiencies in the soil, soil physical properties in acid upland are also poor which include high bulk density (BD), and low total soil pore space, soil permeability, and soil water availability (Mulyani & Sarwani, 2013).

In order to obtain good soybean yield in the young rubber and soybean intercropped system grown on acid upland soil, the soil's physical and chemical properties need to be improved. Application of soil ameliorants such as manure, biochar, or dolomite or combination of them is expected to increase the availability of soil nutrients for plant growth as well as improve soil physical properties. Manure is an organic soil ameliorant derived from animal waste and feed residues, while biochar is a carbon-rich material (C) that is produced from the conversion of organic wastes through incomplete combustion processes or limited oxygen supply/pyrolysis (Nurida, Dariah, & Sutono, 2015; Obia, Mulder, Hale, Nurida, & Cornelissen, 2018). Manure improve soil physical and chemical properties by improving soil aggregation and adding macro and micronutrients to the soil, whereas dolomite is useful to increase soil pH so that increase nutrients availability for plant uptake. Previous studies showed that the application of manure and biochar as organic soil ameliorants to improve soil quality and crop yields in the acid upland soil is highly effective when they were applied in combination with NPK fertilizers (Nurida, Dariah, & Sutono, 2015; Zhu, Peng, Huang, Xie, & Holden, 2014). The use of manure or biochar alone less effective to increase crop yields because the nutrients contained in these organic soil ameliorants were relatively low (Agegnehu, Bass, Nelson, & Bird, 2016; Pandit et al., 2020).

The aim of this study was to quantify the effectiveness of some soil ameliorants applied in combination with a reduced dosage of NPK fertilizer on soil properties and soybean yield in a young rubber and soybean intercropped system on acid upland soil.

MATERIALS AND METHODS

The study was conducted at smallhoder rubber plantation in Sukadana Village, East Lampung Regency (05° 001' 07.0" S and 105 ° 31' 01.4" E) with the altitude of about 300 m above sea level, the mean annual rainfall was between 2,000-2,500 mm/year and the soil textures was sandy clay loam. The study was conducted during the rainy season (April-July) of 2013. The 2-year rubber plants were planted with a spacing of 3 m within and 4.5 m between rows. The spaces between row (inter-row) of rubber plants were cultivated with soybean.

The research used a split-plot design with three replications. The main plot was the dosage of NPK fertilizers, consisting of: 1) 100% dosage of NPK fertilizer based on the recommendation of Upland Soil Test Kit (USTK) and 2) 75% dosage of NPK fertilizer recommendation of USTK. The subplot was the source of soil ameliorants, consisting of: a) Dolomite with a dose of 2 t/ha, b) Manure with a dose of 2 t/ha, c) Manure with dose of 2 t/ha + Rhizobium, d) Biochar SP50 with a dose of 2.5 t/ha and e) Organic fertilizer plus with a dose of 2 t/ha. Biochar SP50 is a soil ameliorant formula consisted of rice husk biochar and manure with a ratio of 1:1, while organic fertilizer plus is organic manure derived from animal waste (cows and chickens) and baglog (mushroom media waste). Before the soil ameliorants were applied, laboratory analyses were conducted to determine the quality of soil ameliorants used. The parameters to be measured were: (1) pH H_2O, C-organic (ashing), N-total (Kjeldahl), P_2O_5, K_2O, CaO and MgO (wet ashing with HNO_3 and $HClO_4$). The results of the chemical analysis of ameliorants are listed in Table 1.

The plot size was 11 m x 4.2 m with the soybean (*Glycine max*) variety used was Tanggamus. Soybean was planted in April 2013 with plant spacing of 15 cm x 30 cm, 2 plants per hole, and harvested in July 2013. The recommended fertilizer dose for soybean is based on USTK, they were 100 kg Urea/ha, 200 kg SP36/ha, and 100 kg KCl/ha.

Dolomite, manure, biochar SP50, and organic fertilizer plus were spread evenly on each plot according to the treatment before the soybean was planted, mixed evenly with soil at a depth of 15-20 cm using a hoe, then incubated for 7 days. Rhizobium bacteria was used as a seed treatment by mixing with soybean seeds with a ratio of 1 pack of Rhizobium (100 g) with 2 kg of soybean seeds. All doses of urea, SP36 and KCl fertilizers were applied at planting time at a distance of 5 cm from the seeds, then covered with soil to avoid direct contact between the soybean seed and the fertilizer applied. Irrigation was conducted by flushing the water using a tool of “gembor” while weeding and controlling of the pests and diseases organisms were conducted as necessary.

Before the treatment applied, 10 sub composite soil samples were taken from each replication, mixed evenly in a plastic bucket, then taken about 1 kg for soil chemical analysis in the laboratory. Soil samples taken for soil chemical analysis at harvest time were 6 subs composite soil samples from each treatment, evenly mixed in plastic bucket, and then taken about 1 kg for soil chemical analysis in the Laboratory. The soil chemical properties parameters analyzed were pH (H_2O and KCl), C-organic (Walkley and Black), N-total (Kjeldahl), K HCl 25%, cation exchange capacity (CEC) and exchangeable Al (NH4OAc 1N pH 7). Soil physical properties analyzed before and after the study were BD (bulk density) and porosity (gravimetry) consisting of total soil pores space (TSP), fast drainage pores (FDP), and available water pores (AWP) using undisturbed soil samples.

The soybean growth and productivity parameters observed were the plant height and yield. Plant height was measured from the soil surface to the leaf tip every week since the soybean crop was 2 weeks old after planting (WAP) until the time of harvesting (8 WAP). The dry grain yield of soybean with a moisture content of about 19% was weighed from each treatment.

The data were analyzed using the SAS System for Linear Models. The treatment showed a significant effect followed by Duncan Multiple Range Test (DMRT) analysis to determine the differences between treatments.

RESULTS AND DISCUSSION

Soil Chemical Characteristics

Table 2 showed that the soil has a low fertility level as indicated by the low to very low of N and K nutrients contained in the soil, very low soil cation exchange capacity (CEC;4.65 cmol(+)/kg), high exchangeable Al content (2.02 cmol(+)/kg) and very acidic soil (pH 3.52). Improvement of soil chemical properties in acid upland soil for soybean was necessary to provide optimal nutrients for crops uptake.

The use of NPK fertilizer at a dose of 75% and 100% of the recommended dose of USTK showed no significant effect on soil chemical properties after the soybean harvested. The reduction of 25% of NPK dose did not affect soil chemical properties when it was applied not in combination with soil ameliorants.

Table 1. Chemical chracteristics of soil ameliorants used on the research

Soil Ameliorants Formula	pH H_2O	C	N	P_2O_5	K_2O	CaO	MgO
		----------- % ---------					
Dolomite, 2 t/ha	9.1	0.39 (7.80)	0.51 (10.20)	1.28 (11.18)	23.00 (3.49)	33.91 (484.43)	0.21 (276.00)
Manure, 2 t/ha	7.8	28.52 (570.40)	1.00 (20.00)	0.69 (6.03)	1.66 (27.55)	1.75 (25.00)	0.60 (7.20)
Biochar SP50, 2.5 t/ha	7.1	32.07 (801.75)	1.73 (43.25)	1.14 (12.44)	1.54 (31.95)	1.89 (33.75)	0.68 (10.20)
Organic plus, 2 t/ha	7.1	22.2 (555.00)	2.09 (52.25)	2.50 (27.29)	1.32 (33.00)	2.48 (62.00)	0.26 (6.50)

Remarks: The number in brackets was the number of elements applied in kg/ha in each plot

Table 2. Soil chemical characteristics before planting and after harvesting of soybean cultivated under young rubber plantation in Sukadana Village, East Lampung, 2013

Treatment	Soil Chemical Characteristics					
	pH H_2O	C-organic	N-organic	K-total	CEC	Exch. Al
		----- % -----		mg/100g	--cmol(+)/kg--	
Before planting	3.52	1.06	0.13	6.00	4.65	2.02
After harvesting						
Main Plot						
100% NPK	3.69 a	1.12 a	0.11 a	2.76 a	4.82 a	1.74 a
75% NPK	3.72 a	1.06 a	0.10 a	2.29 a	4.54 a	1.62 a
Sub Plot						
Dolomite, 2 t/ha	3.86 a	1.09 a	0.10 a	1.79 b	4.41 a	1.51 b
Manure, 2 t/ha	3.69 a	1.12 a	0.10 a	2.91 a	4.68 a	1.77 a
Manure, 2 t/ha + Rhizobium	3.59 a	1.10 a	0.11 a	2.81 a	4.66 a	1.86 a
Biochar SP50, 2.5 t/ha	3.69 a	1.08 a	0.97 a	2.78 a	4.83 a	1.60 b
Organic Fert. Plus, 2 t/ha	3.82 a	1.11 a	0.10 a	3.42 a	4.84 a	1.65 a

Remarks: The numbers followed by the same letter in the same columns are not significantly different based on the DMRT test at 0.05 level; CEC = Cation exchange capacity, Al = alluminum

There was no interaction between NPK fertilization with soil ameliorants to soil chemical properties. The combined application of soil ameliorants with 75% dose of NPK fertilizer did not deteriorate soil chemical properties. There was a decrease in aluminum content in the soil (13.86-19.80%) compared with the initial soil exchangeable Al before planting.

The use of soil ameliorants did not significantly affect soil pH, soil organic C, soil organic N, and soil CEC after the soybean harvest, but there were significant effects on the total of K and exchangeable Al content in the soil. Application of 2 t/ha of dolomite gave the lowest K-total content in the soil compared with the other soil ameliorants tested. These findings illustrated that the availability of K and it enrichment processes in the soil was strongly influenced by the application of soil ameliorants. The application of manure, biochar and organic fertilizer plus contributed to the potassium content in the soil (2.81-3.42 mg/100 g or 27.55-33.00 kg/ha), the highest was given by organic fertilizer plus, while the dolomite application only contributed as much as 1.79 mg/100 g or 3.49 kg/ha (Table 2).

The positive effect of soil ameliorants application on soil chemical properties was the decrease of soil exchangeable Al in the soil, which reduced the toxic effect of aluminum to the soybean crop. The effectiveness of Biochar SP50 to lower the exchangeable Al content in the soil was as effective as dolomite at a dose of 2 t/ha, even though their effectiveness was still under the effect of manure and organic fertilizer plus. The lowest decrease in aluminum content was found in dolomite and Biochar SP50 applications that were reached 25.3% and 20.8%, respectively. Dolomite showed as the most effective soil ameliorant to increase soil pH, therefore can neutralize the negative effect of aluminum on the crops better than other tested ameliorants. A study conducted by Sudaryono, Wijanarko, & Suyamto (2011) found that the application of 500 kg/ha of lime combined with 1 t/ha of manure on acid upland soil in Rumbia, Center of Lampung reduced the toxicity of aluminum up to 50%. The ability to reduce Al toxicity by application of 2.5 t/ha of Biochar SP50 in this study has not been effective yet as compared with dolomite, however, studies indicated that the residual effect of biochar can be found in the succeeding growing seasons (Hale et al., 2020; Nurida, 2014).

Soil Physical Properties

Soil texture at the research site was sandy clay loam with the sand, silt and clay contain were 57%, 13%, and 30%, respectively. Table 3 indicated that the soil bulk density (BD) before planting was high (1.41 g/cm^3) and low (41.2% volume) total soil porosity (TSP). The high sand fraction content in the soils (57%) and the high fast drainage pores (17.40% volume) caused the water to easily lose from the rooting zones as reflected on the low values of available water pores (Table 3). On such soil physical properties, the application of soil ameliorant is very important to support optimum growth and development of crops.

The result of the statistical analysis indicated that there was no interaction between the use of inorganic fertilizers/NPK with soil ameliorants to soil physical properties. NPK fertilizer with 75% and 100% dosages of USTK recommendation had no significant effect on all parameters of soil physical properties. Similar results reported by Soelaeman & Haryati (2012) who found that application of SP36 and rock phosphate fertilizers on Ultisol in East Lampung had an insignificant effect on soil BD and Lin et al. (2019) showed that the application of chemical fertilizers will not show a direct effect on soil physical properties. Agus, Yustika, & Haryati (2006) and Min, Islam, Vough, & Weil (2003) suggested that soil BD has a close relationship with root penetration into the soil, soil drainage, and aeration, while Islam & Weil (2000) suggested that soil BD has a close relationship with soil porosity.

Manure application as much as 2 t/ha significantly improved soil physical properties as shown on lower BD and higher of TSP as compared with other soil ameliorants tested. Application of manure has increased soil organic matter content (Table 2) which in turn lowers the BD. High organic matter content and lower bulk density will have a positive impact on soil porosity and aeration to create a favorable medium for plant growth and microorganism's development in the soil. The effects of Biochar SP50, Manure 2 t/ha, and Manure 2 t/ha + Rhizobium on available water capacity (AWC) were not statistically different in which Biochar SP50 gave the highest (15.25% vol.) AWC followed by Manure (12.95% vol.) and Manure 2 t/ha + Rhizobium (9.85% vol.). Dolomite and Organic Fertilizer Plus applications gave significantly lower AWC as compared with the other three soil ameliorants tested. Previous studies reported that application of biochar increased soil AWC (Nurida, Dariah, & Sutono, 2015; Saletnik, Zagula, Bajcar, Czernicka, & Puchalski, 2018) and increased soil water retention (Novak et al., 2009; Nurida & Jubaedah, 2019; Sukartono & Utomo, 2012; Yu, Raichle, & Sink, 2013). The high formation of micro and mesopores in biochar is responsible for the high capacity of biochar to retain water (Hardie, Clothier, Bound, Oliver, & Close, 2014; Obia, Mulder, Martinsen, Cornelissen, & Børresen, 2016; Shaaban, Se, Mitan, & Dimin, 2013) which is very useful to support the growth and development of soybean crops.

Table 3. Soil physical properties before planting and after harvest of soybean planted among young rubber plamtation in Sukadana Village, East Lampung, 2013

Treatment	Soil Physical Properties			
	BD (g/cm^3)	**TSP (% vol)**	**FDP (% vol)**	**WAC (% vol)**
Before planting	1.41	41.2	17.4	7.0
After harvesting				
Main plot				
100% NPK USTK	1.39 a	41.75 a	15.20 a	11.06 a
75% NPK USTK	1.37 a	43.81 a	16.61 a	11.00 a
Sub Plot				
Dolomite, 2 t/ha	1.36 a	43.3 ab	15.82 a	8.98 b
Manure, 2 t/ha	1.28 b	46.57 a	16.83 a	12.95 a
Manure, 2 t/ha + Rhizobium	1.42 a	39.85 c	13.87a	9.85 a
Biochar SP50, 2.5 t/ha	1.43 a	40.85 bc	13.95 a	15.25 a
Organic Fert. Plus, 2 t/ha	1.40 a	43.68 ab	17.40 a	8.15 b

Remarks: The numbers followed by the same letter in the same columns are not significantly difference based on the DMRT test at 0.05 level; BD = Bulk density, TSP = Total soil pores space, FDP = Fast drainage pores, WAP = Water available pores.

The Growth of Soybean

Statistical analysis showed that there was no interaction between NPK fertilization dose and soil ameliorants application to soybean plant height (Table 4). Reduction of 25% of NPK fertilizer dosage (75 kg Urea/ha, 150 kg SP36/ha and 75 kg KCl/ha) from recommendation by USTK (100 kg Urea/ha, 200 kg SP36/ha and 100 kg KCl/ha) did not affect soybean growth. This finding indicates that the amount of fertilizer applied to soybean intercropped with young rubber plants can be reduced up to 25% from the recommendation without affecting soybean growth.

The effect of soil ameliorants on soybean plant height at 2 and 3 weeks after planting (WAP) varied according to the type of soil ameliorant used. Application of organic fertilizer plus at a dose of 2 t/ha and manure with a dose of 2 t/ha gave the highest plant height, but at 7-8 WAP, all soil ameliorants tested showed not significantly different on plant height. These conditions indicated that the five sources of soil ameliorant tested gave a similar effect on soybean growth in acid upland soil.

Harvested Grains, Residues and Harvest Index

The two dosages of fertilizer applied did not give significantly different soybean yield and weight of crop residues (Table 5). There was also no interaction between the application of NPK fertilizer and soil ameliorants on soybean yield and harvested residues. In contrast, the source of soil ameliorants gave significantly different effect on soybean yield. Dolomite application at a rate of 2 t/ha gave the highest grain yield of 1.52 t/ha and the ratio of grain to residues which is significantly different with manure application, but not significantly different with the use of manure at a dose of 2 t/ha + Rhizobium (1.39 t/ha), Biochar SP50 (1.37 t/ha) and organic fertilizer plus (1.36 t/ha). The application of manure with a dose of 2 t/ha without accompanying with Rhizobium gave the lowest dry grain yield of 1.28 t/ha. Therefore, the management of acid upland soil for soybean should focus on reducing soil acidity.

Grain yield is considered to have more economic value compared with the harvested residues. However, the soybean crop residues is an important source of organic matter when returned back to the soil will improve soil productivity (Barus, 2012). It was found that the weight of soybean grain yield was about 47% out of the weight of harvested residues. The soybean harvested residues consist of roots, stems and leaves in which each weight can be estimated to be around 16%, 200% and 130% of the grain weight produced, respectively (Maswar & Soelaeman, 2016), that was indicating the potential of soybean biomass as a source of organic materials to increase carbon content in the soil (Kätterer et al., 2019).

Intercropping soybean with young rubber plantation will give a positive impact on the growth of rubber as the main crop. Sahuri (2017) reported that the growth of rubber intercropped with seasonal crops is better than rubber monoculture. The intensive maintenance of intercropped crops from weed disturbance and the application of fertilizer to the seasonal crops benefited the rubber plant as the main crop.

Table 4. Plant heigh of soybean intercropped with young rubber smallholder plantation in Sukadana Village, East Lampung, 2013

Treatment	Plant height (cm)						
	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
100% NPK USTK	10.31 a	13.51 a	20.71 a	27.19 a	42.36 a	52.87 a	56.17 a
75% NPK USTK	9.79 a	13.72 a	20.41 a	27.69 a	42.96 a	52.92 a	52.17 a
Dolomite, 2 t/ha	9.70 bc	13.13 ab	21.33 a	28.77 a	46.80 a	55.57 a	56.27 a
Manure, 2 t/ha	10.33 ab	14.60 a	21.90 a	28.93 a	44.70 ab	57.07 a	56.97 a
Manure, 2 t/ha + Rhizobium	9.97 bc	13.20 ab	19.03 a	24.83 a	38.07 b	47.20 a	50.23 a
Biochar SP50, 2.5 t/ha	9.33 c	12.83 b	19.57 a	26.10 a	39.27 ab	49.43 a	52.53 a
Organic Fert. Plus, 2 t/ha	10.90 a	14.30 ab	20.97 a	28.57 a	44.47 ab	55.20 a	54.87 a

Remarks: The numbers followed by the same letter in the same columns are not significantly difference based on the DMRT test at 0.05 level; WAP = weeks after planting.

Table 5. Grain yield, harvest residues, total biomass and harvest index of soybean in intercropping with young rubber plantation in Sukadana Village, East Lampung, 2013

Treatment	Dry Grain (t/ha)	Dry harvested Residues (t/ha)	Grain-Harvest Residues Ratio (%)	Total Biomass (t/ha)	Harvest Index
100% NPK USTK	1.39 a	2.94 a	47.42 a	4.32 a	0.32 a
75% NPK USTK	1.37 a	2.90 a	47.46 a	4.27 a	0.32 a
Lime/Dolomite, 2 t/ha	1.52 a	3.06 a	49.63 a	4.30 a	0.33 a
Manure, 2 t/ha	1.28 b	2.86 a	44.88 b	4.14 a	0.31 a
Manure, 2 t/ha + Rhizobium	1.39 ab	2.83 a	49.37 ab	4.22 a	0.33 a
BiocharSP50, 2.5 t/ha	1.37 ab	2.93 a	46.54 ab	4.30 a	0.32 a
Organic Fert. Plus, 2 t/ha	1.36 ab	2.91 a	46.78 ab	4.27 a	0.32 a

Remarks: The numbers followed by the same letter in the same columns are not significantly difference based on the DMRT test at 0.05 level.

In addition, the intercropping systems will speed up the rubber tapping time as the stem diameter has reached 45 cm measured at a height of 110 cm from the ground (Ferry, Pranowo, & Rusli, 2013).

CONCLUSION AND SUGGESTION

This study found that reducing the amount of NPK fertilizer by 25% from the USTK fertilizer recommendation gave no significant difference with 100% of the recommended dosage of fertilizers by USTK on soybean yield growing in a soybean-young rubber intercropped system. The application of dolomite at a dose of 2 t/ha and Biochar SP50 at a dose of 2 t/ha decreased an exchangeable aluminum up to 1.51 and 1.60 cmol(+)/kg which were equivalent to 25.3% and 20.8% of the initial soil aluminum level (2.02 cmol(+)/kg). Dolomite and Biochar SP50 were found to be the most effective soil ameliorants in reducing soil acidity; therefore, it can be used to neutralize the aluminum content in the soil. So, Biochar SP 50 could be an alternative ameliorant beside dolomite.

The application of Biochar SP50 gave the highest available water capacity/AWC (15.25% vol.), that is an important function to provide sufficient moisture for soybean growth in acid upland. The application of soil ameliorants such as manures + Rhizobium, Biochar SP50 and organic fertilizer plus had a result of no significant difference for dry grain and grain-harvest residues ratio of soybean. Compared to dolomite application. Therefore those ameliorants could be applied as alternatives instead of dolomite

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