The Phosphorus AvailabilityDue to Various Ameliorants in a New Rice Field of Barito Kuala Regency South Kalimantan

ABSTRACT

Aims: To optimize the dose of three ameliorants(biochar, lime, and compost) and their interactions on the availability of macronutrient P

Study design: This research was a laboratory incubation study using soil samples from the newly opened rice fields.

Place and Duration of Study: Paddy field of Ray 7, Balandean Village, Alalak District, Barito Kuala Regency, South Kalimantan Province from May to November 2021.

Methodology: The study used factorial design with the treatments of 1) Biochar, with levels of 0, 10, and 20 t ha^{-1}, 2) Lime, with levels of 0, 2, and 4 t ha^{-1}, 3) Compost with levels of 0, 5, and 10 t $ha^{-1.}$ All were arranged in Completely Randomized Design with three replications. The experimental units were 300 g of soil sample in 81 of 10 cm plastic pots. They immersed up to 2 cm water and incubated to imitated field conditions for three months and then analyzed for the parameters.

Results: Biochar and lime increased available-P quadratically and linearly following orthogonal polynomial analyses. Their interaction was highly significant in increasing available-P. The doses for both could be increased for the maximum availability of P.

Conclusion: Biochar increased P availability with the tendency of increasing beyond the dose of the treatment. The main treatment of compost was not as good as biochar. However, when applied together with biochar and lime, compost affected the solubility of P. However, to increase P availability, the combination of the ameliorants showed a good synergism.

Keywords:Ameliorant, P availability, acid sulfate soil, C, Al, and Fe metals.

1. INTRODUCTION

Acid sulfate soils are generally found in tidal swamp land. These soils are characterized by high soil acidity or low pH values. This is one of the factors that cause acid sulfate fields to be infertile due to the low content of available nutrients and high levels of elements that are toxic to plants. Rice plants planted on it are often poisoned by Fe^{2+}, organic acids, and H_2S (1,2).

Making acid sulfate soils for rice fields is a wise choice because it can prevent the soil from oxidizing which results in soil acidification(3,4). Sulfuric acid in soils, sediments, or substrates occurs naturally under waterlogged conditions(5,6). If the sulfide mineral as a sulfuric acid former has a very large potential, it will have a very bad impact(5,7). Acid sulfate soils develop due to the drainage of parent material rich in pyrite (FeS_2) (8,9), which can be improved by washing to reduce the concentration of toxic compounds such as Fe^{2+}, SO_4^{2-}, H^+, and soil acidity(10,11). Rice productivity in this research location is very low.

Even the first-time rice is planted, all the plants will die. Likewise in the second and third planting seasons. Farmers become lazy or even afraid to plant their fields again(12,13). In addition to water management, soil ameliorants which are often used to improve the fertility of dry soil acid soils can also be used to overcome acid sulfate acid soils. Among the familiar ameliorants are biochar, lime, and compost.

Biochar can reduce soil density by increasing porosity, lowering exchangeable Al and Fe content, and increasing available water content. Biochar also increases the concentration of organic-C, available-P, CEC, exchangeable-K, and exchangeable-Ca(14). Lime application is very effective in improving soil physical properties because of its ability, to reduce useless ions, and increase the availability of Ca, Mg, and P, as well as increasing microbial activity(15). Meanwhile, composting will improve the physical, chemical, and biological properties of the soil(16,17).

The use of the three ameliorants as a single factor has been widely used for dry land acid soils. However, the effectiveness of giving the three ameliorants, either as a single treatment or in combination, in newly opened tidal paddy fields is not yet widely known. Therefore, it is important to do this research to find out the most optimal dose and the interaction of the three so that it can be used by new rice farmers in the research location. Thus, newly opened paddy fields in tidal areas can directly produce rice.

2. MATERIAL AND METHODS

This research was a laboratory incubation study using soil samples from the newly opened rice fields of Ray 7, Balandean Village, Alalak District, Barito Kuala Regency, South Kalimantan Province. The implementation time is from May to November 2021. Incubation and soil analysis are carried out at the Soil Chemistry Laboratory, Soil Department, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru. The ameliorants used were rice husk charcoal, lime, and compost. All materials were purchased from an available farmers' department store.

The study used a Completely Randomized Design (CRD) with three factors and three replications based on the formula (t-1) (r-1) 15, so there were 3 x 3 x 3 = 81 experimental units (experimental units) in the form of a small plastic pot (⦸ 10 cm) with a soil weight of 300 g.

The ameliorant treatment was 1) Biochar, with levels of 0, 10, and 20 t ha^{-1}. The basis for the dose was according to(18,19), as much as 6 and 12 t ha^{-1}, respectively; 2) Lime, with levels of 0, 2, and 4 t ha^{-1}. A dose of 1 t ha^{-1} was according to(20).Meanwhile, a dose of 2 t ha^{-1} was according to(21–23)for acid sulfate soils; 3) Compost with levels of 0, 5, and 10 t ha^{-1}. A dose of 3-6 t ha^{-1} was recommended by(24)for acid soils.

Soil samples were air-dried for two weeks. Then ground and sieved with a 2 mm sieve. Each pot contained as much as 300 g of sample soil minus the weight of each treatment, so that the final weight after treatment remains uniform. The research pot was immersed in a water level of 2 cm and incubated for three months to simulate the actual field conditions. The soil the air-dried.

Randomization of pot numbers was conducted using random numbers available on the internet (random number generator). The data obtained were analyzed statistically using SPSS (Statistical Package for Social Sciences) 25.0 and SAS (Statistical Analysis System) University Edition software. The analysis carried out was Bartlett's homogeneity test, analysis of variance = ANOVA, and DMRT (Duncan's Multiple Range Test) on the main treatment and its interactions. To determine the nature of the curve (linear, quadratic, or cubic) resulting from the treatment, an orthogonal polynomial contrast test was carried out.

3. RESULTS AND DISCUSSION

Soil chemical properties from Ray 7 Balandean Village, Alalak District, Barito Kuala Regency are presented in Table 1.Based on the homogeneity test of variance all data were homogeneous. Meanwhile, the ANOVA of several parameters was summarized in Table 2.

Table 1. Soil chemical properties from Ray 7 Balandean Village, Alalak District, Barito Kuala Regency

No	Chemical Properties	Value	Criteria
1	pH (H_2O; 1:2,5)	3.58	Highly acid
2	CEC (me 100 g^{-1})	4.66	Very low
3	Total-C (%)		
	Biochar	11.30	Very high
	Compost	15.90	Very high
4	Organic-C (Walkley-Black, %)		
	Biochar	19.49	Very high
	Compost	27.43	Very high
5	Total-N (Kjeldahl, %)	0.24	
6	P_2O_5 (Bray, ppm)	0.08	Very low
7	Available-K (KCl, me 100 g^{-1})	0.01	Very low

Table 2. Sources of variance for all parameters

Source of Variance	Parameter					
	Org-C	Soil pH	Bray-P	Soluble		
				Fe	Al	H
Biochar	0.794	0.488	0.000**	0.440	0.143	0.005**
Lime	0.948	0.000**	0.001**	0.188	0.005**	0.000**
Compost	0.508	0.698	0.280	0.292	0.009**	0.002**
Biochar * Lime	0.030**	0.750	0.061	0.271	0.000**	0.000**
Biochar * Compost	0.686	0.270	0.338	0.935	0.001**	0.000**
Lime * Compost	0.980	0.169	0.018*	0.973	0.498	0.000**
Biochar * Lime * Compost	0.990	0.902	0.005**	0.923	0.041**	0.001**
R^2	0.248	0.451	0.651	0.243	0.703	0.833

Organic-C.

Anova recapitulation (Table 2) showed that the combination of biochar-lime showed a significant difference in organic-C concentration. When analyzed further, DMRT presented in the combination treatment can be seen in Table 3.

Table 3. The effect of biochar-lime interaction on organic-C

Biochar (t ha^{-1})	Lime (t ha^{-1})	N	Mean (%)
0	0	9	8.3867a
	2	9	8.3022a
	4	9	11.2544b
6	0	9	9.0011ab
	2	9	9.1256ab
	4	9	8.7600ab
12	0	9	9.3767ab
	2	9	9.7489ab
	4	9	7.4367a

Soil pH.

Anova recapitulation (Table 2) showed that only lime showed a significant difference in soil pH. When analyzed further, the DMRT result can be seen in Table 4. The nature of the increase in pH was a quadratic trend according to the orthogonal polynomial contrast analysis. The trend line can be seen in Figure 1. Looking at the trend line above, it can be ascertained that lime application to increase the pH value has reached the saturation value at doses above 2 t ha^{-1}. In other words, a dose of 3 t ha^{-1} was probably the highest recommendation for newly opened acid sulfate fields. This was in accordance withauthors(21–23).

Table 4. The effect of lime on soil pH

Lime (t ha^{-1})	N	pH (unit)
0	27	3.91 a
2	27	4.12 b
4	27	4.14 b

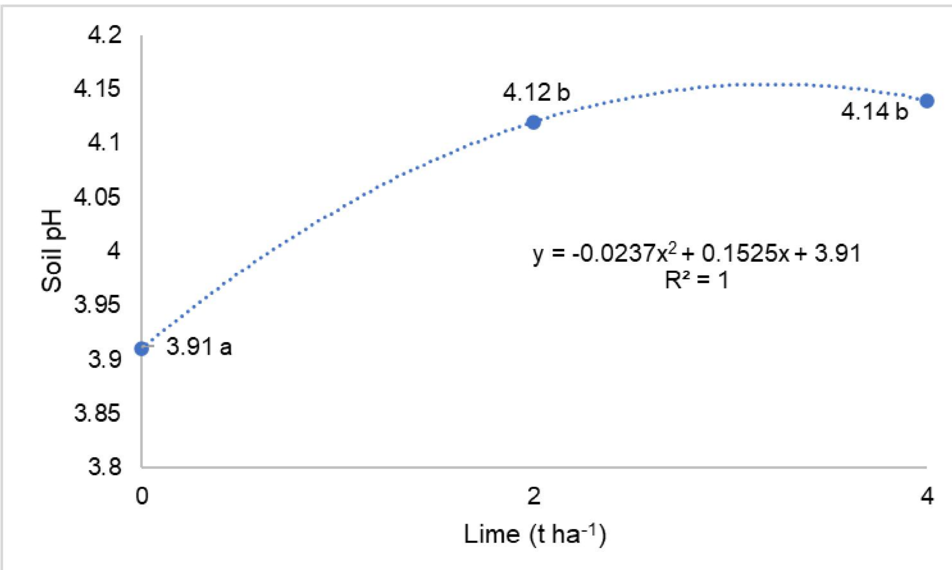

Figure 1. A quadratic trend from orthogonal polynomial contrast for lime treatment to increase soil pH value. Means followed by the same letters are not significantly different at DMRT 5%.

Bray-P.

Anova recapitulation (Table 2) showed that only the main factor of biochar and lime showed significant differences in available P. When viewed with DMRT values in the treatment of biochar and lime, the effects are can be seen in Table 5 and Table 6. When analyzed with orthogonal polynomial contrast the effect of biochar and lime can be seen in Figure 2 and Figure 3. As there was an interaction between lime*compost and biochar*lime*compost on available-P the DMRT on the interaction is presented in Table 7 and Table 8. The interesting fact (Figure 2 and Figure 3) was that to improve P availability, it turned out that the treatment of biochar and lime, showed the possibility of increasing the dose. According to(19) the recommendation for biochar on acid sulfate land is 6-12 tons ha^{-1}. The fact showed that in this study the administration of biochar with this dose still showed an increase in P availability. There was no visible downward trend as previously thought. Likewise with the lime application. Dosage doubled from the recommendation ofseveral authors(21–23) still showed a linear increase. It can be concluded that twice the recommended lime dose can still be used to increase the solubility of P.The effect of ameliorants, especially biochar, on P availability was also in line with others (13,25–27)

Table 5. The effect of biochar on available-P

Biochar ($t\ ha^{-1}$)	N	Bray-P (ppm)
1	27	0.4213 a
0	27	0.8949 b
2	27	0.9827 b

Table 6. The effect of lime on available-P

Lime ($t\ ha^{-1}$)	N	Bray-P (ppm)
0	27	0.5809 a
2	27	0.6855 a
4	27	1.0326 b

Table 7. Interaction effect between lime * compost on available-P

Lime ($t\ ha^{-1}$)	Compost ($t\ ha^{-1}$)	N	Mean (ppm)	
0	0	9	0.5926	a
	5	9	0.5362	a
	10	9	0.6138	a
2	0	9	0.8878	abc
	5	9	0.3849	a
	10	9	0.7838	abc
4	0	9	1.1341	bc
	5	9	1.2606	c
	10	9	0.7130	ab

Table 8. Interaction effect between biochar*lime*compost on available-P

Biochar ($t\ ha^{-1}$)	Lime ($t\ ha^{-1}$)	Compost ($t\ ha^{-1}$)		
		0	5	10
0	0	0.232^{a}	0.355^{ab}	0.947^{abcdef}
	2	1.580^{ef}	0.395^{ab}	0.707^{abcd}
	4	1.712^{f}	1.427^{def}	0.701^{abcd}
6	0	0.383^{ab}	0.359^{ab}	0.409^{ab}
	2	0.639^{abcd}	0.318^{a}	0.319^{a}
	4	0.379^{ab}	0.789^{abcde}	0.197^{a}
12	0	1.163^{bcdef}	0.895^{abcde}	0.486^{abc}
	2	0.445^{abc}	0.441^{abc}	1.326^{def}
	4	1.312^{def}	1.536^{ef}	1.241^{cdef}

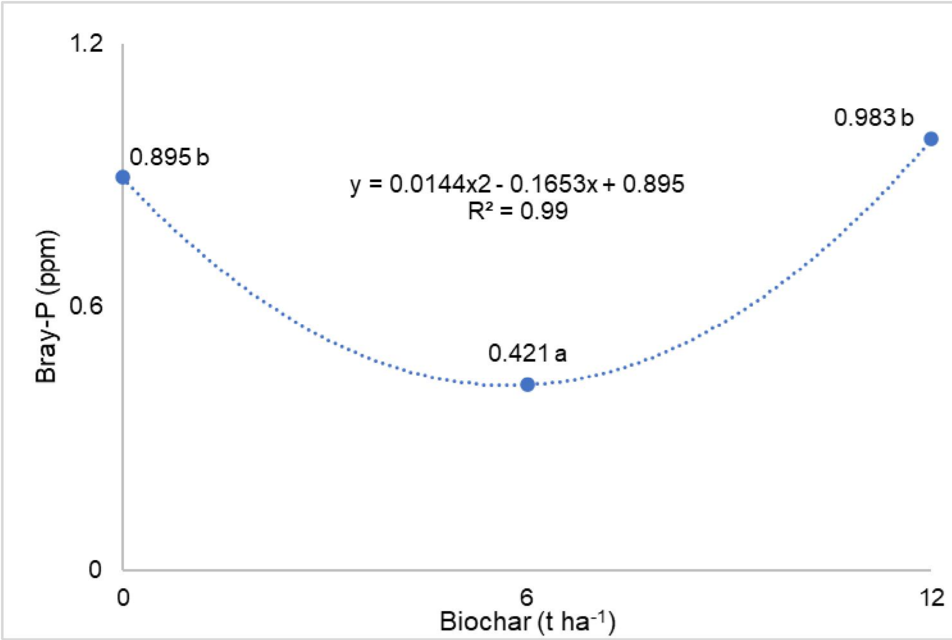

Figure 2. **A quadratic trend from orthogonal polynomial contrast for biochar treatment on available-P. Means followed by the same letters are not significantly different at DMRT 5%.**

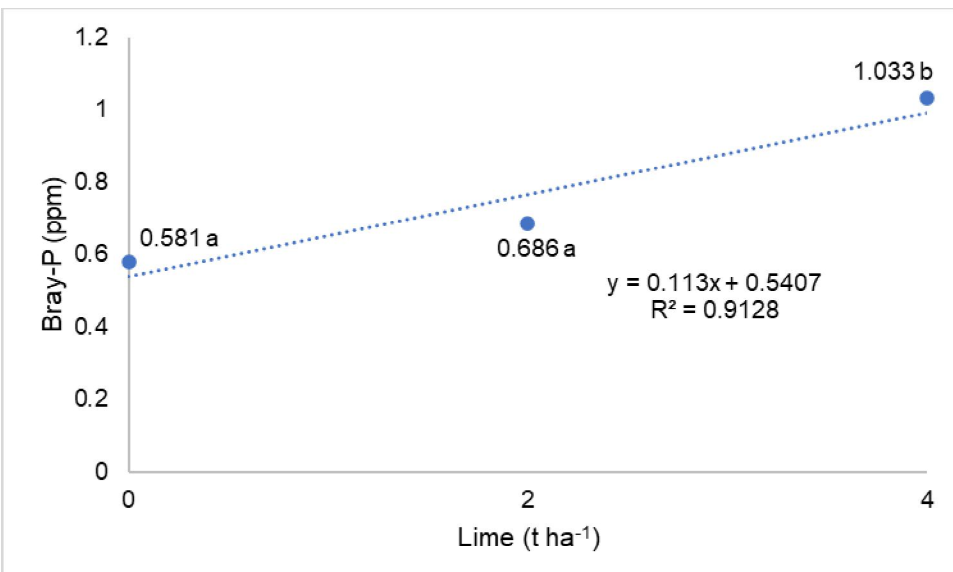

Figure 3. **A linear trend from orthogonal polynomial contrast for lime treatment on available-P. Means followed by the same letters are not significantly different at DMRT 5%.**

Soluble-Fe.

Anova recapitulation (Table 2) showed that none of the factors, either biochar, lime, and compost, or interaction between them influenced soluble Fe.

Exchangeable-Al.

Anova recapitulation (Table 2) showed that the main factor of lime and compost, the interaction of biochar*lime, and the interaction of biochar*compost had significant effects on exchangeable-Al. The effect of the main factor of lime and compost is presented inFigure 4 and Figure 5. Both showed a quadratic trend according to orthogonal polynomial contrast. Meanwhile, the interaction effects of biochar*lime, biochar*compost, and biochar*lime*compost are presented in Table 9-11.

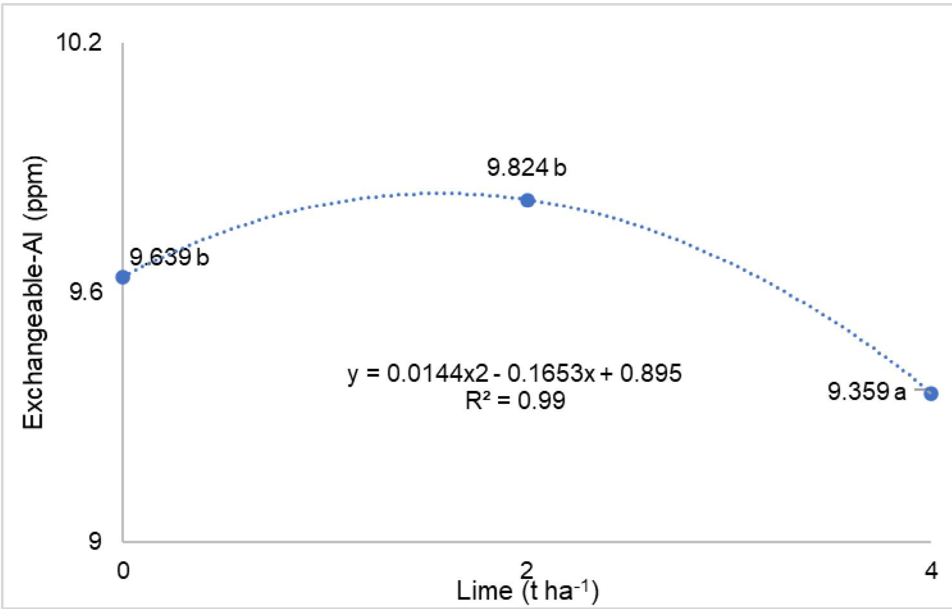

Figure 4. A quadratic trend from orthogonal polynomial contrast for lime treatment on exchangeable-P. Means followed by the same letters are not significantly different at DMRT 5%.

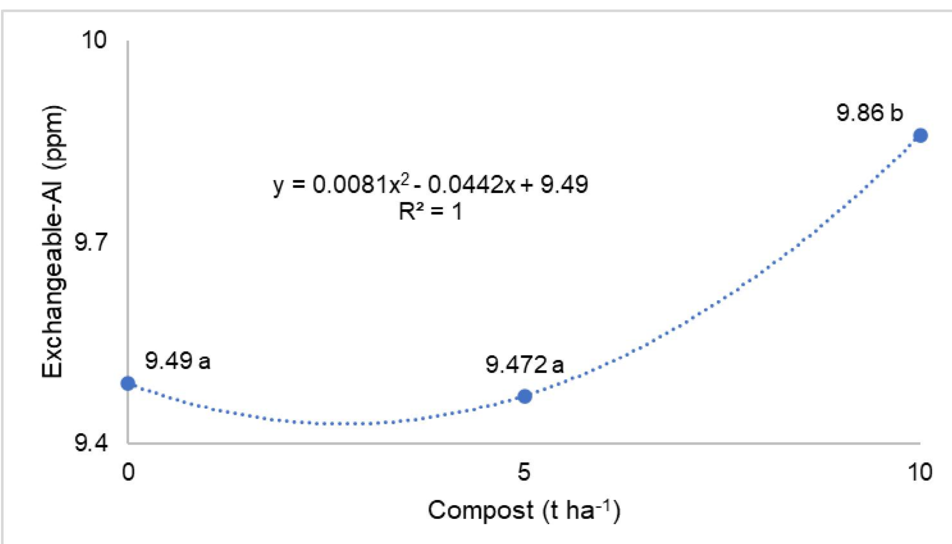

Figure 5. A quadratic trend from orthogonal polynomial contrast for compost treatment on exchangeable-P. Means followed by the same letters are not significantly different at DMRT 5%.

Table 9. **Interaction effect between biochar*lime on exchangeable-Al**

Biochar (t ha^{-1})	Lime (t ha^{-1})	N	Means (%)
0	0	9	9.241 b
	2	9	9.847 cd
	4	9	9.417 bc
6	0	9	9.474 bc
	2	9	9.702 bcd
	4	9	10.108 d
12	0	9	10.201 d
	2	9	9.924 cd
	4	9	8.552 a

Remark: Means followed by the same letters are not significantly different at DMRT 5%.

Table 10. **Interaction effect between biochar*compost on exchangeable-Al**

Biochar (t ha^{-1})	Compost (t ha^{-1})	N	Means (%)
0	0	9	9.231 a
	5	9	9.416 ab
	10	9	9.858 bc
6	0	9	9.330 ab
	5	9	9.654 ab
	10	9	10.300 c
12	0	9	9.909 bc
	5	9	9.347 ab
	10	9	9.422 ab

Remark: Means followed by the same letters are not significantly different at DMRT 5%.

Table 11. **Interaction effect between biochar*lime*compost on exchangeable-Al**

Biochar	Lime	Compost (t ha^{-1})		
(t ha^{-1})		0	5	10
0	0	9.223^{bcdef}	8.897^{abcd}	9.603^{abcde}
	2	$9.627^{cdefghi}$	10.057^{efghi}	9.857^{defghi}
	4	8.843^{abc}	9.293^{cdef}	10.113^{fghi}
6	0	9.203^{bcdef}	9.247^{bcdef}	9.973^{efghi}
	2	9.167^{abcdef}	9.347^{cdef}	10.593^{i}
	4	$9.620^{cdefghi}$	10.370^{ghi}	10.333^{ghi}
12	0	10.153^{fghi}	9.853^{defghi}	10.597^{i}
	2	10.480^{hi}	9.873^{defghi}	9.420^{cdefg}
	4	9.093^{abcde}	8.313^{ab}	8.250^{a}

Remark: Means followed by the same letters are not significantly different at DMRT 5%.

Factor affecting P solubility.

The relationship between Bray-P and other parameters did not show any significant difference, whether in the form of correlation (Table 12) or the following multiple regression: Bray-P = 0.478 + 0.049 organic-C + 0.358 pH + 0.732 soluble-Fe – 0.195 soluble-Al + 0,002 soluble-H (P = 0.118). This was the indication that independent variables were not really involved in the transformation of P.

Table 12. Pearson correlation between parameters

	Bray-P	Organic-C	pH	Soluble-Fe	Soluble-Al	Soluble-H
Bray-P	1.00	0.08	0.06	0.13	-0.21	-0.05
Organic-C	0.08	1.00	-0.17	-0.24*	0.16	-0.30**
pH	0.06	-0.17	1.00	-0.23*	-0.09	-0.06
Soluble-Fe	0.13	-0.24*	-0.23*	1.00	0.09	0.13
Soluble-Al	-0.21	0.16	-0.09	0.09	1.00	0.10
Soluble-H	-0.05	-0.30**	-0.06	0.13	0.10	1.00

4. CONCLUSION

The more biocharapplied the more available-P in the soil. Compost single treatment was not as good as biochar. However, when applied together with biochar and lime, affected the solubility of P. As an ameliorant, lime was sufficient to raise the soil pH, although it was still in the very acidic category. However, to increase the solubility of P, the combination of the ameliorant showed a good synergism.

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