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Calibration of Soil Phosphorus Test for Upland Rice Grown on Typic Kandiudox, Way Pangubuan, Lampung

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ABSTRACT

Calibration of soil P test was conducted for Typic Kandiudox derived from Way Pangubuan, Lampung. A field experiment was carried out in dry and wet seasons. The dry season experiment in 2013 was designed by applying various soil P status: 0 X (very low), ¼ X (low), ½ X (moderate), ¾ X (high), dan X (very high), in which X was the amount of P required to obtain P concentration of 0.2 µg P L^{-1} in soil solution. The wet season experiment was conducted in 2013/2014 with the P treatments of P fertilizer at 0, 8, 16, 33, dan 66 kg P ha^{-1} in the form of SP-36 with 3 replicates. The results showed that Colwell, Morgan-Wolf, and Olsen extraction methods are not suitable to determine P requirement for upland rice grown on Typic Kandiudox. Extraction methods of Bray-1, Truog, Mehlich, HCl 25%, dan Bray-2 are appropriate to estimate P fertilizer requirement for upland rice. Among all of these extractions, Bray-1 and Truog are the most appropriate. The levels of soil P availability extracted using Bray-1 are classified into low (< 12.0 ppm P_2O_5), moderate (12.0-26.0 ppm P_2O_5), and high status (> 26.0 ppm P_2O_5), whereas soil P availability status extracted using Truog consisted of low (< 9.0 ppm P_2O_5), moderate (9.0-15.5 ppm P_2O_5), and high (> 15.5 ppm P_2O_5). Phosphorus fertilizer recommendations for upland rice grown on Typic Kandiudox with low, moderate, and high soil P availability status are 33, 8, and 0-4 kg P ha^{-1}, respectively, which equal to 200, 50, and 0-25 kg SP-36 ha^{-1}, respectively.

Keywords: Phosphorus fertilizer, Phosphorus calibrations, status, Typic Kandiudox, upland rice

ABSTRAK

Kalibrasi uji hara P tanah telah dilaksanakan untuk tanaman padi gogo pada Typic Kandiudox di Way Pangubuan, Lampung. Percobaan lapang telah dilakukan pada musim kering dan musim hujan. Percobaan lapang di musim kering pada tahun 2013 dirancang dengan mengaplikasikan beberapa status P tanah:) X (sangat rendah), ¼ X (rendah), ½ X (sedang), ¾ X (tinggi), dan X (sangat tinggi), dimana X adalah jumlah P tersedia untuk mencapai kosentrasi P dalam larutan tanah sebesar 0,2 µg P L^{-1}. Percobaan pada musim hujan telah dilaksanakan pada tahun 2013/2014 dengan perlakuan beberapa takaran Pupuk P yaitu 0, 8, 16, 33, dan 66 kg P ha^{-1} dalam bentuk SP-36 dengan 3 ulangan. Hasil penelitian menunjukkan bahwa pengkstrak Colwell, Morgan-Wolf, dan Olsen tidak sesuai untuk menetapkan kebutuhan P tanah bagi tanaman padi gogo di tanah Typic Kandiudox. Pengekstrak Bray-1, Truog, Mehlich, HCl 25%, dan Bray-2 adalah pengengekstrak yang lebih sesuai untuk menduga kebutuhan pupuk P untuk tanaman padi gogo. Dari semua pengesktrak yang dicobakan, Bray-1 dan Truog adalah pengekstrak terbaik. Tingkat P tanah tersedia yang diekstrak menggunakan Bray-1 diklasifikasikan ke dalam status hara P tanah rendah (< 12,0 ppm P_2O_5), sedang (12,0-26,0 ppm P_2O_5), and tinggi (> 26.0 ppm P_2O_5), sedangkan untuk status hara P tersedia dengan pengekstrak Truog adalah rendah (< 9,0 ppm P_2O_5), sedang (9,0-15,5 ppm P_2O_5), dan tinggi (> 15,5 ppm P_2O_5). Rekomendasi pupuk P untuk tanaman padi gogo di tanah Typic Kandiudox pada status hara P tersedia tanah rendah, sedang, dan tinggi berturut-turut sebesar 33, 8, dan 0-4 kg P ha^{-1} atau setara dengan 200, 50, and 0-25 kg SP-36 ha^{-1}.

Kata kunci: Kalibrasi fosfor, padi gogo, pupuk fosfor, status fosfor, Typic Kandiudox

INTRODUCTION

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Indonesian population increases from year to year, with the growth rate of about 1.5% yr^{-1}, resulting in a continuous increase in food demand, especially rice as a staple food. Rice self sufficiency that was already reached in 2017 should be maintained sustainability. The extension of rice fields in Indonesia is about 8,1 million ha but it faces the problem of land conversion. The number of irrigated rice fields continously decreases due to land conversion and low productivity. Consequently, the upland area should be developed and utilized for agriculture. Opportunities for agricultural development in the upland area are possible, hence the productivity of potential land resources could be increased through application of technology packages that have been developed by research institutes.

The number Acid soils of upland area in Indonesia is about 108.8 million ha or 69.4% of the total upland area (Tim Peneliti BBSDLP 2014). Hidayat dan Mulyani (2005) *in* Rochayati dan Daria (2012) reported that upland acid soils mainly consist of Ultisols and Oxisols. Ultisols and Oxisols are the soils with low fertility, therefore the inovative technology is necessary to increase their productivities. One of the innovative technologies is the application of balanced fertilizer. The number of upland area that is used as rice fields is about 5.1 million ha and the potential upland rice fields used as intercropping plants can reach more than 2.0 million ha (Toha 2012).

Agricultural development with wise utilization of land resources is the basic of sustainable economic growth. The efficient soil management in sustainable manner will increase the quality of life. To achieve high soil productivity, the use efficiency of fertilizer through soil test programme should be increased as well.

Determination of soil nutrient status in order to formulate fertilizer recommendation with specific location can be done using a soil test, *i.e.* a chemical soil analysis that is simple, fast, and cheap, but reliable, accurate and reproducible. The purposes of soil test are (1) to determine status of soil nutrient requirement and to indicate the level of deficiency or toxicity of certain nutrient on various plants, (2) to determine fertilizer recommendation, and (3) to use the soil test results for economic evaluation of the recommended fertilizer (Melsted and Peck 1973; Widjaya-Adhi 1986).

Olsen, Bray-1, and Modified Truog methods could be used to analyse P of upland soils. The critical concentration limit of P for upland depends on soil types. For maize grown on Typic Paleudult the critical limit is 3,5 ppm P for Olsen method, 5 ppm P for Bray-1 method, and 6 ppm P for Modified Truogh method. For maize grown on Tropeptic Entrostox, the critical limit is 5 ppm P for Olsen method and Bray-1, and 12 ppm P for Modified Truog method (Widjaya-Adhi and Silva 1986). For upland rice grown in Lampung and Sitiung, the selected method was Modified Truog that divided P status into three classes, namely the critical limit for low, medium, and high status, *i.e.* < 7.5; 7.5-15.0; and > 15 ppm P, respectively (Widjaya-Adhi 1986). Therefore, the objective of this experiment was to determine soil P nutrient requirement and P fertilizer recommendation for upland rice grown on acid Typic Kandiudox.

MATERIALS AND METHODS

Location

The calibration experiment was conducted at the farmer's acid upland soil of Typic Kandiudox in Tanjung Ratu Village, Way Pangubuan Sub District, Central Lampung Distric, Lampung Province. The location of the experiment was selected based on P-Bray-1 and P-HCl 25% levels of the topsoil (0-20 cm) with a very low P status. This experiment was conducted during two successive seasons, the dry season 2013 and rainy season 2013/2014. The chararacteristics of soil profile used for the experiment are presented in Table 1.

P-Fertilizer Treatments

The field experiment was carried out for two seasons, dry and rainy seasons. The dry season 2013 was to artificially prepare soil P status by adding P: 0 X (very low), ¼ X (low), ½ X (moderate), ¾ X (high), and X (very high) on plot trials of 25 m x 6 m with 3 replicates. X was the amount of P required to obtain 0.2 mg P L^{-1} in soil solution (Fox and Kamprath 1970) by applying 1,000 kg SP-36 ha^{-1}. The basal fertilizers used were 50 kg urea ha^{-1}, 150 kg KCl ha^{-1}, 2 tons animal manure ha^{-1}, and 500 kg calcite ha^{-1}. The animal manure and calcite were applied before cultivation, whereas urea, SP-36, and KCl were applied before the second cultivation. Then cowpea was planted at 40 cm × 20 cm spacing with two seeds per hole.

The second experiment was conducted during the wet season (2013/2014) with P fertilizer treatment in each artificial soil P status (used in a dry season) with the rates of 0, 8, 16, 33, dan 66 kg P ha^{-1}, which were equal to 0, 50, 100, 200, 300 and 400 kg SP-36 ha^{-1}. Each treatment was conducted

Table 1. Soil properties of Typic Kandiudox of the field experimental site.

Soil Characteristics	Unit	Value	Method
Texture			Pipette
- sand (%)	%	17	
- silt (%)	%	12	
- clay (%)	%	72	
pH H_2O (1:2.5)		4.6	pH meter
pH KCl (1:2.5)		4.2	pH meter
Organic matter:			
C (%)	%	1.47	Kurmies
N (%)	%	0.15	Kjedahl
C/N ratio		9.8	
P_2O_5	ppm	60	HCl 25%
K_2O	ppm	45	HCl 25%
P_2O_5	ppm	18	Bray-1
CEC			NH4OAc, pH 7.0
- Ca	cmol (+) kg^{-1}	1.87	
- Mg	cmol (+) kg^{-1}	0.81	
- K	cmol (+) kg^{-1}	0.04	
- Na	cmol (+) kg^{-1}	0.08	
- Total	cmol (+) kg^{-1}	2.8	
KB (%)		37	NaCl 10%
Acidity			KCl 1N
- Exchangeable-Al	cmol (+) kg^{-1}	0.44	
- H	cmol (+) kg^{-1}	0.25	

in 3 replicates. The plot at the first season (dry season) was divided into 5 units with 5 m × 6 m distance. Dose of urea and KCl applied were 200 kg urea ha^{-1} and 150 kg KCl ha^{-1}. SP-36 and KCl fertilizers were applied as basal treatments before cultivation and incorporated evenly into the soil. Urea was applied two times *i.e.* at 14 days after planting (dap) and 42 dap. The upland rice of Situ Bagendit variety was planted with 40 cm x 15 cm spacing with 5 seeds per hole.

Before fertilizing, composite soil samples were collected from each plot for analysing P status in the laboratorium. Plant height was measured at 30 dap, and at harvesting time (105 dap). The grain and straw were separated, dried and weighed.

Selection of Soil Phosphorus Extraction Methods

The P status of composite soil samples from each plot trial was determined using several methods, *i.e.* Truog, Colwell, Morgan and Wolf (MW), Olsen, Mehlich, HCl 25%, Bray-1, and Bray-2. The effect of P fertilization at various soil P status on the height and yield of upland rice is presented in Table 2. Response of the plant to P application was expressed as percentage of yield (%Y) = Y_0 / Y_{max} x 100%, in which Y_0 is the yield without P application and Y_{max} is the maximum yield at P application trial. Next, the soil data of each P extraction method were correlated to percentage of yield. The criteria to select the extraction method was based on the extractant that had significant correlation coefficient at 5%.

Determination of Soil Phosphorus Requirement Class

Soil phosphorus requirement was determined based on the Modified Variance Analysis (Nelson and Anderson 1977). The procedure is as follows:

1. Calculate ΔY_{max}. $\Delta Y_{max.}$ = ($Y_{max.}$ – Y_0) / $Y_{max.}$, in which $Y_{max.}$ is maximum dried yield affected by P application and Y_0 is dried yield without P application.
2. Compose data according to the increase concentration of P soil testing.
3. Group data into several groups of ΔY_{max}. The criteria used to determine the limit of sub group are as follow: (a) ΔY_{max} should largely enough decrease between the values next to each other, and average of ΔY_{max} should increase, (b) the separation limit is not determined between the same or almost the same two soil testing values, and (c) the group member is at least 2.

Table 2. Effect of P application on height and dried yield of upland rice at each soil P status of Typic Kandiudox in Central Lampung.

P status	Dose (kg P ha^{-1})	Plant height (cm)	Weight of dried grain (Mg ha^{-1})
Very low	0	29.17 a	0.61 a
Very low	18	46.83 b	1.52 b
Very low	36	48.87 b	2.77 c
Very low	72	49.87 b	3.57 c
Very low	144	46.40 b	2.20 b
CV (%)		13.5	12.7
Low	0	48.93 a	1.87 a
Low	18	50.83 ab	2.82 b
Low	36	57.31 b	3.47 bc
Low	72	52.33 ab	3.26 bc
Low	144	54.06 b	3.15 c
CV (%)		13.5	12.7
Medium	0	53.67 a	0.83 a
Medium	18	56.21 ab	1.88 bc
Medium	36	55.90 ab	2.92 b
Medium	72	52.24 a	3.50 c
Medium	144	61.25 b	2.79 ac
CV (%)		13.5	11.7
High	0	49.12 a	2.43 a
High	18	54.91 b	2.78 ab
High	36	55.01 b	3.02 c
High	72	56.98 b	3.34 ab
High	144	59.11 b	3.16 ab
CV (%)		11.5	12.7
Very high	0	52.98 a	2.01 a
Very high	18	54.99 ab	2.72 a
Very high	36	53.73 ab	3.26 a
Very high	72	59.97 b	3.41 a
Very high	144	58.23 ab	3.47 a
CV (%)		13.5	12.7

Note: The numbers followed by the same letters in the same column at each P nutrient status are not significantly different at 5% level of Duncan's Multiple Range Test (DMRT).

4. Calculate pairs of data ($_i$), standard deviation (S_i), and average of $DY_{max.i}$ from group to-I and pooled S from the whole group.
5. Test the difference between two averages of $DY_{max.}$ from successive group using one way student's t-test using the formula below:
   $t = (DY_{max.,I} - DY_{max.,i+1}) / S(1/n_i + 1/n_{i+1})^{0.5}$
6. If the difference of $DY_{max.}$ average between two successive groups is not significant, the two groups are coupled to be one group. Based on the amount of new group, the procedure then is moved back to step 4 and continued to step 5. 1. This procedure is repeated until the average value between two sequential groups is not significantly different.

Determination of P Fertilizer Recommendation

The data of plant response to P fertilizer application at each soil P class were obtained from the calibration experiment. Generalized response curve from each soil testing class was determined using regression analysis. Regression analysis of dried grain yield from each soil testing group was calculated using Ordinary Least Square, with the minimized amount of residual square. The assumption underlying this method is this residual spreads normally and have freedom and the same variance. This polynomial regression is:

$$Y = a + bX + cX^2$$

in which a, b, c = coefficients, X = P fertilizer doses (kg P ha^{-1}), and Y= dried grain yield (Mg ha^{-1}).

Based on the obtained regression equation, the generalized response curve was made in one graph for each soil test group. Based on this curve, dose of optimum P fertilizer was determined. Recommended fertilizer dose is the fertilizer dose that resulted an optimum yield. The assumption used in calculating optimum dose is the optimum yield that is achieved at 90% of the maximum yield. This optimum dose is P fertilizer application that is able to result in 90% of maximum yield.

RESULTS AND DISCUSSION

Plant Response to P Application

Effect of P application to plant height and dried grain yield of rice at each trial of nutrient status is presented in Table 3. P fertilizer doses significantly increased plant height at whole P nutrient status. The effect was not significant started at dose of 18 kg P ha^{-1}.

P fertilizer application significantly increased the dried grain yield at very low to high P status while at very high P status, the effect was not significant. At very low P status, the weight of dried grain yield was the highest, *i.e.* 3.57 Mg ha^{-1} with application of 72 kg P ha^{-1}; at low P status the yield was 3.47 Mg ha^{-1} with application of 36 kg P ha^{-1}; at moderate P status the yield was 3.50 Mg ha^{-1} with application of 72 kg P ha^{-1}; at high P status the yield was 3.34 Mg ha^{-1} with application of 72 kg P ha^{-1} and at very high P status the yield was 3.47 Mg ha^{-1} with application of 144 kg P ha^{-1}. The data showed that at high soil P status, the plant response to P application was not significant.

Soil P Extraction Methods

The concentrations of soil P obtained from various extraction methods and the percentage of yield of upland rice as affected by P status at various doses of fertilizer application are presented in Table 3. Soil P testing values extracted using Truog, Mehlich, HCl 25%, Bray-1, and Bray-2, generally increased with increasing soil P status treatments. Likewise, percentage of plant yield also increased with increasing soil P status treatments. However some soil P status or percentage of yield decreased with increasing soil P status treatments. The period between P fertilizer application (the beginning of the first season) and soil sampling (the beginning of the second season) was about 7 months. During this incubation period, it is expected that the soil condition could reach a steady state, in which P fertilizer would be changed into soil P that can be taken up by crops.

Table 3. Correlation coefficients between crop yield and soil P content extracted using several methods.

Treatment of Soil P Status	Replication	Content of Soil P_2O_5								Percentage of yield
		Truog	Colwell	MW	Olsen	Mehlich	HCl 25%	Bray 1	Bray 2	
		ppm								
Very low	1	3	77	2	22	6	184	6	33	82
Very low	2	1	112	1	17	5	188	5	18	91
Very low	3	5	149	2	35	9	273	10	42	33
Low	1	11	132	2	40	18	263	17	56	36
Low	2	13	100	3	66	24	360	23	89	70
Low	3	15	143	2	54	16	329	22	65	44
Medium	1	15	200	3	83	30	413	25	120	73
Medium	2	16	253	4	24	45	444	27	158	64
Medium	3	23	115	4	24	48	586	39	169	58
High	1	22	303	5	29	51	521	30	166	70
High	2	18	216	4	47	15	277	22	63	69
High	3	7	169	1	52	15	315	14	60	68
Very High	1	22	397	7	146	49	512	24	169	41
Very High	2	24	120	6	160	57	596	50	212	28
Very High	3	6	158	9	63	22	386	30	228	73
Correlation coefficient (r)		0.89**	0.31	0.42	0.44	0.89**	0.88**	0.90**	0.71**	

*) Significant at 5% level; **) very siginificant at 1% level; $r_{0,05\,(15)} = 0{,}49$; $r_{0,01\,(15)} = 0{,}62$.

However, soil heterogenity affects the levels and P soil dynamics, so that it also affects plant growth.

Table 3 shows that the correlation coefficients between soil P testing values and percentage of yield are highly siginificant for Bray-1, Truog, Mehlich, HCl 25%, and Bray-2 extraction methods. Based on these r values, Colwell, Morgan and Wolf, and Olsen extraction methods are considered not suitable to determine P requirement for upland rice in Typic Kandiudox. On the other hand, Bray-1, Truog, Mehlich, HCl 25%, and Bray-2 are suitable to determine P requirement for upland rice. Among all these extraction methods, Bray-1 had the highest correlation coeficient (r = 0,90) and is suggested as the appropriate P extraction method for the acid soil used in this study. Widjaja-Adhi (1986) reported that Modified Truog extraction method could be used to determine P requirement for acid soil of upland rice in Lampung. Nursyamsi *et al.* (2001) reported the results of an experiment conducted on Oxisol in Pelaihari using maize, showing that the appropriate P extraction methods were Bray-1 and HCl 25%; while on Typic Kandiudox Papan Rejo Lampung Utara were Bray-1 and Bray-2 (Nursyamsi *et al.* 2004).

Bray-1 and Bray-2 containing NH_4F and HCl are generally suitable for determining P requirement of acid soils in which most of P in the soils is present as Al-P and Fe-P (Olsen and Sommers 1982). Ion F in both extractants can release P from Al-P and Fe-P bound on mineral surfaces by forming AlF_6^{3-} or FeF_6^{3-} bonds. In addition, the H^+ ion also plays a role in increasing P solubility derived from Al-P and Fe-P forms.

Range of P Nutrient Status for Upland Rice

Phosphorus availability status and P fertilizer recommendation are determined based on P extraction methods that have high r values or very significant, *i.e.* Bray-1 and Truog extraction methods. Calibration of soil test to determine critical limits of soil P based on Bray-1 and Truog extraction methods is presented in Table 4 and 5. The results show that the soil test of Bray-1 (Table 4) and Truog (Table 5) have the high values corresponding to the grain yield difference due to decreased P application ($\Delta Y_{max.}$). Even in the soil test values of Bray-1 and Truog with the concentrations of 50 and 24 ppm P_2O_5 respectively, the yield difference was only 0.25 Mg ha^{-1}. The results show that plant response to P fertilizer on soils with low P status would be high. In contrast, the response would be low for the soils with high P status. Consequently the crops planted on the soil with low P content need more fertilizer than the soil with high P content. The critical limits of P for upland rice based on Bray-1 were 12.0 and 26.0 ppm P_2O_5 (Table 4), while based on Truog extraction method, the critical limits were 12.0 and 37.5 ppm P_2O_5 (Table 5).

Based on the critical limits of P in soil, P availability classes of Bray-1 could be determined as follow: low, moderate, and high for the soil with

Table 4. Critical limit of P content of Typic Kandiudox for upland rice extracted using Bray-1.

Treatment	Replication	Bray 1	ΔY_{max}	Average ΔY_{max}	ni	Si	S pooled	t-calculated	t-table	Critical limit
		ppm P_2O_5	…….Mg ha^{-1}……							ppm P_2O_5
0 X	II	5	3.01	2.95	3	0.104	0.520	7.420	2.718	12.0
0 X	I	6	3.01						1.796	
0 X	III	10	2.83							
¾ X	III	14	2.09							
¼ X	I	17	1.83	1.63	6	0.284	3.788	5.657	2.896	26.0
¼ X	III	22	1.50						1.860	
¼ X	II	23	1.63							
1 X	I	24	1.46							
½ X	I	25	1.30							
½ X	II	27	0.91	0.74	4	0.329				
¾ X	I	38	0.90							
½ X	III	39	0.92							
1 X	II	50	0.25							

Table 5. Critical limit of P content of Typic Kandiudox for upland rice extracted using Modified Truog.

Treatment	Replication	Bray 1 (ppm P_2O_5)	ΔY_{max} (Mg ha^{-1})	Average ΔY_{max} (Mg ha^{-1})	ni	Si	S pooled	t-calculated	t-table	Critical limit (ppm P_2O_5)
0 X	II	1	3.01	2.61	5	0.50	0.227	19.684	19.684	9.0
0 X	I	3	3.06						1.796	
0 X	III	5	2.83							
1 X	III	6	2.05							
¾ X	III	7	2.09	1.55	8	0.51				
¼ X	I	11	1.83	1.57	4	0.22	0.368	4.459	3.707	15.5
¼ X	II	13	1.63						1.943	
¼ X	III	15	1.50							
½ X	I	15	1.30							
½ X	II	16	0.91	0.74	4	0.33				
½ X	III	16	0.92							

P content of <12.0, 12.0-26.0, >26.0 ppm P_2O_5, respectively. Similarly, the P availability classes based on Truog extraction method consist of low, moderate, and high with P content of <9.0, 9.0-15.5, and > 15.5 ppm P_2O_5, respectively (Table 6).

Recommendation of P Fertilizer for Upland Rice

Based on plant response to P fertilizer application, the generalized response curve of upland rice to P fertilzer application at different soil P status can be determined (Figure 1). The dose of fertilizer required by the plant is the amount of fertilizer needed to reach an optimum dose. Optimum dose is assumed as fertilizer dose to achieve 90% of maximum grain yield. The calculation showed that the upland rice grown on Typic Kandiudox with P status of low, moderate, and high needs 33, 8, and 0 kg P ha^{-1}, which equal to 200, 50, and 0 kg SP-36 ha^{-1}, respectively. The soil with high and moderate P status was achieved by applying fertilizer of 200 kg

Table 6. Soil P availability status of Typic Kandiudox for upland rice.

Nutrient status	Soil P content: Bray 1	Soil P content: Truog
	................ppm P_2O_5.....................	
Low	< 12.0	<9.0
Medium	12.0-26.0	9.0-15.5
High	> 26.0	>15.5

Table 7. Fertilizer recommendation for upland rice at different soil P status of Typic Kandiudox.

P Nutrient Class	Regression equation	R^2	Fertilizer Dose: P	Fertilizer Dose: SP-36
			………..…..kg ha^{-1}	……………..
Low	Y_1= -0,00004x^2+0.024x+0.576	98.7	33	200
Medium	Y_2= -0,00002x^2+0,0106x+2.281	94.2	8	50
High	Y_3= -0,00002x^2+0,0102x+2.225	93.0	-	-

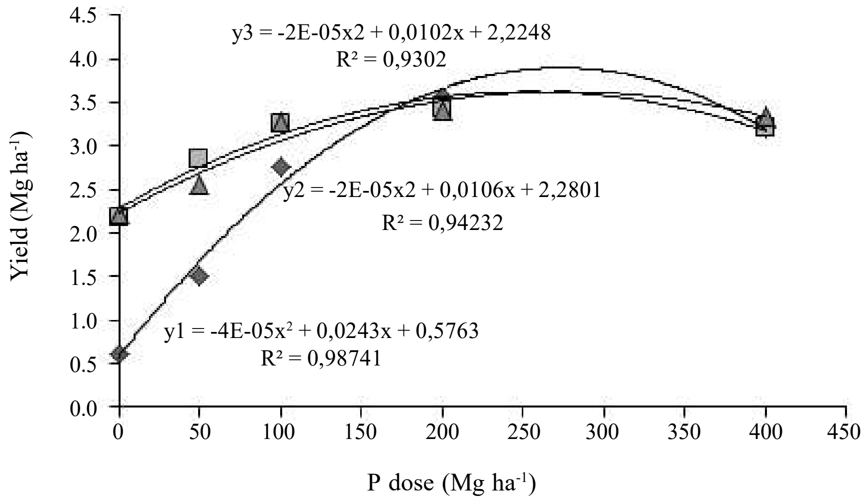

Figure 1. Generalized response curve of upland rice to P application at each soil P status of Typic Kandiudox. ◆: low P status, ■: moderate P status, ▲: high P status.

SP-36 ha^{-1} and 50 kg SP-36 ha^{-1}, respectively. For a very high P status, the soil was fertilized only for nurturing (25 kg SP-36 ha^{-1}) (Table 7). As a comparison, recommendation of P fertilizer for soybean grown on Typic Hapludox at low, moderate, and high P status are 58, 45, and 16 kg P ha^{-1} (Nursyamsi *et al.* 2004).

The soil with low nutrient status showed high plant response to fertilizer application. Therefore, this soil needs a lot of fertilizer. In contrast, the soil with high nutrient status has no response to fertilizer application, thereby this soil only needs a little amount of fertilizer, *i.e* to maintain nutrient status remains high. The soil with moderate nutrient status had lower response to fertilizer application in comparison to low nutrient status, suggesting less fertilizer needed for this soil compared to soil with low nutrient status. Schulte and Kelling (1996) reported that recommendation for phosphorus fertilizer vary with crop species, yield, and soil type. If the soil phosphorus is below the optimum level, the amount of phosphorus recommended will permit a gradual buildup (over 5-8 years) of the available supply. If the soil phosphorus is high, the amount of recommended P will be less than the amount removed by the harvested crops, allowing some decrease in the soil P content. For excessively high test, elimination of part or possibly all of the phosphorus fertilizer allows the soil P to drop to the optimum range.

CONCLUSIONS

Phosphorus application significantly increased plant height and dried grain yield of upland rice at very low to very high P status, but the magnitude of the increase of the yield decreased with the increase of P status. Colwell, Morgan and Wolf, and Olsen extraction methods are not suitable to determine P requirement for upland rice grown on Typic Kandiudox, whereas Bray -1, Truog, Mehlich, HCl 25%, and Bray-2 are appropriate. Among all of these extraction methods, Bray-1 and Truog are the most appropriate extractants for upland acid soils. Phosphorus availability status for Bray-1 extractant are low, moderate, and high, corresponding to < 12.0 ppm P_2O_5, 12.0-26.0 ppm P_2O_5, dan > 26.0 ppm P_2O_5, respectively, whereas for Truog extractant the P availability status are < 9.0 ppm P_2O_5, 9.0-15.5 ppm P_2O_5, and > 15.5 ppm P_2O_5, respectively. The recommendations of P fertilizer for upland rice grown on Typic Kandiudox with low, moderate, and high P status are 33, 8, and 0-4 kg P ha^{-1}, which equal to 200, 50, and 0-25 kg SP-36 ha^{-1}.

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REFERENCES

Fox RL and FJ Kamprath. 1970. Phosphate sorption isotherm for evaluating the phosphate requirement of soils. *Soil Sci Soc Am Proc* 34: 902-907.

Melsted SW and TR Peck. 1973. The Principles of Soil Testing. In: LM Walsh and JD Beaton (eds). Soil Testing and Plant Analysis. *Soil Sci Soc Am Inc*. Madison, Wisc. USA, pp. 13-21.

Nelson LA and Anderson. 1977. Partitioning of soil test-crop response probability. In: Peck TR, JT Cope Jr and DA Witney (eds). Soil Testing: Corelation and Interpreting the analytical result. ASA Special Publ. No. 29. ASA-CSSA-SSSA, Madison, Wisconsin, USA, pp. 19-38.

Nursyamsi D, L Anggria and A Budiayanto. 2001. Pemilihan metode ekstraksi P tanah Inceptisol dan Oxisol untuk tanaman jagung (*Zea mays*). Dalam: Prosiding Seminar Pengelolaan Lahan Kering Berlereng dan Terdegrdasi. Bogor, 9-10 Agustus 2001. Puslitbangtanak. Bogor. Hlm 137-149 (in Indonesian).

Nursyamsi D, MT Sutriadi and U Kurnia. 2004. Metode ekstraksi dan kebutuhan pupuk P tanaman kedelai pada Typic Kandiudox in Papanrejo, Lampung. *J Tanah dan Iklim* 22: 15-25 (in Indonesian).

Olsen SR and LE Sommers. 1982. Phosphorus. In: Al Page (ed). Methods of Soil Analysis. Part 2, Chemical and Microbiological Properties Second Edition. American Society of Agronomy, Inc. and Soil Science Society of America, Inc. Madison,Wisconsin USA, pp. 403-430.

Rochayati S and Ai Dariah. 2012. Pengembangan lahan kering masam: Peluang, Tantangan, dan strategi, serta teknologi pengelolaannya. Dalam: Buku Prospek Pertanian Lahan Kering dalam Mendukung Ketahanan Pangan. Balitbang Pertanian, Kementerian Pertanian. IAARD-PRESS, pp. 187-204 (in Indonesian).

Schulte EE and KK Kelling. Soil and Applied Phosphorus. Extension publication A2520, Understanding Plant Nutrients. Cooperative Extension Publications, University of Wisconsin 4 p.

Tim Peneliti BBSDLP. 2014. Sumberdaya Lahan Pertanian Indonesia. Luas, Penyebaran, dan Potensi Ketersedian. In: E Husen, I Las and Dedi Nursyamasi (eds). BBSDLP (in Indonesian).

Toha HM. 2012. Pengembangan padi gogo mengatasi rawan pangan wilayah marginal. Dalam: Buku Prospek Pertanian Lahan Kering dalam Mendukung Ketahanan Pangan. Balitbang Pertanian, Kemennterian Pertanian. IAARD-PRESS, hal 143-163 (in Indonesian).

Widjaja-Adhi IPG. 1986. Penentuan kelas ketersediaan hara dengan metoda analisis keragaman yang dimodifikasi. Pemberitaan Penelitian Tanah dan Pupuk 5: 23-28 (in Indonesian).

Widjaja-Adhi IPG and JA Silva. 1986. Calibration of Soil Phosphorous test for maize on Typic Paleudults and Trapeptic Eutrustox. *Pemberitaan Penelitian Tanah dan Pupuk*. No.6 (in Indonesian).