COMPARISON OF STATISTICAL MODELS FOR DETERMINATION OF RICE FIELD PHOSPHORUS CRITICAL LEVEL

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Abstract

The method used in the determination of rice field phosphorus nutrient availability classes is a graphical method of Cate and Nelson (1965) and a modified analysis of variance model (Nelson and Anderson, 1977). On the other hand, there are other models commonly used by researchers in determining the nutrients critical levels that are linear plateau, quadratic, and logarithmic models. Different models could produce different nutrient critical levels and economic benefits. This study aims to determine the best model for determination of rice field phosphorus critical level. The research using multilocation experimental data of P fertilization on rice in Java, Sumatera and Lombok. Each trial consisted of four to five levels of P fertilizer treatment. Measured response is dry grain weight (ku/ha). Soil properties measured was total P (25% HCl) nutrient content before the experiment. The design used was a randomized complete block design with three replications. Results showed that sequentially the AIC value of the models are Cate-Nelson <Linear (Ln-X) <Linear (X) <Linear-Plateau (X) = Quadratic (Ln-X) <Linear-Plateau (Ln-X) <Quadratic (X). However, only the model of Linear-Plateau (Ln-X) was significant (P-value < 0.05), while the other models are not significant (P-values> 0.05). Thus the best model is the model of Linear-Plateau with the logarithmic transformation of independent variables X (Ln-X). Critical threshold of 25% HCl-P is obtained at 34 mg P_2O_5/100g.

Keywords: Cate-Nelson, linear plateau, quadratic, logarithmic, AIC.

1. INTRODUCTION

There are several approaches that can be used for the determination of phosphorus and potassium fertilizer doses on paddy rice, which are P and K status maps, the paddy soil test kit (PUTs), Phosphorus and Potassium Decision Support System (PKDSS), and the omission plot fertilizer trials approach. These approaches are complementary each other (Setyorini et al., 2003; Abdulrahman and Sembiring, 2006; Sulaiman, 2010).

Phosphorus and potassium status maps is based on the results of the multilocation soil test field calibration using 25%-HCl extract on a scale of 1: 250,000 and 1:50,000. 1:250,000 scale map is useful for the planning and direction of the national distribution of fertilizer in each province, while 1:50,000 scale maps useful for regional rice paddy fertilizer recommendations.

Three categories of critical levels are used as a reference grouping soil test results that illustrate the extent of the soil P supply, respectively : (1) low status if the test results <20 mg P_2O_5, (2) medium if the test results are 20 - 40 mg P_2O_5, and (3) high status when the test result > 40 mg P_2O_5 (Rochayati and Adiningsih, 2002; Setyorini et al., 2003).

The method used in the determination of nutrient availability classes is a graphical method of Cate and Nelson (1965) and a modified analysis of variance model (Nelson and Anderson, 1977; Setyorini et al., 2003). However, there are other models commonly used by researchers in determining the nutrient critical level which are linear plateau, quadratic, and logarithmic models (Saunders et al., 1987; Mallarino and Blackmer, 1992; Mallarino, 2003; Hamel et al., 2006 ; Izhar, 2012). The results show that different models could produce different nutrient critical levels and economic benefits.

This study aims to determine the best model for determination of rice field phosphorus critical level.

2. METHODOLOGY

This study uses multilocation trials data P fertilization on rice in Java, Sumatera and Lombok (Moersidi et al., 1990; Puslitanak, 1992, 1993; 1994). Each trial consisted of four to five levels P fertilizer treatment. Measured response is dry grain weight (ku/ha). Soil properties measured was the total P (25% HCl) nutrient content before the experiment. The design used was a randomized complete block design with three replications.

Relative yield is defined as the average of the results of the plots that were not fertilized as a percentage of the average results of the fertilized plots at each location. Relative grain yield (dependent variable) associated with P nutrient content (independent variable) was analyzed by some statistical models. Statistical models used are Cate-Nelson, linear plateau, quadratic, and logarithmic. Critical nutrient level is determined at the 100 percent sufficiency level. Criteria used in the selection of the best model is the Akaike Information Criterion (AIC).

3. RESULTS AND DISCUSSION

3.1. Description of the data

Data rice phosphorus fertilization experiment consists of 41 units of multi-location trials. A total of 19 experiments were carried out respectively in Java and Sumatera, while on the island of Lombok as much as 3 pilot sites (Table 1).

Total P content (25% HCl) before experiments ranged from 9-201 mg P_2O_5/100g. Based on the assessment criteria for the chemical nature of soil (Soil Research Centre, 1983) as many as 1 trial location was at very low P levels (<10 mg P_2O_5/100g), 6 locations at low P levels (10-20 mg P_2O_5/100g) , 12 locations were medium levels (21-40 mg P_2O_5/100g), 4 locations were high P levels (41-60 mg P_2O_5/100g), and the 18 pilot sites is very high P levels (> 60 mg P_2O_5/100g) (Table 1).

Table 1. Trial location and total-P content (25% HCl)

No.	Location	25% HCl-P (mg P_2O_5)	No.	Location	25% HCl-P (mg P_2O_5)
	Java		21.	Sungaitarab	52
1.	Watusalam	89	22.	Kubung	77
2.	Benda	39	23.	Sungaisarik	35
3.	Pontang	20	24.	Batangkapas	25
4.	Lohbener	93	25.	Balaiselasa	35
5.	Cilamaya	72	26.	Tilatangkamang	62
6.	Balen	132	27.	Harau	22
7.	Sumbang	127	28.	Triyoso	10
8.	Sirnagalih	104	29.	P1 karangagung	33
9.	Pusakanegara	63	30.	Tanjungsari	12
10.	Plumbon	81	31.	Pemetungbesuki	15
11.	Sumbersono	28	32.	P2 karangagung	11
12.	Mojorayung	23	33.	Sidoarjo	159
13.	Maron	51	34.	Karyadadi	77
14.	Ketitang	86	35.	Wonokerto	163
15.	Slawi	34	36.	Sumbersuro	29
16.	Kemiri	72	37.	Tegalrejo	30
17.	Kepanjen	30	38.	Telangjaya	9
18.	Gurah	56		Lombok	
19.	Gentasari	47	39.	Sakra	82
	Sumatera		40.	Jonggat	105
20.	Kampungdalam	17	41.	Masbagik	201

Table 2. Effect of P fertilization on rice grain yield at 41 sites.

Location	Grain yield with P fertilizer doses treatment (ku/ ha)					CV‖
	P0	P1	P2	P3	P4	
1.	55.50	57.99	51.95	56.77	53.92	4.11
2.	77.95	76.84	71.29	76	75.24	7.02
3.	55.11	54.95	56.77	53.62	58.38	8:20
4.	64.17	66.75	66.75	68.51	68.38	1.13 *
5.	56.30	56.54	55.18	54.56	54.93	3.25
6.	50.28	54.56	55.46	55.9	53.3	8.69
7.	49.36	51.6	54.33	50.53	55.36	6.88
8.	68.33	65.83	68.57	70.48	72.61	8.42
9.	69.22	70.03	68.97	70.19	71.98	1.18 *
10.	45.21	45.76	47.23	48.95	49.23	2.64 *
11.	55.3	55.63	55.53	58.83	61.5	6.79
12.	40.6	47.53	43.56	41.16	49.6	7.37 *
13.	34.6	35.3	35.73	38.9	34.56	5.49
14.	36.1	37.66	40.96	40.76	43.76	9.38
15.	57.3	57	52.63	53.36	52.56	9.53
16.	61.31	60.71	60.07	61.24	60.58	1.83
17.	47.86	49.86	47.53	44	52.06	11.75
18.	57.63	58.8	56.1	56.36	55.46	6.11
19.	63.89	64.03	63.40	68.81	69.68	5.67
20.	72.3	74.63	68.8	71.2	74.3	5.76
21.	65.19	53.27	70.06	48.69	58.3	9.20
22.	58.87	54.1	55.54	52.28	52.73	6.21
23.	58.06	59.97	60.26	59.85	60.45	11.37
24.	50.68	55.66	54.32	62.65	57.60	18.2
25.	50.43	55.72	50.81	58.58	57.11	10.94
26.	50.09	46.58	51.43	48.80	45.24	5.82
27.	61.76	62.78	61.27	63.33	57.82	7.07
28.	76.06	71.57	71.52	73.38	76.59	11.09
29.	36.13	37.31	25.99	32.49	41.69	10.85
30.	50.22	51.81	51.03	52.51	52.98	8.15
31.	61.57	61.51	65.87	63.99	61.13	4.57
32.	40.97	55.74	54.72	56.67	54.66	18.34
33.	58.27	62.16	61.51	59.71	62.55	2.71
34.	58.39	60.95	59.45	61.98	64.77	14.37
35.	68.34	60.32	61.12	60.16	63.02	9.45 *
36.	52.97	53.02	53.17	55.78	-	4.96
37.	40.21	38.87	41.41	38.96	-	8.43
38.	45.6	41.17	48.45	44.04	-	15.09
39.	57.4	57.46	56.4	54.36	-	4.61
40.	52.8	57.36	59.26	54.46	-	7.18
41.	60	62.66	65	61	-	7.66

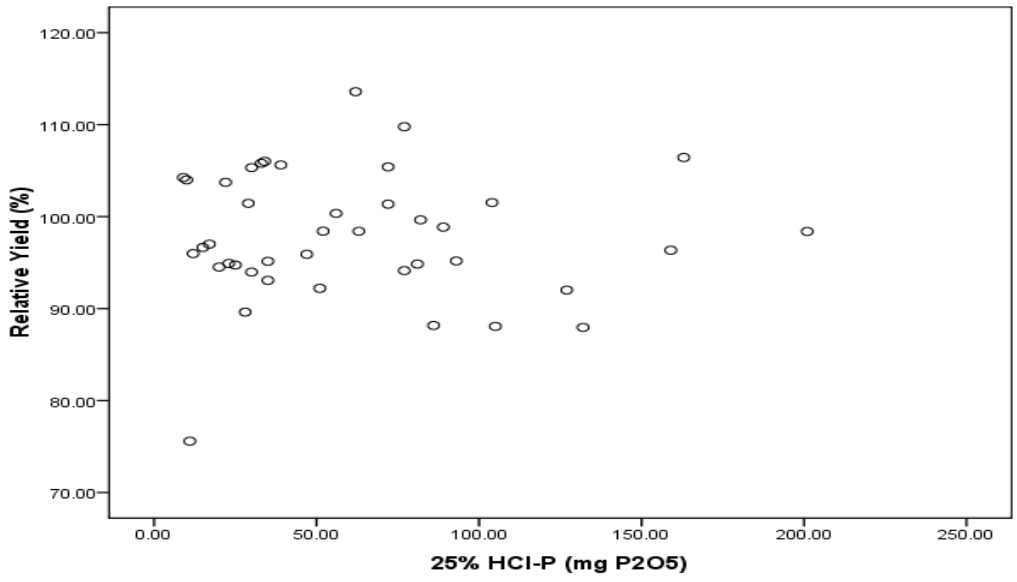
*Significant at α = 5 percent level
‖CV = coefficient of variation

Phosphorus fertilization treatments consist of several levels of P fertilizer, ranged from 0-200 kg TSP/ha. P fertilization experiment in Java using dose levels of P fertilizer with P0 (0 kg TSP/ha), P1 (25% recommendation), P2 (50% recommendation), P3 (75%

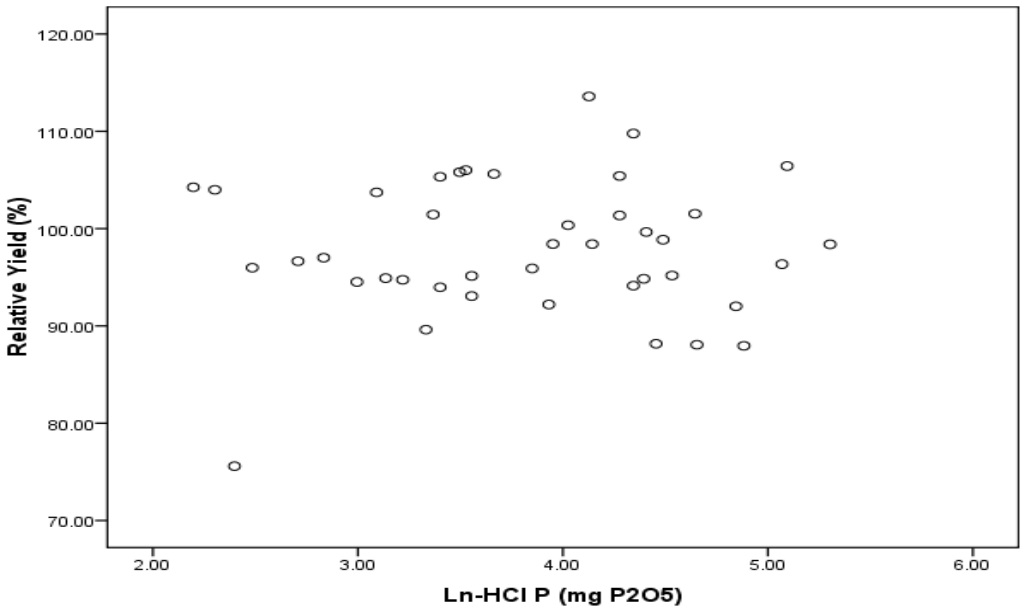
recommendation), and P4 (100% recommendation). P fertilizer recommendations differ between various locations. P fertilization experiment in the Sumatera island, generally using doses of P fertilizer with level of 0, 50, 100, 150 and 200 kg TSP/ha. The P fertilization experiment on the Lombok island, and several locations on the Sumatera island use of fertilizer P with level of 0, 50, 100, and 150 kg TSP/ha.

Rice grain yield in multilocation trials ranged between 17.67 - 88.2 ku/ha with an average of 56.24 ku/ha. Lowest grain yield of rice is on site P1 Karangagung-South Sumatera, while the highest grain yield is on site Kampungdalam, West Sumatera. Results of analysis of variance of rice P fertilization at each location can be seen in Table 2. Significant phosphorus fertilizer treatment on rice grain yield identified on 5 trials from 41 locations. This is likely related to the soil P content of location that generally moderate to very high levels.

Linear correlation of relative grain yield with total-P (25% HCl) was - 0.010 (P-value = 0948), while the linear correlation of relative crop yield with ln-total P was 0.044 (P-value = 0.783) (Figure 1 and 2). This suggests that linear increasing of rice grain yield with increasing total soil-P content was not significant.



. Figure 1. Scatter diagram of relative yield and 25% HCl-P



. Figure 2. Scatter diagram of relative yield and Ln-HCl P

3.2. Model Fitting

Examination of the data showed that the distribution was normal. Kolmogorov-Smirnov statistic value was 0.092 with P-value = 0.200. Normal Q-Q plot shows straight line pattern (Figure 3). .

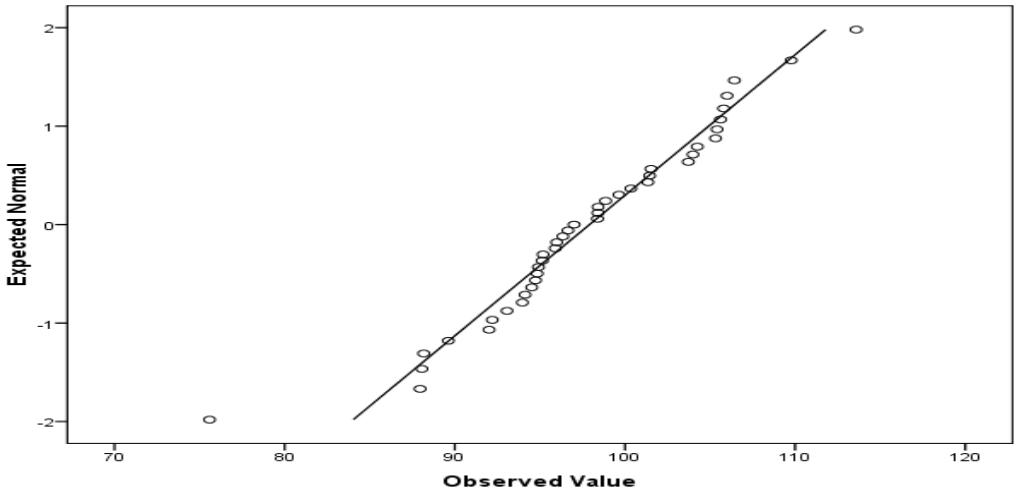


Figure 3. Normal Q-Q Plot of Relative Yield

Results of model fitting for Cate-Nelson, linear-plateau, quadratic, and logarithmic models can be seen in Table 4 and Figure 4 and 5. Model fitting of linear-plateau, quadratic and logarithmic using the original variables X and logarithmic transformation (Ln-X) (Pukhovskiy, 2013). AIC value of linear-plateau (Ln-X) model is higher than the linear-

plateau (X) model, whereas quadratic (Ln-X) and linear (Ln-X) models are lower than quadratic (X) and linear (X) models. Sequentially AIC value of the model is Cate-Nelson <Linear (Ln-X) <Linear (X) <Linear-Plateau (X) = Quadratic (Ln-X) <Linear-Plateau (Ln-X) <Quadratic (X). Cate-Nelson models have smaller AIC values than other models. However, only the model of Linear-Plateau (Ln-X) were significant (P-values < 0.05), while the other models are not significant (P-values > 0.05). Thus the determination of the critical threshold of 25% HCl-P using the model of Linear-Plateau (Ln-X) only. Critical threshold of 25% HCl-P is obtained at 34 mg P_2O_5 /100g.

Table 4. Statistical models for determining the critical threshold of 25% HCl P

Model	Equation	P> |t|	AIC
Cate-Nelson	Y = 92.31 + 3.23 X	0.1826	279.2
Linear-Plateau (X)	Y = 93.80 + 0.14 X, P = 98.40	0.2591	282.0
Linear-Plateau (Ln-X)	Y = 89.69 + 2.48 Ln-X, P = 98.38	<0.0001	282.2
Quadratic (X)	$Y = 97.42 + 0.019 X - 0.00012 X^2$	0.7765	282.9
Quadratic (Ln-X)	$Y = 77.49 + 11.05 Ln\text{-}X - 1.43 (Ln\text{-}X)^2$	0.3576	282.0
Linear (X)	Y = 98.01 - 0.002 X	0.9470	281.0
Linear (Ln-X)	Y = 96.45 + 0.38 Ln-X	0.7776	280.9

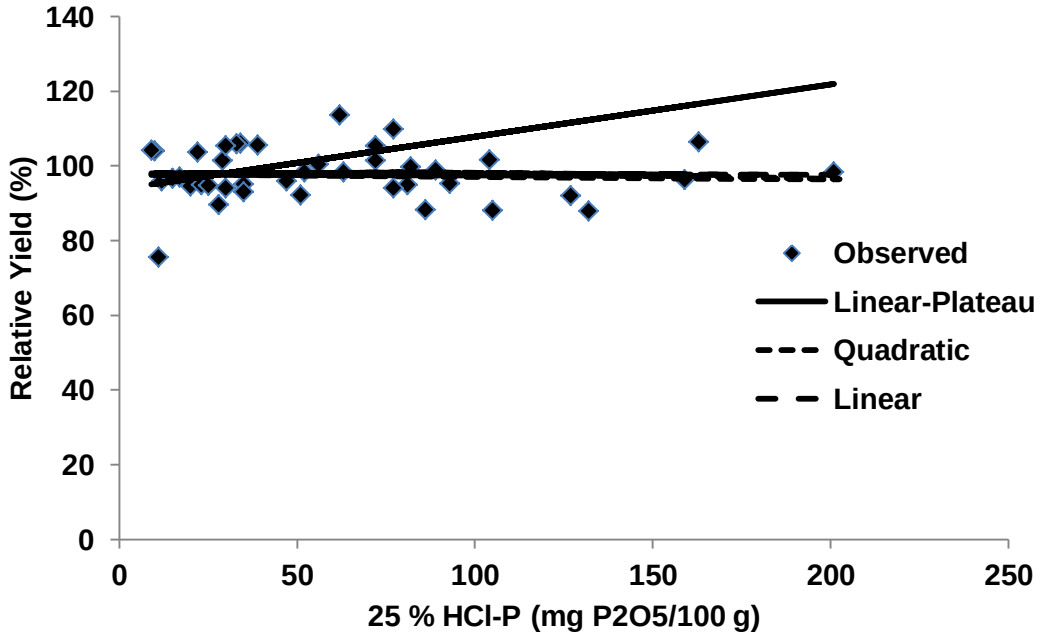
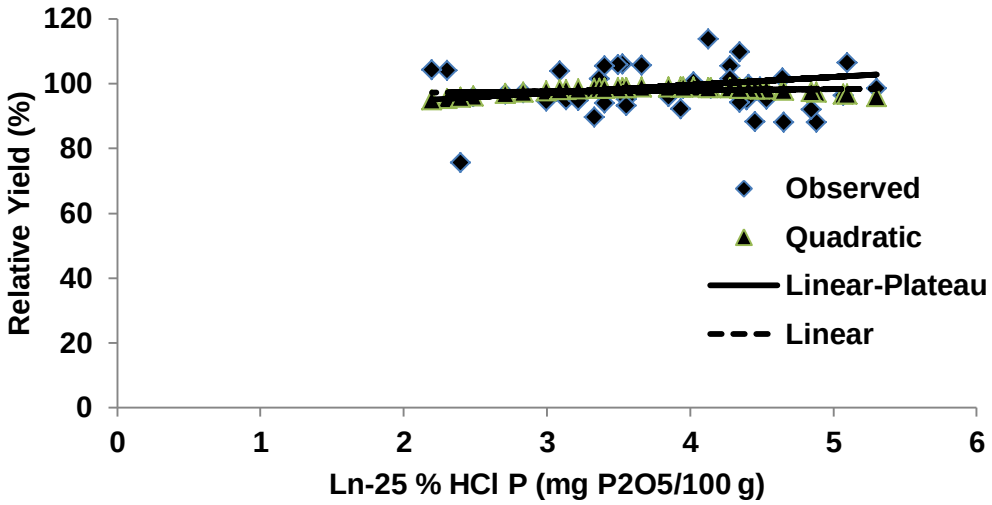


Figure 4. Plot linear-plateau, quadratic, and linear models (X)



. Figure 5. Plot linear-plateau, quadratic, and linear models (Ln-X)

4. CONCLUSION

The best model for determination of rice field phosphorus critical level was Linear-Plateau model with logarithmic transformation of the independent variables X.

5. REFERENCES

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