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# Model Comparisons for Assessment of NPK Requirement of Upland Rice for Maximum Yield

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## ABSTRACT

Upland rice farmers in Malaysia still depend on resultant ash from burning for K and N sources. Efficient use of chemical fertilizers in upland rice needs accurate assessment of required nutrient elements. The present study was performed to determine the N, P, and K requirements of three upland rice varieties grown on idle land (Bukit Tuku soil, AQUIC KANDIUDULT) using four response models. A glasshouse experiment was conducted using 0-200 kg N $ha^{-1}$ (urea, 46%N), 0-120 kg $P_2O_5$ $ha^{-1}$ (TSP, 45% $P_2O_5$), and 0-150 kg $K_2O$ $ha^{-1}$ (MOP, 60% $K_2O$), each at five levels. Three upland rice varieties used in the experiment were Ageh, Kendinga and Strao. The grain yield (14% moisture content) was measured at harvest and fitted using linear (L), linear with plateau (LP), quadratic (Q), and quadratic with plateau (QP) response models. The QP proved itself as the best fitted response model for the determination of fertilizer recommendation rates for maximum yield of upland rice cultivars used. The fertilizer rates were 112 kg N $ha^{-1}$, 78 kg $P_2O_5$ $ha^{-1}$ and 158 kg $K_2O$ $ha^{-1}$ for Ageh (QP); 138 kg N $ha^{-1}$ (LP), 87 kg $P_2O_5$ $ha^{-1}$ (QR), 119 kg $K_2O$ $ha^{-1}$ (QP) for Kendinga; and 125 kg N $ha^{-1}$ (Q), 85 kg $P_2O_5$ $ha^{-1}$ (LP) and 127 kg $K_2O$ $ha^{-1}$ (L) for Strao.

**Keywords: Fertilizer recommendation rates, linear, linear plateau, nutrient requirement, quadratic plateau, upland rice**

## INTRODUCTION

Cultivation of upland rice depends on resultant ash from burning as the nutrient source. Burning supplies a considerable amount of potassium (K). Nitrogen (N) from ash may fulfill only a fraction of the requirement as it is mostly lost in burning. As a result, the amount of these elements may be insufficient for better plant growth. Therefore, application of chemical fertilizers can be a good practice to fulfill the upland rice nutrient requirements. However, nutrient requirement and the efficiency of fertilizer utilisation by the upland rice varieties vary markedly.

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This is due to the inherent plant physiological process (germination, respiration, and dormancy), soil fertility, biological factors and climatic conditions. A better understanding of the various aspects of nutrient use can lead to improved crop yields and reduce cost of production. Apart from adequate supplies of nutrients, other factors, such as water availability, use of high yielding cultivars and the control of diseases, insects and weeds are important factors that contribute to higher crop yields. Due to the increasing cost of chemical fertilizers, fertilizer application should be efficient and sufficient in amounts for nutrients uptake by plants. The most economic fertilizer recommendation is only possible when information on the optimum fertilizer rate has been collected and then made available.

Determination of an optimum amount of fertilizer requires experience which serves as a basis for predicting how the crop will respond to fertilizer application. A simple definition of an optimal rate is that rate which produces maximum economic return (Colwell 1994). Curve fitting techniques are often used to estimate optimal fertilizer rates, but a major problem exists in selecting the best model for a particular soil-cropping situation (Alivelu *et al*. 2003). Yield responses are often described with a quadratic equation. For a quadratic function, yields increase to a maximum with increasing soil test nutrient concentration, then decline in a mirror image of the increments. Since toxicities are not usually encountered, the decline is not real. Furthermore, the maximum is not reached until soil test values are well beyond the expected point of diminishing returns (Cox 1992).

A more recent expression of yield response to soil test nutrient concentration is the linear plateau (LP), or continuation at zero slope, at a maximum yield with increasing nutrient concentration. This approach is extremely direct, leaving no doubt as to the exact predicted critical level. Use of the LP function is becoming more common as routine statistical procedures are now available for calculation. According to Cerrato and Blackmer (1990), the choice of the model will affect the predicted fertilizer rate. When compared to other nutrients, the optimal rate of nitrogenous fertilizer application is important to reduce the environmental impact of excessive N and to increase profitability in crop production (Bilbao *et al.* 2004). However, choosing the fertilizer rate can be complicated because the farmer rationally decides as to whether to choose the minimum or maximum fertilizer rate or possibly some rate between these limits due to financial constrains and cost of fertilizer. The maximum rate gives the largest profit per hectare of land and is the most profitable rate if no other land is available and enough capital is available to buy the fertilizer, whereas the minimum rate gives the highest return of every single fertilizer investment and is the best choice when each investment for fertilizer is limited. To our best knowledge, the upland rice farmers never use any chemical fertilizers. Hence, there is a great potential for yield increment of upland rice by application of chemical fertilizers. However, no information is available on the rates of chemical fertilizers used by the farmer for any upland rice cultivars. Therefore, selection of a response model for the fertilizer rate prediction for maximum yield which directly fulfils the crop's requirement and provide reasonable income to the farmer is crucial to provide the best recommendation to farmers. The objectives of the present study were (i) to determine the requirements of N, P and K for upland rice and (ii) to explore a response model for prediction of nutrient requirements for maximum yield in Bukit Tuku soil.

## MATERIALS AND METHODS

*Planting of Upland Rice*

A glasshouse study was conducted for a duration of five months (from September 2004 to January 2005) at the Faculty of Agriculture glasshouse complex, Universiti Putra Malaysia. The soil (Bukit Tuku series) was ground and sieved to pass through a 2.0 mm sieve size. The soil physico-chemical characteristics are given in Table 1. Approximately 15 kg of the soil was weighed and packed into

TABLE 1

Physical and chemical properties of Bukit Tuku idle soil at two soil depths

| Parameters | | Soil depth (cm) | |
|---|---|---|---|
| | | 0 − 20 | 20 − 40 |
| $pH_W$ | | 4.82 | 4.69 |
| $pH_{KCl}$ | | 3.6 | 3.4 |
| Nitrogen (%) | | 1.89 | 1.3 |
| Phosphorus (mg $kg^{-1}$) | | 19.92 | 18.3 |
| Potassium (mg $kg^{-1}$) | | 58.53 | 32.8 |
| Calcium (mg $kg^{-1}$) | | 488.3 | 306.8 |
| Magnesium (mg $kg)^{-1}$ | | 65.83 | 54.17 |
| Iron (mg $kg^{-1}$) | | 175.4 | 112.9 |
| Aluminium (mg $kg^{-1}$) | | 668 | 629 |
| CEC ($cmol_c$ $kg^{-1}$) | | 5.71 | 5.32 |
| Soil pF (%): | 0 | 46.75 | 47.69 |
| | 1 | 36.79 | 35.95 |
| | 2 | 29.95 | 27.55 |
| | 2.54 | 25.41 | 20.43 |
| | 4.19 | 17.98 | 9.77 |
| | AWC | 7.43 | 10.65 |

each polybag. Seeds of three upland rice varieties (Ageh, Kendinga and Strao) were treated with fungicide (Benlate @ 3 g a.i. per kg seed) before sowing. Ten seeds were dibbled at 4 cm depth in each of the polybags. After emergence, the seedlings were thinned to 8 plants per polybag.

*Experimental Design and Treatments*

Five levels of nitrogenous fertilizer were 0, 50, 100, 150, and 200 kg N $ha^{-1}$. With each dose of nitrogen, a blanket dose of 90 kg $P_2O_5$ $ha^{-1}$ (1.02 g TSP per polybag) and 120 kg $K_2O$ $ha^{-1}$ (1.02 g MOP per polybag) was used. The five levels of phosphorus fertilizer were 0, 30, 60, 90, and 120 kg $P_2O_5$ $ha^{-1}$ , accompanied by a common dose of 150 kg N $ha^{-1}$ (1.67 g urea per polybag) and 120 kg $K_2O$ $ha^{-1}$ (1.02 g MOP per polybag). The five rates of potassium fertilizer were 0, 60, 90, 120, and 150 kg $K_2O$ $ha^{-1}$ accompanied by similar blanket doses of NP mentioned above. A total of 15 treatments were assigned for each of the three upland rice (Ageh, Kendinga and Strao) varieties resulting in 45 individual units. The experimental units were arranged in a complete randomized design with 3 replications (135 polybags). The fertilizer rates were selected based on nutrient uptake of upland rice in a pre-trial experiment. The N fertilizer was applied in 3 equal splits, first at 3 weeks after germination then at early tillering stage, and lastly at panicle initiation (PI). Phosphorus fertilizer was applied at early tillering stage, and K fertilizer application was in two equal splits, first at early tillering and the other at flowering stage. Insecticide (Mapa Malathion 57®) and fungicide (Benlate®) were applied at 2.57 kg a.i. Malathion $ha^{-1}$ and 2.25 kg a.i. Benomyl $ha^{-1}$, respectively, using a knapsack sprayer when necessary during the experiment. Water was applied to field capacity once daily for each polybag. The grain yield was measured at 14% moisture content.

*Statistical Analysis*

The non-linear procedure (PROC NLIN) of SAS (SAS, 2001) was used for comparison of response curves. The response curves were linear (L), quadratic (Q), and linear with plateau (LP), and quadratic with plateau (QP) functions. The yield data was fitted using PROC REG and PROC NLIN methods. The L function model is defined by the following equation.

$$Y = a + bX \qquad [1]$$

where $Y$ is grain yield (g $hill^{-1}$), $X$ is fertilizer application rate (kg $ha^{-1}$), and $a$ (intercept), $b$ (linear coefficient), are constants obtained by fitting data to the model function.

The LP function model is defined by the following equations:

$$Y = a + bX \qquad \text{if } X < C \qquad [2]$$

$$Y = P \qquad \text{if } X \geq C \qquad [3]$$

where $Y$ is grain yield (g $hill^{-1}$), $X$ is fertilizer application rate (kg $ha^{-1}$), and $a$ (intercept), $b$ (linear coefficient), $C$ (critical fertilizer rate, which occurs at the intersection of the linear response and the plateau lines), and $P$ (plateau yield) is the constant obtained by fitting data to the model function.

The Q model is defined by the equation

$$Y = a + bX + cX^2 \qquad [4]$$

where $Y$ is grain yield (g hill$^{-1}$), $X$ is fertilizer application rate (kg ha$^{-1}$), and $a$ (intercept), $b$ (linear coefficient), and $c$ (quadratic coefficient) are constants obtained by fitting data to the model function.

The QP model is defined by following equations:

$$Y = a + bX + cX^2 \qquad \text{if } X < C \qquad [5]$$

$$Y = P \qquad \text{if } X \geq C \qquad [6]$$

where $Y$ is grain yield (g hill$^{-1}$), $X$ is fertilizer application rate (kg ha$^{-1}$), and $a$ (intercept), $b$ (linear coefficient), and $c$ (quadratic coefficient), $C$ (critical fertilizer rate, which occurs at the intersection of the quadratic response and the plateau lines), and $P$ (plateau yield) is the constant obtained by fitting data to the model function.

For the Q model (Eq. 4), predicted maximum yield was obtained by equating the first derivatives of the response equation to zero, solving for X, substituting the values of X into the response equation, and solving for Y. For the L and Q with plateau models (Eq. 2, Eq. 3, Eq. 5, and Eq. 6), the plateau yields represented the maximum yields. The analysis of variance (ANOVA) was performed using PROC ANOVA of the Statistical Analysis System (SAS 2001) and the protected Least Significant Difference Test (LSD) was used for means comparison.

## RESULTS AND DISCUSSION

Grain yields of Ageh, Kendinga and Strao rice varieties showed significant variation with the differing fertilizer rates used. All varieties produced the lowest grain yield at zero N, P and K fertilizer rates (Table 2). The increase in the grain yield following the addition of N as compared to control was the highest (194%) for Kendinga variety followed by Ageh (168%), and Strao (77%). Ageh produced the highest yield at and above 100 kg N ha$^{-1}$. Strao gave maximum grain yield at 100 kg N ha$^{-1}$ but yield declined for additional N. However, Kendinga showed best performance at 150 kg N ha$^{-1}$. For P fertilization, Ageh gained maximum increase (103%) in comparison to control. The minimum yield increase (57%) was observed for Kendinga which was achieved at an application rate of 60-90 kg $P_2O_5$ ha$^{-1}$. However, Kendinga variety showed the highest increase in grain yield (168%) followed with an almost similar yield increase for Strao and Ageh rice varieties in the case of K fertilizer application. This suggests that application of fertilizers contributed to the increase in grain yields significantly for Ageh, Kendinga, and Strao rice varieties.

*Rates of Nitrogen, Phosphorus and Potassium Fertilization for Maximum Yield*

With the exception of some treatments, the majority of the data fitted the models fairly well as indicated by regression ($R^2$) values (Table 3). Based on that, the N, P, and K rates for maximum yield of the three upland rice varieties derived from the 4 response models are shown in Table 4. The amount of fertilizers obtained for maximum yield of the three upland rice varieties differed between the response models used. Several response models did not produce any significant results when the data was evaluated by PROC REG and PROC NLIN methods. Therefore, the fertilizer rates for maximum yield could not be ascertained for the non-significant response models.

TABLE 2
Effect of N, P and K fertilizers rates on yield of upland rice

| Fertilizer Rates | Observed yield | | |
|---|---|---|---|
| | Ageh | Kedinga | Strao |
| kg ha $^{-1}$ | g hill $^{-1}$ | | |
| N | | | |
| 0 | 7.67$^{c}$ | 6.33$^{c}$ | 11.83$^{c}$ |
| 50 | 16.46$^{b}$ | 7.17$^{c}$ | 17.89$^{b}$ |
| 100 | 19.84$^{a}$ | 13.99$^{b}$ | 20.96$^{a}$ |
| 150 | 20.04$^{a}$ | 18.60$^{a}$ | 20.55$^{ab}$ |
| 200 | 20.59$^{a}$ | 17.57$^{a}$ | 17.74$^{b}$ |
| $P_2O_5$ | | | |
| 0 | 10.32$^{b}$ | 10.84$^{c}$ | 9.97$^{b}$ |
| 30 | 16.11$^{ab}$ | 13.95$^{b}$ | 11.01$^{b}$ |
| 60 | 20.45$^{a}$ | 16.34$^{a}$ | 14.95$^{ab}$ |
| 90 | 20.98$^{a}$ | 17.04$^{a}$ | 19.64$^{a}$ |
| 120 | 19.66$^{a}$ | 15.94$^{a}$ | 19.74$^{a}$ |
| $K_2O$ | | | |
| 0 | 12.27$^{c}$ | 6.62$^{c}$ | 13.35$^{c}$ |
| 60 | 17.69$^{b}$ | 14.49$^{b}$ | 15.52$^{b}$ |
| 90 | 17.05$^{b}$ | 15.85$^{ab}$ | 16.49$^{b}$ |
| 120 | 22.55$^{a}$ | 15.90$^{ab}$ | 22.16$^{a}$ |
| 150 | 19.67$^{a}$ | 17.76$^{a}$ | 20.53$^{a}$ |

Means within a column followed by the same letters are not significantly different at 5% level by LSD.

TABLE 3

Relationships between the yield of selected upland rice varieties and the levels of nutrient using several response models

| Nutrient | Variety | Linear | $R^2$ | Linear- Plataeu | Plataeu | $R^2$ |
|---|---|---|---|---|---|---|
| Nitrogen | Ageh | y = 11.04 + 0.06N | $0.73^{ns}$ | y = 8.58 + 0.14N | 20.24 | $0.99^{**}$ |
| | Kendinga | y = 5.95 + 0.07N | $0.87^{*}$ | y = 3.72 + 0.10N | 17.94 | $0.99^{**}$ |
| | Strao | y = 14.90 + 0.03N | $0.39^{ns}$ | y = 11.46 + 0.14N | 19.69 | $0.99^{**}$ |
| Phosphorus | Ageh | y = 12.79 + 0.08P | $0.70^{ns}$ | y = 11.27 + 0.14N | 20.51 | $0.99^{**}$ |
| | Kendinga | y = 12.17 + 0.04P | $0.70^{ns}$ | y = 10.76 + 0.11N | 16.43 | $0.99^{**}$ |
| | Strao | y = 9.42 + 0.09P | $0.93^{**}$ | y = 7.85 + 0.13N | 19.44 | $0.99^{**}$ |
| Potassium | Ageh | y = 13.07 + 0.06K | $0.75^{ns}$ | y =12.27 + 0.13N | 19.24 | $0.99^{ns}$ |
| | Kendinga | y = 8.22 + 0.07K | $0.87^{*}$ | y = 7.10 + 0.12N | 16.56 | $0.99^{**}$ |
| | Strao | y = 10.16 + 0.08K | $0.89^{*}$ | y = 8.42 + 0.14N | 19.59 | $0.99^{**}$ |
| | | Quadratic | $R^2$ | Quadratic-Plataeu | Plataeu | $R^2$ |
| Nitrogen | Ageh | $y = 8.23 + 0.17N - 0.0006N^2$ | $0.97^{**}$ | $y = 7.70+0.22N-0.00099N^2$ | 20.23 | $1.00^{**}$ |
| | Kendinga | $y = 5.10 + 0.10N - 0.0002N^2$ | $0.89^{ns}$ | $y =5.09+0.10N-0.00017N^2$ | 20.37 | $0.99^{ns}$ |
| | Strao | $y = 11.86 + 0.15N - 0.0006N^2$ | $0.99^{**}$ | $y =11.83+0.16N-0.0009N^2$ | 19.75 | $0.99^{ns}$ |
| Phosphorus | Ageh | $y = 10.22 + 0.25P - 0.001P^2$ | $0.99^{**}$ | $y = 10.19+0.26P-0.002P^2$ | 20.46 | $0.99^{*}$ |
| | Kendinga | $y = 10.73 + 0.14P - 0.0008P^2$ | $0.99^{**}$ | $y =10.78+0.14P-0.0008P^2$ | 16.54 | $0.99^{*}$ |
| | Strao | $y = 9.27 + 0.10P - 0.00009P^2$ | $0.93^{ns}$ | $y = 9.27+0.10P-0.00009P^2$ | 39.3 | $0.99^{ns}$ |
| Potassium | Ageh | $y = 12.18 + 0.11K - 0.0003K^2$ | $0.81^{ns}$ | $y = 12.18+0.11K-0.0003K^2$ | 20.6 | $0.99^{ns}$ |
| | Kendinga | $y = 6.83 + 0.15K - 0.00052K^2$ | $0.97^{**}$ | $y = 6.66+0.17K-0.0007K^2$ | 16.78 | $0.99^{*}$ |
| | Strao | $y = 9.53 + 0.11K - 0.0002 K^2$ | $0.91^{ns}$ | $y = 9.53+0.11K-0.0002K^2$ | 23.48 | $0.99^{ns}$ |

Note: $^{**}$, $^{*}$ = significant at 1 and 5% levels, respectively.
$^{ns}$ = non-significant

The yield responded significantly in accordance with the LP response model with increasing N and P rates for all the three upland rice varieties. In the case of K fertilization, Kendinga and Strao showed significant response in LP, whereas the response of Ageh was significant only in the QP model (Table 4). The N, P and K rates for maximum yield of the three upland rice varieties using all the models ranged between 60 and 142 kg N $ha^{-1}$, 51 to 125 kg $P_2O_5$ $ha^{-1}$, and 81 to 158 kg $K_2O$ $ha^{-1}$, respectively (Table 4). The maximum N prediction rates by the response models were in the order: Q > QP> LP for Ageh rice variety, LP > L for Kendinga rice variety, and Q > LP for Strao rice variety. This shows that for Ageh and Strao rice varieties, the Q model tended to give higher maximum fertilizer rates compared to those of LP and QP response models. However, contrasting results were observed for the Kendinga rice variety.

The Q response model resulted in the highest maximum P rates for Ageh (125 kg $P_2O_5$ $ha^{-1}$) and Kendinga (87.50 kg $P_2O_5$ $ha^{-1}$) rice varieties and the L response model suggests maximum for Strao (104.67 kg $P_2O_5$ $ha^{-1}$) rice variety.

The fertilizer rates differed greatly and depended on the response model used. The LP response model suggests the lowest amount of P fertilizer as the maximum dose with the rates for Ageh, Kendinga and Strao rice varieties being 63.96, 51.33 and 85.91 kg $P_2O_5$ $ha^{-1}$, respectively (Table 4).

TABLE 4

Rates of N, P and K maximum yield for three upland rice varieties

| Fertiliser | Variety | Fertiliser rate | | | |
|---|---|---|---|---|---|
| | | Linear | LP | Quadratic | QP |
| | | kg N $ha^{-1}$ | | | |
| N | Ageh | *ns | 82.44 | 141.67 | 112.23 |
| | Kendinga | 85.00 | 138.15 | ns | ns |
| | Strao | ns | 59.95 | 125.00 | ns |
| | | kg $P_2O_5$ $ha^{-1}$ | | | |
| P | Ageh | ns | 63.96 | 125.00 | 78.48 |
| | Kendinga | ns | 51.35 | 87.50 | 83.35 |
| | Strao | 104.67 | 85.91 | ns | ns |
| | | kg $P_2O_5$ $ha^{-1}$ | | | |
| K | Ageh | ns | ns | ns | ns |
| | Kendinga | 117.43 | 81.59 | 144.23 | 119.55 |
| | Strao | 127.00 | 81.36 | ns | ns |

* ns= response not significant at 5% level.
LP= Linear with plateau
QP= Quadratic with plateau

The highest K rates for Ageh, Kendinga and Strao rice varieties were also obtained from different response models. The maximum K rates of Kendinga rice variety showed a significant response to each model used. The highest K rates predicted was in the order: Q > QP > L > LP. These results indicate that the Q response model tended to predict as much as 50% more compared to maximum rates from the LP models. Therefore, selecting the best response model to predict the maximum fertilizer rate is important for any meaningful recommendation to be made. The linear response and plateau functions are now used extensively to relate crop yields to soil test levels and it has been confirmed by many agronomists that this model not only fits most data but also gives an immediate estimate of the critical yield level at the intersection of the two lines (Cox 1996). In the case of the quadratic model, predicted maximum yield and its associated soil test level were almost always excessive, as this model does not often fit the data well in a sufficient range. Cerrato and Blackmer (1990) reported this to be true when comparing models describing corn yield response to N fertilizer. Therefore, it can be concluded that the LP and QP models are the best to describe the reasonable maximum fertilizer rates in this study. However, the different maximum fertilizer rates would be able to produce the maximum yield prediction when solving the equation with several response models.

*Predicted Yields of Three Upland Rice Varieties*

The predicted yield of three upland rice varieties was calculated using the maximum rates obtained from the statistically significant response models in Table 3. The predicted yields of the three upland rice varieties showed mirror image trends as in the maximum fertilizers rates (Table 5). The results showed that the QP response model tends to predict a similar maximum yield value as obtained by Q model but with a lower amount than the maximum N, P and K rates. The maximum predicted yield of Ageh rice variety using maximum N fertilizer rates obtained from the QP (112 kg N $ha^{-1}$) and LP (82 kg N $ha^{-1}$) models were 20.22 and 20.23 g $hill^{-1}$, respectively. This value was obtained by a lower amount of fertilizer than that of Q (141 kg N $ha^{-1}$) with maximum yields being 20.27 g $hill^{-1}$ (Table 5). Similar results were also observed for the maximum predicted yield of Ageh and Kendinga rice varieties using maximum P rates, and Kendinga using maximum K rates (Table 5). However, L and LP predicted higher maximum predicted yields for Ageh, Kendinga and Strao rice varieties, which were congruent with higher fertilizers rates. In this study, maximum predicted yields of Ageh, Kendinga and Strao rice varieties obtained from the LP response model were almost similar to the other response models (Table 5).

Yield estimation using maximum fertilizer rate equations derived from LP and QP response models were lower than those for L and Q response models. Although, Q and QP estimated similar maximum yields, the predicted maximum fertilizers values by Q differed greatly. Cerrato and Blackmer (1990) stated that the Q model tended to overestimate the maximum yields because of the sharpness of the quadratic response curve near economic optimum and maximum and the model often identifies unattainable yields as being the optimum. Therefore, maximum N, P and K rates obtained either by QP or LP can be recommended for Ageh, Kendinga and Strao rice varieties for achieving maximum predicted yield.

TABLE 5
Predicted yield of upland rice using fertilizers rates obtained by response models

| Fertiliser | Variety | Predicted Yield | | | |
|---|---|---|---|---|---|
| | | Linear | LP | Quadratic | QP |
| | | g hill$^{-1}$ | | | |
| N | Ageh | *ns | 20.23 | 20.27 | 20.22 |
| | Kendinga | 11.90 | 17.93 | ns | ns |
| | Strao | ns | 19.69 | 21.24 | ns |
| P | Ageh | ns | 20.50 | 25.85 | 20.45 |
| | Kendinga | ns | 16.42 | 16.86 | 16.54 |
| | Strao | 18.84 | 19.43 | ns | ns |
| K | Ageh | ns | ns | ns | ns |
| | Kendinga | 16.44 | 16.56 | 17.65 | 16.77 |
| | Strao | 20.32 | 19.58 | ns | ns |

* ns= response not significant at 5% level
LP= Linear with plateau
QP= Quadratic with plateau

## CONCLUSION

The grain yield of Ageh, Kendinga and Strao rice varieties were significantly affected by the N, P and K application rates. Addition of N, P and K fertilizers increased the grain yield of all the upland rice varieties with the value ranging from 7 to 22 g hills$^{-1}$ for N, 6 to 18 g hills$^{-1}$ for $P_2O_5$, and 9 to 22 g hills$^{-1}$ for $K_2O$, respectively. The best response model for the upland rice yield data obtained from this experiment was using QP, corresponding to the best fertilizer recommendation rates for Ageh, Kendinga and Strao rice varieties for maximum yield.

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