Critical Concentrations of Nitrogen, Phosphorus and Potassium in Rice Plant[1]

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ABSTRACT

Total land area of paddy plantation in Thailand is approximately eight million hectares. This area has a wide range of soil fertility status. Therefore, nineral nutrient requirements of paddy growing on various soils with different mineral nutrient supplies were investigated at rice experiment stations. Three rates of N, P_2O_5, and K_2O corresponding to O, 37.5, and 75 kg/ha were factorial assigned in four replicates. At harvest the rice straws were sampled and analysed for N, P, and K concentrations. The concentrations of N, P, and K in the rice straw which gave satisfactory rice yields were 0.55, 0.06, and 1.00% respectively.

INTRODUCTION

A field experiment duly replicated a lot of money and labor. To cover a large area of paddy land with a reasonably fine network of fertilizer experiment in search of a suitable formula of fertilizer to be recommended to farmers is time-and money-consuming. Plant and soil analyses, together with soil survey, are of great help to decrease the number of such field experiment to obtain a dependable fertilizer formula for farmers. They are quick to be done and much less expensive.

No systematic analysis of rice plants have been undertaken so far in Thailand to know the tricical levels of nutrient contents to be used for assessing nutrient requirements of variour soil types. Hence the present experiment is the first step of the above-mentioned objective. Analysis of rice plant at harvest also enables the assessment of per-cent recovery by rice plant of fertilizer applied.

MATERIALS AND METHODS

Since 1975, fertilizer experiment of the same design on the effect of nitlogen, phosphorus and potassium have been in progress in the followieg rice experiment stations : namely, Kuan Gut, Rangsit, Pattani, Phan, Ubon, and Phrae.

It is an experiment of factorial arrangement of treatments, replicated four times, having each of the three elements applied at 0, 37.5 and 75 kg per hectare. The experiment, therefore, comprises 27 treatments ($3 \times 3 \times 3$) and 108 plots. Design of the experiment was that of the randomized complete block, and variety grown was RD 1 without exception (Details of treatments were given on Table 2 with analytical results).

Ammonium sulfate, triple superphosphate and potassium chloride were used as sources of nitrogen, phosphorus and potassium. respectively,

In 1976, rice plant samples were collected at the time of harvest, plot

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by plot, from all the treatments of the said experiment at Ubon Rice Experiment Station, amounting to 108 in all.

In 1977, samples of rice plants were collected at the time of harvest from all the replicates of the following seven treatments at Kuan Gut, Rangsit, Pattani, Phan and Ubon.

Trt. No.	Fertilizers. applied (kg/ha)		
	N	P_2O_5	K_2O
9	0	75	75
18	37.5	75	75
21	75	0	75
24	75	37.5	75
25	75	75	0
26	75	75	37.5
27	75	75	75

Samples could not be collected at Phrae Experiment Station owing to failure of .communication. It was expected that changes in nitrogen contents of the rice plants of treatment 9, 18 and 27 would reveal the nitrogen supply conditions of the soil and plant in presence of enough phosphorus and potassium. Referring to the said nitrogen contents to yields of paddy in relation to nitrogen rates would enable the authors to classify them into deficient, optimal and excessive levels of nitrogen supply, In the same way, treatment 21, 24 and 27, would be used for diagnosis of phosphorus conditions, and treatment 25, 26 and 27 for that of potassium conditions.

Time of plant sampling.

Samples of rice plants were collected at harvest. The contents of nitrogen, phosphorus and potassium in the rice plant were quite high at tillering stage and steadily decrease as it grew until maturity. For example, nitrogen per cent at tillering stage was as high as 4% and decreased to about 0.5% towards maturity. Accordingly, if samples were to be taken sometime in the middle of the plant growth, sampling time must be strictly specified to obtain consistent results. Even then, there were problems whether samples should be taken on the same date or on the some physiological stage of the rice plant when two sites of sampling were far from each other and/or varieties grown were different in growing period. Sampliling at harvest was free from the diffficulties mentioned above.

Only the straw was analysed as the nutrient contents of the rice grains were less affected by the change in the nutrient supply conditions of the soil and could therefore give much less information than those of the straw.

RESULTS AND DISCUSSION

Part I – 1976 results

Yield of paddy 1976 experiment in Ubon was shown in Table 1 and analysis of straw taken at harvest was shown in Table 2. The main effects of nitrogen, phosphorus and potassium on paddy yield were highly significant, and their interactions N × P, N × K, and P × K also proved significant. Accordingly, yield was shown in three tables.

In Ubon, shortage of phosphorus was the most acute, as no yield increase was obtainable without phosphorus application whatever rates of nitrogen and potassium. Nitrogen shortage came next and potassium followed. But, as indicated by significant interactions, limiting element changed with the formala of NPK applied.

For an analysis of the paddy straw, three treatments were taken to know nitrogen conditions.

Trt. No.	N	P_2O_5	K_2O	N% in straw
9	0	75	75	0.550
18	37.5	75	75	0.550
27	75	75	75	0.674

There should not have been any shortage of phosphorus and potassium during the growth of the rice plants in these treatments. This was corraborated by yield data in Table 1. Nitrogen in straw was 0.550% for both no-nitrogen and 37.5 kg nitrogen treatments and 0.674% for 75 kg nitrogen treatment. Apparently, critical level should be above 0.550%. Whether it should be above or below 0.674% could not be known from this experiment only.

Concerning the critical level of phosphorus the following three treatments were taken for consideration.

Trt. No.	N	P_2O_5	K_2O	P per cent in straw
21	75	0	75	0.034%
24	75	37.5	75	0.120%
27	75	75	75	0.166%

In this case, conclusion could be drawn quite clearly. With no phosphorus applied, plant snffered from acute shortage of phosphorus and P concentration in plant was as low as 0.034%. With 37.5 kg per hectare of P_2O_5 applied, yield increased significantly and P concentration in straw also increased to 0.120%. Further increase in phosphate application did not significantly increased yield. The critical concentration therefore must lie between 0.034% and 0.120%. But no more can be said from the present experiment.

Concerning critical percentage of potassium, the following three treatments were taken.

Trt. No.	N	P_2O_5	K_2O	K per cent in straw
25	75	75	0	0.429%
26	75	75	37.5	0.743%
27	75	75	75	1.235%

With no potash applied, plant suffered from severe shortage of potassium. At this point, plant had 0.429% K. Application of 37.5 kg of K_2O per hectare significantly increased the rice yield and straw had 0.743% K. Further application of potassium up to 75 kg per hectare, increased the yield significantly again and plant had 1.235% K. Critical concentration of K should be above 0.743%. But it was not known whether this was above or below 1.235%.

It was realized from this experiment that plants of all treatments had not to be analysed. Rather a certain number of plants in key treatments should be analysed and it was better to collect samples from as many places as possible, which was done in 1977. As key treatments, seven treatments were selected, as mentioned in the section of materials and methods.

Part II – 1977 results

Nitrogen

As can be known from yield data shown in Tables 3-1 to 3-5 and Figure 1, at Rangsit, Pattani and Ubon, an application of 37.5 kg of nitrogen in presence of enough of phosphorus and potassium (75 kg each of P_2O_5 and K_2O per hectare) significantly increased the rice yield. Increase in nitrogen application to 75 kg per hectare further increased the rice yield and trend of the response curve at these three stations suggested that further increase in nitro-

gen application say, 100 kg per hectare would increase the yield still further. Nitrogen content of straw at harvest at these stations were never exceeded 0.53%, which was presumed to be below the critical level because there was a good prospect of further increase in yield by the increase in nitrogen application.

At Phan, up to 37.5 kg. of nitrogen significantly increased the rice yield but further increase in nitrogen application to 75 kg per hectare did not increase the yield. Corresponding nitrogen content in straw were 0.50% for no nitrogen, 0.55% for 37.5 kg nitrogen and 0.65% for 75 kg nitrogen application. Critical concentration of nitrogen deduced from the result of this station should be between 0.50% and 0.55%.

At Kuan Gut, with no nitrogen applied, nitrogen concentration of straw was 0.55%, in presence of enough of phosphorus and potassium. In this station also, 0.55% should be around critical level, because nitrogen application increased the rice yield just a litttle, thought significant.

Tanaka and Yoshida (1970) stated that critical level of nitrogen content of rice plant at tillering stage was 2.5%. This was quite probable. As mentioned earlier, nitrogen content of rice plant was quite high at an earlier growth stage. Accordingly the critical level quoted was not contradict to the result obtained in this report. It was only a matter of sampling stage of the rice plant.

Available nitrogen content of the soils reported by Motomura (1973) was shown below. In agreement with the plant analysis and rice yield in this fertilizer experiment, Ubon, Rangsit and Pattani were low in available nitrogen content of the soil and in Kuan Gut and Phan, especially in the latter, vailable nitrogen content was high.

Sites	Available N, P_2O_5, K_2O (ppm) of soil		
	N	P_2O_5	K_2O
Ubon	10	3	28
Rangsit	20	12	302
Pattani	22	21	57
Kuan Gut	35	18	66
Phan	73	18	217

Phosphorus

From the yield data in Tables 3-1 to 3-2 and Figure 2, it could be known that application of 37.5 kg per hectare of P_2O_5 significantly increased the yield in all the stations except for Phan. Further increase in phosphorus application, however, did not increase the yield significantly in any of the five experiment stations. It seems plant requirement for phosphorus was met by the application of phosphorus at the rate of 37.5 kg per hectare.

Turning to phosphorus content in straw at harvest as shown in Table 4, when no phosphorus was applied, P content was 0.015%, 0.017%, 0.028% 0.042% and 0.140%, respectively, at Ubon, Pattani, Rangsit, Kuan Gut and Phan. As yield data suggest, except for Phan, rice plant suffered from phosphorus shortage under this conditions, so

P concentrations mentioned above must have been below the critical level. Percentages increased to, respectively, 0.070%, 0.074%, 0.077%, 0.113% and 0.149% when 37.5 kg per hectare of P_2O_5 was applied. All these percentages must have been above critical level of P content because further increase in phosphate fertilizer application did not result in any increase in rice yield. Accordingly, critical P level must lie between 0.042%, the highest for no P application and 0.070% the lowest for 37.5 kg P application. In all probability it should be much above 0.042%, because at this point, acute shortage was felt. It must be between 0.05% to 0.07%.

Tanaka and Yoshida (1970) stated that when the phosphorus content during vegetative growth was less than 0.2% P, phosphorus deficiency may be suspected and when less than 0.1 per cent, a deficient was very probable. They refer to tillering stage in which P percentage was much higher than that of the rice plant at harvest. Two critical levels were not contradictory.

Potash

As for potash, data were meagre but at Kuan Gut, potash application increased the yield significantly. And rice plant which received no potash fertilizer had a K content of less than 1%. At Pattani station, without K application, rice plant suffered incipient potassium deficiency, and K content was just about 1%. Ishizuka and Tanaka (1951) concluded from water culture experiment that 1% in terms of K_2O was the critical level. Tentatively, it was suggested that 1% K was the critical level.

As written in Part I, in 1976 significant response of potash was observed in Ubon. Plant analyses in 1977 clearly indicated high probability of potash deficiency. Soil analysis done by Motomura also indicated the possibility of potash deficiency (80–100 ppm of available potassium in soil was thought to be the critical level).

TABLE 1. Effect of N P K on the yield of rice at Ubon Experiment Station in 1976.

N-level (kg/ha)	P-level (kg/ha) 0	37.5	75	N means
0	888	1313	1569	1259
37.5	725	1850	1906	1494
75	838	2100	2331	1756
P means	819	1756	1938	

Comparison between	LSD.05	LSD.01
2 N - means by P-level or 2 P - means by N-level	281	381

N-level (kg/ha)	K-level (kg/ha) 0	37.5	75	N means
0	1206	1263	1306	1256
37.5	1319	1656	1506	1494
75	1413	1788	2069	1756
K means	1313	1569	1625	

LSDs for comparison are the same as above.

F value

SV	F
N	18.71**
P	108.19**
K	8.37**
N × P	6.25**
N × K	2.75*
P × K	2.85*
N × P × K	1.09ns

P-level (kg/ha)	K-level (kg/ha) 0	37.5	75	P means
0	844	725	811	819
37.5	1425	1906	1925	1756
75	1669	2075	2063	1938
K means	1313	1569	1625	

LSDs for comparison are the same as above.

TABLE 2. Analysis of straw taken at Ubon in 1976.

No.	Treatment (kg/ha)			Concentration of nutrients in straw				
	N	P_2O_5	K_2O	N%	P%	K%	Ca%	Mg%
1	0	0	0	0.521	0.031	0.762	0.326	0.146
2	0	0	37.5	0.547	0.030	1.273	0.305	0.110
3	0	0	75	0.500	0.037	1.394	0.303	0.095
4	0	37.5	0	0.566	0.115	0.786	0.391	0.134
5	0	37.5	37.5	0.498	0.106	1.172	0.373	0.110
6	0	37.5	75	0.531	0.119	1.394	0.369	0.109
7	0	75	0	0.614	0.142	0.585	0.414	0.156
8	0	75	37.5	0.527	0.128	1.133	0.363	0.111
9	0	75	75	0.550	0.136	1.428	0.375	0.097
10	37.5	0	0	0.671	0.024	0.514	0.313	0.129
11	37.3	0	37.5	6.585	0.029	1.026	0.350	0.097
12	37.5	0	75	0.503	0.025	1.240	0'304	0.077
13	37.5	37.5	0	0.673	0.149	0.458	0.413	0.109
14	37.5	37.5	37.5	0.575	0.129	1.124	0.398	0.132
15	37.5	37.5	75	0.575	0.123	0.312	0.391	0.117
16	37.5	75	0	0.691	0.167	0.333	0.420	0.114
17	37.5	75	37.5	0.575	0.136	1.047	0.404	0.116
18	37.5	75	75	0.550	0.140	1.394	0.435	0.102
19	75	0	0	0.840	0.038	0.424	0.336	0.128
20	75	0	37.5	0.712	0.027	1.090	0.319	0.097
21	75	0	75	0.625	0.034	1.201	0.320	0.097
22	75	37.5	0	0.783	0.149	0.270	0.414	0.106
23	75	37.5	37.5	0.684	0.125	0.796	0.398	0.096
24	75	37.5	75	0.706	0.120	1.355	0.408	0.104
25	75	75	0	0.889	0.184	0.429	0.396	0.096
26	75	75	37.5	0.749	0.179	0.743	0.408	0.099
27	75	72	75	0.674	0.166	1.235	0.406	0.100

TABLE 3. Effect of NPK on the yield of rice at Kuan Gut in 1977.

Yield (N × P means)

N	P 0	P 37.5	P 75	N means
0	1956	3250	3250	2806
37.5	2269	3269	3300	2981
75	2125	3475	3631	3131
P means	2106	3331	3394	

LSD. 05 200 LSD. 01 263

Yield (P × K means) kg/ha

K	P 0	P 37.5	P 75	K means
0	2050	3000	3275	2775
37.5	2138	3463	3294	3031
75	2138	3525	3613	3119

LSD. 05 194 LSD. 01 256 (P means given above)

F value	
N	3.68*
P	111.38**
K	5.56**
N × P	1.35ns
N × K	<1
P × K	1.68ns
N × P × K	<1
CV (%)	13.7

TABLE 3.2 Effect of NPK on the yield of rice at Rangsit in 1977.

N	P 0	P 37.5	P 75	N means
0	1969	2900	2981	2619
37.5	2831	4166	4300	3763
75	2788	4913	4906	4200
P means	2531	3988	4063	

LSD. 05 388 LSD. 01 513

F value	
N	105.34**
P	117.59**
K	<1
N × P	5.91**
N × K	<1
P × K	<1
N × P × K	1.05ns
CV (%)	13.6

TABLE 3.3 Effect of NPK on the yield of rice at Pattani in 1977.

N	P 0	P 37.5	P 75
0	1519	2363	2788
37.5	2088	3144	3325
75	2056	3894	3988

LSD. 05 219 LSD. 01 288

N	K 0	K 37.5	K 75
0	2319	2181	2163
37.5	2856	2788	2913
75	3113	3325	3494

LSD. 05 219 LSD. 01 288

F value	
N	148.43**
P	314.03**
K	1.47ns
N × P	12.70**
N × K	3.30*
P × K	<1
N × P × K	1.89ns
CV (%)	9.6

TABLE 3.4 Effect of NPK on the yield of rice at Phan in 1977.

N	KO			K37.5			K75			N means
	PO	P37.5	P75	PO	P37.5	P75	PO	P37.5	P75	
0	2275	2381	2338	2394	2275	2265	2269	3288	2825	2369
37.5	3050	2650	2650	2738	2863	2656	2763	2681	2813	2763
75	2569	2706	2844	2594	2919	3013	2988	2713	2781	2794

LSD. 05 375 LSD. 01 494

F value	
N	28.74**
P	<1
K	<1
N × P	1.37ns
N × K	<1
P × K	1.21ns
N × P × K	2.23*

TABLE 3.5 Effect of NPK on the yield of rice at Ubon in 1977.

N	P		
	0	37.5	75
0	913	1175	1306
37.5	906	1688	1713
75	1175	2263	2038

LSD. 05 250 LSD. 01 325

F value	
N	47.59**
P	63.16**
K	<1
N × P	5.84*
N × K	<1
P × K	<1
N × P × K	<1
CV (%)	20.7

TABLE 4. NPK percentages in straw at harvest.

K% in straw with varied K supply

	N (kg/ha)			F value of fertilizer expt.
	0	37.5	75	N main effect
Kuan Gut	0.55	0.59	0.62	3.68*
Radgsit	0.41	0.45	0.52	105.36**
Pattani	0.39	0.41	0.53	148.43**
Phan	0.50	0.55	0.65	28.74**
Ubon	0.38	0.46	0.49	47.59**

P% in straw with varied P supply

	P_2O_5 (kg/ha)			P main effect
	0	37.5	75	
Kuan Gut	0.042	0.113	0.184	111.38**
Rangsit	0.028	0.077	0.109	117.59**
Pattani	0.017	0.074	0.114	314.03**
Phan	0.140	0.149	0.141	<1
Ubon	0.015	0.070	0.140	63.16**

N% siraw with varied N supply

	K_2O (kg/ha)			K main effect
	0	37.5	75	
Kuan Gut	0.084	1.169	1.378	5.56**
Rangsit	1.756	1.962	1.944	<1
Pattani	1.003	1.306	1.412	1.47 (N × K)*
Phan	2.056	2.134	2.175	<1 (NPK)*
Ubon	0.406	0.975	1.200	<1

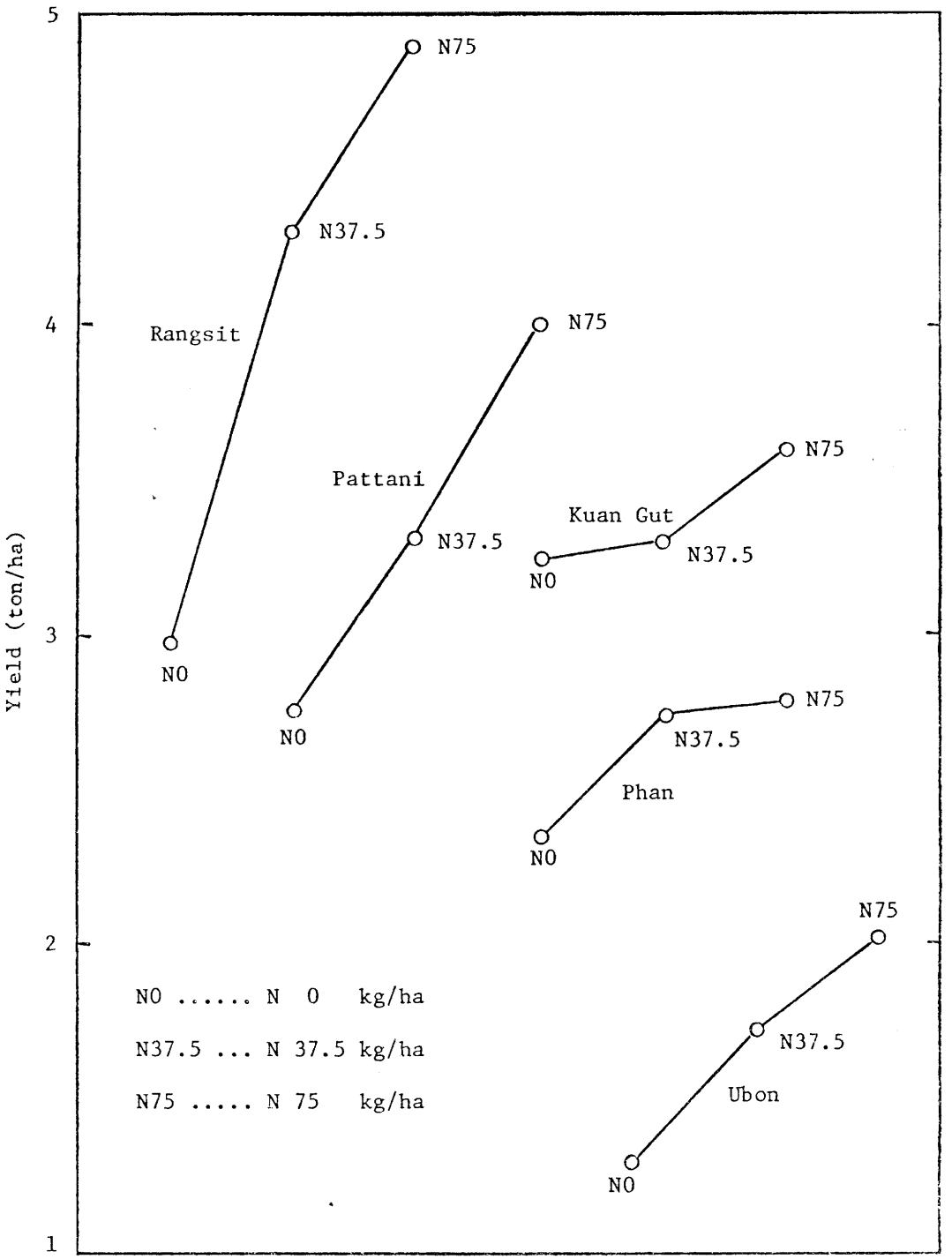

Figure 1. Response to nitrogen in presence of enough P and K.

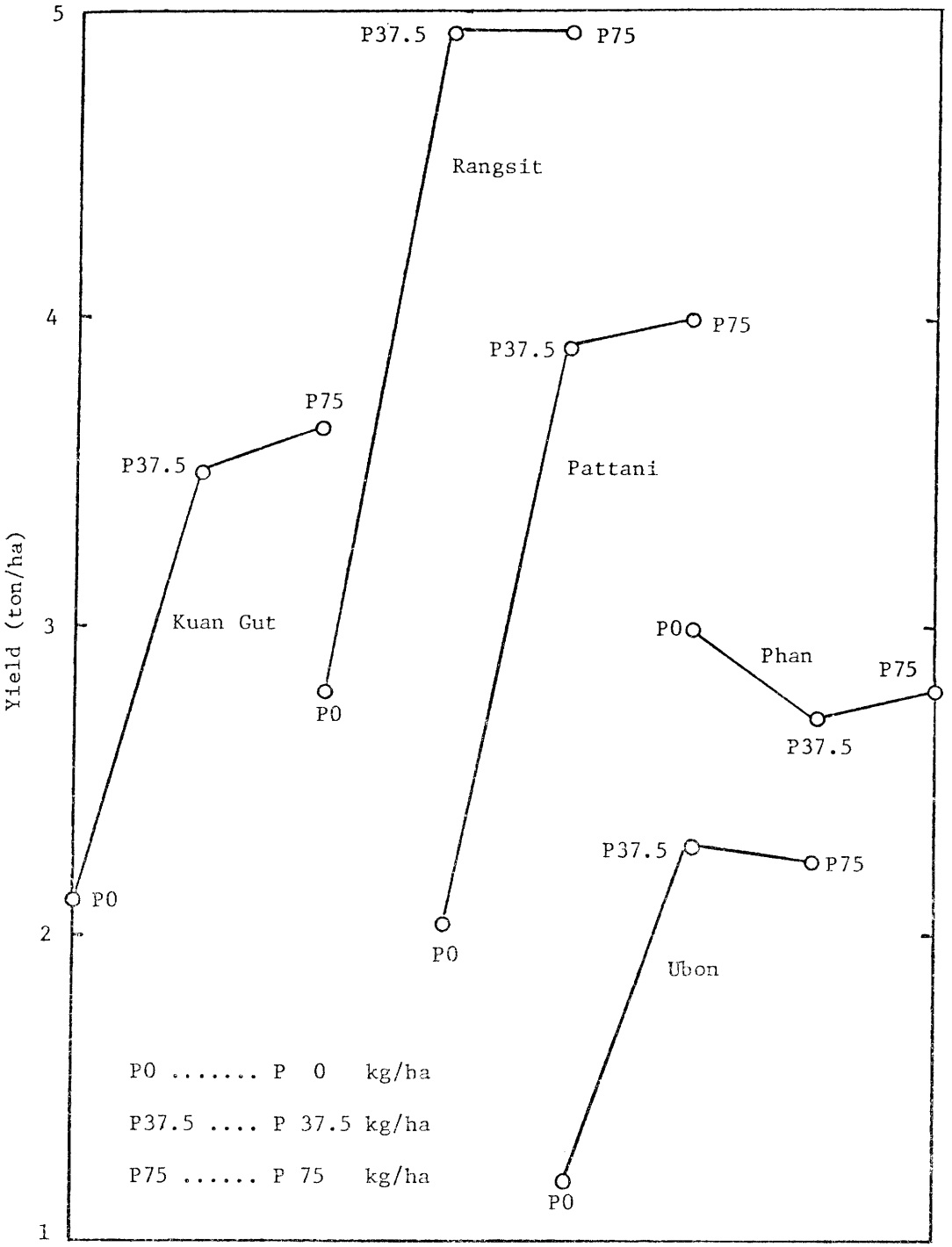

Figure 2. Response to phosphorus in presence of enoug N and K.

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