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ABSTRACT

It was observed by the authors that the potential deficiency of phosphorus may be widely distributed throughout all paddy fields of Thailand, and that the response of plants to phosphorus deficiency might be different with varieties. Therefore, two varieties, Dawk Mali 3, which shows high phosphorus content, and Muey Nawng 62 M, which has extremely low phosphorus content, were selected and compared under the condition of phosphorus deficiency. A striking difference in growth and yield was found: Muey Nawng 62 M failed to produce any grain, whereas Dawk Mali 3 yielded 1 ton/ha of paddy.

The tracer experiment using ^{32}P revealed that Dawk Mali 3 is capable of absorbing soil phosphorus much more efficiently than Muey Nawng 62 M. As far as the authors know, such a varietal difference in the response to phosphorus deficiency caused by the difference in the ability of variety to utilize soil phosphorus has not yet been reported in the world.

The authors believe that this finding is very significant in Thailand where phosphorus deficient soil is distributed very widely throughout the country.

CONTENTS

INTRODUCTION

It is known that different species of plants or different varieties of a species often show marked differences in the resistance to phosphorus deficiency when grown in soil of low phosphorus availability. Many studies indicate that such differences in the resistance to phosphorus deficiency could be attributed to the difference in their ability to absorb phosphorus from soil phosphate in the form of low availability.

However, as far as the authors know, such kind of varietal difference has not yet been reported in the world with the rice plants. Since large areas showing phosphorus deficiency are widely distributed in Thailand, it must be a very important problem to find out the varietal difference of rice in the resistance to phosphorus deficiency and to utilize it for practical purpose.

The authors selected two varieties, Dawk Mali 3 which shows a high phosphorus content, and Muey Nawng 62M showing an extremely low phosphorus content, and carried out the present studies to find out the varietal difference in plant response to phosphorus deficiency of soil.

Acknowledgement

The authors are greatly indebted to and wish to express sincere thanks to Dr. Sala Dasanandana, former Director-General of the Rice Department, Dr. Bhakdi Lusanandana, Director-General of the Department of Agriculture, Dr. Prakob Kanjanasoon, Deputy Director-General of the Department of Agriculture, and Mr. Sombhot Suwanawong, Chief of the Technical Division of the Department, for their generous support and encouragement.

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I. Varietal Difference of Rice in Absorbing Phosphorus from the Soil of Low Phosphorus Availability

Varietal differences in the tolerability to phosphorus deficiency has not so far been reported with rice plants, although some varieties of barley are known to show a strong tolerability to phosphorus deficiency.

FUJIWARA[1] suggested a possibility of varietal differences of japonica rice in utilizing phosphorus from less-soluble phosphate compounds, but more detailed experimental evidences are definitely needed to justify this.

Tropical rice growing conditions are such that phosphorus deficient soils are widely distributed and almost all farmers grow rice with meagre fertilizers. Yet the ranges of varietal differences in growth are very wide indeed. Based on this fact the authors assumed a possibility of existing the varietal differences in the tolerability to phosphorus deficiency in soil, and paid special attention to the varietal differences in phosphorus content of rice plants grown under the same environmental conditions. The authors found that among the recommended local varieties of Thailand, Muey Nawng 62M has remarkably lower content of phosphorus, while Dawk Mali 3 has higher phosphorus content as compared with other varieties as shown in Fig. 1.

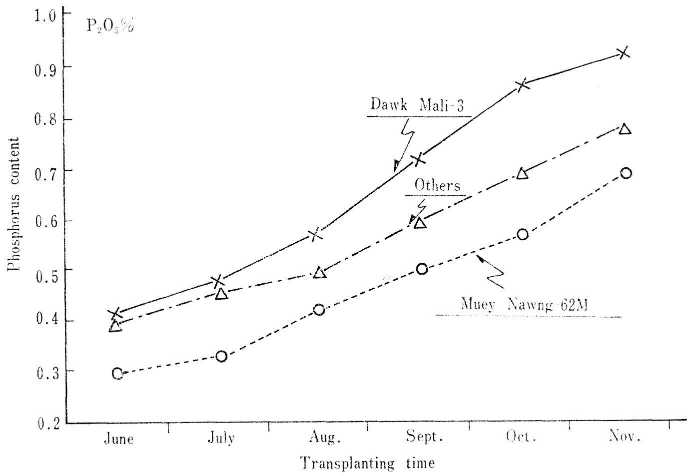


Fig. 1. Varietal difference in phosphorus content

Two alternative interpretations can be attributed to that finding. First, the variety which has high phosphorus content is tolerant to the phosphorus deficiency in soil owing to a high ability to absorb phosphorus from soil. Second the variety with low phosphorus content is tolerant due to low physiological requirement for phosphorus. The following field experiments were conducted to clarify this point.

METHOD

1) Location of experiment:

The experiment was conducted in the paddy field of Klong Luang Rice Experiment Station in Thailand.

2) Characteristics and properties of soil:

The soil of this experimental field belongs to the series of Ongkarak clays, with marked profile development, and is very acidic.

Fertilizer tests so far conducted indicate that this soil lacks nitrogen as well as phosphorus or at least they are not in available form, and larger doses of phosphorus seemed to show no appreciable residual effect in the succeeding crop years.

Mechanical and chemical properties of soil are given in Table 1. The soil is characterized by extremely high clay content, low content of total nitrogen and available phosphorus, low pH and considerably high absorption coefficient of phosphorus. As a result, rice plants growing on the soil suffer easily from phosphorus deficiency.

Table 1. Chemical properties of Klong Luang soil

pH	(H_2O)	4.5
	(KCl)	3.6
Organic matter		2.45 %
C.E.C.		20.0 me/100g D.S.
Exchangeable	Ca	9.60 me/100g D.S.
	Mg	4.64 〃
	K	0.43 〃
	Na	1.00 〃
Available Phosphorus	P_2O_5*	4.7 ppm
Total 〃	〃	296 〃
Phosphorus absorption coefficient		1039 mg/100g D.S.
Texture	Sand	18.43 %
	Silt	31.65 〃
	Clay	49.92 〃

* Bray & Kurz No. 2

3) Varieties:

1) Muey Nawng 62 M, glutinous, photoperiod sensitive, recommended local variety in Thailand.

2) Dawk Mali 3 non-glutinous, photoperiod sensitive, recommended local variety in Thailand.

4) Spacing: 20×20 cm

5) Number of seedlings: three per hill

6) Treatment of fertilizer application:

As shown in Table 2, treatment plots receiving five different levels of phosphorus application, ranging from 0 to 150 kg/ha were set up, with equal amount of nitrogen and potassium for all plots. Fertilizers were applied one day before transplanting as a surface application and chemical form of dressed fertilizers was as follows: N as ammonium sulphate, P_2O_5 as superphosphate, K_2O as potassium sulphate.

Table 2. **Design of field experiment**

Variety	No.	Basal-dressing (kg/ha) N	P_2O_5	K_2O	Top-dressing (kg/ha) N
Muey Nawng 62 M	M-0	37.5	0	75	37.5
	M-1	37.5	25	75	37.5
	M-2	37.5	50	75	37.5
	M-3	37.5	75	75	37.5
	M-4	37.5	150	75	37.5
Dawk Mali 3	D-0	37.5	0	75	37.5
	D-1	37.5	25	75	37.5
	D-2	37.5	50	75	37.5
	D-3	37.5	75	75	37.5
	D-4	37.5	150	75	37.5

7) **Transplanting time:** 15th of August, 1968.

8) **Plant protection:**

Neccessary sprayings to profect the crop against disease and insects pests were conducted.

9) **Replications:** Four times.

10) **Area of one plot:** 25 m^2 (5 m $\times$ 5 m).

11) **Sampling:**

Plant samples were taken at tillering stage, panicle primordia initiation stage, flowering and harvesting stage.

12) **Growth analysis:**

Plant height and number of tillers were measured immediately after sampling and weight of dry matter were determined after drying the samples.

13) **Chemical analysis:**

At least 10 hills of samples were subject to chemical analysis, and methods of analysis were as follows;

Digestion: Wet combustion using $HClO_4$, and H_2SO_4.
Nitrogen: Semimicro Kjeldahl distillation method.
Phosphorus: Ammonium vanadomolybdate method.
Potassium: Dr. Lange's flame photometer at the wave length of 768 mμ.
Iron: O-phenanthroline method.
Silica: Gravimetric method.

RESULTS

A) Growth of plants

On account of the properties of the soil of this experimental field, the growth of rice plants was markedly affected by dressing of phosphorus. (Table 3).

1) Plant height

As shown in Fig. 2, there was no difference in plant height between two varieties throughout their growth except in the no-phosphorus plots where Muey Nawng 62 M was shorter than Dawk Mali 3 because the former suffered much more than the latter from phosphorus deficiency. This difference between two varieties was clearly observed in the middle or later stage of growth. At the stages of flowering and harvesting, for example, Muey Nawng 62 M

Table 3. Plant growth at successive stages of growth

Variety	Treatment	Tillering stage (20/Sept.) Height cm	Tiller number/hill	Dry matter g/hill	Initiation panicle primordia (9/Oct.) Height cm	Tiller number/hill	Dry matter g/hill
Muey Nawng 62 M	M-0	50	2.3	0.7	45	1.9	0.50
	M-1	59	5.2	2.4	70	5.8	5.4
	M-2	61	6.9	3.5	79	6.7	8.5
	M-3	65	5.7	4.3	79	7.9	8.2
	M-4	65	7.1	4.7	76	6.5	7.8
Dawk Mali 3	D-0	56	2.6	1.3	62	3.2	2.7
	D-1	60	8.7	5.7	75	6.3	8.0
	D-2	63	9.3	6.3	78	9.2	10.0
	D-3	62	9.1	6.3	79	9.0	10.4
	D-4	59	7.5	4.6	76	6.7	8.4

Variety	Treatment	Flowering stage (30/Oct.) Height cm	Tiller number/hill	Dry matter g/hill	Harvesting time (3/Dec.) Height cm	Tiller number/hill	Dry matter g/hill
Muey Nawng 62 M	M-0	48	1.9	0.74	53	1.7	1.09
	M-2	118	6.2	13.9	148	4.5	30.5
	M-3	137	7.7	19.1	156	5.0	26.9
	M-4	130	6.8	20.8	149	3.9	18.6
	M-5	139	8.5	28.2	152	4.8	23.4
Dawk Mali 3	D-0	105	3.5	8.7	106	4.2	8.68
	D-1	132	6.8	16.6	141	7.1	23.9
	D-2	137	8.8	24.7	148	7.6	23.6
	D-3	144	10.1	32.3	154	6.6	24.1
	D-4	144	11.5	26.6	141	6.4	21.9

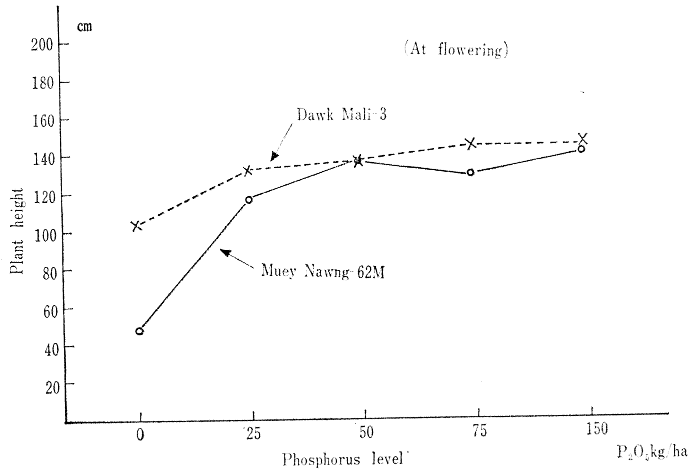


Fig. 2. Plant height

showed only half of the stature of Dawk Mali 3, though in other plots plant height of the two varieties was the same. It was observed that the height of Muey Nawng 62 M in the no phosphorus plot was retarded in an early stage without further increase, while Dawk Mali 3 was able to continue its growth.

2) Number of tillers

It is generally known that phosphorus deficiency induces a retardation of tillering.

Table 3 and Fig. 3 shows that the tillering was reduced extremely with a shortage of phosphorus with both varieties, but Dawk Mali 3 produced always more tillers than Muey Nawng 62 M. This difference may be due to a varietal difference in tillering.

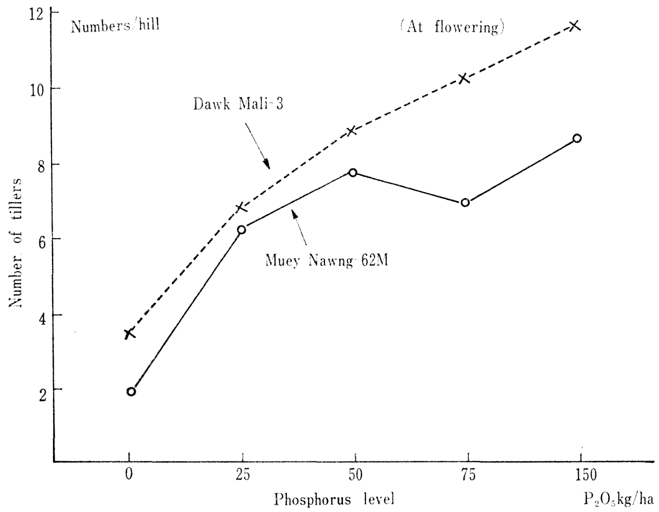


Fig. 3. Number of tillers

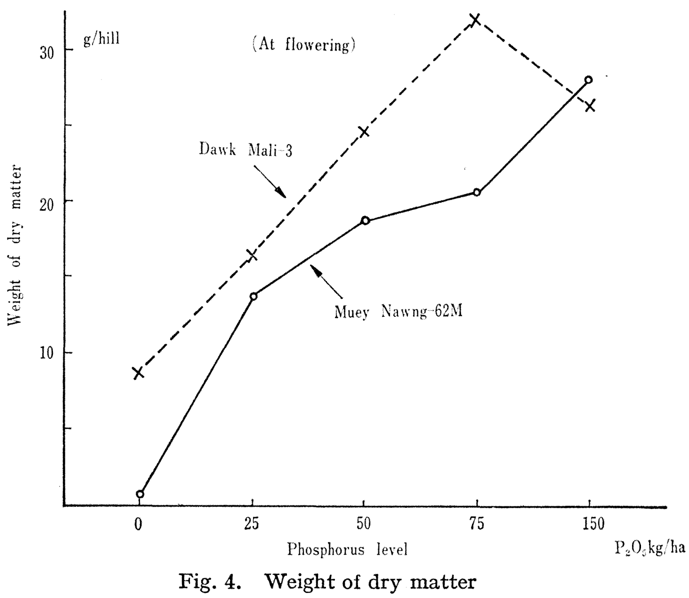


Fig. 4. Weight of dry matter

3) Weight of dry matter

Weight of dry matter is increased in accordance with increasing doses of phosphorus as shown in Fig. 4.

At low levels of phosphorus application, weight of dry matter increased almost in parallel to the increase of phosphorus application suggesting that the rate of 25 P_2O_5 kg/ha was still insufficient for normal plant growth, notwithstanding the fact that the symptom of phosphorus deficiency was not evident.

B) Nutrient content (Table 4)

1) Nitrogen

No marked varietal difference in nitrogen content between the two varieties was observed. Treatments of no-phosphorus, however, showed higher nitrogen content, as shown in Fig. 5.

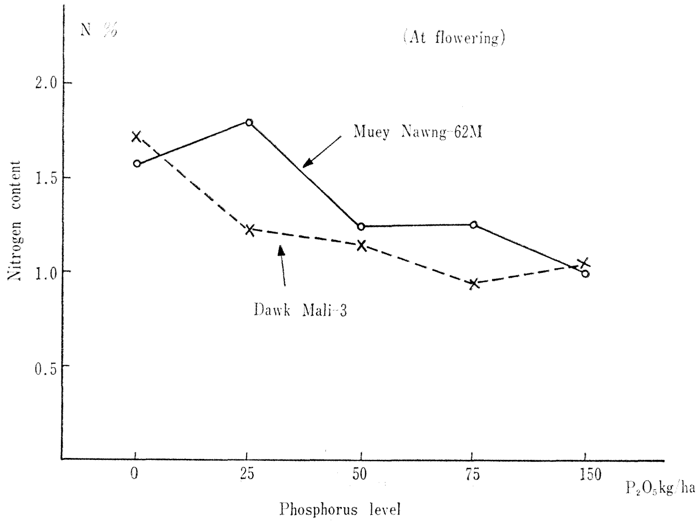


Fig. 5. Nitrogen content

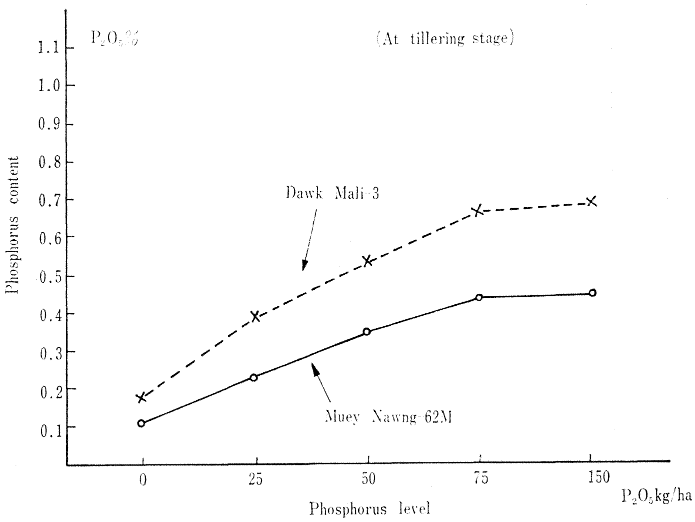


Fig. 6. Phosphorus content

Table 4. Nutrient content and absorption at successive stages of growth

(Variety: Muey Nawng 62 M)

Growth stage	Treat-ment	N		P_2O_5		K_2O		Fe		SiO_2 %	
		%	mg/hill	%	mg/hill	%	mg/hill	%	mg/hill	%	mg/hill
Tilleri g stage (20/Sept.)	M-0	1.57	11	0.11	0.8	2.27	16	0.15	0.1	9.7	68
	M-1	1.79	43	0.23	5.5	2.96	71	0.06	0.1	7.6	181
	M-2	1.24	43	0.35	12.3	3.34	117	0.04	0.1	7.1	250
	M-3	1.24	53	0.44	18.9	3.28	141	0.03	0.1	6.3	270
	M-4	1.01	48	0.45	21.2	2.94	138	0.03	0.1	6.7	316
Initiation panicle primordia (9/Oct.)	M-0	1.50	7.5	0.12	0.6	1.68	8.4	0.22	1.1	10.6	53
	M-1	1.06	56.7	0.27	14.4	3.07	165	0.04	2.3	7.6	411
	M-2	0.83	70.3	0.48	41.1	2.94	249	0.04	3.1	6.8	580
	M-3	1.00	82.0	0.46	37.6	2.86	234	0.03	2.4	7.2	590
	M-4	0.83	64.7	0.57	44.2	2.72	212	0.03	2.6	7.4	577
Flowering stage (30/Oct.)	M-0	1.59	11.8	0.06	0.4	1.78	13.2	0.16	1.2	12.1	90
	M-1	1.10	152.9	0.18	25.0	2.34	327	0.02	2.8	6.9	959
	M-2	0.81	154.7	0.30	57.3	2.21	422	0.02	3.8	5.9	1127
	M-3	0.90	187.2	0.35	72.8	2.30	478	0.02	4.2	6.3	1310
	M-4	0.78	220.0	0.50	141	2.31	651	0.02	5.6	6.4	1805
Harvesting time (3/Dec.)	M-0	1.48	16.1	0.18	2.0	0.47	5.1	0.05	0.5	10.6	116
	M-1	1.01	243.3	0.17	50.7	1.10	335	0.04	13.0	6.8	2087
	M-2	0.72	193.9	0.22	59.3	1.45	390	0.04	11.6	7.5	2010
	M-3	0.68	127.0	0.29	53.7	1.85	344	0.04	7.4	7.5	1386
	M-4	0.83	193.2	0.36	85.1	1.33	312	0.04	10.4	—	—

(Variety: Dawk Mail 3)

Growth stage	Treat-ment	N %	N mg/hill	P_2O_5 %	P_2O_5 mg/hill	K_2O %	K_2O mg/hill	Fe %	Fe mg/hill	SiO_2 %	SiO_2 mg/hill
Tillering stage (20/Sept.)	D-0	1.73	32	0.18	2.3	2.43	32	0.17	0.2	8.0	103
	D-1	1.23	70	0.39	22.2	3.18	181	0.04	0.2	7.1	407
	D-2	1.15	62	0.54	34.1	3.24	204	0.02	0.1	6.0	381
	D-3	0.95	60	0.67	42.3	2.98	188	0.02	0.1	6.1	381
	D-4	1.06	49	0.69	31.8	2.90	133	0.04	0.2	6.6	305
Initiation panicle primordia (9/Oct.)	D-0	1.57	42.5	0.18	4.9	2.70	73	0.06	1.5	6.0	162
	D-1	0.85	68.3	0.41	32.4	2.65	212	0.04	3.0	6.9	553
	D-2	0.73	72.6	0.54	54.0	2.73	273	0.02	1.6	6.5	647
	D-3	0.81	84.6	0.65	67.1	2.52	261	0.02	2.1	6.5	676
	D-4	0.78	65.2	0.68	57.5	2.61	219	0.02	1.6	6.2	523
Flowering stage (30/Oct.)	D-0	1.25	108.8	0.11	9.6	2.38	207	0.01	0.9	6.1	531
	D-1	1.05	174.3	0.18	29.9	2.38	395	0.02	3.3	7.0	1162
	D-2	0.83	205.0	0.35	86.5	2.32	573	0.02	4.9	7.0	1729
	D-3	0.86	277.8	0.43	139	2.42	782	0.02	6.5	7.1	2293
	D-4	0.97	258.0	0.67	178	2.61	694	0.02	5.3	6.4	1702
Harvesting time (3/Dec.)	D-0	1.36	117.9	0.12	12.7	0.76	66	0.04	3.2	7.9	685
	D-1	0.91	218.1	0.16	38.4	1.36	324	0.02	5.9	6.8	1630
	D-2	0.89	209.8	0.29	67.7	1.64	387	0.03	7.1	8.3	1965
	D-3	0.78	188.5	0.40	97.0	1.70	410	0.04	9.7	5.7	1384
	D-4	0.73	159.1	0.46	100.4	1.56	341	0.03	6.7	7.3	1589

2) Phosphorus

Phosphorus content in plants was clearly increased by increasing doses of phosphorus. As shown in Fig. 6, plants of no-phosphorus plots contained as low as 0.1~0.2 P_2O_5 % at the tillering stage. At this stage, plants developed clear symptom of phosphorus deficiency when phosphorus content was less than around 0.3%. Field observation revealed that Muey Nawng 62 M suffered severely from phosphorus shortage in the treatment of 0, and 25 P_2O_5 kg/ha, while, Dawk Mali 3 did not show phosphorus deficiency except in the no-phosphorus plot. As to the varietal difference, Muey Nawng 62 M always showed lower phosphorus content than Dawk Mali 3. This varietal difference was conspicuous, especially in the early stage of growth, and the difference became gradually smaller in the later stage, as shown in Fig. 7.

3) Potassium

In contrast to the phosphorus content, there is no appreciable difference either between treatments or between varieties throughout the growth as shown in Fig. 8.

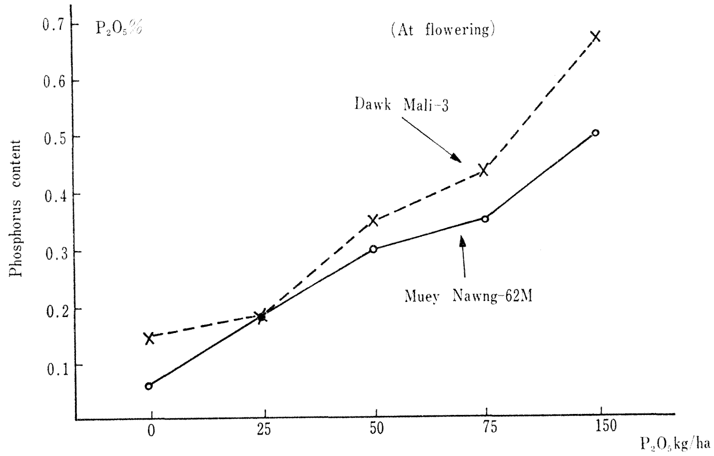


Fig. 7. Phosphorus content

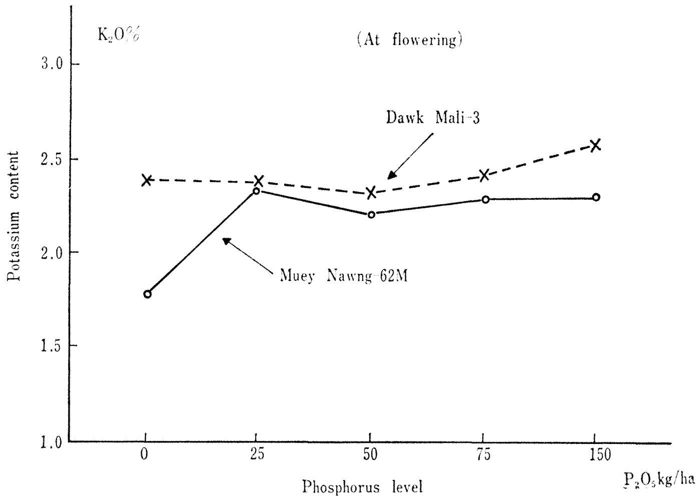


Fig. 8. Potassium content

4) Iron

It is known that iron absorbed by plants exerts a physiological interaction with phosphorus. It is said that a variety having high iron content is liable to be suffered from phosphorus deficiency because iron combines with phosphorus in the plant and changes it into an inactive form. The result shown in Fig. 9 presents an interesting fact that plants grown without phosphorus application have high percentages of iron. It is very likely that the phosphorus shortage disturbed a normal metabolism of iron in the plant resulting in a striking accumulation of iron. However no varietal differences in iron content was observed.

C) Nutrient absorption

From the data on dry matter and contents of nitrogen and potassium it can be said that the absorption of these two nutrients proceeded just following the increase of dry matter. However, a dramatic difference in phosphorus uptake was found between the two varieties. Amounts of phosphorus absorbed by Dawk Mali 3 was far more than that of Muey

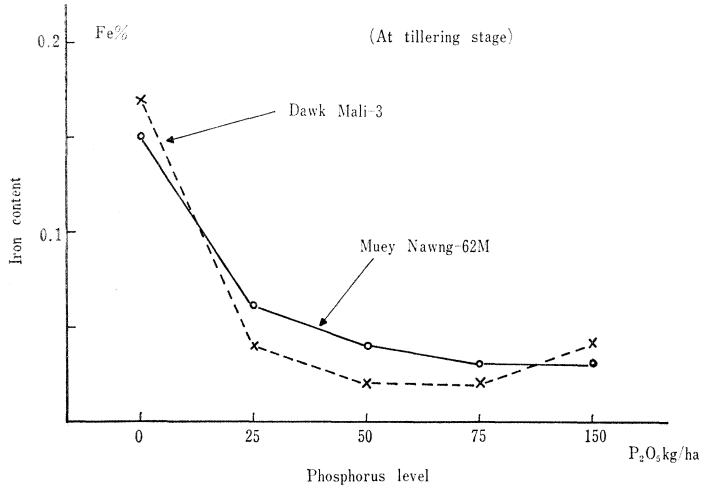


Fig. 9. Iron content

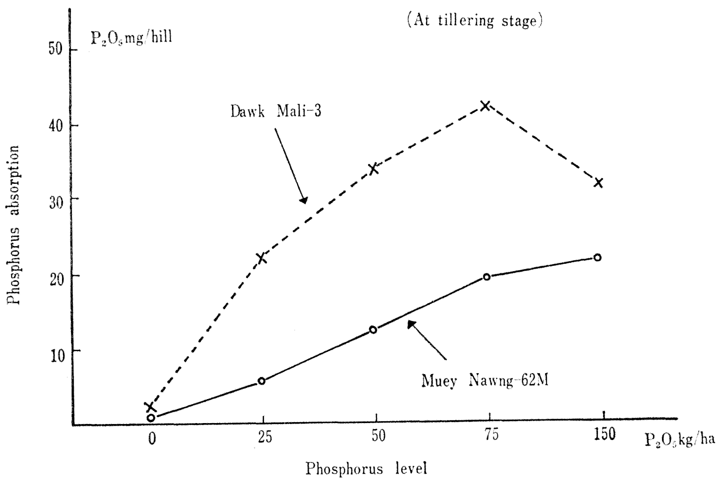


Fig. 10. Phosphorus absorption

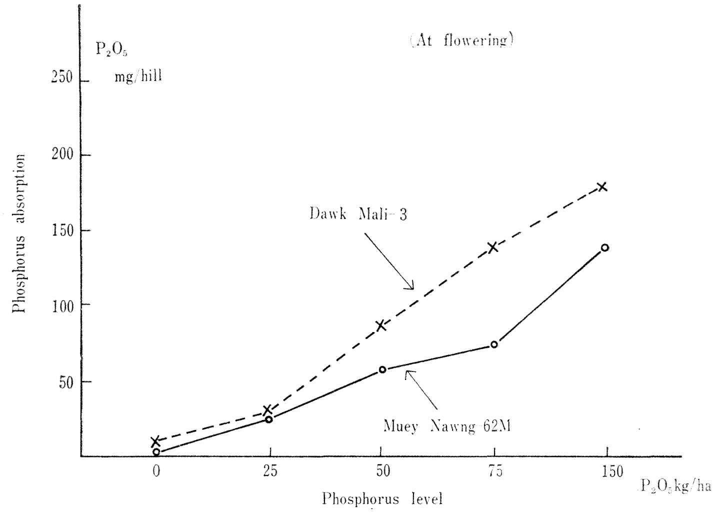


Fig 11. Phosphorus absorption

Table 5. Paddy yield and dry weight of straw at different levels of phosphorus application t/ha

Variety	Treatment $N-P_2O_5-K_2O$ (kg/ha)	Rep. I Grain	Rep. I Straw	Rep. II Grain	Rep. II Straw	Rep. III Grain	Rep. III Straw	Rep. IV Grain	Rep. IV Straw	Mean Grain	Mean Straw
Muey Nawng 62 M	75- 0 -75	0.01	0.12	0.05	0.28	0.07	0.36	0.03	0.24	0.04	0.25
	75- 25-75	1.44	2.66	2.10	3.68	1.27	2.56	1.41	2.66	1.56	2.89
	75- 50-75	2.11	3.36	2.37	3.64	1.81	3.06	2.21	3.64	2.13	3.43
	75- 75-75	1.92	3.28	2.15	3.68	2.10	2.52	2.18	3.92	2.09	3.35
	75-150-75	2.02	3.08	2.22	3.48	1.97	3.12	2.41	5.04	2.16	3.68
Dawk Mali 3	75- 0 -75	0.64	1.06	0.48	0.80	1.92	2.48	0.38	0.72	0.86	1.27
	75- 25-75	1.97	2.38	2.35	2.94	1.89	2.48	2.22	3.04	2.11	2.71
	75- 50-75	2.37	3.10	1.92	3.20	1.66	2.86	3.39	3.40	2.34	3.14
	75- 75-75	2.38	2.98	2.65	3.08	2.48	3.16	2.47	3.04	2.50	3.07
	75-150-75	2.26	2.70	2.28	2.80	2.15	2.80	2.64	3.16	2.33	2.87

Nawng 62M, Figure 10 shows that two times as much phosphorus was absorbed by Dawk Mali 3 as compared to Muey Nawng 62M at tillering stage. The difference became smaller in the later stage of growth as shown in Fig. 11.

Data on nutrient content and uptake are compiled in Table 4.

D) Grain yield

As shown in Table 5 no difference in grain yield between Muey Nawng 62M and Dawk Mali 3 was found with the liberal application of phosphorus. But, when phosphate supply became in short Dawk Mali 3 outyielded Muey Nawng 62M by far, because Muey Nawng 62M suffered much more than Dawk Mali 3 from phosphorus shortage.

The difference between two varieties was conspicuous when phosphorus was not dressed at all; Dawk Mali 3 yielded around 0.9 t/ha of paddy whereas Muey Nawng 62M as low as 0.04 t/ha.

DISCUSSION

The result of this research furnished a very clear experimental evidence that a varietal difference of rice in the resistance to phosphorus deficiency actually exists. Furthermore, it was found that Dawk Mali 3, a resistant variety, is highly able to absorb more phosphorus than other variety does, with a result of high phosphorus content in the plant especially at the tillering stage. At the phosphorus content below around 0.3% typical symptoms of phosphorus deficiency develop; dull or dark bluish green color, thin stalks, small leaves, and retarded lateral growth, as illustrated in the photograph. At the tillering stage, Muey Nawng 62M showed leaf yellowing and premature defoliation, beginning first with lower leaves when phosphate was not applied at all. By contraries, Dawk Mali 3 did not exhibit such a serious symptom as shown in the picture.

With the treatment of 25 P_2O_5 kg/ha, Muey Nawng 62M was suffered slightly from phosphorus deficiency in early stage of growth and then recovered in later stages, but Dawk Mali 3 did not exhibit any symptom of phosphorus deficiency. Thus, with a small dose of phosphorus, varietal difference in the tolerability to the phosphorus deficiency was still observed in early and middle stage of growth.

In all cases, Dawk Mali 3 was superior not only in dry matter production but also in content of phosphorus, suggesting that Dawk Mali 3 has a strong ability to absorb phosphorus from soil.

It is conceivable that the soil used in this experiment has a strong holding power of phosphorus, and as a result phosphorus applied to this soil is easily and quickly turned into less available or unavailable forms. FUJIWARA suggested a possibility of the varietal difference in the ability to utilize phosphorus from less available phosphorus sources in soil. The present research has offered an experimental evidence to his suggestion. OKAJIMA[2] clarified that iron absorbed by plants is combined with phosphorus and depresses the physiological function of phosphorus. However, the varietal resistance found by the authors can not be explained by that iron-phosphorus relationship, because there was no significant difference in iron content between two varieties at different levels of phosphorus supply.

SUMMARY

It was found that when heavy dose of phosphorus was applied there was no difference between Muey Nawng 62M and Dawk Mali 3. But when phosphorus supply was short, Muey Nawng 62M suffered much more than Dawk Mali 3 from phosphorus shortage. The difference between two varieties was very conspicuous when phosphorus was not dressed at all. A field experiment was carried out at the Klong Luang Rice Experiment Station to know the varietal difference in plant response to phosphorus deficiency using two local indica varieties, Dawk Mali 3 and Muey Nawng 62 M.

The result indicates very clearly that the varietal difference in the resistance to phosphorus deficiency actually exists. Without phosphorus application, Dawk Mali 3 yielded around 0.9 ton/ha of paddy while Muey Nawng 62 M obtained as low as 0.04 tons/ha. The resistance of Dawk Mali 3 to phosphorus deficiency was found to be caused by its high phosphorus absorption ability.

This kind of varietal difference of rice plants has not so far been reported. The result of this experiment furnishes a very clear experimental evidence on the varietal difference in

the resistance to phosphorus deficiency.

Phosphorus deficient soil are widely distributed in Southeast Asia and almost all the farmer grow rice without applying fertilizer. Accordingly, under the present conditions of rice growing in Southeast Asia, the practical use of the varietal difference in soil phosphorus utilization should be an important problem.

II. Soil Solution Experiment

Recent advancements in researches[3] on the soil-plant relationship indicate that the availability of nutrient elements depends on both the intensity factor and the capacity factor of the pertinent nutrient elements in the soil. Generally, the intensity factor of phosphorus in the soil can be expressed roughly as the concentration of phosphorus in soil solution, and the capacity factor as total available phosphorus in the soil. The intensity factor is influenced by the application of water soluble phosphorus fertilizer to the soil, while the capacity factor depends on the soil fertility concerning phosphorus that continues to replenish phosphorus in the soil solution.

Thus, these two factors determine the phosphorus availability. An experiment using the soil solution techniques was carried out to examine further the varietal difference found in the feeding power between Muey Nawng 62 M and Dawk Mali 3.

METHOD

1) Design of experiment

The experiment was conducted by pot soil culture method designed as shown in Table 6.

Phosphorus was added at 7 graded levels from 0.001 to 2.0 P_2O_5 g/pot, with the presence of 2.0 g/pot each of N and K_2O in 10 kgs. of Klong Luang soil. Fertilizers were mixed thoroughly with the soil prior to transplanting.

Three 30 day-old seedlings were transplanted to each pot on 20th August. Similar to the previous experiment, two photoperiod-sensitive local rice varieties were used. Dawk Mali 3 which has a stronger tolerability to phosphorus deficient soil and Muey Nawng 62M which is less tolerant. Three replicates were used.

2) Method of soil solution experiment

a. Preparation of soil solution

Fresh soil was taken into centrifugal tube, and centrifuged it for 10 minutes at 10000 r.p.m. The supernatant was taken into sampling bottle. Soil solution thus obtained was stored in refrigerator for use.

Table 6. Design of fertilizer application

No.	N g/pot	P_2O_5 g/pot	K_2O g/pot
1	2.0	0.001	2.0
2	〃	0.01	〃
3	〃	0.05	〃
4	〃	0.1	〃
5	〃	0.5	〃
6	〃	1.0	〃
7	〃	2.0	〃

b. Procedure for phosphorus determination

Phosphorus in soil solution was determined by Stannous oxalate method.

RESULTS

A) Effect of phosphorus application on the concentration of phosphorus in the soil solution of Klong Luang paddy field soil.

As Klong Luang soil has strong holding power to phosphorus, applied fertilizer phosphorus was largely and quickly converted into a insoluble form.

As shown in Fig. 12, the phosphorus concentration in soil solution increased with the increasing phosphorus dose, however, the increase was very little as compared with other soils.

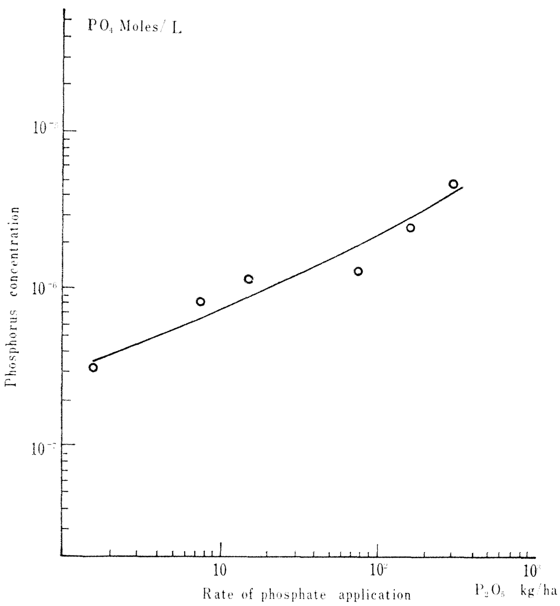


Fig. 12. Effect of phosphorus application on the concentration of phosphorus in the soil solution of Klong Luang soil

B) Change in the phosphorus concentration in soil solution during the plant growth.

The levels of phosphorus concentration in the soil solution showed a close relation to the doses of phosphorus application and the concentration was gradually decreased as time advanced.

As shown in Table 7, when the dose of phosphorus was small, the phosphorus concentration of the soil solution was increased at first and then decreased. On the other hand, when the dose of phosphorus was high, the phosphorus concentration of the soil solution was gradually decreased from the start of the experiment.

C) Effect of phosphorus concentration in soil solution on the phosphorus absorption by plants.

The relationship between the uptake of phosphorus by the plant and the phosphorus concentration of soil solution was shown in Fig. 13. In this figure, the phosphorus concentration of soil solution was represented in terms of calculated mean value, because the phosphorus

Table 7. Change in phosphorus concentration in soil solution during the plant growth (Pot. experiment)

PO_4 Moles/Liter

Level	20/Aug. (Start)	4/Sept. (14)*	9/Sept. (20)	18/Sept. (29)	Calculated mean value
0.001 P_2O_5 g/pot	9.7×10^{-8}	1.6×10^{-7}	9.7×10^{-8}	9.7×10^{-8}	1.1×10^{-7}
0.01	3.2×10^{-7}	5.2×10^{-7}	2.3×10^{-7}	5.5×10^{-7}	3.6×10^{-7}
0.05	8.4×10^{-7}	8.4×10^{-7}	4.8×10^{-7}	4.8×10^{-7}	6.8×10^{-7}
0.1	1.2×10^{-6}	9.7×10^{-7}	4.8×10^{-7}	7.4×10^{-7}	8.3×10^{-7}
0.5	1.3×10^{-6}	9.7×10^{-7}	5.8×10^{-7}	8.1×10^{-7}	9.0×10^{-7}
1.0	2.6×10^{-6}	1.6×10^{-6}	9.0×10^{-7}	1.3×10^{-6}	1.5×10^{-6}
2.0	4.8×10^{-6}	2.1×10^{-6}	2.3×10^{-6}	1.9×10^{-6}	2.6×10^{-6}

* Days after transplanting.

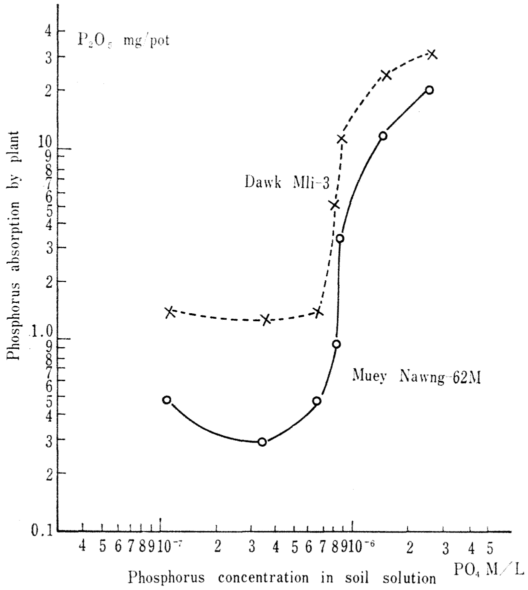


Fig. 13. Relationship between the uptake of phosphorus by plant and the phosphorus concentra tion in soil solution

concentration fluctuated during the growth period. A sudden and distinct increase in phosphorus absorption took place at a point where phosphorus concentration in soil solution exceeded a level of 8×10^{-7} mol/L. At the levels of phosphorus concentration beyond this critical level, the both varieties utilized phosphorus with almost equal efficiency. However, below that critical level, the difference in phosphorus utilization between these two varieties was observed.

The favourable concentration of PO_4 in soil solution was reported by KOYAMA[4-5] to be $10^{-4}\sim10^{-5}$ mol/L based on the field experiment with rice plant. The critical level of phosphorus concentration found in the present experiment is far lower than the favourable one. It is apparent from this result that the varietal difference in feeding power for soil phosphorus is manifested in the soil with a very low phosphorus availability.

III. Pot Experiment by Solution Culture and Soil Culture

In the previous experiment it was found that the nature of tolerance of Dawk Mali 3 to phosphorus deficiency is not due to a lower phosphorus requirement of that variety, but is very likely caused by its high absorption ability for phosphorus. Further research on the absorption ability of this variety was carried out.

METHOD

1) Design of the experiments

The experiments were conducted in both water and soil culture media. The designs for each were shown in Table 8.

Soil culture:

Phosphorus was added at 7 graded levels from 0.001 to 2.0 P_2O_5 g/pot, with the presence of 2.0 g/pot each of N and K_2O in 10 kg of Klong Luang soil. Fertilizers were mixed thoroughly with the soil prior to transplanting.

Water culture:

Culture solutions of the following nutrient composition was used at a rate of 10 liters per pot. Phosphorus at six levels from 0.01 to 5.0 ppm. Potassium at a level of 30 ppm. Nitrogen at a level of 30 ppm and a few drops of saturated Fe-citrate were added.

2) ^{32}P labelling

^{32}P with specific activity of 100 μci/g P_2O_5 was used in these experiments. Labelling with ^{32}P was done at the beginning of the experiment for soil culture and at final renewal of the nutrient solution for water culture.

Table 8. Design of experiment

No.	Water Culture			Soil Culture		
	N ppm.	P_2O_5 ppm.	K_2O ppm.	N g/pot	P_2O_5 g/pot	K_2O g/pot
1	30	0.01	30	2.0	0.001	2.0
2	30	0.02	30	2.0	0.01	2.0
3	30	0.05	30	2.0	0.05	2.0
4	30	0.1	30	2.0	0.1	2.0
5	30	1.0	30	2.0	0.5	2.0
6	30	5.0	30	2.0	1.0	2.0
7	—	—	—	2.0	2.0	2.0

3) Growing

Three 30 day-old seedlings were transplanted to each pot on 20th August. Similar to the previous experiment, two photoperiod-sensitive local rice varieties were used: Dawk Mali 3 which has stronger tolerability to phosphorus deficient soil and Muey Nawng 62 M less tolerable than Dawk Mali 3. Three replicates were used.

4) Sample preparation and Chemical analysis

All the plants from both culture media were sampled one month after transplanting, dried at 70 °C weighed and then subjected to chemical analysis. Nitrogen was determined by semi-micro Kjeldahl distillation method. Phosphorus and iron were measured by ammonium vanadomolybdate and O-phenanthroline respectively using spectrometer. Calcium and Magnesium were determined by EDTA titration method. ^{32}P counting was made by using Geiger-Müller counter. Corrections were made for background and decay factor.

RESULTS

A) Growth process in relation to different levels of phosphorus application

(1) Plant height:

As shown in Tables 9-a and 9-b, plant height was clearly affected by phosphorus levels in culture media. Plants grown by solution culture were always taller than that of soil culture. Dawk Mali 3 showed higher stature than Muey Nawng 62 M at each corresponding level of phosphorus application.

(2) Number of tillers:

Number of tillers was reduced with decreasing phosphorus doses. As shown in Tables 9-a and 9-b, a remarkable varietal differences in number of tillers was manifested with soil culture, though it was not clear with solution culture.

(3) Dry matter:

Response of dry matter was similar to that of plant height and tiller number. A remarkable varietal difference in dry matter production was observed with soil culture, but it was not clear with the solution culture, as shown in Table 9-a and 9-b. As shown in Fig. 14, high correlation was obtained between dry matter production and phosphorus absorption irrespective of variety.

Table 9-a. Effect of phosphorus application on plant growth under water culture condition

Variety	Level P_2O_5 ppm.	28/Aug.		3/Sept.		9/Sept.		18/Sept.		
		Height (cm.)	Tiller number	Height (cm.)	Tiller number	Height (cm.)	Tiller number	Height (cm.)	Tiller number	Weight of dry matter
MUEY NAWNG 62 M	0.01	41.0	3.0	49.3	3.7	61.6	4.3	65.4	4.7	1.67(g.)
	0.02	42.1	3.0	51.5	5.7	62.1	6.3	72.2	7.7	3.15
	0.05	47.5	3.0	55.6	5.7	70.5	7.0	72.8	8.3	4.11
	0.1	44.1	3.0	56.4	9.3	68.1	10.0	79.9	14.0	6.87
	1.0	43.5	3.0	56.3	9.7	76.0	10.3	81.3	14.0	7.05
	5.0	43.7	3.0	56.4	9.3	79.1	11.0	82.7	22.6	9.94
DAWK MALI 3	0.01	40.8	3.0	55.9	3.3	67.7	3.7	74.5	3.3	2.13
	0.02	44.9	3.0	60.1	5.3	70.5	6.7	78.9	6.7	3.65
	0.05	42.4	3.0	64.1	5.7	74.8	8.7	85.8	9.3	5.15
	0.1	46.0	3.0	61.1	7.0	76.8	8.0	87.2	12.3	6.37
	1.0	48.9	3.0	63.0	8.0	84.7	10.0	90.5	14.7	8.03
	5.0	47.9	3.0	68.3	8.3	82.9	9.7	91.6	19.0	8.44

Table 9-b. Effect of phosphorus application on plant growth under soil culture condition

Variety	Level g P_2O_5/pot	28/Aug. Height (cm.)	28/Aug. Tiller number	3/Sept. Height (cm.)	3/Sept. Tiller number	9/Sept. Height (cm.)	9/Sept. Tiller number	18/Sept. Height (cm.)	18/Sept. Tiller number	18/Sept. Weight of dry matter
MUEY NAWNG 62 M	0.001	34.1	3.0	36.7	3.0	41.5	3.0	4.8	2.7	0.37(g.)
	0.01	36.0	3.0	37.6	3.0	38.3	3.0	38.7	2.7	0.25
	0.05	34.0	3.0	36.1	3.0	41.8	3.0	47.9	3.0	0.40
	0.1	36.0	3.0	41.8	3.0	50.3	3.0	55.9	3.0	0.76
	0.5	34.6	3.0	42.4	3.0	55.7	3.3	65.6	5.0	1.23
	1.0	42.2	3.0	50.5	3.7	67.3	5.7	82.7	12.7	3.09
	2.0	38.2	3.0	48.8	3.5	66.5	5.5	81.5	14.0	3.55
DAWK MALI 3	0.001	38.5	3.0	42.6	3.3	51.7	3.3	58.7	4.0	0.83
	0.01	39.1	3.0	43.4	3.0	48.6	3.0	57.0	3.0	0.72
	0.05	40.1	3.0	43.9	3.3	49.4	3.3	59.0	3.3	0.81
	0.1	39.7	3.0	48.9	3.0	60.5	3.7	74.0	6.3	2.09
	0.5	39.4	3.0	50.3	3.7	65.3	6.0	82.9	9.7	3.10
	1.0	41.0	3.0	54.2	5.7	74.6	7.7	85.3	16.3	5.63
	2.0	43.1	3.0	55.6	4.7	71.9	8.7	91.7	19.3	6.25

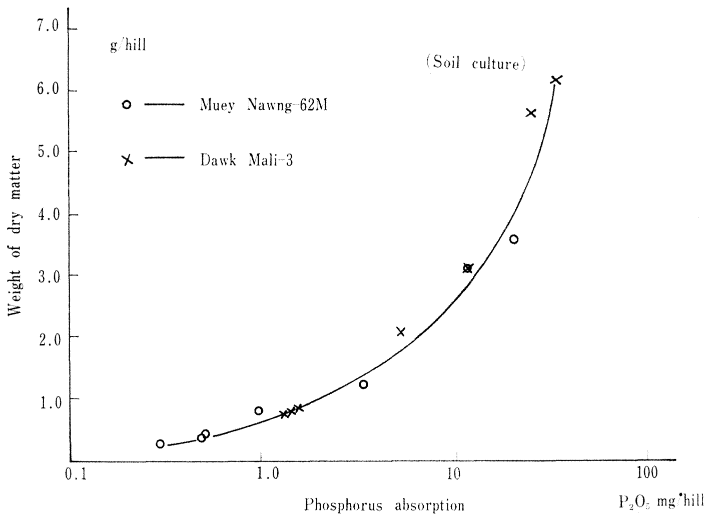


Fig. 14. Relationship between weight of dry matter and phosphorus absorption

B) Nutrient content of plants in relation to phosphorus supply

Effect of phosphorus levels on nutrient contents of plants differs with the method of culture, as shown in Table 10-a and 10-b. With solution culture contents of N, P_2O_5, Fe_2O_3, CaO, and MgO were similar between two varieties. Only the K_2O content of Muey Nawng 62 M was lower than that of Dawk Mali 3.

On the contrary, under the soil culture condition, the contents of N and P_2O_5 were slightly higher with Dawk Mali 3 than Muey Nawng 62M at each corresponding level of phosphorus application, but potassium content was same between these two varieties. However, at the

Table 10-a. Effect of phosphorus supply on nutrient content and absorption by plant under water culture condition (18/Sept.)

Variety	Level P_2O_5 ppm.	N %	N mg/hill	P_2O_5 %	P_2O_5 mg/hill	K_2O %	K_2O mg/hill	Fe_2O_3 %	Fe_2O_3 mg/hill	CaO %	CaO mg/hill	MgO %	MgO mg/hill
MUEY NAWNG 62M	0.01	2.13	35.6	0.21	3.74	3.42	57.1	0.02	1.40	0.25	4.2	0.26	4.3
	0.02	2.28	71.8	0.25	7.88	3.42	107.7	0.02	0.57	0.18	5.7	0.20	6.3
	0.05	2.59	106.4	0.30	12.11	3.79	155.8	0.02	0.78	0.22	9.0	0.17	7.0
	0.1	2.82	193.7	0.35	24.10	3.87	265.9	0.02	1.37	0.21	14.4	0.27	18.5
	1.0	2.84	200.2	0.34	23.09	4.05	285.5	0.02	1.41	0.21	14.8	0.31	21.9
	5.0	3.19	317.1	0.69	67.62	3.35	333.0	0.01	1.39	0.18	17.9	0.32	31.8
DAWK MALI 3	0.01	2.25	47.9	0.31	6.40	3.94	83.9	0.03	0.55	0.29	6.2	0.33	7.1
	0.02	2.36	86.1	0.17	6.25	3.60	131.4	0.02	0.66	0.24	8.8	0.25	9.1
	0.05	2.62	134.9	0.26	12.90	4.66	240.0	0.02	0.77	0.23	11.8	0.21	10.8
	0.1	3.08	196.2	0.38	24.19	4.54	289.2	0.02	1.15	0.18	11.5	0.24	15.3
	1.0	2.94	236.1	0.34	27.95	4.71	378.2	0.02	1.29	0.21	16.9	0.24	19.3
	5.0	3.38	285.3	0.89	72.96	4.46	376.4	0.01	1.18	0.15	12.7	0.27	22.8

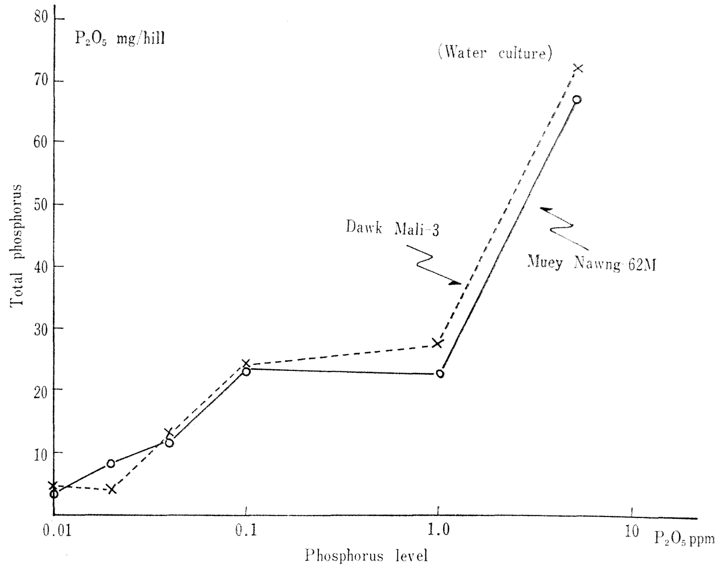
Table 10-b. Effect of the phosphorus supply on nutrient content and absorption by plant under soil culture condition (18/Sept.)

Variety	Level P_2O_5/ pot	N %	N mg/hill	P_2O_5 %	P_2O_5 mg/hill	K_2O %	K_2O mg/hill	Fe_2O_3 %	Fe_2O_3 mg/hill	CaO %	CaO mg/hill	MgO %	MgO mg/hill
MUEY NAWNG 62 M	0.001	2.25	8.3	0.13	0.49	2.55	8.3	0.12	0.44	0.69	2.5	0.46	1.7
	0.01	2.13	5.3	0.12	0.30	2.43	6.1	0.16	0.39	0.96	2.4	0.41	1.0
	0.05	2.25	9.0	0.12	0.50	2.47	9.9	0.23	0.92	0.65	2.6	0.68	2.7
	0.1	2.35	17.9	0.13	0.98	2.62	19.9	0.14	1.09	0.41	3.1	0.47	3.6
	0.5	2.84	34.9	0.29	3.45	3.44	42.3	0.04	0.47	0.39	4.8	0.43	5.3
	1.0	3.22	99.5	0.39	11.84	3.69	114.0	0.03	1.02	0.35	10.8	0.47	14.5
	2.0	3.42	121.4	0.56	20.89	3.76	133.4	0.02	0.78	0.36	12.8	0.45	16.0
DAWK MALI 3	0.001	2.38	19.8	0.16	1.49	2.63	21.8	0.05	0.41	0.66	5.5	0.25	2.1
	0.01	2.44	17.6	0.18	1.35	2.42	17.4	0.06	0.45	0.44	3.2	0.26	1.9
	0.05	2.55	20.7	0.18	1.44	2.78	22.5	0.05	0.39	0.34	2.8	0.32	2.6
	0.1	2.92	61.0	0.22	5.33	3.27	68.3	0.03	0.59	0.35	7.3	0.31	6.5
	0.5	3.28	101.7	0.39	11.96	3.41	105.7	0.02	0.68	0.32	9.9	0.35	10.9
	1.0	3.61	203.2	0.45	25.34	3.74	210.6	0.02	1.18	0.41	23.1	0.38	21.4
	2.0	3.63	226.9	0.53	32.98	3.85	240.6	0.02	1.25	0.31	19.4	0.47	29.4

low level of phosphorus application, the contents of Fe_2O_3, CaO, and MgO in Muey Nawng 62M were higher than that of Dawk Mali 3. Although at higher levels of phosphorus such varietal difference with respect to these elements was not observed. This would probably be accounted for by the phosphorus shortage of Muey Nawng 62M induced by low level of phosphorus application to the soil.

C) Effect of phosphorus supply on the phosphorus absorption by plants

^{32}P tracer experiment clearly demonstrated the nature of varietal difference in phosphorus utilization between two varieties. As shown in Figs. 15 and 16, under the solution culture condition, both varieties utilized the similar amounts of total and added phosphorus labelled with ^{32}P. It may be concluded therefore that there was no varietal difference in



Fig, 15. Varietal difference in phosphorus absorption

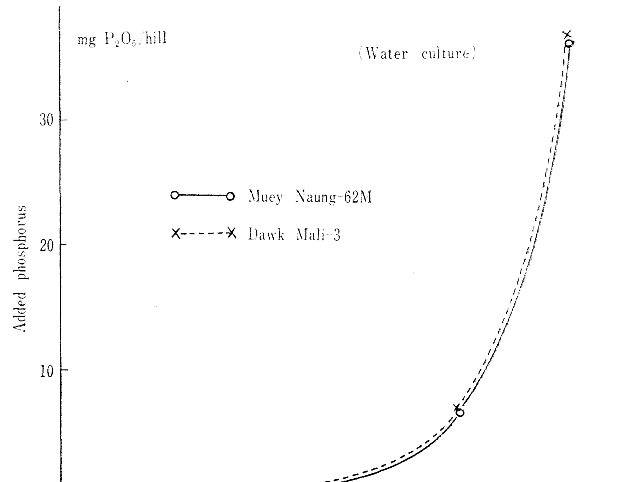


Fig. 16. Varaetal difference in added phosphorus utilization

utilizing water soluble phosphorus as shown in Table 11-a, whereas a marked varietal difference was recognized under soil culture condition with respect to phosphorus absorption as shown in Fig. 17.

The phosphorus fertilizer labelled with ^{32}P was used to discriminate the uptake of fertilizer phosphorus from the uptake of soil phosphorus. The result furnished a clear evidence that the varietal differences in phosphorus absorption depends exclusively on the difference in soil phosphorus utilization as shown in Fig. 18. Thus, it was made clear that the varietal difference is caused by the difference in the feeding power for soil phosphorus; Dawk Mali 3 being a strong feeder of soil phosphorus. In other words, soil phosphorus was more available to Dawk Mali 3 than to Muey Nawng 62 M as shown in Table 11-b.

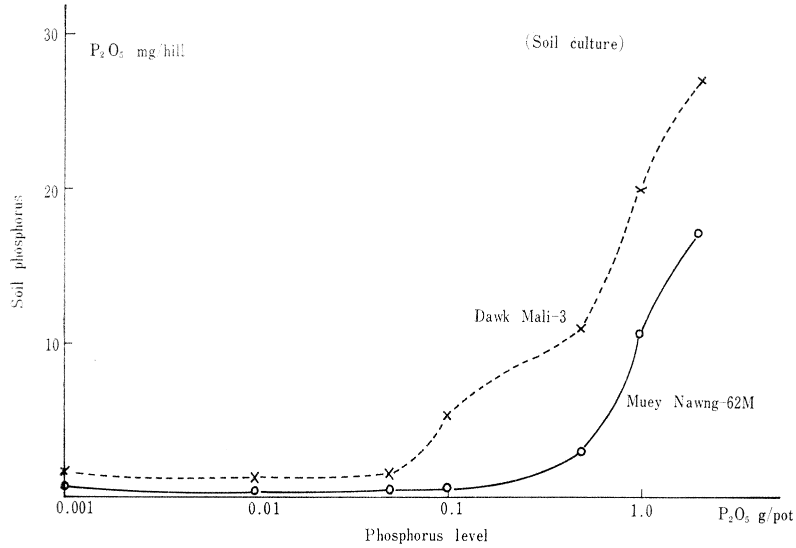


Fig. 17. Varietal difference in soil phosphorus utilization

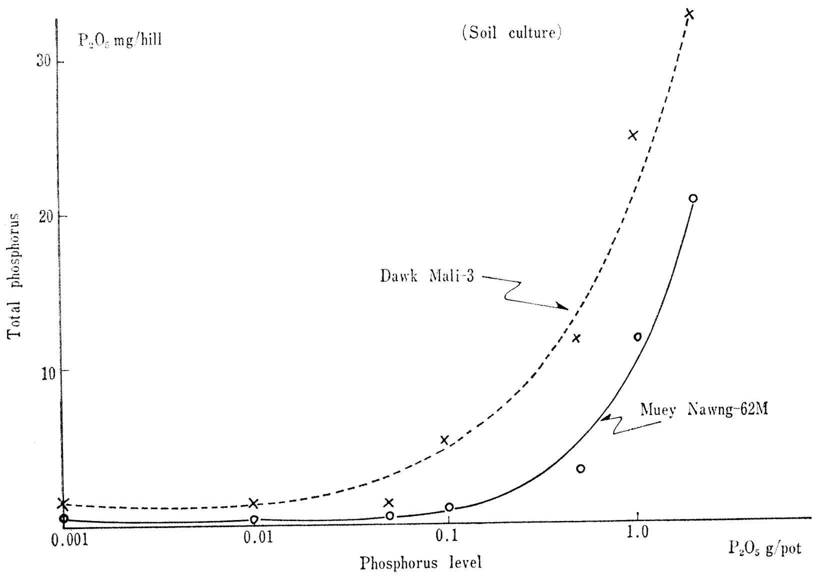


Fig. 18. Varietal difference in total phosphorus utilization

Table 11-a. Effect of phosphorus supply on phosphorus absorption by plant from different sources

(Water Culture)

Variety	Level P_2O_5 ppm.	P_2O_5 mg./hill	Total C.P.M.	Specific activity	Specific activity of source	Contribution % Labelled P_2O_5	Contribution % Non-labelled P_2O_5	Absorbed P_2O_5 mg/hill Labelled P_2O_5	Absorbed P_2O_5 mg/hill Non-labelled P_2O_5	Recovery %
MUEY NAWNG 62 M	0.01	3.74	8573	2292	221000	1.04	98.96	0.04	3.70	40
	0.02	7.88	8771	1113	110500	1.01	98.99	0.08	7.80	40
	0.05	12.11	11231	928	44200	2.10	97.90	0.25	11.86	50
	0.1	24.10	15482	643	22100	2.91	97.09	0.70	23.40	70
	1.0	23.09	14512	629	2210	28.44	71.56	6.57	16.52	66
	5.0	67.62	15979	236	442	53.46	46.54	36.15	31.47	72
DAWK MALI 3	0.01	6.40	8894	1390	221000	0.63	99.37	0.04	6.36	40
	0.02	6.25	12702	2032	110500	1.84	98.16	0.12	6.13	60
	0.05	12.90	13455	1043	44200	2.36	97.64	0.30	12.60	60
	0.1	24.19	15394	636	22100	2.88	97.12	0.70	23.49	70
	1.0	27.95	15400	551	2210	24.93	75.07	6.97	20.98	70
	5.0	72.96	16247	223	442	50.45	49.55	36.81	36.15	74

Table 11-b. Effect of phosphorus supply on phosphorus absorption by plant from different sources

(Soil Culture)

Variety	Level P_2O_5 g/pot	P_2O_5 mg./hill	Total C.P.M.	Specific activity	Specific activity of source	Contribution % P_2O_5 derived from fertilizer	Contribution % P_2O_5 derived from soil	Absorbed P_2O_5 mg/hill P_2O_5 derived from fertilizer	Absorbed P_2O_5 mg/hill P_2O_5 derived from soil	Recovery %
MUEY NAWNG 62 M	0.001	0.49	897	1830	221000	0.8	99.2	0.004	0.49	0.4
	0.01	0.30	874	2913	22100	13.2	86.8	0.04	0.26	0.4
	0.05	0.50	411	825	4420	18.7	81.3	0.09	0.41	0.2
	0.1	0.98	999	1023	2210	46.3	53.7	0.45	0.53	0.5
	0.5	3.45	266	77	442	17.4	82.6	0.60	2.85	0.1
	1.0	11.84	278	24	221	10.9	89.1	1.29	10.55	0.1
	2.0	20.89	416	20	111	18.0	82.0	3.76	17.13	0.2
DAWK MALI 3	0.001	1.49	2245	1504	221000	0.7	99.3	0.01	1.48	1.0
	0.01	1.35	459	339	22100	1.5	98.5	0.02	1.33	0.2
	0.05	1.44	196	136	4420	3.1	96.9	0.04	1.40	0.1
	0.1	5.33	264	50	2210	2.3	97.7	0.12	5.21	0.1
	0.5	11.96	402	34	442	7.7	92.3	0.92	11.04	0.2
	1.0	25.34	1226	48	221	21.7	78.3	5.50	19.84	0.6
	2.0	32.98	642	20	111	18.0	82.0	5.94	27.04	0.3

SUMMARY

To make clear the nature of the varietal difference in the response to phosphorus deficiency which was found by the authors between Dawk Mali 3 and Muey Nawng 62 M, the pot culture experiment designed to compare the response of both varieties under solution culture and soil culture conditions was carried out. The results indicated that no significant varietal difference in plant growth and phosphorus absorption was found under solution culture conditions, whereas a marked varietal difference was recognized under soil culture condition with respect to plant growth and soil phosphorus utilization. Thus, it was made clear that the varietal difference is caused by the difference in the feeding power for soil phosphorus: Dawk Mali 3 being a strong feeder of soil phosphorus.

The phosphorus fertilizer labelled with ^{32}P was used to discriminate the uptake of fertilizer phosphorus from the uptake of soil phosphorus. The result furnished a clear evidence that the varietal differences in phosphorus absorption depends exclusively on the differences in soil phosphorus utilization and therefore on the difference in feeding power between two varieties and not on the difference of either root size or root surface. Nature of interaction between plant roots and the phosphorus sources in the soil needs further studies.

GENERAL DISCUSSION

Many researchers have pointed out that plant species and even varieties of the same species differed in their feeding power for soil phosphorus.

NELSON *et al.*[6] have indicated that corn was stronger feeder for soil phosphorus than tobacco, while cotton was intermediate. BLASER and MCAULIFFE[7] found that Ladino Clover absorbed much more fertilizer phosphorus than orchardgrass. This would indicate a lower feeding power for soil phosphorus in the case of Ladino clover. FULLER[8] showed that soil phosphorus was most available to barley and least available to cantaloupe. FRIED[9] demonstrated that buckwheat and alfalfa absorbed considerably more phosphorus from the soil plus rock phosphate than did crotalaria, oats, beets, or perennial ryegrass.

Observation, as well as plant growth and phosphorus uptake rate have indicated that Dawk Mali 3 variety was a stronger feeder for soil phosphorus than Muey Nawng 62 M, and therefore Dawk Mali 3 showed relatively better plant growth than the Muey Nawng 62 M did on the phosphorus deficiency soil.

Various hypotheses such as, root excretion theories,[10] have been proposed for differences in feeding power of plants. One of these was the carbon dioxide hypothesis, *i.e.*, some plant roots excreted more carbon dioxide than others, leading to a difference in acidity in the soil. This might change the concentration of phosphorus in soil solution around the root system and phosphorus might be absorbed by the plants efficiently.

The second proposal was elemental balance theories. TRUOG[11] suggested that the difference in absorbing phosphorus from rock phosphate in some kinds of plants was influenced by calcium absorption. Since the phosphorus concentration in soil solution increased as calcium concentration decreased, the phosphorus concentration in soil solution would be the greatest when associated with species or varieties that absorbed calcium most.

The third hypothesis was the microbiological interaction theory. McCOMB[12] reported that the coniferous trees grown on the soil with relatively low plant nutrients had been found to be better when mycorrhizal fungi infected the roots. The theory assumes the presence of such fungi which facilitated the phosphorus absorption of the plant.

The fourth consideration was a root-extent theory. The utilization of soil phosphorus should be greater for plants that have a larger absorbing surface.

It was shown from the experimental results that the difference in calcium absorption between Muey Nawng 62 M and Dawk Mali 3 was not great enough to account for their difference in soil phosphorus utilization, as suggested by TRUOG.

Studies with ^{32}P showed that the varietal difference found by the authors was not due to the difference in root size and extensiveness in the soil. FRIED and DEAN[13] proposed that plant species or varieties grown on the soil having two sources of phosphorus, namely, the native soil phosphorus and added fertilizer phosphorus, mixed uniformly throughout the total soil volume will remove varying quantities of phosphorus from the system, but the two sources of phosphorus were equally accessible to the root systems of the plants. Therefore either the proportion or percentage of the total phosphorus absorbed from each source should be independent, provided that the root systems of some species or varieties did not interact differently with one of the phosphorus sources. On the other hand if the difference in the percentage of the total phosphorus absorbed from either of the two sources was found among species or varieties, this could be taken to account that there were differences in the feeding power of root systems, independently to the root size or root surface. This is the case of the varietal difference found with Dawk Mali 3. The variety was able to utilize native soil phosphorus more effectively than Muey Nawng 62 M, thereby a marked difference in percentage of phosphorus derived from fertilizer in plants was obtained.

These results suggested that the difference in feeding power for soil phosphorus between two varieties was not due to elemental balance theories or root-extent theory, but probably due to differences in interaction between plant roots and the phosphorus sources in the soil such as root excretion theories or microbiological interaction theory. However the mechanism of this interaction was not entirely explained yet by the present studies.

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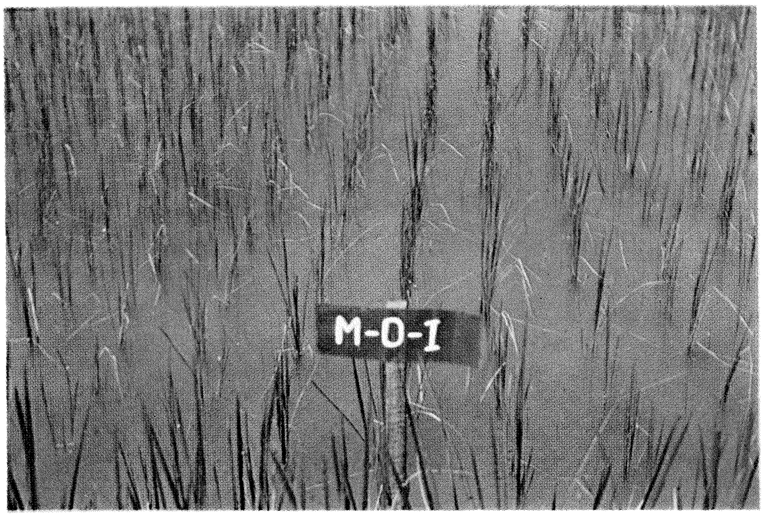
Photo. 1-a. Marked varietal difference in plant growth between Muey Nawng 62 M and Dawk Mali 3, when phosphorus was not applied at all.

(A) 35 Days after transplanting at Klong Luang rice experiment station.



(Meuy Nawng 62 M)

(Dawk Mali-3)

(B) At harvesting time

Right : Muey Nawng 62 M
Left : Dawk Mali 3

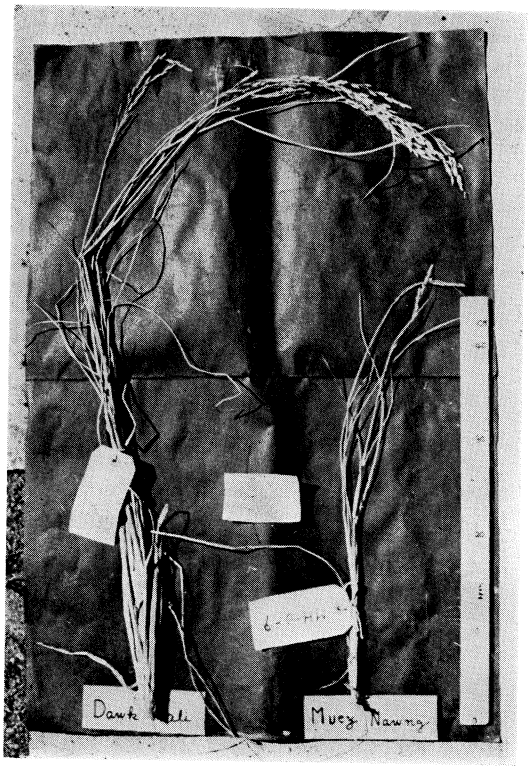
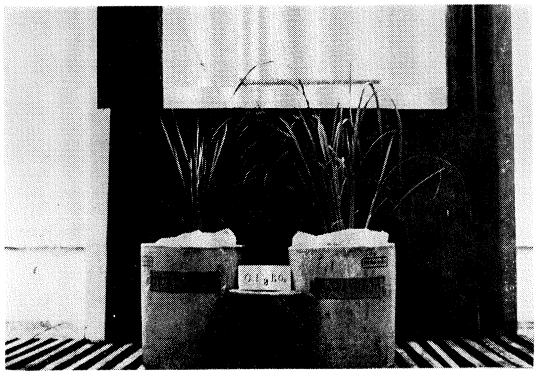


Photo. 2. Difference in plant growth between Muey Nawng 62 M and Dawk Mali 3 at one month after transplanting.

(A) Grown by soil culture

Right : Dawk Mali 3
Left : Muey Nawng 62 M

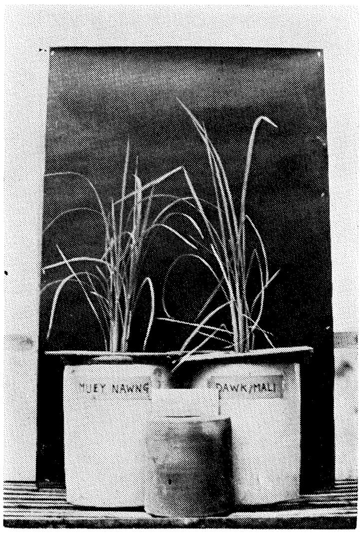
(0.01 g P_2O_5/pot)



(0.1 g P_2O_5/pot)

(1.0 g P_2O_5/pot)

(B) Grown by solution culture Right : Dawk Mali 3
Left : Muey Nawng 62 M



(0.01 ppm P_2O_5)

(0.05 ppm P_2O_5)

(1.0 ppm P_2O_5)