

Nutrient deficiency and physiological disease of lowland rice in Ceylon

1. Relationship between nutritional status of soil and rice growth

YASUO TAKIJIMA. (*National Institute of Agricultural Sciences, Tokyo, Japan*)

and

S. D. I. E. GUNAWARDENA, (*Central Agricultural Research Institute, Peradeniya, Ceylon*)

IN Ceylon, rice is grown chiefly on alluvial as well as low-humic gley soils which are distributed throughout the Island. Parent materials of these soils are derived mainly from weathered products of Khondalite and Charnackite groups of rocks among which acidic schists and gneisses dominate (1). Lateritic weathering of rocks, the most typical soil formation under tropical climates, results in a general supply of soil materials rich in iron and alumina but lacking in nutrient bases and silica. This is one of the possible reasons for low fertility of tropical rice soils compared to that of temperate zones.

Rice plants often show poor growth and nutrient deficiency symptoms or physiological diseases. This is particularly acute in some areas of the wet zone where drainage is imperfect or where flood protection measures are poor. Very few studies have been done on the relationship between available nutrients in the soil and nutritional status of rice plants in this country, except for Bronzing disease of rice which will be considered in a later report. A sampling survey was thus undertaken to investigate nutrient deficiency patterns of general occurrence and those associated with the physiological disease known as Bronzing with a view to remedying these deficiencies which may have a limiting effect on rice production.

Method of survey and chemical analysis of samples

Sampling sites were selected from various parts of the intermediate dry and wet zones to represent a variety of soils and climates (Fig. 1). In the selection of sites preference was given to fields in which the soils had previously been surveyed by Kawaguchi and Kyuma (4) to enable comparison of their results with that of the present survey.

The survey was done from January to February 1968, when the greater part of the rice crop was at the milk-ripe stage of panicle development and the fields were still submerged (Maha 1967/68). Each soil profile was examined and described following the guidelines issued by FAO (2). Surface soil of each site and rice plants showing average growth at the spot were collected and subjected to chemical analysis in the laboratory. Five to ten hills were taken per sample depending on the growth status of rice. In broadcast sown fields two plant samples of one square foot each were taken.

The pH, colour and ferrous iron content were measured from freshly collected wet to semi-wet soils. Available phosphorus (6) and phosphate absorption coefficient (9) were determined using air-dried samples of soil that were passed through a 2 mm sieve. Finely ground rice plant samples were used to determine contents of inorganic elements after digestion with 30 per cent perchloric acid and conc. nitric acid except for total nitrogen which was determined by the Kjeldahl method.

RESULTS AND DISCUSSION

Chemical properties of rice soils

Twenty locations of rice fields were surveyed and their soil conditions are described in Table I. The fields ranged in elevation from 5 to 3,300 feet, the highest being the upper limit of rice cultivation with existing varieties. Twelve of these fields were well to moderately well drained while the others were more or less poorly drained. Soil profiles revealed an immature soil formation, i.e. Apg-ACgcn-IICcn was found most frequently in the sequence of soil horizons, where cn represents the presence of iron concretions produced as a result of lateritic soil formation. Development of a gley colour in these horizons was observed to be somewhat weak due to the considerable accumulation of ferrous iron in the soil under submerged field conditions and as the reddish brown colour of the soil materials was relatively strong compared to gleyzation.

Physical, physico-chemical and chemical characteristics of the soils are shown in Table 2. According to data reported by Kawaguchi and Kyama (4), these surface soils are generally low in organic matter, ammonium nitrogen produced under anaerobic conditions, exchangeable potassium, magnesium and available silica but fairly well supplied with exchangeable calcium and reducible manganese. Contents of total phosphorus are also low with a few exceptions. This tendency is common in Asian rice soils developed under a tropical climate. Available soil phosphorus determined by Olsen's method (6)

varied from traces to 5.7 mg P_2O_5 per 100 gm of soil. No positive correlation was found between total and available phosphorus of the soil. Exchangeable ferrous iron, one of the indicators of soil reduction, was fairly abundant though its concentration differed depending on the soil moisture content at time of sampling. A possible reason for this is that with cultivation of two rice crops per year, complete oxidation of the ferrous iron formed in the soil is unlikely particularly in the poorly drained fields because of the very short rest period between crops. In general, the phosphate absorption coefficient of these soils was high and increased with increase in clay content. Several of these samples had coefficients of more than 2,000 and in this respect are comparable to the volcanic ash soils (Ando Soil) in Japan.

Characteristics in the nutritional status of rice plants

Forty samples of rice plants including indigenous varieties and improved hybrids (H series), showing both normal growth and symptoms of physiological disturbances were collected from 20 locations. Plant samples were divided into five groups based on the symptoms observed, i.e. normal, malnutrition, phosphorus deficiency, potassium deficiency and Bronzing disease. Plants showing poor growth but which could not be clearly attributed to any nutrient deficiency were classed under malnutrition.

Growth characteristics and deficiency symptoms together with incidence of pests and diseases are shown in Table 3. As panicle weights varied widely depending on the stage of ripening, panicle number or straw weight per unit area sampled was considered a better measure of plant growth than panicle weight. Samples taken from the intermediate zone revealed higher production of straw and panicle than those from the wet zone where a decreasing tendency was observed with increase in altitude of the fields surveyed.

Results of nutrient analyses of rice straw samples are shown in Table 4. To obtain the normal mineral composition of Ceylon Indica varieties, chemical analysis was done of 4 panicle samples selected from fields where rice plants were found growing vigorously under conditions of good fertilizer use (Table 5). Contrasting these data of

both straw and panicle with those of Japonica varieties cultured in southern parts of Japan (8), Ceylon Indicas differ in nutrient content as follows :—

- | | |
|---------------------------|--|
| (i) Higher than Japonica | .. N, CaO and Fe_2O_3 |
| (ii) Same as Japonica | .. P_2O_5 and K_2O |
| (iii) Lower than Japonica | .. MgO and SiO_2 |

It may be mentioned that the extremely low MgO and SiO_2 contents of Indica is possibly a manifestation of physiological or edaphological differences between the two groups (Table 3, 4 and 5).

Relationships among soil fertility, growth disturbances and nutrient contents of rice plant

Data recently reported on the chemical properties of soil (4) were used in addition to those obtained by the authors to investigate these relationships.

No striking correlation was observed between contents of nitrogen, potassium, calcium and magnesium in straw, and status of nitrogen and corresponding exchangeable bases in the soil. However, a weak trend in which contents decrease with decrease in exchangeable bases of the soil was detectable among soils having low levels of exchangeable potassium and calcium, below 0.2 me and 2.0 me per 100 g of soil, respectively. These values can be assumed to be the limit below which deficiency of corresponding nutrients occur in plants.

No apparent relationship was found between contents of iron and silica in straw and their status in the soil. However, in the lower range of soil available silica which is less than around 8 mg SiO_2 per 100 gm of soil, silica content in straw appear to decrease as is shown in Fig. 2. According to studies on silica nutrition of rice by Imaizumi and Yoshida (3), Japonica varieties responded to application of silicate fertilizers (slags) in cases where SiO_2 content in straw is less than 11% and soil available SiO_2 less than 10.5 mg. In view of the probably lower requirement of silica by Indica varieties, plants showing silica contents in straw below 8% will need fertilizer management using slags or composts. This problem is to be discussed further in the next report.

A fairly high positive relationship between phosphorus contents in straw and amounts of available phosphorus in the soil was obtained except in a few samples taken from Bombuwela sandy soils which had comparatively high amount of available phosphorus. Further

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studies are deemed necessary on this particular feature of soil phosphorus since Olsen's method (6) developed originally using upland soils may not strictly apply for the lowland soils of the ill-drained type. From the relationships in Fig. 3, a tentative division of criteria in term of soil available phosphorus is possible as follows :—

- (i) Normal (no observable symptoms) .. more than 3 mg.
- (ii) Deficient (symptoms observable frequently) .. 1 to 3 mg
- (iii) Severely deficient (symptoms severe) .. less than 1 mg

In fact, symptoms of phosphorus deficiency of rice plants were observed most frequently in this survey and many samples had phosphorus contents less than 0.4% in straw which was assumed to be the critical point for the occurrence of phosphorus deficiency. Panabokke and Nagarajah (7) suggested a higher frequency of phosphorus deficiency in rice in the dry zone's fields since most rice soils there were low in available phosphorus (below 15 lbs. P_2O_5 per acre) compared to soils in the other zones. As shown in Fig. 4 for 16 sites in Kurunegala District where field experiments were conducted by the authors, the pattern indicated a rather broad distribution of phosphorus deficient areas from the wet to the intermediate zone. This pattern is different from Panabokke and Nagarajah's (7) results but quite similar to the results reported by Kawaguchi and Kyuma (4) who analysed available soil phosphorus soluble in 0.2 N HCl. A high effect of phosphate fertilizers has been recorded in field experiments conducted in the intermediate zone having alluvial soils had been derived from Reddish Brown Podzolic Soils (5). Some of these results will be described in the next report, but it would suffice to state here that phosphorus deficiency is a common malady of most rice fields in Ceylon.

The relationship between growth status and nutritional status of rice plants in the sample survey are shown in Fig. 5.

Nitrogen content in straw low in 'malnutrition' samples but abnormally high in 'bronzed' (Tables 3 and 4). Phosphorus was strikingly low in samples that showed phosphorus deficiency symptoms (Fig. 5). Pottassium content decreased in increasing order with

malnutrition, phosphorus deficiency and bronzing but not in samples showing potassium deficiency. Samples grouped under potassium deficiency showed very stunted growth with dark green colour and appeared to suffer from iron toxicity (10) although iron content in straw of the samples was not so high. Calcium and magnesium contents in straw were somewhat low with samples showing growth disorders. Magnesium content appeared to be positively correlated with samples showing growth disorders. Magnesium content appeared to be positively correlated with phosphorus content as shown in Fig. 7. Hence, it is likely that lack of available magnesium in most soils also limits rice growth and its phosphorus absorption.

Iron and silica contents in straw showed no detectable trend in relation to growth disorders with the exception of 'bronzing'. Plants suffering from bronzing were characterised by high nitrogen, calcium and iron, and extremely low potassium, magnesium and silica in their straw. Occurrence of bronzing and remedial measures will be separately discussed in the next reports.

SUMMARY

Studies were conducted on the relationships between nutritional status of rice soils and plants in Ceylon to obtain fundamental information for efficient fertilizer use.

1. Forty rice plant samples in milk-ripe stage showing various growth disorders were collected from many locations in the wet intermediate zones and the dry zones. These were subjected to chemical analysis for nutrient elements together with rice soils.

2. Phosphorus deficiency was found most frequently in rice plants followed by potassium and silica deficiency and bronzing disease. Each growth disorder had its special feature in respect of nutrient contents in straw.

3. Phosphorus content in straw was highly correlated with available phosphorus in the soil as determined by Olsen's method. The critical amount of soil available phosphorus causing severe deficiency was less than 1 mg P_2O_5 per 100 gm of soil. Poor magnesium-supplying power of rice soils was considered likely to reduce absorption of phosphorus by the plant.

4. Ceylon Indica varieties had lower silica content than Japonica varieties. Although the lower limit of available soil silica was uncertain, silica deficiency appeared to occur when silica content in straw was below 8 per cent.

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Table 1. -Number and location of rice fields surveyed in Ceylon and their soil conditions

Sample No.	Location	District	Elevation (feet)	Drainage of the field	Soil horizon sequence
1	KAITADI*	Jaffna	5	well	Ap-AC-C-IICen
2	PARANTHAN	do.	40	imperfect	Apg-ACen-BCen
3	VAVUNIYA*	Vavuniya	230	moderately well	Apg-AC-IICen
4	MAHA ILLUP-PALLAMA	Anuradhapura	350	moderately well	Apg-ACg-IIC-IIC
5	KARADIYAN ARU	Batticaloa	30	imperfect	Apg-AC-IICgen
6	NALANDA	Matale	840	well	Apg-ACen-Cen-IIC
7	BATALAGODA	Kurunegala	380	imperfect	Apg-Cgen-IIgen
8-1	PANALIYA*	do.	300	poor	Apg-ACg-Cgen-IICg
8-2, 3	Do.*	do.	300	do.	Apg-ACg-Cg-IICg
9	WAGOLLA	Kegalla	400	moderately well	Ap-B-Cg-IICg
10	PERADENIYA	Kandy	1,500	moderately well	Apg-ACg-Cg-IICg
11	MALPANE	do.	1,600	very poor	Apg-ABg-Bg
12	MINUWANGODA*	Colombo	56	imperfect	Apg-AC-IIC
13	PUSSELLAWA	Kandy	3,200	imperfect	Apg-ACg-IICg
14	PUNDALUOYA*	Nuwara Eliya	3,300	moderately well	Ap-ACg-IIC1-IIC2-IIC1cn-IIC2cn-IIC3cn
15	OKKAMPITIYA	Moneragala	430	moderately well	Apg-ABg-Bg
16-1	KARAPINCHA	Ratnapura	500	imperfect	Apg-Cg
16-2	Do.	do.	500	do.	do.
17-1, 2	BOMBUWELA*	Kalutara	20	imperfect	Apg-ACg-IICg
17-3	Do.	do.	20	do.	Apg-ACg-(C)
17-4, 5	Do.	do.	5	very poor	Apg-IICg
17-6, 7	Do.	do.	10	poor	Ap-ACg-IICg-IIC
18	TISSAMAHARAMA	Hambantota	100	imperfect	Apg-ABg-Bg
19	NARAWELA	Galle	30	poor	Apg-ABgh-IICgh (peat)
20	LABUDUWA	do.	20	poor	Apg-ACgh-IIC1gh-IIC2h (peat)

* Farmers' fields, others are farms in Government Experiment Stations.

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Table 2.—Chemical properties of rice soils taken from the sample survey (Surface soil)

Sample No.	Texture	pH (H ₂ O)	Total* N (%)	Total* P ₂ O ₅ (mg./100 gm. soil)	Available† P ₂ O ₅ (mg./100 gm. soil)	Phosphate†† absorption coefficient (P ₂ O ₅ , mg.)	Exchange-able ferrous iron (Fe††, ppm)
1	LS	6.4	0.028	13	2.35	trace	700
2	LS	5.2	0.047	26	3.15	850	do.
3	SCL	6.0	0.128	74	1.65	1,000	do.
4	SCL	5.8	0.085	72	3.85	1,400	—
5	SL	5.0	0.070	26	3.55	1,000	960
6	SiCL	6.0	0.101	97	1.95	1,250	1,470
7	SL	5.8	0.046	28	1.65	1,000	1,000
8-1	LiC	5.2	—	—	0.55	600	1,190
8-2, 3	SCL	5.5	—	—	1.75	1,600	1,180
9	SL	4.9	0.137	72	2.35	700	trace
10	LiC	5.8	0.275	151	4.25	1,500	1,340
11	SCL	6.8	—	—	1.65	1,500	—
12	SL	4.9	0.233	67	5.35	500	700
13	SC	5.2	0.329	174	2.05	1,900	1,410
14	SCL	5.8	—	—	0.85	1,750	—
15	SL-SCL	5.2	0.124	32	1.85	950	—
16-1	LiC-SL	6.3	0.123	36	2.35	700	2,290
16-2	LiC-SL	6.3	0.123	36	1.65	2,00	—
17-1, 2	SL	4.7	—	—	3.35	500	620
17-3	LS	5.4	0.123	62	1.65	850	—
17-4, 5	LiC (humic)	5.9	0.660	—	(trace)	2,000	2,930
17-6, 7	SL-L	4.9	0.123	—	4.85	600	1,020
18	SCL	6.7	0.131	174	5.65	1,250	—
19	LiC	5.4	0.639	154	1.15	2,600	1,330
20	LiC	5.5	—	—	4.25	2,550	1,550

* Reported by K. Kawaguchi and K. Kyuma (4).

† Olsen's method (6).

†† Official method of Department of Agriculture, Japan, (1950). Coefficient is expressed as P₂O₅ mg absorbed by 100gm of soil from 2.5% ammonium phosphate solution.

Table 3.—Growth and nutrient deficiency status of rice plants from the sample survey

Sample No.	Rice variety	Growth stage	Nutrient Deficiency (pests and diseases*)	Panicle numbers (per sq. ft.)	Straw weight (lb./ac.)
1	H-4	milk-ripe	malnutrition (hs)	11.5	2,210
2	H-7	do.	(excess of N)(st)	18.0	2,560
3	H-4	do.	P (st, bs)	17.4	3,430
4	Do.	do.	— (bs)	24.4	11,010
5-1	Do.	do.	maln. (st)	14.3	3,000
5-2	Paravakalian	do.	(st, bs, sb)	16.5	5,130
6-1	H-8	do.	maln. (bs, sb)	18.0	2,930
6-2	Do.	do.	—(hs, sb)	15.8	4,550
6-3	Do.	do.	—(hs, sb)	22.5	7,480
7-1	Do.	do.	—(hs, sb)	17.5	4,560
7-2	Do.	do.	—(hs, sb)	18.0	5,850
7-3	Do.	do.	—(hs, sb)	23.2	6,560
8-1	Do.	do.	maln., PP (hs)	25.0	3,040
8-2	Do.	do.	—(bs)	23.2	6,040
8-3	Do.	do.	—(bs)	28.5	7,870
9	PTB-16	do.	maln. (bs, lb, sb)	7.6	2,560
10-1	H-4	do.	maln., N, P.	11.0	2,590
10-2	Do.	do.	—	18.0	4,060
11-1	Hondarawala	booting	K, PP (lr, hs, bs)	12.2	1,370
11-2	H-4	yellow-ripe	K, PP (lr, hs, bs)	16.2	1,700
12	Do.	milk-ripe	maln. (hs, lb, sb)	7.6	2,800
13-1	Do.	do.	maln., PP (hs) (Bx-like)	19.2	1,690
13-2	Do.	do.	maln., P (hs)	21.6	3,790
14-1	H-7	do.	P (lr, sb) (str)	25.0	2,590
14-2	Do.	do.	maln. (lr, sb) (str)	31.2	3,260
15-1	H-4	do.	—(lr, bs)	33.4	7,050
15-2	H-7	yellow-ripe	—(lr, bs)	41.1	5,790
16-1	H-4	do.	maln. (st, lh, bs, lb, sb)	10.4	2,980
16-2	H-8	do.	— (sb)	24.8	10,570
17-1	H-6	yellow-r.	BB (lh, hs, bs, lb, sb)	10.5	2,350
17-2	H-8	milk-ripe	BB(lh, hs, bs, lb, sb)	24.5	4,260
17-3	H-4	initial-ripe	NN (bs)	9.6	2,300
17-4	H-8	yellow-ripe	—(st, lr, bs, sb)	20.4	4,380
17-5	Do.	do.	—(st, lr, bs, sb)	21.6	5,950
17-6	Do.	milk-ripe	maln., B (lr, bs)	15.0	4,030
17-7	Do.	do.	maln., B (lr, bs)	18.6	3,150
18-1	H-4	do.	—	24.0	6,600
18-2	H-7	do.	— (hs)	24.5	3,720
19	H-8	initial-ripe	maln. N (bs, sb)	12.0	3,460
20	H-4	milk-ripe	— (sb)	24.0	10,630

*N, P, K and B—Nitrogen, phosphorus and potassium deficiency, and Bronzing, respectively. Double letters such as PP indicate severe symptoms; lr—leaf roller; lh—leaf hopper; st—stem borer; hs—Helminthosporium spot; bs—brown spot other than (hs); lb—leaf blast; sb—sheath blight.

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TABLE 4.—Nutrient content in straw of rice plants from sample survey*

Straw weight (lb./ac.)	Sample No.	N %	P ₂ O ₅ %	K ₂ O %	CaO %	MgO %	Fe ₂ O ₃ ppm	SiO ₂ %
2,210	1	1.05	0.37	1.89	0.54	0.39	1,360	8.99
2,560	2	1.38	0.58	2.31	0.78	0.27	720	4.90
3,430	3	0.95	0.33	0.86	0.54	0.25	1,360	9.89
11,010	4	0.81	0.36	1.89	0.59	0.22	720	8.06
3,000	5-1	0.78	0.46	1.25	0.52	0.39	1,360	7.81
5,130	5-2	1.20	0.58	0.41	0.54	0.25	720	5.18
2,930	6-1	1.20	0.42	2.02	0.47	0.41	1,360	8.86
4,550	6-2	1.03	0.45	2.35	0.48	0.33	1,720	10.62
7,480	6-3	0.85	0.49	1.89	0.48	0.24	1,860	10.50
4,560	7-1	0.95	0.22	1.98	0.54	0.11	720	8.12
5,850	7-2	1.51	0.33	1.58	0.41	0.15	1,860	8.90
6,560	7-3	0.91	0.42	1.95	0.46	0.24	720	9.04
3,040	8-1	0.70	0.14	1.58	0.48	0.09	1,360	9.09
6,040	8-2	0.98	0.27	1.47	0.48	0.17	720	7.72
7,870	8-3	0.86	0.35	1.65	0.41	0.22	1,860	8.32
2,560	9	0.76	0.47	0.56	0.54	0.18	720	9.96
2,590	10-1	0.94	0.62	1.80	0.50	0.14	1,860	10.15
4,060	10-2	1.45	0.62	2.02	0.46	0.23	720	9.54
1,370	11-1	1.45	0.18	1.72	0.75	0.24	1,860	9.70
1,700	11-2	1.08	0.17	2.23	0.54	0.20	720	10.67
2,800	12	0.84	0.46	1.95	0.51	0.17	720	6.11
1,690	13-1	1.45	0.20	1.76	0.64	0.08	1,360	9.99
3,790	13-2	1.68	0.18	1.58	0.61	0.15	1,860	6.86
2,590	14-1	1.33	0.22	2.10	0.78	0.12	1,800	8.98
3,260	14-2	1.18	0.46	1.76	0.71	0.16	1,360	9.58
7,060	15-1	0.64	0.33	2.27	0.65	0.17	720	10.31
5,790	15-2	0.48	0.25	3.44	0.63	0.10	1,860	13.41
2,980	16-1	1.18	0.27	1.25	0.67	0.16	1,360	7.57
10,570	16-2	1.04	0.36	1.69	0.60	0.13	1,360	8.06
2,360	17-1	1.88	0.40	0.35	0.65	0.16	1,860	3.58
4,260	17-2	2.00	0.35	0.62	0.76	0.10	2,500	5.05
2,300	17-3	0.90	0.53	1.76	0.64	0.03	1,360	6.33
4,380	17-4	0.56	0.15	1.06	0.59	0.08	1,860	8.21
5,950	17-5	0.70	0.18	1.44	0.65	0.06	720	9.09
4,030	17-6	1.13	0.25	1.08	0.59	0.11	3,570	7.80
3,150	17-7	0.88	0.12	1.18	0.69	0.15	720	8.30
6,600	18-1	1.18	0.48	2.27	0.82	0.09	1,860	12.33
3,720	18-2	0.78	0.38	3.01	0.84	0.24	720	10.83
3,460	19	0.73	0.33	1.37	0.44	0.23	1,860	9.30
10,630	20	1.23	0.58	3.15	0.53	0.18	720	6.47

* Expressed on air-dry weight basis of straw.

TABLE 5. Nutrient content in panicles of rice plants from sample survey*

Sample No.	Location	N %	P ₂ O ₅ %	K ₂ O %	CaO %	MgO %	Fe ₂ O ₃ %	SiO ₂ %
4	Maha Illuppallama	1.25..	0.32..	0.32..	0.23..	0.05..	715..	4.77
15-1	Okkampitiya	1.13..	0.59..	0.35..	0.27..	0.07..	720..	5.31
15-2	Okkampitiya	1.15..	0.65..	0.35..	0.33..	0.05..	1,360..	5.96
6	Nalanda	1.38..	0.76..	0.47..	0.33..	0.06..	1,360..	6.51

* Expressed on air-dry weight-basis.

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urvey*

	SiO_2
	%
715...	4.77
9...	5.31
1000...	5.96
300...	6.51

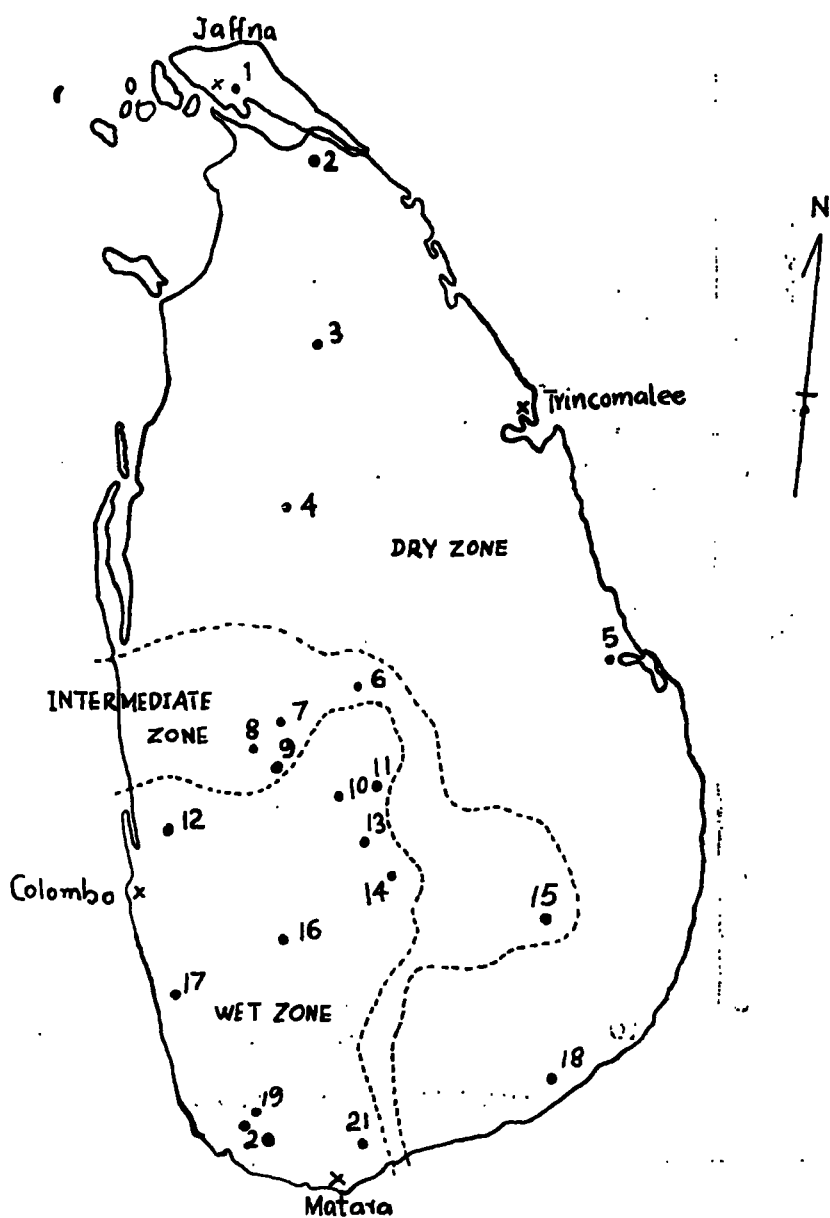


Fig. 1—Location of sampling sites.

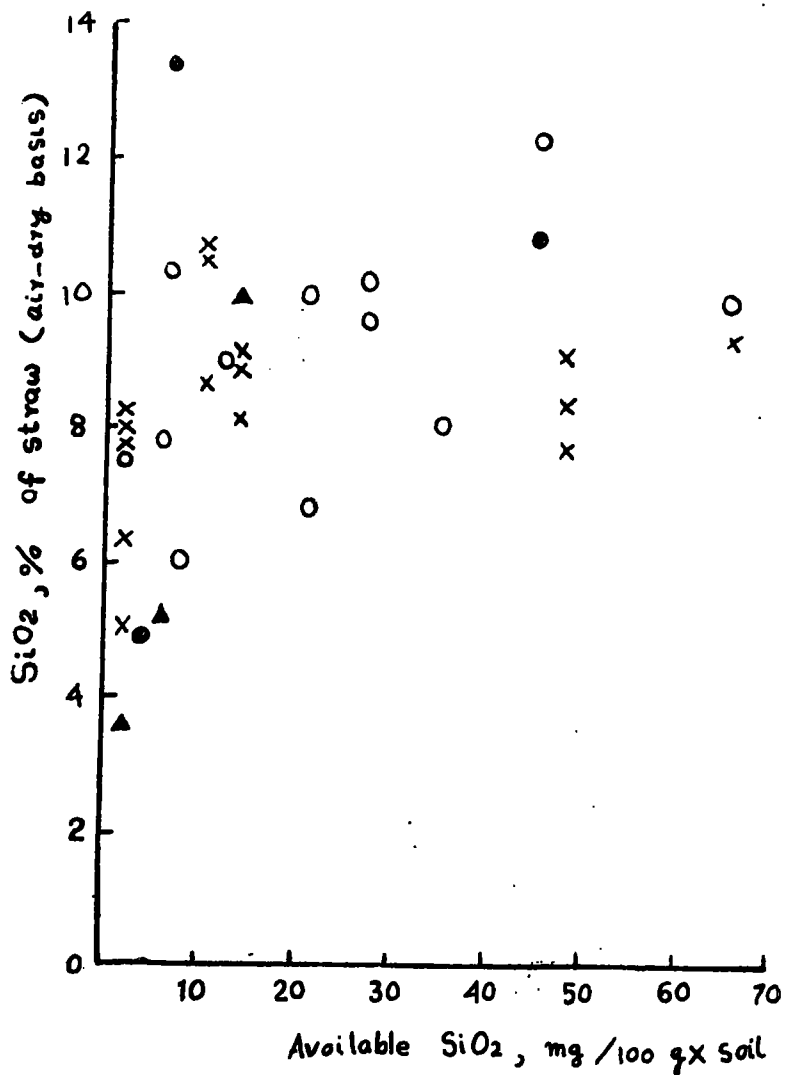


Fig. 2—Relationship between SiO_2 content in straw and available SiO_2 in soil, (Milk-ripe stage).

NUTRIENT DEFICIENCY AND PHYSIOLOGICAL DISEASE OF LOWLAND RICE

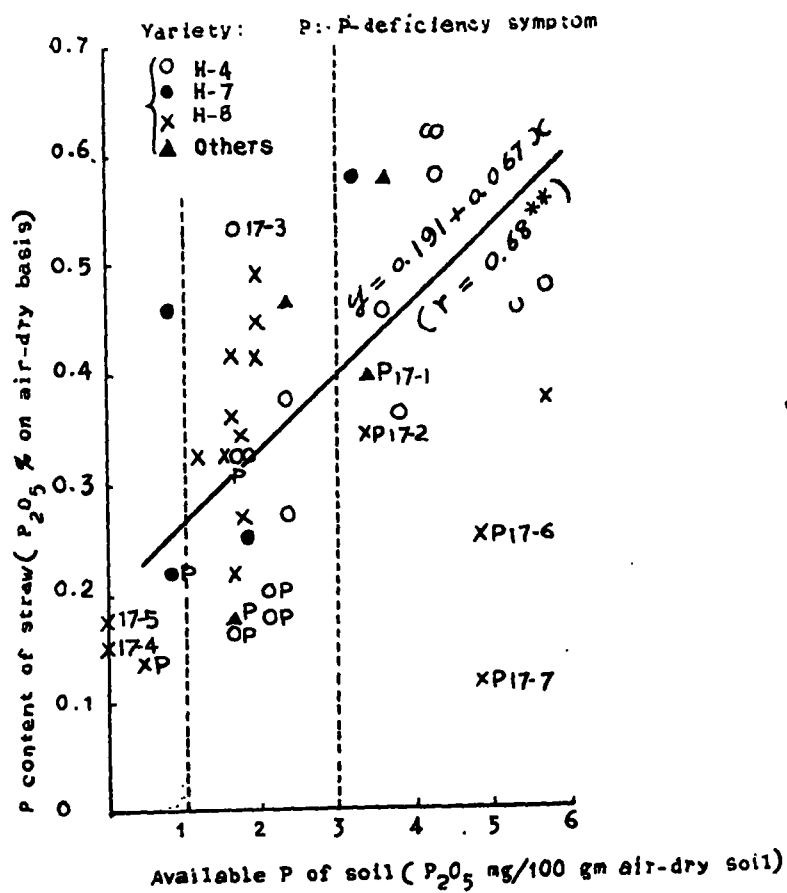


Fig. 3—Relationship between P content in rice straw and available P in soil

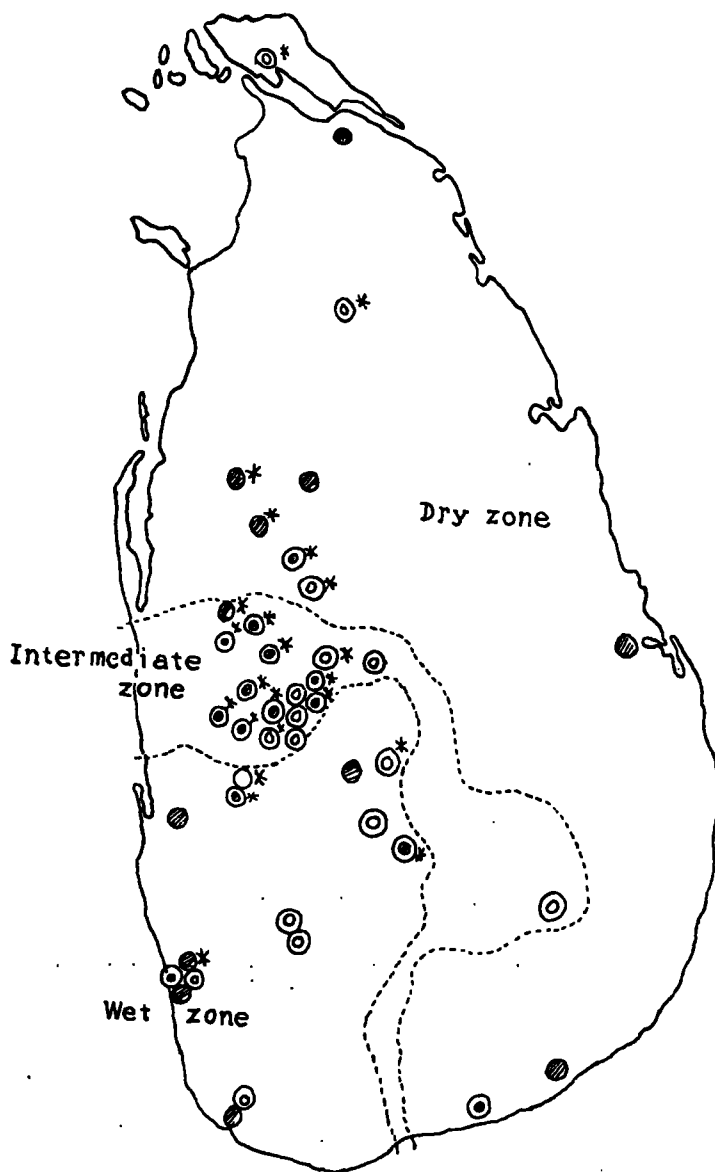


Fig. 4—Distribution Pattern of Available Phosphorus in rice soils.

Legend :		$P_2O_5/100gm. soil$
Normal	..	● >3.0 mg.
Deficient	..	● 1-3.0 mg.
Severely deficient	..	● <1.0 mg.
*Farmer's field.		

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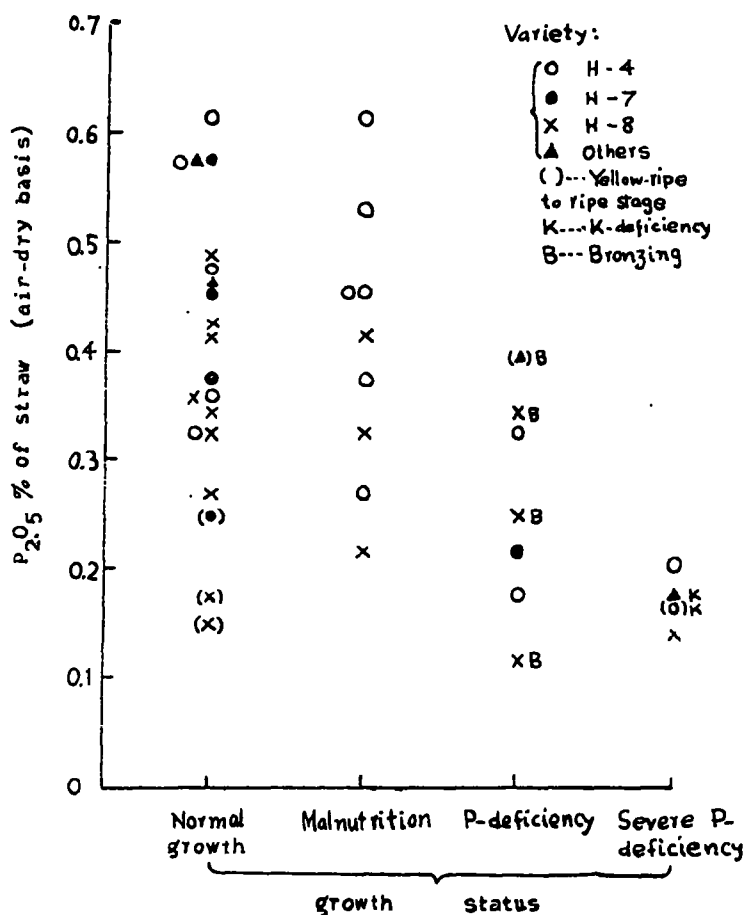


Fig. 5—Relationship between symptom of P—deficiency and P content of rice straw (Milk-ripe stage).

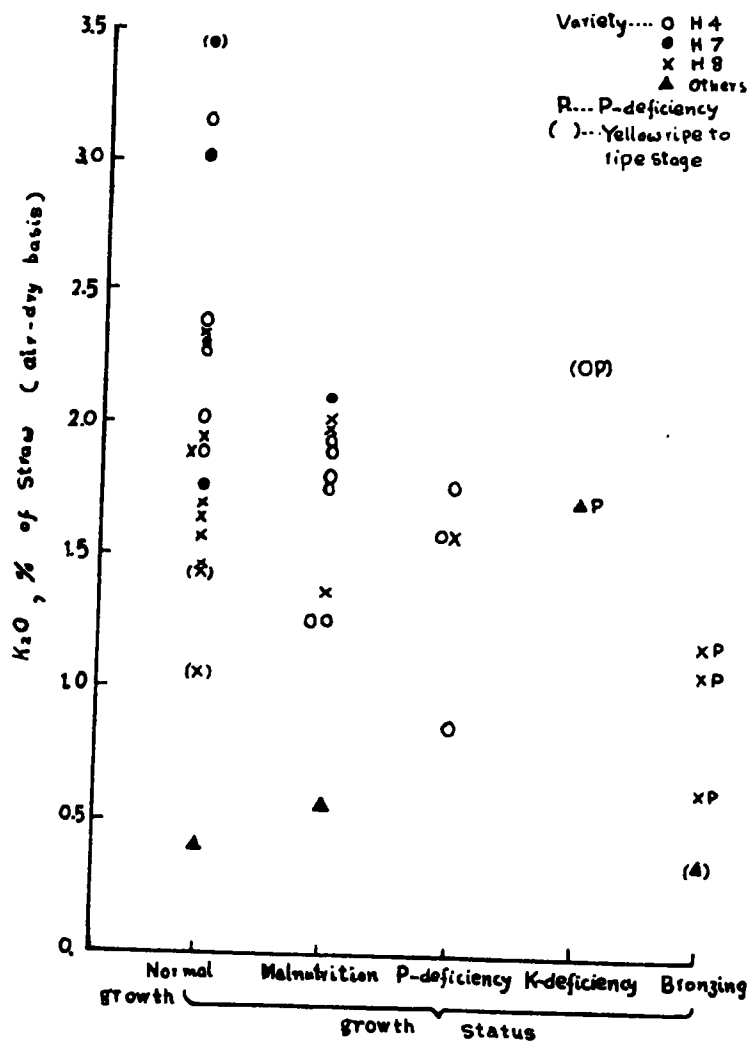


Fig. 6—Relationship between growth status of rice plants and K₂O content in rice straw (Milk-ripe stage).

NUTRIENT DEFICIENCY AND PHYSIOLOGICAL DISEASE OF LOWLAND RICE

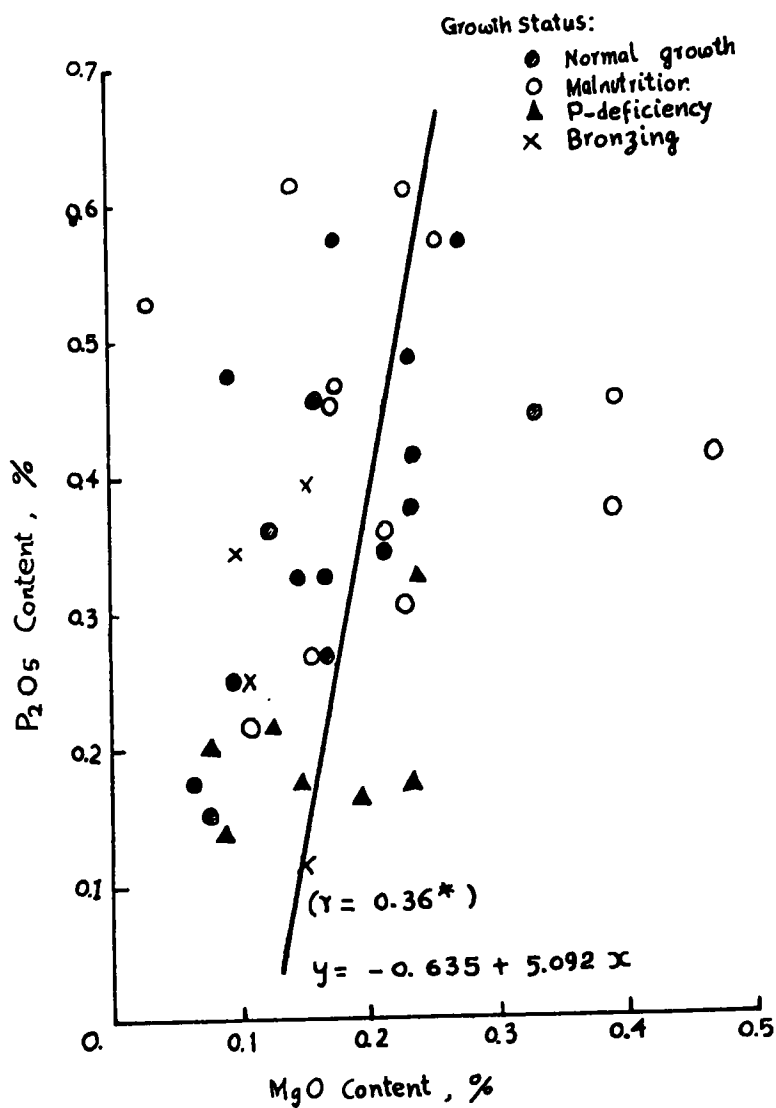


Fig. 7.—Relationship between P and Mg content in rice straw