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Nutrient deficiency and physiological disease of lowland rice in Ceylon

1. Relationship between nutritional status of soil and rice growth

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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.

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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 Kyuma (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 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 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. $P_2 O_5$ 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 HC1. 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 phosporus deficiency symptoms (Fig. 5). Pottassium content decreased in increasing order with malnutrition, phosphorus deficiency and bronzing but not in samples showing potasium defiiciency. 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-IICcn
2	PARANTHAN	do.	40	imperfect	Apg-ACcn-BCcn
3	VAVUNIYA*	Vavuniya	230	moderately well	Apg-AC-IICcn
4	MAHA ILLUP-PALLAMA	Anuradhapura	350	moderately well	Apg-ACg-IIC-IIIC
5	KARADIYAN ARU	Batticaloa	30	imperfect	Apg-AC-IICgcn
6	NALANDA	Matale	840	well	Apg-ACcn-Ccn-IIC
7	BATALAGODA	Kurunegala	380	imperfect	Apg-Cgcn-IIgcn
8–1	PANALIYA*	do.	300	poor	Apg-ACg-Cgcn-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-IIIC1cn-IIIC2cn-IIIC3cn
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-IIIC
18	TISSAMAHARAMA	Hambantota	100	imperfect	Apg-ABg-Bg
19	NARAWELA	Galle	30	poor	Apgh-ABgh-IICgh (peat)
20	LABUDUWA	do.	20	poor	Apgh-ACgh-IIC1gh-IIC2h (peat

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

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

Sample No.	*Texture*	*pH (H_2O)*	*Total* N (%)*	*Total* P_2O_5 (mg./100 gm. soil)*	*Available† P_2O_5 (mg./100 gm. soil)*	*Phosphate†† absorption coefficient (P_2O_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	0.079	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 P_2O_5 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.	de.	—	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.

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

Sample No.	N %	P_2O_5 %	K_2O %	CaO %	MgO %	Fe_2O_3 ppm	SiO_2 %
1	1·05	0·37	1·89	0·54	0·39	1,360	8·99
2	1·38	0·58	2·31	0·78	0·27	720	4·90
3	0·95	0·33	0·86	0·54	0·25	1,360	9·89
4	0·81	0·36	1·89	0·59	0·22	720	8·06
5–1	0·78	0·46	1·25	0·52	0·39	1,360	7·81
5–2	1·20	0·58	0·41	0·54	0·25	720	5·18
6–1	1·20	0·42	2·02	0·47	0·41	1,360	8·66
6–2	1·03	0·45	2·35	0·48	0·33	1,720	10·62
6–3	0·85	0·49	1·89	0·48	0·24	1,860	10·50
7–1	0·95	0·22	1·98	0·54	0·11	720	8·12
7–2	1·51	0·33	1·58	0·41	0·15	1,860	8·90
7–3	0·91	0·42	1·95	0·46	0·24	720	9·04
8–1	0·70	0·14	1·58	0·48	0·09	1,360	9·09
8–2	0·98	0·27	1·47	0·48	0·17	720	7·72
8–3	0·86	0·35	1·65	0·41	0·22	1,860	8·32
9	0·76	0·47	0·56	0·54	0·18	720	9·96
10–1	0·94	0·62	1·80	0·50	0·14	1,860	10·15
10–2	1·45	0·62	2·02	0·46	0·23	720	9·54
11–1	1·45	0·18	1·72	0·75	0·24	1,860	9·70
11–2	1·08	0·17	2·23	0·54	0·20	720	10·67
12	0·84	0·46	1·95	0·51	0·17	720	6·11
13–1	1·45	0·20	1·76	0·64	0·08	1,360	9·99
13–2	1·68	0·18	1·58	0·61	0·15	1,860	6·86
14–1	1·33	0·22	2·10	0·78	0·12	1,800	8·98
14–2	1·18	0·46	1·76	0·71	0·16	1,360	9·58
15–1	0·64	0·33	2·27	0·65	0·17	720	10·31
15–2	0·48	0·25	3·44	0·63	0·10	1,860	13·41
16–1	1·18	0·27	1·25	0·67	0·16	1,360	7·57
16–2	1·04	0·36	1·69	0·60	0·13	1,360	8·06
17–1	1·88	0·40	0·35	0·65	0·16	1,860	3·58
17–2	2·00	0·35	0·62	0·76	0·10	2,500	5·05
17–3	0·90	0·53	1·76	0·64	0·03	1,360	6·33
17–4	0·56	0·15	1·06	0·59	0·08	1,860	8·21
17–5	0·70	0·18	1·44	0·65	0·06	720	9·09
17–6	1·13	0·25	1·08	0·59	0·11	3,570	7·80
17–7	0·88	0·12	1·18	0·69	0·15	720	8·30
18–1	1·18	0·48	2·27	0·82	0·09	1,860	12·33
18–2	0·78	0·38	3·01	0·84	0·24	720	10·83
19	0·73	0·33	1·37	0·44	0·23	1,860	9·30
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_2O_5 %	K_2O %	*CaO* %	*MgO* %	Fe_2O_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.

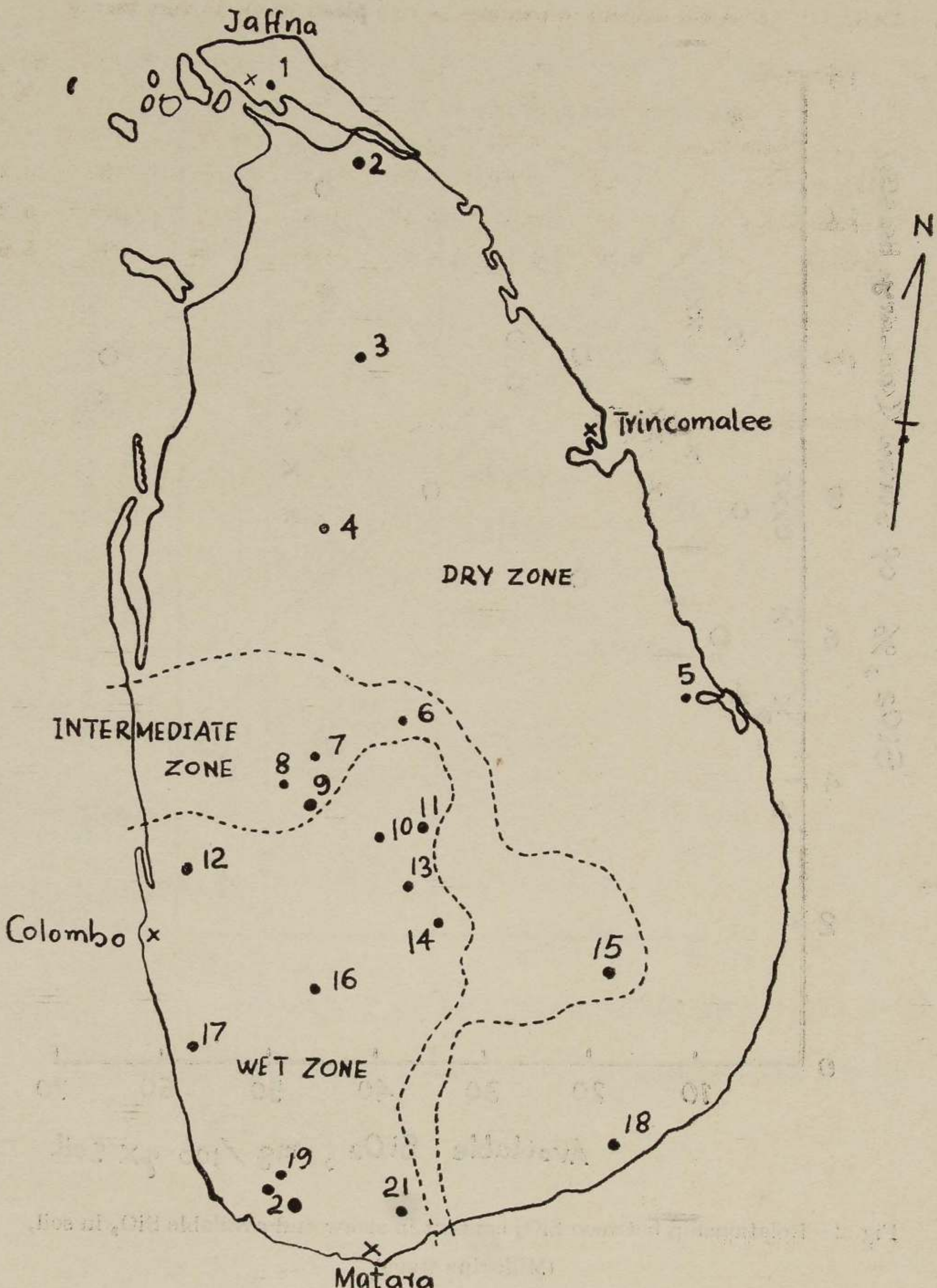

Fig. 1—Location of sampling sites.

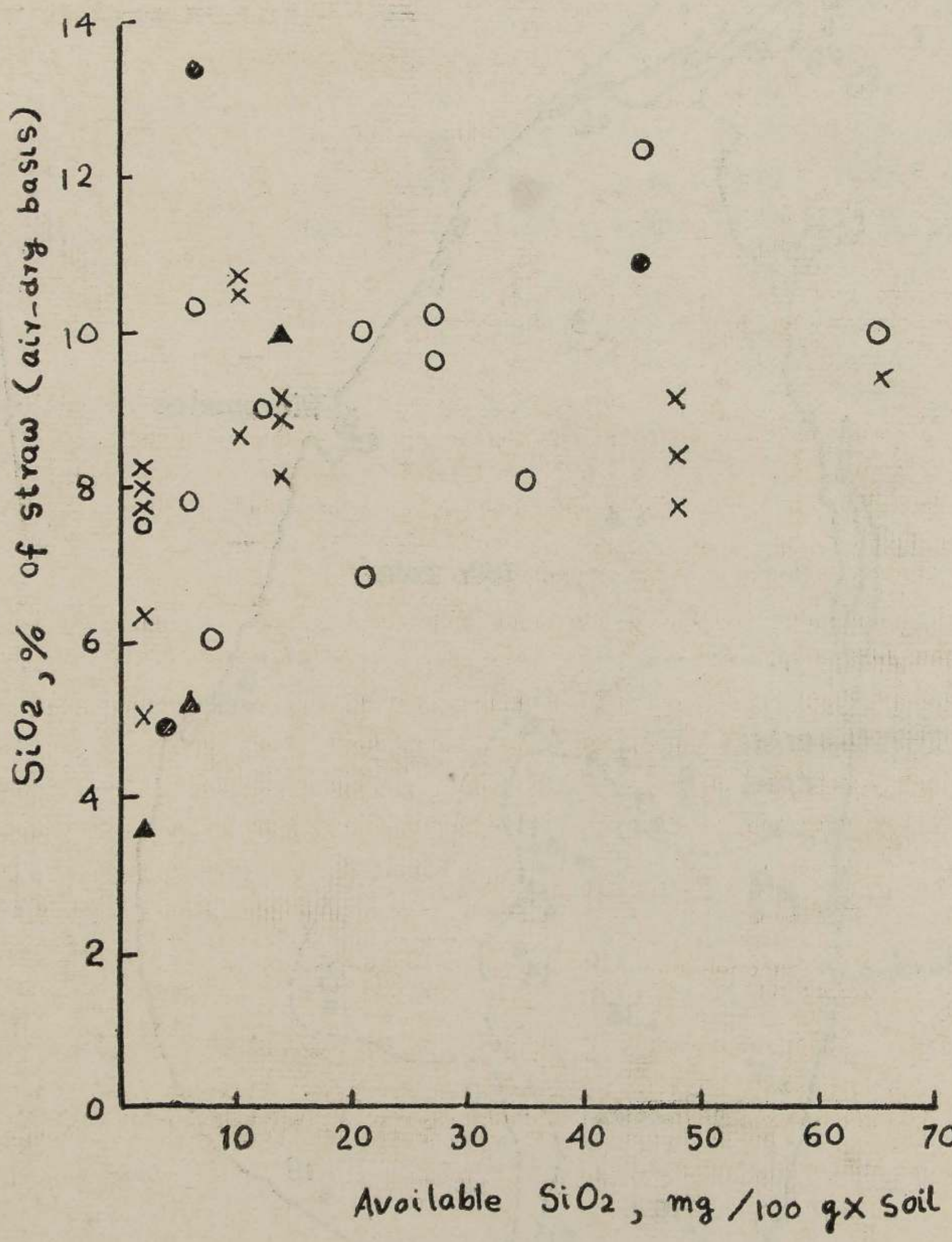

Fig. 2—Relationship between SiO_2 content in straw and available SiO_2 in soil, (Milk-ripe stage).

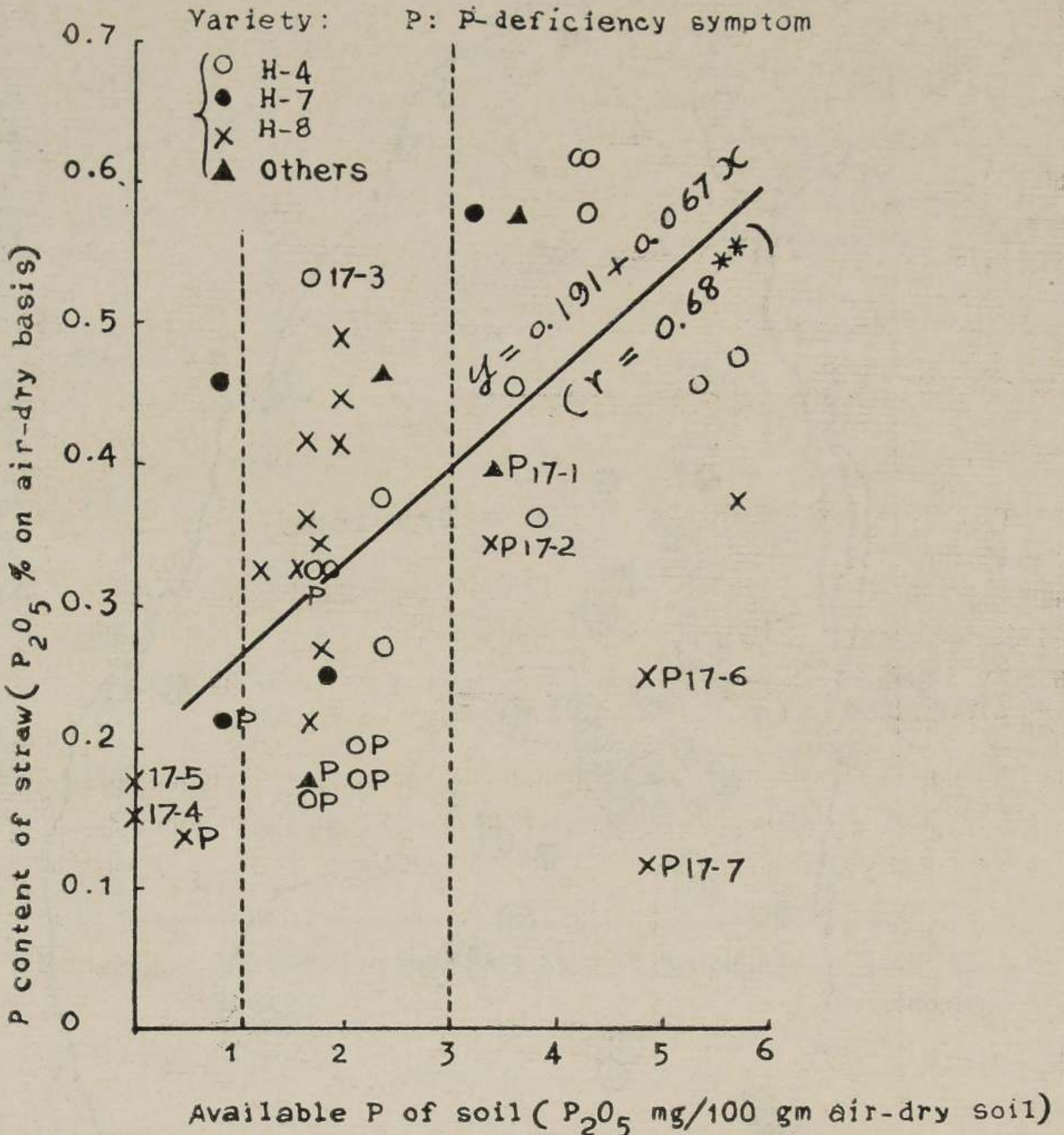

Fig. 3—Relationship between P content in rice straw and available P in soil

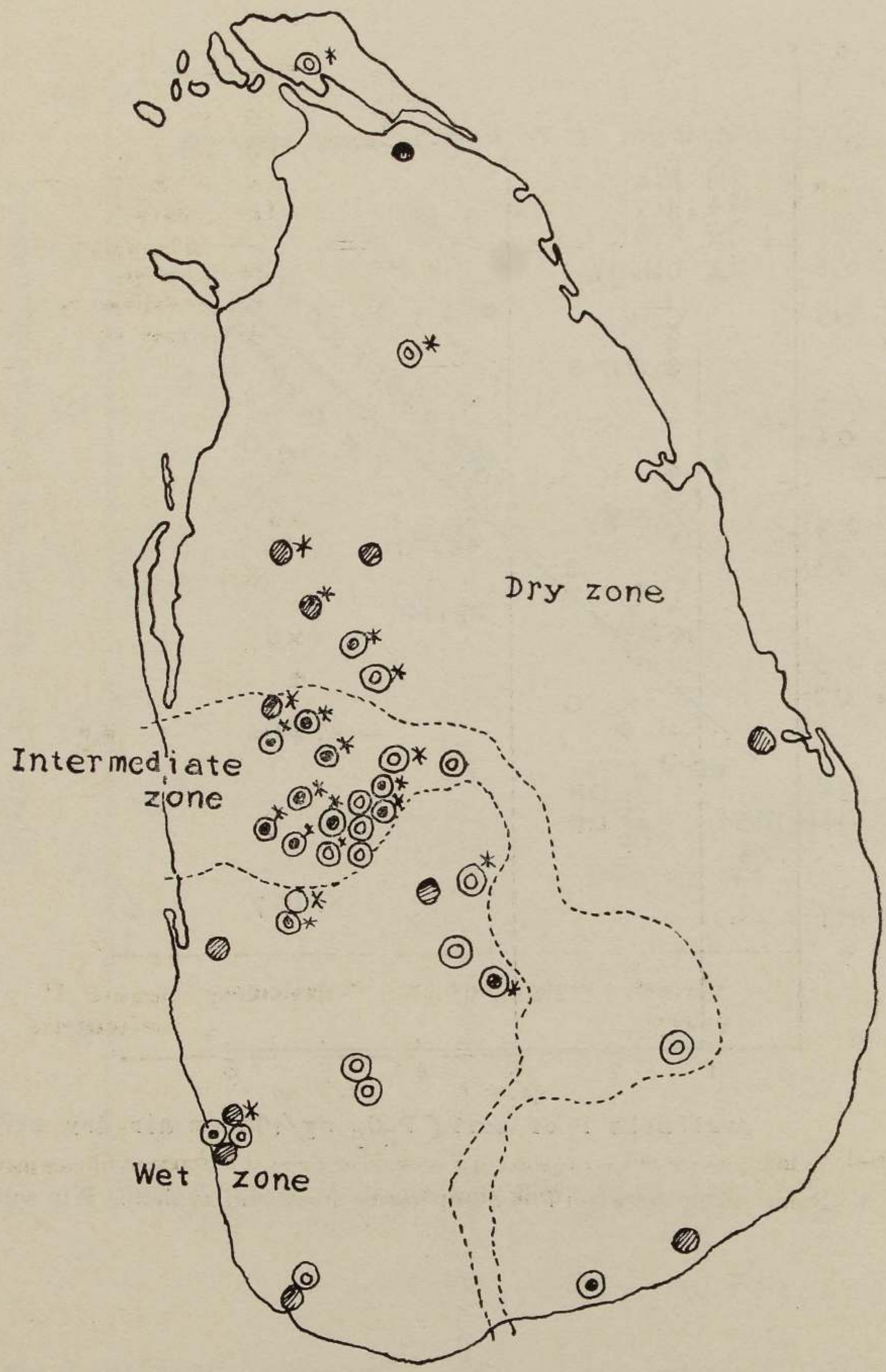

Fig. 4—Distribution Pattern of Available Phosphorus in rice soils.

Legend :

		$P_2O_5/100gm.$ *soil*
Normal	..	● >3.0 mg.
Deficient	..	● 1–3.0 mg.
Severely deficient	..	● <1.0 mg.

*Farmer's field.

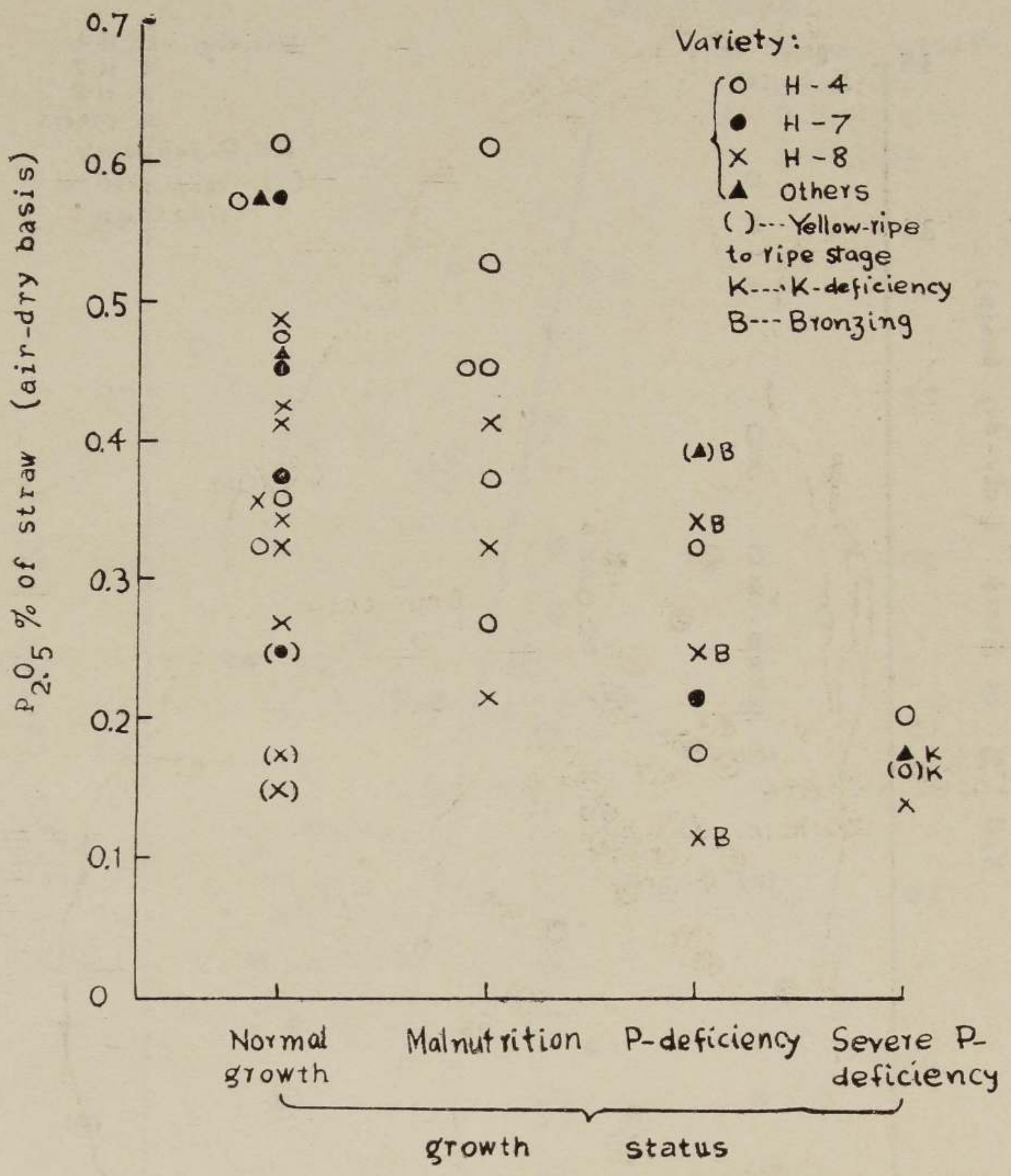

Fig. 5—Relationship between symptom of P—deficiency and P content of rice straw (Milk-ripe stage).

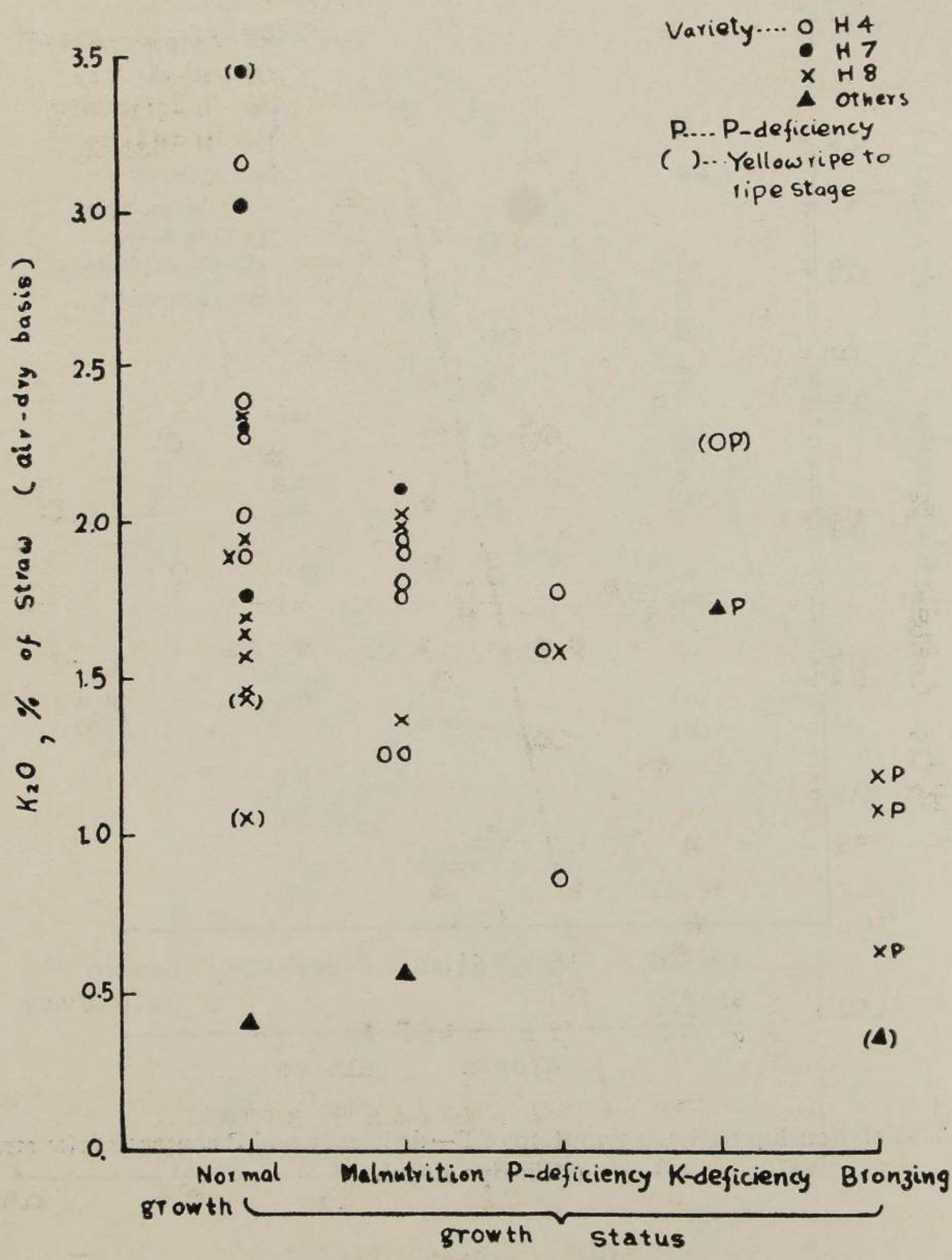

Fig. 6—Relationship between growth status of rice plants and K_2O content in rice straw (Milk-ripe stage).

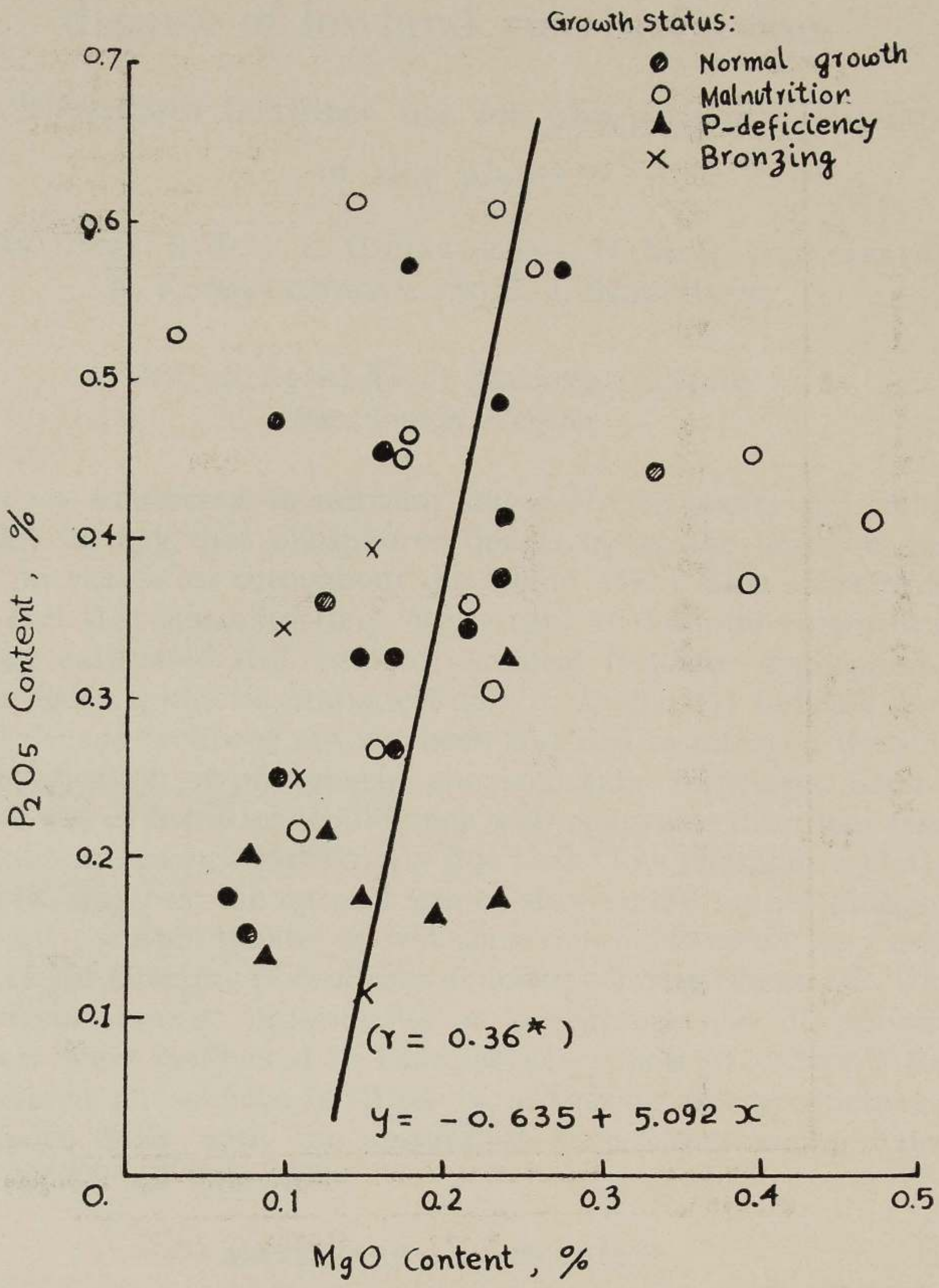

Fig. 7—Relationship between P and Mg content in rice straw

Nutrient deficiency and physiological disease of lowland rice in Ceylon

II. Phosphate fertilizer use for phosphorus deficiency of rice plants

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A survey conducted on nutrient status of rice plants and soil had indicated clearly that phosphorus deficiency is the most common malady in rice fields throughout the Island (11). This substantiated by the fact that approximately 70 per cent of the total extent of rice fields are cultivated still without chemical fertilizer application. As in other Asian countries, statistical data in Ceylon (1) indicate that in the last decade fertilizer use has been confined to nitrogen with little or no application of phosphorus and potassium fertilizers. Such imbalanced use of fertilizers could very well aggravate disorders related to phosphorus balance particularly due to the low phosphorus status of most soils. Further, the current use of slow-acting saphos phosphate, pulverised rock phosphate, in wet zone rice fields could be a contributory factor effecting phosphorus deficiency in rice plants (2). Under these circumstances, experiments on the proper use of phosphate fertilizers were conducted to examine the effects of different forms and doses of phosphorus fertilizer in increasing rice production and this report deals with the results of such experiments done in Maha 1967-68 and Yala 1968.

MATERIALS AND METHODS

Phosphate fertilizers

The forms of phosphate fertilizer used were saphos phosphate, fused magnesium phosphate and concentrated super phosphate. These phosphate fertilizers have P_2O_6 contents of 28 per cent (citric acid soluble), 20 per cent (citric acid soluble) and 42.5 percent (water soluble), respectively.

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Pot experiments

Four soils, Bombuwela sandy and humic, Panaliya clayey and Peradeniya clayey, were used. Properties of these soils been described in a previous report (II).

Pot soil cultures were conducted in the green house at the Central Agricultural Research Institute (C. A. R. I.) using the three forms of phosphate fertilizer. Wagner's pots having a surface area equivalent to 1/500,000 hectare were arranged according to a randomised block design with two or three replicates. All pots received 0.5 gm of N as amonium sulphate and 1 g of K_2O as potassium chloride as a basal application, and 0.5 gm of N as ammonium sulphate as a top-dressing at the primordium initiation stage of growth. Phosphate was added at graded levels, i.e. O, 1, 2 and 3 gm of P_2O_5 per pot as a basal dressing. Approximately 21 day old seedlings of the variety H4 or H8 were transplanted one hill to a pot with three seedlings per hill. The soil in pots was kept flooded with tap water from transplanting till maturity of plants. Endrin (insecticide) was sprayed twice after the plants had reached the maximum tillering stage. Growth was measured every two weeks after planting. Yield data were collected on culm and panicle length, panicle number, and weight of straw and panicle or grain in each pot. Chemical analyses were done on the straw to determine the content of nutrient elements.

Field experiments

These experiments were conducted in Government Experiment Stations at Nalanda, Batalagoda, Karapincha and Bombuwela (sandy and humic). Properties of the field soils have been described in a previous report (11). Field experiments were also carried out in farmers' fields mainly in Kurunegala District where various growth disorders were noticed in rice plants. The soil profiles in these fields were examined and described (Table 1). Some chemical properties of the surface soil are described in Table 2.

Experimental plots were 10 × 20 feet in size and were separated by 1 foot bunds. The experiments were conducted on a randonized block design with two to four replicates. Approximately 21 day old seedlings of the variety H4 or H8 were transplanted at a spacing of 8 inches between rows and 6 inches within the row with 3 seedlings per hill. Some of the experiments in farmers' fields were broadcast sown. All fields were supplied with nitrogen and potassium fertilizers according to the recommendations of the Department of Agricuture for improved varieties (2). Phosphate fertilizers in three forms were added as basal application at the same doses as in the recommendations or at graded levels depending on the soil conditions.

Growth was measured in 20 hills for each plot, two to six times during the season at different stages of the crop. In broadcast experiments growth measurements were done on plants in two, one square foot areas per plot. Yield in each plot was recorded from rice plants harvested from 6 × 6 feet area.

RESULTS AND DISCUSSION

Pot experiments

In Maha 1967-68 three soils were grown with H4. The results are summarized in Table 3. In Panaliya clayey soil, rice plants showed typical phosphorus deficiency symptoms in the absence of applied phospate. Plants were stunted, dark green in colour and did not produce tillers until about 60 days after sowing. Onset of flowering was delayed by 18 days compared to treatments receiving phosphate, reresulting in a very low panicle yield. Plants supplied with phosphorus in the form of saphos phosphate showed similar symptoms upto heading, and the yields were lower than with fused magnesium phosphate and conc. super phosphate. (Fig. 1) Less severe deficiency symptoms were seen in the experiment with Bambuwela sandy soil while with Bombuwela humic (clayey) soil there was no marked growth difference in plants receiving no phosphate and saphos phosphate. The reason for lack of severe phosphorus deficiency symptoms in these two soils is due possibly to these soils being repeatedly fertilized with phosphate fertilizer over a period of years. However, here too fused magnesium and conc. super phosphate were superior to saphos phosphate in straw and panicle yield. Fig. 1 shows the general condition of rice plants grown in Panaliya clayey soil at the maximum tiller number stage.

Similar results were obtained with C. A. R. I. clayey soil taken from the newly established rice fields in front of the Institute (Table 4). This soil is also one typically deficient in phosphorus. Optimum dose of phosphate for getting highest yield was found to be around 1.5 g P_2O_5 per pot containing soil. This dose is equivalent to 750 Kg per hectare.

The residual effect of phosphate fertilizers was examined in the next season, Yala 1968 using the same potted soils. There was no appreciable change in response pattern in the three soils.

The results of chemical analyses of straw taken from the Panaliya soil experiment are given in Table 5. Plants with no phosphate were abnormally high in nitrogen and potassium, and extremely low in phosphorus. The low magnesium and phosphorus contents are probably correlated in these plants. Phosphorus content in the straw increased with increase in level and availability of the phosphate fertilizers. Silica content obtained after determining ash contents of the samples was quite low. The relatively higher contents of silica in the samples grown with fused magnesium phosphate may be attributed to the effect of available silica contained in the fertilizer.

Field experiments

Haigh and Joachim (5) had stated as far back as 1933 that phosphoric acid is the limiting factor determining crop yield in Ceylon's rice soils. They reported later that the form of phosphate, be it either a slow-acting or fast-acting kind, had no difference on rice yields (6). Other investigators too found no signifiicant differences among several kinds of phosphatic fertilizers and because of its low unit cost, saphos phosphate had been recommended for the whole Island (3, 9). Recently, however, the recommendation has been changed to conc. super phosphate for the dry and part of the intermediate zone (2). This revision has been based partly on the results obtained from the fertilizer experiments of FAO Project (12).

Five field experiments were conducted in Government Experiment Stations and 18 experiments in farmers' fields in the wet and intermediate zones from Maha to Yala 1967-68. Saphos phosphate was found to be inferior to the improved phosphate fertilizers in increasing rice growth. Fig 2 gives one example of growth differences obtained at Panaliya. The yield ratio of grain in this experiment was saphos phosphate 56, fused magnesium phosphate 108 and conc. super phosphate 100. Less growth differences were observed among among phosphate fertilizers in the Bombuwela sandy and humic fields. Here the yield ratio of grain with saphos phosphate treatment was 86 and 91, respectively, showing a similar trend as obtained in the pot experiments. Results in Maha 1967-68 experiments are summarized in Table 6. Saphos phosphate was inferior to the other two forms of phosphate in all locations, even in the Acid Swamp Soils (Bombuwela) of the wet zone (8) and especially so in the farmers' fields where little or no fertilizer has been used in the past. Fused magnesium phosphate was generally less effective on initial vegetative growth than conc. super phosphate, but at later stages this difference evened out resulting at times in a higher number of productive tillers (Fig. 2). Better response of rice to this fertilizer recorded in the farmers' fields suggests its suitability for fields which are in strongly reduced condition and highly deficient in available soil phosphorus (7).

Experiments on levels of phosphate fertilizers were conducted on some of the farmers' fields of Kurunegala District. Table 7 gives the summarized results of the experiments. The Nikeweratiya field was very boggy and ill-drained and was claimed to yield usually less than 25 bushels of paddy per acre per season. Plants grown here showed severe deficiency symptoms of phosphorus despite the higher content of soil available phosphorus (Table 2). A striking difference in growth and yield was observed between treatments with saphos phosphate and conc. super phosphate. Increased straw growth and panicle number by the latter phosphate fertilizer account for the increase in grain yield. From these experiments, optimum or sufficient levels of phosphate in the forms of improved phosphate fertilizer can be estimated to be 75 to 150 lbs of $P_2 O_5$ per acre for normal soil or soil slightly deficient in available phosphorus, and 150 to 225 lbs for soil moderately or extremely deficient in available phosphorus. These levels of fertilizer are much higher than those reported by Rodrigo (10) which range from 20 to 120 Kg of P_2O_5 as saphos phosphate.

Absorption of phosphate by the soil

As described already, rice soils in Ceylon are generally deficient in available phosphorus, and characterised by fairly high phosphate available phosphorus, and are characterised by fairly high phosphate (11). Since these alluvial materials were derived mainly from the Reddish Brown Soils (8) produced under laterite formation, they are rich in sesquioxides of iron and aluminium which produce insoluable phosphates.

Fig. 3 gives examples of relationships between concentration of phosphate in reagent solution and amount of phosphate absorbed by the soil. In view of the large accumulation of ferrous iron during the cropping season, it seems that soil iron is active enough to account for the high absorption coefficient of phosphate. Soil alumina might also play a role in this absorption because aluminium phosphates are less available to rice plants (4) and there were instances where phosphate application was very effective in increasing rice production despite the high levels of available soil phosphorus (Bombuwela, Nikeweratiya, etc.)

Considering these results there is ample justification to recommend increased application of phosphate fertilizers to the rice fields. Highly effective phosphate fertilizers other than saphos phosphate should be used even in the wet zone for increasing rice production in low yield areas.

SUMMARY

In view of the widespread occurrence of phosphorus deficiency in rice, pot and field experiments were conducted from 1967 to 1968 to investigate suitable forms and levels of phosphate fertilizer to be used in rice fields.

1. Saphos phosphate that is still recommended to the wet zone by the Department was found inferior to the improved fertilizers, fused magnesium phosphate and conc. super phosphate in raising rice yields. Nutrient composition of straw gave clear evidence as to the degree of availability of the different phosphate fertilizers.

2. Sufficient level of phosphate application was estimated around 150 lbs of P_2 O_5 per acre depending on the degree of phosphorus deficiency of the soil.

Increased application of phosphate fertilizers is recommended taking account of the high absorption of phosphate by the soil. Improved phosphate fertilizers are indicated for use in rice fields in the wet zone instead of saphos phosphate.

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TABLE 1.—Location and soil condition of farmers' rice fields where experiments were conducted

Field No.	*Location*	*Elevation feet*	*Drainage of the field*	*Soil horizon sequence*	*Texture sequence*
1	Tambutta*	300	Well	Ap-AC-(C)	LS-S
2	Galgamuwa*	260	poor	Apcn-C	L-SC
3	Maho*	400	Well	Ap-AC-(C)	SiL-SiL
4	Nikaweratiya	130	poor	Apg-ACg-Cgcn-IIC	CL-SL-SL-HC
5	Polpitigama*	400	well	Ap-ACcn-(C)	SL-LS
6	Hettipola	120	well	Ap-B2-BC-C	LS-LS-L-SL
7	Katupotha	310	well	Ap-AC-IIC	SL-LS-SL
8	Ibbagamuwa	500	imperfect	Ap-C-IICcn	L-LiC-SiC
9	Bingiriya*	110	moderately	Ap-AC-C-IIC	SL-SL-SL-CL
10	Kuliyapitiya	240	poor	Apg-AC-C	SC-LS-S
11	Bogamuwa	500	moderately well	Ap-B2cn-C-IICcn	L-L-SL-SL
12	Pannala*	180	poor	Apg-ACg-Cg	SL-SL-LiC
13	Godigamuwa	560	poor	Apg-C[illegible] Cg-IIICg	SC-SC-SL-LiC
14	Alawwa*	130	imperfect	Apg-[illegible]-Cg	SC-LS-S
15	Panaliya	300	p[illegible]	Apg-A[illegible]g-Cg-IICg	SCL-SCL-SiL-SCL
[illegible]	Warakapola—1	450	[illegible]	Apg-ACg-Cg	CL-L-LS
	Warakapola—2	450	[illegible]	Apg-ACg-Cg	SCL-SL-SL-L

*These fields were used for fertili[illegible] ther than phosphate fertilizers and are [illegible] here for convenience.

TABLE 2.—Some chemical properties of farmers' field soils used for field experiments

Location No.	*Soil colour*		*pH*		*Exchangeable ferrous iron, ppm.*	*Available* P_2O_5 mg/100g soil*	*Phosphate† absorption coefficient*
	On Sampling	*After air-drying*	*H_2O*	*KCL*			
1	2.5 Y4/2	10 YR 6/2	5.5	5.0	tr.	3.35	500
2	2.5 Y4/2	2.5 Y 6/2	6.3	5.1	tr.	10.15	500
3	2.5 Y 7/2	10 YR 7/2	5.6	5.0	tr.	0.85	160
4	N 4/0	2.5 Y 5/2	6.1	4.6	2,140	8.15	800
5	10 YR 7/3	7.5 YR 6/3	5.0	4.7	tr.	1.75	400
6	10 YR 5/4	10 YR 7/4	6.6	5.3	tr.	tr.	400
7	2.5 Y 4/2	10 YR/1	5.8	4.4	tr.	0.85	600
8	10 YR 4/3	10 YR 5/2	5.5	4.7	tr.	2.5	1,250
9	10 YR 4/2	10 YR 7/2	6.6	5.0	tr.	1.05	700
10	2.5 GY 4/1	10 YR 6/2	6.0	5.3	2,160	0.55	800
11	7.5 YR 3.5/4	10 YR 6/4	5.2	5.0	tr.	1.85	700
12	3.5 Y 4/4	10 YR 6/3	5.2	4.5	1,030	1.15	500
13	10 YR 4/2	10 YR 6/4	4.6	4.4	tr.	tr.	1,000
14	2.5 Y 4/4	10 YR 6/3	5.4	4.6	1,110	0.65	1,000
15	7.5 Y 3/2	10 YR 7/4	5.5	5.2	1,801	0.55	600
16-1‡	2.5 Y4 /4	10 YR 6/3	6.0	4.5	1,700	1.05	950
16-2	2 5 Y 3/4	10 YR 6/3	5.3	4.4	2,110	3.95	1,250

* Olsen's method (1954).

† Official method of soil analysis, Japanese Government (1950). Coefficient is defined as mg of P_2O_5 absorbed by 100g of soil from 2.5% amonium phosphate solution.

‡ Colombo District ; the others, Kurunegala District.

TABLE 3.—Effect of forms and doses of phosphate fertilizers on growth and yield of rice. (Po 1expts., Maha 1967-68, H-4)

Soils used	Treatments* (P_2O_5, gm/pot)			Plant height (cm)	Maximum tiller number	Panicle number	Yield (gm/pot) Straw	Panicle	Total
I. Panaliya clayey ..	1.	No. P.	0 ..	95.7 ..	10.0 ..	9.5 ..	15.2 ..	18.9 ..	34.1
	2.	SP	1 ..	10808 ..	37.5 ..	27.0* ..	51.7 ..	47.7 ..	99.4
	3.	,,	2 ..	104.7 ..	47.0 ..	28.0* ..	62.7 ..	50.4 ..	113.1
	4.	FP	1 ..	105.1 ..	53.0 ..	28.5‡ ..	71.3 ..	46.5 ..	117.9
	5.	,,	2 ..	107.0 ..	48.5 ..	24.0‡ ..	67.0 ..	37.3 ..	104.3
	6.	CP	1 ..	106.0 ..	52.5 ..	25.0‡ ..	70.5 ..	37.3 ..	107.8
	7.	,,	2 ..	108.0 ..	43.0 ..	29.0† ..	61.4 ..	45.1 ..	106.5
II. Bombuwela sandy	1.	No. P	0 ..	98.6 ..	32.5 ..	20.5 ..	52.3 ..	51.9 ..	104.2
	2.	SP	1 ..	95.5 ..	34.5 ..	17.5 ..	42.5 ..	48.2 ..	90.7
	3.	,,	2 ..	101.1 ..	31.0 ..	21.5 ..	44.6 ..	57.9 ..	102.5
	4.	,,	3 ..	102.4 ..	30.0 ..	19.5 ..	45.5 ..	49.1 ..	94.6
	5.	FP	1 ..	111.1 ..	41.0 ..	23.5† ..	59.9 ..	57.1 ..	117.0
	6.	,,	2 ..	111.3 ..	40.5 ..	27.0* ..	67.5 ..	63.3 ..	130.8
	7.	,,	3 ..	112.7 ..	39.5 ..	23.5† ..	64.4 ..	48.9 ..	113.3
	8.	CP	1 ..	106.7 ..	43.5 ..	25.0‡ ..	71.5 ..	37.9 ..	109.4
	9.	,,	2 ..	105.3 ..	46.0 ..	27.5‡ ..	70.2 ..	41.6 ..	111.8
	10.	,,	3 ..	114.4 ..	45.5 ..	26.0† ..	62.3 ..	49.5 ..	111.8
	11.	FP+ CP	2 ..	112.5 ..	48.0 ..	25.0† ..	63.5 ..	56.0 ..	118.5

*S/P—Saphos phosphate ; FP—fused magnesium phosphate ; CP—conc. super phosphate.

Chemicald amage by Endrin spray was marked with * to ‡ according to the grade of damage. Results of Combined analysis of variance using 7 treatments of three soils are as follows :

	C.V. (%)	L.S.D.— 5%	1%
Panicle yield :	8.56	10.2	14.8

TABLE 3.— Effect of forms and doses of phosphate fertilizers on growth and yield of rice. (Pot expts., Maha 1967-68, H-4)

	Soils used	*Treatments ** (P_2O_5, *gm/pot*)		*Plant height (cm)*	*Maximum tiller number*	*Panicle number*	*Yeild (gm/pot)*		
							Straw	*Panicle*	*Total*
III.	Bobmuwela humic	1. No. P	0	99.8	36.5	20.5	43.0	56.8	99.8
		2. SP	1	100.5	37.5	18.5	41.0	52.1	93.1
		3. ,,	2	104.5	35.5	19.5	45.3	52.7	98.0
		4. FP	1	101.2	38.5	26.0	53.9	64.4	118.3
		5. ,,	2	108.3	35.0	23.5	48.7	64.5	113.2
		6. CP	1	104.1	38.5	22.7	48.6	58.3	106.9
		7. ,,	2	105.9	40.5	27.0	55.0	63.3	118.3

TABLE 4.—Effect of forms and doses of phoshpate on yield and yield components of rice.—C.A.R.I. clayey soil, Yala 1968, H–4

Treatment* No.	Longest panicle length (cm)	Number of panicles (per pot)	Effective tillers (%)	Yield (gm/pot) Straw	Panicle	Total	Grain	Grain-straw ratio (%)
1. No P	25 2	10.0	83	23.9	12.2	46.1	11.1	46
2. SAP–0.5	27.3	19.5	67	55.6	36.4	92.0	33.9	61
3. ,, –1.0	26.9	22.7	73	58.4	39.2	97.6	36.4	62
4. ,, –1.5	26.0	24.3	72	63.4	42.9	106.3	39.6	62
5. ,, –2.0	26.6	22.0	73	60.9	38.1	99.0	35.3	58
6. FMP–0.5	26.8	22.0	80	55.0	37.4	92.4	34.9	63
7. ,, –1.0	27.0	25.0	75	68.1	44.9	113.0	41.8	61
8. ,, –1.5	27.7	23.4	64	68.0	48.6	116.6	45.3	67
9. ,, –2.0	26.8	23.5	69	65.3	47.2	112.5	44.2	68
10. CSP–0.5	26.8	24.7	73	64.4	38.8	103.2	35.8	56
11. ,, –1.0	27.4	23.0	75	63.4	41.7	105.1	39.2	62
12. ,, –1.5	26.6	25.7	80	66.0	40.9	106.9	38.0	58
13. ,, –2.0	26.5	26.3	71	65.4	49.0	114.4	42.5	65
14. CSP–2.0†	26.5	29.7	76	91.2	49.2	140.4	45.1	49

*SAP—Saphos phosphate ; FMP—Fused Mg. phosphate ; CSP—Conc. Super phosphate

†Applied with higher dose of N and K_2O, (1.5 g. of each).

Analysis of variance on grain yields : C.V—7.44% ; L.S.D.—3.6 (1%) ; 2.6 (5%)

TABLE 5.—Nutrient content in straw of rice plants grown in Panaliya clayey soil under varying forms and levels of phosphate applied to the soil (H–4, Maha 1967/68)

Treatments P_2O_5,gm/pot	N* %	P_2O_5 %	K_2O %	CaO %	MgO %	Fe_2O_3 ppm	SiO_2 %	As %
No phosphate	1.03	0.09	1.42	1.13	0.23	1610	3.76	6.84
Saphosphos.								
1.0	0.66	0.12	1.07	1.05	0.31	1360	2.54	5.98
2.0	0.59	0.18	0.91	1.08	0.24	2500	2.14	5.19
Fused Mg. phos.								
1.0	0.61	0.23	0.95	1.00	0.36	1040	3.31	6.57
2.0	0.60	0.33	1.00	0.95	0.34	720	4.44	7.36
Conc. super phos.								
1.0	0.64	0.28	1.03	0.86	0.36	1610	2.23	5.00
2.0	0.65	0.34	1.00	0.93	0.33	2180	2.34	6.05

Remarks : * Figures are expressed on air-dry weight basis of the sample.

3—K 2316 (3/71)

TABLE 6.—Effect of phosphate fertilizers on rice yields in field experiments (Maha crop 1967-68, H-4 and H-8)

Number of locations	*Forms of phosphate fertilizer*	*Mean grain yield (bushel/acre)*	*Yield difference (Bushel/acre)*	*Yield ratio (%)*
5 Government Stations ..	Saphos phos. ..	67.4 ..	− 5.5 ..	93
	Fused Mg phos. ..	75.3 ..	+ 2.4 ..	102
	Conc. s. phos. ..	72.9 ..	0 ..	100
8 farmers' fields ..	Saphos phos. ..	41.7 ..	−19.6 ..	68
	Fused Mg. phos. ...	68.2 ..	+ 6.9 ..	111
	Conc. s. phos ..	61.3 ..	0 ..	100

Remarks: Standard application of fertilizers was as follows:—

Nitrogen—45 lbs. of N as ammonium sulphate or 39 lbs. of N as urea per acre as basal and top dressing.

Phosphorus—47 lbs. of P_2O_5 per acre as basal dressing.

Potassium—42 lbs. of K_2O per acre as basal and top dressing.

TABLE 7.—Effect of forms and levels of phosphate fertilizer on yield of rice in field experiments

Nikaweratiya clayey soil, Yala 1968—H-7

Treatments: Phosphate	*Treatments: P_2O_5 (lbs./acre)*	*Panicle length (cm)*	*Panicle number (sq. foot)*	*Yield (per acre): Straw (lbs.)*	*Yield (per acre): Grain (lbs.)*	*Yield (per acre): Grain (bushel)*	*Yield ratio of grain (%)*
Saphos	0..	21.8..	20.0..	1888..	2794..	60.7..	100
phosphate ..	75..	22.4..	21.6..	1906..	2894..	62.9..	104
	150..	23.8..	23.7..	1950..	3124..	67.9..	112
	225..	23.8..	22.6..	2203..	3032..	65.9..	109
Conc. super ..	75..	22.9..	24.3..	2687..	3700..	80.4..	132
phosphate ..	150..	23.9..	24.8..	2449..	3853..	83.8..	138
	223..	22.5..	27.4..	2940..	4214..	91.6..	151
Fused Mg. phosphate ..	150..	23.8..	27.6..	3024..	4291..	93.3..	154
Bogamuwa loamy soil, Yala 1968, H-4							
Saphos phosphate ..	0..	26.7..	19.7..	3924..	2821..	61.3..	100
	75..	27.9..	20.7..	3915..	2802..	60.9..	99
	150..	30.0..	17.2..	4690	2994	65.1..	106
	225..	30.2..	16.9..	3867..	2859..	62.2..	101
Conc. super phosphate ..	75..	30.2..	21.7	5306	3377..	73.4..	120
	150..	28.9..	19.7..	5632..	3636..	72.5..	118
	225..	28.7..	21.5..	6064..	3099..	67.4..	110

Remarks :—Other fertilizers common to all treatments were as follows :—

Nitrogen (ammonium sulphate)—75lbs. of N per acre as split application

Potassium (Potassim chloride)—75 lbs. of K_2O per acre as split application.

Analysis of variance on grain yieds at Nikaweratiya: C.V.—6.87%; L.S.D.—5.4 (1%); 4.0 (5%).

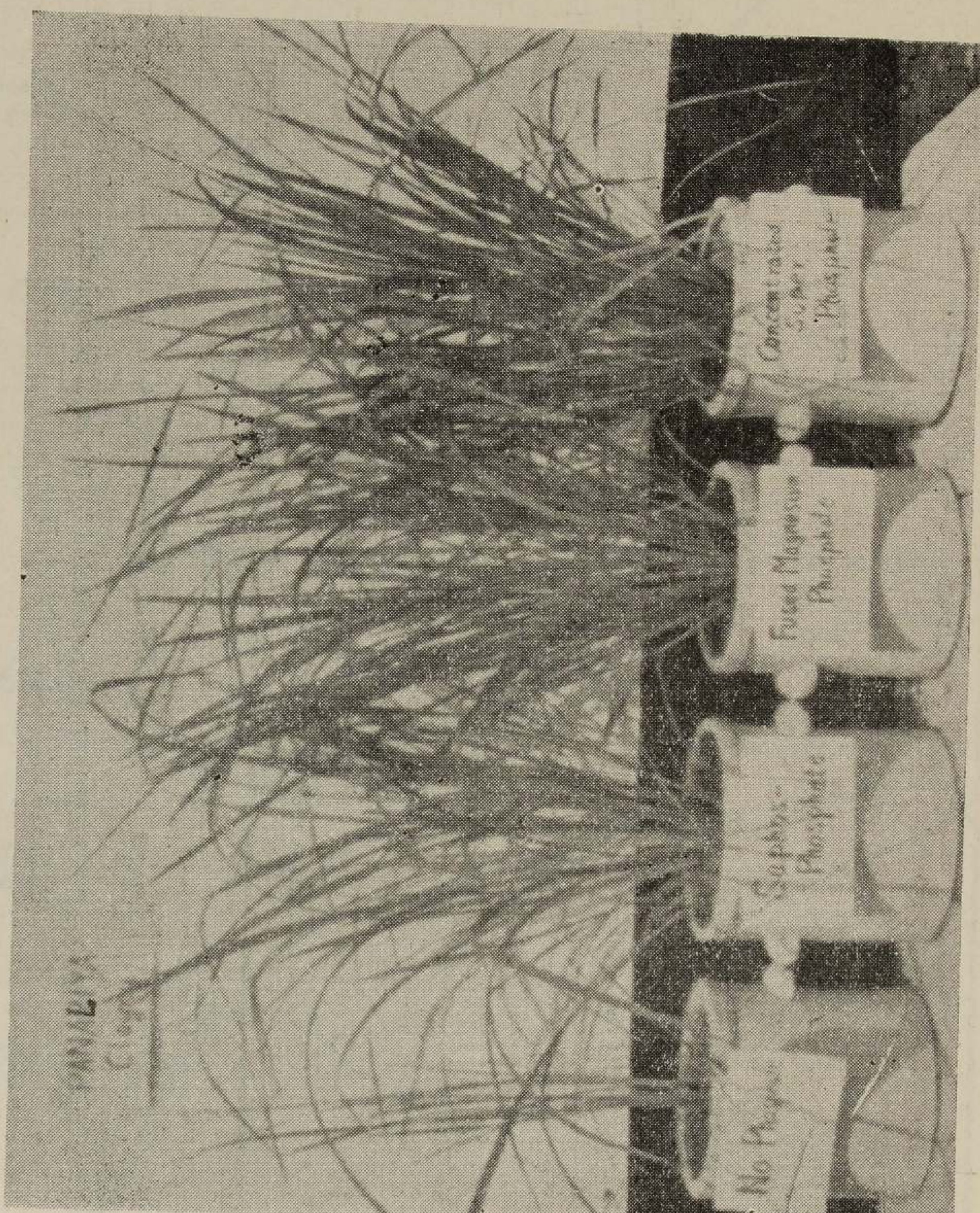

Fig. 1. Growth appearance of plants cultured in Panaliya clayey soil. (Maximum tiller number stage, from left to right. No phosphate, Saphos phosphate, fused magnesium phosphate and conc. superphosphate.)

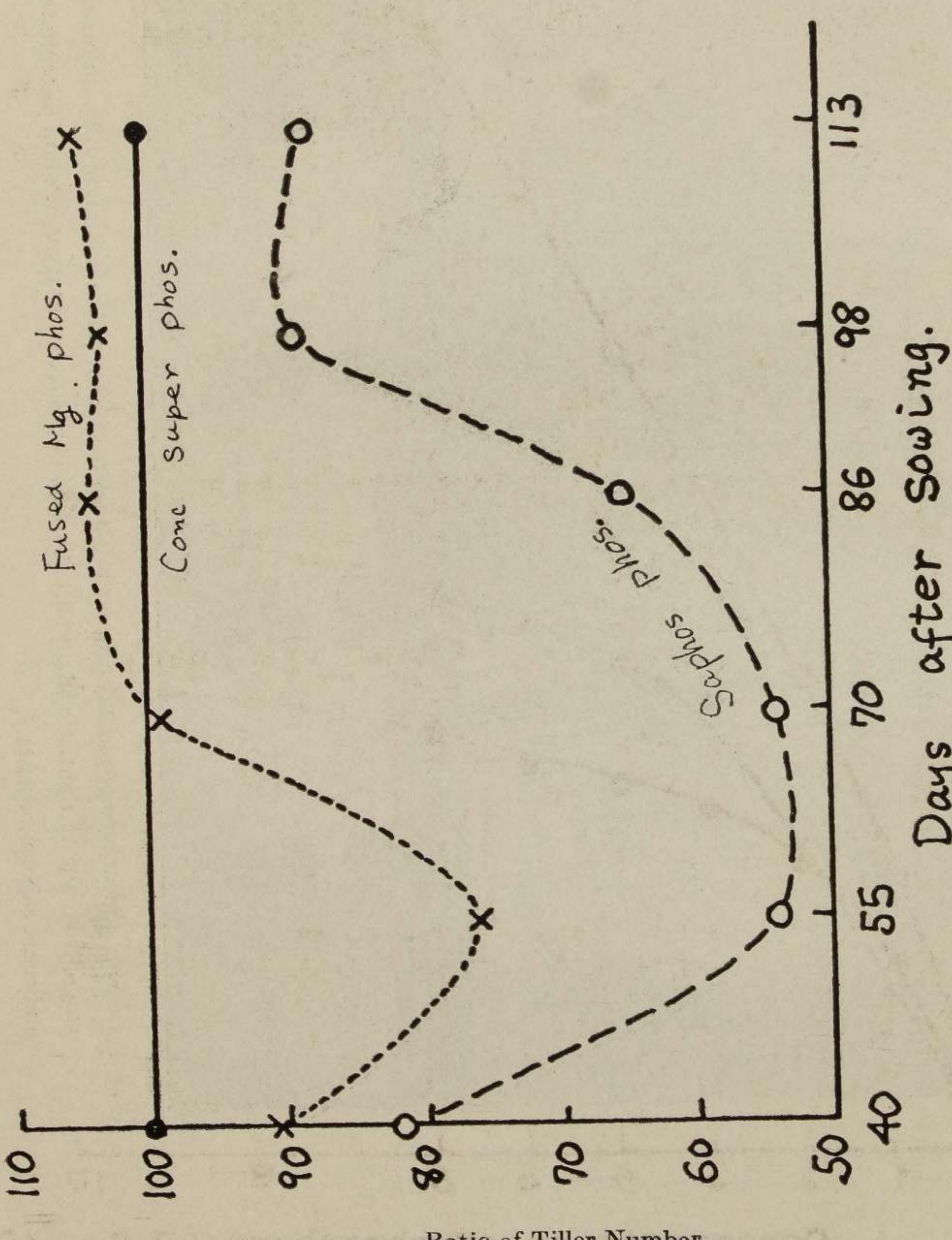

Fig. 2. Comparative growth of rice as affected by forms of phosphate.
(PANALIYA, Maha 1967-68, H-8.)

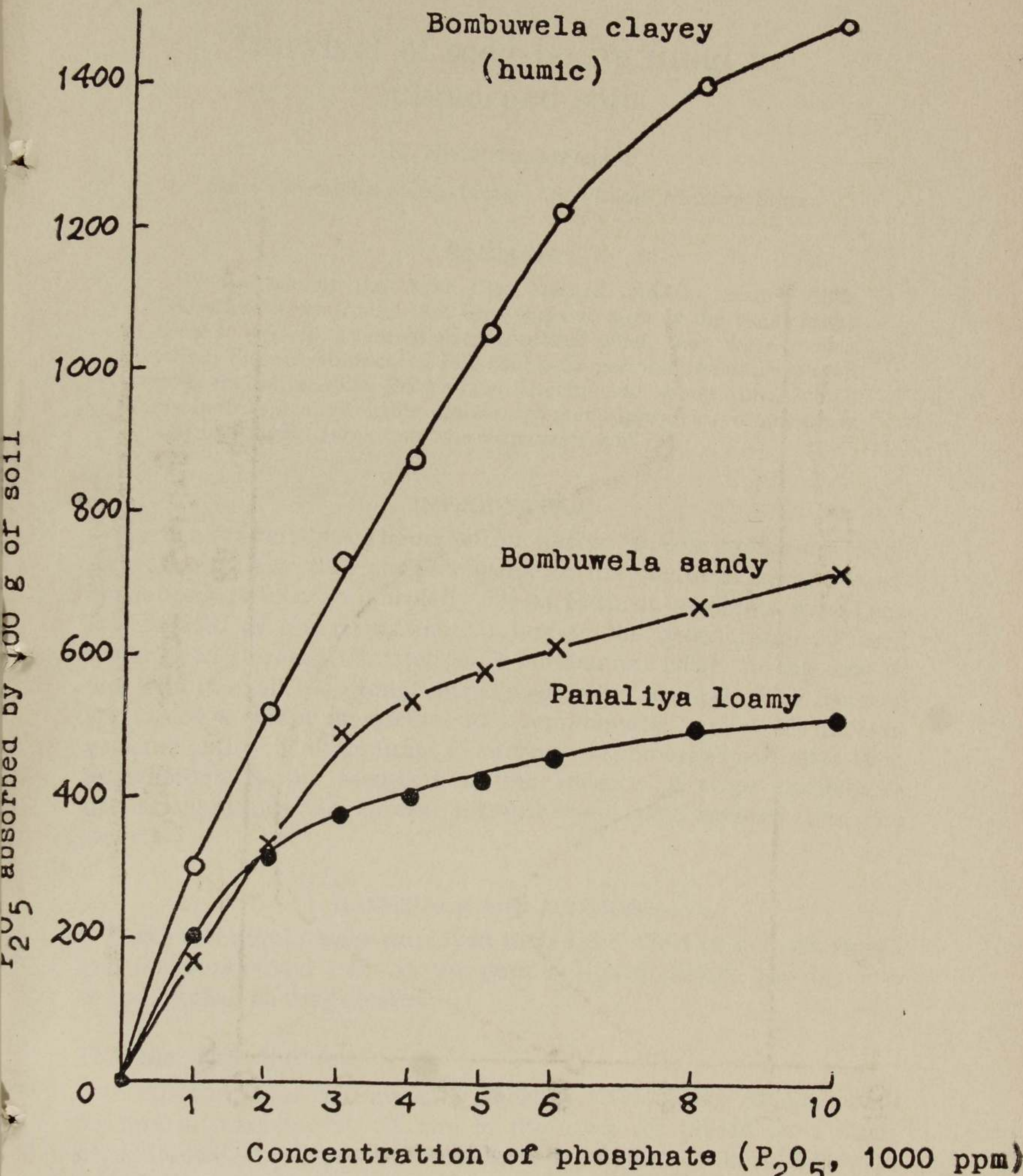

Fig. ?. Phosphate absorption by rice soils with increase of phosphate concentration in the reagent solution.

Survival of seed-borne fungi in submerged soils

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SUMMARY

By the use of the Agar Disc Method and the Buried Slide Technique it was found that the spores of most of the fungi tested showed a good germination percentage when they were placed within the non-submerged soils and poor germination when placed over the same soils. Submerged laterite and sandy soils, which are both typical rice soils, showed greater suppression of germination of fungal spores than the acid peaty soil.

INTRODUCTION

The seed normally harbours within and on its coat numerous fungi. Apart from those that are pathogenic to the seedlings, several seed-borne fungi, which are normally not parasitic on seedlings, have been investigated as organisms contributing to the deterioration of seed material in storage (Christensen & Kaufmann, 1965). In the case of low-land rice, all such fungi introduced to the seed-bed with the seed are forced to adapt themselves to a semi-aquatic habitat. To investigate the ability of these fungi to survive in submerged soil after their introduction to the seed-bed, in the absence of crops residues, a preliminary study was carried out with some fungi isolated from rice seeds.

MATERIALS AND METHODS

Three techniques were employed to find the effect of the submerged and non-submerged soils on the germination of spores and the fate of the hyphae of fungi tested.

The Agar Disc Method

In this technique developed by Jackson (1958), discs of agar about 7.5 mm in diameter by 1.5 mm in thickness are placed on a filter-paper in contact with moist unsterile soil and surface inoculated with fungal spores. After a period of incubation of forty hours, the discs are examined and the percentage germination of spores in four random fields on each of the four replicate discs recorded. Control discs are incubated on moistened filter-paper, in the absence of soil.

As a standard procedure in the experiment described here, discs were incubated for one hour at 27°C, after placing them in contact with the filter-paper, but before inoculation. The discs were prepared from agar composed of Bacto-agar 20 g. and distilled water 1 L. Bacto-peptone incorporated into this medium by Jackson (1958) has been avoided. In treatments involving submergence of soil, soils were kept submerged for fourteen days, at the end of which the water above the soil was blotted out with blotting-paper before the agar discs were placed over them.

The Buried Slide Technique

This technique was based on that devised by China (1953). Microscope slides coated with a film of 2 per cent. agar, in which are suspended spores of the fungus being examined, were buried in cement pots containing submerged and non-submerged soils. After incubation for forty hours at 27°C, the slides were removed, allowed to dry, stained and examined Hundred spores in random microscope fields were counted, and the number which had germinated recorded.

To find the possible effect of roots of rice plants on spores germination, week-old seedlings (var. H 4) were planted with their roots in contact with the agar on the buried slide.

Old's Technique

In this technique (Old, 1965), drops of a suspension of fungal propagules are placed on the soil at certain marked places. After a period of incubation of forty hours, they were recovered by pressing adhesive tape ('Sellotape') against the soil surface. Propagules adhered to the tape which was mounted on a glass-slide with a drop of cotton-blue in lactophenol. Germination of conidia and the growth of hyphal fragments were observed.

The soils for this test were prepared in the same way as for the Agar Disc Method.

Soils

(1) Laterite soil from rice field at Peradeniya, pH 5.0 ; pH and Eh on the fourteenth day after submergence, three inches below the soil surface : 6.3 and 185 m.v., respectively.

(2) Sandy soil from rice field at Gannoruwa, pH 5.55 ; pH and Eh on the fourteenth day after submergence, three inches below soil surface : 5.95 and 215 m.v., respectively.

(3) Peaty soil from Nuwara Eliya. pH 4.2 ; pH and Eh on the fourteenth day after submergence, three inches below soil surface : 5.1 and 245 m.v., respectively.

Fungi

The following fungi were used. All were isolated from surface sterilised rice seed (var. H4) plated on oat meal agar.

1. *Absidia corymbifera* (Cohn) Space. & Trott.
2. *A. cylindrospora* Hagem.,
3. *Apiospera montagnai* Sacc. *Arthrinium* state.,
4. *Aspergillus flavus* Link. ex Fres.,
5. *A. fumigatus* Fres.,
6. *Chaetomium dolichotrichum* Ames.,
7. *C. globosum* Kunze.,
8. *C. olivaceum* Cooke & Ellis.,
9. *Drechslera hawaiiensis* (Bugnicourt) Subramanian & Jain.,
10. *Khuskia oryzae* Hudson, *Nigrospora* state.,
11. *Nodulisporium* sp.,
12. *Phaeotrichoconis crotalariae* (Salam & Rao) Subramanian.,

RESULTS

The spore germination percentage of various fungi tested are presented in Table I. Old's technique was not successful as the recovery of spares from submerged soils was not possible in the case of most fungi.

In all non-submerged soils, the spores on buried slides showed a good germination percentage, while those on agar discs showed poor germination. Under submerged conditions there was a general decrease in the germination percentage observed by both the techniques. Among the three soils tested peaty soil alone showed instances of comparatively good germination ($>50\%$) under submerged conditions. This too was restricted to *Aspergillus flavus, Chaetomium globosum, Absidia, corymbifera* and *A. cylindrospora*. However, *C. globosum* did not show any germination with submerged sandy or laterite soils, irrespective of the technique used. In the submerged treatments, germination percentage was in the order : peaty $>$ laterite $>$ sandy. Increased germination percentage of spores on slides buried in submerged soils, in proximity to rice roots, was observed only in peaty soil. On slides buried in non-submerged laterite soil, five forms showed germination over 50 per cent. while on the agar discs over the same soils, there was no instance of germination over 50 per cent. Sandy soil exhibited comparatively good germination in the non-submerged treatments.

All hyphal fragments, and germ tubes of fungi that germinated on buried slides in submerged laterite soil were seen in different stages of lysis. This was very slight in sandy soil and almost absent in peaty soil.

In all three submerged soils, the agar on regions of the buried slides in contact with rice roots, was sometimes found partially or totally decomposed.

DISCUSSION

In all non-submerged soils, spores on the buried slides showed good germination percentage unlike those on agar discs. This may be due to slightly increased carbon dioxide content within the non-submerged soil. Stover and Freiberg (1958) demonstrated that increased carbon dioxide could result in the stimulated multiplication of *Fusarium oxysporum f. cubense*. Newcombe (1960) substanciated this finding, but pointed out that although the fungus could tolerate and the stimulated by relatively brief exposures to carbon dioxiods, its long term survival in such conditions was prejudiced.

In general, most of the fungi tested showed poor germination under submerged conditions. Soil saturation, besides restricting the oxygen supply to the fungi, may create an environment with a very high content of carbon dioxide. The effect of such high levels of carbon dioxide may be of great significance as demonstrated by Abeygunawardena & Wood (1957) in the case of *Selerotium rolfsii*. It has been reported that even after the flood water is removed, the suppression of the mycoflora persists. The inhibition does not seem to be solely a consequence of oxygen depletion. Carbon dioxide, sulfide, or other toxic agents have been proposed as fungicidal principles generated during flooding (Nitchell & Alexander, 1962). Flooding of soil for the control of widely differing types of fungal pathogens has given encouraging results (Sewell, 1965).

Of the three soils used in this investigation, peaty soil alone is not a rice soil. Relatively good germination of some fungi in proximity to rice roots within submerged peaty soil may be due to the possible absence of most of the bacteria which may be stimulated to a considerable extent in the rhizosphere of rice.

Lysis of germ tubes and hyphal fragments were observed on slides buried within laterite soil. Generally, such lysis may be an outcome of purely internal metabolic changes (autolysis), of contact with enzymes of other organisms, or of exposure to toxic materials (Warcup, 1965). As Sewell (1965) says, "It is possible that while continued lack of activity of resting stages may lead to a gradual decline of numbers through senescence, there is a converse situation that reversion to activity under wrong sort of conditions may lead to an even more rapid disappearance". Chinn & Ledingham (1961) have described 'germination lysis' as a factor in the disappearance of spores of fungi from soil. Thus it is possible that fungistasis may assist in survival rather than help in the eradication of several pathogenic fungi (Dobbs & Hinson, 1953).

Low-land rice is usually sown on a bed very near saturation, and the field is flooded about five days after sowing. The introduced fungi have to face unfavourable conditions from the start. Jones & Seif el Nasr (1940) found that 'mud sowing' wheat seed controlled flag smut so efficiently that it offered an alternative to seed disinfection or the use of resistant varieties. If we may speculate on the possibilities of these fungi colonising the rice seedlings saprophytically, they would have to survive, after their introduction with the sown seed, for at least a fortnight before they could get an opportunity to colonize a dead aerial portion of an outer leaf.

It should be admitted that of the three techniques attempted, Old's technique alone could provide a study of these fungi under natural conditions. The Buried Slide Technique does not appear to be suitable for studies in submerged soil, as agar on the surface of submerged slides is sometimes decomposed, especially when it is in proximity to plant roots.

Unfortunately, there are not many techniques available for such studies under submerged conditions. Glass fibre material (Legge, 1952) has been found to help the funfi to survive for a period much longer than that shown by spores added to soil without it (Stover, 1959). Recovery of 'small' spores from submerged soil by the 'flotation method' of Ledingham & Chinn (1955), is very tedious. A better understanding of the behaviour of fungi within submerged soil is possible only if suitable and simple techniques are evolved to study them without altering the microenvironment.

ACKNOWLEDGEMENTS

My thanks are due to Dr. D. V. W. Abeygunawardena for suggesting the problem, to Mr. George Lanerolle for isolating the fungi, and to the Commonwealth Mycological Institute for identifying them. I am also grateful to Mr. C. Dharmasena and Mr. B. Navaratne of the Division of Agricultural Chemistry for the pH and Eh measurements.

Table 1.—Mean Percentage of Germination of Spores

		Agar Disc Method						Buried Slide Techni'ue								
		Latreite		Sandy		Peaty		Laterite			Sandy			Peaty		
	Control	S.	N.S.	S.	N.S.	S.	N.S.	S.	S+R	N.S.	S.	S+R	N.S.	S.	S+R	N.S.
1. Absidia corymbifera	100	12	0	0	70	16	0	0	0	56	6	0	40	0	60	55
2. A. cylindrospora	98	16	0	0	0	52	0	20	0	42	0	0	76	20	30	70
3. Apiospora montagnei	70	8	26	28	10	0	18	16	0	0	12	0	34	0	0	10
4. Aspergillus flavus	98	0	10	0	60	0	80	8	0	50	0	10	70	0	74	40
5. A. fumigatus	96	36	6	0	26	8	46	0	20	66	16	20	10	26	40	60
6. Chaetomium dolichotrichum	94	0	10	0	20	0	0	22	0	0	8	28	16	0	0	0
7. C. globosum	100	0	0	0	0	70	30	0	0	90	0	0	44	0	0	30
8. C. olivaceum	100	0	0	4	0	0	26	0	0	68	0	0	80	0	0	10
9. Drechslera hawaiiensis	100	0	0	0	0	0	50	0	0	30	0	0	80	0	12	34
10. Khuskia oryzae	100	32	0	0	28	0	10	0	0	36	0	0	70	0	0	16
11. Nodulisporium	68	0	0	0	0	0	0	0	34	10	0	4	10	0	0	0
12. Phaeotrichoconis crotalariae	100	0	0	0	0	0	0	0	0	0	6	0	60	0	20	18

N. S.= Non submerged

S.= Submerged

S. × R.= Within submerged soils in close proximit to rice roots.

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Kikuyu Grass: *Pennisetum clandestinum*, Hochst ex Chiov and its value in the montane region of Ceylon

2. Nutritive value and animal production aspects

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INTRODUCTION

In the first section of this paper, the agronomic aspects of growing kikuyu grass have been dealt with, and it was pointed out that kikuyu is a productive grass which can easily be established and grown in the montane region of Ceylon. This part of the paper deals with the value of kikuyu for animal production.

The nutritive value of a forage is determined not only by characteristics of the forage, but also by other factors such as management and environment. We are thus concerned with a number of related problems. How much forage will the animal consume ? How efficiently is the grass utilised ? What factors affect this utilization ? What are the levels of production that can be obtained from cows fed kikuyu and what supplementation with concentrates is necessary ? These are the questions that we hope to discuss.

REVIEW OF LITERATURE

Several reports have appeared in the literature on the use of kikuyu for milk and meat production (17,315 and 13). Yields of 1000 gallons of milk per acre from kikuyu pastures were reported as early as 1941 by Taylor (17). These results were obtained in a 7 month season with only 34 inches of rainfall with an application of about 500 lbs. of Ammonium Sulphate per acre per year. Colman (3) has shown similar results in his stocking rate trials. He obtained 300 lbs of butterfat (8000 lbs of 4 per cent milk) per acre, applying about 350 lbs Nitrogen, with 65 inches of rainfall. These pastures were being stocked at the rate of 1.3 cows per acre. Beef cattle also appear to do well on kikuyu. In one report (13), steers gained up to 4.4 lbs per acre per day, and these irrigated pasture were stocked at 2 steers per acre. While these and other reports indicate that kikuyu pastures show promise as a crop for animal production, there is scant information on the nutritive value and animal production potential of the grass.

FORAGE INTAKE

Intake is, no doubt, one of the most critical consideration in assessing the nutritive value of a feed. It is generally agreed that dairy animals and cattle, in general, will consume feed at varying rates, depending on a number of factors related to the feed itself and to the management of the feeding programme (12). The maximum limit for temperate cattle is usually at about 3.5 lb of Dry Matter intake per 100 lbs live body weight ; this occured when concentrates were fed liberally. The values reported for forage intake in the tropics are much lower and very often are less than half those reported for ani- animals in temperate regions (10).

Harrison has reviewed the literature on intake of tropical forages and has pointed out some of the problems (8.9). He notes that low dry matter intake is often thought to be due to the high moisture content of the herbage during the rainy season. This however, has not been demonstrated with Napier grass. Harrison (10) obtained very low intake values of about 1.5 per cent ; and was able to increase this intake by 60 per cent in a separate trial by wilting the grass from 20 per cent. to 30 per cent. dry matter. In the temperate regions however, it was found (9) that low dry matter forage, produced by high nitrogen fertilisation, was consumed at the same rate of dry matter intake, as the same forage of higher dry matter content. The consumption was around 2 per cent. body weight. Todd (16), in Kenya, has noted that the dry matter intake of kikuyu by sheep was over 3.0 per cent. live weight. The grass that he used for feeding was wilted overnight, the original moisure content being very high (over 85 per cent.)

TABLE 1.—Intake of fresh kikuyu by cattle and sheep under stall-fed conditions

Description of Forage	*Animals used*	*Intake of dry Matter (% of live weight)*	*Dry Matter % of grass*
30–day growth ..	3, mature heifers ..	2.4 ..	15.0
30–day growth ..	3 milking cows ..	2.7 ..	14.8
30–day growth ..	4, mature rams ..	1.9 ..	17.4
30–day growth cut from 30 day rotationally grazed paddock	4, mature rams ..	2.0 ..	18.8
Average	..	2.25 ..	16.5

The data obtained from trials conducted by the Authors at the Ambawela station in Ceylon, are listed in Table I. In these trials, the animals were stall-fed with fresh, kikuyu grass. A wide range of dry matter intakes have been noted (1.9 to 2.7 per cent.) which do not seem to bear any relationship to the moisture content of the grass. In certain isolated instances, the daily dry matter intake was reduced with an increase in the moisture content of the grass. During the rainy season, the moisture content of the grass was very high, upto 90 per cent. and at these levels there is probably a physical limitation to the quantity of dry matter the animal can injest. From the data collected over the year, it seems that a dry matter intake of between 2 and 2½ per cent. live weight could be expected. Hardison (8) has found about the same level of intake for other tropical forages

DIGESTIBILITY AND NUTRITIVE VALUE

In the assessment of any forage, the intake and the digestibility are closely related. As a general rule, as the intake increase, there is a tendency for the digestibility to decrease due to lowered microbiological efficiency of the fuller rumen. On the other hand, as the digestibility of a forage increases due to its character, the rate of passage of intake increased with digestibility from 2.5 to 3.3 per 100 lbs. intake. When three qualities of of hay were fed to sheep (1), their digestibilities ranged from 46 to 76 per cent. The corresponding rates of intake increased with digestibility from 2.5 to 3.3 lbs. per 100 lbs. live weight per day. Thus it is important to provide a forage that is highly digestible so that in turn it will consumed readily.

A. Effect of species and stage of growth

The nutritive value of forages vary widely between species and between stages of growth within the same species. In order to illustrate some of these effects, table II shows the digestible crude protein (DCP) and total digestible nutrients (TDN) obtained from several trials. Fescue and cocksfoot have been included in the list of grasses because these two temperate grasses are generally considered to be good grasses and when young, have high digestible crude protein and total digestible nutrient content. Pangola grass is somewhat lower in protein, but in its early stages of growth, has TDN values comparable to the temperate grasses. In comparison, kikuyu in its early stages of growth, is even higher in DCP and TDN than these other grasses ; and it seems therefore that kikuyu grass is equal and superior to these other species in this respect.

TABLE II.—Digestible crude protein and total digestible nutrient values of kikuyu and other grasses compared

Grass sp. and stage of growth	*Animals used*	*DCP*	*TDN*	*References*
TALL FESCUE				
Young pasture		*12.8*	*71.2*	11
COCKSFOOT				
Young pasture		*13.4*	*66.5*	11
PANGOLA HAY				
3 week	Sheep	*9.8*	*64.2*	14
6 week		*3.3*	*68.2*	
6 week		*1.3*	*67.3*	
KIKUYU HAY				
3 week	Sheep	*9.6*	*56.3*	
6 week		*8.4*	*56.5*	14
9 week		*4.7*	*57.0*	
KIKUYU GRASS				
3 inch	Sheep	*18.3*	*68.9*	*16*
12 inch		*15.7*	*53.2*	
KIKUYU GRASS*				
young		*20.0*	*68.4*	
12 to-20 inch		*8.8*	*58·7*	4
leaf		—	—	—
stem		*7.6*	*45.5*	
Old		*2.0*	*56.0*	
KIKUYU HAY				
18 week	Sheep	*1.7*	*48.5*	*2*
KIKUYU*				
young		*11.9*	*62.0*	7
KIKUYU GRASS				
5 inch	Sheep	*9.3*	*60.5*	15
KIKUYU GRASS				
30 day, cut	Sheep	*18.1*	*73.2*	
30 day, grazed		*12.8*	*69.9*	authors
30 day, cut	mature heifers			
fed 100 lb/day		*18.6*	*73.0*	authors
fed 120 lb/day		*19.0*	*74.5*	

*calculated from prediction equation (*6*).

It is well known that the nutritive value of temperate grasses declines with extended growth and maturity. Sherrod and Ishisaki (14) found that the nutritive value of pangola and kikuyu also decline with maturity. As noted in Table II, the DCP content declined from almost 10 per cent at 3 weeks to about 5 per cent at 9 weeks after cutting. Campbell (2) reported to DCP level of only 1.7 at 19 weeks of age. While the TDN levels also show a similar trend, they appear to be much less variable than the DCP levels. Todd (16) noted a decline in both DCP and TDN when 3 inch kikuyu was compared with 9-12 inch kikuyu. Sherrod observed only a slight decline in TDN values of kikuyu and pangola upto 9 weeks. Costzee (4) found a dramatic difference in digestible nutrients of the grass between the three stages of growth. Sherrod in addition, noted that TDN had declined to 57.3 and 37 per cent. for pangola and kikuyu respectively at 24 weeks after cutting. The nutritive value of kikuyu leaves is also somewhat higher than that of the stems (4). At Ambawela we have found DCP values ranging from 12.8 to 19.0 and TDN values 69.9 to 74.5 in 30 day rotationally cut or grazed grass. From published reports and our feeding trials it appears that the higher nutritive value in kikuyu grass is obtained when it is cut or grazed once in 20 to 30 days.

B. *Effect of fertilisation*

In addition to the effects of fertilizer application on the growth and yield of grass, it also changes the nutrient content. Webster (15) reviewed a number of reports which have shown that application of fertilizer, particularly nitrogen compounds, have increased crude protein content as much as 3 to 4 per cent. Phosphate values were increased when phosphates were applied as fertilizers. In one trial conducted by Fernando and Andrew (5) at Ambawela, the effects of nitrogen fertilizer applications on kikuyu grass composition was studied. They found that the crude protein level in the grass was increased at all levels of nitrogen application ; rising as much as 7.2 per cent. when 600 lbs. of nitrogen was applied per acre. Of this increase, nearly half was in the form of soluble nitrogen, when sampling was undertaken a few weeks after the fertiliser applied. A large portion of this soluble nitrogen was in the form of nitrate. Although the nitrate levels were higher than those usually considered safe, there have been no indications of nitrate toxicity in animals grazed on the pastures fertilized at recommended levels. Some soluble forms of nitrogen can be utilized by the ruminant provided an adequate supply of energy is provided in the total ration.

C. Effects of Rainfall and Season

It was pointed out in the first section of this paper that the growth of grass varied greatly during the year due to the different climatic conditions. These variations may be as much as 50 per cent. above or below the average growth rate. Along with the variation in growth rate the composition of the grass also varies, affecting the intake and nutritive value. Hardison (8) noted that the dry matter contents of tropical grasses generally vary inversely with the rainfall. During the dry season, at Ambawela, mature kikuyu may contain 35 per cent. dry matter, while in the wet monsoon season, it has been noted to drop as low as 10 per cent. During the dry seasons, grazing animals should be able to obtain their requirements, but during the wet season, as pointed out by Todd, the animal may not be able to consume its full dry matter requirement due to the high moisture content and extreme bulk of this grass.

Hardison (8) notes that the reports in regard to the effects of rainfall and season on forage constituents are conflicting, with the exception of the dry matter content. However, in trials that the authors have conducted, the crude protein content (10 per cent. dry matter) in kikuyu is about 4 per cent. higher in the wet season than in the dry season, while the other constituents such as crude fibre, ash and ether extract appear to alter only slightly. These values were obtained from grass of the same age and may not reflect some of the changes that usually occur in the grass due to the rapid growth in the wet season and the tendency for it to mature more quickly.

The primary effect of rainfall and season appears to be on the growth and dry matter content. At Ambawela during the first few months of the year it is cold and dry, and although the dry matter content is high, the growth of grass is inadequate. During the monsoon seasons although grass is abundant, the high moisture content appears to limit an animals intake.

TABLE III

Milk production potential per cow per day from kikuyu and estimated effects of concentrate feed supplementation

Feeding Programe	*Intake of dry matter lbs per 100 lb. BW*		*Predicted milk production (pints)*		*Feed cost (Rs/pint)*	*Return over feed cost (2) Rs.*
	Forage	*Forage plus conc.*	*Protein*	*TDN*	*(1)*	
Ad lib kikuyu grass pasture without any concentrates	2·0	2·0	35·0	6·0	0·213	1·12
	2·5	2·5	57·0	14·1	0·113	4·05
	3·0	3·0	71·0	21·6	0·089	6·73
	3·3*a*	3·3	88·0*c*	27·0*c*	0·076	8·74
Ad lib kikuyu grass pasture plus 7 lbs concentrate per day	2·0	2·8	65·0	20·6	0·130	5·56
	2·5	3·3*a*	79·0*c*	28·0*c*	0·107	8·20
	3·0*b*	—	—	—	—	—
	3·3*b*	—	—	—	—	—
Ad lib kikuyu grass pasture plus 12 lbs concentrate/day	2·0	3·3*a*	88·0*c*	30·6*c*	0·117	8·56
	2·5*b*	—	—	—	—	—
	3·0*b*	—	—	—	—	—
	3·3*b*	—	—	—	—	—

(1) Feed cost assumed —grass Rs. 0.08 per lb. dry matter
Conc. Rs. 0.20 per lb.

(2) Milk valued at Rs. 0.40 per pint.

a Maximum expected intake when given excellent quality forage and concentrates.

b Above intake capacity.

c These levels may not be reached due to limited intake capacity.

MILK PRODUCTION POTENTIAL AND CONCENTRATE SUPPLEMENTATION

From the data presented above some generalizations could be made about quality and nutritive value of kikuyu, from which the milk production potential can be predicted. Table III presents some of these estimates for levels of intake of grass and concentrates. For the purpose of these calculations it has been assumed that cows on pasture require 40 per cent. more nutrients than those under stall fed conditions, and the maintenance requirements have been revised upwards by this factor. The requirements have been taken from Morrison and Morrison (11) for an 800 lb. cow producing 4 per cent. milk. 20 to 30 day rotationally grazed kikuyu is estimated to contain 18 per cent. DCP and 70 per cent. TDN, while the concentrate available is estimated to contain 16 per cent. DCP and 75 per cent. TDN. The nutrient requirement for milk production is taken as 0.04 lbs of DCP and 0.3 lbs. of TDN per lb. of 4 per cent. milk. The milk production potential was determined by the excess nutrient intake over that required for body maintenance.

It can be seen that in all cases the DCP level is more than adequate and would support more milk production than the levels of energy. While there is sufficient protein to support the production of 35 pints of milk at the 2 per cent. level of forage dry matter intake, there is sufficient energy for only 6 pints. It becomes obvious that the concentrate fed should contain less protein and more energy. However, in Ceylon, the major ingredient available for concentrates is coconut poonac and since this contains 20 per cent. protein, it would be expensive to formulate a low protein, high energy concentrates. This is further aggravated by the lack of energy supplements such as high energy cereals.

It will be noted that as the rate of forage intake increases from the 2 per cent. level to 3.3 per cent. level, the cost of milk production decreases and return over feedcost increases significantly. Since the results of trials conducted show that the level of intake would lie between 2.0 and 2.5 per cent. milk production levels of 6 to 14 pints could be expected from 800 lb. cows on grass alone. With 7 lbs of concentrates, the expected production level is increased to about 20 pints, with a forage intake of 2.0 per cent. Higher levels of concentrate feeding may depress the forage dry matter intake. Therefore a moderate level of concentrate feeding with an attempt to maximize the forage intake is recommended. The best returns over feed cost would lie in the range of 2.0 per cent dry matter intake and a moderate concentrate supplementation of 5 to 10 lbs. of concentrate. This is in agreement with Hardison's (8) estimates for tropical forages. For supplementation of kikuyu grass with the presently available concentrate, the following general recommendation can be made ; for cows producing over 6 pints of milk per day, provide adequate kikuyu grass pasture, free choice mineral lick and water, and feed concentrate at the rate of 1 lb. per 2 lbs. milk produced. Thus a cow producing 20 pints of milk would receive 7 lbs. of concentrate.

MINERAL AND VITAMIN CONTENT

Fernando (5) found that kikuyu would provide potassium, calcium and phoshorus in sufficient quantities to meet the maintenance and production requirements of the lactating cow. Apart from these, it seems that kikuyu when growing in fertile soil and under normal conditions, is similar to other grasses and would provide all necessary minerals except sodium and chlorine. It must be noted, however, that deficiencies of the minor elements in the soil would be reflected in the grass. To meet the above requirements and possible deficiencies, the concentrate fed should include a 3 per cent. mineral mixture. In addition a mineral lick could be provided free choice. A simple mixture such as 1 part mineralized salt mixed with two parts of defluorinated dicalcium phosphate will usually provide any deficient elements.

Under grazing conditions green pastures would provide adequate quantities of vitamin A and D. Silage made with wilted or fresh kikuyu would also be abundant in carotene. Cows that are stall-fed, however, may require supplements of vitamin D. The level of vitamin D required is still in question, but current estimates (12) indicate that about 3,000 iu. of vitamin D per day per 1,000 lb. cow is adequate. The B complex vitamins are available in the forage and in addition are synthesised by the rumen microorganisms, so that no supplementation is required.

CONSERVATION OF KIKUYU GRASS

It is desirable to conserve some of the grass during the rainy season so that it can be fed out to supplement the poor growth during the dry season. In the montane area of Ceylon, during the rainy season the conditions are too wet for hay making, but good results have been obtained with preservation as silage. The chief drawbacks to making silage have been the high moisture content of the grass and the lack of energy. This was overcome by the addition of 5 to 10 per cent. concentrate. When this silage was fed to 4 sheep, it was found to contain 15 per cent. crude protein of which 45 per cent. was digestible. with a TDN value of 49.5 per cent. Since much of this grass was over mature these values are somewhat lower than that could be expected if good quality grass is ensiled. However, when 30 lbs. of this silage was fed to milking cows, to supplement poor pasture during the dry season, these cows were able to maintain their milk production at about the same level as those that had night pasturing. It is therefore recommended that any surplus grass available in the peak periods of growth be ensiled either by wilting to about 70 per cent. moisture content or by adding 5 to 10 per cent. concentrate, wheat bran, rice bran or any other dry, fermentible material. The grass should be chopped if possible and well packed in the silo.

SUMMARY

A review of the information available on the nutritive value of kikuyu grass is presented, including some of the results obtained with kikuyu at the Ambawela station in Ceylon. No information is available on the grazing intake of kikuyu, but under stall-fed conditions, a dry matter intake of about 2.25 per cent live weight could be expected. The high moisture content of the grass, especially during the monsoon period, appears to limit the dry matter intake. Kikuyu grass is very well utilized being especially high in digestible crude protein. The nutritive ratio is narrow and indicates a need for supplementation of kikuyu with an energy concentrate. Milk production levels obtainable, from different levels of intake of kikuyu and concentrate presently available in Ceylon, are predicted and the costs compared. The mineral and vitamin supplementation that is required when feeding kikuyu is also discussed. A note is included on the successful conservation of kikuyu grass as silage.

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Incidence of Anthracnose on different varieties of grapes in Jobner, Rajasthan (India)

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Grape orchards have been expanding rapidly in Rajasthan State in past five years. In orchards of Udaipur, Shri Ganga Nagar and Jaipur, anthracnose incited by *Gloeosporium ampelophagum* (*de Bary*) Eacc. was found to be severe. In vineyard of College of Agriculture, Jobner, different varieties of grapes behaved differently in respect of susceptibility. The present investigation was, therefore, undertaken to know varietal reaction in grape to anthracnose disease.

Incidence on each variety was assessed by randomly selecting and marking four individual young shoots of each vine. Four replicates, each consisting of one vine were studied for each variety. On each marked shoot, one hundred leaves and the side shoots were observed at 10 days interval, from 1st August to 29th September, 1968 and 1969.

Infection index of each variety determined by formulating recognizable grade of infection and calculating by the formula given below, is shown in table 1.

Grade of infection	*Description*
'*' (Healthy)	Twigs completely healthy, with no trace of infection on any part.
'1' (25 per cent)	Twigs show slight infection. About 25 per cent of leaf area covered by spots. Petioles free from infection.
'2' (50 per cent)	Infection moderate, nearly 50 per cent of the leaf area covered by spots. Petioles showing a few spots.
'3' (75 per cent)	Nearly 75 per cent of the leaf area covered by spots. Petioles and twigs bearing numerous sunken spots.

Grade of infection	Description
'4' (100 per cent)	Whole leaf lamina covered by several coalescing and perforated spots. Leaves pale green and drying. The petioles and twigs heavily spotted becoming yellowish or drying.

$$\text{Infection index} = \frac{\text{Class ratings} \times \text{Class frequency} \times 100}{\text{Total no. of leaves} \times \text{Maximum rating of each variety}} \text{ only}$$

TALBE 1.—Infection index of athracnose in different varieties of grapes

Variety	*Infection index* 1968	1969
Anabe shahi	9 50	15 0
Beauty seedless	25 0	30 0
Bharat early	Nil	Nil
Black prince	10 0	15 0
Bhokri	55 75	60 0
Black muscate	—	17 50
Banglore purple	30 0	40 0
Fakri	70 0	75 0
Gulabi	11 25	15 0
Hussaini	Ni.	Nil
Hur	65 50	70 0
Khandari	67 25	70 0
Munaca	60 0	70 0
Selection 7	62 25	65 0
Selection 64	62 25	70 0
Sahibi	10 0	10 0
Thompson seedless	25 0	30 0
White muscate	4 0	5 0
Parlet	10 0	15 0

From the results in above table, it is seen that while varieties, Bharat-early and Hussaini remained completely free from infection, maximum infection was recorded in Fakri and minimum in White Muscate. Varieties Bhokri, Khandari, Selection 94 and Fakri were also found to be highly susceptible at Gwalior by Tripathi and Bhartaria, 1968. Anabe-shahi and and Black Muscate recorded to be highly susceptible at Gwalior and Coimbatore by Randhawa and Singh, 1958, showed infection index lower than 25 under Jobner conditions.

Varieties Bharat-early and Hussaini showing resistance to anthracnose deserve attention in grape improvement programme in Rajasthan.

RESEARCH NOTE

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METEOROLOGICAL REPORT

QUARTERLY WEATHER SUMMARY—OCTOBER TO DECEMBER, 1970

OCTOBER : The southwest monsoon which was weakening towards the end of September, 1970, strengthened again and became active due to the formation of low pressure area in the Bay of Bengal.

On the first two days of the month, evening thundershowers were experienced, with moderate to heavy rain on the 2nd. On the 3rd, the southwesterly airstream which was very shallow increased in depth to 5,000 ft., due to a low pressure area which formed in the Bay of Bengal. Fairly widespread rain was experienced on the 4th and 5th. The low pressure area deepened further and by the 8th had become a depression centred at approximately latitude 14N longtitude 87 East. On the 10th, the depression crossed the Indian coast near Madras. The same day, another low pressure area appeared near the Andaman Islands, deepened into a depression and by the 20th had become a tropical storm with its centre at latitude 16N longitude 86E. This subsequently crossed the East Pakistan coast. During this period, active southwest monsson conditions prevailed and rain was fairly widely experienced over the Island, the heavier falls being reported on the 9th and 10th, 12th to the 15th, and on the 18th and 19th. Due to the incessant rain, local flooding was experienced in the southwest quarter, particularly over the low lying areas of Ratnapura, Kegalle and Colombo districts. However, the Kelani ganga did not reach minor flood level at Colombo. There was an improvement in the weather on the 22nd, only scattered light to moderate rain being experienced. These improved weather conditions prevailed till the end of the month.

The larger monthly totals of rainfall (totals over 30 inches) were experienced in the Yatiyantota-Ginigathhena region and the Gampaha area. Rainfall over the adjoining areas of the southwest quarter ranged from 20 to 30 inches decreasing to 10 to 20 inches along the west coast and 5 to 15 inches in the South. Over the Northern, North-central and Eastern provinces rainfall ranged from 2 to 10 inches. The drought conditions which prevailed over the northwestern region of the Island ended during the month. In particular Mannar which had no rain for 3 consecutive months, experienced 12 rain days during October and a total of 5,36 inches. Rainfall was above average over part of the southwest quarter, but was generally below aerage over the rest of the Island. Day temperature were mainly about or a little above normal, while night temperatures were mainly about or a little below normal. Day humidity ranged from 63 to 82 percent. while night humidity ranged from 78 to 95 per cent. Mean cloud amounts were about or a little above normal, while mean air pressures were a little below normal. Wind mileages were above normal in the south and mainly about normal elsewhere, the direction being generally westerly to southwesterly.

NOVEMBER : During this month, a severe cyclone which struck East Pakistan on the 13th, resulted in unprecedented loss of human lives, due to a tidal wave. This cyclone originated as a low pressure area in the South Bay of Bengal, then developed into a depression and moved as close as

400 miles east of Kankesanturai on the 8th, where it caused fairly high seas around the island west of the Jaffna peninsula. Up to the 13th, the weather and winds over Ceylon were dominated, though midly, by this cyclone. On the 1st and 2nd, rain was widely experienced over the Island, several fairly heavy falls being reported. There was a decrease in the rainfall on the 3rd and 4th, but from the 5th to the 11th, rain was again widely experienced. From the 12th to the 16th, there was an improvement in the weather, but on the 13th a whirlwind was reported to have swept across the village of Evenai in the Valigaman North Division of the Jaffna Peninsula causing damage to houses and trees. On the 18th, a shallow depression was located approximately 200 miles east of Trincomalee and fairly heavy rain was experienced in the North and East. The depression moved westwards and crossed into the Arabian sea over the southern tip of India and the weather improved by the 20th. Due to another low pressure area which deepened into a depression, fairly widespread rain was experienced over the Island from the 25th to 29th, but there was an improvement in the weather on the last day of the month.

The larger monthly totals of rainfall (totals over 30 inches) were in the extreme north of the Island in the Kankesanturai-Kayts area. Rainfall over the rest of the Northern Province ranged mainly from 15 to 30 inches. Over the rest of the Island rainfall was mainly between 10 to 20 inches, except for parts of the Central and Western Provinces where the rainfall was in the range 20 to 30 inches. Rannfall was generally above average, and was below average only at some stations in the southwest quarter and in the East. Day and night temperatures were mainly about or a little above normal. Day humidity ranged from 70 to 84 per cent., while night humidity danged from 81 to 98 per cent. Mean cloud amounts were a little above normal, while mean air pressures were a little below normal. Wind mileages were below normal in the southeast and northeast and about normal elsewhere, the direction being mainly variable.

DECEMBER : A spell of cool, dry weather with cloudless skies prevailed till the 6th. During this period night temperatures were well below average. Nuwara Eliya reported very low humidities on the 4th and 5th, a relative humidity of 25 per cent. being recorded on the 5th morning. North east monsoon conditions set in from the 7th and light rain was experienced in the east and in the hill country. Under the influence of low pressure areas which developed in the Bay of Bengal, fairly widespread rain was experienced over the Island on most days from the 9th to the 17th. There was a decrease in the rainfall from the 18th to the 20th and on the 21st, fair weather prevailed over the Island due to a dry northerly air stream. From the 22nd to the end of the month, rain was again experienced due to an easterly wave that moved across the Island followed by a tropical storm that formed in the Bay of Bengal and moved westwardo along latitude 5 north.

The larger monthly totals of rainfall (totals over 30 inches) were experienced over the eastern slopes of the central hills, particularly in the Badulla, Maturata and Gammaduwa areas. Rainfall oved the adjoining region ranged from 15 to 30 inches. In the southwest quarter and in the Northern and Northcentral provinces rainfall ranged from 2 to 15 inches. Rainfall was generally below average, being above average mainly over the eastern slopes of the central hills and parts of Uva. Day temperatures were well below normal at some inland stations and generally a little below normal elsewhere.

Night temperatures were a little below normal. Ground frost was experienced at Nuwara Eliya on the 22nd morning. Day humidity ranged from 67 to 86 per cent, while night humidity ranged from 74 to 97 per cent. Mean cloud amounts were a little above normal, while mean air pressures were a little below normal. Wind mileages were below normal in the south and mainly above normal elsewhere, the direction being mainly north-north-easterly.

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October, 1970

Station	Temperature F°				Humidity		Amount of Cloud	Rainfall			
	Mean Max.	Offset	Mean Min.	Offset	Night	Day		Amount	Offset	Rain Days	Offset
Anuradhapura	88·8	−0·5	73·4	−0·2	72	93	5·6	10·09	+0·92	14	−2
Badulla	84·1	+1·0	65·4	−0·2	67	92	5·6	3·78	−4·73	13	−4
Batticaloa	87·5	+0·5	66·2	+0·8	70	82	5·4	2·32	−4·69	12	−2
Colombo	85·3	+0·4	75·8	+1·0	78	86	6·6	12·11	−1·83	21	0
Diyatalawa	75·8	−0·7	60·2	−0·5	73	89	5·6	6·55	−3·22	17	−2
Galle	83·5	+0·6	76·0	+0·5	74	79	5·4	9·13	−4·89	20	−1
Hambantota	86·2	+0·1	76·2	+0·7	72	84	5·4	4·92	−0·03	14	+1
Jaffna	86·1	+0·3	77·5	−0·3	77	84	5·4	7·90	−1·69	11	−2
Kandy	82·1	−1·0	+ 0·2	+0·2	74	90	6·4	13·26	+3·08	21	+4
Kankesanturai	87·6	+0·3	76·0	−1·3	72	86	5·8	4·66	−4·07	12	+1
Katunayake	87·0	—	74·9	—	76	88	6·2	18·89	—	21	—
Kurunegala	86·3	−1·0	73·4	+0·1	79	68	6·3	15·67	+2·68	23	+3
Maha Illuppallama	88·0	−1·3	73·1	−0·1	73	88	5·4	6·52	—	14	—
Mannar	86·3	−0·3	77·3	−0·1	79	89	6·2	5·36	−1·24	12	+1
Nuwara Eliya	66·5	−1·2	52·6	+0·2	82	88	6·4	7·44	−1·31	20	−1
Puttalam	88·3	+1·7	76·5	+0·7	74	91	5·4	5·44	−1·40	9	−4
Ratmalana	85·5	+0·1	75·1	0	80	91	6·4	11·53	—	23	—
Ratnapura	87·3	+0·1	72·7	−0·1	82	95	6·1	19·28	−0·34	24	+1
Trincomalee	89·1	+0·8	75·8	0	69	84	5·5	10·07	+0·83	14	−2
Vavuniya	88·1	—	73·1	—	63	78	6·4	6·05	−2·73	17	+2

November, 1970

Station	Temperature F°				Humidity		Amount of Cloud	Rainfall			
	Mean Max.	Offset	Mean Min.	Offset	Night	Day		Amount	Offset	Rain Days	Offset
Anuradhapura	85·3	−0·5	72·7	+1·2	82	95	6·1	13·93	4·15	19	0
Badulla	81·1	+1·7	66·7	+1·2	78	95	6·5	19·43	+8·91	24	+4
Batticaloa	84·8	+0·6	75·0	+0·7	78	90	6·2	10·39	−0·84	21	+3
Colombo	85·3	+0·1	74·4	+1·1	79	90	6·3	18·74	+5·97	17	−2
Diyatalawa	74·8	+0·4	60·6	+0·8	82	97	6·4	18·41	+7·47	22	0
Galle	84·6	+1·0	74·8	+0·6	72	84	5·9	12·77	+0·08	15	−4
Hambantota	85·9	+0·5	75·0	+0·9	75	86	6·0	8·48	+1·10	17	+2
Jaffna	83·1	−1·0	74·6	−0·3	82	93	6·6	25·13	+8·94	17	−1
Kandy	82·4	−0·4	68·6	+1·2	77	92	6·4	14·94	+5·11	24	+7
Kankesantusai	83·4	−0·6	75·0	−0·6	80	88	6·7	34·63	+8·55	19	+3
Katunayake	86·9	—	73·4	—	75	90	6·4	18·17	—	17	—
Kurunegala	86·9	+0·1	72·9	+1·1	81	98	6·7	13·60	+2·52	24	+5
Maha Illuppallama	86·1	+0·5	72·4	+1·4	77	90	6·3	13·54	—	20	—
Mannar	84·0	−0·4	75·8	0	84	93	7·0	16·98	+7·42	18	+1
Nuwara Eliya	68·8	+1·0	53·2	+1·8	84	94	6·6	10·14	+1·93	21	0
Puttalam	85·6	−0·2	73·8	+0·6	81	95	6·2	10·66	+0·62	17	−1
Ratmalana	85·7	−0·6	73·1	−0·1	79	95	6·1	16·88	—	20	—
Ratnapura	89·5	+1·7	72·9	+0·7	80	95	6·6	14·96	+1·04	19	−2
Trincomalee	84·0	+0·3	75·2	+0·3	79	88	6·8	21·72	+7·74	20	+1
Vavuniya	85·2	—	72·1	—	70	81	6·7	17·38	+5·83	22	+4

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Station	Temperature F°				Humidity		Amount of Cloud	Rainfall			
	Mean Max.	Offset	Mean Min.	Offset	Day	Night		Amount	Offset	Rain Days	Offset
Anuradhapura ..	81·2	–2·1	69·6	–0·7	81	95	5·6	6·76	–2·78	13	–4
Badulla ..	75·3	–1·3	64·4	–0·3	84	91	6·2	13·27	+2·45	24	+4
Batticaloa ..	80·4	–1·6	73·2	–0·6	79	88	5·6	11·79	–5·13	20	0
Colombo ..	8·49	–0·7	72·2	–0·2	72	88	4·8	2·36	–4·52	10	–2
Diyatalawa ..	71·1	–1·0	58·3	–0·6	86	97	6·1	12·76	+4·75	23	+3
Galle ..	83·8	+0·2	72·4	–1·0	69	83	4·5	3·63	–3·68	13	–1
Hambantota ..	84·2	–0·6	72·8	–0·4	73	85	5·2	4·02	–0·74	12	0
Jaffna ..	80·9	–1·7	71·7	–1·6	75	85	5·3	2·44	–8·06	7	–7
Kandy ..	79·3	–2·4	65·4	–0·5	76	92	5·6	7·73	–0·56	20	+7
Kankesanturai ..	81·2	–1·7	74·3	–1·0	73	74	5·4	2·72	–7·53	7	–6
Katunayake ..	85·4	—	70·9	—	68	87	4·8	4·53	—	10	—
Kurunegala ..	83·3	–2·3	70·4	–0·4	77	93	5·2	6·69	–0·26	12	–2
Maha Illuppallama ..	81·4	–2·4	69·0	–0·8	75	87	5·8	5·84	—	15	—
Mannar ..	81·0	–1·6	74·1	–0·9	77	81	5·8	7·36	–0·61	10	–3
Nuwara Eliya ..	67·6	–0·1	51·1	+1·6	78	84	6·1	12·89	+5·38	19	+2
Puttalam ..	83·1	–1·8	70·4	–1·0	75	93	5·0	5·90	–0·14	10	–3
Ratmalana ..	86·3	–0·4	70·6	–1·4	70	93	4·8	3·54	—	10	—
Ratnapura ..	88·4	+0·3	70·7	–1·0	75	95	6·0	3·91	–4·50	12	–4
Trincomalee ..	80·2	–1·0	74·4	–0·8	77	81	6·0	10·95	–3·77	15	–3
Vavuniya ..	81·8	—	68·6	—	67	79	5·8	8·71	–2·21	15	–1