The Relationship between Chemical and Physico-Chemical Characteristics of Paddy Soils in the Dry State and on Continued Submergence*

By

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THE Chemical and biological processes that take place in a paddy soil when it is submerged are of a dynamic character. Most of the experiments carried out so far by Soil Chemists on paddy soils have been done with the rice plant in situ; therefore the variations in the Chemical and Physico-Chemical characteristics of paddy soils on submergence in the absence of the rice plant have not been observed and recorded. Three important influences of the rice plant on the soil are :— (*a*) the exudation of oxygen by the rice roots which maintains an oxidized rhizosphere which influence the soil; (*b*) the decaying dead roots make a significant contribution towards the soil organic matter, which in turn intensifies reductive processes in the soil; (*c*) the absorption of nutrients from the soil. A study of the variations in the chemical regime in the absence of the rice plant therefore appears to be an important aspect of soil nutritional relationships of paddy soils.

The main object of this investigation was to study the variations and relationships between the chemical and physico-chemical characteristics of paddy soils in the dry state and on continued submergence.

MATERIALS AND EXPERIMENTAL PROCEDURE

Twenty soils comprising of the following seven groups were studied.

1. Strongly acid lateritic rice soils of the ultra wet zone.
2. Strongly acid humic rice soils.

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3. Ground water podzolic rice soils.
4. Acid lateritic rice soils of the wet zone.
5. Non-Lateritic rice soils of the dry zone.
6. Calcareous rice soils.
7. Non-Lateritic clayey rice soils.

The experiment was carried out under greenhouse conditions in glazed pots with a side opening at the bottom. The pots were filled to the brim and the 2″ of standing water was maintained by daily addition of distilled water.

The dry soil was analysed for carbon, nitrogen, cation exchange capacity, total exchangeable cations, free iron oxide, total iron, easily reducible manganese, total manganese, available silica, available phosphorous, pH and mechanical analysis.

After submergence the following determinations were made in the wet soil at intervals of 2 weeks initially and later at intervals of 4 weeks :— Ammonia, Iron, Manganese, Oxidisable Matter, pH and Redox Potential.

Water percolates were also analysed at intervals for Ammonia, Nitrate, Iron, Manganese, Oxidisable Matter and Conductivity.

pH was measured in situ by placing 2 blank pltinum electrodes seated permanently in each pot 6 in. below the surface of the soil. They were placed near the centre and at a distance of 3 in. apart from each other. The potentials were measured with a Beckman pH meter Model G using a saturated calomel electrode.

Oxidisable matter includes Fe^{+2}, No_2^1 and S^1 among the inorganic constituents and soluble organic matter that is oxidised under relatively mild conditions. This determination would give a measure of the reducing capacity. This is a relative determination and has only comparative significance.

The method is based on the oxidation of the sample with potassium permanganate under standard conditions. The sample (the volume used varied from 1.0 ml to 10 ml) was added to a mixture of 10 ml. of 0.01 N $KMnO_4$, and 10 ml of 1 : 3 H_2SO_4 with sufficient water to make a total volume of 100 ml, in a 250 ml conical flask. The flask was heated in a boiling water bath for 30 minutes along with a blank. By this procedure the factors (strength of $KMnO_4$, acidity of the medium and time of digestion) on which the figure for oxidisable matter depends, were kept nearly constant. Immediately after the digestion

10 ml of 0.01 N Ammonium oxalate solution was added and the excess oxalate back titrated against 0.01N $KMnO_4$. The difference between this reading and the blank reduced to an equivalent of 10cc of the percolate was taken as an index of the concentration of oxidisable matter or the reducing capacity.

About 50 grms of the soil were extracted with a glass tube 24 in. long and 2 cm diameter by inserting it into the pot in a circular motion. This was used for the analysis of the wet soils.

pH and moisture determinations were run on the same sub-sample. The sample was transferred to a tared 50 ml. beaker and the weight of the moist soil quickly determined. An equal weight (volume) of oxygen free distilled water was added, the beaker swirled and the pH determined with a glass electrode. The soil adhering to the electrodes was washed into the beaker with a jet of water. After expulsion of the bulk of water on a water bath the soil was dried further in an oven at 0 I5 and the moisture percentage determined.

The remaining soil was transferred into a 500 ml. conical flask which had been previously weighed. The weight of the moist soil quickly determined; a rough allowance was made for the moisture content on the basis of preliminary experience, and measured amounts of Morgan's solution added to give a soil extractant ratio of approximately 1:5. The flasks were allowed to stand for 24 hours with occasional swirling and the solution filtered through fluted filter paper. This solution was used for the determination of ammonia, iron, manganese and oxidisable matter. Morgan's solution will extract ferrous iron and not ferric iron. These figures will characterise the extent of reduction of the soil. With the aid of the amount of Morgan's solution added and the moisture content of the soil all figures are reduced to ppm of the dry soil. The values for oxidisable matter are reduced to ccs of 0.01N $KMnO_4$ per grm of dry soil.

Standard methods were used for the other determinations.

RESULTS AND DISCUSSION

Dry Soils. The analysis of the dry soils is given in Table 1. The values obtained readily permit the soils to be grouped into seven classes. The average of the seven groups are given in Table II.

pH. The average pH value for the Ultra wet zone soils is 4.84; for the wet zone it is 5.65; for the dry zone 7.26 and for the calcareous soils it is 7.78. The pH rises from ultra wet zone to the dry zone.

Carbon. The carbon values take an opposite trend. It is high for the ultra wet zone soil with 2.4 per cent, for the wet zone it is 1.3 per cent for the dry zone it is 1.1 per cent calcareous soils has a value of 0.8 per cent. The humic soils is highest with 10.4 per cent and ground water podzolic soils is lowest with an average of 0.45.

Nitrogen. The Nitrogen percentages follow the same trend as the carbon values. It is 0.17 per cent for the ultra wet zone soils, 0.11 per cent for the wet zone soils, 0.09 per cent for the dry zone soils and 0.09 for calcareous soils. The Nitrogen content of the humic soils is highest with 0.52 per cent and lowest for the ground water podzols with 0.035 per cent.

Cation Exchange Capacity. The cation exchange capacities increases with the rise in pH; 7.7 for the ultra wet zone soils, 11.9 for the wet zone soils, 15.8 for the dry zone soils. It has a high value of 20.8 for humic soils and a very low value of 1.3 for the ground water podzols.

Total Exchangeable Bases. The total exchangeable bases also increase with the rise in pH. It is 1.5 for the ultra wet zone, 6.1 for the wet zone soils, 8.9 for the dry zone soils and 10.5 for the calcareous soils. It is lowest for the ground water podzols with 0.75.

Available Silica. Available silica also increases with pH. It is 23.5 ppm for the ultra wet zone soils, 76.4 for the wet zone soils, 145.2 for the dry zone soils. It is lowest for the ground water podzols with 6.75 ppm while the humic soils contain 33.5 ppm. The calcareous soils and clayey soils have high values of 143.2 and 142.3 ppm respectively.

Free Fe/Total Fe percentage. The percentage of free iron to total iron decrease with rise in pH. It is highest with 82 per cent for the ultra wet zone, with values of 64 and 49 per cent for the wet zone and dry zone respectively. The humic soils too contain a high value of 70 per cent while ground water podzols are lowest with 38 per cent.

This could be expected as the amount of weathering and leaching is high in the ultra wet zone, less in the wet zone and least in the dry zone. The humic soils too contain a high percentage of free iron to total iron due to the high carbon content which gives rise to organic acids. This value is least for the podzols as they are very highly weathered leached sandy soils.

General. The soils of the ultra wet zone which are strongly acid, low in cation exchange capacity indicate a kaolinite clay.

The non-lateritic rice soils of the dry zone with an average pH of 7.26, high cation exchange capacity of 65.2 m.e. per 100 gms clay, high total exchangeable bases of 37.5 m.e. per 100 gms clay, a high silica content of 145.2 ppm indicate a fair proportion of montmorillonitic clay.

Water Percolates and Wet Soils. The analyses of the water percolates are given in table III. The averages of the groups are given in table IV. The analysis of the wet soils are given in table V and their averages are given in table VI. These are graphically shown in figures 1 to 12.

General. There was a fall in redox potential, an increase of pH with time and an almost total disappearance of nitrate within 14 days of submergence. Ammonia, reduced iron, reduced manganese, oxidisable matter and conductivity reached a peak and then decreased.

Ammonia-Water Percolates. The initial values obtained after a day's submergence run parallel to the initial nitrogen content of the dry soils. It is highest with 33 ppm for the ultra wet zone, with 17 ppm for the wet zone and 6 ppm for the dry zone, while humic soils, ground water podzols, calcareous soils and clayey soils contain 30, 23, 9.5 and 14 ppm respectively.

The peak values too follow the same trend. It is highest with 132 ppm for the ultra wet zone, with 49 ppm for the wet zone and 29 ppm for the dry zone, while the humic soils, ground water podzols, calcareous soils and clayey soils reach 92, 59, 37 and 36 ppm.

The final values for ammonia too take the same trend.

The difference between the initial and maximum value will indicate the degree of ammonification. These values too follow the same trend. It is highest with 99 ppm for the ultra wet zone, with 32 ppm for the wet zone and 23 ppm for the dry zone; while humic soils, ground water podzols, calcareous soils, and clayey soils have values of 62, 36, 27.5 and 22 ppm for the degree of ammonification.

The differences between the maximum value and final value will indicate the degree of denitrification. These values too follow the same trend. It is highest with 78 ppm for the ultra wet zone, with 22 ppm for the wet zone and 18 ppm for the dry zone; while humic soils, ground water podzols, calcareous soils and clayey soils have values of 42, 43, 23.5 and 25 ppm for the degree of denitrification.

When a soil is submerged the oxygen supply is almost completely cut off and anaerobic decomposition of organic matter sets in. Ammonia is the most important product of anaerobic decomposition.

It is postulated that ammonia formed in the bulk of the soil diffuses upwards on a concentration gradient. When it reaches the oxidised surface layer it is converted to nitrate. The nitrate thus formed again on a concentration gradient diffuses downwards and when it reaches the reducing layers of the soil denitrification takes place. During denitrification nitrate acts as an oxygen donor to oxidise the constituents of the soil viz. reduced iron, reduced manganese, oxidisable matter, etc., and nitrogen escapes as a gas. It may be mentioned here that there was no detectable amounts of ammonia or nitrate in the supernatent liquid and there was no detectable amounts of nitrate in the percolates. This indicates that the nitrate formed in the oxidising layer readily diffuses downwards and is quickly denitrified. Ammonification, nitrification and denitrification take place simultaneously. During initial stages of submergence there is more ammonification than denitrification, thus ammonia values rise ; later there is more denitrification than ammonification and the values for ammonia fall.

At the end of the experiment the soils were air dried and analysed for carbon and nitrogen. Eight soils which gave values lower than those obtained before submergence are given below :—

	Before Submergence			*After Submergence*		
	C.	*N.*	*C/N*	*C.*	*N.*	*C/N*
1. Panagoda	3·4	·21	16	3·1	·19	16
2. Bombuwela Peaty	10·4	·52	20	9·8	·50	20
3. Bibile	0·6	·07	8·5	0·6	·06	10
4. Peradeniya	2·4	·15	16	2·3	·14	16
5. Kundasale	0·8	·09	9	0·8	·08	10
6. Matale	1·3	·13	10	1·2	·12	10
7. Ambalantota 1	2·4	·19	13	2·3	·18	13
8. Ambalantota 2	2·2	·17	13	2·1	·16	13

1. Panagoda—net denitrification of 181 ppm in percolate and 163 ppm in the wet soil ;
2. Bombuwela Peaty—has a high initial nitrogen content of .52 ;
3. Bibile—C/N ratio before submergence is low—8.5 and it is raised to 10 ;
4. Peradeniya—has a net denitrification of 231 ppm in the wet soil ;
5. Kundasale—C/N ratio before submergence is low—9.0 and it is raised to 10 ;
6. Matale—has a net denitrification of 243 ppm in the wet soil ;
7. Ambalantota 1—has a high initial nitrogen content of .19 ;
8. Ambalantota 2—has a high initial nitrogen content of .17.

A high initial nitrogen content or a high value for net denitrification either in the wet soil or in the percolate or a low C/N ratio will show detectable losses of nitrogen on submergence by the analyses of dry soils.

These findings are of very important practical significance. Hitherto it was believed that deep-placement of ammonia fertilizers will prevent loss of nitrogen due to denitrification. It could be inferred from this experiment that even with deep-placement of ammonium fertilizers denitrification still takes place ; hence the rate and time of application of ammonium fertilizers are important. In certain instances denitrification is beneficial as it oxidises the reduced products such as ferrous iron which may reach toxic proportions, and keeps them at low concentrations. The peak values of the percolates are reached in about 28 days ; during this period the young rice roots are subjected to an influx of increasing reduced products. The practical significance of this is that the toxicity due to reduced products, which are observed in certain parts of the ultra wet zone, may be averted by keeping the soils submerged for some length of time till the peak value is reached before transplanting.

Reduced Iron-Water Percolates. The initial values are low as very little ferrous iron could be expected on a day's submergence. The maximum values are highest for the ultra wet zone with 252 ppm and as expected it is lower for the wet zone 159 ppm, still lower for the dry zone 38 ppm and least for the calcareous soils with 7 ppm. The humic soils, ground water podzols, and clayey soils have maximum values of 158, 75 and 91.

The final values too follow the same trend.

The difference between the initial and maximum values gives the amount of iron reduced and brought into solution. The differences between the maximum and final values give the amount of ferrous iron oxidised. These values too follow the same trend.

The oxidation of the once reduced iron could be attributed to three causes :

(1) Denitrification.
(2) Oxidation and precipitation in the surface layer where oxidising conditions prevail.
(3) By the slow diffusion of atmospheric oxygen.

Of these oxidation due to denitrification appears to be considerable.

Reduced Manganese-Water Percolate. Manganese does not behave like ammonia and reduced iron. It appears to be closely connected with the initial pH, total manganese content of the soil and the carbon content. When considering the maximum manganese values of the percolates it is evident that for manganese to come into solution there must be sufficient total manganese in the soil, a low pH and a certain amount of carbon. The highest value of 41.8 ppm is obtained for the wet zone where all these conditions are satisfied. Dry zone soils have 26.7 ppm with a high initial pH of 7.28. The ultra wet zone soils have 12.3 ppm as the total manganese content is low.

From the analyses of the dry soils, water percolates and wet soils it appears that the following soils may be deficient in manganese: Panagoda, Bombuwela Peaty and Bombuwela Sandy.

Oxidisable Matter-Water Percolate. Oxidisable matter which gives a measure of the reducing capacity of the percolate follows the same pattern of ammonia and reduced iron.

Conductivity-Water Percolate. Conductivity behaves differently from the rest as it measures the ionisable salts. It is highest for these clayey soils which may contain chlorides, then come the calcareous soils, dry zone soils, ultra wet zone soils, wet zone soils, humic soils and ground water podzols.

Wet Soils. The analyses of the wet soils are given in table V, and the average of the groups are given in table VI; these are graphically shown in figures VI to XII. The wet soils and more particularly their iron contents behave differently from the percolates.

Ammonia-Wet Soils. The initial values appear to depend on the nitrogen content of the dry soils. The maximum values are highest for the clayey soils, dry zone soils and humic soils. There is a similar trend for the final values. The difference between the initial values and the maximum values which will indicate the degree of ammonification that has taken place and the difference between the maximum values and final values which will indicate the amount of ammonia converted back to the original form too follow the same trend.

Reduced Iron, Reduced Manganese and pH-Wet Soils. Variation in pH demands special merit. There is a negative correlation between the initial pH and the increase in pH. The lower the initial pH the greater is the increase.

Initial values of iron seems to depend on the free iron oxide content. The maximum values and the final values depend on the total iron content. It is of great ecological importance to note that though the amount of iron reduced in the soil depends on its iron content, the iron brought into solution depends on its pH. The lower the pH more iron is brought into solution. This is clearly shown in the table below :

	Maximum Fe ppm in percolate	*Maximum Fe ppm in wet Soils*	*pH of dry Soils*
Group 1	252	2,157	4·84
Group 2	158	3,042	4·65
Group 3	75	210	5·47
Group 4	159	4,885	5·65
Group 5	38	1,825	7·26
Group 6	7	930	7·78
Group 7	91	5,162	6·22

The clayey soils with a reduced iron content of 5,162 ppm has only 91 ppm in the percolate with a high pH of 6.22, whereas the ultra wet zone soils with a reduced iron content of 2,157 ppm (less than half that of clayey soils) has as much as 252 ppm in the percolate with a low pH of 4.84.

The peak values of reduced iron in the percolates are correlated to pH, the largest values are reached with the lowest pH and vice versa or in other words the amount of iron brought into solution is proportional to the increase in pH.

From the fore-going results it is evident that duration of submergence as well as the inter-relationships between chemical and physico-chemical properties play a significant role in the chemical equilibria which result at different stages of submergence. The analysis of paddy soils under fields conditions—wet state—is rather impractical as it is not possible to freeze the chemical equilibria. Paddy soils in the wet state have been studied under conditions which permit such analysis. From this experiment it is evident that the status of any constituent for a specific soil group depends mainly on the duration of submergence. Once these curves are constructed under greenhouse conditions for specific soil groups the chemical and physico-chemical environment which the rice roots will be subjected to at different stages of their growth are known. The analysis of paddy soils in the dry state is necessary to characterize the soil group and is alone sufficient in predicting the chemical and physico-chemical status on submergence.

ACKNOWLEDGMENTS

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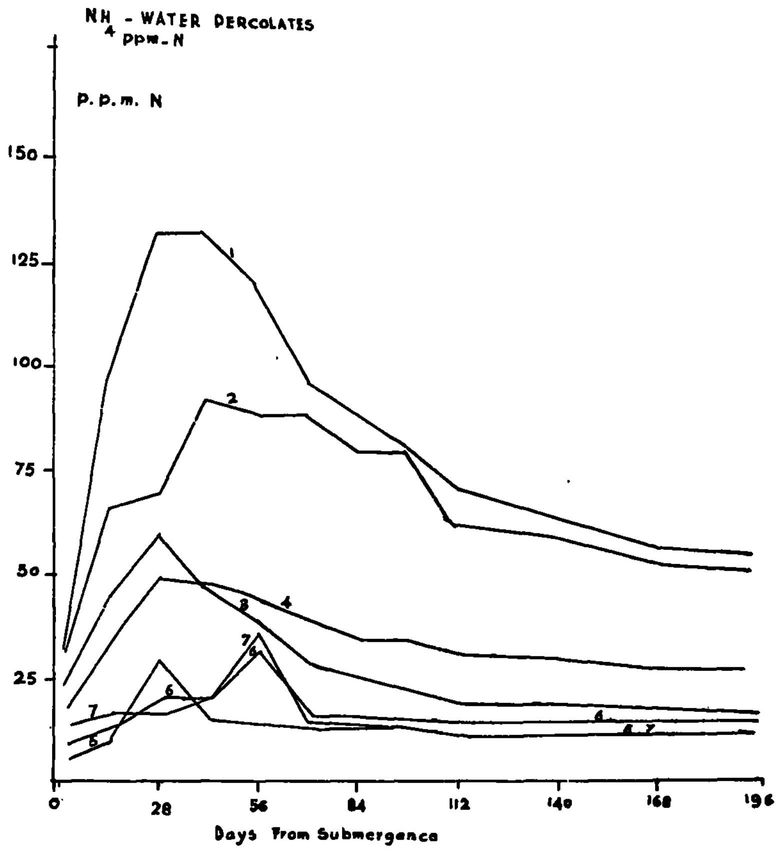

FIGURE 1

1. Strongly acid lateritic rice soils of the ultra wet zone
2. Strongly acid humic rice soils
3. Ground water podzolic rice soils
4. Acid lateritic rice soils of the wet zone
5. Non-lateritic rice soils of the dry zone
6. Calcareous rice soils
7. Non-lateritic clayey rice soils

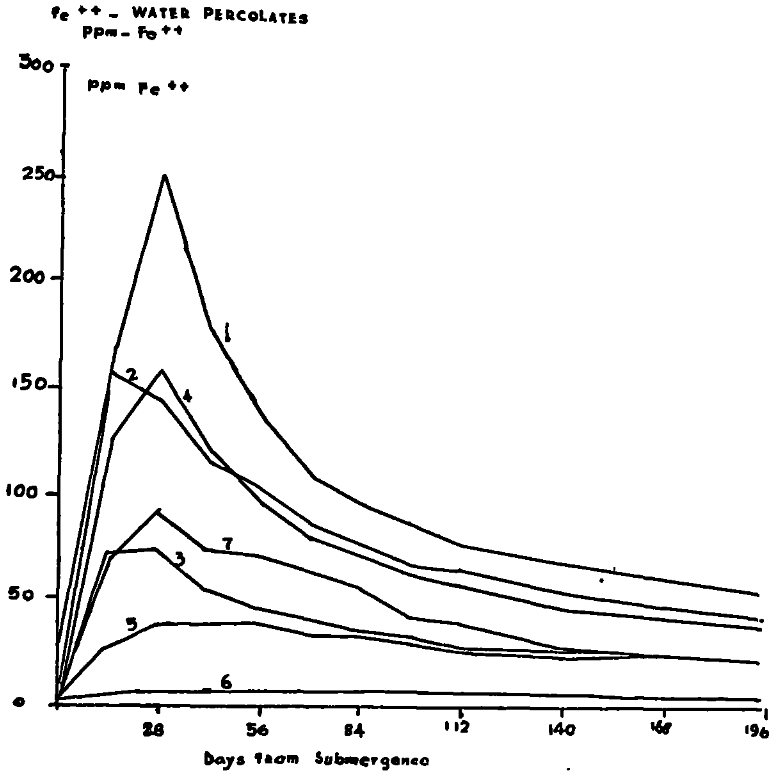

FIGURE 2

1. Strongly acid lateritic rice soils of the ultra wet zone
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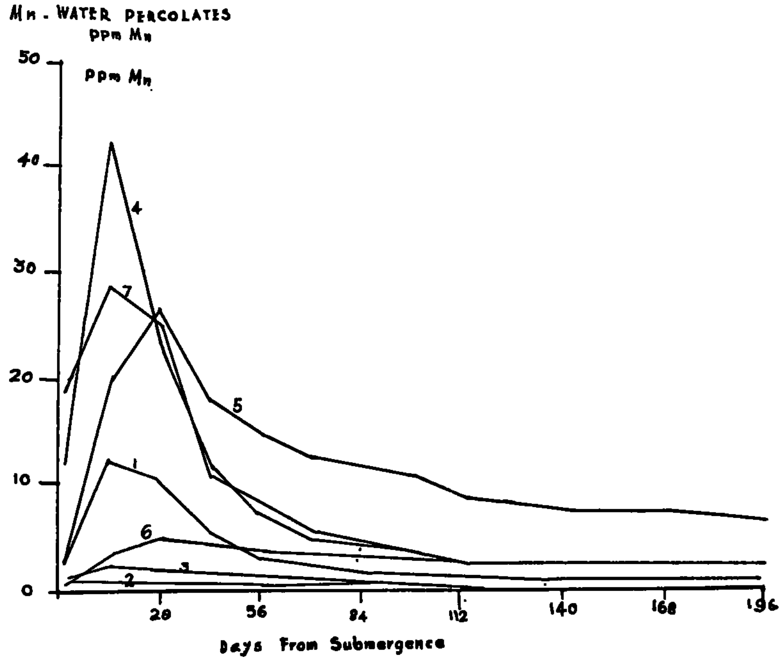

FIGURE 3

1. Strongly acid lateritic rice soils of the ultra wet zone
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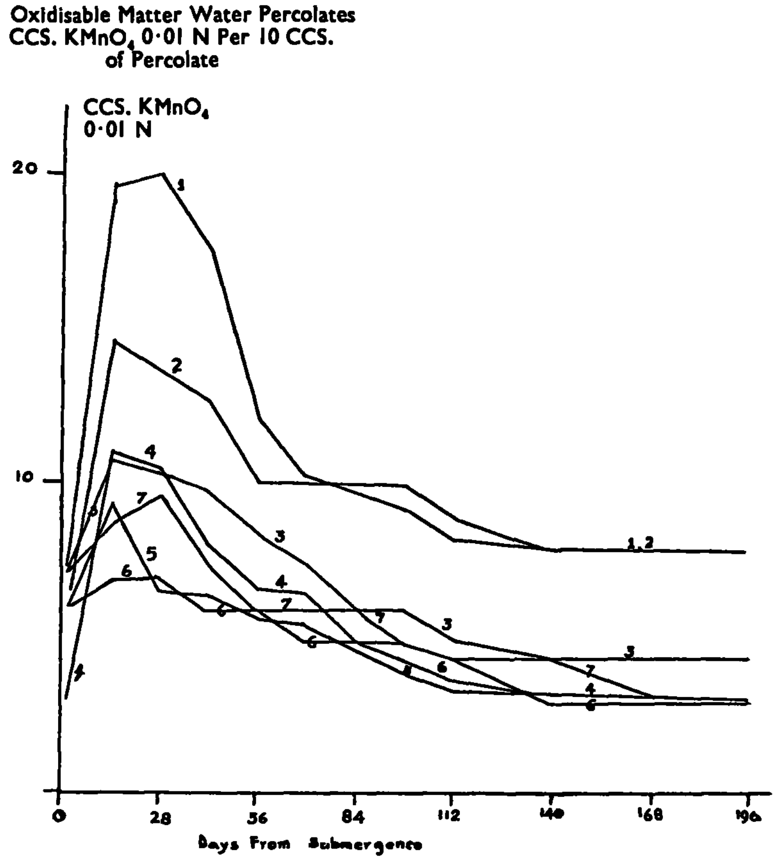

FIGURE 4

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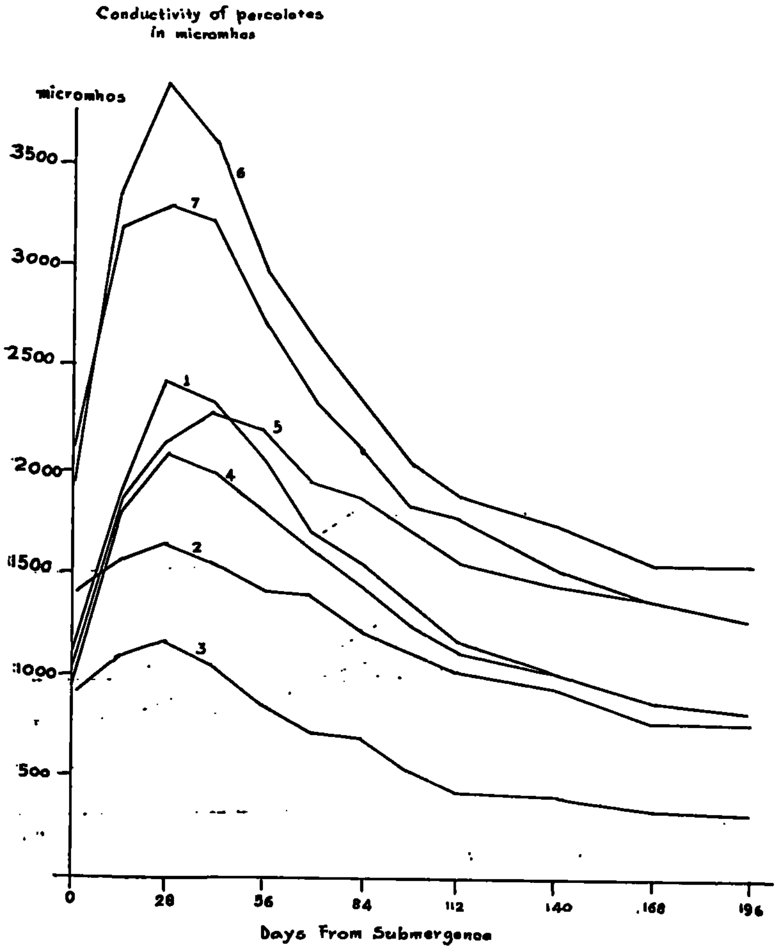

FIGURE 5

1. Strongly acid lateritic rice soils of the ultra wet zone
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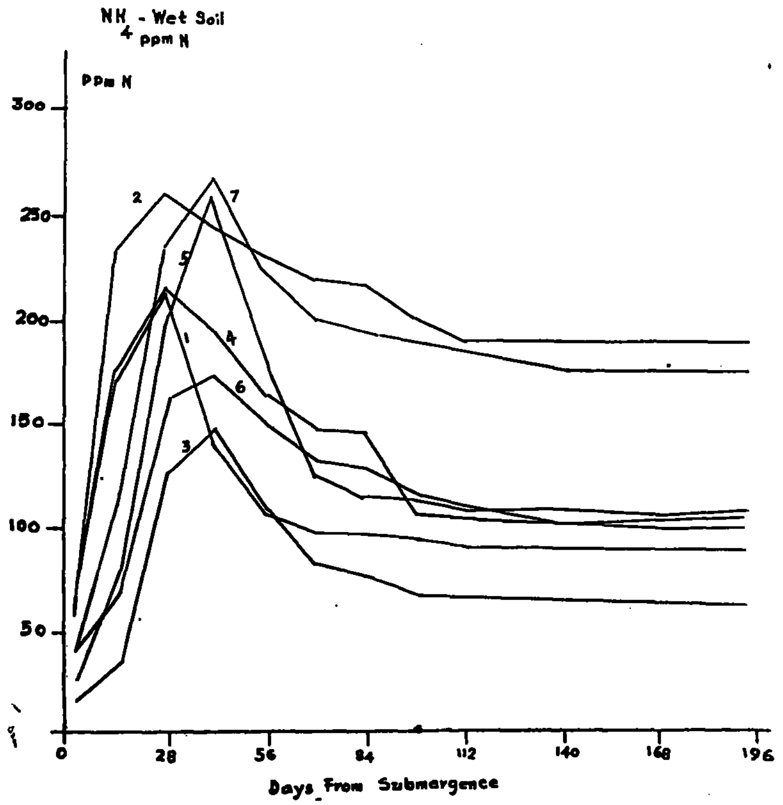

FIGURE 6

1. Strongly acid lateritic rice soils of the ultra-wet zone
2. Strongly acid humic rice soils
3. Ground water podzolic rice soils
4. Acid lateritic rice soils of the wet zone
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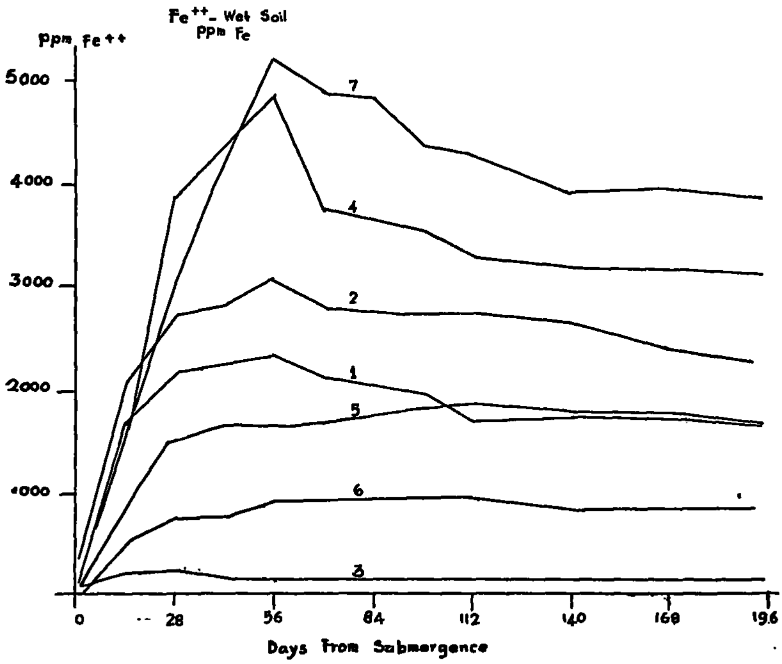

FIGURE 7

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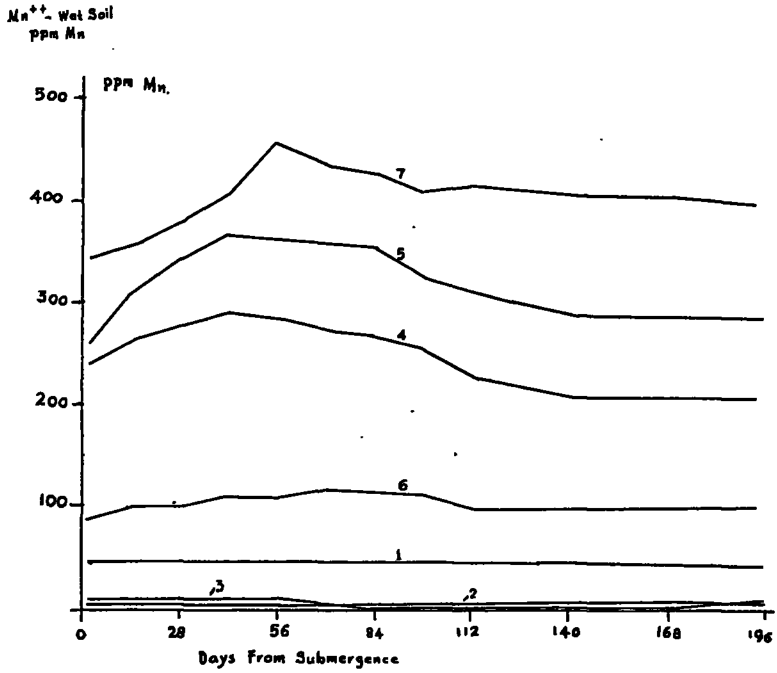

FIGURE 8

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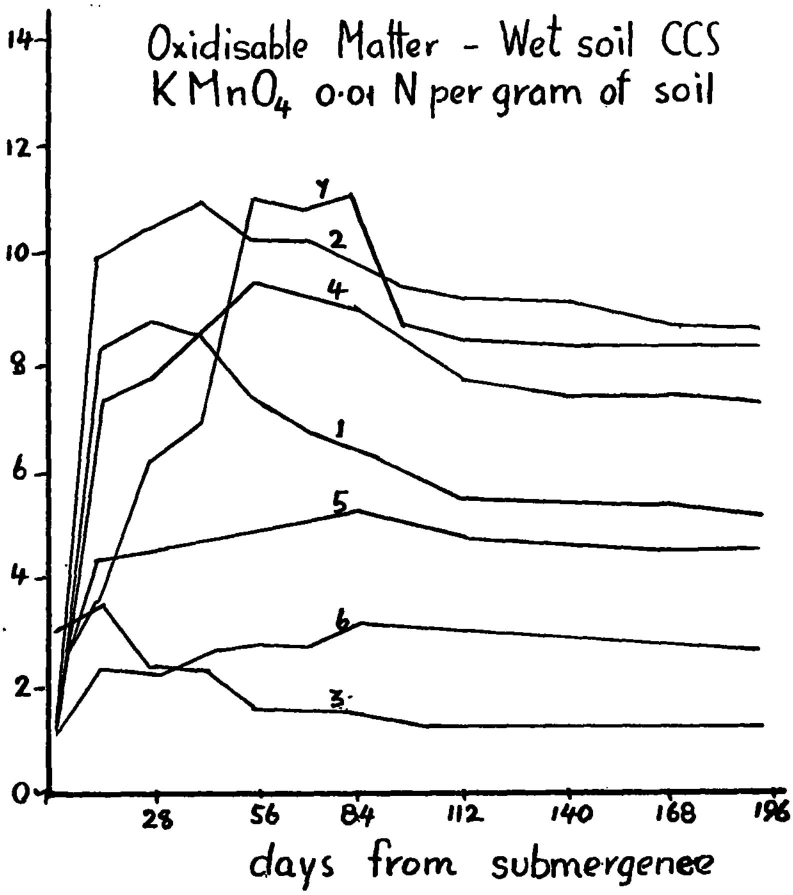

FIGURE 9

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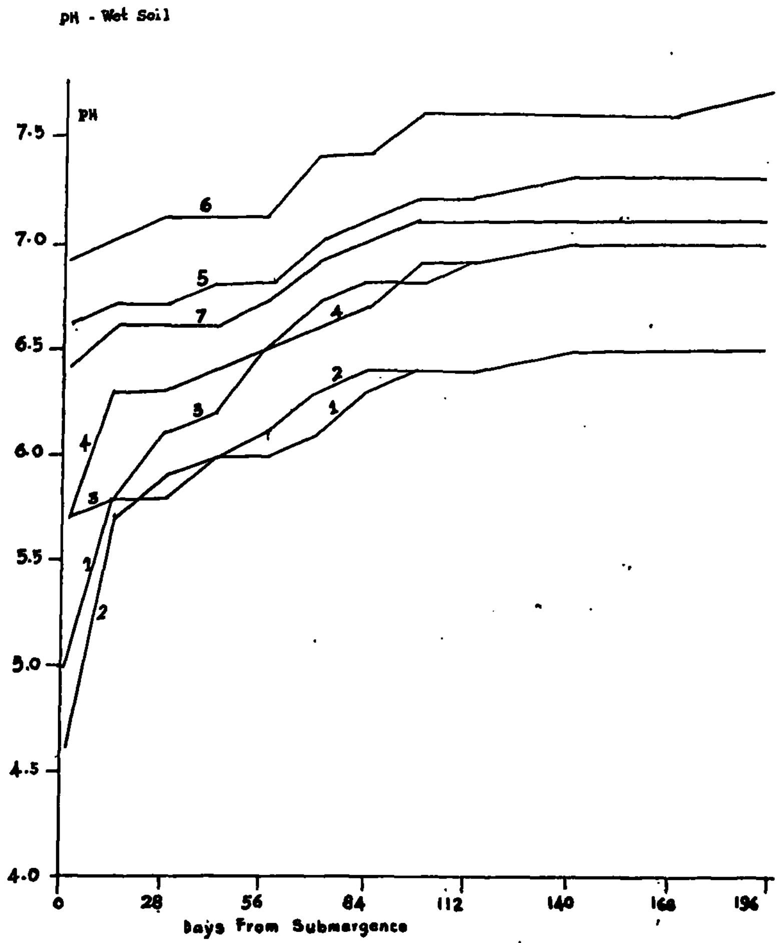

FIGURE 10

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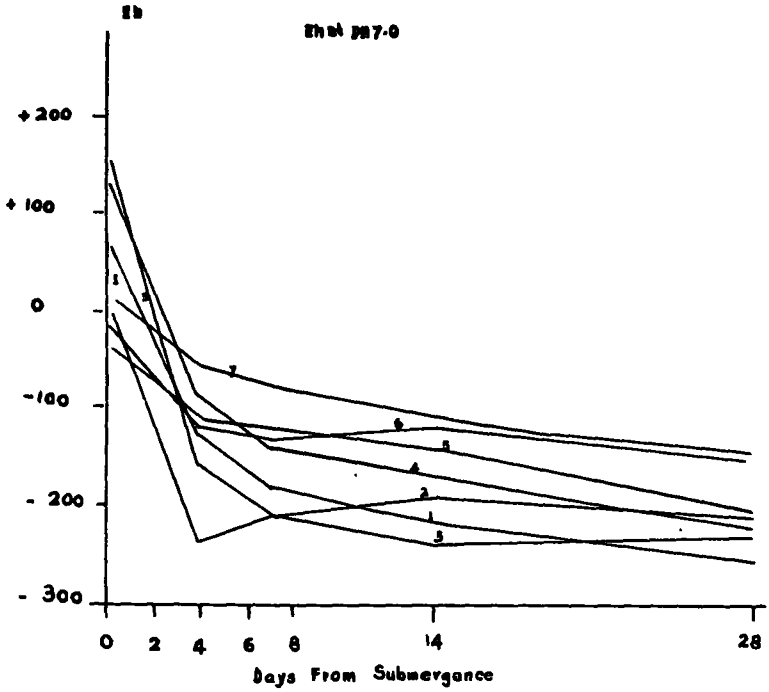

FIGURE 11

1. Strongly acid lateritic rice soils of the ultra wet zone
2. Strongly acid humic rice soils
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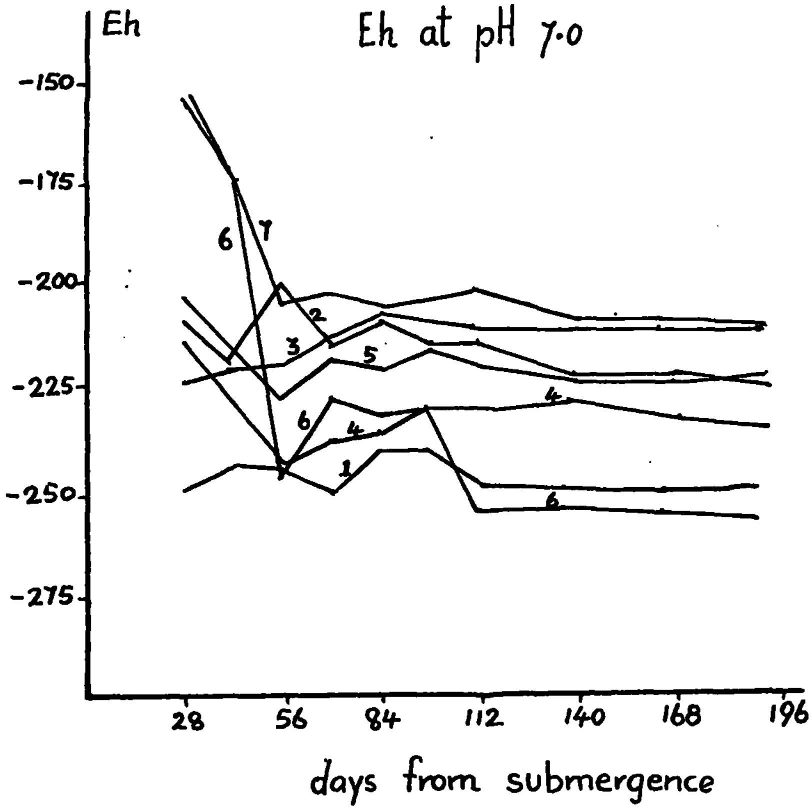

FIGURE 12

1. Strongly acid lateritic rice soils of the ultra wet zone
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7. Non-lateritic clayey rice soils

TABLE I—Dry Soils

	pH	Carbon %	N %	Carbon / N	C.E.C.m.e. per 100 grms Soil	T.E.C.m.e. per 100 grm Soil	Free Fe %	Total Fe %	Easily Reducible Mn %	Total Mn %	Free Fe/Total Fe %	Easily Reducible Mn/Total Mn %	Available P ppm.	Available Sil. ppm	Coarse Sand %	Fine Sand %	Silt %	Clay %
(1) *Strongly Acid lateritic Rice Soils of he ultra Wet Zone—*																		
1. Panagoda	4·86	3·4	·21	16	7·9	0·7	0·52	0·86	·00022	·00640	60	3·4	37·2	14·5	42·8	29·8	6·3	18·0
2. Mirigama	4·65	1·9	·17	11	9·1	1·9	4·35	4·80	·00070	·04600	91	1·5	4·7	39·0	25·2	25·8	8·5	37·0
3. Mapalana	4·70	2·5	·17	15	7·7	1·6	1·42	1·69	·00065	·00470	84	13·8	15·6	20·5	35·0	34·8	5·5	23·5
4. Karapincha	5·14	1·8	·12	15	6·2	1·7	1·98	2·75	·00020	·01300	72	1·5	4·5	20·0	43·4	31·6	6·5	17·0
(2) *Strongly Acid Humic Rice Soils—*																		
1. Bombuwela Peaty ..	4·65	10·4	·52	20	20·8	2·5	1·40	2·00	·00044	·00500	70	8·8	12·5	33·5	14·2	15·6	16·9	38·6
(3) *Ground Water Podzolic Rice Soils—*																		
1. Bombuwela Sandy ..	5·62	0·6	·04	15	1·2	0·7	0·20	0·58	·00019	·00400	34	4·8	7·1	7·0	58·5	35·5	3·0	1·0
2. Batticaloa	5·32	0·3	·03	10	1·4	0·8	0·25	0·63	·00066	·08900	40	0·7	5·1	6·5	49·4	39·7	5·8	3·8
(4) *Acid lateritic Rice Soils of the Wet Zone—*																		
1. Welimada	5·30	1·5	·12	12·5	11·5	4·9	4·35	5·13	·00058	·05100	85	1·2	7·5	83·0	29·2	30·7	12·4	23·5
2. Bibile	5·65	0·6	·07	8·5	5·0	2·8	1·38	2·05	·00132	·03400	67	3·9	5·9	32·5	35·3	41·2	6·5	17·0
3. Peradeniya	5·55	2·4	·15	16	18·6	5·5	5·28	7·63	·00122	·08500	69	1·4	6·5	90·0	13·5	25·2	26·0	30·0
4. Kundasale	6·60	0·8	·09	9	13·0	9·8	1·50	4·44	·00013	·06100	34	0·2	13·1	128·2	35·5	34·5	6·5	23·5
5. Matale	5·38	1·3	·13	10	14·1	8·0	2·62	4·25	·00056	·04770	62	1·7	8·6	73·0	34·8	26·5	7·0	27·0
6. Nalanda	5·41	1·0	·10	10	9·0	5·5	2·85	4·50	·00100	·05200	63	1·9	12·6	51·5	30·6	40·8	5·0	23·0
(5) *Non-lateritic Rice Soils of the Dry Zone—*																		
1. Polonnaruwa	7·30	1·3	·11	12	14·5	10·5	0·92	2·63	·00110	·07300	35	1·5	12·9	98·0	24·3	46·2	7·5	20·0
2. Hingurakgoda	7·47	1·3	·10	13	16·7	10·1	0·65	2·37	·00033	·02800	27	1·2	5·0	129·9	25·0	44·0	3·0	25·0
3. Maha Illuppallama Red ..	6·88	0·8	·07	11	14·1	5·3	2·30	3·31	·00084	·06900	69	1·2	8·3	183	30·4	30·6	8·7	26·8
4. Maha Illuppallama Grey ..	7·39	0·9	·09	10	17·9	9·7	1·00	3·23	·00122	·05700	31	2·1	6·3	170	14·4	49·8	5·4	26·1
(6) *Calcareous Rice Soils—*																		
1. Jaffna	7·78	0·8	·09	9	12·0	10·5	1·05	1·99	·00096	·02400	53	4·0	22·6	143·2	35·1	38·2	8·2	14·8
(7) *Non-lateritic Clayey Rice Soils—*																		
1. Ambalantota 1.	6·43	2·4	·19	13	26·7	15·7	3·25	5·88	·00084	·08200	55	0·66	20·0	156·5	9·3	23·4	11·5	50·0
2. Ambalantota 2.	6·02	2·2	·17	13	26·7	15·9	3·72	6·00	·00043	·08100	62	0·5	15·6	128·2	7·4	20·8	7·8	58·5

TABLE II—Dry Soils—Averages

	pH	Carbon %	N%	Clay %	C.E.C.m.e. per 100 grm. Soil	T.E.C.m.e. per 100 grm. Soil	Available Silica ppm.	Free Fe / Total Fe %	Total Mn. %
1. Strongly Acid lateritic Rice Soils of the Ultra Wet Zone ..	4·84 ..	2·4 ..	·17 ..	23·9 ..	7·7 ..	1·5 ..	23·5 ..	82 ..	·01752
2. Strongly Acid Humic Rice Soils (one soil)	4·65 ..	10·4 ..	·52 ..	38·6 ..	20·8 ..	2·5 ..	33·5 ..	70 ..	·00500
3. Ground Water Podzolic Rice Soils	5·47 ..	0·45 ..	·035 ..	2·4 ..	1·3 ..	0·75 ..	6·75 ..	38 ..	·04650
4. Acid lateritic Rice Soils of the Wet Zone	5·65 ..	1·3 ..	·11 ..	24·0 ..	11·9 ..	6·1 ..	76·4 ..	64 ..	·05512
5. Non lateritic Rice Soils of the Dry Zone	7·26 ..	1·1 ..	·09 ..	24·5 ..	1o·8 ..	8·9 ..	145·2 ..	49 ..	·05675
6. Calcareous Rice Soils (one soil) ..	7·78 ..	0·8 ..	·09 ..	14·8 ..	12·0 ..	10·5 ..	143·2 ..	53 ..	·02400
7. Non-lateritic Clayey Rice Soils ..	6·22 ..	2·3 ..	·18 ..	54·3 ..	26·7 ..	15·8 ..	142·3 ..	59 ..	·08150

TABLE III—Water Percolates

	Initial NH_4 ppm N	Max. NH_4 ppm N	Final NH_4 ppm N	Diff. initial & max. NH_4 ppm N	Diff. max. & final NH_4 ppm N	Initial Fe ppm	Max. Fe ppm	Final Fe ppm	Diff. initial & max. Fe ppm	Diff. Max. & final Fe ppm	Initial Mn ppm	Max. Mn ppm	Final Mn ppm	Diff. initial & max. Mn ppm	Diff. max. & final Mn ppm	Initial oxy: M.	Max. oxy. M.	Final oxy. M.	Diff. initial & max. ox. M.	Diff. max. & final ox. M	Cond. initial micromhos	Cond. max. micromhos	Cond. final micromhos	Cond. diff. initial & max. micromhos	Cond. diff. max. & final micromhos
(1) *Strongly Acid Rice soils of the Ultra Wet Zone*—																									
1. Panagoda ..	80	256	75	176	181	6·5	154	25	147·5	129	0·1	0·4	0	·3	·4	8·6	22·5	13·0	13·9	9·5	1611	3515	983	1904	2532
2. Mirigama ..	12·5	70	43	57·5	27	0·5	350	56	349·5	294	7·0	42	1·8	35	40·2	9·2	21·6	4·0	12·4	17·6	736	2000	663	1264	1337
3. Mapalana ..	9·5	102	50	92·5	52	10	295	82	285	213	1·6	3·0	0	1·4	3·0	7·1	24·5	10·0	17·4	14·5	460	1966	800	1506	1166
4. Karapincha ..	28	116	46	88	70	1·0	218	56	217	162	0·8	3·7	0·8	2·9	2·9	5·3	16·7	5·0	11·4	11·7	840	2231	928	1391	1303
(2) *Strongly Acid Humic Rice Soils*—																									
1. Bombuwela Peaty ..	30	92	50	62	42	18·5	158	45	139·5	113	0·4	0·4	0	0	·4	6·9	14·7	8·0	7·8	6·7	1389	1604	773	215	831
(3) *Ground Water Podzolic Rice Soils*—																									
1. Bombuwela Sandy ..	27	76	15	49	61	2	67	18	65	49	0·4	0·6	0	·2	·6	4·3	10·8	4·0	6·5	6·8	1111	1415	349	304	1066
2. Batticaloa ..	19	41	17	22	24	1·0	82	25	81	57	1·0	3·7	0·5	1·8	3·2	10·0	10·8	5·0	0·8	5·8	672	879	294	207	585
(4) *Acid lateritic Rice Soils of the Wet Zone*—																									
1. Welimada ..	8	41	30	33	11	0	137	50	137	87	8·8	32·5	1·3	23·7	31·2	3·7	16·7	3·0	13·0	13·7	1348	1877	1009	529	868
2. Bibile ..	60	90	40	30	50	0·5	152	32	151·5	120	20·5	78·0	2·0	57·5	76	3·3	19·6	2·0	16·3	17·6	2178	2937	1009	759	1928
3. Peradeniya ..	12	58	36	46	22	0·5	160	33	159·5	127	4·0	41·2	0·6	37·2	40·6	3·3	8·8	4·0	5·5	4·8	475	1547	678	1072	869

4. Kundasale ..	4·5	37	9	32·5	28	0	93	27	93	66	1·9	23·0	4·6	21·1	18·4	3·9	8·8	3·0	4·9	5·8	1066	2343	967	1277	1376
5. Matale ..	3	32	22·5	29	9·5	0·5	225	51	224·5	174	5·9	37·2	0·5	31·3	36·7	2·0	14·7	5·0	12·7	9·7	331	2017	703	1686	1314
6. Nalanda ..	15·5	41	26	25·5	15	0	197	46	197	151	30·0	45·0	3·2	15·0	41·8	1·8	9·8	2·0	8·0	7·8	585	1966	712	1381	1254
(5) *Non-lateritic Rice Soils of the Dry Zone*—																									
1. Polonnaruwa..	7	28	19	21	9	1·0	55	30	54	25	2·4	29·2	8·8	26·8	20·4	8·8	10·8	5·0	2·0	5·8	913	2710	1406	1797	1304
2. Hingurakgoda	10·5	45	12·5	34·5	32·5	0·5	60	26	59·5	34	2·1	17·0	6·2	14·9	10·8	10·0	10·0	4·0	0	6·0	2109	2685	1611	576	1074
3. Maha Illuppallama Red	3	12	8	9	4	0	21	15	21	6	0·4	48·3	3·8	47·9	44·5	2·7	11·8	2·0	9·1	9·8	477	1645	967	1168	678
4. Maha Illuppallama Grey	4	30	6	26	24	0	27	20	27	7	6·5	19·0	7·2	12·5	11·8	2·0	5·9	2·0	3·9	3·9	794	2053	1160	1259	893
(6) *Calcareous Rice Soils*—																									
1. Jaffna ..	9·5	37	13·5	27·5	23·5	0	7	6	7	1	0·4	4·8	2·0	4·4	2·8	6·0	6·9	3·0	·09	3·9	1877	3867	1547	1990	2320
(7) *Non-lateritic Clayey Rice Soils*—																									
1. Ambalantota 1	22	34	11	12	23	6·0	78	21	72	57	30·0	30·5	1·8	0·5	28·7	20·1	20·1	4·0	0	16·1	2047	4070	1547	2023	2523
2. Ambalantota 2	5·5	38	10	32·5	28	3·0	103	25	100	78	7·0	32·0	2·6	25	29·4	6·9	8·8	3·0	1·9	5·8	2109	2959	1009	850	1950

TABLE IV—Water Percolates—Averages

	Initial NH_4 ppm N	Max: NH_4 ppm N	Final NH_4 ppm N	Diff: initial & max: ppm N	Diff: max: & final ppm N	Initial Fe ppm	Max: Fe ppm	Final Fe ppm	Diff: initial & max: Fe ppm	Diff: Max: & final Fe ppm	Initial Mn ppm	Max: Mn ppm	Final Mn ppm	Diff: initial & max: Mn ppm	Diff: max: & final Mn ppm	Initial oxy: matter	Max: oxy: matter	Final oxy: matter	Diff: initial & max: oxy: matter	Diff: max: & final oxy: matter	Cond: initial micromhos.	Cond: max: micromhos.	Cond: final micromhos.	Cond: diff: initial & max: micromhos.	Cond: diff: max: & final micromhos.
1. Strongly Acid lateritic Rice Soils of the Ultra Wet Zone ..	33	132	54	99	78	5·0	252	55	247	197	2·4	12·3	·7	9·9	11·6	7·6	19·9	8·0	12·3	11·9	912	2407	844	1495	1563
2. Strongly Acid Humic Rice Soils (one soil) ..	30	92	50	62	42	18·5	158	45	139·5	118	0·4	0·4	·0	·0	·4	6·9	14·7	8·0	7·8	6·7	1389	1604	773	215	831
3. Ground Water Podzolic Rice Soils ..	23	59	16	36	43	·2	75	22	73	53	1·2	2·2	·3	1·0	1·9	7·2	10·8	4·5	3·6	6·3	892	1147	322	255	825
4. Acid lateritic Rice Soils of the Wet Zone ..	17	49	27	32	22	·3	159	40	1587	119	11·9	41·8	2·0	29·9	39·8	3·0	11·1	3·2	8·1	7·9	997	2058	846	1061	1212
5. Non-lateritic Rice Soils of the Dry Zone ..	6	29	11	23	18	·4	38	23	37·6	15	2·9	26·7	6·5	23·8	20·2	5·9	9·3	3·3	3·4	6·0	1073	2273	1286	1200	987
6. Calcareous Rice Soils (one soil)	9·5	37	13·5	27·5	23·5	·0	7	6	7	1	0·4	4·8	2·0	4·4	2·8	6·0	6·9	3·0	0·9	3·9	1877	3867	1547	1990	2320
7. Non-lateritic Clayey Rice Soils ..	14	36	11	22	25	·5	·91	23	86	68	18·5	28·8	2·2	10·3	26·6	7·5	9·3	3·5	1·8	5·8	2078	3271	1278	1193	1993

TABLE V—West Soils

	Initial NH_4ppm N	Max. NH_4ppm N	Final NH_4ppm N	Diff. initial & max NH_4ppm N	Diff. max. & final NH_4 ppm N	Initial Fe ppm	Max. Fe ppm	Final Fe ppm	Diff. initial & max. Fe ppm	Diff. Max. & final Fe ppm	Initial Mn ppm	Max. Mn ppm	Final Mn ppm	Diff. initial & max. Mn ppm	Diff. max. & final Mn ppm	Initial oxy: M	Max. oxy. M	Final oxy. M	Diff. initial & max. oxy. M	Diff. max. & final oxy M	pH initial	pH final	pH diff: initial & final
(1) *Strongly Acid lateritic Rice Soils of the Ultra Wet Zone*																							
1. Panagoda	195	246	83	51	163	208	1182	860	974	322	3·0	3·8	1·3	·8	2·5	3·0	9·3	3·7	6·3	5·6	4·86	6·30	1·44
2. Mirigama	26	229	110	203	119	107	3006	2440	2899	566	142	162	128	20	34	0·5	9·8	5·6	7·3	4·2	4·65	6·45	1·80
3. Mapalana	29	200	46	171	154	408	2728	2005	2320	723	20	20	12·3	0	7·7	8·4	8·6	6·1	6·2	2·5	4·70	6·60	1·90
4. Karapincha ..	48	183	100	135	83	219	1968	1401	1749	567	18	19·7	15·1	1·7	4·6	1·4	11·2	5·3	9·8	5·9	5·14	6·80	1·66
(2) *Strongly Acid Humic Rice Soils*																							
1. Bombuwela Peaty ..	57	263	187	206	76	328	3042	2250	2714	792	6	6	1·7	0	4·3	2·1	10·9	8·6	8·8	2·3	4·65	6·45	1·80
(3) *Ground Water Podzolic Rice Soils*																							
1. Bombuwela Sandy ..	20	197	60	177	137	75	237	170	162	67	5	5	2·1	0	2·9	1·8	4·8	1·3	3·0	3·5	5·62	6·90	1·28
2. Batticaloa ..	16	196	53	180	143	48	194	120	146	74	0	0	3·0	0	5·1	2·0	2·4	1·2	0·4	1·2	532	7·00	1·68
(4) *Acid lateritic Rice Soils of the Wet Zone*																							
1. Wellmada	34	208	106	174	102	85	5883	3534	5798	2349	247	346	235	99	111	1·3	12·5	9·3	11·2	3·2	5·30	6·90	1·60
2. Bibile	147	159	85	12	74	77	2164	1730	2087	434	190	237	170	47	67	1·3	7·6	3·7	6·3	3·9	5·65	7·00	1·35
3. Peradeniya ..	121	355	124	234	231	239	6596	3348	6357	3253	408	420	295	21	134	3·7	14·8	9·0	11·1	5·8	5·55	6·85	1·30
4. Kundasale ..	20	105	76	85	29	343	4545	2580	4202	1965	233	296	187	63	109	1·8	8·8	5·8	7·0	3·0	6·60	7·05	0·45
5. Matale	27	342	99	315	243	240	7358	4703	7118	2655	199	246	151	47	95	2·5	10·9	10·6	8·4	0·3	5·38	7·00	1·62
6. Nalanda	46	257	120	211	137	64	3014	2505	2950	410	165	222	180	57	42	2·3	6·8	5·5	4·5	1·3	5·41	7·00	1·59
(5) *Non-lateritic Rice Soils of the Dry Zone*																							
1. Polonnaruwa ..	30	263	115	227	148	381	2284	1702	1903	522	478	557	429	79	128	2·0	6·0	5·5	4·0	0·5	7·30	7·30	0
2. Hingurakgoda ..	29	305	84	276	221	102	1284	1212	1182	72	136	146	98	10	48	2·8	5·5	4·2	2·7	1·3	7·47	7·32	–·15
3. Maha Illuppalama Grey ..	12	264	96	252	168	12	1930	1660	1018	261	149	294	205	145	89	1·9	5·1	3·8	3·2	1·3	7·39	7·30	–·09
4. Maha Illuppallama Red ..	25	237	119	212	118	10	2251	2097	2241	154	269	522	395	253	127	2·0	5·0	4·8	3·0	1·1	6 88	7·20	0·32
(6) *Calcareous Rice Soils*																							
1. Jaffna	40	173	93	133	80	9	930	802	921	128	84	114	98	30	16	0·9	3·2	2·8	2·3	0·4	6·90	7·65	0·75
(7) *Non-lateritic Clayey Rice Soils*																							
1. Ambalantota 1 ..	47	253	160	206	93	379	5533	3911	5154	1622	360	470	407	110	63	3·6	11·7	8·1	8·1	3·6	6·43	7·20	0·77
2. Ambalantota 2 ..	34	284	184	250	100	74	5027	3750	4953	1277	320	439	384	119	55	2·1	11·4	8·4	9·3	3·0	6·42	7·00	0·58

Table VI—West Soils Averages

	Initial NH_4 ppm N	Maximum NH_4 ppm N	Final NH_4 ppm N	Diff: initial & max: ppm N	Diff: max: & final ppm N	Initial Fe ppm	Max: Fe ppm	Final Fe ppm	Diff: Initial & max: Fe ppm	Diff: max: & final Fe ppm	Initial Mn ppm	Maximum Mn ppm	Final Mn ppm	Diff: initial & maximum Mn ppm	Diff: Maximum & final Mn ppm	Initial oxy: matter	Maximum oxy: natter	Final oxy: matter	Difference initial & maximum oxy:	Difference maximum & final oxy: matter	pH initial	pH final	pH difference initial & final
1. Strongly Acid lateritic Rice Soils of the Ultra Wet Zone	75	212	85	137	127	236	2157	1677	1921	480	46	48	30	2	9	2·3	8·8	5·2	6·5	3·6	4·9	6·6	1·7
2. Strongly Acid Humic Rice Soils (one soil) ..	57	203	187	206	76	328	3042	2250	2714	792	6	6	1·7	0	4·3	2·1	10·5	8·6	8·4	1·9	4·6	6·5	1·9
3. Ground Water Podzolic Rice Soils ..	18	197	57	179	140	62	210	145	148	65	7	7	3	0	4	1·9	3·5	1·3	1·6	2·2	5·7	7·0	1·3
4. Acid lateritic Rice soils of the Wet Zone ..	66	216	102	150	114	175	4835	3081	4710	1804	240	289	203	49	86	2·1	9·5	7·3	7·4	2·2	5·7	7·0	1·3
4. Non lateritic Rice Soils of the Dry Zone ..	26	259	104	233	155	126	1825	1685	1699	140	258	363	282	105	81	2·2	5·3	4·6	3·1	·07	6·6	7·3	0·7
6. Calcareous Rice Soils (one soil)	40	173	93	133	80	9	930	802	921	128	84	114	98	30	16	0·9	3·2	2·8	2·3	0·4	6·9	7·7	0·8
7. Non lateritic Clayey Rice Soils	41	268	172	227	96	227	5162	3831	4935	1331	340	455	396	115	59	2·9	11·1	8·3	8·2	2·8	6·4	7·1	0·7