Studies on soil conditions in relation to the "Root" and "Leaf" diseases of the coconut palm in Travancore-Cochin.

Part V. Exchangeable cations, cation exchange capacity and pH of coconut soils

BY

K. M. PANDALAI, H. SANKARASUBRAMONEY AND K. P. V. MENON
Central Coconut Research Stations, Kasaragod and Kayangulam

INTRODUCTION

THE principles of stoichiometric replacement of adsorbed bases, mainly calcium, magnesium, potassium and sodium and that of the large dependence of the physical properties of the soil colloids in the nature of adsorbed bases were recognised to have profound consequences in soil science and plant nutrition as a result of the researches of Gedroiz (1918, 1919) in Russia and Hissink (1922) in Holland. It is well known that a reserve of cations is usually held by the soil colloids which can, in general, be readily displaced by biologically produced hydrogen ions from the carbonic acid given off by roots or from acids formed as a result of microbiological processes such as nitrification. Usually, the cations thus involved are calcium, magnesium and potassium in the quantitative order mentioned. The solid phase of alkaline soils thus readily yields cations to the soil solution as hydrogen ions become available for ion exchange. In acid soils of the humid regions, however, it is not merely a matter of hydrogen ion concentration of the soil solution, but is really the fact that much calcium and magnesium have been displaced from the colloids by hydrogen ions and then leached out of the soil. The soil conditions are, as a rule, more complicated if sodium also comes into the picture, because the sodium colloid has very different properties than the calcium one. In this case reclamation of the soil will have to be effected to displace and leach away all sodium and put back the calcium into the colloid. These considerations show that the study of the cation exchange properties of soils give information which has very important bearing on soil conditions orientating optimum plant growth.

As a part of a major investigation on the soil conditions in relation to the incidence of root and leaf diseases of the coconut palms in the Travancore-Cochin area (Kerala State), the different aspects concerning the cation exchange capacity and the correlated hydrogen ion concentration of the soils, etc. were also carefully studied. The results of determinations of the total exchangeable cations, cation exchange capacity and hydrogen ion concentrations in the soil samples are presented in this paper. Earlier papers in this series (Sankarasubramoney *et al.*, 1954, 1955, 1956 and Pandalai *et al.*, 1958) have dealt with the major nutrient status of the soils in relation to the incidence of disease in the palms.

MATERIALS AND METHODS

The different soil samples examined in this investigation have been described including details of profile, collection, sampling, etc., in the first paper of this series (Sankarasubramoney *et al.*, 1954). Since it was initially ascertained that most of the soil samples contained no free calcium or magnesium carbonates, the method of leaching them with semi-normal acetic acid as suggested by Williams (1928) was followed for the determination of the total exchangeable cations as well as the exchangeable calcium, exchangeable magnesium and exchangeable potassium. The total exchangeable cations in the acetic acid leachings were determined also by William's method (1929). Exchangeable calcium and exchangeable magnesium were determined according to the method of Hillebrand and Lundell (1929) and Epperson (1928) respectively and exchangeable potassium by the procedure described by Hamid (1926). It was, however, found that some of the soils contained fair amounts of free calcium and magnesium carbonates, and in such cases the methods suggested by Bray and Willhite (1928) were adopted for the determination of the total exchangeable bases. Hissink's method (1923), according to the details described by Piper (1944), was used to estimate the exchangeable calcium and exchangeable magnesium. The base exchange capacity was determined by one of the methods suggested by Parker (1929). The exchangeable hydrogen in the soil samples was calculated by subtracting the value for the total exchangeable bases (expressed in milligram equivalents) from the value for the base exchange capacity, as suggested by Parker *(loc. cit.)*. The percentage base saturation of the soil samples was calculated by using the formula:—

$$\text{Percentage base saturation} = 100 - \frac{\text{Exchangeable hydrogen} \times 100}{\text{Base exchange capacity}}$$

For the determination of the hydrogen ion concentrations Kuhn's colorimetric method (1930) was employed and the values obtained checked from time to time by measurements in a 'Radiometer pH meter'.

RESULTS AND CONCLUSIONS

EXCHANGEABLE CATIONS AND THE CATION EXCHANGE CAPACITY OF SOILS. EXCHANGEABLE HYDROGEN AND PERCENTAGE BASE SATURATION

In Tables 1, 2, 3 and 4 are presented the mean values for the contents (in milligram equivalents for 100 grams of the soil) of total exchangeable cations, cation exchange capacity, exchangeable hydrogen and the percentage base saturation (i. e., the extent to which the colloidal complex is occupied by exchangeable bases) of the soil samples examined from both healthy and diseased coconut areas. The mean values for the pH are given in Table 5. The results of the determination of the exchangeable potassium have been presented in the third paper of this series (Sankarasubramoney *et al.*, 1956) and those of the exchangeable calcium and magnesium in the fourth (Pandalai *et al.*, 1958). Tables 6 to 13 give the values for the cation exchange capacity, exchangeable hydrogen, the percentage base saturation and hydrogen ion concentrations of the soil samples of which Tables 7, 9, 11 and 13 give in abstract form the mean values, their range and the number of values for each group and horizon. In all these, the oven dry soil has been chosen as the basis for expressing the percentages.

TABLE I

Total exchangeable bases

Group	Horizon	Soil type			
		Sandy	Alluvial loam	Red loam	Laterite
Diseased	A	1·63	2·83	1·08	2·69
	B	1·43	3·79	0·83	2·02
	C	—	—	—	2·27
Healthy	A	2·49	4·18	2·62	1·73
	B	1·62	4·31	3·59	1·71
	C	—	—	—	1·92

TABLE 2

Base exchange capacity

Group	Horizon	Soil type			
		Sandy	Alluvial loam	Red loam	Laterite
Diseased	A	2·70	7·90	5·95	8·10
	B	3·03	7·00	5·75	6·88
	C	—	—	—	6·58
Healthy	A	3·45	6·20	5·00	6·50
	B	2·52	5·60	6·86	7·10
	C	—	—	—	9·20

TABLE 3

Exchangeable hydrogen

Group	Horizon	Soil type			
		Sandy	Alluvial loam	Red loam	Laterite
Diseased	A	1.07	5·08	4·86	5·41
	B	1·60	3·15	4·92	4·86
	C	—	—	—	4·32
Healthy	A	0·97	1·90	2·37	4·77
	B	0·83	1·27	3·27	5·39
	C	—	—	—	7·28

TABLE 4

Percentage base saturation

Group	Horizon	Soil type			
		Sandy	Alluvial loam	Red loam	Laterite
Diseased	A	62·5	37·3	24·5	30·6
	B	60·1	52·5	13·7	24·8
	C	—	—	—	31·3
Healthy	A	70·5	72·0	53·7	22·5
	B	67·4	78·4	59·4	25·9
	C	—	—	—	23·7

The following conclusions could be drawn from the results of Tables 1 to 4:—

1) In the soil samples from the healthy areas belonging to the sandy, alluvial loam and red loam types, there is a greater amount of total exchangeable bases, a lesser amount of exchangeable hydrogen and, consequently, a higher value for percentage base saturation than in the samples from the corresponding diseased areas.

2). The values for the samples from laterite areas are not so consistent. Regarding total exchangeable bases, the samples from diseased areas have a higher content than those from healthy areas. The values for exchangeable hydrogen are comparatively lower for the samples from the A horizon of healthy areas, while for those from B and C horizons they are higher. The percentage base saturation values are higher in the samples from the A and C horizons of diseased areas, while there is no significant difference between the B horizon samples.

3) With regard to the values for the cation exchange capacity, samples from diseased areas belonging to both the horizons of the alluvial loam type to the A horizon of the laterite and red loam type and the B horizon of the sandy type have higher values than the corresponding samples from healthy areas. In the case of the A horizons of the sandy areas and C horizons of the laterite areas, the samples from healthy localities have higher values. There is no significant difference between healthy and diseased areas as far as the samples from the B horizons of the laterite areas are concerned.

This shows that in the case of the laterite areas there is no significant difference between healthy and diseased localities in any of the cation exchange values. With regard to the other three soil types, it is found that the exchange complex of soils of healthy areas are saturated with cations to a greater degree than the soils of the diseased areas, although the values for the exchange capacity do not show up any difference. This is to be naturally expected since the exchange capacity of a soil is, in general, directly proportional to its clay and organic matter content and also since it has been found that there is no difference between healthy and diseased areas in the clay and organic matter content of the soil (Sankarasubramoney *et al.*, 1954).

Again, looking at the relation

between the lime status of the soil and the saturation of the exchange complex, it is seen that the healthy areas have, in general, a higher total calcium content than diseased areas. From this it might be expected that there is a higher degree of saturation of the exchange complex in the healthy areas. While this conclusion is found to hold good for soils belonging to the sandy, alluvial loam and red loam types, those belonging to the laterite type show certain inconsistencies. This may, perhaps, be due to the calcium in such soils existing as rather large granules of carbonate which may not be able to react completely with the colloidal exchange material. The higher the saturation of the complex, the greater is the ability of the soil to supply cations to the growing plant.

It is well known that a high calcium concentration in the complex serves to maintain favourable soil structure, also as the content of the exchangeable cations of the soil falls, the reaction of its aqueous suspensions becomes more acid. Among soils of similar composition there is an obvious relationship between the reaction of the soil as expressed by its pH and its content of exchangeable bases. This generalisation does not apply to all the soils since the acidic properties of a soil are known to vary not only with the relative proportions of mineral and organic matter, but also with the composition of the mineral absorbing complex.

It does not seem to be possible to say definitely that the percentage base saturation values of the soils have any correlation with the disease incidence since the soils from laterite areas show a variation from the general conclusion arrived at for soils from other areas viz., that the exchange complex of the soils from healthy areas are saturated with cations to a greater degree than those from diseased areas. However, in view of the fact that this difference is so significant for the soils from the three other soil types and that the total calcium status of the soils of healthy areas is definitely higher than those of diseased areas, it appears very desirable to plan some field experiments designed for improving the cation status of diseased areas and to ascertain the overall effect of the treatment on the disease factors. This might include the application of ash and calcium carbonate or lime to the soils of gardens in which the disease is prevalent and noting the response of the trees to the treatment. In addition to the possibility of saturating the exchange complex, the addition of lime and ash to the soils will also influence the pH of the soils concerned.

HYDROGEN ION CONCENTRATION

In Table 5 the mean values for the pH of the soil samples examined are given.

TABLE 5

pH Values

Group	Horizon	Soil type			
		Sandy	Alluvial loam	Red loam	Laterite
Diseased	A	7·0	5·6	5·0	5·0
	B	6·8	5·8	4·6	5·1
	C	—	—	—	4·7
Healthy	A	7·2	7·2	6·5	6·4
	B	7·1	6·9	6·5	6·2
	C	—	—	—	6·2

The results show clearly that there are significant differences between healthy and diseased areas, the former having definitely higher pH values than the latter. The values of some of the samples of the diseased areas appear to be too low for normal healthy plant growth, being in some cases as low as 4.6. It is only in the diseased areas of the sandy soil type that the pH values are found to be round about the neutral point. This aspect has some important bearing on healthy palm growth.

In general, it may be said that palm growth is adversely affected by pH values lower than 5.0 and higher than 8.5. Among the important soil reaction correlations which are of practical and scientific interest are the interactions between pH values and (1) exchangeability of calcium and magnesium, (2) the solubility of aluminium and iron and the micro-nutrients, (3) the availability of phosphorus and (4) the activity of soil micro-organisms. There are thus direct and indirect effects. It is known that soils with low pH values are base unsaturated and in most cases are extremely calcium deficient and this indeed was the case observed with most soils in the present study. The calcium status of the soils from diseased areas was definitely lower than that from healthy areas. This directs attention to the possibility that this may be a factor in the soil conditions orientating disease. The tilth of soils in calcium deficient areas is also usually poor since the presence of calcium in the exchange complex is known to confer a granular structure to the soils. Strongly acid soils have relatively low magnesium and potash contents and the opinion is also held that even the availability of nitrogen will be low.

When the pH of a mineral soil is low, appreciable amounts of aluminium, iron and manganese pass into solution and invariably assume phytotoxic proportions. Trenel and Alten (1934) have shown that in culture solutions, aluminium acts as a specific root poison below pH 5.0. A set of soil conditions which caused the sudden and entire wilting of coconut palms on account of soil conditions becoming increasingly acidic and consequently with high aluminium and iron in solution has been described by Pandalai *et al.* (1954). Acidic soils (pH 6.0 – 7.0) have, however, the advantage of maintaining a satisfactory state of availability of almost all the micronutrients except molybdenum. While in the case of alkaline soils, except for molybdenum, availability of the other micro-nutrients tends to be very low. According to Wallace (1951), troubles due to micro-nutrient deficiencies and excesses can generally be controlled by regulating the pH of the soil.

The correlation of phosphorus avilability and soil reaction is also rather complicated due to the several interactions involved. In the zone of slight acidity phosphorus is readily available, while in the zone of high acidity it combines with iron and aluminium compounds present under such conditions forming highly complex insoluble compounds, particularly if these have been dehydrated (Russell, 1954). On the alkaline side the phosphorus is known to combine with calcium forming tricalcium phosphate which although not readily available to the plant is much more available than iron or aluminium phosphates. Such fixation effects seem to be at a minimum and consequently phosphorus availability maximum at a pH range from 6·0 to 7·0. Too much acidity of the soil is detrimental to biological processes such as nitrification and nitrogen fixation which provide the two important naturally available nitrogen resources of the soil.

Again, an unsatisfactory consequence of low pH values which is generally the result of low base saturation of the exchange complex is the one met with in soil situations with high water tables or in places where the soil is very shallow with an impermeable layer close to the surface. During the rainy seasons in such localities there is a tendency to form a second water table near the surface. Under such conditions anaerobic decompositions of soil organic matter take place and give rise to organic acids (Sankarasubramoney, 1953). This increased acidity in the soil also appears to be correlated with the incidence of certain disease conditions in the palms other than the root and leaf diseases. The pH of the soils in some low-lying coconut areas have in some cases recorded values as low as 3.6. If there would be a sufficient soil reserve of bases like calcium carbonate in the sub-soil layers, the acidity of water would have been materially reduced. The effects of these soil conditions have not been studied, although it is known that these have detrimental influence on the physiological processes of the palm. Pandalai *et al.* (1957) have described severe foliar yellowing in the palms, particularly of the outer whorls of leaves usually observed soon after the commencement of rains. This has been attributed to the sudden changes in the soil conditions on account of water-logging of the root rhizosphere of the palms.

Certain diseases of plants caused by the attack of parasitic fungi upon the roots have been reported to be favoured by an acid reaction of the soils, for instance, the tobacco wilt caused by *Fusarium oxysporium* (Johnson, 1921), banana wilt (Wardlow, 1941), tomato wilt (Harrison, 1929) and internal root rot of tea (Tunstall, 1929). Whether the root infecting fungi *Rhizoctonia solani*, *R. bataticola* and *B. theobromae* isolated by Menon and Nair (1949) from the infected roots of the coconut palms are influenced by such soil reactions and what exactly is this influence have not been ascertained fully.

The results and the discussions given above show that the maintenance of a soil pH in the range of 6.0 – 7.0 when the biological regime of the soil conditions would be somewhat satisfactory should be aimed at. Availability of all plant nutrient factors appears to be most favourable at this range without being extreme. This is also the soil reaction region which is found in most healthy coconut soils.

SUMMARY

(i) The results of studies on the exchangeable cations, exchangeable hydrogen, percentage base saturation and the pH of coconut soils from healthy as well as root and leaf infected areas have been presented and discussed.

(ii) Soils belonging to the sandy, alluvial loam and red loam from healthy localities exhibit comparatively higher values for exchangeable cations and percentage base saturation and, consequently, low values for exchangeable hydrogen than from the diseased areas. The difference between the healthy and diseased areas in the three types of soils is significant enough leading to the conclusion that these factors may be positively correlated with disease incidence. The case of laterite soils appears to be slightly different.

(iii) Soils of the diseased areas have definitely lower hydrogen ion concentrations than the corresponding soils of the healthy areas.

(iv) The various effects of low pH values of soil which might directly and indirectly orientate healthy conditions in the palms have been briefly discussed.

(v) The possible adverse influences which water logging of the soil may bring about, particularly the formation of increased total acidity have been pointed out.

(vi) The conclusion appears to be justified that there is urgent need for regulated liming of coconut soils, especially in the root and leaf infected areas of Travancore-Cochin

REFERENCES

1. Bray, R. H. and Willhite, F. M., (1929) *Ind. and Eng. Chem. Anal. Edn.*, **1: 144.**
2. Epperson, A. W., (1928) *J. Amer. Chem. Soc.*, **50: 321.**
3. Gedroiz, K. K., (1918) (1919) See H. J. Page. *Trans Inter Soc. Soil Sci. Comm.*, 2 (1926) A. 208.
4. Hamid, M. A., (1926) *Analyst*, **51: 450.**
5. Harrison, A. L., (1940) *Rept. Texas Agric. Exp. Stn.* for 1939. p-12.
6. Hillebrand, W. F. and Lundell, G. E. F., (1929) *Applied Inorg. Analysis*, p-497.
7. Hissink, D. J., (1922) *Int. Mitt. Bodenk* **12: 81.** (1923) *Soil Sci.*, **15: 269.**
8. Johnson, J., (1921) *J. Agric. Res.*, **20: 515.**

9. Kuhn, S., (1930) Zeit Pflanz Dung, 18 A: 309.

10. Menon, K. P. V. and Nair, U. K., (1949) The wilt disease of coconuts in Travancore-Cochin. *Indian Coconut J.*, 3: 5-9, and 40-44.

11. Pandalai, K. M. *et al.*, (1954) Observations on the sudden wilting of coconut palms. *Indian Coconut J.*, 7: 107-116. Soil conditions in relation to root and leaf diseases of the Coconut palm in Travancore-Cochin, Part IV. *Indian Coconut J.*, 11: 49-66. (1958). The Problem of seasonal foliar yellowing in the coconut palm. *Indian Coconut J.* 11: 19-28.

12. Parker, F. W., (1929) *J. Amer, Soc. Agronomy.*, 21: 1030.

13. Piper, C. S., (1944) "Soil and Plant Analysis" *Waite Agricultural Res. Inst. Monograph.*

14. Russell, E. W., (1954) *E. J. Russell's "Soil Conditions and Plant Growth"*. Longmans Green & Co., Ltd., London. p-451.

15. Sankarasubramoney, H., (1953) *M. Sc. Thesis.* Travancore University. Studies on some soil conditions in relation to the root and leaf disease of the coconut palm in Travancore-Cochin.

16. Sankarasubramoney, H. *et al.*, (1954) Studies on soil conditions etc. Part II *Indian Coconut J.* 8: 5.

17. — Part II *Ibid*, 9: 20.

18. — Part III *Ibid*, 9: 90.

19. Trenel, M. and Alten, F., (1934) *Angew Chem.*, 47: 813.

20. Tunstall, A. C., (1929) *Quart. Indian Tea Assn.*, 68.

21. Wallace, T., (1951) Cawthorn Lecture cited in World Crops., 3: 224.

22. Wardlaw, C. W., (1941) Nature, 147: 380.

23. Williams, R., (1928) *J. Agric. Sci.*, 18: 439.

24. — (1929) *Ibid*, 19: 589.

TABLE 6

Exchangeable hydrogen, base exchange capacity,
(in mgm. equivalents per 100 gms.)
percentage base saturation and pH of the soil samples belonging to the type
SANDY (SANDY LOAM)

Diseased areas					Healthy areas				
Lab. No.	Base ex. capacity	Ex. Hydrogen	Base saturation	pH	Lab. No.	Base ex. capacity	Ex. Hydrogen	Base saturation	pH
1	3·25	0·85	73·8	6·5	19	2 95	0·51	82·7	6·5
2a	3·25	1·29	60.3	6·0	20	2·45	1·29	47·3	6·0
2b	2·60	0·70	73·0	5·0	21	2·45	1·29	72·0	6·8
3	3·90	2·67	31·5	6·0	22a	1·50	0·30	80·0	6·4
4	3·25	1·84	43·4	6·0	22b	1·50	0·46	69·3	6·6
5a	1·96	1·42	27·6	6·5	23	1·50	0·54	64·0	7·6
5b	1·96	1·42	27·6	6·0	24	1·50	0·54	64·0	7·4
6a	4·90	4·74	3·3	6·5	25a	8·50	2·58	69·6	7·8
6b	7·35	7·19	2·2	6·0	25b	8·50	1·54	71·9	8·0
6c	1·47	0·99	32·7	7·0	26	6·50	2·10	67·7	7·8
7	2·95	0·17	94·2	7·0	27a	2·50	0·19	92·4	7·4
8	2·45	0·06	98·6	7·5	27b	4·00	2·40	40·0	7·4
9	2·50	0·09	96·4	7·2	28a	1·00	0·44	56·0	7·6
10	2·00	0·28	86·0	7·2	28b	1·50	0·86	42·7	7·6
11	2·50	1·53	38·8	6·8	28c	1·00	0·58	42·0	7·8
12	3·00	0·06	98·0	7·4	29	2·50	0·82	67·2	6·3
13	3·50	2·54	27·4	7·0	30a	2·00	0·32	84·0	7·6
14	5·00	4·04	19·2	7·0	30b	2·00	0·48	76·0	6·8
15	3·00	1·06	64·7	7·8					
16	0·50	0·02	96·0	7·0					
17	1·00	0·28	72·0	7·6					
18	3·00	1·24	58·7	8·0					

TABLE 7

Abstract of table 6

Factor		Diseased		Healthy	
		A. Horizon	B. Horizon	A. Horizon	B. Horizon
Base ex. capacity	Mean	2·70	3.03	3·45	2·52
	Range	1·00-3·90	0·50-5·00	1·50-8·50	1·17-6·50
Ex. Hydrogen	Mean	1·07	1·60	0·97	0·89
	Range	0·06-2·67	0·02-4·31	0·51-2·06	0·40-2·10
Base Saturation	Mean	62·5	60·1	70.5	67·4
	Range	27·4-98·6	12·7-98·0	64·0-82·7	47·3-80·0
pH	Mean	7.0	6·8	7·2	7.1
	Range	6·0-7·8	5·5-8·0	6·5-7·9	6·0–7·8
No. of values		10	8	6	6

TABLE 8

Base exchange capacity, exchangeable hydrogen,
(in mgm. equivalents per 100 gms.)
percentage base saturation and pH of the soil samples belonging to the type

ALLUVIAL LOAM

Diseased areas					Healthy areas				
Lab. No.	Base ex. capacity	Ex. Hydrogen	Base saturation	pH	Lab. No.	Base ex. capacity	Ex. Hydrogen	Base saturation	pH
31	8·00	3·36	58·0	5·8	47	7·50	3·58	52·3	6.6
32	6·50	2·98	54·2	6.0	48a	6.50	2·74	57·8	5·6
33	11·50	6·78	41·0	6.4	48b	6·00	3·20	46·7	6·0
34	11·00	6·36	42·2	5·8	49a	7·50	5·26	29·9	6·8
35	4·50	2·90	35·6	6·0	49b	6.50	4·98	23·4	6·8
36	7·50	0·92	81·1	6·0	50a	3·00	0·76	74·7	7·4
37a	7·00	4·28	38·9	5·4	50b	2·50	0·58	76·8	6·8
37b	7·00	1·64	76·6	6·2	51a	4·50	0·26	94·2	7·8
38	7·50	1·58	79·0	6·8	51b	6·00	0·84	86·0	7·4
39a	4·50	3·06	32·0	4·2	51c	4·50	0·14	96·9	7·6
39b	21·00	18·44	12·2	4·2	52a	4·00	0·08	98·0	7·8
40	5·00	2·60	48·0	5·2	52b	4·00	0·32	92·0	7·6
41	3·50	2·46	29·7	3·9	53	5·50	0·86	84·4	6·8
42	3·00	2·04	32·0	4·0	54	8·50	2·12	75·1	6·8
43	7·00	5·96	14·9	6·2	55	6·00	0·24	96·0	7·8
44	5·50	3·58	34·9	6·4	56	7·00	1·00	85·7	6·8
45	9·00	5·48	39·1	6·2	57	6·00	1·20	80·0	7·4
46	10·00	5·12	48·8	6·0	58	5·00	0·68	86·4	7·4

TABLE 9

Abstract of table 8

Factor		Diseased		Healthy	
		A. Horizon	B. Horizon	A. Horizon	B. Horizon
Base ex. capacity	Mean	7·90	7·00	6·20	5·60
	Rage	4·50–12·80	3·00–11·00	5·00–7·59	2·80-8·50
Ex. Hydrogen	Mean	5·08	3·15	1·90	1·27
	Range	2·46–10·25	0·92–6·36	0·24–5·12	0·20 2·97
Base saturation	Mean	37·3	52.5	72·0	78·4
	Range	14·9 58·0	32·0–81·1	26·7–96·0	52·3–95·0
pH	Mean	5·6	5·8	7·2	6·9
	Range	3·9–6·4	4·0–6·8	6·6–7·8	5·8–7·7
No. of values		8	8	6	6

TABLE 10

Base exchange capacity, exchangeable hydrogen,
(in mgm. equivalents per 100 gms.)
percentage base saturation and pH of the soil samples belonging to the type

RED LOAM

Diseased areas					Healthy areas				
Lab. No.	Base ex. capacity	Ex. Hydrogen	Base saturation	pH	Lab. No.	Base ex. capacity	Ex. Hydrogen	Base saturation	pH
59	3·50	2·70	22·9	4·2	68	6·50	4·07	37·4	5.5
60	4·00	1·92	52·0	5·8	69	5·20	1·89	63·6	4·5
61a	5·00	4·12	17·6	4·4	70a	5·85	3·44	41·2	6·0
61b	5·00	4·44	11·2	4·2	70b	9·10	2·96	67·5	6·0
62a	4·00	2·64	34·0	6·4	71a	13·00	2·55	80·4	7·5
62b	4·50	2·74	39·1	6·4	71b	18·20	8·80	46·2	7·0
63	7·00	5·16	26·3	5·8	72	3·00	1·16	61·3	6·6
64	12·50	11·86	5·1	4·0	73a	3·50	1·90	45·7	6·6
65	5·50	4·86	11·6	4·2	73b	4·00	2·80	30·0	7·6
66	5·50	5·15	5.8	4·4	74	3·50	1·26	64·0	7·4
67a	6·50	6·42	1·2	4·2	75a	4·50	2·42	46·2	7·6
67b	4·50	4·34	3·6	4·0	75b	4·00	2·48	38·0	6·8
					76	4·50	2·18	51·6	7.2
					77a	4·00	1·84	54·0	6.4
					77b	7·00	5·16	26·3	6.4

TABLE 11

Abstract of table 10

Factor		Diseased A. Horizon	Diseased B. Horizon	Healthy A. Horizon	Healthy B. Horizon
Base ex. capacity	Mean	5.95	5·75	5·00	6·86
	Range	3·50–12·50	5·50–7·00	3·50–7·48	3·75-15·60
Ex. Hydrogen	Mean	4·86	4·92	2·37	3·27
	Range	1·92-11·86	4·28-5·38	1·16-4·07	1·89-6·18
Base saturation	Mean	24·5	13·7	53·7	58·4
	Range	5·1-52·0	2.4–26.3	37·4-64·0	37·8-63.6
pH	Mean	5·0	4·6	6·5	6·5
	Range	4·0-6·4	4.1-5·8	5·5 7.4	4·5-7·3
No. of values		5	4	5	5

TABLE 12

Base exchange cpacity, exchangeable hydrogen.
(in mgm. equivalents per 100 gms.)
percentage base saturation and pH of the soil samples belonging to the type
LATERITE

Diseased areas					Healthy areas				
Lab. No.	Base ex. capacity	Ex. Hydrogen	Base saturation	pH	Lab. No.	Base ex. capacity	Ex. Hydrogen	Base saturation	pH
78	6·00	4·64	22·7	5·4	90	6·50	4·66	28·3	6·8
79	6·50	5·22	19·7	5·4	91	6·50	5·46	16·0	6·6
80	7·00	4·44	36·6	4·4	92	9·50	8·54	10.0	7·0
81	6·00	4·24	29·3	4·2	93	6·00	4·56	14·0	6·4
82	6·00	4·80	20·0	4·2	94	4·50	2·26	48·8	6·2
83	5·00	3·64	27·2	4·4	95	5·50	3·42	37·5	6·2
84	5·50	5·42	1·5	4·2	96	6·00	4·56	14·0	5·4
85	4·50	3·86	14·2	4·2	97	6·50	5·30	18·5	5·2
86	12·50	5·54	55·5	6·8	98	9·00	6·20	31·1	5·6
87	9·50	3·98	58·1	6·8	99	7·00	4·84	30·9	5·8
88a	8·50	3·54	58·4	6·8	100	9·00	7·08	21·3	5·8
88b	8·00	5·76	28·0	4·4	101	7·00	5·08	27·4	5·6
89	11·00	9·00	18·2	4·4	102	7·00	5·24	25·1	7·4
					103	9·00	6·84	24·0	7·2
					104	15·00	13·16	12·3	6·4

TABLE 13

Abstract of table 12

Factor		Diseased			Healthy		
		A. Horizon	B. Horizon	C. Horizon	A. Horizon	B. Horizon	C. Horizon
Base ex. capacity	Mean	8·10	6·88	6·50	6·50	7·10	9·20
	Range	5·00–12·50	5·50–9·50	4·50 8·25	6·00–7·00	4·50–9·00	5·50–15·00
Ex. Hydrogen	Mean	5·41	4·86	4·32	4·77	5·39	7·28
	Range	3·64–9·00	3·98–5·42	3·86–4·65	4·56 5·24	2·26–7·06	3·42–13·16
Base saturation	Mean	30·6	24·8	31·3	22·5	25·9	13·7
	Range	18·2–55·5	1.5–58·1	14·2–43·2	14.0–30·9	16·0–49·8	10·0–37·5
pH	Mean	5·0	5·1	4·7	6·4	6·2	6.2
	Range	4·2–6·8	4·2–6·8	4·2–5·6	5·4–7·4	5·8–7·2	5·6–7·0
No. of values		5	4	3	5	5	5