FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE

ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION

AGP: [illegible]/75/1
April 1975

Agronomy and
Physiology

Fourth Session of the FAO Technical Working Party on
Coconut Production, Protection and Processing

Kingston, Jamaica 14 – 25 September 1975

MINERAL NUTRITION OF ROOT (WILT) AFFECTED COCONUT PALM

by

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SUMMARY

The mineral nutrition of root (wilt) affected coconut palm was thoroughly investigated by carrying out a nutritional survey, collecting soil and leaf samples of perfectly healthy and diseased palms covering all the major coconut growing soil groups of Kerala State. The chemical analyses of these samples for both macro and micronutrients confirmed the accumulation of NPK in diseased palms. Nitrogen status of soils of disease affected tracts is higher than that of healthy soils. Among the secondary nutrients, deficiency of S is evident. Imbalances in cationic ratios viz. K/Na, K/Mg, K/(Ca+Mg) and K/(Na+Ca+Mg); and anionic ratios viz. P/S and N/S are quite apparent. Similarly, the deficiencies of Fe, Mn, Mo and Zn in particular in diseased palms are the other findings of great importance.

INTRODUCTION

The root (wilt) disease of coconut palm which is the most serious threat to coconut industry of Kerala, inflicts an annual loss of about rupees 300 million, and is still spreading at a slow but steady pace to fresh areas. Previous reviews on the subject (Menon, 1961; Verghese, 1961; Lal, 1964 and 1968) reveal that soil sickness characterised by low pH, poor drainage, low microbial activity together with mineral deficiencies, particularly of Ca and Mg, play a decisive role in the incidence of the disease. The deficiencies or excesses of certain trace elements are also strongly indicated. The results of tissue analysis ruled out the possibility of direct involvement of major nutrients (NPK) in the incidence of disease but stressed on the probable deficiencies of secondary nutrients (Ca and Mg) and to some extent Fe. The imbalance in nutrient ratios such as K/Mg and K/Ca had also been observed in the diseased tissues. Beneficial effect on the redemption of foliar yellowing was also reported due to the application of $MgSO_4$, $FeSO_4$ and elemental sulphur.

Investigations from other angles viz., mycology, virology, bacteriology and nematology have indicated the association of more than one factor in the incidence of the disease, clearly showing the complex nature of the problem. Despite the multi-disciplinary approach to unravel the mystery, it has still remained elusive. Even though investigations have been centered around various aspects of the disease since the birth of this century, a systematic approach to the nutrition of disease affected palm was made only recently. This paper proposes to encompass the results of the detailed investigations carried out at this Institute on the nutrition of root (wilt) affected coconut palm.

In the studies taken up earlier upto 1968, selection of sites for collection of soil and leaf samples was confined to the disease affected belt. Robert Cecil (1969) showed that leaf nutrient composition of diseased and healthy palms (apparently healthy) from disease affected tract were almost similar but different from that of healthy tract. He observed that leaf Ca and Mg levels were invariably lower in palms growing in disease affected area irrespective of the condition of the palm. Similarly sum of the cations in leaf (K+Ca+ Mg) and the ratios viz. K/Ca and K/Mg were higher in all these palms. This showed the co-existence of diseased and healthy-looking palms side by side and that the appearance of disease symptoms on the apparently healthy palms was only a matter of time. The study was restricted only to major nutrient analysis in a limited number of leaf samples and no consideration was given to soil aspects. A detailed nutritional survey was, therefore, taken up in order to study the macro and micronutrient status of different soils and healthy and disease affected palms.

MATERIALS AND METHODS

The survey covered the major coconut growing soil groups of Kerala State viz. laterite, alluvial, reclaimed, coastal sandy and sandy loam from both healthy and disease affected areas. The general characteristics of the Kerala soils are presented in Table 1. The total number of samples (733) from different soil groups was catagorised into seven groups based on the condition of palm and area sampled, viz. (i) Healthy (healthy area), (ii) Apparently healthy (transition zone), (iii) Apparently healthy (disease affected zone), (iv) Foliar yellowing (transition zone), (v) Foliar yellowing (disease affected zone), (vi) Foliar yellowing + Rubbery kernel (transition zone) and (vii) Foliar yellowing + Rubbery kernel (disease affected zone). The transition zone borders the healthy and disease affected tracts (Fig.I). The palms selected for sampling were invariably in the middle stage of disease with all the characteristic symptoms manifested on the foliage, foliar yellowing being the predominant one. As rubbery kernel of nut (bad quality nut with thin and rubbery copra) is also associated with the disease in some cases, these samples were treated separately. Soil and leaf samples were collected at intervals of 6.5 km or according to availability. Soil samples up to a depth of 50 cm were collected from the basins of five palms at each location and composited. Similarly representative leaf (numbered 14th, Fremond et al. 1968) samples were also drawn from the same palms and composited. All the samples were analysed for major and micro nutrients by standard methods (Jackson, 1967). The data were statistically analysed by computer using analysis of variance technique.

RESULTS

Major nutrients (N, P and K):

Generally total nitrogen content of healthy soils is lower than that of disease affected area with the exception of coastal sand and sandy loam (Table 2). In reclaimed soil, even though there is a marked increase in total nitrogen in the diseased soils, the statistical analysis failed to show any significance which may probably be due to the high variation. Available P did not differ while exchangeable K was lower in diseased tract in sandy loam and reclaimed soil though only in the former was there any statistical significance.

In the case of leaf levels of these nutrients (Table 3) healthy palms showed lower levels as compared to the diseased and in most of the cases the differences were statistically significant. Generally speaking the tendency of these nutrients is to accumulate in the diseased palms. The higher levels of nitrogen corroborates with the levels in soils, however accumulation of P and K does not correspond to their respective soil levels.

The level of sodium was found to be significantly higher in alluvial and reclaimed soils in healthy zone.

Secondary elements (Ca, Mg and S):

There was no difference in exchangeable Ca and Mg of soil between healthy and diseased zones (Table 4). In contrary, sulphur status was generally lower in diseased tract and significantly so in alluvial and sandy loam. Leaf levels also more or less followed the same pattern (Table 5).

Trace elements (Fe, Mn, Zn, Cu, B, Mo and Al):

Among the soil micronutrients (Table 6a, b and c) Fe was significantly higher in laterite and coastal sandy in healthy zone. Easily reducible and active Mn fractions were significantly higher in laterite, coastal sandy and sandy loam soils of healthy tract, while exchangeable Mn was higher in sandy loam. Zinc was found in significantly higher concentrations in healthy zone in alluvial, reclaimed and coastal sandy soils. The trend was similar in other soils also, but not significant. Molybdenum status of alluvial soil in healthy zone was significantly low as compared to the diseased zones.

Foliar levels of micronutrients (Table 7a and b) showed that Zinc was invariably lower in diseased palms. Manganese was significantly higher in healthy palms growing on coastal sand and sandy loam. Even though a similar trend was observed in other soils also, the difference between healthy and diseased palms was not significant. Iron content of healthy palms on alluvial and laterite was significantly higher than that of diseased palms on the same soils. In healthy palms on coastal sand, the molybdenum content was significantly higher than that in diseased palms. The trend was similar on other soils, but not significant. Boron content of healthy palms was higher in alluvial.

In the case of Al which is considered as a toxic element, the healthy palms were found to contain significantly higher amounts of Al in all soils as compared to diseased palms.

DISCUSSION

In as much as the etiology of the disease is still unknown, it is important to bear in mind the complex nature of the symptoms and the results of investigations carried out in allied fields while discussing the nutritional aspects. Nutrient regimes in soil may have a direct bearing on the incidence of disease in case of absolute deficiencies or toxicities or it may well predispose the plant to the invasion of pathogens. Likewise, the leaf levels of nutrients may either be a direct reflection of soil nutrient status or a consequence of the impaired metabolism after the plant takes up the disease. Distinction of these two types may be achieved without bias if comparison is made of leaf levels of diseased and healthy palms along with their soil levels simultaneously. The methodology followed in this work renders such a comparison and is a distinct advantage over that of past works. For convenience in discussion two terms have been used throughout the text, viz. a) 'diseased soils' which refers to the soils in the disease affected area and b) 'deficient' which refers to palms or soils whose nutrient concentration in question is comparatively lower than that of healthy.

The grouping of the data under seven catagories clearly shows that the apparently healthy palms are more towards the diseased condition as far as the nutrient status is concerned. From this point of view these palms may be looked upon as an early stage in the development of the disease. From the foregoing observations on the soil and leaf nutrient status of different catagories, at least some nutrients stand out vividly giving a consistent and clear cut pattern in all soil groups with respect to the disease incidence. Higher content of N in soil which is also reflected in the leaf may be pointed out as a factor which may succumb the plants to pathogen attack because of the higher succulency the plants would likely to develop. A higher content of K in leaf of diseased palms on most of the soils barring only reclaimed and coastal sandy cannot be accounted for by the exchangeable K status in soil. In the case of leaf P also a similar trend was noticed. Such variations from the normal may be caused by the physiological derangement in the palm as a result of the disease itself. These observations rule out the possibility of the association of major nutrient deficiencies with the disease.

With regard to Ca and Mg no regular pattern is apparent. Moreover the results do not agree with the previous observations made by Cecil (1969) that low levels of Ca and Mg in palm may be the major factors responsible for the disease incidence. However imbalances in the cationic ratios in diseased palms are clearly evident (Fig.2A). The ratios K/Na, K/Mg, K/(Ca+Mg) and K/(Na+Ca+Mg) are considerably lower in healthy palms indicating the predominance of K in diseased palms. In all these cases it is interesting to note that there is a step by step increase until the palms get foliar yellowing, the apparently healthy palms being intermediary between the healthy and palms showing either foliar yellowing or both foliar yellowing and rubbery kernel. When the total content of monovalents (K+Na) and that of divalents (Ca+Mg) were compared (Fig.3) the values showed a steady increase in the total monovalents with increasing disease intensity and divalents just the reverse trend. In this context it is appropriate to refer to the recent work of Wahid et al. (1974) who showed that the mean values of total monovalents in leaf decreased and divalents increased with increase in root CEC of the palm. The existence of pectin degrading fungi (Lily and Jayasankar, 1974) on the diseased roots has been reported. Pectin being responsible for nearly 100% of root CEC (Crooke et al., 1960) the decomposition of root pectin by the invaded organism may be expected to lower the root CEC and hence increase the absorption of monovalents in preference to divalents. Such a possibility cannot be overlooked and merits further investigation. It was also reported (McLean et al., 1956) that in some crops an increasing nitrogen level in soil may also increase the root CEC in which case a higher root CEC and a higher foliar level of divalents may be expected as nitrogen level is high in diseased palms. However, in coconut no increase in root CEC was observed with increase in either N, P or K (Wahid - unpublished data).

Among the secondary nutrients S seems to be of importance. Even though the available S content in healthy is significantly higher only in alluvial, in other soils also a similar trend is quite apparent. Sulphur contents of leaf also follows a similar pattern with a very few exceptions. Sulphur being a constituent of certain amino-acids, which go into the formation of protein, the protein metabolism may be adversely affected. Another striking evidence of the S deficiency may be obtained from N/S and P/S ratios (Fig.2B). Both these ratios are higher in the diseased palm which is suggestive of the hidden hunger of this nutrient. The widening of these ratios cannot be attributed solely to the increase in either N or P, as the absolute amounts of S in leaf and soil are also generally lower in the disease affected tract. The work of Southern (1969) on sulphur deficiency in coconut is pertinent in this context. He found that main symptoms manifested by a sulphur deficient palm were orange yellow leaves, arching and weakening of rachis. Colouration may vary from greenish yellow to bright yellow and in some cases vivid orange. The deficient palm produces nuts of normal meat thickness but on drying they collapse to a thin rubbery copra possessing very poor physical and chemical characteristics. These observations, especially on the rubbery nature of copra which is associated with root (wilt) disease in some cases but not in all, are of great importance as far as the results of the present study are concerned.

Among the micronutrients, Cu and B do not seem to play a role in the incidence of disease. The main emphasis may be placed on Zn, Mn, Fe and Mo in this group of nutrients. The difference in Zn content of both soil and leaf between healthy and diseased tract is the most contrasting of all. The diseased palm, in general, showed a very low concentration of less than 10 ppm while healthy palms registered a mean value well above 15 ppm. Zn/P ratio is also more than double as compared to that of diseased (Fig.2C).

In the case of Mn, different fractions gave different patterns in soils and the relation of a single fraction with the disease was also not consistent in different soils. However, leaf values were considerably lower in the diseased palms and in coastal sand the diseased palms gave extremely lower values (less than 10 ppm) as against a mean value of 83.6 ppm in healthy palms. As in the case of Zn, Mn/P ratio is also considerably higher in healthy palms (Fig.2C).

Molybdenum and Fe content of soils did not show much relation to the disease though the latter is higher in healthy zone in laterite soil. The leaf concentration of these two nutrients, however, were lower in diseased palms similar to that of Mn. As the border between levels of sufficiency and deficiency is very narrow in the case of Mo, any value less than that observed in healthy palm may be viewed with suspicion. A higher ratio of P/Fe in diseased palms was also observed (Fig.2C).

These findings go to show that one or more of nutrient deficiencies may be involved in the incidence of the disease. It may also be pointed out that the symptoms manifested by the diseased palm may not be the consequence of the deficiency of one particular nutrient but a combination of symptoms involving many nutrient deficiencies and the imbalances of nutrients discussed. By and large, the study has given sufficient insight into the probable nutrient deficiencies associated with the disease. It is also interesting to note that excepting Cu and B, the contents of all other trace elements including Al in the diseased palms are lower than in healthy palms. The leaf contents of Cu and B are lower in diseased palms only in alluvial soil.

Based on these observations future lines of work from the nutritional point of view may be directed towards elucidation of nutrient deficiencies of S, Zn, Mn, Mo and Fe in the root (wilt) affected palms. Field experiments on the effect of application of these nutrients are in progress.

ACKNOWLEDGEMENTS

We express our deep sense of gratitude to Dr. K.V. Ahamed Bavappa, Director, for not only suggesting the problem, but also for his constant encouragement at various stages of the work. We are also thankful to Mr. S.S. Pillai, Statistician and Mr. K.V. Sathe, Junior Statistician, Institute of Agricultural Research Statistics, for computer analysis of the data and also to Messrs. Jacob Mathew and M.V. George, Statisticians of this Institute for their help.

The value

How you select the parent palms?

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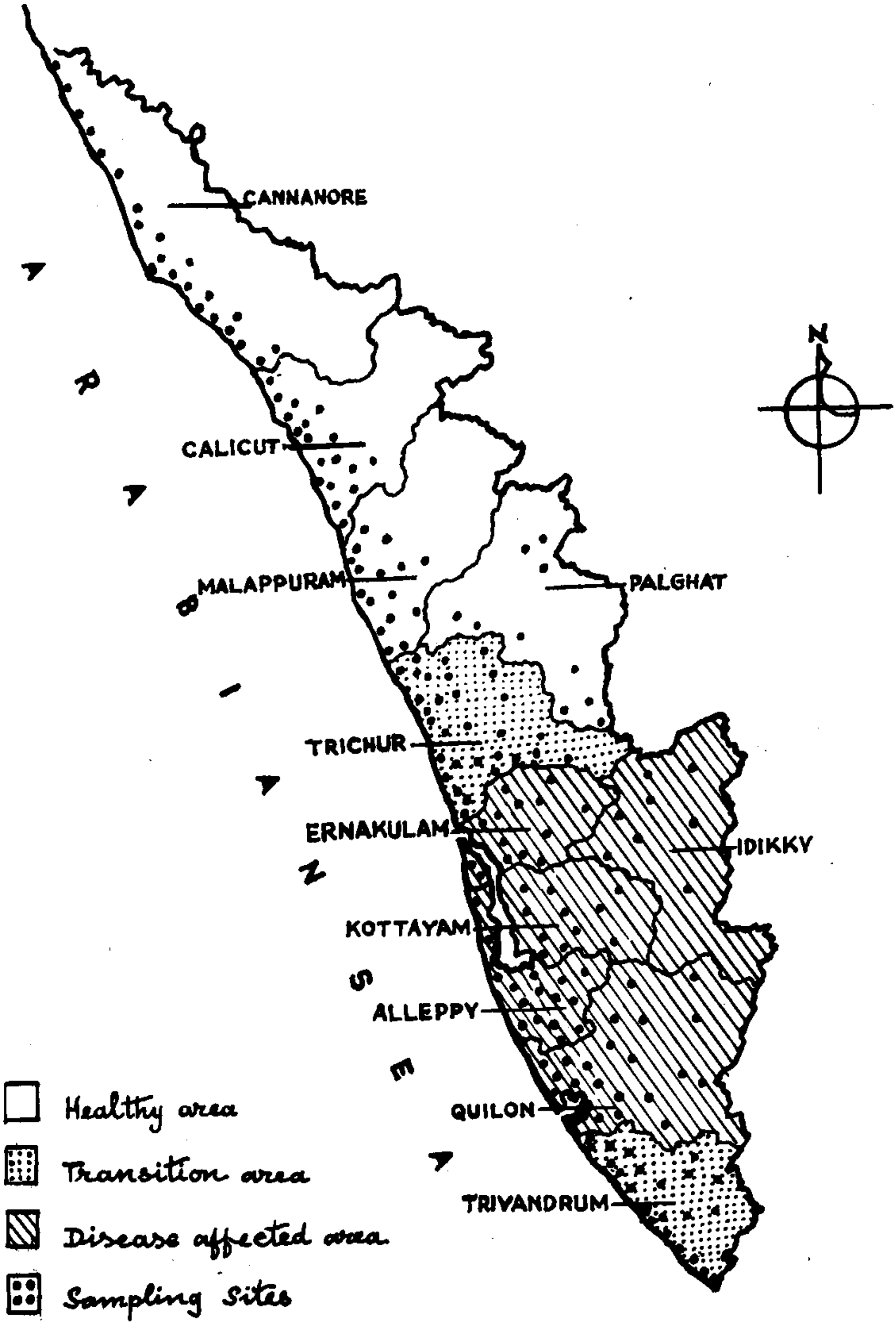

Fig. 1 Map of Kerala showing healthy, root (wilt) affected and transition areas with sampling sites.

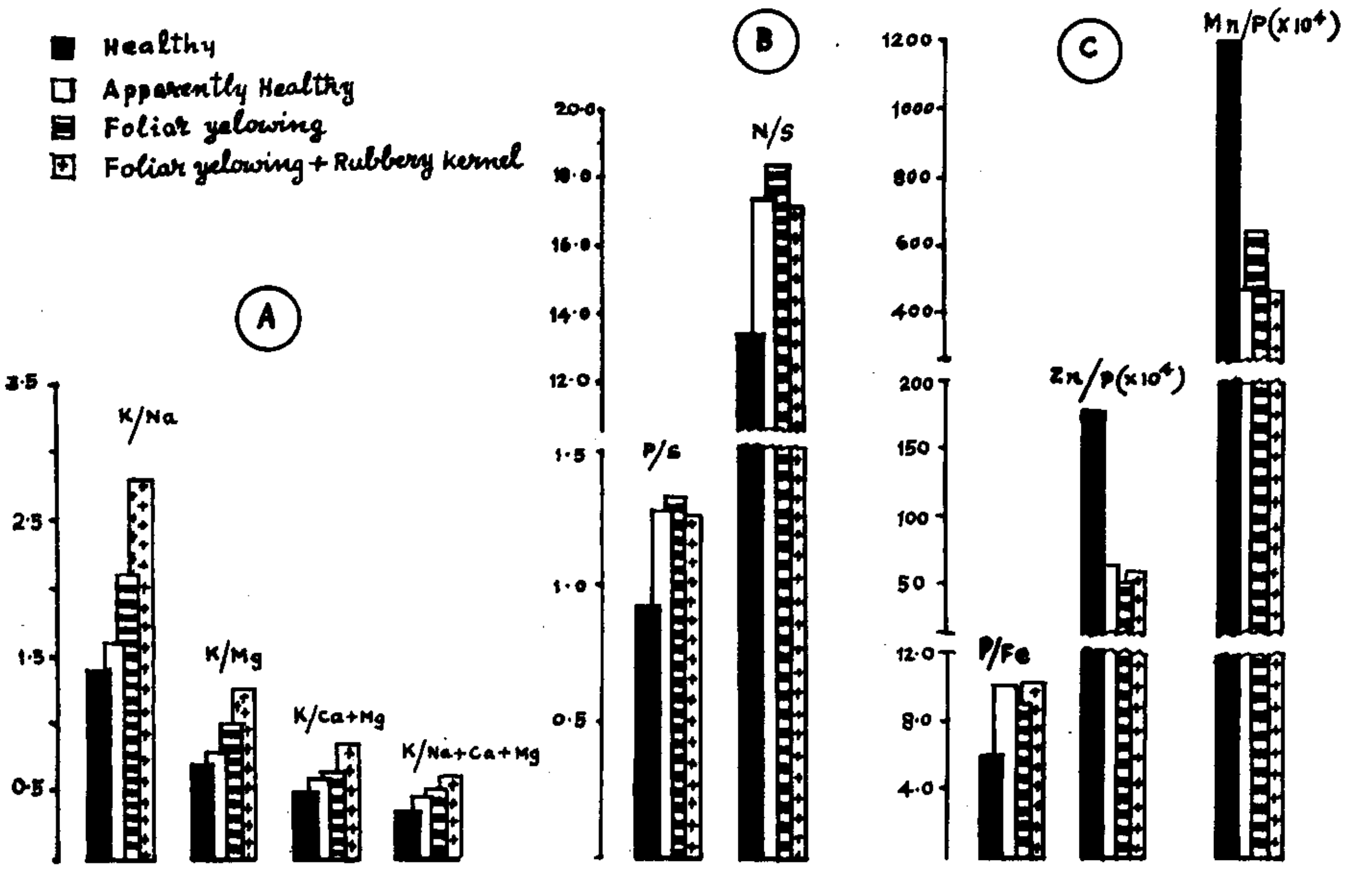

Fig. 2 Comparison of cationic, anionic and micronutrient ratios in leaves of healthy and root (wilt) affected palms.

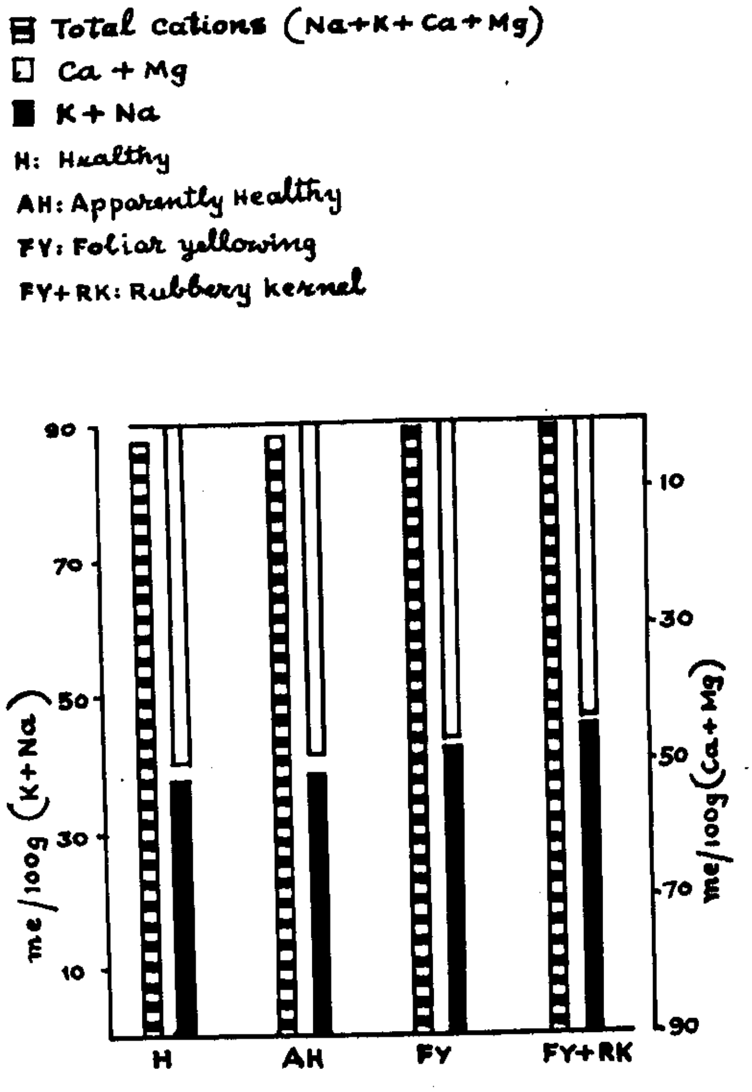

Fig. 3 Comparison of mono and divalent cations in healthy and root (wilt) affected leaves.

Table 1. General physico-chemical properties of the soils

Soil group	Mechanical composition (%)			pH (1:2.5 soil:) water	Organic Carbon(%)	C E C (me/100 g)
	Clay	Silt	Sand			
Laterite	16.8 (9.6-39.2)	10.5 (2.2-20.0)	64.4 (49.2-86.8)	5.72 (4.0-6.8)	0.55 (0.06-1.8)	5.1 (1-14.4)
Alluvial	17.9 (9.2-31.6)	6.9 (1.0-16.0)	75.1 (50.4-89.2)	5.79 (4.2-7.1)	0.69 (0.03-1.81)	4.4 (0.7-11.3)
Reclaimed marshy*	15.0 (9.0-26.4)	3.9 (0.0-13.6)	78.7 (64.0-91.0)	4.76 (3.7-6.5)	0.68 (0.23-2.91)	4.1 (0.6-24.3)
Coastal sandy	6.8 (3.6-10.8)	0.8 (0.0-7.8)	92.4 (87.2-95.4)	6.67 (5.2-8.3)	0.13 (0.00-0.46)	0.5 (0.4-5.4)
Sandy loam	17.0 (8.8-30.2)	3.8 (0.6-14.0)	79.4 (69.4-90.2)	5.81 (4.8-8.6)	0.31 (0.06-1.44)	3.7 (1.0-11.7)

Parentheses denote ranges

* This includes pokkali, kaippadu, kari soils and kayal reclamations. Generally, these soils are acid saline or acid sulphate and coconuts are grown on raised beds.

Table 2. Major nutrients (NPK) and Na status (ppm) of soils in relation to root(wilt disease)

Soil group / Category (Nutrient)	Laterite N	Laterite P	Laterite K	Laterite Na	Alluvial N	Alluvial P	Alluvial K	Alluvial Na	Reclaimed N	Reclaimed P	Reclaimed K	Reclaimed Na	Coastal sandy N	Coastal sandy P	Coastal sandy K	Coastal sandy Na	Sandy loam N	Sandy loam P	Sandy loam K	Sandy loam Na
1 Healthy	469.0	8.46	95.11	69.30	379.4	8.06	78.77	433.34	451.5	5.44	61.13	300.38	269.4	16.13	13.61	33.61	432.3	10.81	104.90	66.65
2 Apparently healthy (Transition)	564.4	7.79	66.94	68.23	732.9	15.00	98.64	78.71	528.9	5.67	45.89	52.44	155.0	11.25	12.88	24.75	399.2	15.15	56.92	42.73
3 Apparently healthy (Diseased)	687.5	3.55	83.43	58.36	665.0	21.16	67.41	54.69	620.0	11.12	44.71	137.94	346.8	10.91	12.23	33.55	499.8	45.20	49.49	40.98
4 Foliar Yellowing (Transition)	584.5	9.07	87.27	74.40	881.3	7.63	103.38	65.38	440.0	5.00	12.50	10.00	NA	NA	NA	NA	498.3	27.17	35.50	61.33
5 Foliar Yellowing (Diseased)	858.9	6.03	82.96	64.11	619.7	5.86	76.67	56.95	886.9	10.42	35.35	68.35	396.4	5.56	16.64	59.43	432.2	35.47	35.50	49.07
6 Foliar Yellowing + Rubbery Kernel (Transition)	835.0	12.97	125.17	87.64	771.7	5.67	97.83	46.67	NA	NA	NA	NA	130.0	24.00	13.00	20.00	210.0	13.00	24.00	50.00
7 Foliar yellowing + Rubbery Kernel (Diseased)	876.0	4.30	83.80	65.50	1253.6	4.81	90.50	70.81	1068.8	10.75	53.25	94.25	198.6	11.57	13.71	30.14	451.4	18.43	37.21	48.14
Mean	635.9	7.75	93.49	66.67	687.9	11.19	81.66	151.82	690.0	9.27	48.43	137.25	292.7	12.17	13.69	37.24	450.4	28.38	57.25	49.13
SE/plot	382.4	16.20	57.19	62.81	695.6	43.73	62.56	123.97	733.3	10.86	33.17	182.20	280.9	10.64	10.78	41.06	640.9	33.31	69.68	38.64
F ratio	6.94**	1.29	2.43*	0.21	2.95*	0.45	0.76	3.54**	1.34	0.94	4.51	3.61**	1.20	2.25	0.31	1.09	0.11	4.69**	3.37**	1.65
Conclusion	7563427		6142735		7462351		1274536				172354	137524						3547261	1237456	

* P = 0.05, ** P @ 0.01
NA : Data not available

N : Total nitrogen
P : Bray, extractable
K and Na : N NH_4 OAc(PH 7) exchangeable

Table 3. Major nutrients (NPK) and Na concentrations in leaf (%) in relation to root (wilt) disease

Soil group	Laterite				Alluvial				Reclaimed				Coastal sandy				Sandy loam			
Nutrient / Category	N	P	K	Na	N	P	K	Na	N	P	K	Na	N	P	K	Na	N	P	K	Na
1 Healthy	1.225	0.112	0.867	0.325	1.659	0.120	0.928	0.377	1.697	0.130	0.913	0.391	1.735	0.116	0.686	0.445	1.734	0.129	0.849	0.333
2 Apparently healthy (transition)	1.894	0.143	1.101	0.302	1.940	0.134	1.004	0.316	1.878	0.141	0.892	0.379	1.656	0.134	0.675	0.381	1.964	0.144	1.049	0.385
3 Apparently healthy (Diseased)	1.852	0.127	0.913	0.332	1.853	0.130	0.950	0.359	1.770	0.125	0.866	0.382	1.790	0.144	0.668	0.339	1.858	0.145	0.835	0.362
4 Foliar yellowing (Transition)	1.795	0.127	1.285	0.262	1.878	0.136	1.144	0.388	1.565	0.134	0.612	0.415	NA	NA	NA	NA	1.800	0.128	0.892	0.290
5 Foliar yellowing (Diseased)	1.831	0.122	1.328	0.296	1.760	0.124	0.995	0.345	1.708	0.130	1.012	0.360	1.783	0.148	1.014	0.335	1.758	0.136	1.123	0.331
6 Foliar yellowing + Rubbery kernel (Transition)	1.853	0.136	1.366	0.258	1.812	0.133	1.793	0.183	NA	NA	NA	NA	1.750	0.110	0.450	0.660	1.750	0.119	1.750	0.200
7 Foliar yellowing + Rubbery kernel (Diseased)	1.927	0.135	1.398	0.339	1.722	0.121	1.202	0.219	1.756	0.122	0.908	0.285	1.771	0.142	0.896	0.391	1.975	0.155	1.370	0.343
Mean	1.819	0.127	1.079	0.307	1.783	0.126	1.041	0.340	1.746	0.129	0.914	0.379	1.753	0.135	0.751	0.385	1.838	0.140	0.985	0.349
S E / Plot	0.193	0.021	0.411	0.118	0.193	0.020	0.459	0.150	0.195	0.019	0.386	0.142	0.201	0.023	0.377	0.112	0.193	0.021	0.403	0.162
F Ratio	5.54**	14.73**	11.13**	1.42	5.62**	1.55	3.69**	2.61*	1.70	1.27	0.58	0.77	0.51	1.86**	2.16	2.97*	6.21**	3.58**	5.21**	0,66
Conclusion	7236541	2674351	7654231		2436571		6742531	1132576						537621		612357	7934561	7325146	6752413	

*P = 0.05, **0.01

NA = Data not available

Table 4 Secondary nutrient status of soils (ppm) in relation to root(wilt) disease

Soil group	Laterite			Alluvial			Reclaimed			Coastal sandy			Sandy loam		
Nutrient / Category	Ca	Mg	S	Ca	Mg	S	Ca	Mg	S	Ca	Mg	S	Ca	Mg	S
1 Healthy	458.8	152.5	30.95	486.1	217.8	94.65	426.9	201.8	134.06	421.6	63.5	4.94	480.0	116.3	17.58
2 Apparently healthy (Transition)	332.6	113.4	41.55	314.3	165.4	19.86	404.4	130.0	18.44	250.0	58.0	0.00	407.9	110.0	11.58
3 Apparently healthy (Diseased)	385.0	128.0	28.82	353.5	129.8	19.91	660.6	229.3	86.65	440.9	60.0	2.77	298.8	80.4	1.51
4 Foliar yellowing (Transition)	442.7	134.4	13.27	385.0	149.0	19.13	130.0	174.0	426.00	NA	NA	NA	480.0	134.0	0.00
5 Foliar yellowing (Diseased)	382.9	143.5	28.79	445.6	135.4	7.86	564.6	233.5	50.00	500.6	84.3	6.50	346.3	90.4	3.31
6 Foliar yellowing + Rubbery kernel (Transition)	481.1	148.1	23.33	353.3	148.0	4.33	NA	NA	NA	100.0	0.0	0.00	660.0	120.0	0.00
7 Foliar yellowing + Rubbery kernel (Diseased)	440.0	325.2	26.20	430.0	182.5	18.06	330.0	129.0	136.50	374.3	63.4	1.43	417.1	93.4	2.36
Mean	415.2	144.6	30.28	406.0	164.6	35.02	531.7	207.6	69.47	415.6	64.8	3.60	501.0	97.7	6.66
SE/plot	277.8	145.2	37.93	311.8	112.0	82.79	521.9	233.6	107.30	412.2	53.8	11.64	356.7	73.9	15.32
F ratio	1.64	3.14**	1.53	0.80	2.04	3.61**	1.15	0.47	6.37**	0.53	0.72	0.49	1.11	1.21	4.65**
Conclusion		7165432				1324756			471352						1257346

* P = 0.05, ** 0.01

NA : Data not available

Ca and Mg : N NH_4OA_c (PH 7) exchangeable

S : Morgan's reagent (N_aOA_c + HOA_c) extractable.

Table 5. Secondary nutrient concentration (%) in leaf in relation to root (wilt) disease

Soil group / Category (Nutrient)	Laterite Ca	Laterite Mg	Laterite S	Alluvial Ca	Alluvial Mg	Alluvial S	Reclaimed Ca	Reclaimed Mg	Reclaimed S	Coastal sandy Ca	Coastal sandy Mg	Coastal sandy S	Sandy loam Ca	Sandy loam Mg	Sandy loam S
1 Healthy	0.323	0.363	0.120	0.327	0.434	0.130	0.322	0.436	0.164	0.384	0.395	0.162	0.402	0.349	0.139
2 Apparently healthy (Transmission)	0.336	0.352	0.108	0.336	0.332	0.169	0.352	0.391	0.138	0.404	0.510	0.122	0.346	0.381	0.106
3 Apparently healthy (Diseased)	0.337	0.347	0.113	0.336	0.371	0.119	0.337	0.379	0.146	0.403	0.425	0.123	0.366	0.360	0.135
4 Foliar yellowing (Transition)	0.303	0.372	0.103	0.311	0.355	0.091	0.258	0.558	0.189	NA	NA	NA	0.280	0.396	0.125
5 Foliar yellowing (Diseased)	0.359	0.295	0.109	0.311	0.327	0.111	0.360	0.369	0.157	0.460	0.448	0.132	0.364	0.343	0.131
6 Foliar yellowing + Rubbery Kernel (Transition)	0.350	0.306	0.121	0.279	0.305	0.097	NA	NA	NA	0.372	0.318	0.118	0.294	0.388	0.155
7 Foliar yellowing + Rubbery kernel (Diseased)	0.348	0.317	0.095	0.314	0.346	0.101	0.307	0.313	0.149	0.316	0.463	0.115	0.314	0.307	0.145
Mean	0.335	0.342	0.113	0.322	0.368	0.114	0.338	0.385	0.152	0.402	0.428	0.138	0.361	0.355	0.131
S E / Plot	0.092	0.099	0.031	0.082	0.109	0.035	0.116	0.103	0.039	0.118	0.104	0.031	0.092	0.101	0.032
F Ratio	1.07	2.96**	2.25*	0.75	3.09**	2.43*	0.59	2.84*	1.12	0.98	2.11	4.98**	2.66*	1.11	3.74**
Conclusion		4123765	6135247		1347256	1352764		412357				153267	1352764		6713542

*P = 0.05, **P = 0.01

NA = Data not available

Table 6 a. Micronutrient status of soils (ppm) in relation to root(wilt) disease

Soil group	Laterite			Alluvial			Reclaimed			Costal sandy			Sandy loam		
Category / Nutrient	Fe	Zn	Mo	Fe	Zn	Mo	Fe	Zn	Mo	Fe	Zn	Mo	Fe	Zn	Mo
1 Healthy	11.33	1.70	0.07	7.23	2.44	0.02	17.75	2.15	0.04	5.32	1.97	0.01	4.45	0.88	0.02
2 Apparently healthy (Transition)	5.92	0.81	0.03	3.86	0.96	0.04	11.11	0.04	0.05	2.88	0.46	0.02	4.62	0.44	0.02
3 Apparently healthy (Diseased)	5.27	0.68	0.05	4.44	0.61	0.04	14.94	0.35	0.04	2.55	0.37	0.01	4.86	0.90	0.02
4 Foliar yellowing (Transition)	6.73	0.69	0.04	5.25	1.24	0.05	69.50	0.35	0.03	NA	NA	NA	5.83	0.45	0.01
5 Foliar yellowing (Diseased)	7.54	1.02	0.05	5.90	0.88	0.05	9.69	1.09	0.04	3.07	0.28	0.01	4.78	0.33	0.02
6 Foliar yellowing + Rubbery kernel (Transition)	4.97	1.82	0.04	6.83	0.62	0.05	NA	NA	NA	1.00	0.50	0.00	5.00	0.50	0.03
7 Foliar yellowing + Rubbery kernel (Diseased)	3.10	0.55	0.04	8.50	0.75	0.05	6.63	1.19	0.04	2.29	0.49	0.00	4.29	0.04	0.02
Mean	7.46	1.20	0.05	5.96	1.20	0.04	14.23	0.90	0.04	3.66	0.97	0.01	4.71	0.61	0.02
SE/plot	5.66	1.01	0.13	4.32	0.81	0.02	11.50	0.71	0.02	2.17	0.47	0.01	2.64	0.66	0.01
F ratio	10.40**	10.42**	0.49	2.66*	17.05**	8.17**	10.89**	17.35**	0.51	6.06**	45.80**	1.13	0.33	5.59**	2.90*
Conclusion	1542367	6152437		7165432	1425763	5476321	413257	175432		152376	167235			3164257	6517324

* P = 0.05, ** 0.01

NA : Data not available

Fe : N NH_4OA_c (P^H 3)

Zn : NH_4OA_c - Dithizone

Mo : Ammonium Oxalate (P^H3.3)

Table 6 b. Micronutrient status of soils (ppm) in relation to root (wilt) disease

Soil group	Laterite				Alluvial				Reclaimed				Coastal sandy				Sandy loam			
Nutrient / Category	Mn (W.S)	Mn (Exch.)	Mn (E.R)	Mn (active)	Mn (W.S)	Mn (Exch.)	Mn (E.R)	Mn (active)	Mn (W.S)	Mn (Exch.)	Mn (E.R)	Mn (active)	Mn (W.S)	Mn (Exch.)	Mn (E.R)	Mn (active)	Mn (W.S)	Mn (Exch.)	Mn (E.R)	Mn (active)
1 Healthy	1.25	14.95	54.05	70.37	1.25	10.33	39.92	51.48	1.53	6.22	7.42	15.76	0.14	0.72	3.34	4.19	1.16	14.63	45.43	62.19
2 Apparently healthy (Transition)	0.88	16.55	39.09	56.50	0.45	13.48	32.65	46.59	2.46	4.99	6.51	13.88	0.05	0.05	0.05	0.15	1.62	8.33	25.42	31.48
3 Apparently healthy (Diseased)	0.61	6.32	17.92	26.89	0.46	8.04	31.61	40.10	0.85	3.24	4.44	8.50	0.05	0.18	0.57	0.81	1.23	4.03	8.99	14.24
4 Foliar yellowing (Transition)	1.63	11.10	27.03	39.76	0.14	9.73	30.33	40.19	5.55	1.25	1.25	8.05	NA	NA	NA	NA	0.48	2.98	5.37	8.83
5 Foliar yellowing (Diseased)	0.34	8.54	27.89	36.76	2.05	8.55	27.88	38.48	0.12	1.81	2.62	4.54	0.00	0.16	0.73	0.89	2.04	5.33	8.27	15.65
6 Foliar yellowing + Rubbery kernel (Transition)	0.23	8.73	30.16	39.12	2.47	9.48	38.62	50.57	NA	NA	NA	NA	0.00	0.00	0.00	0.00	3.20	7.60	9.00	19.80
7 Foliar yellowing + Rubbery kernel (Diseased)	0.04	6.31	27.75	34.46	2.86	9.84	36.13	48.21	0.00	0.99	1.79	2.79	0.10	0.36	0.36	0.81	0.84	5.33	6.42	12.59
Mean	0.82	11.81	36.72	49.73	1.29	9.67	33.94	44.81	0.94	3.38	4.35	8.66	0.08	0.38	1.56	2.01	1.39	7.16	18.27	26.38
SE/Plot	1.04	9.99	26.88	34.23	1.59	9.43	31.95	37.68	1.40	6.20	8.77	14.22	0.21	1.10	3.53	4.51	1.76	9.28	21.58	27.34
F ratio	8.07**	7.15**	10.71**	10.57**	6.75**	0.62	0.39	0.41	9.59**	1.44	0.89	1.75	0.72	1.01	2.56*	2.35*	1.64	4.84**	12.41**	12.47**
Conclusion	4123567	2146537	1265743	716573	7651324				421357						153726	157326		1265734	1263574	1265374

*P = 0.05, ** 0.01
NA = Data not available

Mn (W.S.): Water soluble
Mn (Exch.): N NH_4OAC (pH 7) exchangeable
Mn (E.R.): 0.2% Hydroquinone in N NH_4OAC - Easily reducible
Mn (Active): Sum of (W.S.) + (Exch.) + Mn (E.R.)

Table 6 c. Micronutrient status of soils (ppm) in relation to root (wilt) disease

Soil group / Nutrient / Category	Laterite Cu	Laterite B	Laterite Al	Alluvial Cu	Alluvial B	Alluvial Al	Reclaimed Cu	Reclaimed B	Reclaimed Al	Coastal sandy Cu	Coastal sandy B	Coastal sandy Al	Sandy loam Cu	Sandy loam B	Sandy loam Al
1 Healthy	2.42	0.22	12.74	2.14	0.35	17.65	2.20	0.24	65.19	1.23	0.15	8.07	2.62	0.20	28.15
2 Apparently healthy (Transition)	3.51	0.36	19.28	2.34	0.24	25.59	1.04	0.33	44.69	0.73	0.16	0.00	2.00	0.27	6.37
3 Apparently healthy (Diseased)	2.03	0.32	37.20	2.53	0.26	37.65	2.19	0.26	33.31	1.73	0.16	1.68	2.10	0.17	11.41
4 Foliar yellowing (Transition)	3.47	0.28	43.98	2.80	0.22	32.98	0.80	0.67	221.00	NA	NA	NA	0.36	0.18	13.67
5 Foliar yellowing (Diseased)	4.45	0.28	47.79	3.44	0.21	35.22	1.91	0.26	55.36	1.29	0.20	0.00	3.02	0.22	7.54
6 Foliar yellowing + Rubbery kernel (Transition)	5.48	0.22	26.82	2.78	0.19	23.75	NA	NA	NA	0.00	0.48	2.00	12.00	0.48	1.00
7 Foliar yellowing + Rubbery kernel (Diseased)	2.97	0.24	25.85	3.49	0.27	29.36	3.40	0.25	79.31	0.57	0.33	0.71	3.29	0.29	11.19
Mean	3.27	0.28	25.84	2.71	0.26	29.11	2.08	0.27	53.62	1.25	0.18	3.54	2.47	0.22	13.07
SE/plot	3.10	0.26	37.20	2.08	0.24	40.10	1.61	0.18	66.11	2.13	0.11	4.86	3.49	0.14	20.95
F ratio	5.99**	2.06	4.87**	1.31	0.81	0.79	2.19	2.42*	3.36**	0.53	4.84**	3.77**	2.05	2.70*	3.62**
Conclusion	6524713		5436721					423571	471523		675321	165725		6725143	1437526

* P = 0.05, ** 0.01

NA : Data not available

Cu : 0.02 M EDTA extractable

B : Hot water soluble

Al : N KCL exchangeable.

Table 7 a. Micronutrient concentrations (ppm) in leaf in relation to root (wilt) disease

Soil group	Laterite				Alluvial				Reclaimed				Coastal sandy				Sandy loam			
Category / Nutrient	Fe	Zn	Mo	Mn	Fe	Zn	Mo	Mn	Fe	Zn	Mo	Mn	Fe	Zn	Mo	Mn	Fe	Zn	Mo	Mn
1 Healthy	256	19.72	0.660	157.8	340	18.98	0.703	103.8	268	16.97	0.572	77.9	226	20.47	1.306	83.6	181	24.65	0.720	161.1
2 Apparently healthy (Transition)	163	9.12	0.540	94.9	136	10.14	0.440	45.2	236	11.89	0.140	49.0	110	13.13	0.734	9.0	172	13.33	0.561	46.0
3 Apparently healthy (Diseased)	129	6.05	0.287	90.1	161	6.94	0.449	86.9	192	6.69	0.268	33.4	160	7.11	0.296	9.4	168	6.28	0.342	52.6
4 Foliar yellowing (Transition)	196	8.37	0.430	114.0	136	7.75	0.228	66.4	364	18.50	0.480	94.5	NA	NA	NA	NA	136	5.83	0.347	61.5
5 Foliar yellowing (Diseased)	142	8.79	0.263	102.2	178	7.29	0.561	93.5	250	5.25	0.347	66.7	152	3.64	0.217	9.0	181	4.88	0.289	36.3
6 Foliar yellowing + Rubbery kernel (Transition)	157	7.72	0.249	81.5	143	8.00	0.468	46.5	NA	NA	NA	NA	189	2.00	0.000	0.0	217	8.00	0.230	18.00
7 Foliar yellowing + Rubbery kernel (Diseased)	153	10.55	0.352	63.9	137	8.44	0.358	64.2	226	7.00	0.640	61.9	154	5.64	0.664	11.6	152	6.71	0.487	36.0
Mean	184	11.65	0.456	112.2	199	10.53	0.503	81.5	231	8.79	0.393	55.2	178	11.91	0.730	37.1	172	10.76	0.453	68.0
S E / Plot	86	7.19	0.375	91.9	97	6.50	0.399	73.5	112	6.06	0.379	93.9	99	7.45	0.613	39.7	84	5.65	0.516	64.5
F Ratio	15.0**	25.86**	8.99**	5.29**	14.95**	12.01**	2.53**	1.60	1.86	10.05**	2.26	0.72	2.60*	15.05**	8.28**	13.62**	0.51	44.39**	2.57**	13.70**
Conclusion	1426753	1725463	1247356	1452367	1536724	1276453	1563274			412735			163752	123756	127356	173256		1267345	1274356	1432576

*P = 0.05, **P = 0.01
NA = Data Not available.

Table 7 b. Micronutrient concentrations (ppm) in leaf in relation to root (wilt) disease

Soil group	Laterite			Alluvial			Reclaimed			Coastal sandy			Sandy loam		
Nutrient / Category	Cu	B	Al	Cu	B	Al	Cu	B	Al	Cu	B	Al	Cu	B	Al
1 Healthy	7.37	10.27	17.91	12.16	18.71	19.48	3.75	16.96	16.82	5.00	10.97	23.13	6.32	12.45	14.85
2 Apparently healthy (Transition)	5.60	9.44	4.42	4.56	8.77	3.14	7.37	13.62	6.32	11.50	12.55	6.60	7.13	11.31	4.15
3 Apparently healthy (Diseased)	6.44	12.86	5.04	7.00	10.92	4.69	6.32	13.79	4.63	6.60	16.64	4.76	7.22	11.74	3.60
4 Foliar yellowing (Transition)	7.93	10.72	4.71	2.56	7.54	2.63	1.25	14.00	5.10	NA	NA	NA	3.35	10.37	5.72
5 Foliar yellowing (Diseased)	7.26	10.81	4.05	7.67	11.41	5.08	7.46	14.65	4.83	9.31	14.57	2.85	7.63	10.20	3.48
6 Foliar yellowing + Rubbery kernel (Transition)	5.52	12.38	3.46	10.02	6.10	3.08	NA	NA	NA	2.50	12.00	2.50	3.80	12.00	4.00
7 Foliar yellowing + Rubbery kernel (Diseased)	6.93	9.24	3.29	5.00	9.21	2.89	10.08	14.25	5.19	10.47	8.43	4.54	11.94	11.59	5.29
Mean	6.62	10.86	8.45	7.74	12.00	7.74	6.51	14.58	6.96	7.27	13.03	11.43	7.36	11.43	6.09
SE/plant	6.04	4.38	7.44	5.61	5.39	6.17	5.92	5.74	4.23	6.62	4.19	4.03	6.32	5.03	4.91
F ratio	0.84	3.66	32.01**	5.97**	11.94**	25.10**	1.77	0.74	21.17**	2.13	6.64**	84.21**	1.85	0.61	20.76**
Conclusion		3654127	1342567	1653724	1537246	1532674			127453		352617	123756			1472635

* F = 0.05, ** 0.01

NA : Data not available.