Investigations on the Possible Relationship between the Nutritional Status of Soils and the Incidence of "Bunchy Top" Disease of Bananas (*Musa* Sp.)*

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Introduction

Banana (*Musa* sp.) constitutes an important group of fruit crops cultivated extensively in the tropical regions of the world. The world acreage under this crop is about 1.0-1.5 million acres. In India banana is one of the most important fruit crops cultivated over an area of approximately 0.4 million acres which is about one-fifth of the total area under fruits. Kerala, Madras, Andhra Bombay, Mysore, Assam, West Bengal and Bihar are the chief banana producing centres in this country. Kerala tops the list with an area of 100,000 acres under banana and an annual production of 65,000 tons. The largest number of varieties are also cultivated here, the chief among them being *Nendran*, *Palayamthodan*, *Poovan*, *Monthan* *Kadali* and *Rasakadali*.

Of all the diseases of banana the most destructive is the "Bunchy Top". The incidence of this disease was reported from Orissa, Andhra, Bombay, Bihar and Assam as early as 1940. In Kerala, too, this disease first appeared in the same year. It has now spread throughout the State and devastated the industry causing heavy loss and distress to the growers. The most widely cultivated varieties, viz., *Nendran* and *Palayamthodan* are highly susceptible to the disease. Other varieties like *Kadali* and *Poovan* are also susceptible to infection and some of the finest varieties of banana in the State are even facing total extinction. Capoor (1959) has reported that this disease which covered an area of only 900 sq. miles around Kottayam in 1946 had by 1950 spread over an area of 3,000 sq. miles. The annual financial loss on account of this disease is estimated at nearly six crores of rupees.

"Bunchy Top" disease being of virus origin as reported by various investigators, curative measures are considered ineffective. Eradication of the diseased plants was

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** Published by kind permission of the University of Kerala, Trivandrum therefore, the only method recommended and practised to prevent its spread. The breeding of resistant varieties appears to be difficult as most of the edible and seed-bearing varieties are susceptible to the disease.

No attempt has so far been made in this country or elsewhere to investigate the nutritional status of soils in relation to the "Bunchy* Top" of banana to see if soil conditions act as a predisposing factor for the incidence of this disease. Considering the economic importance of the banana crop to Kerala State and the extent of damage caused by the disease, a study of soil conditions in relation to the incidence of the disease was considered essential.

Review of Literature

Magee (1927) has reported that the incidence of "Bunchy Top" disease of banana was first observed in Fiji about the year 1879. According to Fahmy (1924) the incidence of the disease in Egypt was observed as early as 1901. Bryce (1921) has reported the appearance of "Bunchy Top" in the Colombo District of Ceylon in 1913. The prevalence of this disease in Australia was reported about the same time by Smith (1924) and Magee (1927). The incidence of the disease has also been reported from Ellis Islands by Campell (1926), Wallis Islands by Simmonds (1933) and from Bonnin Islands by Gadd (1926). In India unconfirmed reports of the occurrence of the disease have been made from Calcutta by Hector (1925), from Cuttack by Padwick (1940) and from Assam by Nandi (1941). The disease is believed to have been introduced into Kerala from Ceylon about the year 1940.

Early investigators attributed various causes for the incidence of the disease. Knowles and Jepson (1912) regarded the causative organism as of fungus origin, whereas Fahmy (1924) attributed the malady to nematode agency. Smith (1924), describing the occurrence and symptoms of the disease in Australia, attributed it to fungal or bacterial infection of the roots or corm. Goddard ;(1925) reported that the vector responsible for the transmission of the disease was the banana aphid, ***Pentalonia nigronervosa*** and that the disease was of virus origin. The results of experiments conducted by Magee (1927) confirmed these findings. Subsequent studies by Magee (1940) on virus-vector relationship have shown that the aphids become infective after feeding on the diseased plants for a minimum period of 17 hours and that the virus gets transmitted by infected aphids in about one hour and a half or more of feeding on susceptible plants. The vector *Pentalonia nirgonervosa* retains the infective capacity for a period of 13 days after removal from the diseased plants and the incubation period ranges from a few hours to 2 days. According to Magee (1953) all species of *Musa* producing edible seedless fruits and all the fertile seed-bearing species examined by him were susceptible to this disease. Some degree ofresistance was, however, exhibitted by the Gros Michel variety (*Musa* sp.) probably for physiological reasons.

Very little work has been done on the nutritional status of soils as a predisposing factor in the incidence of the "Bunchy Top" disease of banana. Such studies have been made in the case of other crop diseases like the root rot (wilt) of coconut and the mandarin orange decline. Thus Sankarasubramony *et al* (1954) have shown that the nutrient elements like N, P and K accumulated in the leaf tissues of diseased coconut palms, Iyer and Iyengar (1956) in their studies on the decline of citrus in Wyanad have reported that the chemical analysis of the soils revealed satisfactory levels of N, P and K, but the availability of these nutrients was limited because of low pH and the consequent poor lime status.

Janssen (1929) was one of the first to investigate the relationship between plant nutrition and the incidence of virus diseases. According to him increasing levels of nitrogen increased both the aphid population and the susceptibility of potato plants to infection by leaf roll and Y-viruses. Spencer (1935) concluded that nitrogen increased the susceptibility of tobacco to mosaic virus and Brierley and Stuart (1946) reported that increasing the level of nitrogen for onions increased their susceptibility to infection by yellow dwarf virus. In giving an account of the "Bunchy Top" disease of banana, Wardlaw (1935) stated that field observations indicated that more vigorous and rapidly growing plants are most susceptible to the disease.

Phosphorus is essential for the multiplication of virus in host cells and may increase their susceptibility to attack by viruses and other disease agents. Spencer (1935) found that in tobacco, phosphorus increased susceptibility to virus disease as long as plant growth benefitted from the extra phosphorus. Bawden and Kassanis (1949) were of the view that phosphorus is more important than even nitrogen and potassium in regulating host susceptibility, However, Sankarasubramony *et al* (1954) found no significant difference in the phosphorus status of healthy and diseased areas in their study of soil conditions in relation to the root rot (wilt) disease of coconut palms.

Bryce (1921) has reported that the incidence of "Bunchy Top" in Bonnin Islands is attributed to the deficiency of potassium in the soil and that the application of potassic fertilisers greatly reduced the incidence of the disease. According to Janssen (1929) and Spencer (1935) potassium decreases the susceptibility of plants to virus diseases. Similar observations have been made by Tisdale and Dick (1942) in respect of cotton wilt and by Patel and Nair (1936) in relation to the shoot rot of coconut palm. Sankarasubramony *et al* (1955) in their study of the root rot (wilt) disease of coconut have shown that as compared to healthy areas the soils from diseased areas were lower in available potash. Nair (1961) has reported that potash manuring of rubber, affected by 'die-back', in conjunction with nitrogen suppressed the disease and increased the yield of rubber within a period of one year from the date of application of the fertilisers.

According to Evans and Troxler (1953) calcium tends to reduce the incidence of *Blossom end rot* in tomatoes. Ramakrishnan and Damodaran (1956) reported that liming of soil reduced the period of viability of the pathogen of panama wilt disease of banana in two months while in the control the viability extended up to 4 months. Brun and Champion (1954) observed that the blue disease of bananas in French Guinea was associated with magnesium deficiency. They have demonstrated the effectiveness of magnesium in any form against this disease especially as dolomite. Mariakulandai and Dorairaj (1958) in their study of orange decline noted that higher magnesium content was associated with healthy trees and that the ratio of calcium and magnesium to potassium decreased considerably from healthy to affected trees.

In view of the relationship between the nutritional status of soils and the incidence of several virus diseases of different crops reported in literature, an attempt has been made in the present study to investigate the nutritional status of soils as a predisposing factor in the incidence of the "Bunchy Top" disease of banana. In addition to soil samples from diseased and healthy areas, leaf smples of infected and non-infected plants were also analysed in connection with this study. As it has been observed by some farmers that the incidence of the disease is not severe in fields where lime is applied, an experiment was laid out to study whether the liming elements, calcium and magnesium, could be a predisposing factor in the incidence of this disease.

Materials and Methods

1. Analysis of soil and leaf samples

Three districts, Quilon, **Ernakulam** and Cannanore were selected for the investigation of the nutrient status of soils in relation to the incidence of the "Bunchy Top" disease. Of these, Quilon and Ernakulam are representative of the infected areas of the State while Cannanore represents a non-infected area. From each of these districts two types of soils, (sandy and laterite) were taken for the study. The relevent details of the districts and the location and the type of soils are given below:

	District	Rainfall mm	Temp °F Max	Mm		Location from where soil samples were	Type of soil
1	Quilon						
	(Diseased area)	2600-3000	90	72	8000	Quilon	Sandy
						Kottarakara	Laterite
2	Ernakulam						
	(Diseased area)	3000-3600	95	68	5800	Alwaye	Sandy
						Muvattupuzha	Laterite
3	Cannanore						
	(Healthy area)	3500-4000	100	60	25,000	Payyannur	Sandy
						Taliparamba	Laterite

Twenty representative soil samples were collected from each area under both diseased and healthy plants. The soil samples were collected 3 feet away from the base of the plant and to a depth of 12". In addition, 5 samples were collected from each area from a depth of 12" - 36". The details of the samples collected are given below:

	District.	Soil Type: Sandy				Laterite			
		Healthy		Diseased		Healthy		Diseased	
		0" - 12"	12" 36"	0" - 12"	12 - 36"	0" - 12"	12" - 36"	0" - 12"	12" - 36"
		No. of samples collected							
1	Quilon	20	5	20	5	20	5	20	5
2	Ernakulam	20	5	20	5	2.0	5	20	5
.3	Cannanore	20	5	—	-	20	5	—	
	Total	60	15	40	JO	60	15	40	10

The soil samples collected were dried in the shade, ground in a porcelain mortar and sieved through a 2 mm sieve. The material thus prepared was used for laboratory examination.

2. *Leafsamples*

Twenty representative samples for analysis were collected from both diseased and healthy plants in each area. The selections were confined to those plants from whose base soil samples were taken for analysis. The leaf samples were dried in the shade, powdered in a grinder and the powdered material used for the analysis.

Standard analytical procedures were followed in all the estimations.

II. *Fertiliser Experiment*

With a view to finding out whether the nutritional status of the soil, especially the level of calcium and magnesium, is a factor in the incidence of "Bunchy Top" disease, an experiment was laid out with the following five treatments:

A. Control
B. N. P. K. Mixture
C. N. P. K. + Ca
D. N. P. K. + Mg
E. N. P. .. + Ca + Mg

The experiment was conducted in a randomised block design with 6 replications using thirty (5x6) reinforced concrete pots of size 60 cm diameter and 60 cm height coated inside with bitumen. Coarse grained river sand passing through a i screen and washed successively with 2 percent HC1 and 2 percent HNO_3 and then in running water until free from acid was used for filling in the pots. 150 kg of the washed and dried sand was used for each pot.

A basal dressing with 13.6 kg cattle manure was done for each pot before filling, along with adequate amounts of the trace elements in the form of Manganese sulphate (6.16 g), Zinc sulphate (8.8 g), Copper sulphate (7.84 g), Ferrous sulphate (10.0 g), Boric acid (5.2 g) and Molybdic acid (1.5 g) The pots were filled with sand mixed with the basal manures after plugging the holes at the bottom with glass wool. The 150 kg sand added to each pot was sufficient for filling the pot to a height of 7.5 cm from the top.

The banana variety used for experiment was *Nendran*, locally known as *Ethan.* The healthy suckers were collected from a non-infected garden in the vicinity of the Agricultural College, Vellayani. The mother plants were observed throughout their growth period and thirty suckers, almost uniform in size, were collected after satisfying that the garden was free from the disease. They were air-dried for two days before planting as is the practice in that locality. The suckers were planted at the centre of the pot by scooping out the sand. The planting was done on 17-11-1962.

For the treatments, C and E. calcium was applied in the form of $CaCO_3$ (biproduct calcium carbonate supplied by M/s FACT, Ltd., Alwaye containing 37.1% CaO and 1.55% MgO) at the rate of 0.5kg per plant. The application was done in a circular layer 30 cm below the surface and away from the rhizome of the banana sucker. This treatment was given before planting the suckers. For treatments D and E magnesium was supplied as pure $MgCO_3$ (47.3% MgO) at the rate of 56 g per pot. This was mixed with the sand before filling in the pots.

For all treatments except the control 9:9:9 grade NPK mixture (supplied by M/s FACT Ltd., Alwaye) was applied at the rate of 2.5 kg per plant in three split doses of ⅓ the quantity each time at monthly intervals. The first dose was given on 16-12-1962.

The banana suckers were pot-watered lightly on the day of planting. Light irrigation was given till the suckers sprouted and started growing. With the first application of the fertiliser mixture one month after planting the quantity of water applied was increased. Equal quantities of water were applied to all the pots daily.

The aphids *Pentalonia nigronervosa* required for transmission were reared on healthy plants and then allowed to feed on diseased plants for a period of 7 days. The aphids were collected on 10-1-1963 and half-starved for 24 hours. They were then released into the leaf sheaths of young leaves at the rate of thirty numbers for one plant. A pandal was provided for the plants to maintain shade and humid conditions for a period of 5 days from the date of release of the aphids on 11-1-1963.

The height of plants, number of leaves and the length and width of leaves were observed at weekly intervals from

20-12-1962 to 4-4-1963. Occurrence of the disease was identified by observing the following symptoms:

(i) Development of chlorotic streaks and dots on the petiole, leaf blade and mid-rib;

(ii) Upright position of leaves, curling of leaf margins, scorching, splitting of leafblades and brittle nature;

(iii) Shortening of leaf size, both in length and width,

(iv) Reduction in further growth and elongation of petiole and production of clusters of leaves-

Representative samples were drawn from the potted plants under the different treatments and analysed for calcium and magnesium.

Results

1. *Soil Analysis*

(i.) *Soil reaction (pH)*

The pH values of the soils studied are presented in Table I.

TABLE I

pH values of soils of healthy and diseased areas at two different depths

District	Soil type	Depth of soil 0"-12" (Mean of 20 samples) Healthy	Diseased	12"-36" (Mean of 5 samples) Healthy	Diseased	Statistical significance 't' 0"-12"	12"-36"
Quilon	Sandy	6.10	5.95	5.66	5.36	0.18	1.60
Ernakulam	,,	5.98	5.87	5.32	5.20	0.46	0.74
Cannanore	,,	5.48		4.90			
Mean		5.87	5.91	5.30	5.28	0.23	0.23
Quilon	Laterite	5.27	4.97	5.20	4.88	0.91	2.90***
Ernakulam		5.39	5.29	4.88	4.78	0 60	0.43
Cannanore	,,	5.48	...	5.36	...		
Mean	,,	5.48	5.13	5.15	4.83	1.60	2 88***

*** Significant at 0. 01 level

It can be seen from the data presented that without exception the soil from the diseased plants are more acidic compared to areas of healthy plants.

(ii.) *Organic carbon, nitrogen and C/N ratio*

The organic carbon and nitrogen and the C/N ratios of the soils studied are given in Table II.

TABLE II

Organic carbon, nitrogen and C/N ratio of soils of healthy and diseased areas at two different depths (oven-dry basis)

District	Soil type	Depth of soils 0″— 12″ (Mean of 20 samples) Healthy	Diseased	12″—36″ (Mean of 5 samples) Healthy	Diseased	Statistical significance 't' 0″— 12″	12″— 36″
			Organic Carbon (per cent)				
Quilon	Sandy	0.66	0.83	0.52	0.61	6.40***	2.94***
Ernakulam		0.70	0.87	0.33	0.42	2.36**	0.80
Cannanore		0.81	...	0.65	...		
Mean		0.72	0.85	0.50	0.53	3.65***	6.40***
Quilon	Laterite	0.75	0.99	0.43	0.50	5.10***	2.20*
Ernakulam		0.98	1.05	0.47	0.53	1.09	1.12
Cannanore		1.15		0.44			...
Mean		0.96	1.02	0.52	0.52	1.40	2.70**
			Nitrogen (per cent)				
Quilon	Sandy	0.052	0.064	0.042	0.048	11.30***	2.72**
Ernakulam	,»	0.059	0.064	0.026	0.033	1.99*	2.72**
Cannanore		0.069	...	0.045			
Mean		0.069	0.069	0.038	0.040	1.59	0.03
Quilon	Laterite	0.059	0.072	0.038	0.042	3.70***	1.40
Ernakulam		0.079	0.083	0.043	0.044	0.67	3.40***
Cannanore		0.091	...	0.037	,.		
Mean		0.076	0.078	0.039	0.043	0.67	1.90
			C/N ratio				
Quilon	Sandy	12.72	12.95	12.38	12.62	0.55	0.34
Ernakulam		11.90	14.02	12.54	12.92	2.85***	1.65
Cannanore		11.82		13.81	..		
Mean		12.14	13.49	12.92	12.77	3.70***	0.40
Quilon	Laterite	12.80	13.31	11.36	11.90	1.40	1.20
Ernakulam		12.56	12.85	10.86	11.90	0.48	1.40
Cannanore		12.78		11.66			
Mean		12.71	13.08	11.30	11.90	1.20	1.20

* Significant at 0.1 level
** Significant at 0.05 level
*** Significant at 0,01 level

The soils from areas of diseased plants had a higher content of organic carbon as compared to those of healthy plants in both soil types and at the two different depths. The values were also statistically significant for the sandy soils of Quilon and Ernakulam districts and the laterite soils of Quilon district at 0" - 12" depth. They were also significant at depth 12" - 36" in respect of the sandy and laterite soils of Quilon district. The nitrogen content of the soils from areas of healthy plants is lower than that of the diseased plants at both the depths. The higher values of total nitrogen in the diseased areas are significantly different from those of healthy areas in sandy soils of both Quilon and Ernakulam at both the depths and in the laterite soils of these two districts at 0" -12" and 12″–36″ respectively. The C/N ratio of the sandy soils of the diseased areas of Ernakulam district is 14.02 as against 11.90 in the healthy areas and the difference is significant. The mean value for the sandy soils in the two groups of districts also showed a significantly higher ratio in the diseased areas. The values of the C/N ratios are, however, not significant in the other areas.

(iii) *Phosphorus*

Table III gives data on total and available phosphoric acid content of the soils studied.

TABLE III

Total and available phosphorus in soils of healthy and diseased areas at two different depths (oven-dry basis)

District	Soil type	Depth of soils 0″—12″ (Mean of 20 samples) Healthy	Diseased	12″—36″ (Mean of 5 samples) Healthy	Diseased	Statistical significance 't' 0″–12″	12″–36″
		Total P_2O_5 (percent)					
Quilon	Sandy	0.030	0.028	0.023	0.021	2 .00**	3 20**
Ernakulam		0.022	0.027	0.017	0.015	1.16	2 65**
Cannanore		0.036		0.025			
Mean		0.029	0.027	0,022	0.018	1.52	2.74**
Quilon	Laterite	0.050	0047	0.037	0.034	0.94	0 50
Ernakulam		0.038	0.033	0026	0.015	4.10***	7.00***
Cannanore		0.045		0.035			
Mean		0.045	0.040	0.033	0.025	2 30**	2.10**

Table III-Continued

Available P_2O_5 (percent)

Quilon	Sandy	0.0047	0.0052	0.0048	0.0059	0.66	1.90*
Ernakulam		0.0033	0.0035	0.0016	0.0018	0.40	0.97
Cannanore		0.0028	...	0.0025	—		
Mean		0.0036	0.0044	0.0033	0.0039	1.66	1.04
Quilon	Lateritc	0.0017	0.0022	0,0004	0.0008	1.78*	1.50
Ernakulam		0.0008	0.0009	0.0004	0.0003	0.76	0.62
Cannanore		0.0015		0.0006			
Mean		0.0013	0.0016	0.00045	0.00052	0.78	0.18

* Significant at 0.1 level
** Significant at 0.05 level
*** Significant at 0.01 level

The total P_2O content is seen to be higher in areas of healthy plants as compared to diseased areas except in the sandy soils of Ernakulam district where the reverse is true. The higher values of total P_2O_5 are significant only for the depth of 0″–12″ in the sandy soils of Quilon and the laterite soils of Ernakulam. The mean values for the two groups of districts also recorded significantly higher content in healthy areas of laterite soils at 0″–12″ and at 12″–36″ in both soil types. The available P_2O_5 is slightly higher in the diseased areas as compared to the healthy areas, but the values are significant only in the laterite soils of Quilon district at the depth 0″–12″ and in the sandy soils of this district at the depth 12″–36″.

(iv) *Potassium*

The data in Table IV give the distribution of total and available potash in the soils.

The total potash content is higher in soils studied at both depths in areas of healthy plants as compared to diseased areas in the sandy and laterite soils of this district at both depths. However, the sandy and laterite soils of Ernakulam have a slightly higher content of potassium in the diseased areas. The mean values for these two soils in the two groups of districts are higher in healthy areas at both depths and these are significantly different from those of the diseased areas. Available potash is higher in the healthy areas in all the soils studied. The healthy areas of Ernakulam district have a significantly higher concentration of available potash

TABLE IV

Total and available potasssium in soils of healthy and diseased areas at two different depths (over-dry basis)

District	Soil type	Depth of soils 0"–12" (Mean of 20 samples) Healthy	Diseased	12"–36" (Mean of 5 samples) Healthy	Diseased	Statistical significance 't' 0"–12"	12'–36"
		Total K_2O (percent)					
Quilon	Sandy	0.044	0.034	0.030	0.018	4.00***	5.80***
Ernakulam		0.037	0.039	0.027	0.029	0.28	0.45
Cannanore		0:081	—	0.081	—	—	
Mean		0.054	0.036	0.046	0.024	4.80***	2.06*
Quilon	Laterite	0.055	0.043	0.037	0.030	3.50***	2.60**
Ernakulam		0.037	0.044	0.030	0.029	3.15***	0.09
Cannanore		0.057	—	0.066	—	—	—
Mean		0.050	0.043	0044	0.029	2.43**	2.70
		Available K_2O (percent)					
Quilon	Sandy	0.00052	0.00047	0.0005	0.0003	0.43	1.67
Ernakulam		0.0005	0.0003	0.0002	0.0001	3.20***	0.58
Cannanore		0.0007		0.0007			—
Mean		0.0006	0.0004	0.0005	0.0002	4.00***	2.09*
Quilon	Laterite	0.0009	0.0008	0.0005	0.0003	1.06	1.90*
Ernakulam		0.0007	0.0006	0.00032	0.00028	0.94	0.44
Cannanore		0.0009		0.0012	—	—	—
Mean		0.0008	0.0007	0.0006	0.0003	0.71	1.05

* Significant at 0.1 level

** Significant at 0.05 level

*** Significant at 0.01 level

at 0″–12″ in the sandy soils. The mean values for the sandy soils of the two groups of districts are higher in the healthy areas at both depths. The healthy areas of Cannanore district have a higher content of total potassium at both depths as compared to the diseased areas of Quilon and Ernakulam

(v) *Calcium*

Data relating to the total and exchangeable calcium in the soils are presented in Table V.

Total and exchangeable calcium are higher in soils of healthy areas as compared to those of the diseased areas in all the soils though the higher values are not significant in many cases. Significantly higher values are obtained in respect of the laterite soils of Quilon district at 0″–12″ and the sandy and laterite soils of Ernakulam at 12″–36″. The higher values of exchangeable calcium are significant only in respect of the laterite soils of Quilon district at both depths. The mean values for these two soils in the two groups of districts showed a higher content of available potash at 12″–36″ depth.

(vi) *Magnesium*

Table VI gives data relating to the total and exchangeable magnesium content of soils.

The soils from areas of healthy plants had a significantly higher content of magnesium in both soil types of Quilon and Ernakulam districts at 0″–12″ depth. The mean value of MgO in respect of the sandy soils under the two groups of districts was also significantly higher for the healthy areas. Significantly higher values of exchangeable magnesium are observed for the laterite soils of Ernakulam district at 0″–12″ and for the sandy soils of both districts at 12″–36″. The healthy areas of Cannanore have higher contents of exchangeable magnesium as compared to the soils of the other two districts. The mean values for all the districts taken together show a significantly higher content of exchangeable magnesium in the sandy soils at both depths and in the laterite soils at 12″–36″.

2. *Leaf Analysis*

The results of chemical analysis of healthy and diseased leaf samples collected from these districts are presented in Table VII.

The data indicate a higher content Of nitrogen in the diseased leaf samples than in the healthy samples. The higher values are significant in all areas except the sandy area of Ernakulam district. The mean figure for the nitrogen content of all the districts taken together also recorded a significantly higher value. In the case of phosphorus and potassium, too, the diseased leaf samples from all the areas have higher values and the difference is statistically significant. The calcium content of the diseased leaf samples is, however, significantly lower in the diseased leaves as compared to the healthy ones. Similarly, the magnesium content also is lower in the diseased samples, though the difference is not significant in respect of the laterite soils.

II. *Fertilizer Experiment*

The average height of plants and the number of leaves per plant as on the day of release of the aphids and the number of days taken for the appearance of disease symptoms are recorded in Table VIII.

TABLE V

Total and exchangeable calcium in soils of healthy and diseased areas at two different depths (oven-dry basis)

District		Depth of soils 0″—12″ (Mean of 20 samples)		12″—36″ (Mean of 5 samples)		Statistical significance Y	
		Healthy	Diseased	Healthy	Diseased	0″–12″	12″–36″
		Total CaO (per cent)					
Quilon	Sandy	0.090	0.081	0.073	0.054	1.12	1.09
Ernakulam	,,	0.133	0.118	0.095	0.077	1.53	2.08*
Cannanore	,,	0.092	—	0.078	--	—	—
Mean	,,	0.105	0.106	0.082	0.066	0.76	2.10**
Quilon	Laterite	0.126	0.101	0.091	0.081	1.84*	1.03
Ernakulam	,,	0.128	0.114	0.095	0.081	0.09	2.80**
Cannanore	,,	0.105		0.087	—		
Mean	,,	0.120	0.108	0.091	0081	1.32	1.64
		Exchangeable Calcium (me./100 g)					
Quilon	Sandy	2.03	1.99	1.48	1.26	0.41	1.31
Ernakulam	,,	3.28	2.71	1.30	1.16	1.52	1.12
Cannanore	,,	2.39		1.96			—
Mean	,,	2.56	2.35	1.58	1.21	0.95	3.00**
Quilon	Laterite	2.83	2.38	1.54	1.09	1.83*	2.64**
Ernakulam	,,	2.80	2.62	1.04	0.98	0.63	0.06
Cannanore	,,	2.49	—	1.54			—
Mean	,,	2.70	2.50	1.37	1.04	1.20	2.97**

*Significant at 0.1 level

**Significant at 0.05 level

TABLE VI

Total and exchangeable magnesium in soils of healthy and diseased areas at two different depths (oven-dry basis)

District	type	Depth of soils (Mean of 20 samples)		12″–36″ (Mean of 65 samples)		Statistical significance	
		Healthy	Diseased	Healthy	Diseased	0″–12″	12″–36″
		Total MgO (percent)					
Quilon	Sandy	0.074	0.065	0.065	0.060	2.03**	0.94
Ernakulam		0.092	0.079	0.060	0.059	2.29**	0.30
Cannanore		0.071	'	0.060	—	—	—
Mean		0.079	0.072	0.062	0.060	1.91*	0.53
Quilon	Laterite	0.096	0.081	0.054	0.047	1.96*	1.26
Ernakulam		0.110	0.094	0.058	0.049	1.89*	1.33
Cannanore		0.059	—	0.080		· -	— .
Mean		0.088	0.087	0.060	0.048	0.22	2.50**
		Exchangeable magnesium (me./100g)					*
Quilon	Sandy	0.33	0.31	0.26	0.10	0.78	10.90***
Ernakulam		0.37	0.33	0.30	0.17	0.82	4.50***
Cannanore		0.49		0.43			
Mean	,;	0.40	0.32	0.32	0.13	2.90***	4.40***
Quilon	Laterite	0.42	0.39	0.30	0.29	0.66	0.42
Ernakulam		0.59	0.50	0.40	0.38	1.94*	0.82
Cannanore		0.47	—	0,53	—		
Mean		0.49	0.45	0.41	0.34	1.75	2.07**

Significant at 0.1 level
** Significant at 0.05 level
*** Significant at 0.01 level

TABLE VII

Chemical composition of healthy and diseased leaf samples (oven-dry basis)

District	Sandy area (Mean of 20 leaf samples)		Lateritic area (Mean of 20 leaf samples)		Statistical significance 't'	
	Healthy	Diseased	Healthy	Diseased	Sandy area	Lateritic area
			N (per cent)			
Quilon	2.10	2.21	2.76	2.87	2.50**	3.69***
Ernakulam	2.86	2.92	2.78	2.88	0.96	3.40***
Cannanore	2.08		2.52			
Mean	2.35	2.56	2.69	2.88	2.63**	6.78***
			P_2O_5 (per cent)			
Quilon	0.50	0.56	0.52	0.76	2.67***	15.00***
Ernakulam	0.53	0.62	0.48	0.53	5.70***	6.50***
Cannanore	0.37	—	0.39	-		
Mean	0.47	0.59	0.46	0.65	8.90***	9.70 ***
			K_2O (percent)			
Quilon	2.29	3.08	3.88	4.24	18.00***	5.20 ***
Ernakulam	3.66	4.63	3.31	3.97	6.30***	5.80***
Cannanore	2.82	—	2.88	-	—•	
Mean	2.92	3.86	3.36	4.10	6.00***	8.50***
			CaO (per cent)			
Quilon	0.67	0.54	0.62	0.52	2.70**	3.60***
Ernakulam	0.59	0.48	0.63	0.57	3.90***	2.56**
Cannanore	0.67		0.66			
Mean	0.64	0.51	0.64	0.54	5.10***	4.30***
			MgO (per cent)			
Quilon	0.462	0.413	0.459	0.403	2.42**	1.60
Ernakulam	0.531	0.461	0.461	0.432	3.40***	0.50
Cannanore	0.332		0.443			
Mean	0.442	0.437	0.455	0.417	0.30	2.38**
			CaO + MgO / $_2$O			
Quilon	0.49	0.31	0.28	0.22	7.80***	5.30***
Ernakulam	0.32	0.20	0.34	0.25	6.30***	4.80***
Cannanore	0.35		0.38			
Mean	0.39	0.26	0.33	0724	6.50***	8.00***

* Significant at 0.1 level
** Significant at 0.05 level
*** Significant at 0.01 level

TABLE VIII

Growth measurements of plants on the day of release of aphids and the time taken for the appearance of disease symptoms

Treatment	Average height of plants cm	Average number of leaves per plant	No. of days taken for the appearance of symptoms
A. Control	76.7	7.33	34.30
B. N. P. K	95.8	7.33	30.00
C. N. P. K + Ca	81.3	8.50	30.20
D. N. P. K + Mg	87.0	8.33	42.70
E. N. P. K + Ca + Mg	91.0	8.67	53.00
Critical difference	9.99	0.91	12.82
Inference	B E D $\overline{\text{C A}}$	E C D B A	$\overline{\text{E D}}$ ACB

The data indicate that the plants under treatments B, E and D are not significantly different in height. So also, the difference in height between E, D and C is not significant. The height of plants under treatment B is, however, significantly different from that of plants under treatments C and A.

The number of leaves under treatments E, C and D is significantly more than that under the treatments B and A. However, there is no significant difference between treatments E, C and D.

There has been considerable variation in the time taken for the appearance of disease symptoms under the different fertiliser treatments. Of all the treatment combinations studied, treatment E (N. P. K + Ca + Mg) delayed the incidence of disease to the greatest extent, viz., 23 days, over the N. P. K treatment. The time taken for the appearance of symptoms in treatment E is significantly different from that in treatments A, C and B. The plants under treatment D (N. P.K. + Ca) showed delayed appearance over treatments A, C and B but the delay is not significant. The difference between the times taken by E and D, though not significant, is approaching significance.

The average growth measurements of plants at the time of appearance of symptoms and at the final observation on 4-4-1963 are presented in Table IX.

From the above data it can be seen that after the appearance of the first symptoms further growth is reduced or almost curtailed. The size of leaves, both in length and width, is also reduced considerably.

Data relating to the calcium and magnesium content of leaves under the different treatments are given in Table X.

TABLE IX

Average growth measurements of plants at the the time of appearance of disease symptoms and at the final observation

Treatmentt	At the first appearance of disease symptoms				At the final observation			
	Height of plants cm	No. of leaves per plant	Length of leaf cm	Width of leaf cm	Height of plant cm	No. of leaves per plant	Length of leaf cm	Width of leaf cm
A., Control	114.0	12.2	102.3	48.8	118.8	17.7	61.8	17.3
B. N. P. K	139.7	11.8	118.2	52.2	142.3	18.8	57.3	15.2
('. N. P. K + Ca	128.0	13.2	112.0	50.2	130.7	20,8	65.,2	15.0
D,N. P. K + Mg	137.0	14.2	123.3	51.8	140.5	19.8	78.3	23.0
E.N.P.K.+Ca+Mg	161.8	16.3	135.7	58.7	162.0	20.2	96.2	31.5

TABLE X

Calcium and magnesium contents of leaf samples under different treatments

Treatment	CaO (per cent)	MgO (per cent)
A. Control	1.10	3.346
B, N. P. K	1.24	0.352
C. N. P. K Ca	1.44	0.404
D. N. P. K + Mg	1.21	0.604
E. N. P. K + Ca + Mg	1.60	0.562
Critical difference	0.12	0.093
Inference	E C B DA	D E C B A

The results indicate that the uptake of calcium in treatments E and C is significantly different from that in treatments B, D and A. The difference between E and C is also significant. No significant difference is obtained between treatments B and D and between D and A. But the uptake in treatment B is significantly higher than in A. The uptake of magnesium under treatments D and E was significantly more than that in A, B and C. There was, however, no significant difference between treatments D and E.

Plates I–XI show the general appearance of the plants under the various treatments.

Discussion

Though it is widely accepted that the disease "Bunchy Top", threatening one of the premier horticultural crops of Kerala is caused by a virus, it has to be admitted that the environment and soil characteristics do exert a certain influence on the incidence and spread of the disease. In the present investigation detailed studies were made on the chemical characteristics of soils and leaf samples from both healthy and diseased areas.

The results indicate that the diseased areas are more acidic when compared to the healthy areas (Table I). In the case of the sandy soils, the difference is not appreciable, but it is very pronounced in the case of the laterite soils. As far as nitrogen is concerned, the soils of the diseased areas, as well as, the diseased leaf samples contain a higher level of this constituent. In the case of phosphorus, too, the same situation holds with a greater content of P_2O_5 both in the soils of diseased areas, as well as, in the diseased leaf samples. With regard to potassium the soils of healthy areas contain more of this element than those of the diseased areas, and there is considerable accumulation in the diseased leaf samples.

An entirely different situation holds with respect to calcium and magnesium. In the case of soils of healthy regions both constituents are seen to be significantly higher than in soils of diseased areas. The healthy leaves also contain significantly higher quantities of the two elements compared to diseased leaf samples.

These data point to several interesting possibilities. It is to be appreciated that the total contents of nitrogen, phosphoric acid and potash in the soils studied are by no means at a level to be considered high in relation to the fertility status. These low total levels are incapable of contributing any injury due to "excess", and to attribute any relation between the quantities of these elements in the soils studied and the incidence of the disease will be unwarranted. However, it is very clear that with the incidence of the disease, the translocation of nitrogen, phosphorus and potassium from the leaves is severely affected, possibly due to the physiological disturbances occurring as a result of the infection. It is also interesting to note that potassium accumulation occurs in the diseased leaves to a much greater extent than nitrogen and phosphorus, indicating that this element plays an important role, either before, during or after the incidence of the disease.

By far the most significant observation from the soil and leaf analysis data is the unique role of calcium and magnesium. These constituents are invariably higher in the soils of healthy areas and invariably lower in the diseased tissues. No accumulation of these elements occurs in the dis. eased **leaves,** in striking contrast to the situation regarding nitrogen, phosphorus and potassium. It is therefore clear that either immediately before the incidence of the disease or during infection, a drastic change has occurred in the absorption and translocation of calcium and magnesium in the plant. i IK exact period at which the disturbance occurs resulting in lower absorption or translocation of these two elements needs further investigation. The results clearly indicate that calcium and magnesium may hold interesting clue to a prevention of infection and that the calcium + magnesium/ potassium ratio in the leaves may provide a measure of the susceptibility of bananas to the incidence of the disease. This is further brought out by the results of the experiment where the disease was reproduced in healthy bananas and the significant difference in the time-lag observed in calcium and magnesium trials as compared to other treatments, between the date of release of aphids and the appearance of first symptoms.

In this experiment the aphids for the transmission of the virus disease were released in the leaf sheaths of differently treated healthy plants 55 days after planting the suckers. Growth characters of the plants, such as height, number of leaves and the length and width of leaves were measured at weekly intervals and the time taken for the first appearance of the symptoms noted. The disease symptoms were first shown by the plants under treatment B thirty days after the release of the aphids. But treatments E (N. P. K + Ca + Mg) and D (N. P. K + Mg) showed much more delayed appearance of symptoms as compared to the other treatments. Statistically there is significant difference in the delay in the appearance of symptoms in treatment E over treatments A, B and C and is approaching significance over treatment D. The difference between treatments D, A, C and B is not, however, significant.

These results indicate the possibility of an important relationship existing between the calcium and magnesium status of soils in which bananas are grown and the proneness or susceptibility of the plants to incidence of "Bunchy Top" disease. The calcium and magnesium treated plants have withstood the attack of the virus for a considerably longer period than the plants in the other treatments. That this is not a chance factor is indicated by the fact that the appearance of symptoms in these plants was delayed by as much as 76 and -77 days in two cases compared to 30 days in the N. P. K-treated plants. The overall difference in the delay in the appearance of the symptoms in the two treatments (i.e., B and E) is also highly significant.

The soil and leaf analytical data reported earlier, show that the soils of healthy areas contain much more quantities of calcium and magnesium than the diseased areas and that the healthy leaves contain more of these two constituents than diseased leaves. This fact, along with the correlation observed between the calcium-magnesium treatments and the delay in the appearance of the symptoms, would indicate that these two elements are vital in any attempt to ontrol or regulate the incidence of the "Bunchy Top" disease. A possibility is indicated of a proportion of calcium and magnesium in the soil being able to create conditions of resistance in the plant, and perhaps a sufficiently long period of resistance, rendering the virus ineffective up to the time of emergence of the bunch. If this can be achieved, it would be an important step towards a possible solution of this problem.

Summary and conclusions

An attempt has been made in the present investigation to find out how far the chemical characteristics of the soil act as a predisposing factor in the incidence of the disease. Soil samples were collected from the base of healthy and infected plants representing the soil types of the region, and analysed for nitrogen, phosphorus, potassium, calcium and magnesium. Soil reaction and organic carbon were also determined. Leaf samples collected from healthy, as well as, diseased plants were analysed for nitrogen, phosphorus, potassium, calcium and magnesium.

In addition to the study of soils and plant materials an experiment was also conducted for the elucidation of the influence of calcium and magnesium, singly and in combination, on the incidence of the disease. Disease-free suckers were planted in differently treated pots and after the suckers had established the insect vector previously fed on diseased plants were given free access to the plants for the transmission of the virus. Morphological observations like height of plants, number of leaves and length and width of leaves were made periodically and correlated with the time of exhibition of characteristic disease symptoms. Leaf samples were collected from the plants and analysed for the uptake of calcium and magnesium in order to find out whether there is any characteristic variation in the uptake of these nutrients.

The analysis of soils in general showed that the soils of infected regions are more acidic, higher in organic matter, higher in nitrogen and available phosphorus, but lower in total potassium and calcium and very low in magnesium. The leaf analysis of healthy and diseased plants revealed a comparatively high amount of nitrogen, phosphorus and appreciably high content of potassium in infected leaves. The plant-growth experiments have revealed that the application of lime in combination with N. P. K has little effect on the incidence of the disease as measured by the delay in infection, while magnesium alone or in combination with calcium exerts an appreciable influence on the incidence of the disease by delaying the appearance of symptoms.

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Plate I. Healthy banana plants — General View (Before transmission of virus)

Plate II.— A healthy banana plant

Plate III.– Healthy banana plants under different treatments

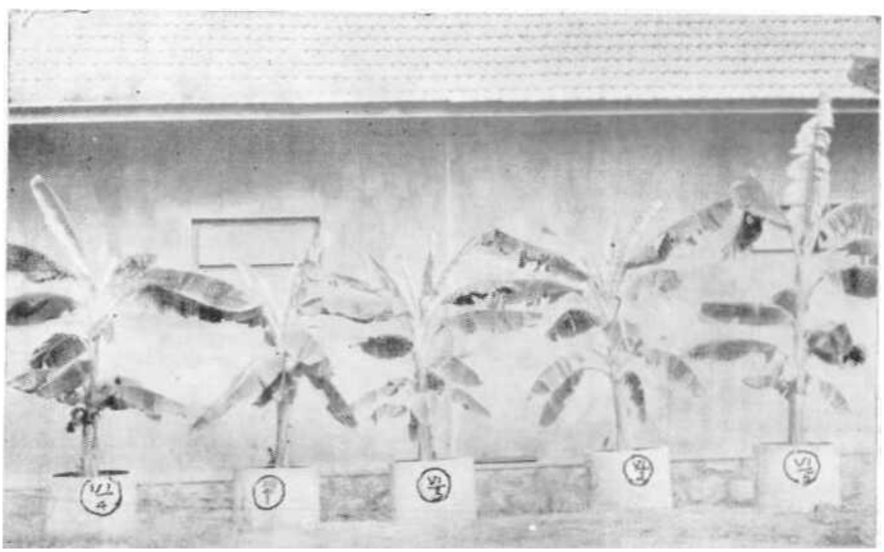

Plate IV.– Diseased banana plants under different treatments

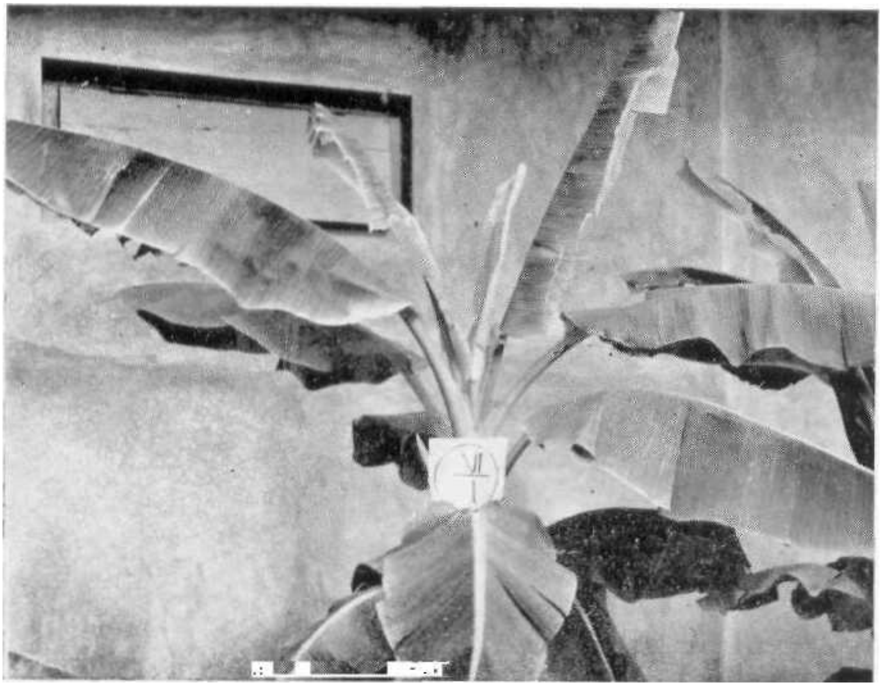

Plate V.– Diseased banana plant under treatment A (Control)

Plate VI.– Diseased banana plant under treatment B (NPK)

Plate **VII.—** **Diseased** banana plant under treatment C (NPK+Ca)

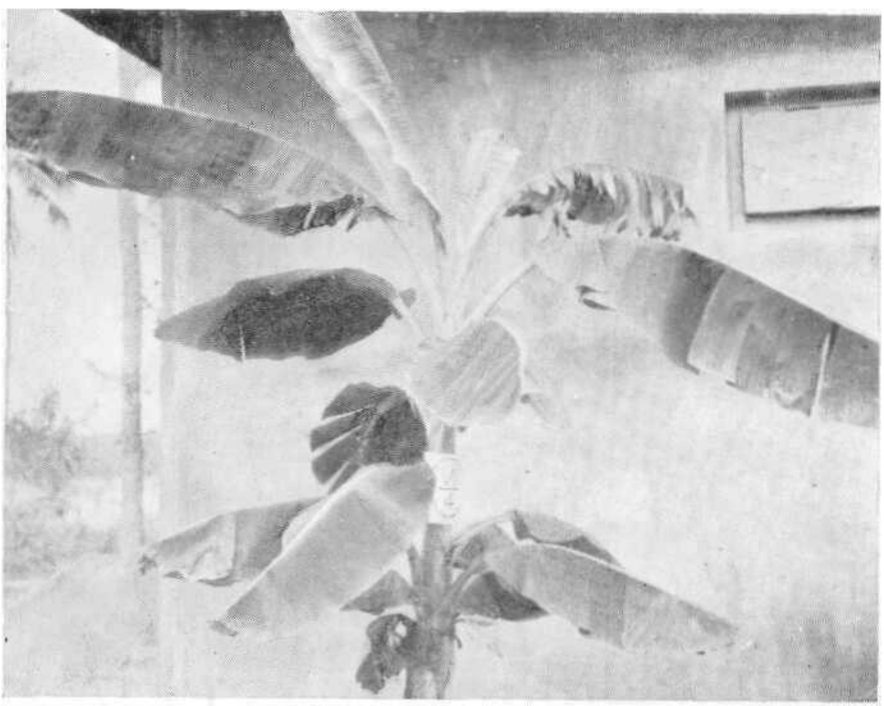

Plate **VIII.—** Diseased banana plant under treatment D (NPK+Mg)

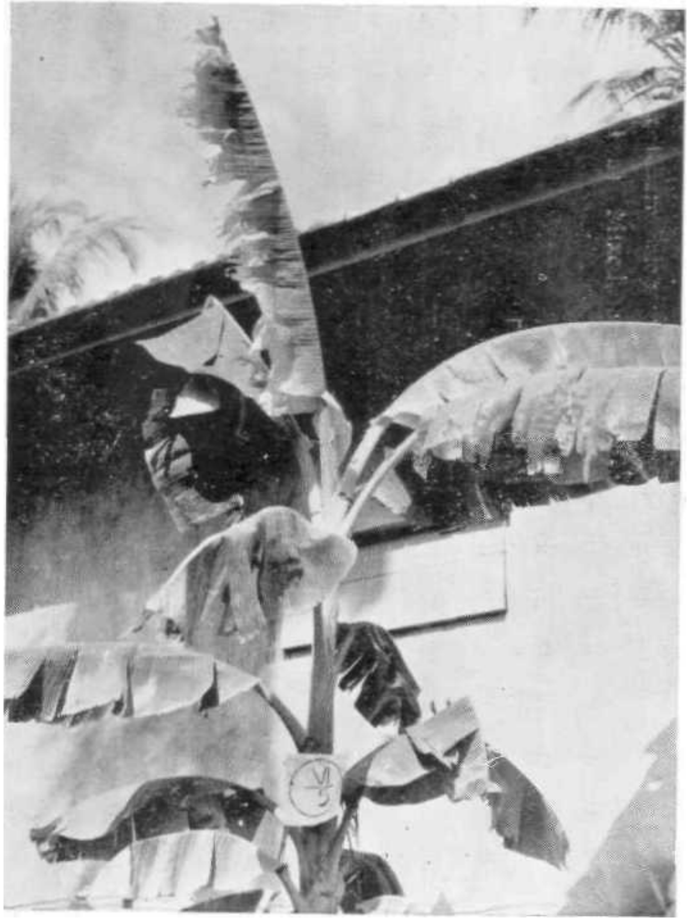

Plate IX. — Diseased banana plant under treatment E (NPK+Ca+Mg)

Plate X.— A healthy banana plant under treatment E (NPK+Ca+Mg)

Plate XI.— Diseased banana plants — General View

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