Nutritional Status of Soils and the Incidence of the 'Bunchy Top' Disease of Bananas (*Musa* sp.)

PART III. CALCIUM OXIDE/MAGNESIUM OXIDE RATIO IN PLANTS AS A FUNCTION OF THE SOIL CONTENTS OF CALCIUM AND MAGNESIUM AND ITS RELATIONSHIP TO 'BUNCHY TOP' INFECTION *

C. K. N. AND C. K. GEORGE[2]

Agricultural College and Research Institute, Vellayani

Received for publication August 21, 1966

Systematic studies on the possibility of the control of the 'Bunchy Top' disease through predetermined nutritional environments were undertaken at the Agricultural College and Research Institute, Vellayani, from 1962 onwards as part of a long range programme of the Principal and Additional Director of Agriculture (Research). A survey was conducted during the first year of the investigation on the nutrient status of the soils of disease-prevalent and disease-free areas which revealed that the soils of the disease-prevalent areas were low in calcium and magnesium. The results of studies made on the basis of these findings indicated a possible relationship of host nutrition with calcium and magnesium and the incidence of the Bunchy Top disease in banana. (Nambiar and Nair, 1965). During 1964–65 a detailed sand culture trial was conducted with different forms and levels of calcium and magnesium in various combinations. The calcium and magnesium carbonate treated plants with 1000 g CaO and 150 g MgO in the sand medium (0.6% CaO and 0.1% MgO on the basis of the weight of sand or a CaO/MgO ratio of 6:1) arrested the incidence of the disease until the emergence of the bunch (Nair and Pillai, 1966). As further investigations were considered necessary for confirming these results the present study was undertaken under partial field conditions with calcium oxide and magnesium carbonate treatments under different CaO/MgO ratios.

A detailed review of the literature on this subject is not attempted here as it has been included in the earlier papers on this subject. (Nambiar and Nair, 1965 and Nair and Pillai, 1966).

Materials and Methods

To study the effect of different CaO/MgO ratios in the soil on the incidence of the Bunchy Top disease of banana, an experiment under partially controlled field conditions was laid out in randomised block design with the following 10 treatments in three replications :

* Condensed from the thesis submitted by C. K. George to the University of Kerala in partial fulfilment of the requirements for ths M. Sc. (Agri.) degree in Agronomy, 1966 Published by kind permission of the University of Kerala, Trivandrum.

1. Principal and Additional Director of Agriculture (Research)
2. Post graduate student.

3- Lockarel, R. L. and Asomaning, E. J. A. (1965) Mineral Nutrition of Cocoa (*Theobroma cocoa* L.) II. Effects of swollen shoot virus on the growth and nutrient content of plants grown under nutrient deficient, excess and control conditions in sand culture. *Trop. Agriculturist, 42:* 39-53.

4. Nambiar, P. K. D. and Nair, C. K. N. (1965) Investigations on the possible relationship between the nutritional status of soils and the incidence of the Bunchy Top disease of bananas (*Musa* sp.). *Agr. Res. J. Kerala.* 3: 78-99.

5. Nair, C. K. N. and Pillai, K. Sivasankara (1966) Nutritional status of soils and the incidence of Bunchy Top disease of bananas *(Musa* sp.). II. Significance of calcium/magnesium ratio in the nutrient medium and in plants *Agr. Res. J. Kerala,* 4: 86-105.

6. Piper, C. S. (1950) *Soil and Plant Analysis.* Interscience Publishers, New York.

7. Sreenivasa Rao, Y. V. (1933) Biochemical aspects of the virus discharge of plants. *Proc. Twentieth Sci. Cong.,* p. 453.

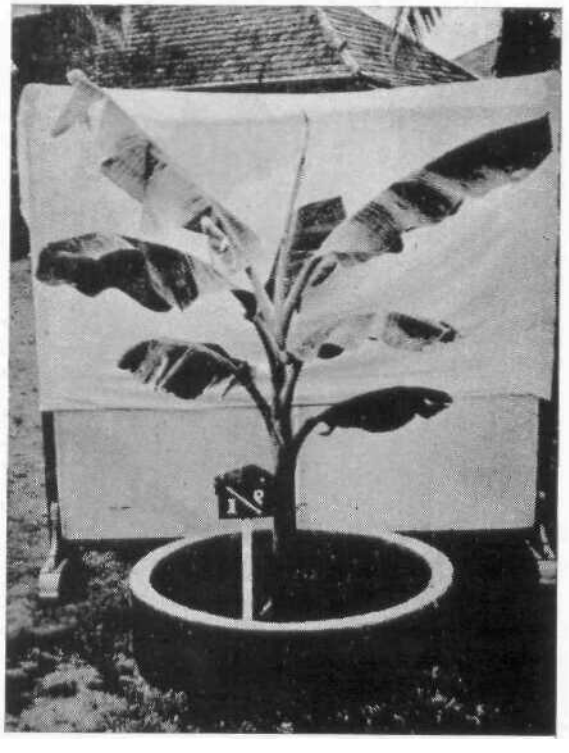

PLATE X. Banana plant under treatment No. 9 (CaO : MgO ratio at 0.2% MgO level) before the transmission of virus

PLATE XL Banana plant under treatment No. 9 (CaO : MgO ratio 9 : 1 at 0.2% MgO level) after the disease incidence

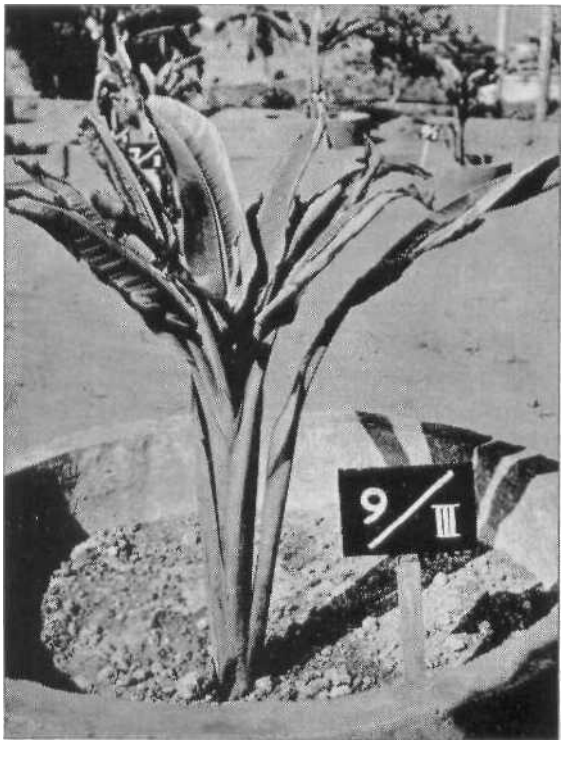

PLATE XII. Diseased daughter sucker under treatment No. 9 (CaO : MgO ratio 9 : 1 at 0.2% MgO level)

PLATE VII. Banana plant under treatment No. 6 (CaO : MgO ratio 3 : 1 at 0.2% MgO level) before the transmission of virus

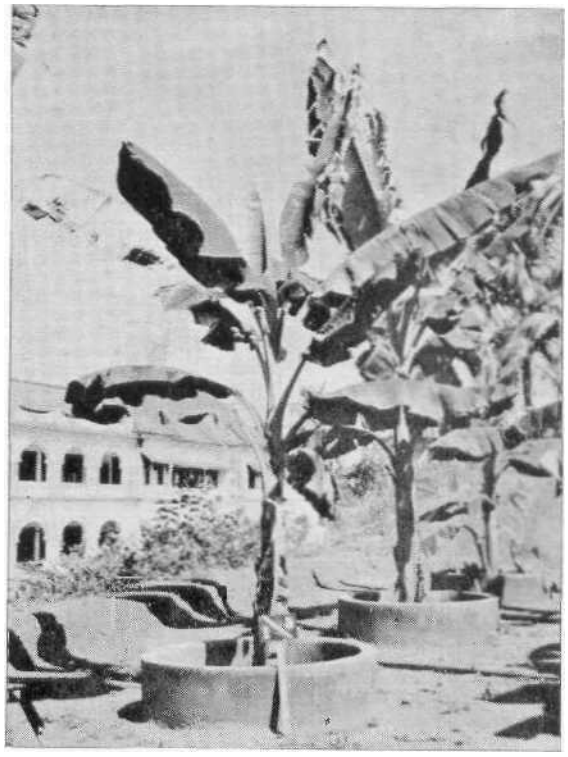

PLATE VIII. Banana plant under treatment No. 6 (CaO : MgO ratio 3 : 1 at 0.2% MgO level) after the disease incidence

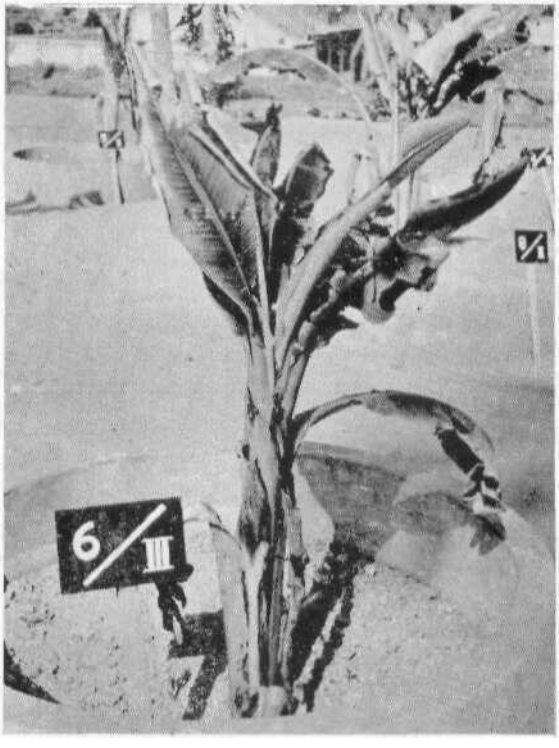

PLATE IX. Diseased daughter sucker under treatment No. 6 (CaO : MgO ratio 3 : 1 at 0.2% MgO level)

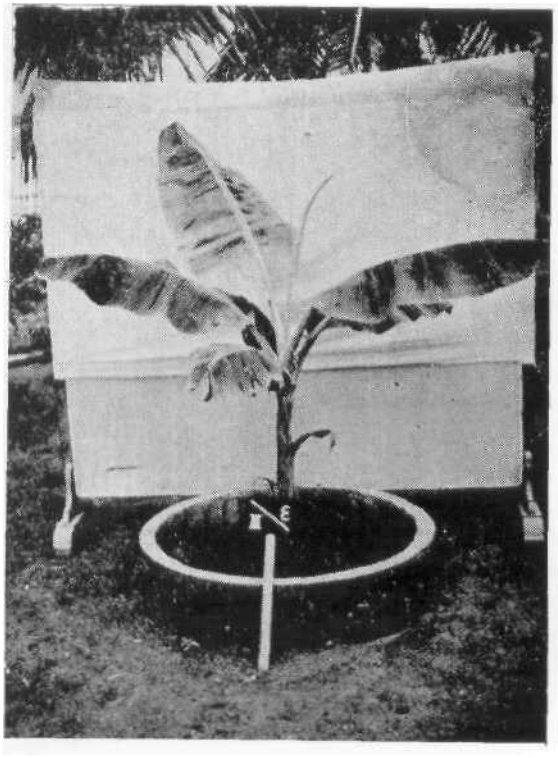

PLATE IV. Banana plant under treatment No. 3 (CaO : MgO ratio 1 at 0.2% MgO level) before (he transmission of virus

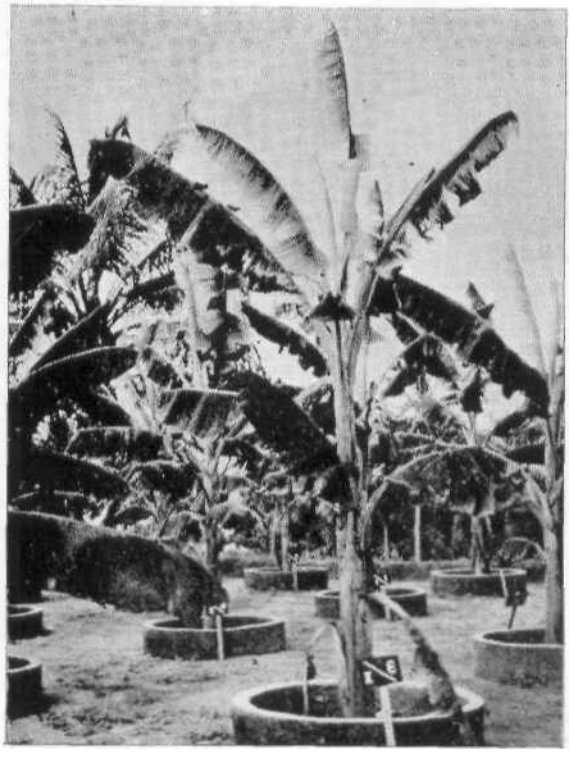

PLATE V. Banana plant under treatment No. 3 (CaO : MgO ratio 6 : 1 at 0.2% MgO level) after the disease incidence

PLATE VI. Diseased daughter sucker under treatment No. 3 (CaO : MgO ratio 6 : 1 at 0.2% MgO level)

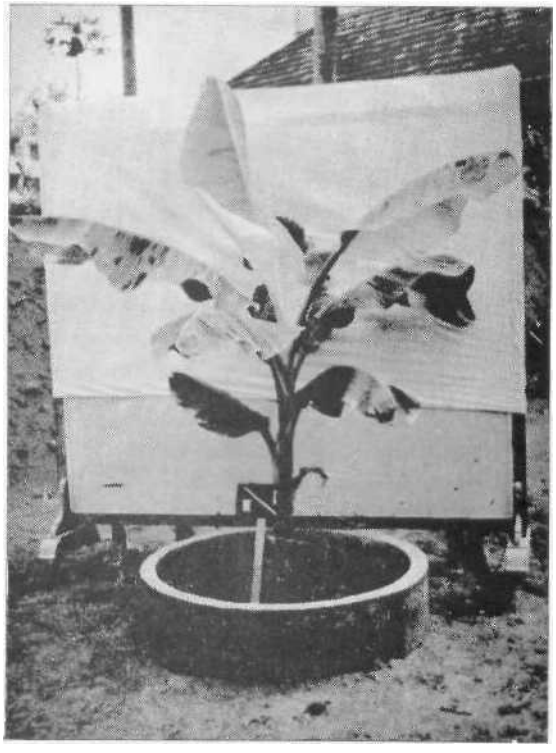

PLATE I. Banana plant under treatment No. 1 (Control) before the **transmission** of virus

PLATE H. Banana plant under treatment No. 1 **(Control)** after the disease incidence

PLATE III. Diseased daughter sucker under treatmet No. 1. (Control)

ratio may bear a relationship to the resistance of banana plants to infection by the Bunchy Top virus. It would seem desirable to carry out further investigations on this aspect of the problem.

Summary and Conclusions

Experiments were laid out under semi-field conditions to study whether a desired CaO/MgO ratio within the leaf could be obtained by adjustment of the CaO/MgO ratio in the soils in which the banana plants were grown. The absorption of calcium and magnesium and nitrogen, phosphorus and potassium by plants from soils containing varying levels of calcium and magnesium at constant levels of nitrogen, phosphorus and potassium, was studied. The plants were allowed to be infected by releasing the virus carrying aphids after the initial period of growth, to study whether there was any resistance to the incidence of Bunchy Top. The results are summarised below:

I Varying the levels of calcium and magnesium in the soils resulted in varying the CaO/MgO ratio within the leaf. However, such variations did not follow any fixed pattern.

2. All the plants in the experiment contracted the disease. Even the plants with a CaO/MgO ratio of 3.71 in the leaf were infected with the Bunchy Top disease and no resistance to infection by the virus was observed. The earlier observations of Nair and Pillai that a CaO/MgO ratio of 3.5 to 4 in the leaf could successfully delay the incidence of the disease could not be confirmed by the present study conducted under semi-field conditions.

3. The absorption of nitrogen, phosphorus and potassium by the banana plants before and after the incidence of the disease showed the same trend as reported earlier by Nair and Pillai. The uptake of nitrogen by the plants decreased with increasing levels of calcium and magnesium. There was an increase in the nitrogen content of leaves after the incidence of the disease. The same trend was observed in the case of phosphorus and potassium

4. The absorption of calcium and magnesium followed the same trend as was reported earlier by Nair and Pillai. All the plants had a higher content of calcium and magnesium in the leaf before the incidence of the disease than after infection. Beyond a certain level of calcium the absorption of this element from the soil was independent of its concentration in the soil. An increased absorption of magnesium is favoured by a lower concentration of calcium in the soil.

5. In no case in the present study, a $CaO+MgO/K_2O$ ratio of 1.0 could be obtained in the leaf. It is therefore possible that the resistance to Bunchy Top virus noted by Nair and Pillai may really be correlated to the ratio of $CaO+MgO/K_2O$ in the loaf and not merely to the ratio of CaO/MgO.

Acknowledgement

The authors are grateful to Shri E. J. Thomas, Junior Professor of Statistics for assistance in the statistical analysis and interpretation of data and to Shri C. M. George, Professor of Agronomy, for his interest in this work.

References

1. A. 0. A. C. (1960) *Official Methods of Analysis.* Association of Official Agricultural Chemists, Washington, D. C.

2. Jackson, M. L. (1958) *Soil Chemical Analysis.* Prentice Hall Inc., N. J.

to increased absorption or disturbed translocation. It may be noted that the potassium content of the plant tissues in all the present experimental treatments was higher than what was reported by Nair and Pillai (1966) for plants which delayed the infection by an appreciable period of time.

The higher contents of nitrogen, phosphorus and potassium in plants under different treatments in the present investigation than in the case of the resistant plants in the sand culture studies of Nair and Pillai (1966) would lead one to suppose that these three elements, when present in larger quantities than a possible optimum, would favour conditions of easy infection by the Bunchy Top virus.

Absorption of calcium and magnesium by the plants

The absorption of calcium by the banana plants follows an entirely different pattern from that of nitrogen, phosphorus and potassium. The amount of calcium in the leaves is much higher before the incidence of the disease than after infection. This is in agreement with the results reported by Nair and Pillai (1966). All the calcium treated plants had more calcium in the leaf than the control. The absorption of calcium by plants under different treatments before infection is not significantly different indicating that beyond a certain level of calcium further additions to the nutrient medium will have no effect on tissue composition with respect to this element.

The absorption of magnesium by the plants follows an identical trend as calcium, except that the highest magnesium level was seen in plants growing on a soil with a CaO/MgO ratio of 3:1. This indicates that a lower concentration of calcium in the nutrient medium favours an increased absorption of magnesium. All the plants contained appreciably higher quantities of magnesium before the incidence of the disease than after infection by the virus.

Calcium and magnesium thus present an entirely different picture from nitrogen, phosphorus and potassium. While the concentrations of calcium and magnesium in the healthy plants is much higher than in the infected plants, the situation is reversed in the case of nitrogen, phosphorus and potassium. The same results were reported by Nair and Pillai earlier (1966). It can be concluded from these results that unlike the other major nutrient elements, either the absorption of calcium and magnesium is slowed down after the onset of the disease or appreciable quantities of these elements are translocated from the leaf to the other parts of the plant after infection. Calcium and magnesium thus play a rather unique role in Bunchy Top infection and resistance of plants to attack by the virus.

CaO/MgO rath and $CaO+MgO/K_2O$ ratio in leaf

The CaO/MgO ratio in the leaf of plants under different treatments does not show any significant correlation with disease incidence or resistance in the present investigations. This is a notable difference observed from the results of Nair and Pillai (1966) who found a significant correlation between CaO/MgO ratio in the leaf and delay in infection by the virus. However, it is important to note that in the plants which withstood the infection in their experiments they had obtained a $CaO+MgO/K_2O$ ratio of 1.0, which none of the experimental plants in the present study attained. This ratio for all treatments in the present study was much lower than 1.0. It is therefore possible that the $CaO+MgO/K_2O$ ratio in the Jeaf, rather than the CaO/MgO

Absorption of nitrogen by the plants

Data from the present study indicate that the uptake of nitrogen by the plants decreased with increasing levels of calcium and magnesium. There was an increase in the nitrogen content of leaves after the incidence of the disease as compared to that before the infection. Higher content of nitrogen in the virus infected leaves of plants than in healthy leaves has been recorded by Sreenivasa Rao (1933) and by Lockarel and Asomaning (1965). It is seen from the present results that the nitrogen content of infected banana leaves is not only higher than in healthy leaves, but also fairly constant for all the treatments. While the absorption of nitrogen by plants before the incidence of the disease showed significant variation, it is of interest to note that there was no significant difference in the uptake of nitrogen by plants under different treatments after the incidence of the disease. The higher concentration of nitrogen in the leaves after the incidence of the disease and its fairly equal magnitude in plants under different treatments need not necessarily indicate an equal rate of absorption by all plants, but may also point to a possibilty of disturbed translocation of the element from the affected leaves. It is significant to note that the amount of nitrogen in the leaves of all the plants under different treatments in the present study is higher than the quantity reported by Nair and Pillai (1966) in the leaves of plants which resisted infection either for a fairly long period of time or throughout the growth period.

Absorption of phosphorus by the plants

The application of calcium and magnesium causes a decreased uptake of phosphorus by the plants before the incidence of the disease, the highest absorption being in the soil with a CaO/MgO ratio of 3:1. After the incidence of the disease also the highest absorption of phosphorus among treated plants was seen in the case of those growing on soils with the CaO/MgO atio of 3:1, at the lowest level of magnesium used. The quantities of phosphorus in the leaves after the incidence of the disease was higher than in healthy leaves before infection. A comparison of these data with those presented by Nair and Pillai (1966) does not show any correlation with disease infection, although the phosphorus content in the leaves of resistant plants as reported by them was very much lower. The indications from such a comparison are that a lower, rather than higher, content of phosphorus in the plant tissue is what would lend resistance to virus infection. The increased concentration of phosphorus noticed in the plant leaves after the incidence of the disease not necessarily point to an increased absorption of the element after the disease has set in, but may also be due to disturbance in the mechanism of translocation.

Absorption of potassium by the plants

The application of calcium and magnesium has a retarding influence on the absorption of potassium by the banana plant before the incidence of the disease. The maximum potassium uptake among the treated plants was in the case of those growing on soil with a CaO/MgO ratio of 3:1 and the minium for 9:1. After the incidence of the disease, the potassium contents of leaves of all the affected plants were higher. The pattern of potassium absorption, both before and after the incidence of the disease closely followed that of phosphorus. The higher potassium content of leaves of diseased plants may either be due

(1965) had noted that the ratio of calcium to magnesium in the nutrient medium significantly influenced the incidence of the Bunchy Top disease and that an appropriate treatment combination of these elements could delay the disease symptoms by several days over the control. The subsequent studies of Nair and Pillai (1966) under controlled sand culture conditions indicated that by regulating the calcium to magnesium ratio in the nutrient medium, and consequently within the plant tissue, the incidence of the Bunchy Top disease could be successfully delayed until the emergence of the bunch. Nair and Pillai (1966) reported that a calcium oxide to magnesium oxide ratio of 6:1 in the nutrient medium, and 3.5 to 4.0 in the leaf, could possibly enable the banana plants to withstand attack by the Bunchy Top virus over the entire growth period of the banana plant.

The present study was undertaken as a continuation of the work of Nair and Pillai (1966), under semi-field conditions. Calcium oxide to magnesium oxide ratios in the soil of 3:1, 6:1 and 9:1 under three different levels of these nutrients were tried and their effect in delaying the incidence of the Bunchy Top disease observed. It can be seen from the results that all the plants, in all the treatments contracted the disease sooner or later. The differences in the time observed for the onset of the disease symptoms between treatments were not statistically significant. The early incidence of the disease in the present study in all the different treatments, as compared to treatments under controlled sand culture conditions, may be taken as an indication of the preponderance of many uncertain soil factors affecting or upsetting the calcium magnesium ratio, both in the nutrient medium and within the plant tissue. One such uncertain factor could be the large amount of organic matter applied to the plants in the present study, amounting to 7.5% on the weight of the soil which would have exerted an appreciable influence on the mobility of calcium and magnesium in the soil and their availability to the plant. Another uncertain factor in the present investigations could well be the concentration of the virus inoculum. It may be noted that in the present study the number of aphids released per plant was 100, while in the previous investigations of Nambiar and Nair (1965) and Nair and Pillai (1966) the number of aphids per plant was 30 and 20 respectively. The effect of the concentration of the virus inoculum on the incidence of the disease and the ability of the plant to withstand infection is yet another aspect of these investigations which may require further study. The early incidence of the disease could also have been related to the comparatively larger quantities of nitrogen in the plant tissue, as compared to the lower nitrogen in the plant reported in the studies of Nair and Pillai (1966). In the case of calcium and magnesium, and phosphorus and potassium, notable differences have been observed in the plant tissue contents of these elements when data from the present studies are compared with those of Nair and Pillai (1966). It would thus appear that the absorption of nitrogen, phosphorus, potassium, calcium and magnesium in the present study has not followed any definite pattern or proportion, and consequently a reproduction of conditions which favoured resistance of the plants to virus infection as in the case of previous sand culture studies, was strictly not possible.

ratio in the leaf for the levels of 0.1% and 0.2% MgO, but the difference for the levels of 0,2% and 0.05% MgO was significant. No significant difference was noticed for the three levels of MgO in the ratio 6:1. In the 9:1 ratio all the three levels of MgO were significant and the highest ratio of CaO/MgO in the leaf was for the MgO level of 0.2% followed by the 0.1% level. The leaf of the control plants had a mean CaO/MgO ratio of 1.88 which was lowest among all the treatments The 0.2% MgO level in the ratio 9:1 resulted in the maximum CaO/MgO ratio in the leaf.

(vii) *$CaO + MgO/K_2O$ ratio:* The data in Table XIII reveal that the $CaO+MgO/K_2O$ ratio in the leafbefore the transmission of virus was significantly higher for the treated plants as compared to the control. The CaO/MgO ratio of 6:1 produced the highest $CaO + MgO/K_2O$ ratio in the leaf while there was no significant difference between the 9:1 and 3:1 ratios. Among the different levels of MgO within the ratio 3:1 the differences were found significant. The level of 0.2% MgO had the highest $CaO + MgO/K_2O$ ratio in the leaf, while the lowest ratio was produced by the 0.1% level. In the 6:1 ratio only the 0.2% MgO level was significant. For the different levels of MgO in the ratio 9:1 significantly higher $CaO+MgO/K_2O$ ratio was found for the 0.2% MgO level followed by the level of 0.1% MgO. The control plants had the minimum $CaO+MgO/K_2O$ ratio of0.52 while all the other treatments had higher ratios. The highest $CaO+MgO/K_2O$ ratio of 0.78 was for the MgO level of 0.2% in the CaO/MgO ratio of 9:1.

TABLE XIII

Mean $CaO+MgO/K_2O$ ratio in the leaf for different CaO/MgO ratios in the soil before the transmission of virus

Level of MgO (per cent)	CaO/MgO ratio in the soil			
	0	3:1	6:1	9:1
0	0.52			
0.05		0.69	0.65	0.63
0.10		0.62	0.65	0.67
0.20		0.73	0.82	0.78
Mean	0.52	0.68	0.71	0.69

CD (5% level) for comparison between ratios — 0.015
Do between levels of MgO within ratios ~ 0.025

Discussion

The possibility of control of Bunchy Top disease of bananas by the manipulation of nutritional environment and the consequent building up of resistance of the plant tissue to virus attack has been a novel line of investigation in this field, initiated as a long-range programme of research of the Principal and Additional Director of Agriculture (Research). Nambiar and Nair

MgO in the 6:1 ratio resulted in higher absorption of magnesium than the 0.05% and 0.1% levels of MgO. In the 9:1 ratio there was higher absorption of magnesium for the 0.05% level of MgO over the 0.1% level. Between the 0.1% and 0.2% levels of MgO there was no statistically significant difference in the absorption of this element. The maximum uptake of 1.07% of this nutrient was for the level of 0.05% MgO in the ratio 3:1, and the lowest absorption of 0.53% for the MgO level of 0.2% in the ratio 9:1. The control plants contained 0.88% MgO.

The data on the uptake of magnesium after the incidence of the disease indicated significant differences between treated and untreated plants. The variations in the absorption of magnesium among the three ratios were also significant, the maximum absorption being for the ratio 3:1 and the minimum for the 9:1 ratio. In the ratio 3:1 the maximum absorption was for the 0.05% level of MgO. There was no difference in the uptake of magnesium between the levels of 0.05% and 0.1% MgO in the ratio 6:1 and both were lower in the absorption of magnesium than the 0.2% MgO level. A similar trend was noticed for the ratio 9:1 also. When the data were further analysed by the covariance technique and adjusted for the magnesium absorbed before the incidence of the disease it was found that there was real variation among the three ratios in the absorption of magnesium.

(vi) *CaO/MgO ratio:* The data in Table XII show that the calcium and magnesium treated plants had significantly higher CaO/MgO ratios than the control. The different ratios of CaO/MgO in the soil also had significant effect on this ratio in the plants. The CaO/MgO ratio in the leaf increased with increase in this ratio in the soil. For the same ratio of 3:1 in the soil it was found that there was no variation in the CaO/MgO

TABLE XII

Mean CaO/MgO ratio in the leaf for different CaO/MgO ratios in the soil before the transmission of virus

Level of MgO (per cent)	CaO/MgO ratio in soil			
	0	3:1	6:1	9:1
0	1.83			
0.05		2.08	3.68	3.70
0.10		2.94	3.67	4.19
0.20		2.96	3.79	5.61
Mean	1.88	2.66	3.71	4.50

C.D (5% level)	for comparison between ratios	—	0.178
Do	between levels of MgO within ratios		0.308

(v) *Magnesium* The results in Table XI reveal that the absorption of magnesium was significantly higher in the calcium and magnesium treated plants as compared to the control. The comparison among the ratios was also significant, the maximum absorption being noticed for the ratio 3:1 followed by the 6:1 ratio. Within the different ratios the absorption of magnesium varied considerably. In the ratio 3:1 the highest absorption was for the level of 0.05% MgO. The level of 0.2%

TABLE XI

Mean MgO content of leaf samples for different CaO/MgO ratios in the soil (per cent on oven dry basis)

Level of MgO (per cent)		CaO / MgO ratio 3:1	6:1	9:1
		Before transmission of virus *		
0				
0.05		1.07	0.66	0.67
0.10		0.76	0.67	0.60
0.20		0.90	0.80	0.53
Mean	0.88	0.93	0.71	0.60
		After incidence of disease **		
0	0.83			
0.05		1.00	0.61	0.62
0.10		0.71	0.65	0.57
0.20		0.85	0.78	0.49
Mean	0.83	0.85	0.68	0.56
		After incidence of disease adjusting for MgO content before transmission of virus		
0	0.72			
0.05		0.74	0.68	0.69
0.10		0.70	0.72	0.69
0.20		0.73	0.74	0.67
Mean	0.72	0.72	0.71	0.68

* C. D. (5% level)	for comparison between ratios	0.040
Do	between levels of MgO within ratios	0.070
** C. D. (5% level)	for comparison between ratios	0.036
Do	between levels of MgO within ratios	0.062
***C. D. (5% level)	for comparison between adjusted means —	0.037

TABLE X

Mean CaO content of leaf samples for different CaO/MgO ratios in the soil (per cent on oven dry basis)

Level of MgO (per cent)	CaO/MgO ratio 0	3:1	6:1	9:1
Before transmission of virus *				
0	1.67			
0.05		2.22	2.48	2.46
0.10		2.24	2.45	2.52
0.20		2.64	3.01	3.01
Mean	1.67	2.37	2.65	2.66
After incidence of disease **				
0	1.58			
0.05		2.05	2.37	2.37
0.10		2.10	2.32	2.46
0.20		2.54	2.91	2.90
Mean	1.58	2.23	2.53	2.58
After incidence of disease adjusting for the CaO content before transmission of virus ***				
0	1.81			
0.05		2.12	2.40	2.40
0.10		2.17	2.33	2.45
0.20		2.59	2.76	2.75
Mean	1.81	2.29	2.50	2.53

* C. D. (5% level) for comparison between ratios 0.034
Do between levels of MgO within ratios 0.058
** C. D. (5% level) for comparison between ratios 0.019
Do between levels of MgO within ratios 0.033
*** C. D. (5% level) for comparison between adjusted means 0.135

was 2.90%. The minimum absorption of 1.58% CaO was for the control plants. Further analysis of the data on calcium uptake after the incidence of the disease adjusting for the calcium uptake before the transmission of virus also showed that there was significant difference between the treated and untreated plants.

(iii) *Potassium:* Data relating to the uptake of potassium before and after the incidence of the disease are presented in Table IX. The variation in the level of K_2O in the treated and untreated plants was found to be significant. The maximum absorption of 4.94% K_2O was in the control plants, while the plants receiving the highest levels of CaO and MgO had the minimum absorption of 4.50%. Significant difference was also seen in the absorption of potassium among the three ratios of CaO/MgO. The maximum absorption before the transmission of virus was for the 3:1 ratio and the least for the ratio 9:1. Further, the difference in the absorption of potassium was significant among the three levels within the ratio 6:1. Though the effects of the levels of MgO at 0.05% and 0.1% were statistically equal within the ratio 9:1, significant difference was noticed for the absorption of potassium between the levels 0.1% and 0.2% MgO.

The statistical analysis of the data on the absorption of potassium after the incidence of the disease revealed significant differences. The ratio 3:1 was superior to the ratio 6:1 and 9:1 for the uptake of potassium. The control plants showed the maximum absorption of 5.24% K_2O while the plants receiving the highest levels of CaO and MgO showed only 4.49%. There was significant difference in the uptake of potassium among the three levels of MgO in the same ratio. The data on the absorption of potassium after the incidence of the disease adjusted for the potassium uptake before the incidence showed that there was significant difference among the various treatments. In this case also the maximum absorption of potassium was for the control plants. The application of calcium and magnesium in increasing doses reduced the absorption of potassium in all the treatments except the one in which CaO and MgO were given in the ratio 3:1 with a MgO level of 0.2%.

(iv) *Calcium*: The data in Table X reveal that the difference in the uptake of calcium by the calcium and magnesium treated plants over control was significant. Of the three ratios of CaO/MgO used, the ratios 9:1 and 6:1 provided significantly higher amounts of calcium in the leaf than the 3:1 ratio. The maximum absorption was for the ratio 9:1 which was closely followed by the ratio 6:1. Comparison of the three levels of MgO in the ratio 3:1 revealed that there was no difference in the uptake of calcium between the levels of 0.05% and 0.1% MgO. But for the level of 0.2% MgO the absorption of calcium was significantly higher than in the other two levels. Similar results were obtained for the different levels of MgO in the ratio 6:1. In the ratio 9:1 all the three levels were statistically significant. Maximum absorption of calcium was seen in the ratios 6:1 and 9:1 with the MgO level 0.2%, while control plants had only the least absorption.

The data on the uptake of calcium after the incidence of the disease indicated that all the calcium and magnesium treated plants had significantly higher calcium absorption than the control plants. The maximum absorption was noted for the ratio 9:1 and the minimum for 3:1. In the same ratio there was significant difference in the absorption of calcium for tbe different levels of magnesium, the maximum absorption being for 0.2% MgO in all the cases. The plants receiving 0.2% level of MgO in the ratio 6:1 had the highest uptake of 2.91% CaO after the incidence of the disease. The uptake of calcium for the level of 0.2% MgO in the 9:1 ratio

TABLE IX

Mean K_2O content of leaf samples for different CaO/MgO ratios in the soil (per cent on oven dry basis)

Level of MgO (per cent)	0	CaO / MgO ratio 3:1	6:1	9:1
		Before transmission of virus *		
0	4.94			
0.05		4.80	4.86	4.69
0.10		4.83	4.77	4.67
0.20		4.83	4.65	4.50
Mean	4.94	4.82	4.76	4.62
		After incidence of disease **		
0	5.24			
0.05		5.20	5.02	4.95
0.10		5.00	4.98	4.88
0.20		5.16	4.90	4.62
Mean	5.24	5.12	4.97	4.82
		After incidence of disease adjusting for the K_2O content before transmission of virus ***		
0	5.22			
0.05		5.19	5.01	4.96
0.10		4.99	4.98	4.89
0.20		5.15	4.91	4,65
Mean	5.22	5.11	4.97	4.83

* C. D, (5% level)	for comparison between ratios	—	0.036
Do	between levels of MgO within ratios		0.061
** C. D (5% level)	for comparison between ratios		0.015
Do	between levels of MgO within ratios	—	0.026
*** C. D. (5% level)	for comparison between adjusted means		0.054

The statistical analysis of the data on the uptake of phosphorus after the incidence of the disease revealed that the absorption of phosphorus was significantly different among the three ratios of CaO and MgO. The maximum absorption was found for the ratio 3:1 followed by the 6:1 ratio. The uptake of phosphorus within each ratio for the three levels of MgO was also significant except for 0.05% MgO level in the ratio 6:1. The analysis of co-variance to find out the actual difference in the absorption of phosphorus after adjusting for the data before the incidence of the disease indicated that there was significant difference among the various treatments. The maximum absorption was for the CaO/MgO ratio of 3:1 at the 0.05% MgO level with the adjusted mean uptake of 0.95% P_2O_5.

TABLE VIII

Mean P_2O_5 content of leaf samples for different CaO/MgO ratios in the soil (per cent on oven dry basis)

Level of MgO (per cent)		CaO/MgO ratio 3:1	6:1	9:1
		Before transmission of virus *		
0	0.93			
0.05		0.97	0.88	0.86
0.10		0.89	0.86	0.82
0.20		0.84	0.80	0.76
Mean	0.93	0.90	0.85	0.81
		After incidence of disease **		
0	0.95			
0.05		0.96	0.93	0.92
0.10		0.93	0.91	0.86
0.20		0.88	0.85	0.80
Mean	0.95	0.92	0.90	0.86
		After incidence of disease P_2O_5 for the nitrogen content before transmission of virus ***		
0	0.94			
0.05		0.95	0.93	0.92
0.10		0.92	0.92	0.87
0.20		0.88	0.85	0.82
Mean	0.94	0.92	0.90	0.87

* C. D. (5% level) for comparison between ratios — 0.027
Do between levels of MgO within ratios 0.048
** C. D. (5% level) for comparison between ratios — 0.015
Do. between levels of MgO within ratios - 0.026
*** C. D. (5% level) for comparison between adjusted means — 0.031

calcium oxide and magnesium carbonate treated plants were found to contain significantly higher levels of phosphorus over the control. Significant differences were also noted in the uptake of phosphorus among the three ratios of CaO/MgO. The highest level of absorption was for the ratio 3:1 and the lowest for the 9:1 ratio, The absorption of phosphorus within the three ratios of CaO and MgO was significant only for the 0.2% level of MgO The maximum uptake of 0.97% P_2O_5 was seen in the ratio 3:1 with 0.05% MgO level.

TABLE VII

Mean nitrogen content of leaf samples for different CaO/MgO ratios in the soil (per cent on oven dry basis)

Level of MgO (per cent)		CaO/MgO ratio 3:1	6:1	9:1
		Before transmission of virus *		
0	3.07			
0.05		3.00	2.78	2.69
0.10		2.81	2.64	2.61
0.20		2.70	2.55	2.51
Mean	3.07	2.84	2.66	2.61
		After incidence of disease		
0	3.28			
0.05		3.15	2.91	2.78
0.10		2.91	2.75	2.68
0.20		2.94	2.62	2.56
Mean	3.28	3.01	2.76	2.67
		After incidence of disease adjusting for the nitrogen content before transmission of virus		
0.	3.15			
0.05		3.06	2.90	2.80
0.10		2.88	2.79	2.73
0.20		2.97	2.69	2.63
Mean	3.15	2.97	2.79	2.72

* C. D. (5 % level) for comparison between ratios 0.022
Do between levels of MgO within ratios 0.039

difference was also noticed in the uptake of nitrogen among the three ratios of CaO/MgO or within the different levels of these nutrients in the same ratio. Further analysis of the data on the absorption of nitrogen after adjusting for the nitrogen uptake before the incidence of the disease also failed to indicate any significant difference among the various treatments. It was clear that the incidence of the disease had brought all plants under the different treatments on a par as far as the uptake of nitrogen was concerned.

(ii) , *Phosphorus* : The data on the absorption of phosphorus by the banana plant before and after the transmission of the virus are presented in Table VIII. The

TABLE VI

Number of days taken for the appearance of disease symptoms after the release of the first batch of aphids

CaO/MgO ratio	Level of MgO (per cent)	Replication I	Replication II	Replication III	Mean number of days
	0	24	24	25	24.33
3:1	0.05	32	25	29	28.67
	0.10	34	28	30	30.67
	0.20	41	34	35	36.67
6:1	0.05	25	30	32	29.00
	0.10	32	41	43	38.67
	0.20	29	25	46	33.33
9:1	0.05	28	30	30	29.33
	0.10	23	28	46	32.33
	0.20	32	25	30	29.00

Summary of analysis of variance

Source	Sum of squares	D. F.	Variance	Variance ratio
Total	1612.80	29		
Replications	178.40	2	89.20	1.67
Treatments	475.46	9	52.83	0.99
Error	958.94	18	53.28	

All the daughter suckers which were allowed to stand after the removal of the pseudostems also contracted primary infection and showed typical Bunchy Top disease symptoms.

3. *Nutrient contents of leaf samples*

(i) Nitrogen '• The data on the mean nitrogen content of the leaf samples before the transmission of the virus and after the incidence of the disease are presented in Table VII. The results indicate that before the inoculation of the virus there was significant variation in the uptake of nitrogen due to treatment effects. The control plants showed a maximum absorption of nitrogen, viz., 3.07% which decreased with increase in the levels of calcium and magnesium. The comparison of the three ratios of CaO/MgO also showed significant difference, the maximum uptake of nitrogen being for the ratio 3:1 followed by the ratio 6:1. The variations in the uptake of nitrogen among the levels of MgO within the three ratios were also significant.

However, the data after the incidence of the disease show no significant difference in the uptake of nitrogen in the calcium oxide and magnesium carbonate treated plants over control. No significant

TABLE V

Mean width of leaves for different CaO/MgO ratios in the soil

CaO/MgO ratio	Level of MgO (per cent)	Mean width of leaves (cm)		
		x	y	z
	0	50.00	29.00	14.17
3:1	0.05	47.17	23.83	13.67
	0.10	47.17	26.33	14.00
	0.20	48.33	35.17	15.50
6:1	0.05	48.33	25.00	14.17
	0.10	50.83	29.33	18.50
	0.20	49.50	31.00	13.83
9:1	0.05	45.83	24.67	14.83
	0.10	51.50	38.83	15.67
	0.20	48.50	25.50	13.00

Summary of analysis of variance

Source	D. F.	Variance ratio		
Total	20			
Replications	2	0.347	1.482	1.257
Treatments	9	0.292	0.858	0.476
Error	18			

x Data on the day of release of first batch of aphids

y ,, removal of pseudostems

z — ,, removal of daughter suckers

TABLE 1V

Mean length of leaves for different CaO/MgO ratios in the soil

CaO/MgO ratio	Level of MgO (per cent)	Mean length of leaves (cm)		
		x	y	z
	0	100.33	116.00	48.83
3 : 1	0.05	100.17	107.67	39.50
	0.10	91.83	108.17	44.67
	0.20	90.33	116.00	43.67
6 : 1	0.05	95.33	106.50	44.33
	0.10	96.67	113.83	51.50
	0.20	98.67	11650	40.50
9 : 1	0.05	84.00	96.17	40.50
	0.10	94.33	122.33	42.00
	0.20	87.33	108.00	38.83

Summary of analysis of variance

Source	D. F.	Variance ratio		
Total	29			
Replications	2	1.459	0.329	1.434
Treatments	9	1.018	0.397	0.580
Error	18			

x — Data on the day of release of first batch of aphids

y — ,, removal of pseudostems

z — ,, removal of daughter suckers

TABLE III

Mean number of leaves for different CaO/MgO ratios in the soil

CaO/MgO ratio	Level of MgO (per cent)	Mean no of leaves		
		x	y	z
	0	9	18	10
	0.05	8	16	14
3: 1	0.10	7	18	12
	0.20	8	16	14
	0.05	9	17	13
6: 1	0.10	8	17	15
	0.20	9	18	11
	0.05	8	18	13
9 1	0.10	9	17	15
	0.20	9	17	14

Summary of analysis of variance

Source	D. F.	Variance ratio		
Total	29			
Replications	2	4.906*	0.559	0.142
Treatments	9	1.219	1.060	1.201
Error	18			

* Significant at 5% level

x - Data on the day of release of the first batch of aphids

y - ,, removal of pseudostems

z - ,, removal of daughter suckers

TABLE II

Mean girth of plants for difiFeront CaO/MgO ratios in the soil

CaO/MgO ratio	Level of MgO (per cent)	Mean girth of plants (cm)		
		x	y	z
	0	31.50	56.50	22.00
3:1	0.05	27.67	47.50	25.83
	0.10	25.50	49.33	25.00
	0.20	27.33	46.50	26.83
6:1	0.05	29.17	51.00	24.67
	0.10	28.00	47.33	28.83
	0,20	30.00	51.33	21.50
9:1	0.05	26.57	46.83	25.50
	0.10	27.83	48.67	26 50
	0.20	27.33	50.83	20.67

Summary of analysis of variance

Source	D. F	Variance ratio		
Total	29			
Replications	2	0.071	0.276	0.138
Treatments	9	0.547	1.036	0.211
Error	18			

x — Data on the day of release of the first batch of aphids

y - „ removal of pseudostems

z - „ removal of daughter suckers

TABLE I

Mean height of plants for different **CaO/MgO** ratios in the soil

CaO/MgO ratio	Level of MgO (per cent)	Mean height of plants (cm)		
		x	y	z
	0	111.33	200.85	68.17
3 : 1	0.05	103.50	170.33	47.17
	0.10	95.50	172.33	67.67
	0.20	99.00	168.50	67.33
6: 1	0.05	100.33	178.17	63.50
	0.10	106.17	176.50	66.50
	0.20	105.00	191.17	59.33
9 : 1	0.05	94.00	174.00	63.50
	0.10	100.61	175.83	61.83
	0.20	94.17	171.17	48.17

Summary of analysis of variance

Source	D. F	Variance ratio		
Total	29			
Replications	2	0.174	0.556	1.789
Treatments	9	0.326	0.342	0.345
Error	18			

x — Data on the day of release of the first batch of **aphids**

y — ,, removal of **pseudostems**

removal of daughter suckers

gallons per plant. A low temperature and humid conditions congenial for aphid population was maintained by providing a canopy over the experimental plot with bamboo poles and coconut leaves one day prior to the release of the aphids. The infective aphids were released on 27-10-1965 in the topmost leaf axil of plants at the rate of 50 aphids. To ensure the chances for infection the aphids were released a second time after 7 days at the same rate The canopy was removed on 6-11-1965 and Folidol E. 605 (0.05%) was sprayed immediately to destroy the aphids.

The following growth characters of the plants were recorded at weekly intervals :

(i) Height of plants as measured from the base of the pseudostem to the apex ;

(ii) The girth of plants near the base of the pseudostems ;

(iii) The number of leaves that had fully opened and

(iv) The length and maximum width of leaves.

The development of the disease was watched by observing the following symptoms :

(i) Presence of irregular, modular, dark green streaks along the petiole, lamina and mid-rib;

(ii) Shortening of the length and width of leaf;

(iii) Curling up of leaf margins, scorching, brittle ness and splitting of the leaf blade and

(iv) Reduction in the length of the petiole, erect position of the leaf and Bunchy Top.

The number of days taken for the appearance of disease symptoms under each treatment was noted separately. Chemical analysis of leaves before and after the transmission of the virus was also carried out. The first samples were collected 3 days before the release of aphids and the second samples 63 days afterwards. Nitrogen was estimated by the Kjeldahl method as given by Piper (1950). Phosphorus and potassium were determined by the method adopted by the A. 0. A. C. (1960). The versenate method as given by Jackson (1958) was followed for the estimation of calcium and magnesium.

Results

1. *Growth characters*

The mean growth measurements taken on rhe day of release of aphids, the day of lopping off of pseudostems and on the day of removal of the daughter suckers are given in Tables I–V. Statistical analysis showed that the data under the different treatments were not significantly different indicating that all the plants had equal growth rate.

2. *Number of days taken for the appearance of disease symptoms*

The number of days taken for the appearance of the disease symptoms on the plants are given in Table VI. Statistical analysis of the data shows that there is no significant difference between the treatments in respect of the time required to produce disease symptoms. However, it is noteworthy that the control plants contracted the disease earlier than the treated plants. The CaO/MgO ratio of 6:1 with 0.1% ' MgO level delayed the incidence of the disease by a maximum period of 15 days on an average over the control plants.

1.	CaO 0.0% and MgO 0.0%	Control
2.	CaO 0.6% and MgO 0.1%	6 : 1 ratio
3.	CaO 1.2% and MgO 0.2%	"
4.	CaO 0.3% and MgO 0.05%	"
5.	CaO 0.3% and MgO 0.1%	3 : I ratio
6.	CaO 0.6% and MgO 0.2%	
7.	CaO 0.15% and MgO 0.05%	
8.	CaO 0.9% and MgO 0.1%	9 : 1 ratio
9.	CaO 1.8% and MgO 0.2%	"
10.	CaO 0.45% and MgO 0.05%	

In addition to the above treatments all plants received a basal application of farmyard manure (0.57% N, 0.34% P_2O_5, 0.49% K_2O, 0.55% CaO and 0.05% MgO) at the rate of 75 kg per plant, ammonium sulphate (20.3% N) at 900 g, superphosphate (16.2% P_2O_5) at 1360 g and muriate of potash (50.4% K_2O) at 1360 g. Micronutrients were also applied in the form of copper sulphate, ferrous sulphate, manganese sulphate, zinc sulphate and sodium borate at the rate of 12 g of each chemical per plant and ammonium molybdate at the rate of half a gram. The calcium and magnesium contents of the soil and manure were taken into account in applying calcium and magnesium in the different ratios. Calcium oxide of 56.8% purity and magnesium carbonate of 36.7% MgO content were used for the experiment.

Reinforced concrete rings of diameter 1 m and length 1.5 m with a capacity of one ton soil were implanted in the experimental plot at a distance of 2.5 m centre to centre either way for planting the banana suckers. The banana variety used was *Nendran* which is known to be highly susceptible to Bunchy Top disease. The suckers (average weight 2 kg and girth 30 cm) were collected from a disease-free plantation in the vicinity of the Agricultural College and Research Institute, Vellayani.

The soil collected from the rings after driving them into the ground was thoroughly mixed and a representative sample analysed for its mechanical and chemical composition. It was found to be a sandy clay loam containing 0.06% N, 0.07% P_2O_5, 0.09% K_2O, 0.27% CaO and 0.08% MgO. One ton of the soil was refilled into each ring upto the ground level. Banana suckers were planted at a depth of 25 cm in the centre of the rings on 31-8-1965. The pseudostems of all plants were cut off on 29-12-1965 to study the performance of the daughter suckers.

The entire quantity of farm yard manure and half the dose of fertilisers and micronutrients were applied as basal dressing. The rest of the fertilisers was applied in two equal split doses 60 and 150 days after planting. The balance of the trace elements was given after 90 days. Calcium oxide and magnesium carbonate were applied in eight equal doses at 30 day intervals from 28-8-1965. Thus one fourth the total quantity of fertilisers and one half the total dose of calcium oxide and magnesium carbonate benefited only the daughter suckers.

Light irrigation was given daily for one month for the proper sprouting of the suckers. Thereafter the plants were watered on alternate days at ths rate of 5