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

PART II. SIGNIFICANCE OF CALCIUM/MAGNESIUM RATIO IN THE NUTRIENT MEDIUM AND IN THE PLANTS*

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The 'Bunchy Top' is the most devastating of diseases infesting the banana plant. In view of its seriousness and the heavy loss incurred by banana growers, a long range programme of research was initiated in 1962 at the Agricultural College and Research Institute, Vellayani, as a research project of the Principal & Additional Director of Agriculture (Research) to investigate whether the nutritional status of the soil acts as a predisposing factor in its incidence. Earlier studies had shown that the appearance of the disease symptoms was delayed significantly by application of calcium and magnesium. (Nambiar and Nair, 1965) The present study was undertaken to investigate the possibility of further delaying or completely arresting the disease by application of different forms and levels of these elements.

Review of Literature

A detailed discussion of the history of the Bunchy Top disease and its distribution is included in the work of Nambiar (1963). It has now been established that the causative organism is a virus and that its vector is the banana aphid, *Pentalonia nigronervosa* (Goddard, 1925; Magee, 1927; Hutson and Malcom, 1930). According to Magee (1953) there are two types of infection, the primary and the secondary. Primary infection is caused by the planting of diseased suckers, whereas in secondary infection, plants which are initially healthy contract the disease at some later stage in its growth. Primary infected plants never grow to maturity to form fruits, while secondary infected ones may or may not form a bunch depending on the stage of growth at which the infection takes place.

Except for the original investigation of Nambiar and Nair (1965) very little work has been reported in literature on the host nutrition of banana in relation to the Bunchy Top disease. These authors found that the soils of the highly infected areas in Kerala generally contained a higher level of nitrogen and also observed higher percentages of this element in the diseased leaf samples. The increased susceptibility of various crops to virus diseases as a result of enhanced nitrogen nutrition has been

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reported by several workers (Spencer, 1942; Chessin, 1957; and Sasthry and Nariani, 1962).

As regards the relationship between the incidence of Bunchy Top disease and phosphorus nutrition, Nambiar and Nair (1965) noted that the available phosphoric acid content of the soils in the diseased areas was considerably higher than that ofthe healthy areas. The leaves of the diseased plants also contained a higher level of this element. According to Bawden and Kassanis (1947) phosphorus is more important than nitrogen in increasing susceptibility, for in the absence of adequate phosphorus, increasing levels of nitrogen reduce the concentration of virus in the plant. The relationship between phosphorus nutrition and the susceptibility of crops like tobacco and sunnhemp to virus diseases has been investigated by Sasthry (1962). Sasthry and Nariani (1962), Sasthry and Vasudeva (1963) and by Varma (1963).

Potassium is often credited with imparting disease resistance to plants. In his study of the tobacco mosaic virus Sasthry (1962) observed that the number of local lesions was maximum at low potassium levels. Sasthry and Nariani (1962) found that with no potassium there was increased percentage of infection of tobacco curl virus, while at higher levels of this element there was a slight decrease in the incidence of the disease. Nambiar and Nair (1965) noted a higher concentration of total and available potassium in soils of healthy areas as compared to diseased areas. It was also observed that there was a higher percentage of this element in the diseased plants as well, which they attributed to impaired translocation consequent on physiological disturbances occurring as a result ofvirus infection.

The importance of calcium in plant nutrition is evident from the fact that in the absence of this element miotic division becomes aberrant and suppressed (Sorokin and Sommer, 1940). According to Srivastava (1963) calcium is effective in improving the growth of the banana plant in all its aspects, such as the fresh weight of roots, leaves and stems, the leaf area and the dry weight of the leaves, Ramakrishnan and Damodaran (1956) noted that liming the soil helped to reduce the period of viability of the Panama wilt disease from four to two months. Nambiar and Nair (1965) have reported that soils of Bunchy Top disease free areas contained a higher level of total and exchangeable calcium Further, the calcium content of the healthy plants was higher than that of the diseased ones.

The deficiency of magnesium in banana is known to manifest itself in a pronounced compression of young leaves which start unfurling before they have emerged completely from the sheathing leaf base. Nambiar and Nair (1965) found that the soils of disease free areas contained appreciably higher levels of total and exchangeable magnesium. The leaves of healthy plants also contained a higher level of this element and they have reported that the application of magnesium alone had a beneficial effect in delaying the incidence of the disease. According to Cook (1950) the tapering disease of coconut is caused by a deficiency of this element. The relationship between magnesium nutrition and the incidence of the virus disease of other crops has been investigated by Alvin (1950), Chessin and Scott (1955), Hoveland *et al* (1958) and by Varma (1964)

The ratio of calcium to magnesium has been found to be important in the incidence of plant diseases Brunich (1923) carried out the analysis of a number of soil samples in relation to the incidence of the Bunchy Top disease and found that soils from severely affected plots contained a large excess of magnesium over calcium. According to Jones (1950) a MgO/CaO ratio of more than one is generally harmful to plants. Garman and Mattis (1956) found that a low calcium-magnesium ratio of leaf compared to that of fruit is associated with the occurrence of 'Bitter pit* (Baldwin spot) of apples. Nambiar and Nair (1965) observed that the ratio of calcium and magnesium to potassium was lower in the leaves of Bunchy Top affected banana plants as compared to healthy ones. They found that a treatment combination of calcium and magnesium helped to delay the development of symptoms by 46 days over control

Materials and Methods

To study the effect of different forms and levels of calcium and magnesium on the incidence of the Bunchy Top disease of banana, an experiment was laid out in randomised block design with the following 21 treatment combinations in three replications

1. NPK
2. NPK + CaO
3. NPK + $CaCO_3$
4. NPK + $MgCO_3$ (I)
5. NPK + $MgSiO_3$ (I)
6. NPK + $MgSO_4$ (I)
7. NPK + CaO + $MgCO_3$ (I)
8. NPK + CaO + $MgSiO_3$ (I)
9. NPK + CaO + $MgSO_4$ (I)
10. NPK + $CaCO_3$ + $MgCO_3$ (I)
11. NPK + $CaCO_3$ + $MgSiO_3$ (I)
12. NPK 4 $CaCO_3$ + $MgSO_4$ (T)
13. NPK + $MgCO_3$ (II)
14. NPK + $MgSiO_3$ (II)
15. NPK + $MgSO_4$ (II)
16. NPK + CaO + $MgCO_3$
17. NPK + CaO + $MgSiO_3$ (II)
18. NPK + CaO 4 $MgSO_4$ (II)
19. NPK + $CaCO_3$ + $MgCO_3$ (II)
20. NPK + $CaCO_3$ + $MgSiO_3$ (II)
21. NPK + $CaCO_3$ + $MgSO_4$

The rates at which the nutrients were applied were as follows :

Nitrogen	500 g	N per plant	
Phosphorus	500 g	P_2O_5	
Potassium	500 g	K_2O	
Calcium	1000 g	CaO	
Magnesium (I)	150 g	MgO	,,
(II)	750 g	MgO	,,

N, P and K were supplied in the form of a mixture (1 : 1 : 1) consisting of ammonium sulphate, superphosphate and muriate of potash, and analysing 9.30 per cent CaO. Calcium was supplied in two forms, commercial calcium oxide (86.38% CaO and 2.45% MgO) and calcium carbonate (36,98% CaO and 1.53% MgO). Magnesium carbonate, magnesium silicate and magnesium sulphate used were also of commercial grade containing 32.54, 17,38 and 15.36 per cent MgO respectively. In addition to these treatments the micronutrients were applied in the form of chemically pure manganese sulphate, zinc sulphate, copper sulphate, ferrous sulphate, molybdic acid and boric acid so as to supply per plant 3 g Mn, 3 g Zn, 3 g Cu. 3 g Fe, 1,5 g Mo and 1.5 g B respectively.

Reinforced concrete pots of size 60 cm diameter and 60 cm height were used in this study. Coarse grained beach sand from Cape Comorin, washed several times with water to remove soluble salts and nutrients, was used to fill the pots. The banana variety used was *Nendran*, which is known to be highly susceptible to Bunchy Top disease. The suckers used as planting material were procured from a disease free plantation in Kulasekaram.

The pots were arranged at a distance of 2.5 01 from one another. The holes at the bottom of the pots were plugged with glass wool and the pots were filled with granite pieces to a depth of about 5 cm from the bottom. Above this layer each pot was filled with 150 kg of sand mixed with 9 kg of farm yard manure (0.54% N, 0.33% P_2O_5, 0.47 % K_2O, 0 57 % CaO and 0 04 % MgO). There was a clearance of about 7.5cm above the sand.

On 25-8-1964 the banana suckers were planted at a depth of about 23 cm at the centre of the pot after scooping out the sand. The NPK mixture, micro-elements, calcium and magnesium were applied in eight split doses at intervals of 11 days. The first application of calcium and magnesium commenced on the 11th day and that of the NPK mixture and trace elements on the 12th day of planting. The application of the 8 split doses was completed by the 89th day. To the plants which survived beyond this period additional dose of NPK was given at a total rate of 2.1 kg per plant in 28 instalments at intervals of four days. The fertilisers were applied around the plants after removing the sand to a depth of 5 cm (2") with the least possible injury to the roots. The micro-elements were applied through the irrigation water.

The suckers were watered lightly on the day of planting. For the first two months watering was done twice daily, later increasing it to six times a day. The quantity of water was adjusted to moisten the sand, but not to leak out through the hole at the bottom. Each plant was given three gallons of water daily.

The vector of the virus, *Pentalonia nigronervosa*, was reared on healthy plants in another area and then allowed to feed on diseased plants for seven days. They were then collected and starved for 24 hours before use for transmission of virus. To provide optimum temperature and humidity conditions for infection by the virus, a temporary canopy with coconut leaves was erected over the plants two days prior to inoculation. Each plant was further protected with baskets made of plaited coconut leaves mounted on a tripod stand. To ensure a satisfactory humidity level, the ground was moistened twice a day for seven days, two days before and five days after the inoculation. The temperature below the canopy was found to be 25°C. Twenty infective aphids were released on each plant on 12-10-1964, forty seven days after planting. The aphids were allowed to feed on the plants for five days and then destroyed with a spray of endrin.

The following growth characters were recorded at weekly intervals:

(i) The height of plants as measured from the surface of the sand to the apex of the crown;

(ii) The girth of the plant at the base;

(iii) the number of leaves that had emerged and fully opened; and

(iv) the length and maximum width of the leaves.

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

(i) Formation of chlorotic streaks and dots on the petiole, leaf blade and midrib;

(ii) the upright position of leaves, curling of leaf blades and brittleness;

(iii) shortening of the leaf in length and width; and

(iv) reduction in further growth and elongation of petiole.

The fifth leaf that emerged after the inoculation of the vector was used for chemical analysis. The leaves from the three replications were separately dried, powdered and sampled. Nitrogen was estimated by the Kjeldahl method as outlined by Piper (1958). Phosphorus, calcium and magnesium were estimated by methods adopted by the A. 0. A. C. (1958).

Results

7. *Growth characters*

Table I gives the average growth measurements of the plants on the day of inoculation of the virus. Details of the same characters at the time of appearance of symptoms and at the final observation are presented in Tables II and III.

TABLE I

Average growth measurements of the banana plants under various treatments on the day of inoculation of the virus

	Treatment	Height cm	Girth cm	No. of leaves	Length of leaf cm	Width of leaf cm
1.	NPK	56.7	18.8	4.2	50.0	31.66
2.	NPK+CaO	55.3	19.2	40	42.6	22.20
3.	$NPK+CaCO_3$	56.0	19.3	5.0	61.0	34.50
4.	$NPK+MgCO_3$ (I)	44.3	15.0	4.0	51.6	26.33
5.	$NPK+MgSiO_3$ (I)	55.0	18.3	4.6	57.0	34.66
6.	$NPK+MgSO_4$ (I)	49.7	16.0	3.0	55.6	32.00
7.	$NPK+CaO+MgCO_3$ (I)	48-0	18.0	4.3	53.2	33,50
8.	$NPK+CaO+MgSiO_3$ (I)	53.0	16.7	4.3	48.5	28.66
9.	$NPK+CaO+MgSO_4$ (I)	43.7	160	4.3	50.0	26.00
10.	$NPK+CaCO_3+MgCO_3$ (I)	52.7	17.3	4-3	64.3	36.33
11.	$NPK+CaCO_3+MgSiO_3$ (I)	65.0	21.7	3.0	55.4	35.00
12.	$NPK+CaCO_3+MgSO_4$ (I)	51.0	15.3	3.3	47.7	29.30
13.	$NPK+MgCO_3$ (II)	53.0	18.3	4,6	61.5	33.20
14.	$NPK+MgSiO_3$ (II)	51.0	17.0	4.0	53.0	32.30
15.	$NPK+MgSO_4$ (II)	49.7	16.3	4.0	47.6	2883
16.	$NPK+CaO+MgCO_3$ (II)	52.3	16.7	4.6	57.3	33.00
17.	$NPK+CaO+MgSiO_3$ (II)	53.7	16.[illegible]	5.0	57.0	34 00
18.	$NPK+CaO+MgSO_4$ (II)	53.3	18.0	4,3	54.0	32.00
19.	$NPK+CaCO_3+MgCO_3$ (II)	48.3	16.3	3.6	56.5	29.50
20.	$NPK+CaCO_3+MgSiO_3$ (II)	49.0	16.3	4.0	57.4	34,20
21.	$NPK+CaCO_3+MgSO_4$ (II)	49,0	16.3	3.6	55.0	33.66

TABLE II

Average growth measurements of the banana plants under various treatments at the time of appearance of symptoms

Treatment	No. of days from inoculation	Height cm	Girth cm	No. of leaves	Length of leaf cm	Width of leaf cm
1. NPK	41.0	70.3	22.2	9.0	64.3	35.0
2. NPK + CaO	56.3	63.5	20.0	10.0	69.5	33.5
3. NPK + $CaCO_3$	59.3	75,5	22.5	10.5	59.5	25.5
4. NPK + $MgCO_3$ (I)	38.6	53.6	16.8	8.0	52.6	28.0
5. NPK + MgSiOs CD	43.0	60.0	17.5	8.0	61.0	32,0
6. NPK + $MgSO_4$ (0	65.3	59.0	20.8	8.0	63.0	35.0
7.* NPK + CaO + $MgCO_3$ (I)	240.0	191.0	55,3	32.0	146.0	59.0
8, NPK + CaO + $MgSiO_3$ (0	74.0	80.0	23.0	11.0	79.0	38.0
9, NPK + CaO + $MgSO_4$ (I)	51.3	61.2	19.0	11.3	62.0	30.0
10. NPK + $CaCO_3$ + $MgCO_3$ (I)	88.0	88.6	22.0	14.6	85.6	48.0
11. NPK + $CaCO_3$ + MgSiO (I)	54.3	85.0	25.2	10.3	71.6	29.3
12. NPK + $CaCO_3$ + $MgSO_4$ (I)	45.3	66.3	30.3	8.0	65.3	32.3
13. NPK + $MgCO_3$ (II)	45.6	66.6	30.6	9.6	58.0	28.0
14, NPK + $MgSiO_3$ (II)	42.3	66.3	21,0	9.0	57.6	28.3
15. NPK + $MgSO_4$ (II)	46.3	63.0	20,3	8.6	56.0	27.3
16. NPK + CaO + $MgCO_3$(II)	71.0	80.9	23.5	11.6	83.3	43.0
17. NPK + CaO + $MgSiO_3$ (ID	58.3	73,3	21.0	10.6	75.0	42.0
18. NPK + CaO $MgSO_4$ (ID	42,6	70.6	20.5	9.0	65.0	33.0
19. NPK + $CaCO_3$ + $MgCO_3$ (II)	43.3	65,0	20.3	8.6	61.3	27,3
20. NPK + $CaCO_3$ + MgSiO (II)	47.3	82.0	23.0	103	75.0	38.5
21. NPK + $CaCO_3$ + $MgSO_4$ (II)	51.3	64.5	18.6	9.3	57.6	26.0

* Data on the date of emergence of bunch

TABLE III

Average growth measurements of the banana plants under various treatments at final observation

Treatment	No. of days from planting	Height cm	Girth cm	No. of leaves	Length of leaf cm	Width of leaf cm
1. NPK	130	73.0	22.8	12.3	34.6	14.0
2. NPK+CaO	130	67.0	21.0	14.5	24.0	10.0
3. $NPK+CaCO_3$	130	76.0	22.7	14.0	31.5	9.0
4, $NPK+MgCO_3$ (I)	130	57.3	19.3	13.3	24.3	11.0
5. $NPK+MgSiO_3$ (I)	130	61.0	25.8	13.0	23.3	10.6
6. $NPK+MgSO_4$ (I)	130	63.0	21.0	13.0	23.0	10,0
7.* $NPK+CaO+MgCO_3$ (I)	240	191.0	55.3	32.0	146.0	59.0
8. $NPK+CaO+MgSiO_3$ (I)	130	80.0	23.0	13.0	44.0	28.0
9. $NPK+CaO+MgSO_4$ (I)	130	62.0	19,3	14,6	32.0	14.0
10. $NPK+CaCO_3+MgCO_3$(I)	160	91.8	26.2	17.3	53.0	31.3
11. $NPK+CaCO_3+MgSiO_3$ (I)	130	86.3	26.0	12.6	45 3	11.0
12. $NPK+CaCO_3+MgSO_4$ (I)	130	69.0	21.2	11.6	27.6	8.6
13. $NPK+MgCO_3$ (II)	130	67.6	21.6	146	17.6	11.3
14. $NPK+MgSiO_3$ (II)	130	77.3	21.6	12.6	28.3	8.6
15. $NPK+MgSO_4$ (II)	130	63.5	20.8	12.6	29.0	10.6
16. $NPK+CaO+MgCO_3$ (II)	130	82.2	24.3	14.3	64.0	27.6
17. $NPK+CaO+MgSiO_3$ (II)	130	73.6	21.5	12.6	42.6	16.0
18. $NPK+CaO+MgSO_4$ (II)	130	73.0	21.3	13.0	34.0	9.3
19. $NPK+CaCO_3+MgCO_3$ (II)	130	67.0	21.0	13.6	30.3	11.3
20. $NPK+CaCO_3+MgSiO_3$ (II)	130	83.5	23.5	12.0	36.0	14.5
21. $NPK+CaCO_3+MgSO_4$ (II)	130	64.3	19.2	11.0	36.0	11.3

* Data on the date of emergence of bunch.

The data in Table I indicate that the growth measurements of plants under the various treatments are not significantly different. Table II shows that the growth of the plants was almost uniform till the time of infection. After the appearance of symptoms, however, there was considerable difference in the rate of growth of the plants under the different treatments. The data in Table III show that the plants under treatment 7 (calcium oxide + magnesium carbonate at lower level), treatment 10 (calcium carbonate + magnesium carbonate at lower level) and treatment 16 (calcium oxide + magnesium carbonate at higher level) showed better growth than the others at the time of the final observation, the maximum growth being for plants under treatment 7.

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

Table II shows the average number of days **taken** for the appearance of the disease symptoms after the release of **aphids.** The data reveal that treatment 7 (calcium oxide + magnesium carbonate at the lower level) delayed the disease to a considerable period viz., 199 days over control. Treatment 10 (calcium carbonate and magnesium carbonate at lower level) was the next best which delayed the disease by 47 days and this difference was also significant. Treatment 8 (calcium **oxide+magnesium** silicate at the lower level) also showed a trend of delaying the disease viz., by 34 days over control, though this difference was not **statistically** significant.

TABLE IV

Comparison of different forms and levels of calcium and magnesium in relation to the incidence of Bunchy Top disease

Comparison *		Mean no. of days for appearance of symptoms	Critical diff.	Inference*
No Calcium	Ca_0	46.01		
vs			3.84	Ca Ca_0
Calcium	Ca	70.25		
Calciumoxide	CaO	84.80		
vs			11.72	Ca^1 Ca"
Calcium carbonate	$CaCO_3$	55.50		
Magnesium	$MgCO_3$	87.75		
between	$MgSiO_3$	53.20	11.72	Mg^1 Mg" Mg^{111}
forms	MgSO<	50.30		
Magnesium	Mg_0	52.20		
carbonate	Mg,	122.20	11.72	Mg_1 Mg_2 Mg_0
between levels	Mg_2	53.30		
Magnesium	Mgo	52.20		
silicate between	Mg_1	57.10	11,72	Mg_1 Mg_0 Mg_2
levels	Mg_2	49.30		
Magnesium	Mg_0	52.20		
sulphate	Mg_1	53.87	11.72	Mg_1 Mg_0 Mg_2
between levels	Mg_2	46.73		

* Ca_0 - No calcium
Ca — Calcium treated
Ca^1 Calcium oxide
Ca" — Calcium carbonate

Mg_0 – No magnesium.
Mg_1 Magnesium at lower level.
Mg_2 _ Magnesium at higher level-
Mg^1 — Magnesium carbonate.
Mg" Magnesium silicate.
Mgl" — Magnesium sulphate.

Table IV gives the summary of the results relating to the effects of different forms and levels of calcium and magnesium on the incidence of the disease. The application of calcium delayed infection by 24 days over no calcium and the difference was significant. Among the different forms of calcium used, calcium oxide delayed the symptoms by an average of 29 days over the calcium carbonate treatment. When the different forms of magnesium are compared it is seen that magnesium carbonate delayed the incidence of the disease by a significant period of 38 days over magnesium sulphate. Magnesium silicate and magnesium sulphate do not differ significantly in their effect on delaying the incidence. Among the different levels of magnesium in the various forms it is found that magnesium at the lower level delays the incidence of the disease considerably, while there is no perceptible effect for the treatment at the higher level. The difference in the effects due to magnesium levels when applied in the sulphate form is not significant. Magnesium carbonate at the iower level delays the incidence of the disease by 69 days over the highest level and by 70 days over no magnesium treatment.

3. *Nutrient content of leaf*

Data relating to the nutrient contents of the leaf samples of plants under the various treatments are given in Tables V, VI. and VII.

(i) Nitrogen

The nitrogen content of the plants which received calcium treatment is significantly higher than that of the plants which received no calcium. Between the different forms of calcium used, calcium carbonate treated plants contained significantly more nitrogen than those which received the calcium oxide treatment. In the magnesium treated plants, the highest uptake of nitrogen is observed for the lowest level of magnesium applied. For the different forms of magnesium tried, the nitrogen content of leaves decreased in the order, magnesium sulphate, magnesium silicate and magnesium carbonate.

(ii) Phosphorus

Leaf samples of plants receiving no calcium contained significantly higher levels of phosphorus over those which received calcium. As for the effect of the form in which this element was supplied, it is noted that calcium carbonate treated plants contained significantly higher levels of phosphorus over the plants receiving calcium oxide. There is considerable variation in the uptake of phosphorus for the different treatments of magnesium. The lowest uptake is noted for the lower level of this element, the higher and lower levels of magnesium application resulting in higher absorption of phosphorus Among the different forms of magnesium used, the phosphorus uptake is found to vary in the ascending order with the magnesium carbonate, magnesium silicate and magnesium sulphate treatments.

(iii) Potassium

The data in Table Vt indicate that the treatment with calcium results in decreased absorption of potassium and that calcium carbonate treated plants contain appreciably more potassium than those which received calcium oxide. From Table VII it is seen that the potassium content in magnesium sulphate treated plants is higher than that in the silicate and carbonate treated ones, and the difference is significant. Irrespective of the form of magnesium, the highest uptake of potassium is noted for the highest level of magnesium application.

TABLE V

Composition of the leaf samples
(Expressed as per cent on oven dry basis)

	Treatment	N	P_2O_5	K_2O	CaO	MgO
1.	NPK	2.93	0.77	3.73	1.27	0.35
2.	NPK + CaO	2.69	0.67	3.45	2.33	0.40
3.	NPK + $CaCO_3$	2,69	0.65	3.40	1.96	0.38
4.	NPK + $MgCO_3$ (I)	2.91	0.69	3.66	1.33	0.78
5.	NPK + $MgSiO_3$ (I)	2.87	0.72	3 69	1.30	0.68
6.	NPK + $MgSO_4$ (I)	2.76	0.67	3.48	1.29	0.65
7.	NPK + CaO + $MgCO_3$ (I)	2.26	0.51	2.94	2.60	0.69
8.	NPK + CaO + $MgSiO_3$ (I)	2.45	0.63	3.27	2.13	0.67
9.	NPK + CaO + $MgSO_4$ (I)	2.72	0.65	3.68	1.70	0.52
10.	NPK + $CaCO_3$ + $MgCO_3$ (I)	2.45	0.56	3.08	2.35	0.68
11.	NPK + $CaCO_3$ + $MgSiO_3$ (I)	2.68	0.66	3.64	1.77	0.56
12.	NPK + $CaCO_3$ + + $MgSO_4$ (I)	2.64	0.74	3.80	1.69	0.56
13,	NPK + $MgCO_3$ (II)	2.68	0 76	3.68	1.27	0,75
14.	NPK + $MgSiO_3$ (II)	2.89	0.79	3.80	1.24	0.73
15.	NPK + $MgSO_4$ (II)	2.89	0.76	3.36	1.24	0.70
16.	NPK + CaO + $MgCO_3$ (II)	2.55	0.68	3.36	2.70	0.78
17.	NPK + CaO + $MgSiO_3$ (II)	2.57	0 71	3.48	2.24	0.73
18.	NPK + CaO + $MgSO_4$ (II)	2.92	0.77	3.73	2.42	0.73
19	NPK + $CaCO_3$ + $MgCO_3$ (II)	2.90	0.78	3.74	2.24	0.78
20.	NPK + $CaCO_3$ + $MgSiO_3$ (II)	2.71	0.75	3.55	2.23	0,77
21.	NPK + $CaCO_3$ + $MgSO_4$ (II)	2.83	0.75	3.68	2.33	0.76
	Critical difference	0.0049	0.01	0.005	0013	0.009

Inference :

Nitrogen : 1, 18, 4, 19, 14, 15, 5, 21, 6, 9, 20, 2, 3, 13, 11, 12, 17, 16, 8, 10, 7

Phosphorus: 14, 19, 1, 18, 13, 15, 20, 21, 12, 5, 17, 4, 16, 2, 6, 11, 3, 9, 8, 10, 7

Potassium : 12, 14, 19. 1, 18, 5, 15, · 13, 21, 4, 11, 20, 6. 17, 2, 3, 16, 8, 10, 7

Calcium : 16, 7, 18, 10, 21, 17, 19, 20, 8, 3, 11, 9, 12, 2, 4, 5, 6, 1, 13, 14, 15

Magnesium : 4, 16, 19, 20, 21, 13, 14, 17, 18, 15, 7, 5, 10, 8, 6, 11. 12, 9, 2, 3, 1

TABLE VI

Comparision of different forms and levels of calcium in relation to the composition of the leaves of plants

Nutrient		Ca_0	Comparison *: No calcium vs calcium	Ca	Ca^{1}	Comparison *: Calcium oxide vs calcium carbonate	Ca''
1. Nitrogen	Mean	2.85		2.65	2.58		2.70
	C. D.		0.022			0.067	
	Inference		Ca_0Ca			$Ca^{11}Ca^{1}$	
2. P_2O_5	Mean	0.74		0.68	0.[illegible]6		0 70
	C. D.		0.015			0.015	
	Inference		Ca_0Ca			$Ca^{11}Ca^{1}$	
3. K_2O	Mean	3.68		3.49	3.56		3.42
	C. D.		0.059			0.180	
	Inference		Ca_0Ca			$Ca^{1}Ca^{11}$	
4. CaO	Mean	1.42		2,12	2.16		2.07
	C. D.		0.065			0.180	
	Inference		$CaCa_0$			$Ca^{1}Ca^{11}$	
5. MgO	Mean	0.66		0.64	0.65		0 64
	C. D.		0.0045			0.0045	
	Inference		Ca_0Ca			$Ca^{1}Ca^{11}$	

* Ca_0 No calcium

Ca Calcium treated

Ca^{1} Calcium oxide

Ca^{11} Calcium carbonate

fiv) ***Calcium***

From the data in Table VI it may be noted that in calcium treated plants the level of this element is nearly 50 per cent more than those that do not receive the treatment. Between the two forms of calcium tried, the uptake of calcium is significantly higher in the calcium oxide treated plants than in the calcium carbonate treated ones. Among the different forms of magnesium tried the uptake of calcium was highest with the carbonate and it decreased for the magnesium silicate and sulphate treatments.

TABLE VII

Comparison of different forms and levels of magnesium in relation to the composition of the leaves of plants

Nutrient		Mg between forms *			$MgCO_3$ between levels **			$MgSiO_3$ between levels			$MgSO_4$ between levels		
		Mg^{1}	Mg^{11}	Mg^{111}	Mgo	Mg_1	Mg_2	Mg_0	Mg_1	Mg_2	Mgo	Mg_1	Mg_2
1. Nitrogen	Mean	2.63	2.70	2.79	2.77	254	2.71	2.77	2.67	2 72	2.77	2 71	2.88
	C. D.		0.067			0.067			0.067			0.067	
	Inference	$Mg^{111}Mg^{11}Mg^{1}$			Mg_0 Mg_2 Mg_1			Mgo Mg_2 Mg_1			Mg_2 Mg_0 Mg,		
2. P_2O_5	Mean	0.66	0.71	0.72	0.70	0 59	0.72	0.70	0.67	0.75	0.70	0 69	0.76
	C. D.		0,015			0.015			0.015			0015	
	Inference	$Mg^{111}Mg^{11}Mg^{1}$			Mg_2 Mgo Mg_1			Mg_2 Mgo Mg_1			Mg_2 Mg_0 Mg_1		
3. K_2O	Mean	3.41	3.57	3.68	3.53	3.23	3.59	3.53	3.53	3.61	3.53	3.65	3.70
	C. D.		0.180			0.180			0.180			0.180	
	Inference	$Mg^{111}Mg^{11}Mg^{1}$			Mg_2 Mg_0 Mg_1						Mg_2 Mg_1 Mg_0		
4, CaO	Mean	2.08	1.82	1,28	1.52	2.09	2,07	1 52	1.73	2.24	1.52	1.56	2.03
	C. D.		0.180			0.180			0 180			0.180	
	Inference				Mg, Mgs Mgo			Mg_2 Mg_1 Mgo			Mg_2 Mg_1 Mg_0		
5. MgO	Mean	0.74	0.69	0 65	0·38	0.72	0.77	0.38	0.64	0.74	038	0.58	0.73
	C. D.		0.0045			0.0045			0.0045			0.0045	
	Inference	$Mg^{1}Mg^{11}Mg^{111}$			Mg_2 Mg_1 Mgo			Mg_2 Mg_1 Mgo			Mgi Mg_1 Mgo		

Mg^{1} Magnesium carbonate
Mg^{11} Magnesium sili
Mg^{m} Magnesium sulphate

** Mgo No magnesium
Mg_1 Magnesium at lower level
Mg2 Magnesium at higher level

TABLE VIII

Inter-relationships between Calcium, Magnesium and Potassium in the leaf samples under the different treatments

Treatment	CaO / MgO	CaO+MgO / K_2O
1. NPK	3.6	043
2. NPK+CaO	5.8	0.79
3. NPK + $CaCO_3$	5.2	0.68
4. NPK+$MgCO_3$	1.7	0.57
5. NPK+$MgSiO_3$ (I)	1.9	0.54
6. NPK + $MgSO_4$ (I)	2.0	0.57
7. NPK+CaO+$MgCO_3$ (I)	3.7	1.12
8. NPK + CaO+$MgSiO_3$ (I)	3.2	0.85
9. NPK + CaO+$MgSO_4$ (I)	3.4	0.60
10. NPK+$CaCO_3$+$MgCO_3$ (I)	3.5	0.99
11. NPK+$CaCO_3$+$MgSiO_3$ (I)	3.2	0.64
12. NPK+$CaCO_3$ + $MgSO_4$ (I)	3.0	0.59
13. NPK+$MgCO_3$ (IT)	1.7	0.55
14. NPK + $MgSiO_3$ (II)	1.7	0.52
15. NPK+$MgSO_4$ (II)	1.8	0.53
16. NPK+CaO + $MgCO_3$ (II)	3.4	1.03
17. NPK+CaO+$MgSiO_3$ (II)	3.0	0.86
18. NPK+CaO + $MgSO_4$ (II)	3.3	0.84
19. NPK+$CaCO_3$+$MgCO_3$ (II)	2.8	0.81
20. NPK+$CaCO_3$+$MgSiO_3$ (II)	2.9	0.86
21. NPK+$CaCO_3$+$MgSO_4$ (II)	3.0	0.84
Critical difference	0 049	0.012

Inference:

CaO/MgO : 2, 3, 7, 1, 10, 9, 16, 18, 8, 11, 12, 17, 21, 20, 19, 6, 5, 15, 4, 13, 14

CaO+MgO/K_2O : 7, 16, 10, 17, 20, 8, 19, 2, 3, 11, 9, 12, 4, 6, 13, 5, 15, 14, 1

(v) Magnesium

The data in Table VI reveal that the absorption of this element is higher for the no calcium treatment as compared to the calcium treated plants. When the two forms of calcium are compared it is seen that the uptake of magnesium is significantly higher with the oxide than with the carbonate. Table VII shows that the level of this element in plants varies in ascending order with increasing levels of magnesium application. Among the different forms of magnesium used, plants treated with the carbonate form contained appreciably higher levels of this element, than those treated with the silicate and the sulphate.

4. *CaO/MgO ratio*

Table VIII gives the mean CaO/MgO ratio in the leaves of plants under the different treatments and the statistical interpretation of the results is presented in Table IX.

It may be noted that the calcium treated plants have a mean CaO/MgO ratio of 3.54 while for those receiving no calcium this ratio is only 2.06, the difference being significant. For the calcium oxide treatment the CaO/MgO ratio is 3.70 and for the carbonate treatment it is 3,37. In this case also the difference is significant. Among the different forms of magnesium used, the highest CaO/MgO ratio of 2.80 is obtained for the treatment with magnesium carbonate. For the sulphate and silicate treatments the ratios are 2.75 and 2.65 respectively and the differences are significant.

TABLE IX

Comparison of different forms and levels of Calcium and Magnesium in relation to the CaO/MgO ratio in the leaves of plants

	Comparison *		Mean	C. D.	Inference *
1.	No Calcium	Ca_0	2.06	0.049	Ca C_0
	vs Calcium	Ca	3.54		
2,	Calcium oxide	CaO	3.70	0.057	Ca^1Ca^{11}
	vs Calcium carbonate	$CaCO_3$	3.37		
3.	Magnesium	$MgCO_3$	2.80		
	between	$MgSiO_3$	2.75	0.061	$Mg^1Mg^{11}Mg^{111}$
	forms	$MgSO_4$	2.65		
4.	Magnesium carbonate	Mgo	4.90		
	between	Mg_1	2.96	0.061	$Mg_0Mg_1Mg_2$
	levels	Mg_2	2.63		
5.	Magnesium	Mg_0	4.90		
	silicate between	Mg_1	2.77	0.085	$Mg_0Mg_1Mg_2$
	levels	Mg_2	2.53		
6,	Magnesium	Mg_0	4,90		
	sulphate	Mg_1	2,79	0.085	$Mg_0Mg_1Mg_2$
	between levels	Mg_2	2 51		

* Ca_0 No Calcium
Ca Calcium treated
Ca^1 Calcium oxide
Can Calcium carbonate
Mgo No Magnesium
Mg_1 Magnesium at lower level
Mg2 Magnesium at higher level
M^1 Magnesium carbonate
Man Magnesium silicate
Mg^{111} Magnesium sulphate

The CaO/MgO ratio appears to have a marked influence in delaying the incidence of the disease. Plants in treatment 7 (calcium oxide and magnesium carbonate at lower level) had a wide CaO/MgO ratio of 3.7 and it is significant that the appearance of disease symptoms in them was delayed by as many as 199 days over the control. Treatment 10, which ranked second in delaying the disease, also had a wide ratio of 3.5.

5. *CaO + MgO I K_2O ratio*

The $CaO+MgO/K_2O$ ratios of the leaves of plants under the different treatments are presented in Table VIII and the statistical interpretation of the results is given in Table X.

TABLE X

Comparison of different forms and levels of Calcium and Magnesium in relation to the $CaO+MgO/K_2O$ ratio in the leaves of plants

Ccomparison *		$\frac{CaO+MgO}{K_2O}$ Mean	C. D	Inference *
No Calcium	Ca_0	0.53		
vs Calcium	Ca	0.82	0.012	$CaCa_0$
Calcium oxide	CaO	0.87		
vs Calcium carbonate	$CaCO_3$	0.77	0.006	Ca^1Ca^{11}
Magnesium	$MgCO_3$	0.85		
between	$MgSiO_3$	0.71	0.02	$Mg^1Mg^{11}Mg^{111}$
forms	$MgSO_4$	0.67		
Magnesium	Mg_0	0.64		
carbonate	Mg_1	0.90	0.03	$Mg_1Mg_2Mg_0$
between levels	Mg_2	0.80		
Magnesium	Mg_0	0.64		
silicate between	Mg_1	0.67	003	$Mg_2Mg_1Mg_0$
levels	Mg_2	0.75		
Magnesium	Mg_0	0.64		
sulphate between	Mg,	0.60	0.03	$Mg_2Mg_0Mg_1$
levels	Mg_2	0.74		

Ca_0 No Calcium
Ca Calcium treated
Ca^1 Calcium oxide
Ca^{11} Calcium carbonate
Mgo No Magnesium
Mg_1 Magnesium at lower level
Mg_2 Magnesium at higher level
Mg^1 Magnesium carbonate
M^{11} Magnesium silicate
Mg^{111} Magnesium sulphate

It is noted that the plants treated with calcium had a wider CaO + MgO / K_2O ratio than the plants receiving no calcium and that calcium oxide induced a wider ratio than calcium carbonate. The differences were significant. Among the three forms of magnesium, plants treated with magnesium carbonate had a wider ratio than those treated with the silicate and sulphate forms, Higher levels of magnesium induced a wider ratio than lower levels.

Discussion

Though the Bunchy Top disease of banana is of virus origin, soil conditions soil reaction and host nutrition appear to **exert** a powerful influence on the incidence of this disease. Lack of nutrients in adequate quantities and in correct proportion is one of the several factors which predisposes plants to infection by fungi, bacteria, virus and nematodes.

The earlier investigation by Nambiar and Nair (1965) has shown that the incidence of Bunchy Top disease is more pronounced. in areas where the soil is more acid and contain higher levels organic matter and nitrogen. The acidic nature of the soils and the resultant imbalance in the uptake of nutrients may be a factorcontributing to the Bunchy Top disease in banana.

The importance of host nutrition in the incidence of diseases is evident from the fact that the multiplication of viruses which are systemic in the host plant is confined to the living cells only (Bawden, 1960). If is, therefore, to be expected that any change in the supply of essential nutrients to the plants will not only affect the growth of the plant, but also affect the virus activity. In the case of the tobacco mosaic virus it has been observed that some nutrients stimulated and some others inhibited it depending on the virus-host system, (Varma, 1963) A similar relationship is considered possible in the case of the Bunchy Top disease of banana.

The available evidence in literature shows that excessive nitrogen is a decisive factor favouring the incidence of many fungus and vims diseases of plants. This is true of the incidence of mosaic in tobacco, (Sasthry and Nariani, 1963) and the susceptibitlity **of** cauliflower to virus attack (Broadbent and Martin 1959). The analysis of leaf samples of diseased and healthy banana plants indicated that the diseased samples contained about 2,4 per cent more nitrogen than the healthy leaves. Further, it is significant that in the absence of calcium and magnesium the uptake of nitrogen is appreciably higher, and the higher the nitrogen content of the leaves, the earlier the incidence of the disease.

Phosphorus is **intimately** connected with the multiplication of virus in host cells and may inhibit or increase virus concentration in plants (Varma, 1963). Nambiar and Nair (1965) found a higher concentration of available phosphorus in the soils of diseased areas as compared to soils of healthy regions. They also found that diseased leaf samples contained a higher phosphorus content than healthy ones. In the present study it has been observed that the application of calcium reduced the absorption of phosphorus. As compared to the zero and higher levels of magnesium application, the absorption of phosphorus at the lower level is found to be very low A higher uptake of phosphorus is found to accompany the early appearance of disease symptoms.

Potassium is found to be responsible for increasing the resistance of certain crops to specific diseases. Higher potassium levels have been noted in leaf samples by

Nambiar and Nair (1965) in the case of the Bunchy Top disease of banana, by Pandalai *et al* (1958) in the case of the root (wirl) disease of coconut and by Mariakulandai and Dorairaj (1958) in the case of orange decline. In the present study also the uptake of potassium is seen to be influenced by the application of calcium and magnesium and it is found to be related to the incidence of the Bunchy Top infection.

The uptake of calcium and magnesium appears to be closely related to the incidence of the Bunchy Top disease. Nambiat and Nair (1965) noted that the level of total and exchangeable calcium and magnesium in the disease free areas of Kerala was appreciably more than that of the infected regions. The calcium and magnesium contents of the healthy leaves was also significantly more than that of the diseased samples. This has been confirmed by the results of the present study as well.

In general it can be seen that the uptake of nutrients by the banana plant is a significantly interdependent process, the presence or absence of any one element in the soil, and its form and quantity vitally affecting the absorption of another by the plant. This great interdependence in absorption of nutrients will explain the wide variations in the quantity of the nutrient elements observed in the plant and spotlights the importance of balanced nutrition to avoid a drastic difference in the cellular components of the plant. The appreciable difference in the chemical composition of the diseased and healthy tissue, points to the fact that the maintenance of a proper ratio among the major nutrient elements may hold the key to increased resistance of the banana plant to infection by the Bunchy Top virus. The data from these investigations show that nitrogen, phosphorus, potassium, calcium and magnesium may each have its own decisive role to play ia the incidence of the disease, an elucidation of which may require further detailed study. Special emphasis was given in the present work to the role played by calcium and magnesium only and the manner in which the elements may affect the resistance of banana to Bunchy Top infection.

The most note-worthy observation in the present study has been the significance of the CaO/MgO ratio in delaying the incidence of the disease. All plants with a CaO/MgO ratio of either above or below 3.5-3.7 in the leaf showed lesser resistance and got the infection relatively earlier. However, whether or not the CaO/MgO ratio of 3.5-3.7 is critical or significant in respect of the incidence of the disease needs further investigation.

The CaO + MgO/K_2O ratio appears to be another factor related to the incidence of disease in plants, Nambiar and Nair (1965) observed that this ratio tended to decrease from the healthy to diseased plants- In the present study also, the plants where the manifestation of the disease symptoms was delayed or which got no infection had [illegible]r ratios, while the plants which got the infection earlier had a low ratio.

From the available data it may be concluded that calcium or magnesium alone does not help to delay the infection significantly, but a combination of the two does materially contribute towards increased resistance to infection. It is also significant that unlike nitrogen, phosphorus and potassium, which apparently accumulate in diseased tissue, possibly due to some disturbance in the mechanism of translocation, no such accumulation is seen in the case of calcium and magnesium. While a higher content of calcium and magnesium is noticed in healthy plants and in plants which had delayed infection, over diseased plants or those where the incidence of infection was earlier, an accumulation of these elements apparently does not take place in the tissues. This might indicate that unlike the other elements, the incidence of the disease is dependent or conditional on the disturbance of a certain level of absorption of calcium and magnesium by the plant. When this level is upset the disease sets in and the accumulation of the nutrients does not take place. It is thus to be presumed that calcium and magnesium are predisposing factors in relation to Bunchy Top infection, while nitrogen, phosphorus and potassium only contribute to a disturbed metabolism within the plant after infection.

Summary and Conclusions

Considering the economic importance of banana and the loss sustained through the scourge of the Bunchy Top disease, a long range programme of research on the possible control of the disease through nutritional treatments was initiated in the Agricultural College and Research Institute, Vellayani, in the year 1962, as a research project of the Principal and Additional Director of Agriculture (Research). In the first series of investigations it was found that calcium and magnesium have a major role in delaying the incidence of the Bunchy Top disease. In the present investigation an attempt was made to study the effect of different forms and levels of calcium and magnesium on the incidence of this disease as a continuation of the previous work. Twenty one treatment combinations were tried in a pot experiment in the randomised block design with three replications. The plants were inoculated with the aphids collected from Bunchy Top infected plants.

The analysis of the leaf *samples in* general showed that the early infected plants have a high content of nitrogen, phosphorus and potassium. The experiment confirmed that calcium and magnesium have a decisive influence in delaying or arresting the disease and that the $CaO+MgO/K_2O$ ratio in the plants may be critical in this respect. The main conclusions from this study are the following :

1. There is a higher concentration of nitrogen, phosphorus and potassium in the leaf samples from the infected plants than in the healthy ones. No such relationship exists in the case of calcium and magnesium, which indicates a different role played by these elements as compared to nitrogen, phosphorus and potassium.
2. The plants which delayed the infection have a higher content of calcium and magnesium as compared to plants which had earlier infection.
3. The Calcium oxide/Magnesium oxide ratio seems to have a roie in delaying the incidence of the disease. The plants which had resisted infection by 199 days had a ratio of 3,7 and those which resisted the disease '. by 47 days over the control had a ratio of 3.5.
4. Calcium oxide + Magnesium oxide/ Potassium oxide ratio is nearer to one in plants which delayed the incidence of the disease or were free from the disease.
5. Calcium alone does not have a significant role in delaying the disease.
6. Magnesium alone does not have a significant role in delaying the disease.
7. Calcium and magnesium in definite proportions in the plants may have a significant role in delaying the disease.

8. Calcium oxide/Magnesium oxide and Calcium oxide + Magnesium oxide/ Potassium oxide ratios in plants have a major role in delaying the disease. It appears that a CaO/MgO ratio of 3.5 to 4.0 or a CaO + MgO/K_2O ratio of one or near one in the plant tissue can successfully resist the incidence of the Bunchy Top disease until the emergence of the bunch.

Further work is indicated to confirm these findings and to arrive at the critical ratio.

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PLATE I. Experimental Plot-General View.

PLATE II. Shading the plants for inoculation.

PLATE. III. **Diseased** banana plant
(Control)

PLATE IV. Healthy banana plant
(Treatment 7)

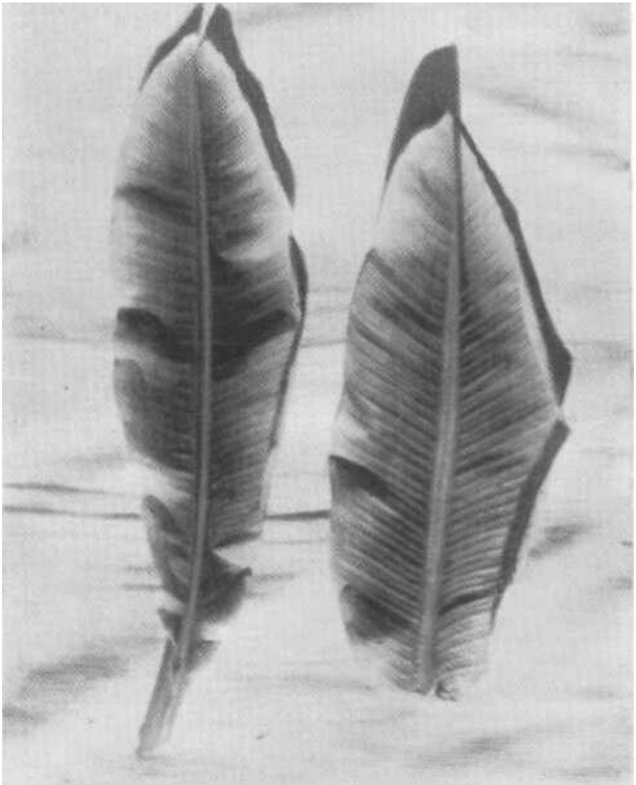

PLATE V. Leaves from plant under treatment , showing dark green streaking along the midrib and along the secondary veins **of** the **lamina,** upward rolling and chlorosis of the margin of the lamina.

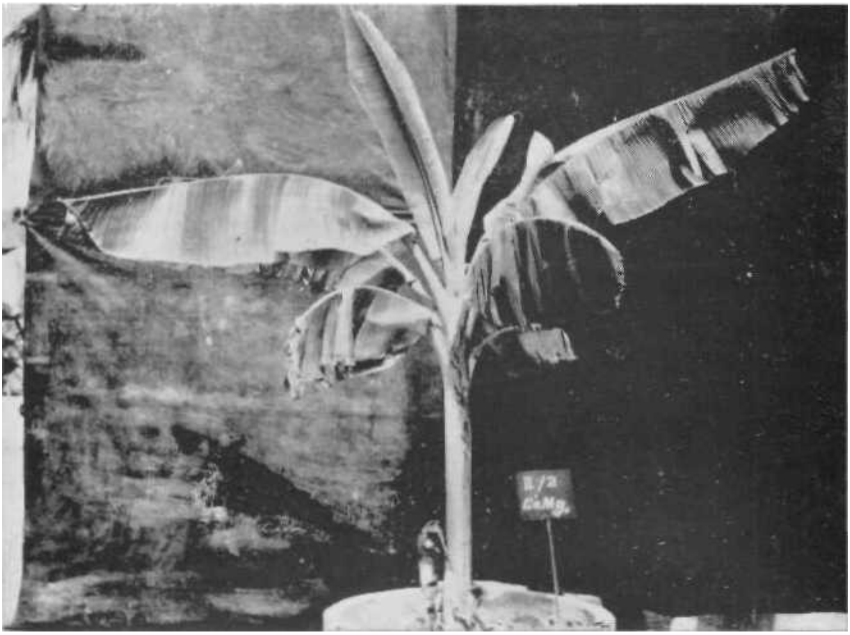

PLATE VI, Diseased banana plant
(Treatment 2)

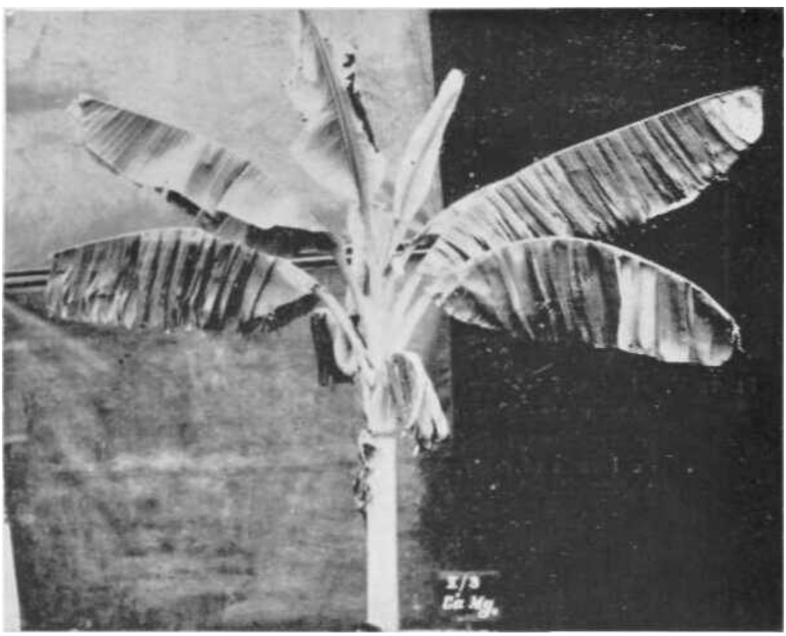

PLATE VII. Diseased banana plant
(Treatment 3)

PLATE VIII, Diseased banana plant
(Treatment 4)

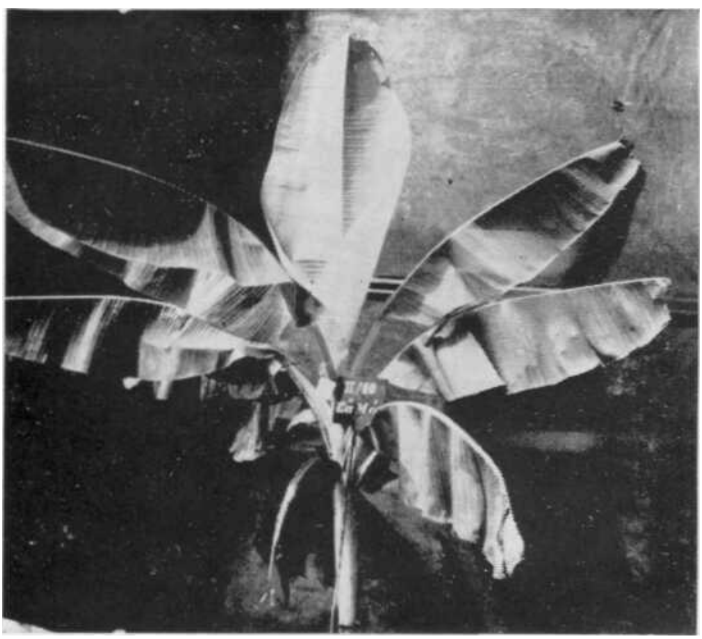

PLATE **IX. Diseased** banana plant
(Treatment **10)**

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