NUTRITIONAL STATUS OF SOILS AND THE INCIDENCE OF THE BUNCHY TOP DISEASE OF BANANAS (*Var Java*) - Part VI

EFFECT OF APPLICATION OF CALCIUM AND MAGNESIUM TO SOIL ON THE RATIO OF CALCIUM OXIDE/MAGNESIUM OXIDE IN THE PLANT AND ITS RELATION TO BUNCHY TOP INFECTION

By

P BALAKRISHNA PILLAI, B. Sc (Ag)

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)
OF THE UNIVERSITY OF KERALA

DIVISION OF AGRONOMY
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
VELLAYANI, TRIVANDRUM

1968

C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Shri P. Balakrishna Pillay under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

PRINCIPAL
AGRICULTURAL COLLEGE &
RESEARCH INSTITUTE,
VELLAYANI, TRIVANDRUM
7th AUGUST 1968

(C.K.H. NAIR)
SPECIAL OFFICER FOR ESTABLISHMENT
OF AGRICULTURAL UNIVERSITY AND
DEAN, FACULTY OF AGRICULTURE,
UNIVERSITY OF KERALA

LIBRARY

ACKNOWLEDGEMENT

The author wishes to place on record his deep gratitude and indebtedness to Dr. C.K.N. Nair, M.Sc., Ph.D. (Cornell), D.R.I.P.(Oak Ridge), Principal of the Agricultural College till 1-1-1968 and now Special Officer for establishment of Agricultural University and also Dean of the Faculty of Agriculture, University of Kerala, for suggesting and planning the present investigation, for his constant encouragement, constructive criticisms and valuable suggestions.

Prof. C.M. George, B.Sc.(Ag.), M.S.A. (Toronto), Professor of Agronomy for his encouragement, valuable suggestions and the help rendered.

Prof. P. Kumara Pillai, M.Sc., M.S.(U.S.A.), Vice-Principal-in-charge, Agricultural College and Research Institute, Vellayani for the excellent facilities provided for the successful conduct of this study.

Shri. E.J. Thomas, M.Sc., M.S.(IOWA), Junior Professor of Statistics for the valuable advice in statistical lay out of the experiment and analysis of the data.

And all the members of the staff of the Division of Agronomy Plant Pathology and Chemistry for the help rendered in various ways for the successful completion of this work.

The author is also grateful to the Government of Kerala for deputing him for the M.Sc.(Ag.) Course in Agronomy.

P. BALAKRISHNA PILLAY

C O N T E N T S

LIST OF FIGURES

LIST OF PLATES

1. General view of the healthy banana plants before inoculation
2. General view of the banana plants after appearance of symptoms
3. Healthy banana plant of treatment No. 1 before inoculation
4. Diseased banana plant of treatment No. 1 after the disease incidence
5. Healthy banana plant of treatment No. 2 before inoculation
6. Diseased banana plant of treatment No. 2 after the disease incidence
7. Healthy banana plant of treatment No. 3 before inoculation
8. Diseased banana plant of treatment No. 3 after the disease incidence
9. Healthy banana plant of treatment No. 4 before inoculation
10. Diseased banana plant of treatment No. 4 after the disease incidence
11. Healthy banana plant of treatment No. 2 (Replication V) after inoculation
12. Healthy banana plant of treatment No. 3 (Replication IV) after inoculation with a healthy daughter sucker
13. Healthy banana plant of treatment No. 4 (Replication IV) after inoculation
14. Diseased daughter sucker of treatment No. 1 (Replication V)

INTRODUCTION

INTRODUCTION

Bunchy top is one of the most destructive of all the known diseases of banana. It is also known as "Cabbage top", "Curly top" and "Strangles" in different countries. A detailed account of the origin and extent of the disease, and the economic loss brought about by it, is given in the earlier works in these series.

Banana is one of the most important fruit crops of India. It is cultivated over an area of approximately 184,000 hectares which is about one-fifth of the total area under fruits in this country. Kerala, Madras, Andhra Pradesh, Mysore, Assam, West Bengal and Bihar are the chief banana producing States. Kerala tops the list with an area of 46,600 hectares and an annual production of 344,900 tonnes.

The study of the nutritional status of soil and plant as predisposing factors to infection by Bunchy top disease of banana, has been initiated as part of a continuing research programme at the Agricultural College and Research Institute, Vellayani from 1962 under Dr. C.K.H. Nair, Principal. The survey conducted during the first year of investigation showed that soils of disease-free areas had lower contents of major nutrients, nitrogen, phosphorus and potassium and higher contents of secondary elements, calcium and magnesium. Leaf samples of healthy and diseased banana plants also followed the same pattern as soils.

VELLAYANI
AGRICULTURAL COLLEGE & RESEARCH INSTITUTE
LIBRARY

The experiment conducted during the same year based on the survey showed that a combination of calcium and magnesium in the nutrient medium could bring about a significant delay in the appearance of disease symptoms.

Sand culture experiment conducted during 1964-65 with different forms and levels of calcium and magnesium showed that appropriate combination of calcium and magnesium in the nutrient medium arrested the incidence of the disease for a significant period. Treatments supplying calcium oxide and magnesium oxide at 0.6 per cent and 0.1 per cent respectively, on the basis of the weight of sand arrested the incidence of the disease till the emergence of the bunch.

Experiments during 1965-66 to confirm the results of sand culture experiments under semi field conditions showed that resistance to Bunchy top infection could have been actually related to the ratio of calcium oxide plus magnesium oxide/potassium oxide in the plant tissue and not merely to the ratio of calcium oxide/ magnesium oxide in the nutrient medium.

During 1966-67 it was found that the ratios of calcium oxide/magnesium oxide in leaf and root were slightly higher in the plants which withstood infection than those which showed symptoms. A marked lowering in the ratio was observed in the infected plants after symptom appearance.

Further investigations were necessitated for confirming these earlier results on some other varieties of banana. It has been observed that the seed forming non-edible varieties show a relatively high degree of resistance to the virus. Among the edible varieties Java, Monthan, Charapadati, Ennabaniyan, Rasakadali etc. were found to be relatively less susceptible to infection by the virus. In the present studies the relatively resistant Java variety was used, as against the variety Nendran in all the previous investigations. The infected virus concentration was also vastly increased, as the number of aphids released on the healthy plants was 100 for each plant as against 20 or 25 in the previous experiments.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

1. History and distribution of the disease

The precise origin of the Bunchy top disease of banana is unknown. The disease is now widespread in Australia, Ceylon, India, Malayasia, Pacific islands, Egypt and Central Africa. A review on the history and occurrence of the disease is given by Nambiar and Nair (1965).

2. Causative organism and mode of transmission

It has been proved that the disease is of viral origin transmitted by the banana aphid, Pentalonia nigronervosa Coq. (Goddard 1925, Magee 1927, Hutson and Malcom 1930).

3. Incubation period and virus vector relationship

Magee (1927, 1940) has reported that the aphids fed on diseased plants for 24 hours acquired the virus and after 2 days of incubation, transmitted it to the healthy plants by feeding on them for 2 hours. In his experiments on Cavendish variety, he noticed that when aphids were released at the rate of 150 to 200 per plant, all of them showed disease symptoms within a period of 28 to 29 days. Magee has also reported that in the Gros Michel variety, the virus requires 35 to 45 days to manifest itself. Investigations at Vellayani

(1958) reveal that this is true of almost all cultivated varieties under the climatic conditions existing in the station.

4. Symptoms of the disease

Nagoo (1957) recognised two types of infection, primary and secondary. Secondary infection can appear at any stage of the growth of the plant and is caused by the aphid transmission of the virus. The virus is systemic in nature and so the daughter suckers arising from infective mother plants will have primary infection.

Whether a plant is having primary infection or secondary infection, the disease symptoms are characteristic, destructive and easily recognisable. The initial symptoms appear on the leaf as irregular, nodular dark green streaks along the secondary vein, midrib and petiole. Successive leaves are shortened in length and width. The leaf margin is curled up, scorched, fragile and sometimes splits apart. In later stages, the length of the petiole is reduced, the leaves stand erect and produce a rosetted appearance of "Bunchy top".

5. Disease resistance

Nagoo (1953) reported that none of the cultivated varieties of Musa spp. is found immune to the disease. He observed that the varieties Gros Michel and Veimama have a high degree of resistance. He attributed

VELLAYANI

this to physiological and structural characteristics. The variety Cavendish was found to be highly susceptible (Magee 1943). Most of the cultivated varieties of banana in Kerala State have been found to be susceptible to infection by the virus. However, variation in the intensity of infection has been observed. The most popular and widely cultivated varieties viz. Nendran and Palayanthodan are more susceptible than the other less popular varieties of banana.

Magee (1953) observed that more vigorous and rapidly growing plants are more susceptible and liable to be infected by the virus. Age of the plant is also a factor for infection, younger plants reacting to the disease more quickly than older ones. Plants growing on impoverished soils are less easily ravaged by the disease, than those in rich soils.

Host nutrition

A review of literature on the effect of host nutrition on virus infection and activity can be seen in the work of Nambiar and Nair (1965) and Pillay and Nair (1966) in connection with the earlier investigations of this problem.

Nutrition controls the growth and constitution of plants. There is no doubt, that virus activity is influenced by the host plant metabolism. The entry,

movement and multiplication of virus and external expression of symptoms, are all influenced by the supply of nutrients and the host plant physiology.

Effect of plant nutrients on virus infection

Different nutrients play different roles in the resistance of plants to infection by virus. This has been reviewed with special reference to Bunchy top infection by previous workers as Nambiar and Nair (1966), Nair and Pillay (1966), Nair and George (1966) and Nair and Vikraman Nair (1967).

Nitrogen

Janssen (1929) was one of the initial workers 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) reported 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.

Srecnivasa Rao (1933) reported that the leaf of virus infected plants contained more nitrogen than healthy leaf.

The investigations of Varadaraja Ayengar (1933) on the spike disease of sandal indicated that by prolonging the vegetative phase, nitrogen favoured the incidence of virus disease. Folton (1943) and Aronz (1949) observed that a deficiency of nitrogen caused earlier appearance of leaf roll symptoms on potatoes. Kendrich et al (1951) observed that virus concentration was reduced to a minimum by low nitrogen application in tomatoes infected with tobacco mosaic virus. Kruger (1951) reported that nitrogen application increased the susceptibility of potato plants to leaf roll virus infection and produced leaves congenial to the growth and multiplication of virus. Ponching Cheo et al (1952) recorded that virus assays of the expressed sap of the spinach plants showed virus concentration in proportion to the growth of the plants induced by nitrogen application. Similar results were obtained by Weathers and Pound (1954). Broadbent et al (1952) found that heavy application of nitrogenous fertilizers increased the susceptibility of cauliflower to mosaic virus.

Wunscher (1952) reported that increasing amounts of nitrogen increased the susceptibility of potatoes to virus infection through aphids. According to Diercks (1953),

potato plants in the low-nitrogen group reacted negatively to infection by X-virus. He recommended moderate supply of nitrogen as a method of control.

Commoner et al (1953) compared the nitrogen contents of tobacco leaf discs at various intervals after inoculation with tobacco mosaic virus and observed a net increase in protein content as a concomitant of virus synthesis. Best and Gallus (1953) reported that the concentration of protein nitrogen was higher in leaves of infected plants throughout the growing period. Borges and Boato (1953) showed that both total and soluble nitrogen in diseased Brassica chinensis had increased. Pound and Weathers (1953) found in Connecticut Havana No. 38 tobacco that virus activity of expressed sap was directly correlated with plant growth.

Virus transmission studies by Boring and Dierckx (1955) on healthy potato plants indicated that heavy nitrogen application was effective in masking the symptoms caused by virus, but the treatment was ineffective in the infected progeny. From experiments with two species of Nicotiana, Holms and Pound (1953) noted that the deficiency of nitrogen caused mild virus symptoms and low virus concentration, while the same were markedly increased at higher concentration of the nutrient. Dawdon (1953) cited the work of Broadbent and Heathcote who found that the incidence of cauliflower mosaic virus increased with more nitrogen.

Bawden (1959) explained the reason for high susceptibility of plants raised under abundant nitrogen supply to virus infection. According to him it was due to the increase in succulence of the leaves which resulted in greater injury of leaves, producing more and larger wounds through which infective virus particles could enter easily. De Robertis (1959) demonstrated that nitrogen applications reduced symptoms of wheat streak mosaic virus, but led to the appearance of virus symptoms in the case of Rembrandt tulips.

Weathers (1960) found that the development of concertic symptoms in Eureka lemon Poncirus trifoliata was correlated with increased nitrogen application.

Varma (1961) observed that in the case of tobacco plants virus concentration increased steadily in proportion to nitrogen application. Orlob and Army (1961) concluded from their work on barley yellow dwarf virus that virus infection affected the nitrogen metabolism by reducing the total nitrogen in the leaves and increasing it in the roots. Sastry and Mariani (1962) found that the percentage of infection by the tobacco leaf curl virus in tobacco increased with increased nitrogen, but application in conjunction with phosphorus showed a decreasing trend in infection with increasing levels of phosphorus. This is in contradiction with the findings of Bawden and Kassanis

(1930). Gastry and Vasudeva (1962) indicated that sunhemp mosaic virus concentration was directly correlated with growth of sunhemp plants in respect of nitrogen. According to Sadasivan (1963), nitrogen levels that increased plant growth also increased virus concentration and vice versa. Nitrogen ions had a profound influence on virus multiplication.

Broadbent and Weathers (1964) failed to get any effect from urea and mono-ammonium phosphate sprays on tomatoes infected with tobacco mosaic virus. Carpenter (1964) and Weathers (1964) found that nitrogen nutrition of the host had no effect on the transmission of bean yellow mosaic virus.

Eskarous et al (1964) obtained increased protein and peptide nitrogen in tobacco plants inoculated mechanically with tobacco mosaic virus.

Lockarel and Ascanning (1965) found high nitrogen content in the leaf tissues of virus infected cocoa plants.

Prusa et al (1966) observed that nitrogen contents of the plants had no significant relationship to the incidence of hop curl disease.

Singh and Bhargava (1966) found that virus concentration coincided with growth of the plant even at

concentrations which caused stunting in watermelons infected with watermelon mosaic virus.

Narayanaswamy and Ramakrishnan (1966) working on Pigeon peas infected with sterility mosaic virus found a decrease in chloroplastic protein and an increase in cytoplasmic protein in the diseased leaves. A decrease in C : N ratio was observed due to virus infection, and this reduction was attributed to the reduction in carbohydrate content and increase in nitrogen content of diseased leaves.

Nambiar and Nair (1965) and Nair and Pillai (1966) also noted significant difference in nitrogen content of banana leaves due to the incidence of Bunchy top disease. Nambiar and Nair (1965) showed that nitrogen content of soils taken from infected areas was high in comparison to healthy areas. Comparative leaf analysis indicated that the diseased leaves contained more nitrogen than the healthy ones. Nair and Pillai (1966) concluded that the uptake of nitrogen was significantly influenced by magnesium and calcium. It was also shown that higher nitrogen content led to an early incidence of infection. Nair and George (1966) reported that there was an increase in nitrogen content of leaves after the incidence of the disease than before it. Also the nitrogen content of infected plants remained fairly constant in the control and in the plants

REVIEW OF LITERATURE

REVIEW OF LITERATURE

1. History and distribution of the disease

The precise origin of the Bunchy top disease of banana is unknown. The disease is now widespread in Australia, Ceylon, India, Malayasia, Pacific islands, Egypt and Central Africa. A review on the history and occurrence of the disease is given by Nambiar and Nair (1965).

2. Causative organism and mode of transmission

It has been proved that the disease is of viral origin transmitted by the banana aphid, Pentalonia nigronervosa Coq. (Goddard 1925, Magee 1927, Hutson and Malcom 1930).

3. Incubation period and virus vector relationship

Magee (1927, 1940) has reported that the aphids fed on diseased plants for 24 hours acquired the virus and after 2 days of incubation, transmitted it to the healthy plants by feeding on them for 2 hours. In his experiments on Cavendish variety, he noticed that when aphids were released at the rate of 150 to 200 per plant, all of them showed disease symptoms within a period of 28 to 29 days. Magee has also reported that in the Gros Michel variety, the virus requires 35 to 45 days to manifest itself. Investigations at Vellayani

(1952) reveal that this is true of almost all cultivated varieties under the climatic conditions existing in the station.

4. Symptoms of the disease

Magee (1927) recognised two types of infection, primary and secondary. Secondary infection can appear at any stage of the growth of the plant and is caused by the aphid transmission of the virus. The virus is systemic in nature and so the daughter suckers arising from infective mother plants will have primary infection.

Whether a plant is having primary infection or secondary infection, the disease symptoms are characteristic, destructive and easily recognisable. The initial symptoms appear on the leaf as irregular, nodular dark green streaks along the secondary vein, midrib and petiole. Successive leaves are shortened in length and width. The leaf margin is curled up, scorched, fragile and sometimes splits apart. In later stages, the length of the petiole is reduced, the leaves stand erect and produce a rosetted appearance of "Bunchy top".

6. Disease resistance

Magee (1953) reported that none of the cultivated varieties of Musa spp. is found immune to the disease. He observed that the varieties Gros Michel and Veinamma have a high degree of resistance. He attributed

VELLAYANI

this to physiological and structural characteristics. The variety Cavendish was found to be highly susceptible (Magee 1943). Most of the cultivated varieties of banana in Kerala State have been found to be susceptible to infection by the virus. However, variation in the intensity of infection has been observed. The most popular and widely cultivated varieties viz. Nendran and Palayanthodan are more susceptible than the other less popular varieties of banana.

Magee (1953) observed that more vigorous and rapidly growing plants are more susceptible and liable to be infected by the virus. Age of the plant is also a factor for infection, younger plants reacting to the disease more quickly than older ones. Plants growing on impoverished soils are less easily ravaged by the disease, than those in rich soils.

Host nutrition

A review of literature on the effect of host nutrition on virus infection and activity can be seen in the work of Nambiar and Nair (1965) and Pillay and Nair (1966) in connection with the earlier investigations of this problem.

Nutrition controls the growth and constitution of plants. There is no doubt, that virus activity is influenced by the host plant metabolism. The entry,

movement and multiplication of virus and external expression of symptoms, are all influenced by the supply of nutrients and the host plant physiology.

Effect of plant nutrients on virus infection

Different nutrients play different roles in the resistance of plants to infection by virus. This has been reviewed with special reference to Bunchy top infection by previous workers as Nambiar and Nair (1966), Nair and Pillay (1966), Nair and George (1966) and Nair and Vikraman Nair (1967).

Nitrogen

Janssen (1929) was one of the initial workers 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) reported 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.

Srecnivasa Rao (1933) reported that the leaf of virus infected plants contained more nitrogen than healthy leaf.

The investigations of Varadaraja Ayengar (1933) on the spike disease of sandal indicated that by prolonging the vegetative phase, nitrogen favoured the incidence of virus disease. Folton (1943) and Aronz (1949) observed that a deficiency of nitrogen caused earlier appearance of leaf roll symptoms on potatoes. Kendrich et al (1951) observed that virus concentration was reduced to a minimum by low nitrogen application in tomatoes infected with tobacco mosaic virus. Kruger (1951) reported that nitrogen application increased the susceptibility of potato plants to leaf roll virus infection and produced leaves congenial to the growth and multiplication of virus. Ponching Cheo et al (1952) recorded that virus assays of the expressed sap of the spinach plants showed virus concentration in proportion to the growth of the plants induced by nitrogen application. Similar results were obtained by Weathers and Pound (1954). Broadbent et al (1952) found that heavy application of nitrogenous fertilizers increased the susceptibility of cauliflower to mosaic virus.

Wunscher (1952) reported that increasing amounts of nitrogen increased the susceptibility of potatoes to virus infection through aphids. According to Diercks (1953),

potato plants in the low-nitrogen group reacted negatively to infection by X-virus. He recommended moderate supply of nitrogen as a method of control.

Commoner et al (1953) compared the nitrogen contents of tobacco leaf discs at various intervals after inoculation with tobacco mosaic virus and observed a net increase in protein content as a concomitant of virus synthesis. Best and Gallus (1953) reported that the concentration of protein nitrogen was higher in leaves of infected plants throughout the growing period. Borges and Boato (1953) showed that both total and soluble nitrogen in diseased Brassica chinensis had increased. Pound and Weathers (1953) found in Connecticut Havana No. 38 tobacco that virus activity of expressed sap was directly correlated with plant growth.

Virus transmission studies by Boring and Dierckx (1955) on healthy potato plants indicated that heavy nitrogen application was effective in masking the symptoms caused by virus, but the treatment was ineffective in the infected progeny. From experiments with two species of Nicotiana, Holms and Pound (1953) noted that the deficiency of nitrogen caused mild virus symptoms and low virus concentration, while the same were markedly increased at higher concentration of the nutrient. Dawdon (1953) cited the work of Broadbent and Heathcote who found that the incidence of cauliflower mosaic virus increased with more nitrogen.

Bawden (1959) explained the reason for high susceptibility of plants raised under abundant nitrogen supply to virus infection. According to him it was due to the increase in succulence of the leaves which resulted in greater injury of leaves, producing more and larger wounds through which infective virus particles could enter easily. De Robertis (1959) demonstrated that nitrogen applications reduced symptoms of wheat streak mosaic virus, but led to the appearance of virus symptoms in the case of Rembrandt tulips.

Weathers (1960) found that the development of exocortis symptoms in Eureka lemon Poncirus trifoliata was correlated with increased nitrogen application.

Varma (1961) observed that in the case of tobacco plants virus concentration increased steadily in proportion to nitrogen application. Orlob and Army (1961) concluded from their work on barley yellow dwarf virus that virus infection affected the nitrogen metabolism by reducing the total nitrogen in the leaves and increasing it in the roots. Sastry and Mariani (1962) found that the percentage of infection by the tobacco leaf curl virus in tobacco increased with increased nitrogen, but application in conjunction with phosphorus showed a decreasing trend in infection with increasing levels of phosphorus. This is in contradiction with the findings of Bawden and Kassanis

(1939). Sastry and Vasudeva (1962) indicated that sunhemp mosaic virus concentration was directly correlated with growth of sunhemp plants in respect of nitrogen. According to Sadasivan (1963), nitrogen levels that increased plant growth also increased virus concentration and vice versa. Nitrogen ions had a profound influence on virus multiplication.

Broadbent and Weathers (1964) failed to get any effect from urea and mono-ammonium phosphate sprays on tomatoes infected with tobacco mosaic virus. Carpenter (1964) and Weathers (1964) found that nitrogen nutrition of the host had no effect on the transmission of bean yellow mosaic virus.

Dakaroua et al (1964) obtained increased protein and peptide nitrogen in tobacco plants inoculated mechanically with tobacco mosaic virus.

Lockarel and Assmanning (1965) found high nitrogen content in the leaf tissues of virus infected cocoa plants.

Prusa et al (1966) observed that nitrogen contents of the plants had no significant relationship to the incidence of hop curl disease.

Singh and Bhargava (1966) found that virus concentration coincided with growth of the plant even at

concentrations which caused stunting in watermelons infected with watermelon mosaic virus.

Narayanaswamy and Ramakrishnan (1966) working on Pigeon peas infected with sterility mosaic virus found a decrease in chloroplastic protein and an increase in cytoplasmic protein in the diseased leaves. A decrease in C : N ratio was observed due to virus infection, and this reduction was attributed to the reduction in carbohydrate content and increase in nitrogen content of diseased leaves.

Nambiar and Nair (1965) and Nair and Pillai (1966) also noted significant difference in nitrogen content of banana leaves due to the incidence of Bunchy top disease. Nambiar and Nair (1965) showed that nitrogen content of soils taken from infected areas was high in comparison to healthy areas. Comparative leaf analysis indicated that the diseased leaves contained more nitrogen than the healthy ones. Nair and Pillai (1966) concluded that the uptake of nitrogen was significantly influenced by magnesium and calcium. It was also shown that higher nitrogen content led to an early incidence of infection. Nair and George (1966) reported that there was an increase in nitrogen content of leaves after the incidence of the disease than before it. Also the nitrogen content of infected plants remained fairly constant in the control and in the plants

Nambiar and Nair (1966) reported that there was a higher concentration of available potash in the soils of healthy areas as compared to the diseased banana areas. They also observed higher concentration of potash in the diseased leaf samples of banana as compared to the healthy. Nair and George (1966) found that there was an increase in potassium content of leaves after the incidence of the disease. Also it was noted that potassium content of the plant tissue in all the treatments was higher than what was reported by Nair and Pillai (1966) for plants which delayed infection by an appreciable period of time.

Calcium

Calcium is a constituent of cell wall of plants and is present as calcium pectate in the middle lamella. The influence of calcium on virus disease was known to the research workers even from the early times of investigations of plant virus diseases.

Queensland Agricultural Journal (1932) reported that sulphur was applied at the rate of 8 cwt. per acre together with Island fertiliser followed with 8 to 10 cwt. per acre of basic super containing 45 per cent lime and 17 per cent phosphoric acid around the banana stool to a radius of 3 to 4 feet. All the suckers were taken from Bunchy top Stalk, but none got the disease. The report

further says that the foliage was of excellent colour and the growth of the plants were exceptionally good. The old diseased stalks similarly treated were throwing out vigorous centre leaves.

Report of the Ministry of Agriculture, Australia (1923) showed that the use of complete fertilizer, lime, basic phosphate or disinfection with various fungicidal preparations, failed to prevent the occurrence of the Bunchy top disease.

Srenivasa Rao (1933) observed that the spike diseased sandal leaves contained only one fourth of calcium that was present in healthy leaves. According to Varadaraja Ayengar (1933) the low calcium content in virus infected leaves was due to the disturbance in the calcium-nitrogen metabolism of the diseased plants which resulted in reduced translocation of calcium.

Sorokin and Sommer (1940) have reported that in the absence of calcium, mitotic division becomes aberrant or suppressed. Calcium is also known to have a role in nitrogen metabolism of plants.

The studies of Boring and Dierks (1955) indicated that excess lime application masked symptoms of leaf roll and streak disease of potato.

Chossin and Scott (1955) observed that calcium deficiency in Nicotiana glutinosa plants had no influence

on the size of the local lesions formed on the leaves infected by tobacco mosaic virus. Subsequent trials by Chessin and Scott (1958) showed a specific reduction in the infection of tobacco mosaic virus on calcium deficient H. glutinosa plants. According to them calcium deficiency affected the intrinsic cell susceptibility to infection rather than offering mechanical resistance to virus entry.

Shaw and Bamborahi (1956) showed that calcium accumulated in young local lesions of tobacco mosaic virus on Nicotiana.

From analytical studies, Loring and Waits (1957) concluded that calcium was an integral constituent of tobacco mosaic virus.

The trials conducted by Hoveland et al (1958) brought out that potato leaf roll virus interfered with the uptake of calcium by the host plant.

Murray (1959) from his studies on the deficiency symptoms of banana concluded that calcium deficiency, unlike those of other nutrients, manifests itself only at later stages of growth viz. 4th or 5th leaf stage. This symptom appears as a gradual loss of colour, in narrow band along the margin. He also stated that roots tend to be short, stubby and much branched and are very susceptible to fungus attack.

Parthasarathi and Rao (1962) noted lesser percentage of calcium in the spike diseased sandal leaves.

From the analysis of sixteen soil profiles, Mahoodkar and Yadav (1962) found a higher calcium content in the soils of spike diseased sandal trees.

By growing Petunia hybrida and Nicotiana tabacum in sand culture at different levels of calcium, Varma and Varma (1963) observed that higher levels of calcium increased the virus concentration in the infected leaves of both plants.

Srivastava (1963) reported that calcium is found to be effective in improving the growth of banana plant in all its aspects. Adequate amount of calcium significantly increased the fresh weight of the roots, leaves, stem and entire plant, leaf area and dry weight of the leaves.

According to Sadasivan (1963), calcium deficiency reduces the number of local lesions by affecting intrinsic cell susceptibility rather than by mechanical resistance to entry of viruses. Welton (1964) found that the susceptibility of Lincoln peas to inoculation with bean yellow mosaic virus by Myzus persicae was unaffected by addition of calcium chelates.

Sastry (1965) observed that above an optimum level of calcium, growth of Crotalaria juncea was retarded

and concentration of cunhemp mosaic virus reduced.

Prusa et al (1963) found that in hop plants infected with hop curl disease, the content of calcium was higher than in healthy one.

It was observed by Nambiar and Nair (1965) that soils from sites of healthy plants in both laterite and sandy areas showed a higher content of total and exchangeable calcium. Analysis of healthy and diseased leaves showed significantly higher values in the healthy plants. Nair and Pillai (1966) concluded that the uptake of calcium had a major role in the incidence of the Bunchy top disease. The plants which had delayed infection had a higher percentage of calcium than the plants which got disease earlier.

Nair and George (1966) observed higher calcium content in leaves of banana before incidence of the disease than after infection. The absorption of calcium by plants under different treatments before infection was not significantly different indicating that beyond a certain level of calcium, further additions to the nutrient medium would have no effect on tissue composition.

Magnesium

Hale et al (1946) showed that magnesium content was consistently higher in beet plants infected with beet

yellow virus than the healthy plants and that the difference varied with the degree of infection.

Rykhoff and Smirnova (1948) found that when half leaves of Nicotiana glutinosa plants inoculated with tobacco mosaic virus were kept submerged for seven days in a 0.1% solution of magnesium sulphate, multiplication of virus was markedly depressed.

Cooke (1950) found that the tapering disease of coconut was caused by the deficiency of magnesium.

Alvin (1950) in determining the cause of leaf rot disease of Anona glabra found that it was due to magnesium deficiency. The fact that the disease can be controlled by the addition of potassium sulphate was attributed to the mobilisation of magnesium in the soil by base exchange.

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.

Chessin and Scott (1955) stated that calcium and magnesium deficiencies had no apparent influence on the size and local lesions on Nicotiana glutinosa induced by tobacco mosaic virus.

The chemical analysis of tobacco mosaic virus by Loring and Waritz (1957) strongly confirmed the view that magnesium was an integral viral ingredient.

Mariakulandai and Dorairaj (1958) in their study on 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.

According to Hitior and Izard (1958) magnesium sulphate failed to reduce the activity of tobacco mosaic virus.

Hoveland et al (1958) from their studies on tobacco noticed that leaf roll virus affected the magnesium absorption of the host plant.

It was found that incidence of oil palm crown disease and little leaf increased where potassium was applied alone, but this was counterbalanced by the addition of magnesium (Anonymous 1958).

Murray (1959) stated that the deficiency of magnesium on the banana plant appears as a very pronounced compression of young leaves and they start unfurling before they have completely emerged from the sheathing leaf base. A gradual loss in colour and

appearance of brown spots are seen on the leaf blade from the 4th or 5th leaf. Murray (1960) has again stated that magnesium deficiency in banana increases the percentage of phosphorus in the leaf.

Shepherd and Pound (1960) studied the effect of magnesium nutrition in Nicotiana tabacum on the multiplication of tobacco mosaic virus. Magnesium developed deficiency symptoms at 0.5 ppm. Assays showed a consistent though small, reduction in virus concentration in magnesium deficient plants.

Varma (1964) studied the effect of magnesium nutrition on multiplication of tobacco mosaic virus in Nicotiana tabacum and Petunia hybrida and found that virus concentration increased with increase in magnesium concentration.

Wolton (1964) reported that susceptibility of Lincoln peas to inoculation with bean yellow mosaic virus by Myzus persicae was unaffected by addition of magnesium chelate.

Prusa et al (1965) showed that infection of hop plants with hop curl disease was noticeably inhibited by spraying or irrigation with salts of magnesium.

Sastry (1965) observed that above a certain optimum magnesium level growth of Crotalaria juncea infected with sunhemp mosaic virus was retarded and virus concentration reduced.

Analytical studies of Lockarel and Anomaning (1965) on the leaf samples of cocoa affected by swollen shoot virus showed lesser content of magnesium than in healthy leaves.

Sastry (1966) studied the effect of magnesium application to cluster beans on the production of local lesions by sunhemp mosaic virus. He noticed that the level of magnesium optimum for plant growth produced maximum number of local lesions on the leaves of cluster beans.

Nambiar and Nair (1965) showed that the soils from the sites of healthy banana plants were higher in total and exchangeable magnesium compared to diseased areas. Healthy leaf samples were high in the content of magnesium as compared to the diseased. The work of Nair and Pillai (1966) showed that there was a high content of magnesium in the leaves of banana plants which had delayed infection, compared to those which had earlier infection. Nair and George (1966) reported that increased absorption of magnesium by banana plants was favoured by lower

concentrations of calcium and that all the plants contained appreciably higher quantities of magnesium before the incidence of the disease than after infection by the virus.

Calcium plus Magnesium

Investigations carried out on plant viruses in relation to host nutrition indicated that calcium and magnesium in combination greatly affected their activities.

Robert (1933) studied the effect of potassium, calcium and magnesium ions, singly and in combination on bean plant and found that potash when associated with magnesium, materially retarded calcium absorption and when combined with calcium, markedly reduced magnesium absorption.

Sainik (Jr) et al (1952) have observed that the uptake of minor elements in wheat and sorghum was maximum at a calcium/magnesium ratio of approximately 4 : 1.

Brun (1954) in French Guinea observed that banana plants affected by blue disease have low content of calcium and magnesium and the symptoms were controlled by the addition of lime and magnesium.

Ghosain and Scott (1955) investigated the effect of mineral nutrition on the size of the local lesions

formed on the leaves of Hicotiana glutinosa after virus infection. They found that additions of calcium and magnesium in the nutrient medium had no apparent influence on the size of local lesions produced on the leaves.

Garman and Mathis (1956) stated that low calcium magnesium ratio of leaf compared to that of fruit is associated with the occurrence of bitter pit (baldwin spot) of apples.

Wambeke (1957) investigated the reasons for the yellowing of oil palms and found that a low concentration of magnesium and calcium in the foliage was associated with the disease. Application of 0.5 kg. of magnesium sulphate and 1.5 kg. of calcium carbonate followed by 0.5 to 1.0 kg. of potash-magnesia several months later was found to be beneficial.

Lahousse (1964) stated that in the plant soil, calcium and magnesium have a chemical colloidal reciprocal action. If calcium / magnesium ratio is less than 1.5, the calcium condition in the soil is able to counteract any physiological risks resulting from excess magnesium.

Nair et al (1966) noticed that cellular degeneration and disorganisation were the slowest in plants

growing on a soil with a CaO/MgO ratio of 3. They have also observed that a definite CaO/MgO ratio in the plant tissue, rather than in the nutrient medium, may contribute towards resistance to cellular changes consequent on virus infection.

The investigations of Nambiar and Nair (1965) showed that soils collected from disease prevalent banana areas were poor in calcium and magnesium. The analysis of the diseased leaf samples of banana also revealed that calcium and magnesium were lower than in healthy ones. Elaborate studies were conducted by Nair and Pillai (1966) who found that the leaves of healthy banana plants supplied with calcium and magnesium had a CaO/MgO ratio of 3.5 to 4. These plants inhibited the expression of disease symptoms until the emergence of the bunch.

Nair and George (1966) found that resistance to Bunchy top virus may be correlated to the ratio of calcium oxide plus magnesium oxide / potassium oxide in the leaf and not merely to the ratio of calcium oxide / magnesium oxide.

Nair and Vikraman (1967) observed that CaO/MgO ratio in leaf and root of banana were slightly higher in the plants which withstood infection than those which

showed symptoms. A marked lowering in the ratio was observed in the infected plants after symptom appearance.

Calcium plus magnesium / potassium

Recent studies on calcium, magnesium and potassium show that the ratios of these nutrients in host plants influence the activity of the virus. Some works are suggestive that these ratios control the structure, development and multiplication of the virus in the infected plants.

Panzer (1957) studied the effect of calcium plus magnesium / potassium ratios in bean plants inoculated with tobacco mosaic virus and found that greatest lesion numbers were seen in the medium of high magnesium with low potassium and calcium, and in the medium of high calcium and low magnesium and potassium.

The investigations of Crowley and Hanson (1960) revealed that addition of potassium together with reduction of calcium in the nutrient medium produced considerable increase in the concentration of virus in tomato root meristem.

Roscoum (1962) noticed that the infectivity of tobacco necrosis virus, cucumber mosaic virus and

tobacco ring spot virus was inhibited by the application of calcium and magnesium in the nutrient solution. He remarked that the inhibitory effect of calcium and magnesium was decreased by potassium application.

Nambiar and Nair (1965) reported that calcium oxide plus magnesium oxide / potassium oxide ratio in the leaves had a bearing on the incidence of Bunchy top disease of banana. The ratio was lower in diseased leaf samples compared to the healthy. Further experiments by Nair and Pillai (1966) revealed that a CaO + MgO / K_2O ratio of one or near about one in the plant tissue could successfully resist the incidence of Bunchy top disease until the emergence of the bunch. George and Nair (1966) concluded that the resistance of Bunchy top virus might be correlated to the ratio of calcium oxide plus magnesium oxide / potassium oxide ratio in the leaf, and not merely to the ratio of calcium oxide / magnesium oxide.

Sulphur

Arenz (1949) found that regeneration of potatoes infected with potato leaf roll virus could be effected only by application of nitrogen. This effect was favoured by application of sulphate. According to him this was due to the higher formation of plant protein.

Suss (1956) observed that in healthy potato leaves sulphur was uniformly distributed but in those infected by potato leaf roll virus, it accumulated in the veins though uptake was less than in the healthy.

Ling and Pound (1962) reported that in tobacco plants grown without sulphur or with sub-optimal sulphur, accumulation of tobacco mosaic virus was markedly and consistently less than that in plants receiving optimum sulphur levels.

Sastry (1965) noted that growth of Crotalaria juncea and concentration of sunhemp mosaic virus were reduced at levels of sulphur above the optimum for growth.

Prusa et al (1965) found that hop curl disease of hop plants did not bring about any change in sulphur content in the plants.

Micronutrients

Srivastava (1964) in his studies on the response of banana to micronutrients observed that zinc proved most helpful for the growth of the plants. Copper, boron and molybdenum helped better growth of the subterranean parts and some root characters and manganese showed useful effect but not of a high order.

Micronutrients produced deficiency and toxic symptoms in plants, similar to virus infection. This has

aroused the attention of many workers and led to the investigation of the part played by micronutrients in plant virus diseases.

Zinc

Yarwood (1954) demonstrated that the susceptibility of Phaseolus vulgaris leaves to tobacco mosaic virus was induced by 10 minutes immersion in 0.001 to 0.003 per cent zinc sulphate. The same treatments decreased the number of tobacco mosaic lesions on Nicotiana glutinosa leaves.

The investigation of Holms and Pound (1955) brought out that tobacco grown in culture solutions recorded maximum virus concentration at the optimum level of zinc for plant growth.

Rich (1956) got promising results with zinc sulphate which reduced the percentage of diseased plants per plot from 8.6 to 3.0.

Trials of Hitier and Izard (1953) indicated that zinc sulphate had no effect in controlling tobacco mosaic virus disease.

Prusa et al (1965) found that hop curl disease of hop plants was noticeably inhibited by spraying or irrigation with salts of zinc.

Garcia (1966) got increased virus concentration and local lesion production in tomato plants infected by tobacco mosaic virus by zinc sprays.

Boron

Shephard and Pound (1959) noted that in boron deficient tobacco plants virus concentration was lesser in the early periods of infection, but later increased considerably. Similar results were also obtained by Sastry et al (1964) in sunhemp.

Ford et al (1964) concluded that potato virus X concentration in Nicotiana tobacum increased more slowly initially, but later reached higher concentrations in inoculated leaves of boron deficient plants than in those with sufficient boron. Boron deficiency did not alter virus translocation.

Prusa et al (1965) reported that hop curl disease was noticeably inhibited by spraying or irrigation with salts of boron.

According to Milbrath et al (1966) in a disease of sweet berry in which a virus and boron deficiency were involved, trees sprayed with boron produced normal fruits and leaves.

Iron

Analytical studies of Loring and Woods (1957) showed that iron was a constituent of virus.

Pound and Welkie (1958) noted that the intensity of mosaic virus symptom was less in the iron deficient tobacco plants.

According to Parthasarathi and Rao (1962) spike disease in sandal caused reduction in the absorption and translocation of iron which produced chlorotic leaves. They observed a high accumulation of iron in the root tips, which later led to decay.

Sastry (1964) concluded that the optimum level of iron for plant growth was congenial for maximum virus multiplication in sunhemp.

Zelenova (1964) reported that insufficient iron and manganese diminished symptoms of infection of cucumber mosaic virus in cucumber (Cucumis sativus).

Nadi and Roychaudhiri (1966) observed in potato plants that concentration of potato virus X was less at low levels of iron. Deficiency of iron appeared to limit virus multiplication.

Prusa et al (1965) found in hop curl disease of hop plants that there was no difference in iron concentration before and after the incidence of the disease.

Manganese

Studies of Sreenivasa Rao (1933) showed that manganese content is higher in virus infected plants.

From the trials on tobacco plants, Holtie and Pound (1958) observed that intensity of mosaic disease symptom was reduced with a decrease in manganese supply, but concentration of virus reached a higher level than in normal plants.

Carmen (1963) reported that manganese deficient tobacco plants were more susceptible to cucumber mosaic virus and cabbage virus.

Experiments of Gastry (1964) on sunhemp mosaic virus brought to light that manganese deficient plants had higher virus concentration.

Carpenter (1964) showed that transmission of bean yellow mosaic virus by aphids was unaffected by manganese nutrition of the host.

Zolonova (1964) observed that insufficient manganese in the nutritive medium diminished symptoms of infection with cucumber mosaic virus on cucumber.

Prusa et al (1965) showed that hop curl disease in hop plants was noticeably inhibited by spraying or irrigation with salts of manganese.

Molybdenum

The observations of Hitier and Izard (1959) showed that ammonium molybdate failed to control the mosaic disease of tobacco plants.

Pirone and Pound (1962) observed that mosaic virus infected tobacco plants when grown at different molybdenum levels produced higher virus concentration in plants receiving molybdenum at optimum for plant growth.

According to Sastry (1962) virus concentration is positively correlated with plant growth. He found that the maximum concentration of virus was obtained at the level optimum for growth at all stages following inoculation.

Prusa et al (1963) showed that hop curl disease of hop plants was inhibited by spraying or irrigation with salts of molybdenum.

Copper

According to Loring and Waritz (1957) copper is an intrinsic ingredient of tobacco mosaic virus.

Sastry (1963) noticed that the levels of copper favouring optimum growth of sunhemp increased the concentration of virus in plant tissue.

Sastry (1964) confirmed these results by further experiments.

Chlorine

Dierckx (1953) found that excess chloride in the soil amendments strongly accelerated the movement of X virus of the potato plant.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment was conducted at the Agricultural College and Research Institute, Vellayani during 1967-68 to study the relationship between the nutritional status of soil and the incidence of Bunchy top disease of banana. The effect of application of calcium oxide and magnesium oxide in the ratio of 3 : 1 at different rates in the soil on the incidence of Bunchy top disease and the CaO/MgO ratio within the plants was studied under partially controlled field conditions.

A. MATERIALS

1. Reinforced cement concrete rings

Thirty reinforced cement concrete rings, each with a capacity to hold one ton of soil, were implanted in the experimental plot at a distance of 2.5 meters, centre to centre either way, for planting the banana suckers. The rings were 1.6 metres long with a radius of 50 cm. and they restricted the spread of roots of each plant laterally and prevented the mingling of treatment effects.

Soil

Each pit was filled with one ton of soil. Before the pits were filled in, the soil was mixed with N P K

fertilisers, lime and magnesium carbonate. The mechanical and chemical compositions of the original soil are given below.

Mechanical composition of soil
(Expressed as percentage on oven-dry basis)

Coarse sand	-	42.36
Fine sand	-	14.24
Silt	-	8.37
Clay	-	31.24

Chemical composition of soil
(Expressed as percentage on oven-dry basis)

Nitrogen	-	0.046
Total phosphoric acid		0.109
Potash (K_2O)	-	0.156
Calcium oxide	-	0.140
Magnesium oxide	-	0.037

Banana suckers

The variety 'Java' was used as the planting material. The suckers were collected from the Agricultural College and Research Institute, Vellayani.

Vector

Banana aphids, Pentalonia nigronervosa Coq., reared on diseased plants, were collected along with plant

tissues and released on healthy experimental plants at the rate of 100 aphids per plant.

Manures and fertilisers

No organic manure was used. Nitrogen, phosphorus and potassium were supplied through fertilisers.

(i) Nitrogen

Ammonium sulphate containing 20% N and ammonium phosphate containing 16% N were used at the rate of 480 gm. and 1088 gm. respectively per plant.

(ii) Phosphoric acid

Ammonium phosphate containing 20% P_2O_5 was applied at the rate of 1088 gm. per plant (mixed with the soil).

(iii) Potash

Muriate of potash containing 54.55% K_2O was used at the rate of 2930 gm. per plant (mixed with the soil).

(iv) Secondary elements

Slaked lime analysing 61.93% CaO and magnesium carbonate containing 46.93% MgO were used to supply calcium and magnesium respectively. The quantities of secondary elements applied were as per the treatment levels.

The liming materials and muriate of potash were first thoroughly mixed with the soil and left over for a few days. The first instalment of ammonium phosphate was mixed with the soil only after ensuring there was no free lime and that the soil pH was acid. The soil was then filled in the cement concrete rings. There were three more applications of ammonium phosphate at weekly intervals.

B. METHODS

1. Lay out

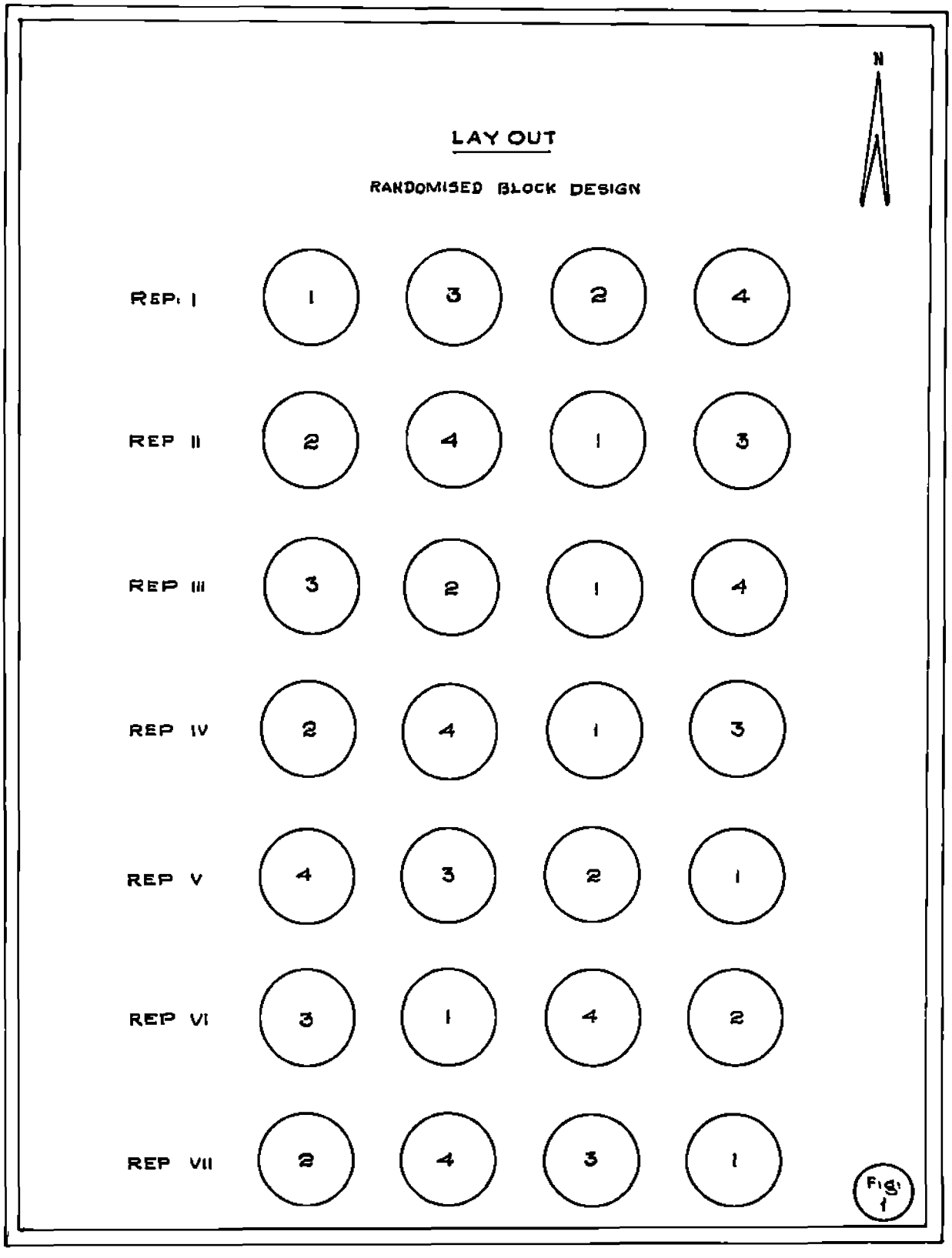
The experiment was laid out in randomized block design with four treatments and seven replications.

2. Treatments

Three levels of calcium and three levels of magnesium with CaO/MgO ratio of 3 : 1 were compared. The treatments were as follows:

1. CaO 0.00% and MgO 0.00% - Control
2. CaO 0.15% and MgO 0.05%
3. CaO 0.30% and MgO 0.10%
4. CaO 0.60% and MgO 0.20%

Calcium oxide and magnesium oxide were applied on the basis of the above percentage in one ton of soil used in each concrete pit.


N
LAY OUT
RANDOMISED BLOCK DESIGN
REP. I
1
3
2
4
REP II
2
4
1
3
REP III
3
2
1
4
REP IV
2
4
1
3
REP V
4
3
2
1
REP VI
3
1
4
2
REP VII
2
4
3
1
FIG. 1

VELLAYANI * LIBRARY * AGRICULTURAL RESEARCH INSTITUTE

3. Sterilization of pit

Sterilization of the concrete cylinders was done by stuffing trash and dry leaves inside and burning and then removing the ash before filling.

4. Application of fertilizers and secondary nutrients

The entire quantity of muriate of potash, slaked lime and magnesium carbonate were applied to the soil, thoroughly mixed and allowed to lie over for a week.

The soils

One fourth of the ammonium phosphate was then mixed with the soil and the pits were filled. The remaining quantity of ammonium phosphate was applied in three equal weekly instalments. 480 gm. of ammonium sulphate was applied on 18-12-1967, 45 days after planting. The ammonium phosphate and ammonium sulphate were applied and mixed with the top soil to a depth of 4 inches.

5. Planting

Planting was done in the centre of the ring on 2-11-1967. Planting was done in such a way that the rhizome was completely below the soil surface. Twelve plants, randomly selected were planted in an adjacent plot to check whether the suckers were originally disease-free.

6. Irrigation

Watering was done thoroughly, prior to planting for compacting the soil in the ring. Light irrigation was given daily for one month and thereafter the plants were watered every alternate days with equal quantities of water, to keep the soil sufficiently moist.

7. Spraying

All plants were sprayed with foliidol E.605 (0.02 per cent) at an interval of 10 days from 3-12-1967, to prevent any natural infection through aphids. This was continued till 10 days before inoculation.

8. Release of aphids

A cool and moist atmosphere was provided by forming a pandal over the experimental plants, just one day prior to the liberation of aphids. To provide congenial conditions, the floor was moistened a day prior to inoculation and this was continued for 5 days. Inoculation was done on 31-1-1968 when the plants were three months old. Infective aphids at the rate of 100 per plant were released in the axils of the top most leaves of all the plants. This portion was covered with banana leaves to provide humid conditions.

The aphids were supplied by the Professor of Plant Pathology and released on the bananas under

arrangements made by him. In normal experiments of this type the number of aphids released is 20, while in this experiment 100 aphids each were released as specially requested.

The pandal was removed on 6-2-1963, 5 days after inoculation and folidol E.605 (0.02 per cent) sprayed to destroy the aphids.

9. Recording of observations

(a) Plant growth

The growth characteristics of the plants recorded were the following:

(i) Height of the plant: The height of the plant was measured from the base of the pseudostem to the apex.

(ii) Girth of the plant: The girth of the plant was measured near the base of the pseudostem.

(iii) Number of leaves: The number of fully opened leaves was counted and recorded.

(iv) Length and width of leaves: The length of each leaf was taken from the proximal to the distal end of the lamina. The width was measured at the middle region of the leaf.

(b) Disease symptoms

The following symptoms were observed for the Bunchy top disease:

(i) Presence of irregular, nodular dark green streaks seen along secondary veins of the leaf blade, along leaf stalk and along the lower portion of the midrib.

(ii) Shortening of length and width of leaf.

(iii) Harsh and brittle nature of petiole and lamina, corrugated nature of mature leaves and upward rolled margins of young leaves.

(iv) Absence of normal elongation of the petiole causing leaves to assume an unusually erect position, thus leading to the 'rosette' condition.

(c) Chemical analysis

Analysis of samples of soil, leaf and root were done for nitrogen, phosphorus, potassium, calcium and magnesium. The samples were taken from all the 28 plants before and after the transmission of virus. The first sample was taken 3 days before the release of the aphids and the second 60 days afterwards.

Nitrogen was estimated by Kjeldahl method as given by Piper (1950). Phosphoric acid and potash were determined by the method adopted by the A.O.A.C. (1960). Versene (disodium dihydrogen ethylene diamine tetra-acetic acid) method as given by Jackson (1958) was adopted to estimate calcium and magnesium.

RESULTS

RESULTS

Growth measurements of all plants were recorded at weekly intervals from two months after planting and were continued for four months. Height of plants, girth of pseudostem, number of fully opened leaves and length and width of leaves were recorded. Inoculation with infective aphids was done on 31-1-1968 ie. 90 days after planting. The number of days taken for the appearance of disease symptoms was noted. Samples of soil, leaf and root were collected from all treatments before and after the transmission of virus and chemically analysed for nitrogen, phosphorus, potassium, calcium and magnesium.

Growth characteristics

The average growth measurements such as height and girth of the plants, number of fully opened leaves and length and width of the leaves observed at weekly intervals are presented in Tables I to V. There was increased growth rate for all characters till the appearance of disease symptoms. The plants ceased to increase their height and girth after the occurrence of the disease. The length and width of newly emerged leaves of the diseased plants decreased and later the leaves failed to emerge fully.

The growth measurements two days before and 105 days after inoculation were statistically analysed. The analysis of variance tables are given in Appendices I to X.

TABLE I

Average growth measurements at weekly intervals

Height of plants in cm.

Date of measurement	Treatment 1	Treatment 2	Treatment 3	Treatment 4
8-1-68	138.00	130.39	124.84	113.43
15-1-68	141.43	133.86	127.14	115.71
22-1-68	146.71	136.87	129.00	118.14
29-1-68	152.00	139.66	130.29	119.57
5-2-68	154.71	144.14	135.43	123.29
12-2-68	156.86	147.00	136.86	126.43
19-2-68	158.57	149.43	137.29	126.14
26-2-68	159.43	150.71	138.86	128.14
4-3-68	161.29	153.00	139.71	130.86
11-3-68	163.29	155.55	142.14	132.86
18-3-68	164.86	155.71	143.43	134.43
25-3-68	163.71	159.29	147.71	138.71
1-4-68	165.14	162.71	147.71	139.14
8-4-68	165.14	162.71	147.71	139.14
15-4-68	165.14	162.71	147.74	139.14
22-4-68	165.14	162.71	147.74	139.14
29-4-68	165.44	162.71	151.71	141.40
6-5-68	165.62	162.71	151.71	141.40

TABLE II

Average growth measurements at weekly intervals

Girth of plants in cm.

Date of measurement	Treatment 1	Treatment 2	Treatment 3	Treatment 4
8-1-68	38.29	36.00	35.00	31.86
15-1-68	40.14	38.29	35.86	32.86
22-1-68	42.43	39.00	36.57	33.71
29-1-68	43.86	40.29	37.71	35.00
5-2-68	45.00	41.00	38.14	35.29
12-2-68	46.43	41.43	38.71	36.86
19-2-68	46.14	42.86	39.56	37.14
26-2-68	46.43	44.29	40.43	38.00
4-3-68	49.00	45.00	40.86	38.86
11-3-68	49.86	45.29	41.43	39.29
18-3-68	49.86	45.86	42.00	40.14
25-3-68	50.29	47.14	42.00	40.86
1-4-68	50.29	47.42	43.41	42.14
8-4-68	50.29	48.71	45.00	43.67
15-4-68	50.30	49.00	45.67	44.67
22-4-68	50.31	50.00	46.28	45.00
29-4-68	50.41	50.85	47.67	46.14
6-5-68	50.62	52.14	48.40	47.00

AGRIC. COLL. VELLAYANI LIBRARY

TABLE III

Average growth measurements at weekly intervals

Number of fully opened leaves

Date of measurement	Treatment 1	Treatment 2	Treatment 3	Treatment 4
8-1-68	5.00	5.00	3.71	3.86
16-1-68	5.86	6.42	4.12	4.12
22-1-68	6.71	6.00	6.00	4.86
29-1-68	7.57	6.86	6.71	5.71
5-2-68	8.15	7.86	6.42	6.57
12-2-68	8.71	7.86	7.14	7.00
19-2-68	9.42	8.57	7.86	8.00
26-2-68	10.00	9.57	8.04	8.42
4-3-68	10.42	9.86	8.86	8.57
11-3-68	11.14	10.57	9.14	9.14
18-3-68	11.86	11.14	10.14	9.57
25-3-68	12.71	11.71	10.86	10.28
1-4-68	12.71	12.14	11.28	10.57
8-4-68	12.71	12.42	11.57	10.86
15-4-68	13.57	13.14	12.42	11.57
22-4-68	13.71	13.42	12.86	11.86
29-4-68	13.86	14.42	13.42	12.42
6-5-68	14.42	15.00	14.00	11.57

TABLE IV

Average growth measurements at weekly intervals

Length of leaves in cms.

Date of measurement	Treatment 1	Treatment 2	Treatment 3	Treatment 4
8-1-68	122.43	119.29	105.86	93.29
15-1-68	123.33	124.66	113.00	105.00
22-1-68	131.17	124.25	110.00	101.40
29-1-68	129.83	122.83	120.50	105.85
5-2-68	134.50	123.14	118.80	110.86
12-2-68	134.71	123.67	120.85	111.23
19-2-68	134.71	122.14	117.71	112.71
26-2-68	131.67	135.57	118.00	114.28
4-3-68	129.14	133.85	122.14	115.42
11-3-68	125.28	137.71	124.57	116.42
18-3-68	130.14	131.28	121.42	122.14
25-3-68	129.85	133.42	122.28	123.00
1-4-68	124.42	136.14	121.28	117.14
8-4-68	125.85	130.71	122.42	116.42
15-4-68	109.67	112.28	94.00	104.28
22-4-68	102.85	118.71	96.67	101.14
29-4-68	100.28	116.14	100.67	105.28
6-5-68	89.85	130.00	90.00	110.57

TABLE V

Average growth measurements at weekly intervals

Width of leaves in cms.

Date of measurement	Treatment 1	Treatment 2	Treatment 3	Treatment 4
8-1-68	41.86	42.00	37.00	35.86
15-1-68	45.33	45.66	42.00	40.00
22-1-68	44.83	43.75	38.60	36.20
29-1-68	47.00	44.83	45.25	41.17
5-2-68	52.50	46.71	42.00	42.57
12-2-68	49.42	46.28	43.71	41.28
19-2-68	47.85	47.14	44.85	44.00
26-2-68	47.42	49.00	45.00	44.14
4-3-68	43.85	49.14	45.28	44.28
11-3-68	41.28	48.28	45.57	43.71
18-3-68	43.14	48.71	44.14	45.14
25-3-68	43.85	46.42	45.14	46.85
1-4-68	43.85	43.85	46.00	45.14
8-4-68	43.85	41.28	45.57	39.67
15-4-68	34.85	34.71	34.42	36.28
22-4-68	34.14	34.57	33.71	32.40
29-4-68	36.28	34.85	30.28	33.17
6-5-68	29.00	35.43	31.57	35.14

There was significant difference between the treatments before the transmission of the virus showing that growth rate was not uniform for all treatments. After the transmission of the virus there was no significant difference in growth characters between the treatments.

Appearance of disease symptoms

The number of days taken for the appearance of symptoms in the diseased plants under various treatments are given in Table VI. The analysis of variance is given in Appendix XI. There was significant difference between the treatments.

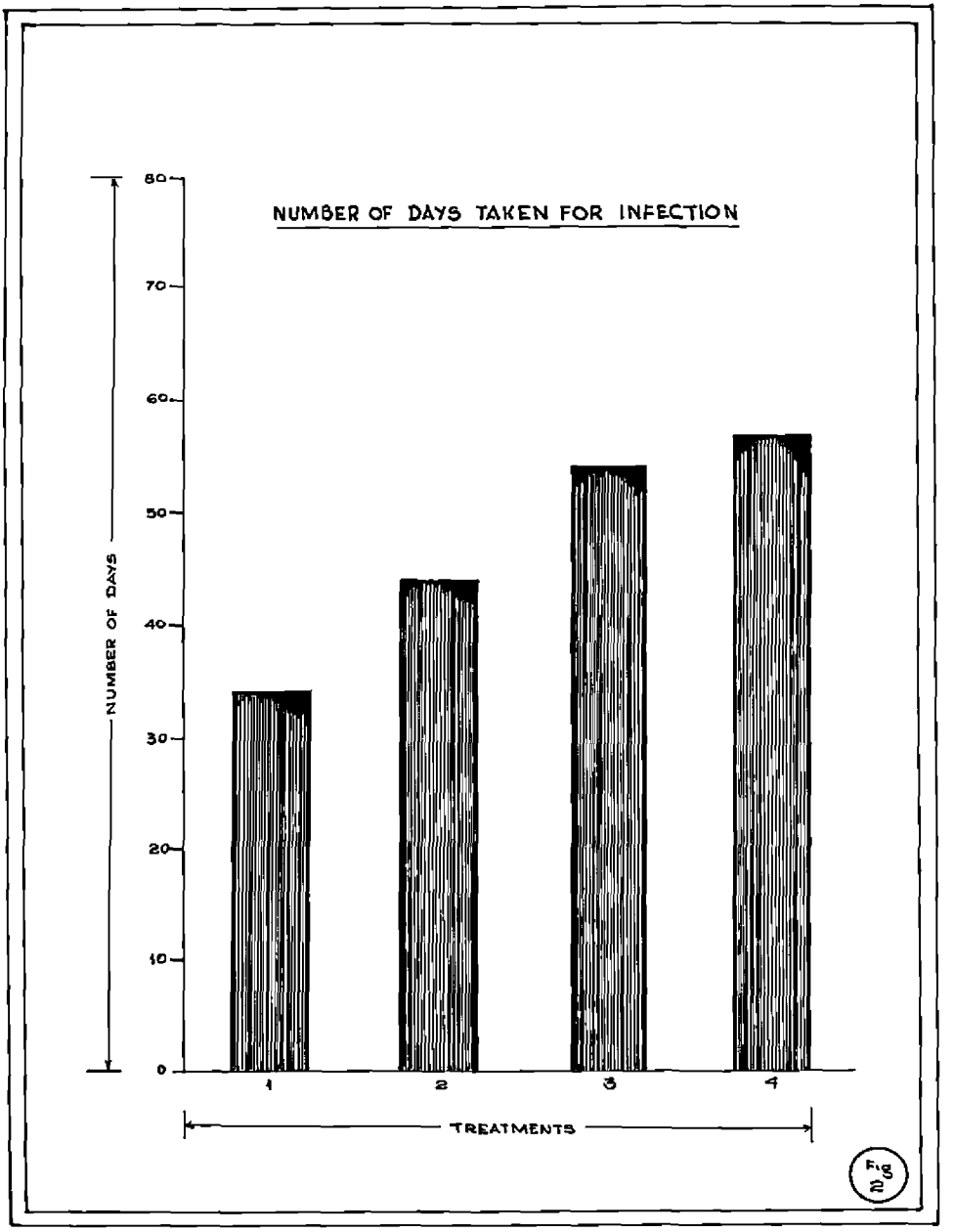
It can be seen from Table VI, that the control plants contracted the disease earlier than the treated plants. The number of days taken for infection varied from 30 to 42 for control and 32 to 75 for treated plants. Some plants in treatments 2, 3 and 4 have withstood infection for 250 days after planting, that is, till the end of the experimental observations. It is expected these will give normal bunches. The number of plants infected in the treatments 1, 2, 3 and 4 were seven, five, six and four respectively. Treatment 4 had only four infected plants out of seven inoculated, followed by treatments 2, 3 and 1. The plants under treatments

TABLE VI

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

Blocks	Treatment 1	Treatment 2	Treatment 3	Treatment 4
I	30	42	48	63
II	32	32	64	58
III	34	38	48	H
IV	34	H	42	H
V	42	H	H	54
VI	34	62	68	H
VII	34	48	75	58

H = Healthy plants.


NUMBER OF DAYS TAKEN FOR INFECTION
NUMBER OF DAYS
80
70
60
50
40
30
20
10
0
1
2
3
4
TREATMENTS
FIG 21

The mean phosphorus content of leaf samples before the transmission of virus is furnished in Table XII.

There was no significant difference in the uptake of phosphorus in the calcium oxide and magnesium oxide treated plants over the control. The maximum content of 0.461 percent phosphoric acid was seen in treatment 4.

TABLE XII

Mean phosphoric acid (P_2O_5) content of leaf samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.400	0.377	0.419	0.461

(11) Phosphorus status after the incidence of the disease

The statistical analysis of the data on the uptake of phosphorus after the incidence of the disease showed that the absorption of phosphorus was not significant between the treatments. The maximum absorption was found for treatment 4. The analysis of variance and the mean uptake of phosphorus after the incidence of the disease are furnished in Appendix XV and in Table XIII.

TABLE XIII

Mean phosphoric acid (P_2O_5) content of leaf samples after the incidence of the disease.

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.421	0.301	0.414	0.479

(c) Potassium

(1) Potassium status before the transmission of virus

The analysis of variance for the uptake of potassium before the transmission of virus is presented in Appendix XVI. It was seen that the variations between the calcium oxide and magnesium oxide treated and the control plants were statistically not significant.

The mean uptake of potassium before the transmission of virus is shown in Table XIV. Maximum absorption of 4.796% potash was in control plant, while plants receiving the highest levels of calcium oxide and magnesium oxide had the minimum content of 4.009%.

POTASH CONTENT OF LEAF SAMPLES

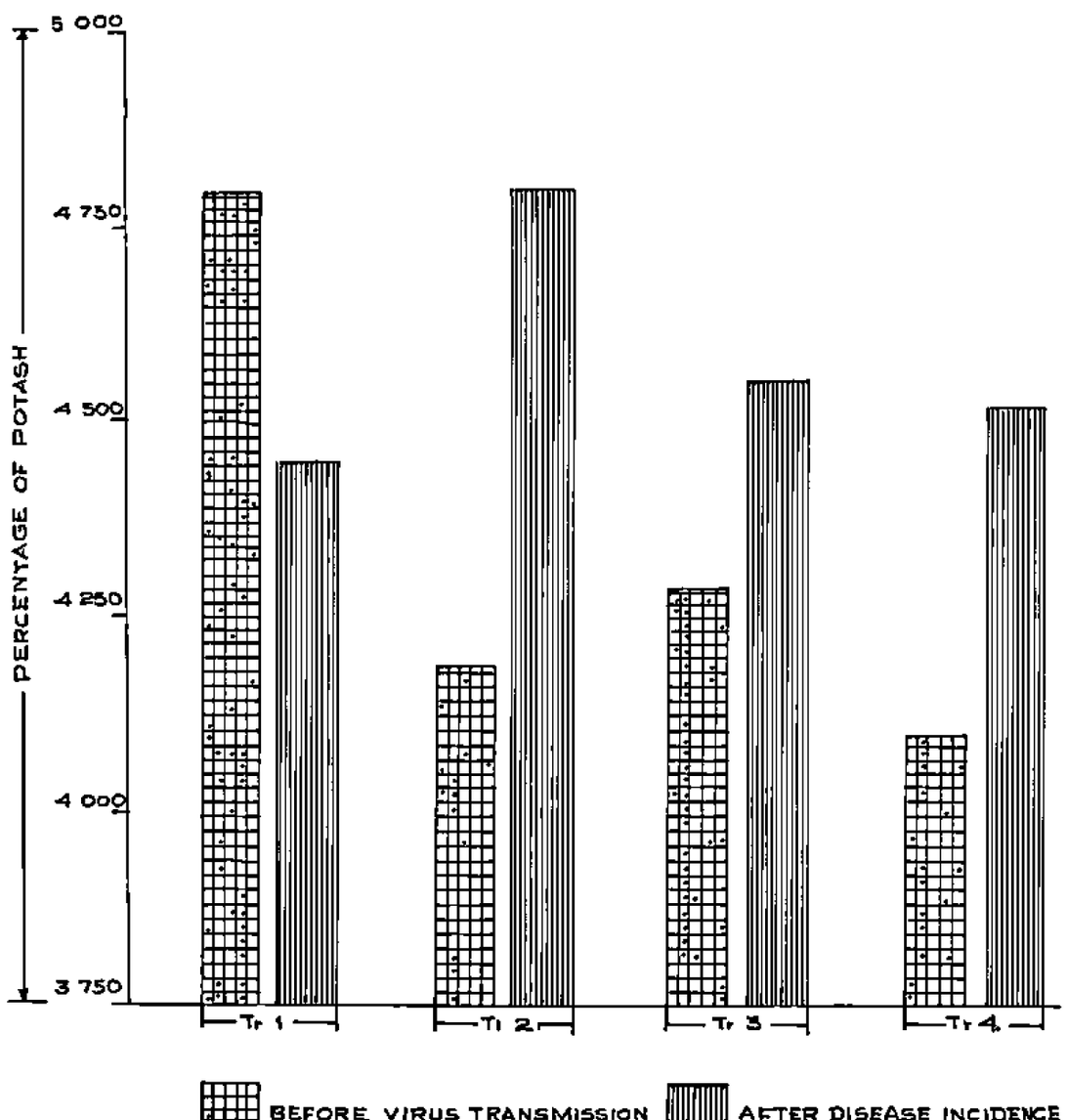


Fig 5

TABLE XIV

Mean potash content of leaf samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
4.796	4.186	4.287	4.099

(ii) Potassium status after the incidence of the disease

The data on the absorption of potassium after the incidence of the disease were analysed statistically and the analysis of variance is given in Appendix XVII. There was no significant difference in the uptake of potassium in the calcium oxide and magnesium oxide treated plants over the control.

The mean uptake of potassium after the incidence of the disease is given in Table XV. Treatment 2 showed the maximum absorption of 4.796%, while the plant receiving highest levels of calcium oxide and magnesium oxide ie. treatment 4 showed 4.617%. The control plants showed the lowest value of 4.447%.

The application of calcium oxide and magnesium oxide in increasing doses reduced the absorption of potassium in all treatments.

TABLE XV

Mean potash content of leaf samples after the incidence of the virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
4.447	4.706	4.552	4.617

(d) Calcium

(i) Calcium status before the transmission of the virus

The data on the uptake of calcium before the transmission of virus were analysed statistically. The analysis of variance given in Appendix XVIII shows that the difference in the uptake of calcium by the calcium oxide and magnesium oxide treated plants over control was significant.

The mean uptake of calcium by the various treatments before the transmission of virus is given in Table XVI. The application of calcium oxide and magnesium oxide in increasing doses increased the absorption of calcium. In control the calcium uptake was the lowest. The maximum percentage of calcium is. 0.646 was in treatment 4.

VELLORE

CALCIUM OXIDE CONTENT OF LEAF SAMPLES

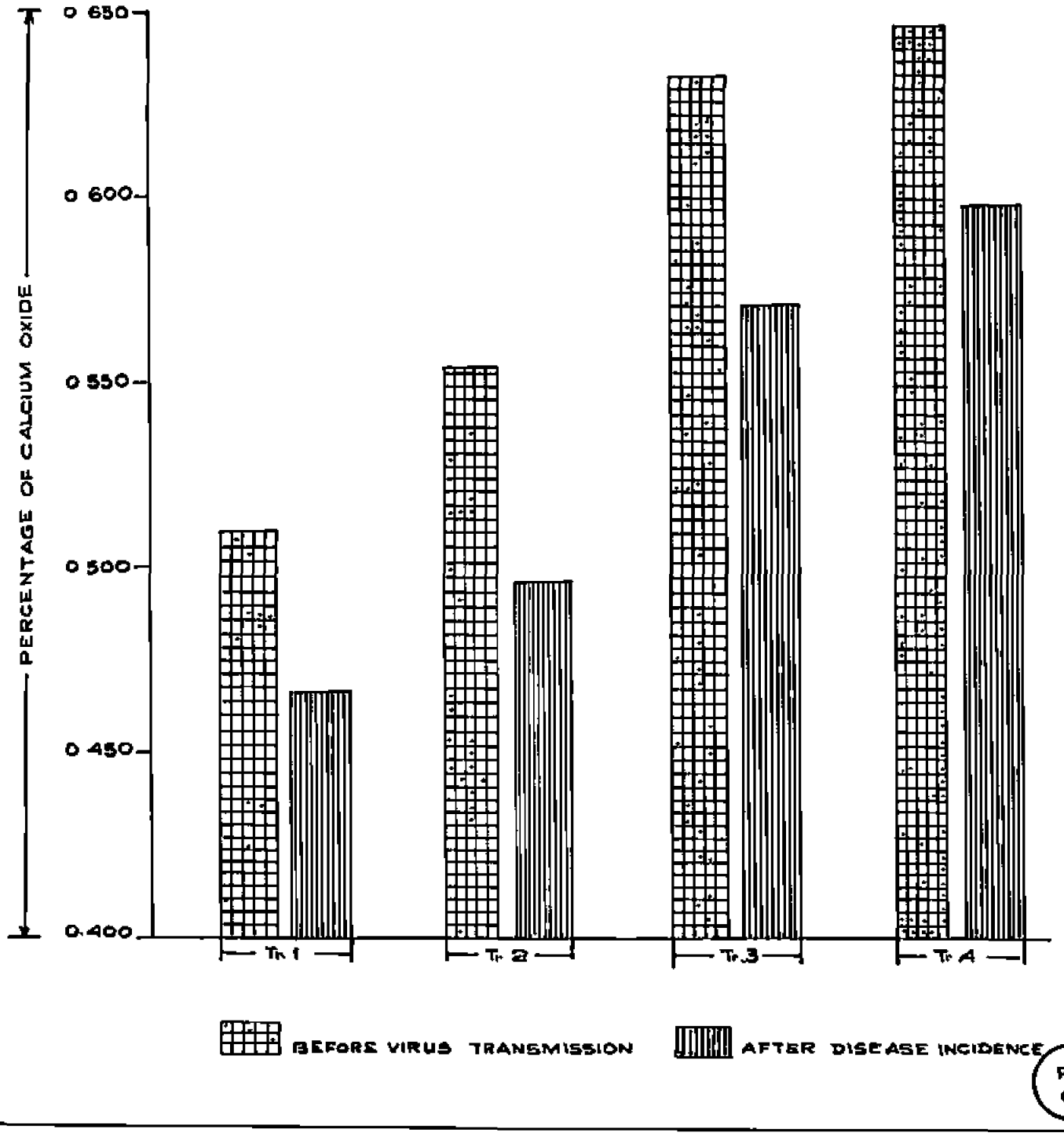


Fig 6

TABLE XVI

Mean calcium oxide content of leaf samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.609	0.664	0.633	0.646

Critical difference at 5% level : 0.084

(ii) Calcium status after the incidence of the disease

The statistical analysis of the data of calcium uptake after the incidence of the disease indicated that all the calcium oxide and magnesium oxide treated plants had significantly higher calcium content than the control plants. The analysis of variance is shown in Appendix XIX.

The mean uptake of calcium is given in Table XVII. Treatment 4 had the maximum content of 0.593% of calcium. The lowest calcium percentage of 0.466 was for control.

TABLE XVII

Mean calcium oxide content of leaf samples after the incidence of the disease

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.466	0.426	0.671	0.698

Critical difference at 5% level : 0.025

(c) Magnesium

(1) Magnesium status before the transmission of virus

The data of magnesium uptake before the transmission of the virus were analysed statistically and the analysis of variance is given in Appendix XX. The difference in the uptake of magnesium between the treatments was significant.

The mean uptake of magnesium by the various treatments before the transmission of virus is shown in Table XVIII. The application of calcium oxide and magnesium oxide in increasing doses increased the absorption of magnesium.

MAGNESIUM OXIDE CONTENT OF LEAF SAMPLES

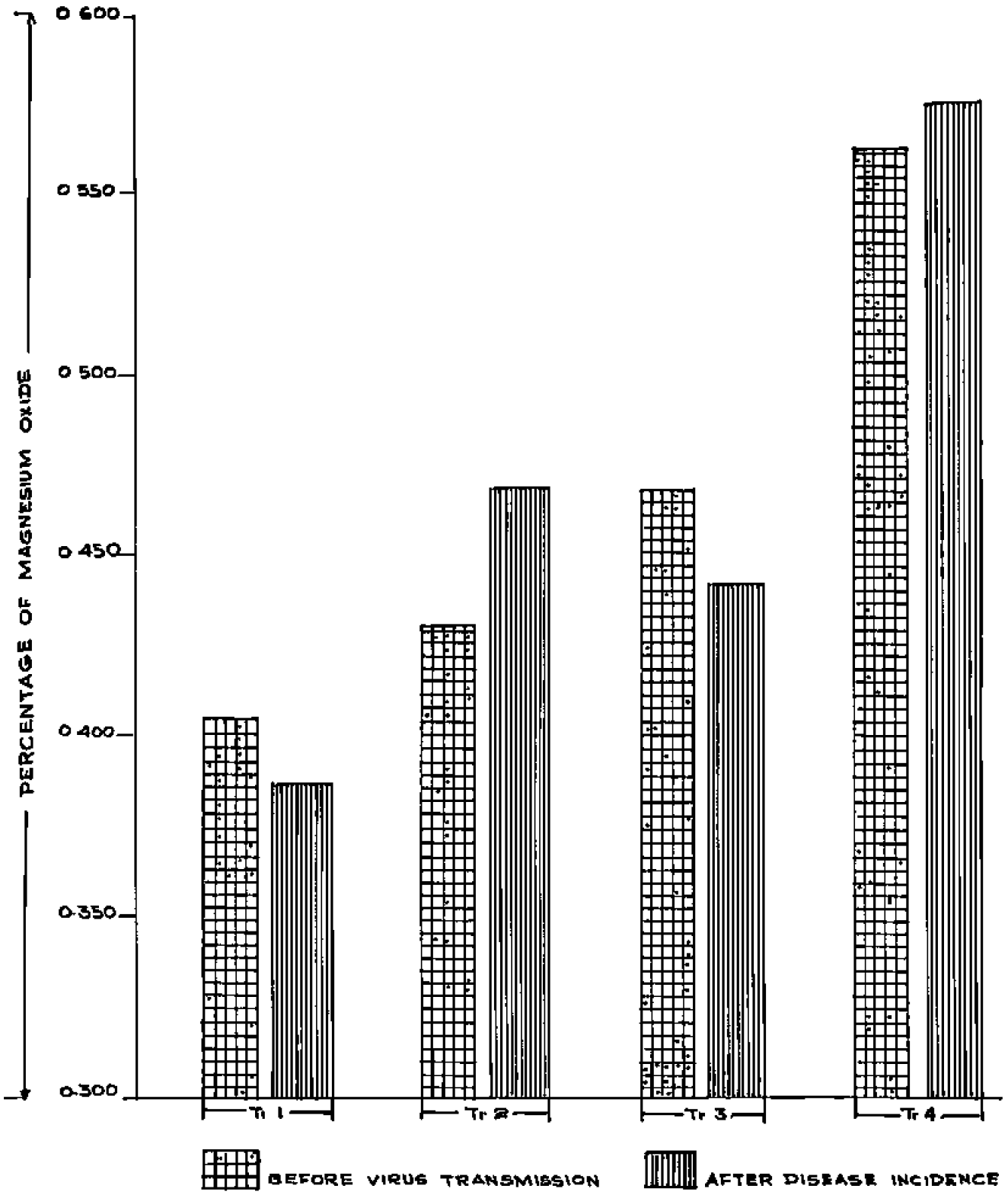


Fig 7

TABLE XVIII

Mean magnesium oxide content of leaf samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.405	0.430	0.468	0.563

Critical difference at 5% level : 0.105

(11) Magnesium status after the incidence of the disease

The statistical analysis of the data on the uptake of magnesium after the incidence of the disease indicated significant difference between treated and untreated plants. The analysis of variance is given in Appendix XXI.

The mean uptake of magnesium is furnished in Table XIX. The maximum content of 0.576% MgO was in treatment 4 and the lowest of 0.396% in the control.

The mean phosphorus content of leaf samples before the transmission of virus is furnished in Table XII.

There was no significant difference in the uptake of phosphorus in the calcium oxide and magnesium oxide treated plants over the control. The maximum content of 0.461 percent phosphoric acid was seen in treatment 4.

TABLE XII

Mean phosphoric acid (P_2O_5) content of leaf samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.400	0.377	0.419	0.461

(11) Phosphorus status after the incidence of the disease

The statistical analysis of the data on the uptake of phosphorus after the incidence of the disease showed that the absorption of phosphorus was not significant between the treatments. The maximum absorption was found for treatment 4. The analysis of variance and the mean uptake of phosphorus after the incidence of the disease are furnished in Appendix XV and in Table XIII.

TABLE XIII

Mean phosphoric acid (P_2O_5) content of leaf samples after the incidence of the disease.

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.421	0.301	0.414	0.479

(c) Potassium

(1) Potassium status before the transmission of virus

The analysis of variance for the uptake of potassium before the transmission of virus is presented in Appendix XVI. It was seen that the variations between the calcium oxide and magnesium oxide treated and the control plants were statistically not significant.

The mean uptake of potassium before the transmission of virus is shown in Table XIV. Maximum absorption of 4.796% potash was in control plant, while plants receiving the highest levels of calcium oxide and magnesium oxide had the minimum content of 4.009%.

POTASH CONTENT OF LEAF SAMPLES

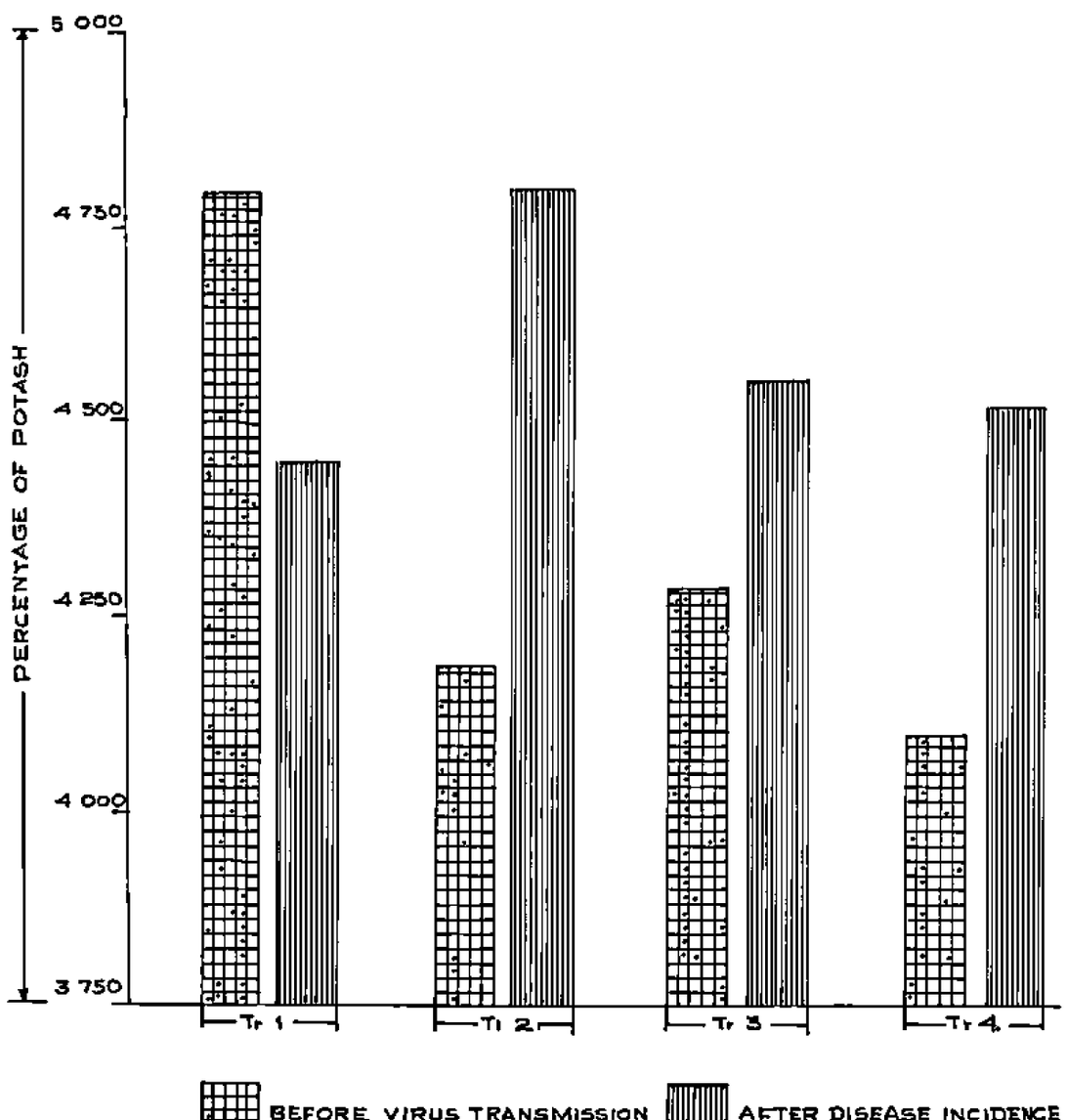


Fig 5

TABLE XIV

Mean potash content of leaf samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
4.796	4.186	4.287	4.099

(ii) Potassium status after the incidence of the disease

The data on the absorption of potassium after the incidence of the disease were analysed statistically and the analysis of variance is given in Appendix XVII. There was no significant difference in the uptake of potassium in the calcium oxide and magnesium oxide treated plants over the control.

The mean uptake of potassium after the incidence of the disease is given in Table XV. Treatment 2 showed the maximum absorption of 4.796%, while the plant receiving highest levels of calcium oxide and magnesium oxide ie. treatment 4 showed 4.617%. The control plants showed the lowest value of 4.447%.

The application of calcium oxide and magnesium oxide in increasing doses reduced the absorption of potassium in all treatments.

TABLE XV

Mean potash content of leaf samples after the incidence of the virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
4.447	4.706	4.552	4.617

(d) Calcium

(i) Calcium status before the transmission of the virus

The data on the uptake of calcium before the transmission of virus were analysed statistically. The analysis of variance given in Appendix XVIII shows that the difference in the uptake of calcium by the calcium oxide and magnesium oxide treated plants over control was significant.

The mean uptake of calcium by the various treatments before the transmission of virus is given in Table XVI. The application of calcium oxide and magnesium oxide in increasing doses increased the absorption of calcium. In control the calcium uptake was the lowest. The maximum percentage of calcium is. 0.646 was in treatment 4.

VELLORE

CALCIUM OXIDE CONTENT OF LEAF SAMPLES

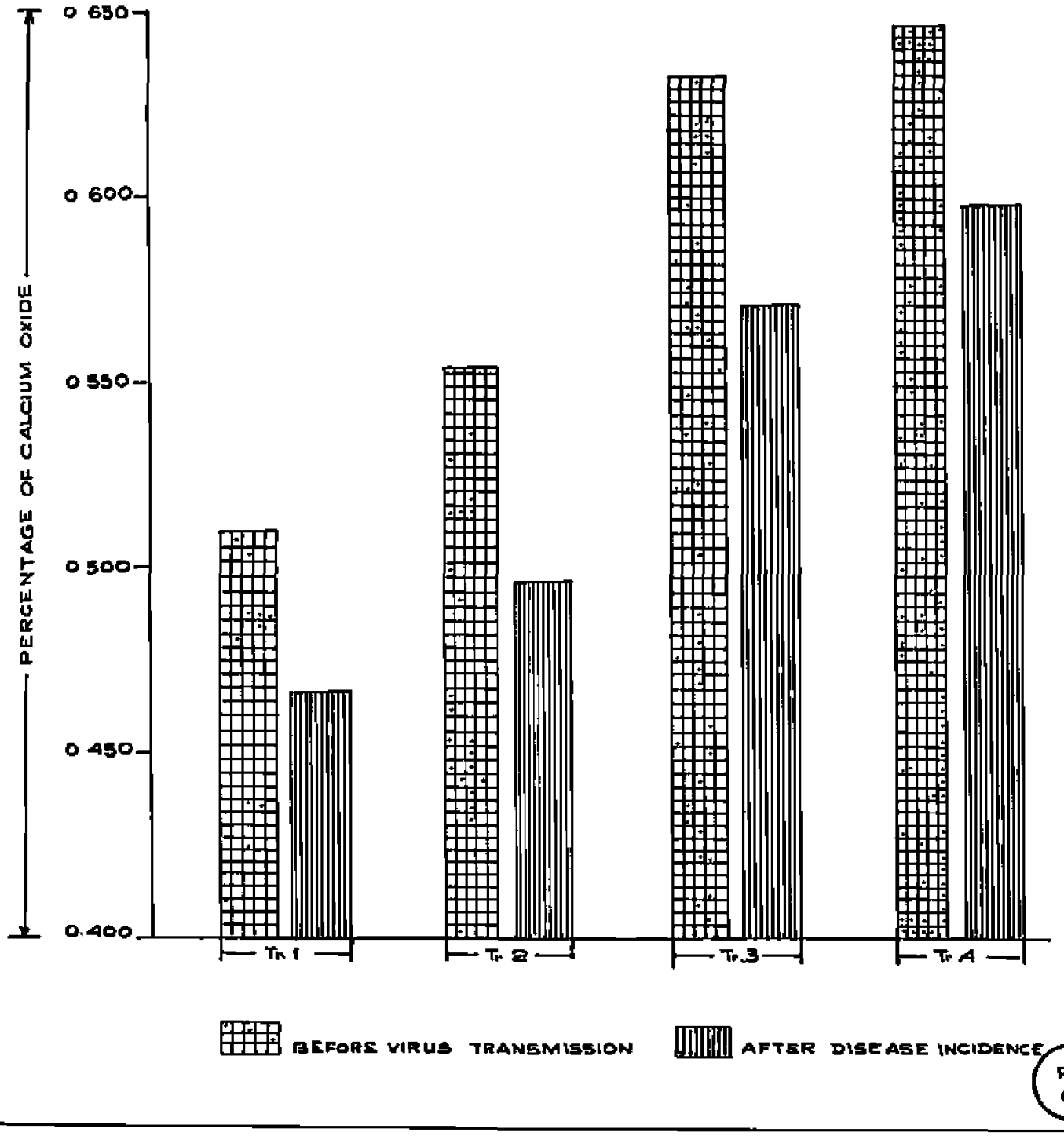


Fig 6

TABLE XVI

Mean calcium oxide content of leaf samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.609	0.664	0.633	0.646

Critical difference at 5% level : 0.084

(ii) Calcium status after the incidence of the disease

The statistical analysis of the data of calcium uptake after the incidence of the disease indicated that all the calcium oxide and magnesium oxide treated plants had significantly higher calcium content than the control plants. The analysis of variance is shown in Appendix XIX.

The mean uptake of calcium is given in Table XVII. Treatment 4 had the maximum content of 0.593% of calcium. The lowest calcium percentage of 0.466 was for control.

TABLE XVII

Mean calcium oxide content of leaf samples after the incidence of the disease

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.466	0.426	0.671	0.698

Critical difference at 5% level : 0.025

(c) Magnesium

(1) Magnesium status before the transmission of virus

The data of magnesium uptake before the transmission of the virus were analysed statistically and the analysis of variance is given in Appendix XX. The difference in the uptake of magnesium between the treatments was significant.

The mean uptake of magnesium by the various treatments before the transmission of virus is shown in Table XVIII. The application of calcium oxide and magnesium oxide in increasing doses increased the absorption of magnesium.

MAGNESIUM OXIDE CONTENT OF LEAF SAMPLES

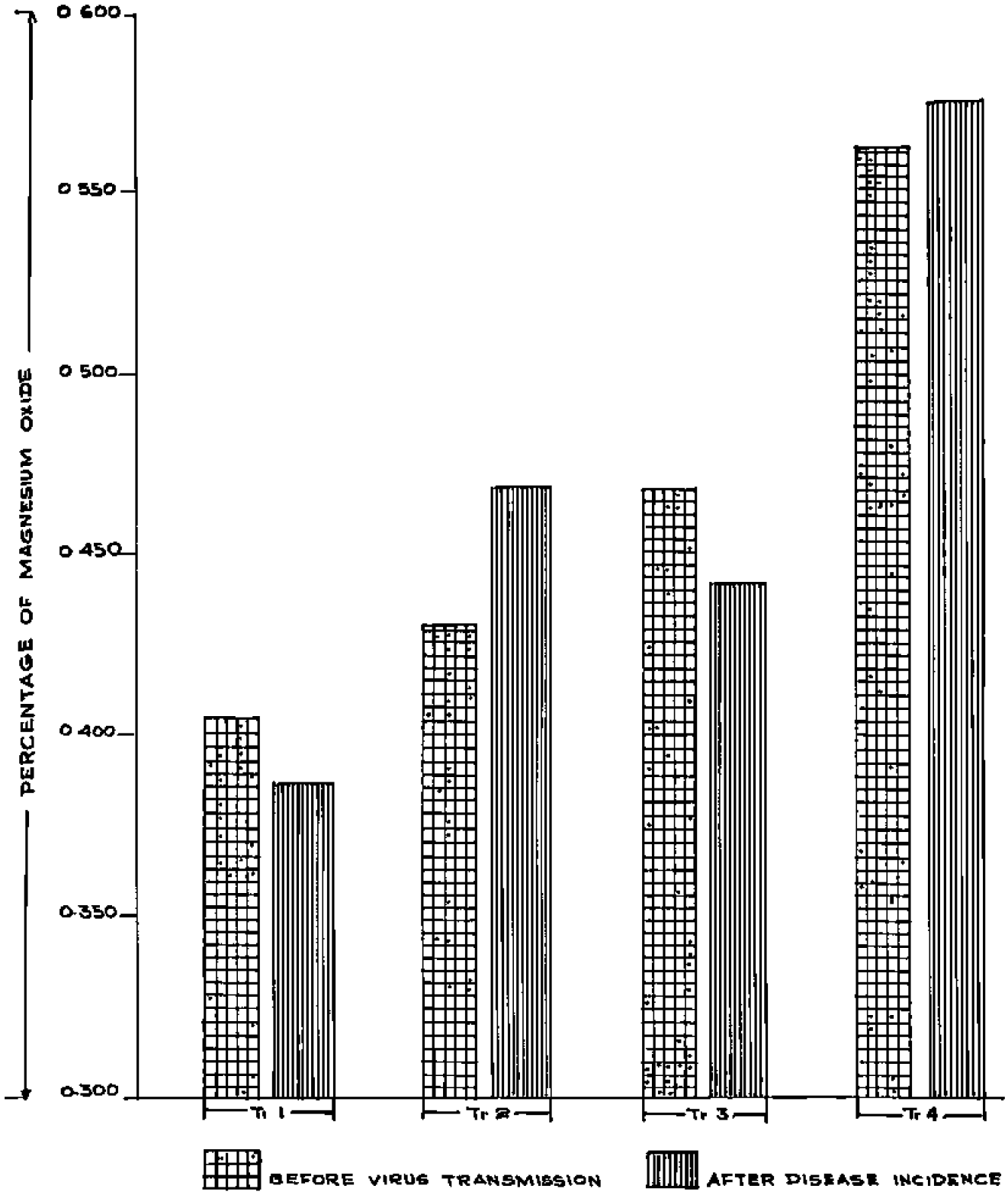


Fig 7

TABLE XVIII

Mean magnesium oxide content of leaf samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.405	0.430	0.468	0.563

Critical difference at 5% level : 0.105

(11) Magnesium status after the incidence of the disease

The statistical analysis of the data on the uptake of magnesium after the incidence of the disease indicated significant difference between treated and untreated plants. The analysis of variance is given in Appendix XXI.

The mean uptake of magnesium is furnished in Table XIX. The maximum content of 0.576% MgO was in treatment 4 and the lowest of 0.396% in the control.

TABLE XIX

Mean magnesium oxide content of leaf samples after the incidence of the disease

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.386	0.468	0.443	0.576

Critical difference at 5% level : 0.134

(f) Calcium oxide/magnesium oxide ratio

(i) The ratio before the transmission of virus

The analysis of variance table is furnished in Appendix XXII and it showed no significant difference between the treatments. The highest ratio of 1.446 was obtained in the control and there is a gradual decrease of the ratio in the calcium oxide and magnesium oxide treated plants. The lowest ratio of 1.193 was in treatment 4. Table XX presents the mean CaO/MgO ratio in the leaf before the transmission of virus.

CALCIUM OXIDE / MAGNESIUM OXIDE RATIO OF LEAF SAMPLES

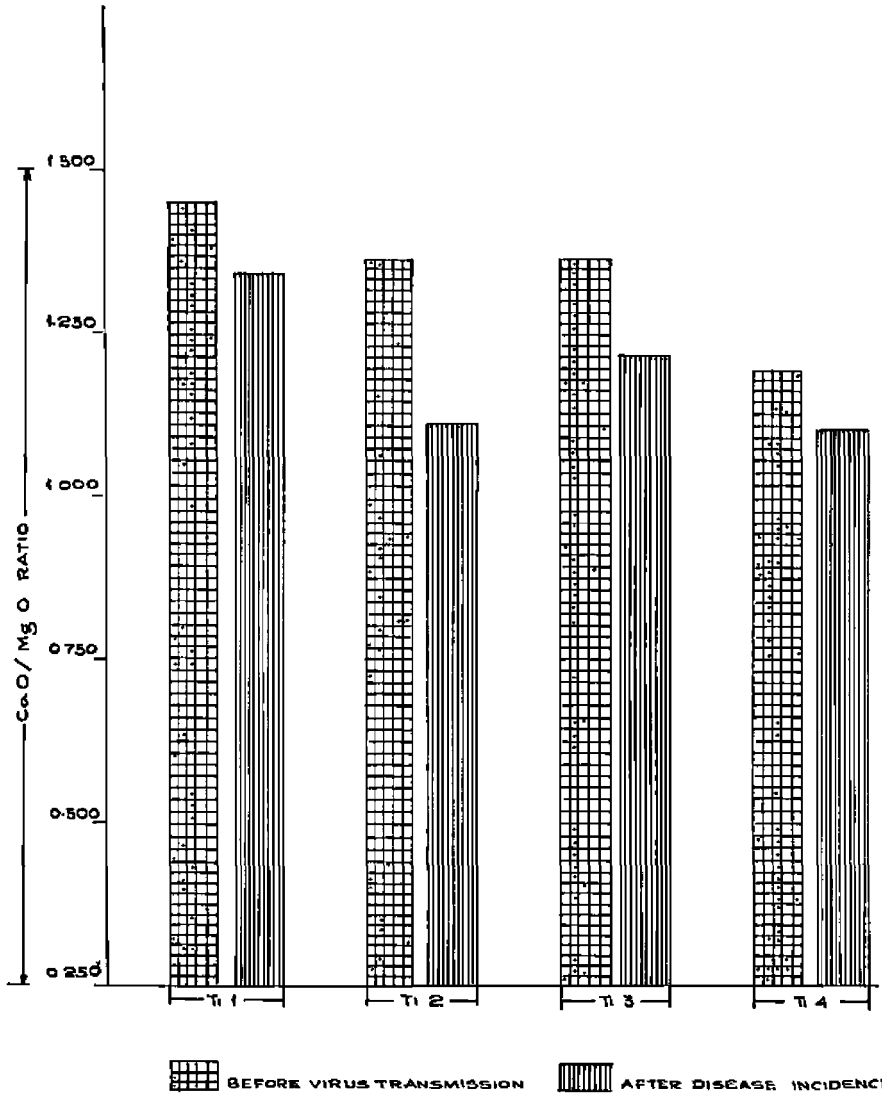


Fig 8

TABLE XX

Mean CaO/MgO ratio of leaf samples before the transmission of virus

Treatment 1	Treatment 2	Treatment 3	Treatment 4
1.446	1.357	1.361	1.193

(11) The ratio after the incidence of the disease

Appendix XXIII gives the analysis of variance and Table XXI presents the mean CaO/MgO ratio in the leaf after the incidence of the disease. The difference between the treatments is not significant. The highest ratio of 1.337 was in control.

TABLE XXI

Mean CaO/MgO ratio leaf samples after the incidence of the the disease

Treatment 1	Treatment 2	Treatment 3	Treatment 4
1.337	1.109	1.217	1.102

(g) Calcium oxide plus magnesium oxide/potassium oxide ratio

(i) The ratio before the transmission of the virus

The analysis of variance is given in Appendix XXIV. There was significant difference between the treatments.

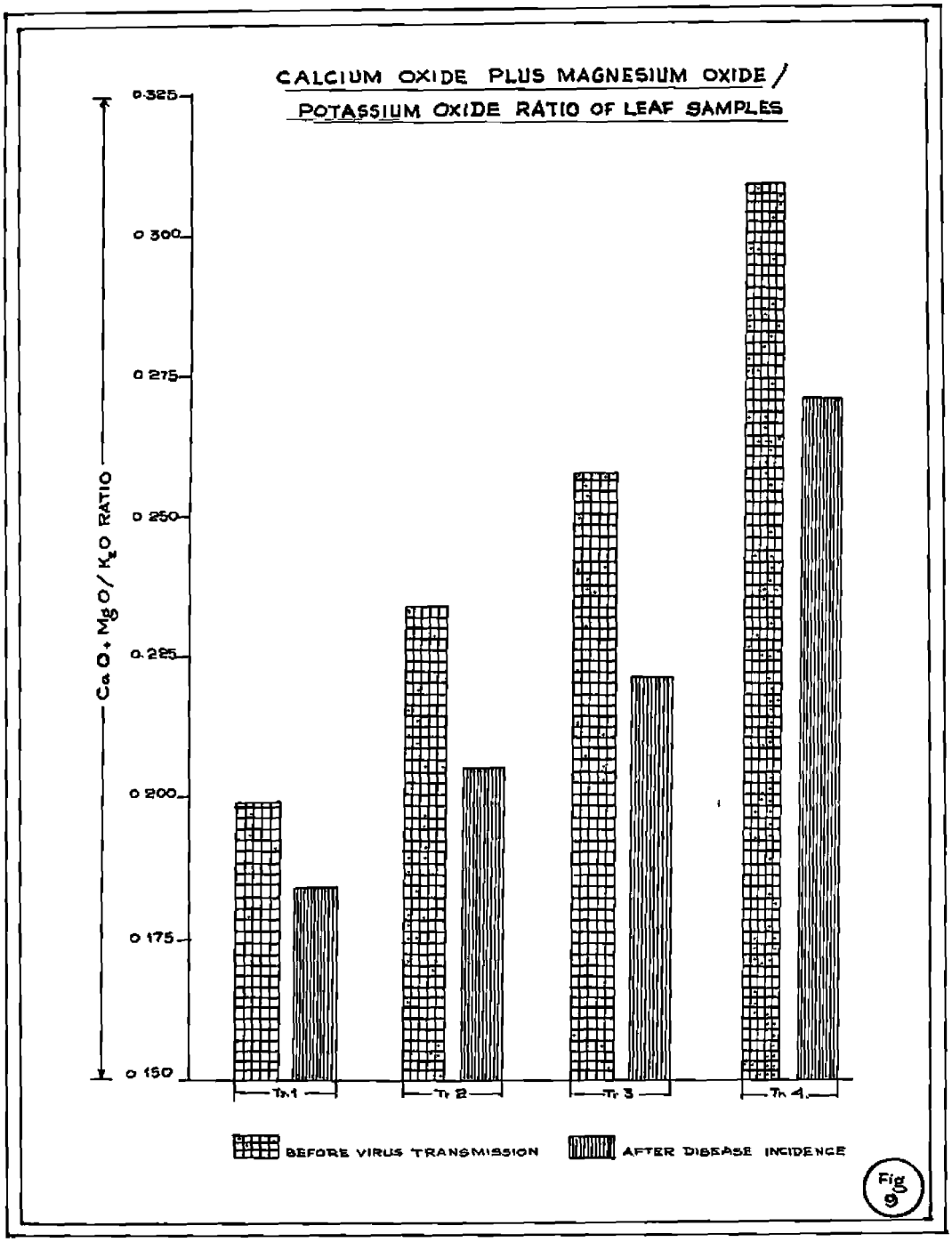
The mean value is furnished in Table XXII. There is a gradual increase in the ratio by the application of calcium oxide and magnesium oxide to the soil. Although the CaO:MgO ratio in the soil was maintained at 3:1 of added calcium and magnesium, the absolute quantities of CaO and MgO seem to have an effect in causing a gradually ascending ratio of $CaO+MgO/K_2O$ in the leaves. The lowest value of 0.199 was in treatment 1 and 0.309 was the highest value for treatment 4.

TABLE XXII

Mean $CaO + MgO/K_2O$ ratio of leaf samples before the transmission of virus

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.199	0.234	0.253	0.309

Critical difference at 5% level : 0.049


CALCIUM OXIDE PLUS MAGNESIUM OXIDE /
POTASSIUM OXIDE RATIO OF LEAF SAMPLES
CaO + MgO / K2O RATIO
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
Tr 1
Tr 2
Tr 3
Tr 4
BEFORE VIRUS TRANSMISSION
AFTER DISEASE INCIDENCE
Fig 9

(ii) The ratio after the incidence of the disease

Appendix XXV gives the analysis of variance and Table XXIII presents the mean value of $CaO + MgO/K_2O$ ratio. There is no significant difference between the treatments.

In this case also there is a gradual increase in the ratio by the application of calcium oxide and magnesium oxide. The maximum value of 0.271 was for treatment 4 followed by treatment 3. The lowest value of 0.184 was for the control.

TABLE XXIII

Mean $CaO + MgO/K_2O$ ratio of leaf samples after the incidence of the disease

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.184	0.205	0.221	0.271

Nutrient content of root samples

(a) Nitrogen

(i) Nitrogen status before the transmission of virus

The data on the nitrogen content of root samples are given in Table XXIV. The analysis of variance is presented in Appendix XXVI. There is no significant

NITROGEN CONTENT OF ROOT

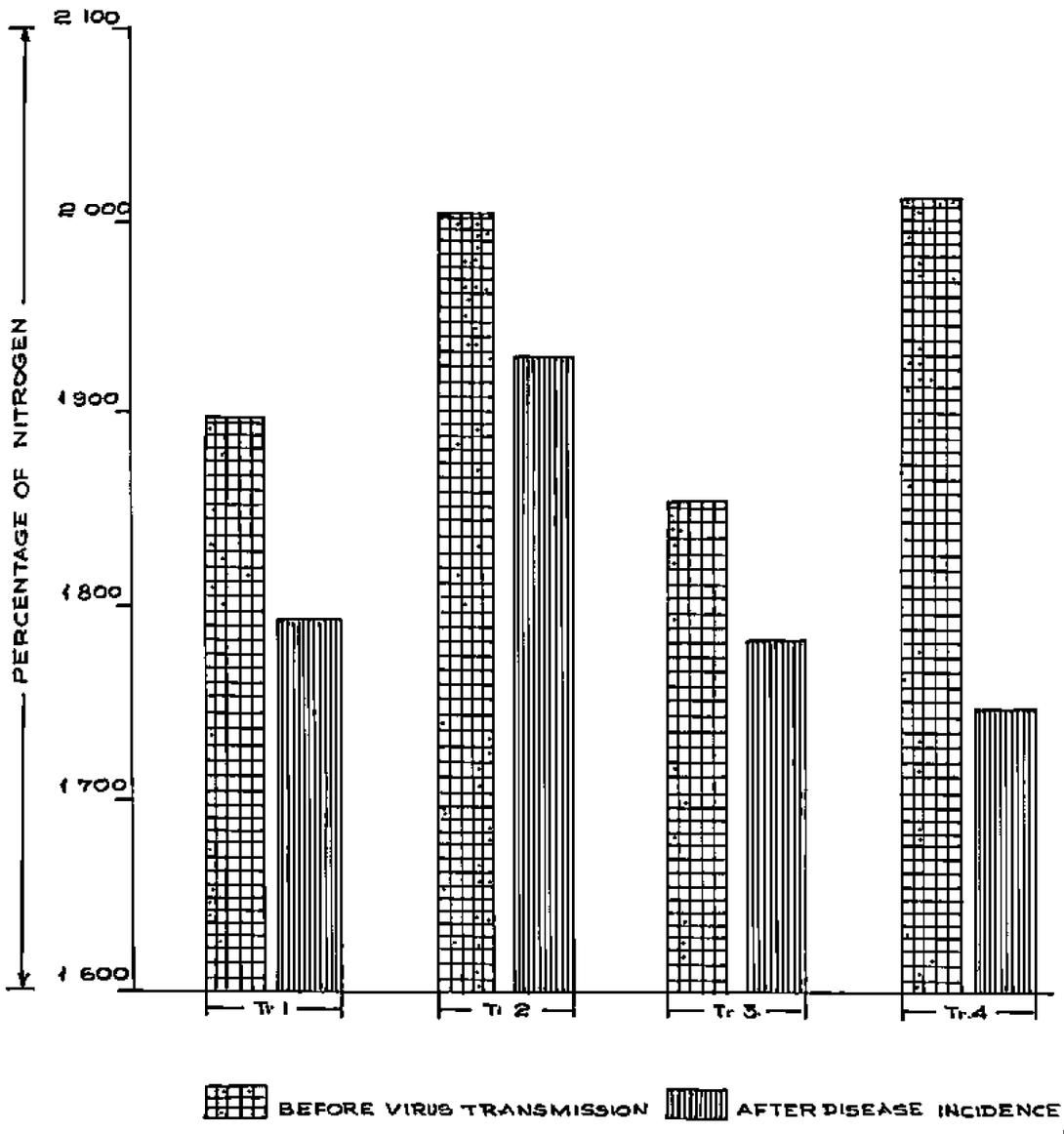


Fig 10g

variation between the treatments.

Treatment 4 had the highest content of nitrogen in roots followed by treatment 2. Treatment 3 and control showed the lowest percentages.

TABLE XXIV

Mean nitrogen content of root samples before the transmission of virus

(Expressed as percentage on oven dry basis)

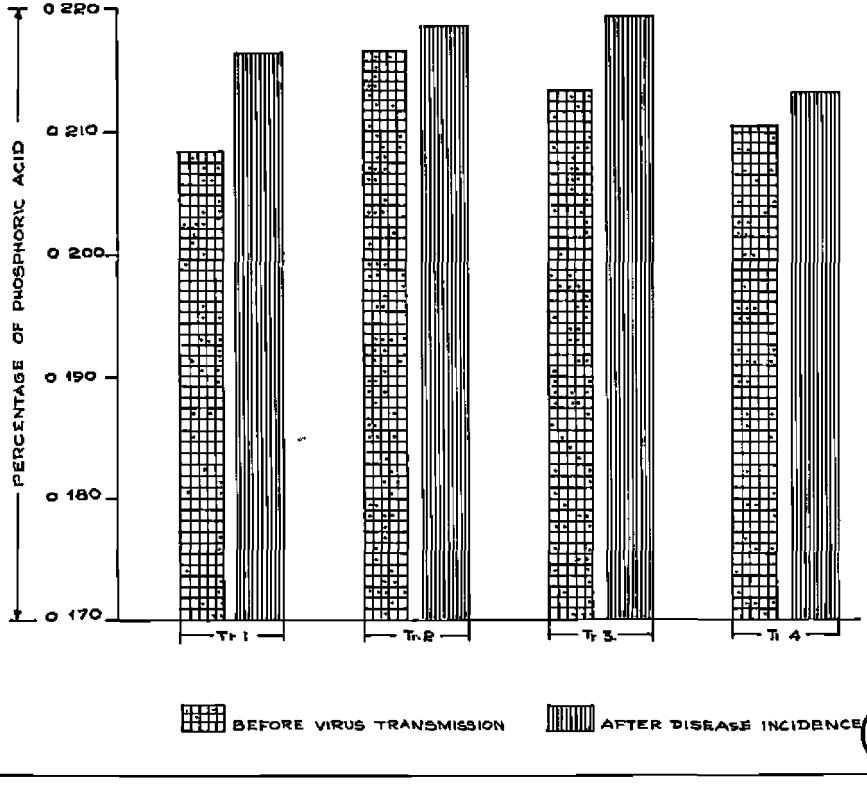
Treatment 1	Treatment 2	Treatment 3	Treatment 4
1.897	2.004	1.856	2.012

(ii) Nitrogen status after the incidence of the disease

The data were subjected to statistical analysis and the analysis of variance is given in Appendix XXVII. The difference in the nitrogen content of root samples after the incidence of the disease in the calcium oxide and magnesium oxide treated plants over control was not significant.

The mean nitrogen content in the root samples after the incidence of the disease is given in Table XXV.

Treatment 2 showed the highest value of 1.930 followed by treatment 1 (control). Treatment 4 had the lowest value of 1.749.


PHOSPHORIC ACID CONTENT OF ROOT
PERCENTAGE OF PHOSPHORIC ACID
0 220
0 210
0 200
0 190
0 180
0 170
Tr 1
Tr 2
Tr 3
Tr 4
BEFORE VIRUS TRANSMISSION
AFTER DISEASE INCIDENCE
Fig 11

(ii) Phosphorus status after the incidence of the disease

The data on the phosphorus status after the incidence of the disease were analysed statistically. The analysis of variance given in Appendix XXIX shows that the difference in the uptake of phosphorus by the calcium oxide and magnesium oxide treated plants over control was not significant.

The mean uptake of phosphorus by the various treatments after the incidence of the disease is given in Table XXVII.

TABLE XXVII

Mean phosphoric acid (P_2O_5) content of root samples after the incidence of the disease.

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.216	0.218	0.219	0.213

(c) Potassium

(i) Potassium status before the transmission of virus

The data on the potash content of roots before the transmission of virus were analysed statistically. The analysis of variance table is given Appendix XXX. The difference in the potash content between the treatmentswas significant.

POTASH CONTENT OF ROOT

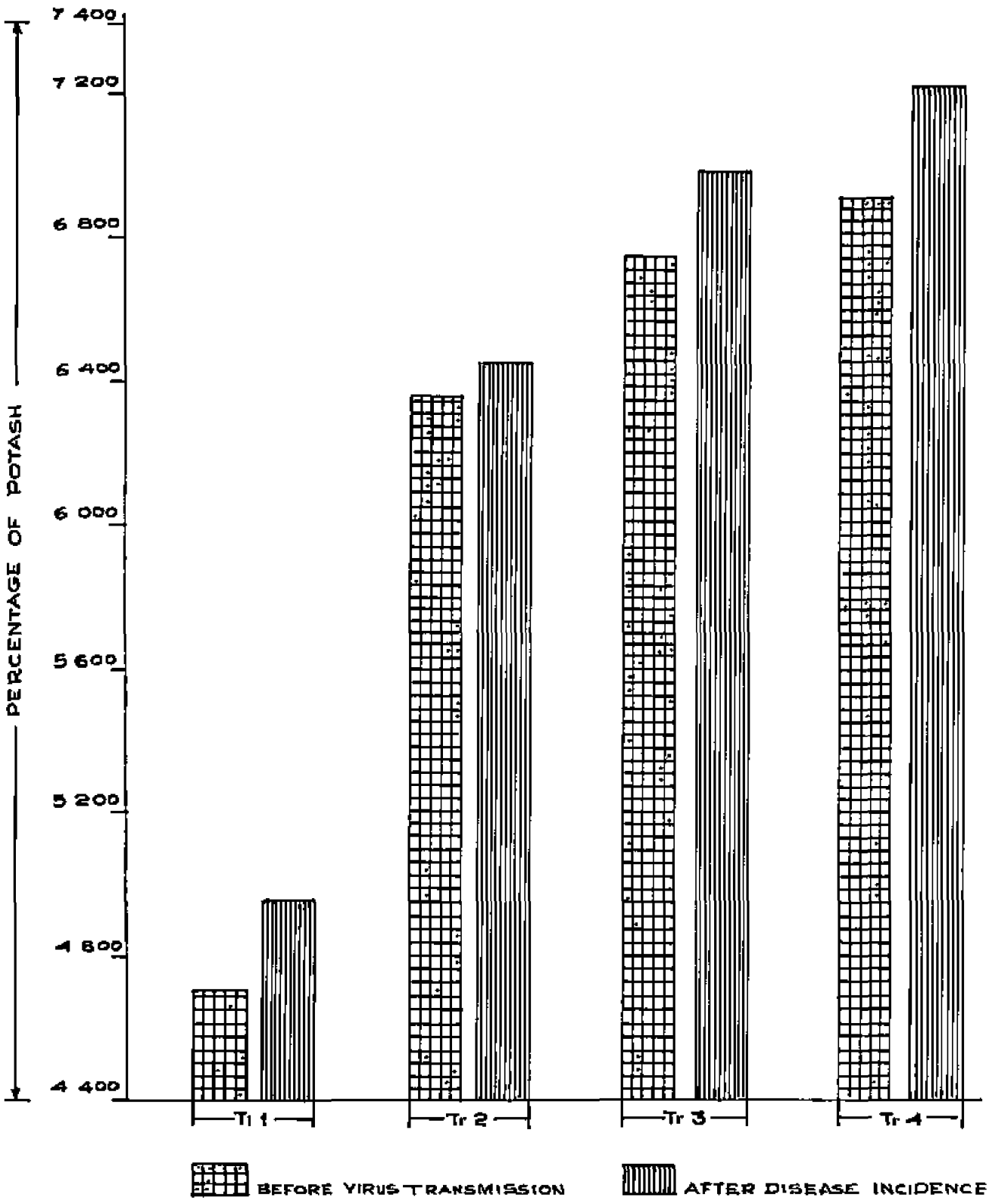


Fig 12

The mean uptake of potash content before the transmission of virus is furnished in Table XXVIII.

The maximum potash content was noticed in treatment 4 followed by treatments 3 and 2. The lowest was in control.

It was evident that the uptake of potash content before the transmission of virus is increased with increase in levels of calcium oxide and magnesium oxide application.

TABLE XXVIII

Mean potash content of root samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
4.704	6.364	6.749	6.911

Critical difference at 5% level : 1.271

(ii) Potassium status after the incidence of the disease

The analysis of variance for the potash content of root samples after the incidence of the disease is given in Appendix XXXI. There is significant variation in the content of potash due to treatment effects.

The mean potash content after the incidence of the disease is given in Table XXIX. The potash content of roots is increased with increase in levels of calcium oxide and magnesium oxide.

The maximum content of potash is in treatment 4 ie. 7.222% followed by treatment 3 and 2. The lowest value of 4.959% is in control.

TABLE XXIX

Mean potash content of root samples after the incidence of the disease

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
4.959	6.456	6.983	7.222

Critical difference at 5% level : 1.357

(d) Calcium

(i) Calcium status before the transmission of virus

The data on the uptake of calcium oxide before the transmission of virus were analysed statistically. The analysis of variance is given in Appendix XXXIII. It shows that the difference in the uptake of calcium between the treatments is not significant.

CALCIUM OXIDE CONTENT OF ROOT

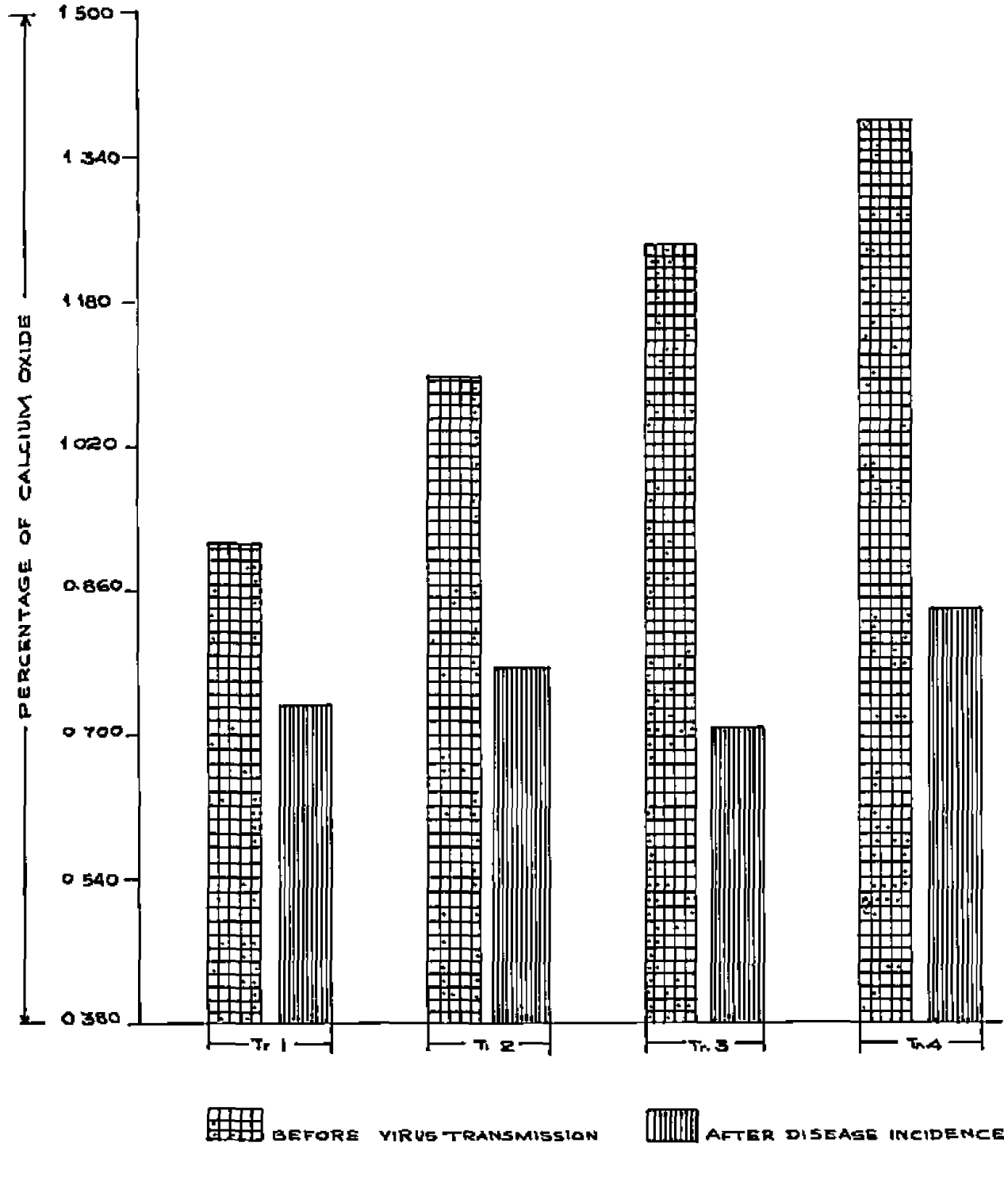


Fig. 13

The mean uptake of calcium by the various treatments before the transmission of virus is furnished in Table XXX. The calcium content of roots showed a tendency to increase with increase in levels of calcium oxide and magnesium oxide. The control plants showed the lowest calcium content of 0.913%. The highest content of calcium was in treatment 4 and the percentage of calcium oxide was 1.331.

TABLE XXX

Mean calcium oxide content of root samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.913	1.101	1.247	1.331

(ii) Calcium status after the incidence of the disease

The analysis of variance is furnished in Appendix XXXIII. There is no significant difference between the treatments.

The mean CaO content of roots is furnished in Table XXXI. The plants receiving the highest levels

of calcium oxide and magnesium oxide showed the maximum percentage of 0.843% of CaO. The lowest was for the treatment 3.

There is a decrease in the CaO content of the roots after the incidence of the disease.

TABLE XXXI

Mean calcium oxide content of root samples after the incidence of the disease
(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.739	0.779	0.713	0.843

(c) Magnesium

(1) Magnesium status before the transmission of virus

The statistical analysis of the data on the uptake of magnesium oxide before the transmission of virus indicated significant difference between treated and untreated plants. The analysis of variance is given in Appendix XXXIV.

The mean uptake of magnesium oxide is given in Table XXXII. The magnesium oxide content of roots increased with increase in levels of calcium oxide and magnesium oxide. The maximum MgO content of 1.251% was in treatment 4 and the lowest of 0.810% was in control.

MAGNESIUM OXIDE CONTENT OF ROOT

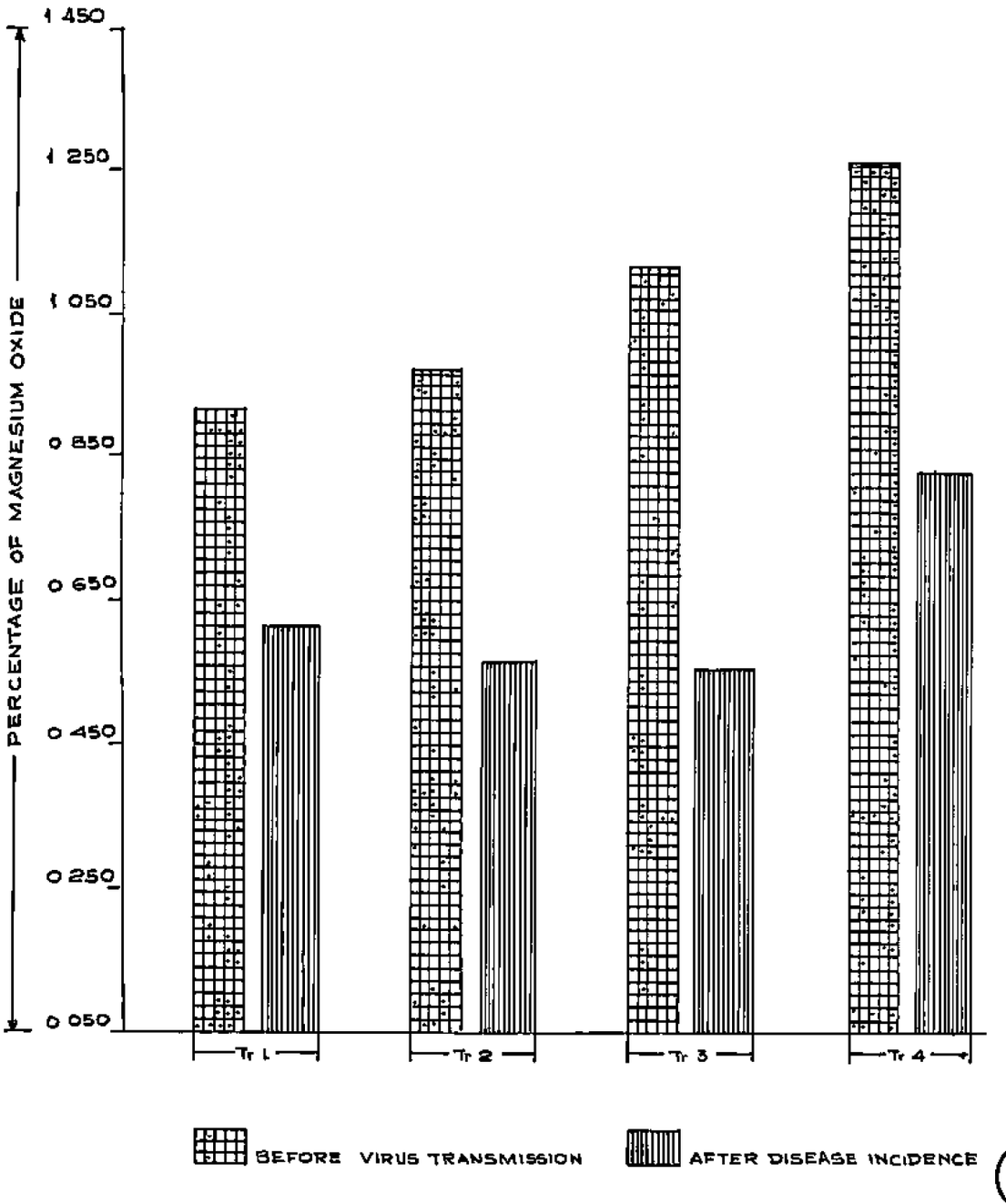


Fig 14

TABLE XXXII

Mean magnesium oxide content of root samples before the transmission of virus

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.010	0.060	1.113	1.251

Critical difference at 5% level : 0.172

(ii) Magnesium status after the incidence of the disease

The analysis of variance furnished in Appendix XXXV showed significant difference between the treatments.

The mean uptake of magnesium oxide after the incidence of the disease is given in Table XXXIII. The maximum uptake was in treatment 4 and the lowest was in treatment 3.

There was a marked decrease in the magnesium oxide content after the incidence of the disease in all the treatments.

TABLE XXXIII

Mean magnesium oxide content of root samples after the incidence of the disease

(Expressed as percentage on oven dry basis)

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.609	0.562	0.559	0.830

Critical difference at 5% level : 0.202

(f) Calcium oxide/magnesium oxide ratio

(i) The ratio before the transmission of virus

The analysis of variance table is furnished in Appendix XXXVI and there is no significant difference between the treatments. Table XXXIV presents the mean CaO/MgO values.

TABLE XXXIV

Mean CaO/MgO ratio of root samples before the transmission of virus

Treatment 1	Treatment 2	Treatment 3	Treatment 4
1.073	1.144	1.123	1.138

CALCIUM OXIDE / MAGNESIUM OXIDE RATIO OF ROOT

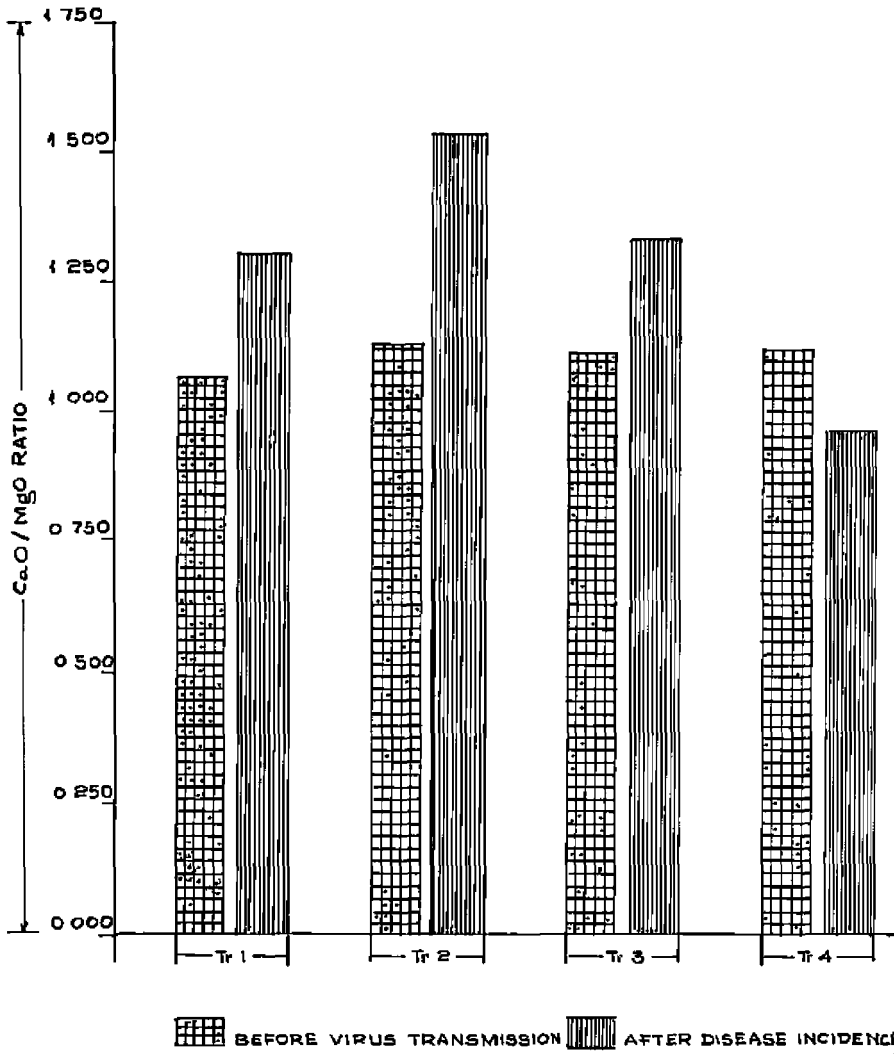


Fig 15

(ii) The ratio after the incidence of the disease

Appendix XXXVII gives the analysis of variance and Table XXXV presents the mean CaO/MgO ratio in the roots after the incidence of the disease. There is no significant difference between the treatments.

TABLE XXXV

Mean CaO/MgO ratio of root samples after the incidence of the disease

Treatment 1	Treatment 2	Treatment 3	Treatment 4
1.315	1.556	1.352	0.935

(g) Calcium oxide plus magnesium oxide/potassium oxide ratio

(i) The ratio before the transmission of virus

The analysis of variance is given in Appendix XXXVIII and there is no significant difference between the treatments. The mean values are presented in Table XXXVI.

TABLE XXXVI

Mean CaO + MgO/K_2O ratio of root samples before the transmission of virus

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.394	0.332	0.389	0.334

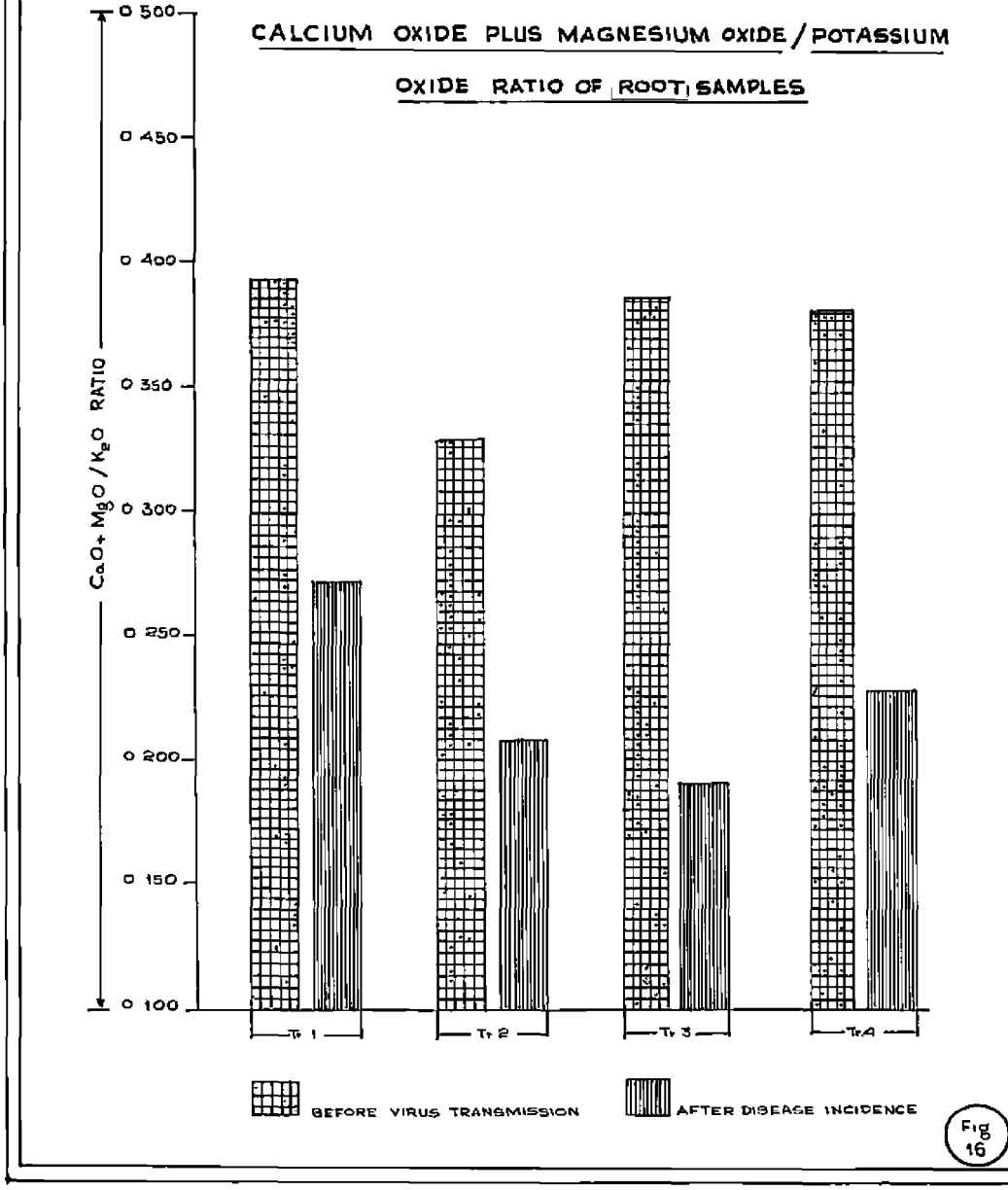

CALCIUM OXIDE PLUS MAGNESIUM OXIDE / POTASSIUM OXIDE RATIO OF ROOT SAMPLES
CaO + MgO / K2O RATIO
0 500
0 450
0 400
0 350
0 300
0 250
0 200
0 150
0 100
Tr 1
Tr 2
Tr 3
Tr 4
BEFORE VIRUS TRANSMISSION
AFTER DISEASE INCIDENCE

Fig 16

(11) The ratio after the incidence of the disease

Appendix XXXIX gives the analysis of variance and there is no significant difference between the treatments. The mean values are presented in Table XXXVII.

TABLE XXXVII

Mean $CaO + MgO/K_2O$ ratio of root samples after the incidence of the disease

Treatment 1	Treatment 2	Treatment 3	Treatment 4
0.274	0.210	0.192	0.229

DISCUSSION

DISCUSSION

The investigations on the nutritional status of soils and the incidence of the Bunchy top disease of banana were started at the Agricultural College and Research Institute, Vellayani as a continuing programme of research from 1962. Successive postgraduate students were put on to this research, to work out of different aspects of the problem. The earlier investigations on the subject by Nambiar and Nair (1965) had revealed that the soils of infected regions were 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 application of lime in combination with N P K had little effect on the incidence of the disease as measured by the delay in infection, while magnesium alone or in combination with calcium was found to exert an appreciable influence on the incidence of the disease, by delaying the appearance of symptoms. Further studies by Nair and Pillai (1966) had indicated that leaf samples from infected plants had a higher concentration of nitrogen, potassium and phosphorus than in those from healthy ones. No such relationship existed in the case of calcium and magnesium, which indicated a different role played by these elements as compared to

nitrogen, phosphorus and potassium. The plants which delayed the infection had a higher content of calcium and magnesium as compared to plants which contracted the disease earlier. It was also noted that the calcium oxide/magnesium oxide ratios in the leaves had a decisive influence in delaying the incidence of the disease. A calcium oxide/magnesium oxide ratio of 3.5 or a calcium oxide plus magnesium oxide/potassium oxide ratio of near about 1.00 in the leaves was seen to be critical in respect of delaying the symptoms of the Bunchy top disease. Calcium or magnesium alone did not have any significant influence in delaying the incidence of the disease. Subsequent studies by Nair and George (1966) revealed that the CaO/MgO ratio in the leaves was not the critical factor, but it was the CaO + MgO/K$_2$O ratio which had an effect in delaying the incidence of the disease. Anatomical studies by Nair, Sreenivasan and Sreekumari Amma (1966) had revealed that in the case of diseased plants growing on soils with CaO/MgO ratio of 3.0 the parenchyma, xylem and phloem cells of the leaf sheath had dimensions approaching that of healthy plants. Cell degeneration and disorganisation were seen greatly retarded in plants growing on soils with a CaO/MgO ratio of 3.0. It was considered possible that a definite CaO/MgO ratio in the plant tissue, rather than in the nutrient medium, is what would contribute towards resistance to cellular changes consequent on virus infection.

The present studies were aimed at elucidating the possibility of controlling the CaO/MgO ratios or the CaO + MgO/K$_2$O ratios in the leaves by regulating the contents of calcium, magnesium and potassium in the soils and observing the effect on the incidence of infection by the Bunchy top virus. The effect of different total quantities of calcium and magnesium in the nutrient medium, but with the same CaO/MgO ratio, on the absorption of calcium, magnesium and potassium by the plants was also studied. Root tissue studies were also made in the present investigations which had not been seriously conducted earlier. Since the previous works had shown that calcium, potassium and magnesium in the plant tissue had an appreciable influence in delaying infection and imparting resistance to the plants, it was also considered desirable to increase the concentration of the virus and note its effect. As against the usual number of 20-25 aphids released on healthy plants, 100 aphids per plant were released in the present investigations. The variety of banana used was 'Java', which is believed to be somewhat naturally resistant to Bunchy top infection, the idea being to study whether under calcium-magnesium treatments, the natural resistance of the variety could be maintained even with vastly increased virus concentration.

The present studies have shown that there was increased growth rate for all characters of the plants till the appearance of disease symptoms. The plants ceased to increase their height and girth after the occurrence of the disease. It was noticed that the control plants contracted the disease earlier than in all other treatments. It was also noted that in some cases a delay of 75 days after inoculation had occurred before the appearance of the symptoms, while in certain other cases the plants had withstood infection for more than 250 days after planting (as the observations closed on the 250th day). Further data on these plants have not been recorded. However, it is likely that these plants will have their full life cycle completed without incidence of Bunchy top. A notable observation from the present experiment is that the daughter suckers in two calcium-magnesium treatments had no primary infection, although the mother plants were fully infected. The daughter sucker in the control experiment had primary infection (see photographs). It would thus appear that a sufficiency of calcium and magnesium in the soil could completely prevent the occurrence of primary infection in suckers of diseased plants. This is an aspect which requires fuller and more complete investigation. It may be relevent in this context to note that similar observations had been recorded from Australia as early as 1923, but could not be confirmed by any other workers on the Bunchy top disease of bananas.

VELLAYANI AGRICULTURE LIBRARY

On the absorption of nutrients from the soil, the present studies had indicated that there is a marked decrease in the uptake of nitrogen by the plants with increasing calcium and magnesium in the soil. Treatment 4 in the present studies which had the highest content of calcium and magnesium in the soil had the lowest absorption of nitrogen. It is also interesting to note that cases of lowest incidence of the disease or the longest delays observed before infection, were in the case of plants which had the lowest nitrogen in the tissue. It is therefore possible that calcium and magnesium may have, besides a direct role in the plant tissue, an indirect effect also in the control of the disease through their influence on the absorption of other nutrient elements. There was no significant difference in tissue phosphorus between control and treated plants. In the case of potash, calcium and magnesium had a positive effect namely that of increasing absorption by the plant tissues after incidence of the disease. The quantity of potash observed in the tissue of healthy plants was always higher than those in infected plants, indicating the decisive role of this element in the control or, delaying the infection by the Bunchy top virus. The absorption of calcium and magnesium by the plants was also directly correlated to the soil contents of calcium and magnesium.

The nutrient contents of the tissues, however, followed an erratic course in the case of the treatments. This indicates that however much one attempts to control soil ratios of nutrients, the process of absorption follows a certain course which cannot be predicted with precision. While the uptake of nitrogen was very decisively influenced by the presence of calcium and magnesium, phosphorus was not. In the case of potash, maximum absorption by the plant was noticed in the absence of calcium and magnesium before the transmission of virus. Plants receiving highest level of calcium and magnesium had the lowest content of potash, although, after the incidence of the disease, the lowest value was observed in the case of control plants. In the case of calcium and magnesium, the absorption by the plant was directly related to their concentration in the soil. The calcium oxide/magnesium oxide ratio in the leaf in the various treatments showed no significant difference before the transmission of virus. This ratio was also not significantly different, after the incidence of the disease. In the case of calcium oxide + magnesium oxide/potassium oxide ratio, there was significant difference between the treatments before the incidence of the disease. This ratio gradually increased depending on the concentration of calcium and magnesium in the soil. Although the CaO/MgO ratio in the soil was maintained at 3:1, the absolute quantity of CaO/MgO had an effect in

causing a higher ratio of CaO + MgO/K_2O in the leaves. The lowest value was noticed in the case of control and the highest value in the case of treatment 4 which had the maximum concentration of calcium oxide and magnesium oxide in the ratio 3:1 in the soil. It is significant to note in this connection that the longest delay in the incidence of the disease was noticed in the case of plants with the highest CaO + MgO/K_2O ratio. The present studies would therefore indicate that the CaO + MgO/K_2O ratio in the plant tissue is related to the resistance of the plants to Bunchy top disease but the exact magnitude of the ratio at which the plants become resistant or the manner and method of control of the ratio in the plant tissue are matters for further investigation. It does not appear that controlling the plant nutrient ratios in the soil can give any desired CaO + MgO/K_2O ratio in the plant tissue.

In the case of root tissue studies, a notable observation is that the absorption of nitrogen and phosphorus was not significantly different in treatments. However, in the case of potash there was significant difference. The amount of root potash was increased with increasing quantity of calcium and magnesium in the soil. The root potassium is directly proportional to the amount of calcium and potassium present in the soil. It is also interesting to note that the maximum contents of potash in the root tissue coincided with the maximum delay to Bunchy top infection. Root calcium

was also dependent on the soil concentration of the element. However, after the incidence of the disease, there was a decrease in the content of calcium in the roots, which can be explained as due to increased rate of translocation within the plant. The magnesium oxide contents in the root tissue also followed the same pattern as calcium. A very interesting observation in this connection is that the $CaO + MgO/K_2O$ ratio in the roots is not significantly different between treatments before the incidence of the disease. However, after the incidence of the disease, the ratio is seen considerably lowered in all treatments. It is possible that this may either be due to differential absorption of the nutrients or due to translocation from the roots to the disease affected portions of the plant.

The present studies have more or less convincingly indicated that the calcium oxide plus magnesium oxide/ potassium oxide ratio in the plant tissue exerts some influence on the resistance of the tissue to infection by the Bunchy top virus. It is however difficult to conclude what exactly the ratio should be in order to totally prevent infection, or the manner and method of ensuring such a ratio within the plant tissue. An observation which is of interest in this connection is that all healthy

plants which withstood infection had a CaO/MgO ratio in the leaf tissue, of slightly above 1.00, irrespective of treatments. Whether control of plant nutrients in the soil medium will ensure a desired ratio in the plant tissue will require investigations under much more controlled conditions than could be made available in the present study.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

Experiments were laid out under semi-field conditions to study the effect of combined application of calcium oxide and magnesium oxide at different concentrations to soil in the ratio of 3:1. The absorption of calcium, magnesium, nitrogen, phosphorus and potassium by plants from soils containing varying quantities of calcium oxide and magnesium oxide 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:-

1. All the plants in the control contracted the disease earlier than the treated plants. The number of days taken for infection varied from 30 to 42 for control and 32 to 75 for treated plants. Some plants in treatments 2, 3 and 4 have withstood infection for 250 days after planting, that is till the end of the experimental observations. It is expected these will give normal bunches.

2. 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.

3. Calcium and magnesium may have, besides a direct role in the plant tissue, an indirect effect also in the control of the disease through their influence on the absorption of other nutrient elements. The absorption of calcium and magnesium by the plants was directly related to their concentration in the soil.

4. Although the CaO/MgO ratio in the soil was maintained at 3:1, the absolute quantity of CaO/MgO had an effect in causing a higher ratio of $CaO + MgO/K_2O$ in the leaves. The lowest value was noticed in the case of control and the highest value in the case of treatment 4 and which had the maximum concentration of CaO/MgO in the ratio 3:1 in the soil.

5. The longest delay in the incidence of the disease was noticed in the case of plants with the highest $CaO + MgO/K_2O$ ratio.

6. The maximum content of potash in the root tissue coincided with the maximum delay to Bunchy top infection.

7. The present studies have more or less convincingly indicated that the $CaO + MgO/K_2O$ in the plant tissue exerts some influence on the resistance of the tissue to infection by the Bunchy top virus.

REFERENCES

REFERENCES

Akuno, S. and Kooja, K.	1958	Studies on potassium content of virus diseased tobacco plants cultivated by different quantities of potassium. Bull. Fac. Agri. Kagoshima. Uni.1. 4 to 8
Alvin, P.	1950	Mineral deficiencies and leaf foot disease in Agave sisalana Rev. Cereo. 8: 222-232
Anonymous	1958	Annual Report of the Cameroons Development Corporation 1957 1-39.
Arenz, B.	1949	Potassium experiments on the influence of different kinds of fertilizing on healthy and leaf rot infested potatoes. Z. Pfl. Ernakr. Dung. 47. 114-131.
Bawden, F.C.	1955	Plant Pathology Development. Effect of Nitrogen on Cauliflower mosaic virus. Rep. Rothamsh. exn. Sta. 1954. 80-85
----------	1960	Plant viruses and virus diseases. Waltham, Mass, U.S.A. 277-286
Bawden, F.C. and Kassanis, B.	1950	Some effects of host nutrition on the multiplication of virus. Ann. Appl. Biol. 37: 216-228
Best, R.J. and Gallus, H.P.C.	1959	Some effects of mosaic virus on nitrogen and phosphorus metabolism in tobacco plants Nature, 172, (4373): 147.

Bouley, W.P. and Corbett, W.	1930	(a) Bon. Luxon. Exp. Sta. Chesnut (1927) (b) Ibid - 1930.
Borges and Beato	1953	Determination of nitrogen in Brassica chinensis L. infected with turnip yellow mosaic virus Proteins. 22(42): 149-154
Bode, O.	1949	The effect of fertilising on the spread of potato leaf roll. Nachr. Biol. Zentralanst. Braunschweig. 1 (11): 143-161.
Boring, K. and Dierckx, R.	1955	Experiments on the effects of mineral salt nutrition on the susceptibility of potato plant to leaf roll and streak disease. Revue. Landw. J. 32: 276-323.
Brun, J.	1954	Blue disease of banana in French Guinea. Congr. Int. Botan. Paris. 8: 18-20.
Brunnich, J.C.	1923	Report of the Agricultural Chemist. Ann. Rept. Queensland. Dept. Agri. & Stock for the year 1922-23: 28-31.
Broadbent, L. and Weathers, C.W.	1954	The epidemiology of tomato mosaic - The effect on TMV - infected plants of nutrient of foliar sprays and of steaming the soil. Ann. appl. Biol. 54: 23-30.
Brun, J. and Champion, J.	1954	Le "Bleu" du Bananier en Guinee francaise ('Blue disease' of the Banana in French Guinea) Fruits d' outremer 8(6) 266-269

Bryce, G.	1921	The "Dancby Top" plantain disease. Dept. Agric. Ceylon. leaflet No.18:2.
Carmon, H.	1963	Further studies in manganese nutrition of tobacco in relation to virus infection and synthesis Diss. Abstr. 23: 1863-1864.
Carpenter, C.P.	1964	Some factors determining the level of Bean Yellow mosaic virus. Transmission by aphids. Diss. Abstr. 23 (1): 38.
Chessin, M. and Scott, H.A.	1955	Calcium deficiency and infection of Nicotiana glutinosa by tobacco mosaic virus. Phytopathology 45: 233-235.
Commoner, B, Semiober, Dorothy, L. and Dicts Phyllis, H.	1953	Relationship between tobacco mosaic virus, biosynthesis and nitrogen metabolism of the host. J. Gen. Physiol. 36 (6): 807-830.
Cooke, F.C.	1950	The tapering disease of coconuts. Ceylon Coconut Quart. 1 (1): 17-21.
Crowley, N.C. and Hanson, J.B.	1960	The infection of apical meristems of tomato roots with tobacco mosaic virus after treatment with ethylene diamine tetra acetic acid. Virology 12: 603-606.

De Robertis, A.	1958	Phytopathological aspects of the application of nitrogenous fertilisers. Experiments and observations on the reduction of symptoms of certain virus diseases (wheat streak mosaic virus and Tulip breaking virus) Terra nuclease 8 (2): 25-30.
Dierckx, R.	1953	The influence of mineral salt nutrition on the rapidity of movement and spread of X-virus in the potato plant. Z. Pfl. Ern. A (4) 6: 262-288.
Eskarous, Josephine, K. and Naguib, M.S.	1964	Carbohydrate and nitrogen content of virus-diseased tobacco plant Experimentia, (20) (11): 618-619.
Folton, M.W.	1948	The effect of temperature, moisture and nitrogen on the development of leaf roll symptoms in the Irish Potato. Amer. Potato J. 25. 60-61.
Ford, Richard, E. and Bateman, D.E.	1964	Boron nutrition of Nicotiana tobacum and its influence on the multiplication and translocation of potato virus X. Phytopathology 54 (11): 1405-1408.
Ganguly, B, Pushkaranath and Upretic, C.C.	1963	Effect of nutrition on plant growth and concentration of potato virus x and y. Indian potato J. 5: 44-47.
Garcia, J.L.	1965	Effect of temperature and zinc on development of Tobacco mosaic virus in resistant and susceptible tomatoes. J. Agric. Sci. Puerto Rico 49 (1): 112-132.

VELLAYANI
LIBRARY

Garman, P. and Mathis, W.T.	1956	Studies of mineral balance as related to occurrence of baldurin spot in Connecticut. Conn. Agri. Exp. Sta. Bull. 601: 19.
Goddard, E.J.	1933	"Bunchy Top" in bananas. Queensland Agric. J. 24: 424-429.
Hale, J.D. Watson, H (Arion) A and Hull, R.	1946	Some cases of chlorosis and necrosis of sugar beet foliage. Ann. Appl. Biol. 33(1): 13-28.
Holms, K. and Pound, G.S.	1956	Zinc nutrition of Nicotiana tabacum L. in relation to multiplication of tobacco mosaic virus. Virology 1: 406-423.
----------	1956	Host nutrition in relation to concentration of potato virus x and tobacco ring spot virus. Phytopathology 45: 567-573.
Hitier, H. and Izard, C.	1953	Attempts at tobacco mosaic control by chemotherapy and hybridisation and genetic selection. Ann. Inst. Nat. Tabac. Forcrac. 3: 85-96. (Engl. Summ.)
Hoveland, C.S., Borger, K.C. and Darling, H.M.	1953	Effect of mineral nutrition on the expression of potato leaf roll virus symptoms. Soil Sc. Soc. Am. Proc. 18: 53-55.
Jackson, M.L.	1953	Soil chemical analysis. Prentice Hall. Inc. New York.

Jansson, J.J.	1929	Tidschr. Plantenziekten 35: 119.
Jones, H.T.	1950	Magnesium as a plant nutrient. Soils and Fertilizers. 14: 235.
Kender, W.J. and Smith, C.R.	1964	Effects of specific viruses, virus complexes and nitrogen nutrition on the growth mineral composition and flowering of strawberry. Proc. amer. Soc. hort. Sci. 84: 302-309.
Kendrick, J.B., Middleton, J.T. and Chapman, H.D.	1951	The influence of nutrition upon Tobacco mosaic virus infected tomatoes. Abs. Phytopathology. 41: 940.
Kruger, F.H.	1951	The influence of unbalanced fertilising on potato degeneration. Z. Acker-u. P. Pfl. Bau. (formerly J. Landw) 93: 369-388.
Kozlowsker, A.	1950	Relation between absorption of potassium and phosphorus by potato and the development of virus disease in their tissue. Abr. Amer. Potato, J. 27. 298.
Lahousse	1964	Magnesium, fifth major element in plant nutrition. Agricultural Digest. 2: 1-3.
Lockerol, R.L. and Ascoming, 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. Agric. 42: 39-53.

Loring, H.S. and Waritz, H.S.	1957	Occurrence of iron, copper, calcium and magnesium in tobacco mosaic virus. Science. 125: 646-648.
Ling, K.C. and Pound G.S.	1962	Sulphur nutrition of Nicotiana tabacum in relation to multiplication of tobacco mosaic virus. Phytopathology. 52 (2): 165-168
Magee, C.J.A.	1927	Investigations on the Bunchy top disease of Banana. Bull. Coun. Sci. Industry. Res. Inst. 30: 64
----------	1940	A transmission studies on the Bunchy top virus. J. Aust. Inst. Agric. Sci. 6: 109-110
----------	1948	Transmission of Bunchy top to banana varieties. J. Austr. Ins. Agric. Sc. 14: 18-24
----------	1953	Some aspects of the Bunchy top disease of banana and other Musa spp. J. Proc. R. Soc. N.S.W. 87: 1-18
----------	1953	Presidential address before Royal Society of New South Wales Proc. Roy. Soc. N.S.W. 87: 3-18
Mariakulandai, A and Dorairaj, J.D.	1968	Some chemical aspects of Mandarin orange decline in Wynad. South Ind. Hort. 6: 23-31

Martin Provel and Carpenter	1964	Culture in artificial media symptoms of 6 nutrient elements in the banana. Fertilite. 3: 6-8
Hilbrath, J.A., Bolwil, B and Compton, O.C.	1966	A disease of sweet cherry in which a virus and a boron deficiency are involved. Abs. Phytopathology, 56 (2): 145-153
Nair, C.K.N. and George, C.K.	1966	Nutritional status of soils and the incidence of Bunchy top disease of Bananas (Musa sp.) - IV 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. Kerala Agric. Res. J. 4 (2): 99-121
Nair, C.K.N. and Sivasankara Pillai	1966	Nutritional status of soils and the incidence of Bunchy top disease of Bananas (Musa sp.) II Significance of calcium/magnesium in the plant. Kerala Agric. Res. J. 4 (1): 96-105
Nair, C.K.N., Srinivasan, K. and Sreekumari Amma, J.	1966	Nutritional status of soils and the incidence of the Bunchy top disease of Bananas (Musa sp.) - IV. Anatomical variations in virus infected and healthy plants as a function of calcium-magnesium ratio in soil. Kerala Agric. Res. J. 4: 122-136

Nair C.K.N. and Vikraman Nair	1967	Nutritional status of soils and the incidence of Bunchy top disease of Bananas (Musa sp.) - V. Effect of combined application of calcium and magnesium to soil on the ratio of calcium oxide/magnesium oxide in the plant and its relation to Bunchy top infection. M.Sc.(Ag.) Thesis, Uni. Kerala.
Narayanaswamy P. and Ramakrishnan, K.	1966	Studies on the sterility of mosaic disease of Pogion Pea III - Nitrogen metabolism of infected plants. Proc. Ind. Acc. Sci. 63 (6)
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 Bunchy top disease of bananas. Agri. Res. J. Kerala. 3 (1): 78-90.
Orlob, G.B. and Army, D.C.	1961	Some metabolic changes accompanying infection by Barley yellow dwarf virus. Phytopathology, 51 (11): 768-775
Papacolo Montes, A. and Wilkinson, R.E.	1959	The effect of nitrogen, phosphorus and potassium levels on growth and virus content of excised tobacco-mosaic virus infected tomato roots. Abs. Phytopathology, 49 (4): 229

Parthasarathi, K and Rao, P.S.	1962	Studies on sandal spike 11. Physiological significance of disturbed iron balance in the spike disease of sandal (Santalum album L.). Proc. Indian. Acad. Sci. 56: 99-106
Patel, and Nair, A.P.R.	1936	Natural and induced resistance to shoot rot in cocomut Proc. Indian. Acad. Sci. 3(B): 432-37
Pen-Ching Cheo, Pound, G.S. and Weathers, L.G.	1952	The relation of host nutrition to the concentration of cucumber virus I in spinach. Phytopathology 42: 377-381
Penger J.S.	1957	The effect of mineral salts on local lesion formation by Phaseolus vulgaris inoculated with tobacco mosaic virus Phytopathology 47: 748-751
Pirone, T.P. and Pound, G.S.	1962	Molybdenum nutrition of Nicotiana tabacum L. in relation to the multiplication of tobacco mosaic virus. Phytopathology 52: 822-827
Pound, G.S. and Wolkio, G.W.	1958	Iron nutrition of Nicotiana tabacum L. in relation to multiplication of tobacco mosaic virus. Virology 5: 371-381
Pound, G.S. and Weathers, L.G.	1963	The relation of host nutrition to multiplication of Turnip Virus 1. in N. glutinosa and N. multivalvis Phytopathology, 43 (12):669-674

Prusa, V., Pikl, J. and Holmova, J.	1955	Nutritional effects on the hop curl disease and comparison of diseased and healthy hop plant. Biologia. Pl. 7(6): 425-436
Rich, S.	1956	Chemotherapy of lettuce big vein. Plant Dis. Reptr. 40 (6): 412-416
Rossouw	1962	The effect of certain monovalent and divalent cat ions and detergents on plant virus infection Plan. Abstr. 22: 2936
Ryjkoff, V.L. and Smirnova M.N.D.V.A.	1948	The effect of magnesium ions and acridine preparations on the accumulation of virus protein in plants affected with tobacco mosaic virus. Microbiology, 17(3): 267-270
Sadasivan, T.S.	1963	Scope of inorganic nutrition and plant virus multiplication Bull. National Inst. Sci. Ind. 24: 1-10
Sankaransubramony, H., Pandalai, K.M. and Menon, K.P.V.	1964	Investigations on soil conditions in relation to disease of coconut palms in Travancore-Cochin Indian Coconut J. 8: 6-35
Sastry K.S.M.	1962	Effect of Molybdenum nutrition on multiplication and concentration of sunhemp mosaic virus. Current Science, 31: 347-349

Sastry K.S.M.	1962	Effect of copper nutrition on multiplication and concentration of virus on sunhemp mosaic virus. Current science 32: 519-520
----------	1965	Effect of calcium, magnesium and sulphur nutrition on multiplication of sunhemp mosaic virus. Ind. J. agric. Sci. 35(4): 315-321
----------	1966	Effect of calcium, magnesium and sulphur nutrition of guar plants on local lesion formation by sunhemp mosaic virus. Indian Phytopathology 19: 38-40
Sastry K.S.M. and Nariani T.K.	1962	Effect of host plant nutrition on the growth and susceptibility of tobacco plants to infection with tobacco leaf curl virus. Ind. J. Agric. Sc. 12: 232-35
Sastry K.S.M. and Vasudeva R.S.	1962	Effect of host plant nutrition on multiplication and concentration of the sunhemp mosaic virus. Ind. J. Agric. Sci. 33(2): 118-128
----------	1963	Effect of host plant nutrition on the movement of Sunhemp mosaic virus. Ind. Phytopathology 16: 143-150

Schorbakov, A.P.	1949	Some changes in the anatomical structure of the stem of the soyabean under the influence of calcium and magnesium Botan. Zhur. 34: 205-209
Schlogel, D.E., Gold, A.H. and Rawlins, T.E.	1953	Suppressing effect of radioactive phosphorus on symptoms and virus content of mosaic tobacco plant. Phytopathology 43(4): 206-209
Shepherd, R.J. and Pound G.S.	1959	Influence of boron and magnesium nutrition of Nicotiana tabacum on the multiplication of tobacco mosaic virus. Phytopathology 50: 26-30
----------	1960	Magnesium nutrition of Nicotiana tabacum in relation to multiplication of tobacco mosaic virus. Phytopathology 50: (3) 195-198
Shaw, M. and Samborski, D.J.	1956	The physiology of host parasite relations I. The accumulation of radioactive substances at infection of facultative and obligate parasite including tobacco mosaic virus. Canad. J. Bot. 34(3): 389-405
Singh, B. and Bargava, K.S.	1966	Host nutrition in relation to multiplication of watermelon mosaic virus. Phytopathology. 56(1):26-33
Spencer E.L.	1937	Influence of host nutrition on systemic development of tobacco mosaic. Plant Physiology. 12: 825-832

Srecnivasa Rao, Y.V.	1933	Biochemical aspects of the virus discharge of plants Proc. Twentieth. Sci. Cong. 452
Srivasthava, R.P. and Singh J.R.	1962	Deficiency symptoms of macroelements in banana as a guide to its nutrition. Sci. & Cult. 28(9):427-428
Srivastava, R.P.	1963	Deficiency symptoms of nitrogen, phosphorus and potassium in banana, Fertilizer news 8: 1-6
----------	1964	Effect of micronutrients on growth characteristics of banana - Part 1. Fertilizer news 9: 1-8
----------	1964	Response of banana to differential microelement application. Plant Food Review 4(2): 4-8
Suss A.	1956	On the uptake and distribution of sulphur in healthy and virus diseased plants demonstrated by means of radioactive sulphur. Prakt. Bl. Pfl. Bau. 51(6): 181-185
Tisdale, H.B. and Dick, J.B.	1942	Cotton wilt in Alabama as affected by potash supplements and as related to varietal behaviour and other important agronomic problems. J. Amer. Soc. Agron. 34: 405-426
Tomkins, C.M.	1926	Influence of the environment on potato mosaic symptoms. Phytopathology 16 (9) 691-699

Varadaraja Iyengar, A.V.	1938	Lime in relation to spike disease of sandal. Chron. Botany 4: 205-206
Varma, J.P.	1961	Nitrogen nutrition of Turkish tobacco (Nicotiana tabacum L. in relation to multiplication of tobacco mosaic virus. Indian J. Microbiol. 1: 97
----------	1963	The effect of phosphorus on multiplication of tobacco mosaic virus in Turkish tobacco plants Science & Culture. 29: 92-93
----------	1964	Effect of magnesium nutrition on multiplication of tobacco mosaic virus. Ind. J. Microbiol. 2 (4): 177-182
Varma, G.S. and Varma, J.P.	1961	The effect of potassium nutrition in multiplication of tobacco mosaic virus. Indian J. Microbiol 1: 43-49
Volk, J, Bodo, O and Hanschild	1952	Studies on the question of a correlation between manuring and aphide colonisation in potato stands (note I) Z. Pfl. Krankh 59: 3-4
Wambeke, A.	1957	Contribution to the study of symptoms of yellowing in oil palms. Bull. Agric. Congo. Belge. 48: 889-904
Wardlaw, C.W.	1935	Diseases of banana and Manila hemp plants. Macmillan & Co. Ltd., London. page 615

Weathers, L.G.	1960	The effect of host nutrition on the development of exocortis in Poncirus trifoliata. Abs. Phytopathology 50(1): 36
Weathers, L.G. and Pound, G.S.	1954	Host nutrition in relation to the multiplication of tobacco mosaic virus in tobacco. Phytopathology 44: 74-80
Wellhie, G.W. and Pound, G.S.	1957	Manganese nutrition of Nicotiana tabacum in relation to multiplication of tobacco mosaic virus. Abs. Phytopathology 47(1): 36
Welton, R.E.	1954	Susceptibility of peas to aphid inoculation with Bean yellow mosaic virus. Diss. Abst. 24 (8): 3048
William, B, Allington, D, Edward, F and Laird (Jr.)	1954	The infection of Nicotiana glutinosa with tobacco mosaic virus as affected by potassium nutrition. Phytopath. 44(6): 297-299
Wilson, J.H.	1956	Effect of nutrition and light intensity on symptom of leaf roll virus infection in the potato plant. Ann. Appl. Biol. 43: 273-287
Wunschor, C.	1952	The influence of fertilising on the development and health of potatoes. Z. Acker. U. Pfl. Ban. 94: 377-421
Yarwood, C.E.	1954	Zinc increases susceptibility of Bean leaves to Tobacco mosaic virus. Phytopathology, 44: (5): 230-233

Zelenova, I.V. 1964 Effect of insufficient iron and manganese in the nutritive medium on some aspects of metabolism in cucumber (Cucumis sativus) infected with cucumber mosaic virus. Dokl. Akad. S-kh. Nauk. 8: 12-22

APPENDICES

APPENDIX I

Analysis of variance

Height of plants before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	32851.50	27		
Block	23293.00	6	3882.16	11.476 **
Treatments	3469.64	3	1156.546	3.419 *
Error	6088.86	18	338.27	

* Significant at 5% level
** Significant at 1% level

APPENDIX II

Analysis of variance

Height of plants after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	31092.80	27		
Block	22689.80	6	3781.63	10.231**
Treatments	1781.80	3	593.97	1.618
Error	6621.10	18	367.77	

** Significant at 1% level

APPENDIX III

Analysis of variance

Girth of plants before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	1290.71	27		
Block	789.71	6	131.62	11.07 **
Treatments	301.00	3	100.33	9.12 **
Error	206.00	18	11.44	

** Significant at 1% level

APPENDIX IV

Analysis of variance

Girth of plants after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	1818.860	27		
Block	730.357	6	121.726	2.223
Treatments	103.427	3	34.476	0.637
Error	985.180	18	54.726	

APPENDIX V

Analysis of variance

Number of fully opened leaves before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	86.96	27		
Block	46.21	6	7.70	6.81**
Treatments	20.38	3	6.70	6.01**
Error	20.37	18	1.13	

** Significant at 1% level

APPENDIX VI

Analysis of variance

Number of fully opened leaves after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	234.68	27		
Block	125.43	6	20.91	3.99*
Treatments	14.97	3	4.99	0.952
Error	94.28	18	5.24	

* Significant at 5% level

APPENDIX VII

Analysis of variance

Length of leaves before the transmission of virus

Source	S.S.	D.F.	Variance	Variance ratio
Total	15386.9	27		
Block	10335.9	6	1722.65	16.56**
Treatments	3179.1	3	1059.70	10.19**
Error	1871.9	18	103.99	

** Significant at 1% level

APPENDIX VIII

Analysis of variance

Length of leaves after the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	32450.43	27		
Block	12248.93	6	2041.88	2.642
Treatments	6203.83	3	2067.94	2.675
Error	13907.67	18	772.65	

APPENDIX IX

Analysis of variance

Width of leaves before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	1221.71	27		
Block	548.21	6	91.37	4.76**
Treatments	327.71	3	109.24	5.69**
Error	345.79	18	19.21	

** Significant at 1% level

APPENDIX X

Analysis of variance

Width of leaves after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	1221.71	27		
Block	548.21	6	91.37	4.76**
Treatments	327.71	3	109.24	5.69**
Error	345.79	18	19.21	

** Significant at 1% level

APPENDIX XI

Analysis of variance

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

Source	S.S.	D.f.	Variance	Variance ratio
Total	3481.30	21		
Treatments	2029.83	3	676.61	8.39**
Error	1451.47	18	80.61	

** Significant at 1% level

APPENDIX XII

Analysis of variance

The nitrogen content of leaf samples before transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	12.941	27		
Replications	9.021	6	1.5030	20.147**
Treatments	1.877	3	0.6250	8.378**
Error	1.343	18	0.0746	

** Significant at 1% level

APPENDIX XIII

Analysis of variance

The nitrogen content of leaf samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	12.134	27		
Block	4.217	6	0.7029	0.368
Treatments	4.473	3	1.4910	0.781
Error	3.444	18	0.1910	

APPENDIX XIV

Analysis of variance

The phosphoric acid (P_2O_5) content of leaf samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.19637	27		
Replications	0.02668	6	.00445	0.65
Treatments	0.04747	3	.01582	2.33
Error	0.12222	18	.00679	

APPENDIX XV

Analysis of variance

The phosphoric acid (P_2O_5) content of leaf samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.127	27		
Block	0.018	6	0.003	0.75
Treatments	0.036	3	0.012	3.00
Error	0.073	18	0.004	

APPENDIX XVI

Analysis of variance

The potash content of leaf samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	10.060	27		
Replications	2.291	6	0.3320	1.21
Treatments	2.052	3	0.6840	2.15
Error	5.717	18	0.3176	

APPENDIX XVII

Analysis of variance

The potash content of leaf samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	6.000	27		
Replications	1.089	6	0.1815	0.74
Treatments	0.484	3	0.1613	0.65
Error	4.427	18	0.2460	

APPENDIX XVIII

Analysis of variance

The CaO content of leaf samples before the transmission of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.309	27		
Block	0.113	6	0.0189	3.203*
Treatments	0.087	3	0.0296	5.016*
Error	0.107	18	0.0059	

* Significant at 5% level

APPENDIX XIX

Analysis of variance

The CaO content of leaf samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.244	27		
Replications	0.075	6	0.0125	2.55
Treatments	0.081	3	0.0270	6.51**
Error	0.088	18	0.0049	

** Significant at 1% level

APPENDIX XX

Analysis of variance

The MgO content of leaf samples before the transmission of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.641	27		
Replications	0.279	6	0.0465	5.23**
Treatments	0.102	3	0.0340	3.83*
Error	0.160	18	0.0089	

* Significant at 5% level

** Significant at 1% level

APPENDIX XXI

Analysis of variance

The MgO content of leaf samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.639	27		
Replications	0.159	6	0.0265	1.93
Treatments	0.132	3	0.0440	3.21*
Error	0.248	18	0.0137	

* Significant at 5% level

APPENDIX XXII

Analysis of variance

The CaO/MgO ratio in the leaf before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	4.361	27		
Block	2.174	6	0.3623	3.383*
Treatments	0.257	3	0.0858	0.8003
Error	1.930	18	0.1072	

* Significant at 5% level

APPENDIX XXIII

Analysis of variance

The CaO/MgO ratio of leaves after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	3.0489	27		
Block	1.0060	6	0.1676	1.689
Treatments	0.2868	3	0.0956	0.863
Error	1.7861	18	0.0992	

APPENDIX XXIV

Analysis of variance

The CaO + MgO/K_2O ratio of leaves before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.1144	27		
Block	0.0334	6	0.00556	2.809*
Treatments	0.0452	3	0.01506	7.626
Error	0.0358	18	0.00198	

* Significant at 5% level

APPENDIX XXV

Analysis of variance

The CaO + MgO/K_2O ratio of leaves after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.6543	27	0.02423	
Block	0.1300	6	0.02166	1.62
Treatments	0.2838	3	0.09460	0.71
Error	0.2405	18	0.01336	

APPENDIX XXVI

Analysis of variance

The nitrogen content of root samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	2.7193	27		
Replications	2.1180	6	0.3530	1.340
Treatments	0.1270	3	0.4230	1.605
Error	0.4743	18	0.2325	

APPENDIX XXVII

Analysis of variance

The nitrogen content of root samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	1.8363	27		
Block	1.4311	6	0.2385	13.38**
Treatments	0.1332	3	0.0444	2.49
Error	0.3220	18	0.0179	

** Significant at 1% level

APPENDIX XXVIII

Analysis of variance

The phosphoric acid (P_2O_5) content of root samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.04325	27	0.001601	
Block	0.01067	6	0.001778	0.99
Treatments	0.00025	3	0.000083	0.046
Error	0.03233	18	0.001796	

APPENDIX XXIX

Analysis of variance

The phosphoric acid (P_2O_5) content of root samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.03275	27		
Block	0.00639	6	.00115	0.81
Treatments	0.00013	3	.000043	0.0303
Error	0.02573	18	.00143	

APPENDIX XXX

Analysis of variance

The potash content of root samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	47.023	27		
Block	2.333	6	0.333	0.33
Treatments	21.430	3	7.160	6.07**
Error	23.157	18	1.286	

** Significant at 1% level

APPENDIX XXXI

Analysis of variance

The potash content of root samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	60.627	27		
Replications	2.602	6	0.433	0.296
Treatments	21.657	3	7.219	4.923*
Error	26.368	18	1.465	

* Significant at 5% level

APPENDIX XXXII

Analysis of variance

The calcium oxide content of root samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	1.209	27		
Replications	0.593	6	0.099	0.483
Treatments	0.846	3	0.282	1.375
Error	0.370	18	0.205	

APPENDIX XXXIII

Analysis of variance

The calcium oxide content of root samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.960	27		
Block	0.447	6	0.0743	2.84
Treatments	0.142	3	0.0473	1.81
Error	0.371	18	0.0261	

VELLAYANI LIBRARY

APPENDIX XXXIV

Analysis of variance

The magnesium oxide content of root samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	1.693	27		
Replications	0.775	6	0.129	5.37**
Treatments	0.477	3	0.159	6.62**
Error	0.441	18	0.024	

** Significant at 1% level

APPENDIX XXXV

Analysis of variance

The magnesium oxide content of root samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	1.385	27		
Block	0.384	6	0.064	1.91
Treatments	0.407	3	0.135	4.11*
Error	0.594	18	0.033	

* Significant at 5% level

APPENDIX XXXVI

Analysis of variance

The CaO/MgO ratio of root samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	1.975	27		
Block	0.790	6	0.131	2.03
Treatments	0.023	3	0.007	0.11
Error	1.162	18	0.0645	

APPENDIX XXXVII

Analysis of variance

The CaO/MgO ratio of root samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	6.4525	27		
Block	0.8637	6	0.1443	0.59
Treatments	1.1763	3	0.3917	1.60
Error	4.4085	18	0.2448	

APPENDIX XXXVIII

Analysis of variance

The CaO + MgO/K_2O ratio of root samples before the transmission of virus

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.1830	27		
Block	0.0695	6	0.01158	2.136
Treatments	0.0160	3	0.00530	0.978
Error	0.0976	18	0.00542	

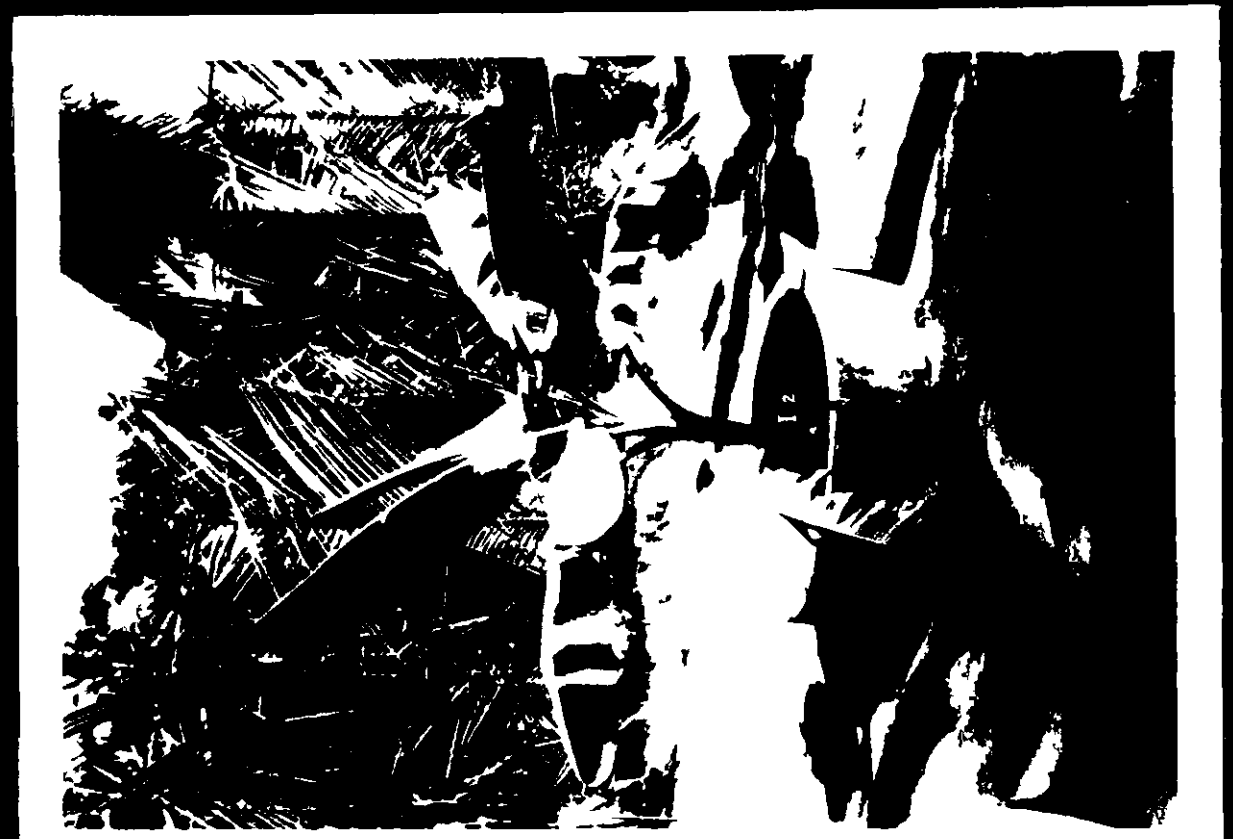
APPENDIX XXXIX

Analysis of variance

The CaO + MgO/K_2O ratio of root samples after the incidence of the disease

Source	S.S.	D.f.	Variance	Variance ratio
Total	0.1323	27	0.00514	
Block	0.0336	6	0.00560	1.28
Treatments	0.0263	3	0.00876	2.00
Error	0.0789	18	0.00438	

ILLUSTRATIONS




I-5