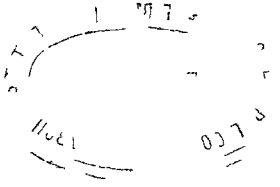
# INVESTIGATIONS ON THE POSSIBLE RELATIONSHIP BETWEEN THE NUTRITIONAL STATUS OF SOILS AND THE INCIDENCE OF "BUNCHY TOP" DISEASE OF BANANAS *(Musa species)*



BY

P. K. DAMODARAN NAMBIAR

**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 & RESEARCH INSTITUTE
VELLAYANI, TRIVANDRUM

AUGUST 1963

# 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.K. Damodaran Nambiar under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

C.K.N. NAIR,
PRINCIPAL.

C.K.N. NAIR,
PROFESSOR OF AGRONOMY.

Agricultural College &
Research Institute,
Vellayani/Trivandrum.
20th August, 1963.

# A C K N O W L E D G M E N T S

THE author wishes to place on record his deep sense of gratitude and indebtedness to:

DR. C.E.N. NAIR, M.Sc., Ph.D. (Cornell), D.R.I.P. (Oak Ridge), Professor of Agronomy and now Principal, Agricultural College and Research Institute, Vellayani for suggesting and planning the present investigation and for his encouragement, suggestions and criticisms.

SRI. E.J. THOMAS, M.Sc., M.S. (Iowa), Senior Lecturer in Statistics for help in the statistical layout of the experiment and analysis of data.

SRI. M. RAMANATHA MENON, M.Sc. (Ag)., M.S. (Ohio), Research Officer and Virus Pathologist for help and assistance during the course of the investigation.

THE author is also grateful to THE GOVERNMENT OF KERALA for deputing him for the Post-graduate course.

P.K. DAMODARAN NAMBIAR.

# CONTENTS

LIST OF TABLES

# LIST OF ILLUSTRATIONS

8. Diseased banana plant under treatment D. (N.P.K. + Mg)

9. Diseased banana plant under treatment E. (N.P.K. + Ca+Mg)

10. A healthy banana plant under treatment E showing no symptoms when plants under other treatments showed disease symptoms.

11. General view of the diseased plants after disease symptoms appeared.

# I N T R O D U C T I O N

Banana (*Musa species*) constitutes an important group of fruit crops cultivated extensively in tropical regions of the world. The world acreage under banana is about 1 to 1.5 million acres. In India, banana is considered to be one of the most important fruit crops. It is regarded as a fruit of value both by the rich and the poor. It occupies more land than any other fruit crops except mango. Its cultivation extends over an area of about 0.4 million acres which is about one-fifth of the total acreage under fruits in this country.

In recent years, banana has gained much importance and popularity from the fact that it is found to be one of the most valuable crops for implementing the drive for increased food production. Valued as a fruit, vegetable and processed product, it provides a supplementary food for millions of people. In a densely populated country like India, where the population is increasing at a rapid rate and where suitable land is limited for extension of cultivation, banana will make perhaps one of the easiest crops for intensive exploitation. Of late, an attempt is also being made to export banana to other countries to earn the hard needed foreign exchange.

Banana cultivation in many countries of the world is threatened with, and affected by, a serious disease "Bunchy Top". The disease is so disastrous that it has practically wiped out the banana industry in many centres in New south wales and

Queensland in Australia. India is no exception and is also facing serious destruction of the crop from this disease.

Kerala, Madras, Andhra Pradesh, Bombay, Mysore, Assam, west Bengal and Bihar are the chief banana producing centres of India. Kerala tops the list with an annual acreage of 100,000 acres and an annual production of 65,000 tons. It is in Kerala that the largest number of varieties are cultivated, the chief among them being Poovan, Nendran, Palayanthodan, Monthan, Kadali, and Rasakadali (Musa species).

Of all the diseases of banana, the most destructive is the "Bunchy Top". The incidence of this disease was reported from Orissa, Andhra Pradesh, Bombay, Bihar and Assam as early as 1940. In Kerala State also the disease first appeared in 1940. It has now spread throughout the State and has devastated the industry, causing heavy loss to the growers. The annual financial loss at a modest estimate is calculated to be of the order of Rs. six crores. Capoor (1950) has reported that the disease which covered an area of 900 square miles in central Travancore around Kottayam in 1946 had by 1950 covered an area of 3000 square miles.

In Kerala, the majority of the cultivated varieties have been found susceptible to the disease. The most widely cultivated varieties namely Palayanthodan and Nendran are highly susceptible. Other varieties like Kadali, Nenpoovan, Adakkakanan, Kurim Kaadli, Chalipoovan, Kunhinendran, Peykannan (Musa species) are also susceptible to infection. Some of the finest varieties of bananas grown in this State are facing extinction.

"Bunchy Top" disease being of virus origin as reported by various investigators, curative measures are considered difficult for the reason that the spread of infection is throughout the tissues of the affected plant. In Australia, where the disease was so destructive, eradication of the diseased plants is the only method practised to prevent its spread. It was reported that in Travancore from 1943 to 1947, about 600,000 plants were destroyed in a vain attempt to prevent the spread of the disease. Breeding resistant varieties seems to be difficult because most of the edible varieties that have been tested as well as seed bearing varieties, have been found to be susceptible to the disease.

No attempt has so far been made in this country or elsewhere to investigate the nutritional status of the soils and to study whether the soil conditions act as a predisposing factor for the incidence of "Bunchy Top" of banana. Such attempts have been made in respect of other crop diseases such as the root (wilt) disease of coconut, and the mandarin orange decline.

Considering the economic importance of this crop to the State, the extent of damage caused by the disease, and heavy loss caused for the growers, the study of soil conditions as a predisposing factor in the incidence of the disease is worth intensive investigation.

In the present study, an attempt has been made to investigate the nutritional status of the soil from diseased and healthy areas. Besides, leaf samples of diseased and healthy plants

were also analysed for their major plant nutrients.

There is an observation by some growers that the incidence of the disease is not severe in fields where lime is applied. Based on this practical observation, an experiment was laid out to study whether the nutritional status of the soil, especially of calcium and magnesium, acts as a predisposing factor in the incidence of the disease. This thesis embodies the observations and results of the experiment.

# REVIEW OF LITERATURE

## 1. Disease occurrence and distribution

Magee (1927) has reported that the incidence of "Bunchy Top" disease of banana was first observed in Fiji about the year 1879, and that the banana industry was severely affected with the concomitent abandonment of many plantations. According to Fahmy (1924) the incidence of the disease in Egypt was observed as early as 1901 and had since been a limiting factor in banana production. Petch (1913) and Bryce (1921) has reported the appearance of "Bunchy Top" in Ceylon in the district of Colombo in 1913. They have also reported that from Colombo, the disease had spread rapidly to other areas in the country, causing heavy damage to banana plantations. The presence of the disease in Australia was reported about the same time by Darnel Smith (1924) and Magee (1927). The introduction of this disease to New South Wales was reported to be through infected suckers in the year 1913. The incidence of the disease has also been reported from Ellice Islands by Campbell (1926), Wallis Islands by Simonds (1933) and from Bonin Islands by Gadd (1926). A disease similar to "Bunchy Top" of bananas was reported on Manila hemp or Abaca (Musa textilis) in Phillipine Islands. Thus the disease has a wide geographical distribution.

In India, the disease was believed to have been introduced from Ceylon about the year 1940, into Travancore and Cochin. The incidence of the disease has now been reported from many States

namely Bombay, Andhra Pradesh, Orissa and Assam. No systematic survey has been undertaken in this country to estimate the extent of damage. According to Verghese (1945), the disease seems to have appeared in Travancore in the year 1941. Unconfirmed occurrence of the disease has been reported from Calcutta by Hector (1925), from Cuttack by Padwick (1940), from Sabour by Roy and Sharma (1952) and from Assam by Mandi (1941). According to Kamat and Patel (1951) a report of survey showed an incidence of 25-70 percent in Khandish, 10-15 percent in Poona and 25-30 percent in Surat.

The incidence of the disease was first reported in Kerala from the District of Kottayam, from where it spread to other areas in the State. The disease is now rampant in the Districts of Trichur and Kottayam. For a long time the incidence of this disease was not reported from Madras and Mysore States. But recently the disease was noticed in Tanjore District of Madras and south Kanara District of Mysore.

No report on the incidence of the disease is seen from the important banana growing countries like west Indies, Central and South America, Canary Islands, part of Africa, Java, Sumatra, Burma, Siam, Indo China and China. In India, the disease incidence has not been reported from Uttar Pradesh and Madhya Pradesh.

2. Causative Organism

Earliest investigators on "Bunchy Top" attributed various causes for the incidence of the disease. Knowles and Jepson (1912), the earliest investigators on Bunchy top in Fiji Islands, regarded the causative organism as of fungus origin. Loos and

Foaden (1902) and Fahmy (1924) attributed the malady to nematode agency. Darnel Smith (1924) describing the occurrence and symptoms of the disease in Australia, attributed it to fungal or bacterial infection of the roots or corm. In his attempt to determine whether the banana aphid was a vector of the disease, negative results only were obtained. Goddard (1925) reported that the vector responsible for the transmission of the disease was the banana aphid, Pentalonia nigronervosa and the disease was of virus origin. The results of experiments conducted by Magee (1927) confirmed the causative organism as virus and the vector for the transmission of the disease as the banana aphid, Pentalonia nigronervosa.

The experiments conducted in various countries have shown that the virus is not sap-transmissible. Menon (1959) has confirmed this. Being systemic in nature, the spread of the disease was found to be primarily through the use of diseased suckers. Banana aphid was found to be responsible for causing secondary infection. It was also established that secondary infection can occur at any stage of growth and that winged and wingless adult forms and nymphs were efficient in virus transmission.

The studies carried out by Magee (1940) on virus-vector relationship have shown that aphids become infective after feeding on diseased plants for a minimum period of 17 hours and that the virus gets transmitted by infected aphids in one and a half or more hours of feeding on susceptible plants. The vector, pentalonia nigronervosa retains the infective capacity for a period of 13 days after removal from the diseased plants. The incubation period

ranged from few hours to 2 days. Aphids fed on diseased plants for 3 days, starved for 3 hours and released on youngest leaves of healthy plants at 20 numbers on each plant, were able to transmit the disease. The symptoms appeared in 35 to 45 days (Progress report of the Scheme of Research on"Bunchy Top" disease of Banana in Kerala State, 1956-57).

3. Symptoms of the disease

The primary infected plants (diseased suckers) seldom makes normal growth but remain stunted in growth (9" - 24" in height) with a large number of narrow, corrugated leaves, more erect than normal, with a rosette appearence. The leaves are harsh and brittle and may sometimes be more dark green than normal with yellowish, upwardly-rolled margins. Dark green dots are seen in the lamina, midrib and petiole. The infected plants make little growth after the first symptoms are noticed. The leaf stalks (petioles) fail to elongate. In advanced stages of the disease, decayed appearence of the root system is also noticed. Bunches are generally not produced in the primary infected plants.

Secondary infection may occur at any stage in the growth of the plant, from its emergence to the stage of throwing out the bunch. Those plants infected at the later stage of growth may produce a small bunch of stunted fruits.

4. Disease resistance

Magee (1953) has reported that all the species of Musa, producing edible seedless fruits, and all the fertile seed

bearing species examined by him were susceptible to this disease, even though the intensity of attack varied. Cavendish, (Musa Species) an important commercial variety was reported to be highly susceptible. Some degree of resistance was reported in Gros Michel variety (Musa species) from the failure to get infection by standard methods of inoculation. The display of resistance was substantiated by field observations in Fiji and Borneo. According to Magee (1953), the factor which contributes to the resistance may be physiological. In Kerala, under natural conditions, most of the varieties were found susceptible to the disease.

5. Nutritional status of soils

The growth of plants is so profoundly influenced by soil conditions that it can safely be assumed that these also exert a powerful effect on plant virus diseases. Lack of plant nutrients in sufficient quantity and in correct proportion is one of the several factors that predispose plants to infection by fungi, bacteria, viruses and nematodes. Several plant diseases are influenced so seriously by soil deficiencies that much of the damage from them can be avoided by soil treatment. Outstanding examples are wheat rootrot, sugar beet seedling blight, fusarium wilt of cotton, common scab of potatoes, and powdery mildew and rust of cereals.

(a) Soil condition in relation to diseases

Physical properties of soil such as drainage, water hold-

ing capacity, ease of penetration by roots and retention of plant nutrients have much to do with its suitability for many agricultural uses to which it is put. According to Menon and Nair (1951), the root (wilt) disease of coconut was more severe and acute in areas with poor soil aeration such as water logged condition, soils with poor moisture retentive capacity, a high water table, shallow soil depth, and poor drainage. They have also reported that other diseases of coconuts have a more or less similar distribution. Sheppard (1927) as quoted by Menon and Pandalai (1958) was of opinion that unhealthy appearance of coconut palms at Pointe aux Sables was due to water logged condition of the soil in some areas and to a deficiency of moisture in other parts. A similar observation was also made by Menon et al (1952) with regard to root infection caused by R. Solani, R. Bataticola and Bacillus theo bromae on coconut seedlings. They reported that worse infections were noticed in low lying areas under badly drained condition or high water table within 3 or 4 feet below the surface of the soil. Similarly Bronze leaf wilt of coconut has been reported to occur in water logged conditions and unsatisfactory condition of water supply within the tissues of the palm. Park (1932), in giving an account of serious outbreak of a disease similar to Bronze leaf wilt in Trinidad, stated that the condition was brought about by severe drought. He has also reported that the disease was worse on poorly cultivated land and on land which in wet weather becomes water logged and swampy. Verghese (1934) and Menon (1946-54)

carried out extensive investigations on soil conditions in relation to root and leaf disease of coconut palm and the data obtained by them revealed significant difference between the soils of healthy and diseased areas. They found that a large proportion of the localities in the diseased group has water table or some impermeable layer near the surface.

Asana (1959) has reported that one of the causes of root destruction in citrus decline was the injury from accumulation of nitrite under water logged conditions. Ramakrishnan (1954) was of the view that insufficient moisture during summer months was instrumental for the incidence of the disease. Narasimha Rao (1948) considered unfavourable soil conditions and defective cultural practices as a predisposing factor in the Mandarin orange decline.

Mardlaw (1935) has stated that occurrence of "Bunchy Top" disease with marked virulence under tropical, subtropical and temperate conditions showed that climatic factors exercise little influence either on its incidence or development. It was reported that the disease occured with maximum intensity during hot months of January to March when aphids were plentiful.

Bryce (1921) has reported that "Bunchy Top" incidence was much more severe and prevelant in banana fields which have been allowed to run for several years from the date of planting.

Studies on the seasonal incidence of the vector of "Bunchy Top" virus in Kerala showed that it was relatively abundant during November to January and scarce during April to

July (Progress report of the Scheme of Research on "Bunchy Top" disease of bananas, 1956-57, Agriculture College, Vellayani). The general indications were that dry weather from January to May and heavy rains from June to August seemed to adversely affect the aphid population and that the period of succulent growth of plants which came after heavy rains was favourable to them.

Bain et al (1934, 1937) in their studies to correlate soil factors with occurrence of Bronze leaf wilt of coconut, concluded that the physical conditions and allied water relationships of soil were of prime concern. Sankarasubramoney (1954) has carried out similar work with regard to root and leaf disease of coconut palm in Kerala and their results were in general agreement with those of Bain.

(b) Soil reaction as related to diseases

Gardner (1935) stated that soil reaction in the neutral or slightly alkaline range is the most optimum for the growth of the majority of crops. Productivity is considerably impaired when the soil is too acidic or too alkaline. Acid soils have been found to contain varying quantities of soluble alumina and manganese and these elements have been shown to be toxic to plants. Acidity means a deficiency of available calcium and it is one of the causes for the depressed growth of many crops in acid soils. Phosphorus availability is also impaired in acid soils. According to Verghese (1934) and Menon (1946-54), the pH values were lower in the diseased areas as compared with those

of healthy areas in respect of root (wilt) disease of coconut. Low pH values adversely affect the availability of major plant nutrients and micro nutrients which in turn affect the growth of the plant. At low pH values many plant nutrients are not in an available form.

(c) Mineral nutrients of soils in relation to diseases

In many diseases, the influence of the environment or soil conditions may be of equal importance like the organism which is related to the disease condition. Similarly the interaction of many limiting factors come into play in the causes of physiological disorders. Whether or not a disease is due to pathological or physiological causes, the soil conditions may form, to a very large extent, the orienting factor. Adequate nutrition from a favourable root environment would maintain the plants in a healthy state with a greater degree of disease resistance.

Several workers have investigated the nutritional status of soil from healthy and diseased areas in respect of certain diseases in other crops. Sankara Subramoney (1954, 55 and 56) and Pandalai et al (1958, 59) studied in detail the nutrient status of soil in relation to root (wilt) disease of coconuts. They have reported that soils of diseased tracts have comparatively lower contents of certain nutrients. Sankara Subramoney (1954) has also shown that nutrients like nitrogen phosphorus and potassium accumulated in the leaf tissues of the diseased coconut palms. Similar work has also been carried out by Mariakulandai and John Durairaj (1958) in their study of mandarin

orange decline. Govinda Iyer (1955) in his studies on the decline of citrus in Wyanad has reported that chemical analysis of soil revealed satisfactory contents of nitrogen, phosphorus and potash, but their availability was limited because of low pH and consequent poor lime status. The literature on the relationship of diseases with major plant nutrients in soil is summarised below.

i. Nitrogen

As a constituent of protoplasm, nitrogen is an important plant nutrient intimately involved in the activity of every living cell. The excess or deficiency of nitrogen has very marked effects on plant growth. Insufficient nitrogen reduces yields drastically and also decreases the quality of the plant product. On the other hand an excess of nitrogen results in a stimulation of vegetative growth which may result in delayed maturity, and in extreme cases, in a decrease in yields. Size of cells is increased with a decrease in cellwall thickness. As a result the tissues are more susceptible to attack by disease organisms.

Janssen (1929) was one of the first to investigate the relation between plant nutrition and incidence of virus diseases. He found that in respect of potato, the better the plants were fed, the more likely they were to become infected. Increasing nitrogen increased both the aphid population and the susceptibility of potato plants to infection by leafroll and Y-viruses.

Spencer (1935) concluded that nitrogen specifically increased the susceptibility of tobacco plants to mosaic virus and increased its concentration in sap. He further concluded that the virus from nitrogen deficient plants was weight by weight less infective

than virus from plants supplied with abundant nitrogen.

Brierley and Stuart (1946) found that increasing the nitrogen level for onions increased both their susceptibility to infection by yellow dwarf virus and severity of symptoms produced.

Ross and Coworkers (1947) suggested that fertilizers increased virus infection by increasing plant susceptibility, and found no effect on aphid population. Bawden and Kassanis (1948) have stated that both nitrogen and phosphorus increased susceptibility to infection only when applied in amounts that increased growth. They further found that the effects of both nitrogen and phosphorus on virus production were correlated with their effect on plant growth. Combined supplements of both nutrients to tobacco plants, doubled the virus concentration in sap and increased the total virus per plant. According to them nitrogen alone increased neither growth nor virus concentration.

Broad bent et al (1952) concluded that the application of dung or sulphate of ammonia to potato crop in Britain increased the aphid population. They have also reported that application of dung increased the incidence of both leaf roll and Y-viruses, and sulphate of ammonia that of leaf roll.

Broad bent (1954) has also reported that heavy nitrogen dressing increased susceptibility of cauli flower to mosaic virus.

Pardlaw (1939) in giving an account of "Bunchy Top" disease of bananas stated that field observations indicated that more vigorous and rapidly growing plants are most susceptible to this disease. Rishbeth (1954) as quoted by Choma (1959) has reported that addition of nitrogenous manure increased the Panama wilt

Pritchett (1926) has reported the result of an experiment in Philippines which showed that application of ammonium sulphate to sugarcane affected by mosaic virus disease has given an increased yield over the control plot and it would appear that application of nitrogen somewhat mitigates the loss of weight which is a normal accompaniment of mosaic diseases.

Wilson (1955) has reported that increased nitrogen supply to infected potato plant with leaf roll virus greatly reduced the intensity of leaf symptoms at Rothamstead Experimental Station.

Sankarasubramoney (1954) and Pandalai (1958-59) in a study of rootwilt disease of coconut, concluded that total nitrogen content of soils in the diseased area was higher in case of sandy and alluvial soils while in red loam the reverse was the case. In the case of laterite soils, the healthy localities had a higher nitrogen status in the A horizon only.

ii. Phosphorus

Phosphorus plays an important role in the nutrition of plants. Being present in all living tissues, its role in life processes such as photosynthesis, breakdown of carbohydrates and transfer of energy within the plant, is of great significance. It is the major constituent of the nucleus of the cell and is present in cytoplasm where it is involved in the organisation of cells and transfer of hereditary characters. Growth is arrested when the supply of phosphorus is limited in the soil and the plant appears stunted in growth with poorly developed roots, and deep green colour of leaves. A deficiency of phosphorus may lead to delay in maturity. At both strong acidity and alkalinity, there is fixation or reversion of

phosphates in the soil and the availability to plant gets reduced. Soil reaction between 6.5 and 7.5 is most favourable for phosphate availability. According to Lyon et al (1952), no other element with the possible exception of nitrogen, has been found to be so critical for plant growth in the field as phosphorus since a lack of this element may result in a decrease in the ease with which other elements are absorbed by plants.

Phosphorus is essential for the multiplication of virus in host cells and may increase their susceptibility to attack by viruses and other disease agents. Spencer (1939) found that in tobacco, phosphorus increased susceptibility to virus disease as long as plant growth benefitted from extra phosphorus. Bawden and Kassanis (1948) were of the view that phosphorus is more important than even nitrogen or potash in regulating host susceptibility. They further reported that the greatest susceptibility in tobacco to mosaic disease was when plants were supplied with nitrogen and phosphorus in concentrations optimum for plant growth. They found that phosphorus increased both the growth of plants and concentration of virus in the sap.

Sankarasubramoney et al (1954) in their studies on soil conditions in relation to the root (wilt) disease of coconuts came to the conclusion that there was no significant difference in phosphoric acid status of soils, both total and available, between healthy and diseased areas.

iii. Potash

Potassium, one of the major elements in plant nutrition, plays vital functions in plant metabolism. Its participation in photosynthesis is one of its important functions and as such an adequate

supply of potash is essential. The need to replenish the potassium status of soil is all the more important in crops such as coconut and banana which are heavy feeders of potash.

Russel (1950) stated that the content of potash in plants is larger than any of the other major nutrients except nitrogen. Nightingale (1931) has suggested that Potassium has a marked influence on the reduction of nitrates and syntnesis of proteins in plants. Vall (1940) and Nightingale (1942) have attributed the importance of potash to carbondioxide assimilation and synthesis of simple sugars and starch. It takes part in the water economy of plants, enables to withstand drought, and helps in maintaining the turgor in plant cell. Much information has been furnished on the influence of this element on plant growth by Miller (1938). Nightingale (1943) and Steinburg (1951). Potassium has been known to regulate protoplasmic swelling in plant cells and directly influences enzyme action and physiological activity. It is known to have an important role in buffer systems in plants. It is known to influence translocation of carbohydrates. There is evidence to show that movement of iron in the plant is facilitated by potassium and hence it has a direct effect on the formation of chlorophyll.

There are certain inter-relationships between potassium and other elements. Additions of nitrogen and phosphorus to soils reduce the absorption of potassium, especially if available soil potassium is limited. If conditions are such that the plants absorb high amounts of calcium and magnesium, the absorption of

potassium may be limited. On the other hand, potassium absorption may be so high that often calcium and magnesium absorption are hindered.

A lack of sufficient potash for normal growth causes disturbances in one or more vital plant processes resulting in the appearance of visual symptoms of disorders. The deficiency of potassium in plant is manifested by stunted growth, yellowing and drying up of leaf tips and leaf margins in older leaves.

It has been reported by many investigators that potassium is instrumental in increasing resistance of certain crops to specific diseases. It is not definitely known whether potassium enables the plant to withstand attacks of organisms, or organisms become established more easily on potassium deficient plants.

Bryce (1921) has reported that the application of potash has been found to reduce Rhizoctonia disease on jute in India, besides greatly increasing the yield. He has also stated that the incidence of "Bunchy Top" disease in Bonin Islands is attributed to deficiency of potash in the soil and that application of potash manures greatly reduced the incidence of the disease.

According to Janssen (1929), a deficiency of potash favoured aphid reproduction and spread of virus diseases. Broadbent et al (1952) reported that in Britain the aphid population was decreased by application of muriate of potash.

Spencer (1935) found that potassium decreased susceptibility to virus disease at levels that increased plant growth. Tisdale and Dick (1942) has reported that cotton wilt can be controlled by the use of suitable varieties and with the use of fertilisers

containing adequate amounts of potash and that varieties differ with respect to potassium requirement and withstanding wilt attack. Patel and Nair (1936) have observed that soil application of potash as potassium sulphate considerably reduced the incidence of shootrot in coconut palm.

According to Haley and Ried (1943), the role of the element in diseases is not well understood but they were of opinion that susceptibility to leaf spot disease in tobacco crop was associated with potassium deficiency.

Hoffer (1949) has pointed out that when potassium deficiency occurs in corn, iron accumulates at the nodes of stalk which interferes with translocation of nutrients to the roots resulting in weakening of roots and rendering them susceptible to fungal attack.

Bawden and Kassanis (1949) have indicated that potassium slightly reduced the virus content of the sap although it usually increased the total amount of virus per plant.

According to Allington and Laird (1954), potassium deficiency enhanced the susceptibility of tobacco to infection by mosaic virus. The receptivity to the virus persisted longer and at a much higher level in the low potassium plants than in those plentifully supplied with potassic fertilisers.

The investigations of Brun (1954) have confirmed the conclusion that the blue disease of banana was due to an unbalanced potassium-magnesium ratio.

Sankara Subramoney *et al* (1956), in their study of root

wilt disease of coconut, have shown that compared to healthy areas, the soils from diseased areas were lower in available potash.

It has been mentioned in the annual report of the Cameroons Development Corporation (1957) that most rapidly growing oil palms become affected by crown disease and little leaf disease where potassium was applied alone, but this was counter-balanced by the addition of magnesium. Nair (1961) has reported that potash manuring of rubber affected by 'die back', along with nitrogen, suppressed the disease and increased the yield of rubber within a period of one year from the date of application of the fertilizers.

Potassium promotes the development of thicker outer walls in the epidermal cells and firm tissues which are less subject to collapse. Plant diseases have been greatly retarded by the use of potassic fertilisers.

iv. Calcium

Calcium is an essential element in all plant tissues and a deficiency of this element disrupts the utilisation of all other nutrient ions. It is known to be a constitutent of cell wall of plants and is present as calcium pectate in the middle lamella. It seems to be essential for the continued growth of apical meristems and particularly for the proper growth and functioning of root tips. Sorokin and Sommer (1940) have reported that in the absence of calcium, miotic division become aberrant or suppressed. Calcium is also known to have a role in the

nitrogen metabolism of plants. According to Nightingale (1937), in the absence of calcium some species of plants atleast are unable to absorb or assimilate nitrates.

Calcium is important from the point of view of fertility status of soils. It neutralises the soil acidity and provides the base for the neutralisation of organic acids in plants. Calcium enhances the fixation of nitrogen by symbiotic and non-symbiotic organisms and helps in nitrification. It renders phosphorus in acid soils available and promotes bacterial decomposition of organic matter. Its role in reducing the toxicity of trace elements is well known. York et al (1955) who studied the potassium-calcium interrelationships in soils and plants, have shown that calcium ions may inhabit absorption of potassium by plants. There is good evidence that lime influences the concentration of exchangeable and water soluble potash in soils.

A deficiency of calcium renders the cell walls thin and permeable, affecting to some extent the osmo-regulations in the cells and reducing the activity of growing points especially root tips. A lack of calcium may also add to the poor tilth of soil and adversely affect the activities of certain soil micro-organisms. According to Russel (1950), calcium deficiency results in the stunting of root system and indirectly allows other substances to accumulate in the tissues. The young leaves of calcium deficient plants are severely distorted with tips hooked back and margins curved. Scorching or than chlorotic streaks are also seen on leaf. Russel (1950) has observed that

a high level of calcium resulted in depression of the uptake of potassium and magnesium.

Van Vanbeke (1957) has reported that malformation of crown and yellowing of leaflets common in oil palms in Belgian Congo are associated with calcium and magnesium deficiencies.

Evans and Troxler (1953) have reported that application of 1000 lbs. of calcium oxide and 2 sprays of 1 percent calcium chloride solution reduced the incidence of Blossom end rot in tomatoes from 17.7 to 13.1 percent. They have also reported that injection of tomato fruits with sterile calcium glucosite solution completely prevented the disorder.

Ramakrishnan and Damodaran (1956) reported that liming of soil reduced the period of viability of the pathogen of panama wilt disease to two months while in the control the viability extended upto 4 months.

v. Magnesium

Magnesium is the one and only mineral constituent of chlorophyll molecule, the green colouring matter of the plant. A large proportion of magnesium present in plants therefore is in the chlorophyll bearing organs, although seeds are also relatively rich in this element. Magnesium plays a role in the phosphate metabolism of plants and indirectly, therefore, in the respiratory mechanism. It is largely required by oil seed crops as it promotes the formation of oils and fats. Magnesium ions appear to be specific activators for a number of enzymes including certain transphosphorylases, dehydrogenases and carboxylases.

Deficiency of magnesium usually results in the development of characteristic chlorosis. Its deficiency in the soil causes serious injuries to plants. Magnesium deficiency can arise in plants either from a true deficiency in soil or from an unbalanced proportion of nutrients, which is often associated with high level of manuring.

Gammon et al (1953) have shown that the quantity of magnesium in sandy soils is correlated with organic matter content. Garner et al (1930) have given evidence to show that magnesium content of the soil is not always a good index of the adequacy of this element for plant use. Magnesium deficiency is known to go alongside of deficiencies of calcium in ordinary soils. An excessive use of potassium fertilisers may cause magnesium deficiency. Large dressing of lime may also induce magnesium deficiency in the crops.

Magnesium deficiency in the soil results in reduced photosynthetic activity and may impart lack of resistance to disease attack.

Hale (1947) has reported that the chlorosis and bronzing of oil palms in certain localities in West Africa was attributed to the combined effect of potassium and magnesium deficiency. Cooke (1950) attributed magnesium deficiency as a possible cause for the tapering disease of coconut.

Brun and Champion (1954) have reported that the blue disease of bananas in French Guinea was associated with magnesium deficiency and demonstrated the effectiveness of magnesium in any

form but chiefly as dolomite. They have also indicated the importance of combining magnesia with potassium fertilisers.

Pandalai et al (1958) have reported that total or exchangeable magnesium in the soil has little bearing on the incidence of root wilt disease of cocoanut, although a major symptom of root diseased trees is the chlorosis of the leaves.

Mariakulandai and John Dorairaj (1958) have reported in their study on orange decline that higher magnesia content is associated with healthy conditions of trees. The same workers have further reported that the ratio of calcium plus magnesium/potassium decreased considerably from healthy to affected leaves.

Shepherd and Pound (1960) have reported that tobacco infected with mosaic virus and grown in liquid culture with magnesium, developed typical deficiency symptoms at 0 and 0.5 ppm., but the assays showed a consistent, though small, reduction in virus in magnesium deficient plants.

vi. Micro nutrients in relation to diseases

It has been reported by a number of investigators that certain micro nutrients also appear to orientate the health or disease of plants. The specific role of micro nutrients in relation to plant and microbial growth has not been intensively studied. It is suggested that several micro nutrient elements are active through certain enzyme systems. Copper, iron and molybdenum are capable of acting as electron carriers in the oxidation-reduction enzyme systems. Zinc and manganese also function in enzyme systems which are necessary for important

reactions in plant metabolism. Molybdenum and manganese have been found to be essential for certain nitrogen transformations in micro organisms and plants. Molybdenum is thought to be essential for the process of nitrogen fixation, both symbiotic and non-symbiotic. It must be present in plants if nitrates are to be metabolised into amino acids and proteins. Zinc is thought to be concerned in the formation of certain growth hormones and in the reproduction processes of certain plants. Copper is involved in respiration and in the utilisation of iron. A boron deficiency decreases the rate of water absorption and of translocation of sugar in plants and iron is essential for the synthesis of proteins contained in the chloroplasts.

Nutritional balance among trace elements is essential, but more difficult to maintain.

Bhatt (1945), Naik (1948) and Mukherjee (1949) were of opinion that 'die back' of citrus in India is due to deficiency of nutrients including micronutrients such as zinc. According to them zinc sprays have definitely benefited citrus in several areas. Marudarajan (1949) has attributed the orange decline to the deficiency of trace elements including zinc, boron and manganese. But supply of these elements failed to produce any favourable response.

Innes (1949) found no relationship between manganese content of palm leaf tissue and root and leaf disease of coconuts. Martyn (1948) has reported that injection of trees with iron, boron, copper etc., had no effect on the budrot of palms in

PLATE 11
GENERAL VIEW OF DISEASED PLANTS

Jamaica. He has also reported that liming improved the condition and it might be due to the release of deficient plant food ingredients in forms available to the palms.

According to Rumley and Thomas (1951), zinc has some effect on virus that causes orange decline, as borne out by their observation that soaking cuttings affected by carnation-mosaic virus in solutions of zinc sulphate or calcium chloride, freed them from the virus.

Singh and Singh (1953) attributed the 'die back' of citrus in Uttar Pradesh to copper deficiency and Chowdhury (1954) has attributed it to zinc deficiency in Assam.

Yarwood (1955) has demonstrated enhanced susceptibility of phaseolus vulgaris leaves to tobacco mosaic virus, induced by 10 minutes immersion in 0.001 to 0.03 percent zinc sulphate. He has also reported that the same treatment decreased the number of tobacco mosaic lesions on Nicotiana glutenosa leaves.

Shepherd and Pound (1960) has reported that Nicotiana tabaccum grown in nutrient solutions, low or lacking in boron, showed characteristic deficiency symptoms and eventually ceased growth.

From the foregoing literature review, it can be seen that soil conditions and environments in many cases act as predisposing factors in the incidence of diseases. The old adage "prevention is better than cure" applies to the health of plants as to human beings. Maintenance of soil fertility and providing the nutrients in correct proportion are thus the key to the health

and vigour of plants and their resistance to diseases.

The present study has been undertaken with the object of investigating the nutritional status of soils in relation to the incidence of "Bunchy Top" disease on banana. Such a study will be useful to ascertain whether soil conditions act as predisposing factors in the incidence of the disease.

# MATERIALS AND METHODS

## A. MATERIALS

### 1. Soil Samples

3 districts (two diseased and one healthy) were selected for the investigation of the nutrient status of the soils. In each of these districts, two types of soils were taken for the study.

The details of districts, location and type of soils are given below:

| District | Location from where soil samples collected | Type of soil | Remarks |
|---|---|---|---|
| 1. Quilon | 1. Quilon | Sandy | Diseased area |
| | 2. Kottarakara | Laterite | |
| 2. Ernakulam | 3. Alwaye | Sandy | Diseased area |
| | 4. Moovattupuzha | Laterite | |
| 3. Cannanore | 5. Payyannur | Sandy | Healthy area |
| | 6. Taliparamba | Laterite | |

A brief description of the above areas is given below:

#### i. Quilon District

The district, with an area of about 8000 acres under bananas, has a well distributed rainfall. The annual rainfall ranges from 2600 to 3000 mm. with a maximum mean temperature of 90°F during March-April and minimum temperature of 72°F during January.

Sandy soils are found along the coastal area. Kottarakara, with laterite soils, is to the interior, 24 kilometers east of Quilon.

ii. Ernakulam District

Alwaye with sandy loam soils is situated close to the coastal area, and Koovatupuzha with laterite soils is located about 40 kilometers to the interior and at an elevation of about 180 meters above mean sea level. The rainfall of the district ranges from 3000 to 3800 mm. The maximum mean temperature of the locality is 95°F and minimum temperature 68°F. The area under banana is 5,800 acres in this district.

iii. Cannanore District

The district with an area of 25,000 acres under banana is situated in North Kerala. The annual rainfall of the district ranges from 3500 to 4500 mm., distributed over 120 days and received mainly during the south-west monsoon (June to September). Payyannur, with sandy soils is located in the coastal area and Taliparamba, with laterite soils is situated 25 kilometers to the interior at an elevation of 45 meters. The highest temperature of the tract is 100°F in April-May and lowest minimum temperature of about 60°F in December-January.

Twenty representative soil samples were collected from each area, and under both diseased and healthy plants. The soil samples were collected 3 feet away from the base of the plant and to a depth of 12". Besides, 5 samples were collected to a depth of 12" to 36". The details of samples collected are given in page 31.

| District | Soil Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sandy | | | | Laterite | | | |
| | Healthy | | Diseased | | Healthy | | Diseased | |
| Depth | 0"-12" | 12"-36" | 0"-12" | 12"-36" | 0"-12" | 12"-36" | 0"-12" | 12"-36" |
| Quilon | 20 | 5 | 20 | 5 | 20 | 5 | 20 | 5 |
| Ernakulam | 20 | 5 | 20 | 5 | 20 | 5 | 20 | 5 |
| Cannanore | 20 | 5 | -- | - | 20 | 5 | -- | - |
| Total | 60 | 15 | 40 | 10 | 60 | 15 | 40 | 10 |

2. Leaf samples

Twenty representative leaf samples for analysis were collected from both healthy and diseased plants from each area. The selections were confined to those plants from whose base soil samples were taken for analysis.

B. METHODS OF ANALYSIS

Brief outline of the methods adopted for the analysis of the soils is presented below:

Preparation of soil samples and leaf samples

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

The leaf samples were dried in shade, powdered well in a grinder and the powdered material was used for analysis.

Chemical Analysis

The methods of analysis adopted in the study were those of

the A.O.A.C.(1950), "Soil and Plant Analysis" by Piper (1950) and "Soil Chemical Analysis" by Jackson (1957).

Soil samples were tested for pH and analysed for available phosphoric acid, available potash, exchangeable calcium and magnesium, organic carbon, total nitrogen, total phosphoric acid, potash, calcium and magnesium as detailed below:

i. Soil moisture

Moisture was determined by drying at 105°c for 6 hours.

ii. pH

The pH was determined in 1:2.5 soil-water suspension using glass electrode.

iii. Organic carbon

The wet digestion method of Walkley and Black (1934) as modified by Walkley (1935) was used.

Known quantity of powdered soil was treated with potassium dichromate and sulphuric acid. The excess potassium dichromate was titrated back with ferrous sulphate solution using diphenylamine as indicator. From the volume of potassium dichromate used the organic carbon was calculated.

iv. Organic matter

By multiplying the organic carbon content by the factor 1.72 the organic matter content was arrived at.

v. Available phosphorus

Available phosphorus was determined by Dickman and Bray's method as given by Jackson (1957). Weighed quantity of the soil was extracted with ammonium fluoride-Hcl extracting medium. The phosphorus in the extract was estimated colorimetrically using a

Klett-Summerson Colorimeter.

vi. Available Potassium

Available potassium was estimated by turbidimetric method. The weighed soil sample was extracted with Morgan's reagent and the turbidity developed in the extract by adding sodium cobaltinitrite solution, was estimated colorimetrically using a Klett-Summerson Colorimeter.

vii. Exchangeable Calcium

The exchangeable calcium was estimated by leaching the soil with neutral ammonium acetate, precipitating as oxalate, and titrating against standard potassium permanganate.

viii. Exchangeable Magnesium

The magnesium in the filtrate from calcium estimation was precipitated as magnesium dihydrogen phosphate and determined gravimetrically.

ix. Total Nitrogen

Total nitrogen was determined by the Kjeldahl method as given by Piper (1950).

x. Total phosphoric acid

Total phosphoric acid was determined by the method as adopted by the A.O.A.C. (1950).

xi. Potassium

Potassium was determined by sodium cobaltinitrite method as given by the A.O.A.C. (1950).

xii. Calcium

Calcium was determined by the method as given by the A.O.A.C. (1950).

xiii. Magnesium

Magnesium was determined by the method as given by the A.O.A.C. (1950).

The analysis of plant material for major nutrients (nitrogen, phosphorus and potassium) and for calcium and magnesium was done by the methods as given by the A.O.A.C (1950) and 'Soil and Plant Analysis' by Piper (1950).

(C) EXPERIMENT

With a view to study whether the nutritional status of the soil, especially calcium and magnesium, is a factor in the incidence of "Bunchy Top" disease, an experiment was laid out with major nutrients plus calcium and magnesium.

1. Treatments and Lay out

The experiment was laid out as follows:

Treatments:

A. Control

B. N.P.K. mixture

C. N.P.K. + Calcium

D. N.P.K. + Magnesium

E. N.P.K. + Calcium + Magnesium

Lay out

The pots were arranged in a randomised block design as recommended by Panse and Sukatme (1957) with 6 replications. A spacing of 2.4 meters was given between the plants both ways.

2. Banana suckers

The variety of banana used for the experiment was Nendran,

known locally as "Kothan". In Kerala, Nendran is one variety that is highly susceptible to the disease under natural conditions. Artifical transmission of the disease by release of aphids was also found successful in this variety (Progress report of the Scheme of Research on "Bunchy Top" disease of bananas in Kerala State for the year 1956-57).

The healthy banana suckers for the experiment were collected from a garden in the vicinity of the College. The garden was completely free from the disease. The mother plants were observed throughout its growth period for the incidence of the disease and healthy suckers were collected only after satisfying that the garden was free from the disease.

Nendran variety is a crop of 10 months duration. 30 banana suckers, almost uniform in size, were collected two days prior to the planting date. The suckers were air-dried for two days, before planting as practised in the locality.

3. Pots for the experiment

Thirty numbers of reinforced concrete pots of size 60 cm. diameter and 60 cm. height were given two coatings with bitumin paint to prevent the plant roots from absorbing nutrients from the cement material of the pot. Hewitt (1950), in studying the trace element nutrition of plants, adopted the method of painting the pots with bitumin to prevent absorption of extraneous elements.

4. Sand

Coarse grained river sand was used for the experiment. It was sieved in ¼" sieve, treated with 2 percent Hydrochloric acid,

then with 2 percent Nitric acid and washed free of acids in a current of running water. Each pot contained 150 kg. of washed, dried sand.

5. Manures

(a) Cattle manure

13.6 kg. of well decomposed farm yard manure was mixed with the sand in each pot. The analysis of cattle manure showed the following percentage of plant nutrients:

| | | |
|---|---|---|
| Nitrogen | -- | 0.62% |
| Phosphoric acid | -- | 0.36% |
| Potash | -- | 0.49% |
| Calcium oxide | -- | 0.58% |
| Magnesium oxide | -- | 0.04% |

(b) Lime (calcium carbonate)

Byeproduct calcium carbonate obtained from the Fertilisers and Chemicals, Travancore Ltd., Alwaye, was used for the experiment. 6 kg. of calcium carbonate was used for 12 plants in two treatments.

The analysis of the calcium carbonate for calcium and magnesium gave the following values:

| | | |
|---|---|---|
| CaO | -- | 57.10% |
| MgO | -- | 1.55% |

(c) N.P.K. Fertiliser mixture

N.P.K. fertiliser mixture (9:9:9) from the Fertilisers and Chemicals, Travancore Ltd., was used for the experiment. 2.5 kg. of 9:9:9 mixture was applied per plant in all treatments except

the control. The analysis of the fertiliser mixture showed a calcium content of 9.7 percent. Half the phosphoric acid in the mixture was in water soluble form.

(d) Magnesium carbonate

Chemically pure magnesium carbonate containing 47.3 percent magnesium oxide was used for the experiment. 672 g. of magnesium carbonate was used for 12 plants in 2 treatments.

(e) Micro nutrients

The micro nutrients namely manganese, zinc, copper, iron, boron and molybdenum, were applied in all pots and these micro nutrients were supplied as magnesium sulphate, zinc sulphate, copper sulphate, iron sulphate, boric acid and molybdic acid respectively.

Cattle manure and macro nutrients were given to all the plants including the control at the following rates as basal dressing.

Cattle manure 13.6 kg. per plant

Micro nutrients per plant

| Chemical used | Quantity | To supply the micro nutrient | Quantity |
|---|---|---|---|
| Manganese sulphate | 6.16 g. | Manganese | 2 g. |
| Zinc sulphate | 8.8 g. | Zinc | 2 g. |
| Copper sulphate | 7.84 g. | Copper | 2 g. |
| Iron sulphate | 10.0 g. | Iron | 2 g. |
| Boric acid | 5.2 g. | Boron | 1 g. |
| Molybdic acid | 1.5 g. | Molybdenum | 1 g. |

N.P.K. Mixture

For treatments B,C,D & E,N.P.K. mixture at 2.5 kg. per plant was used.

Calcium carbonate

0.5 kg. per plant for treatments C & E was given.

Magnesium carbonate

For treatments D & E, magnesium carbonate at 56 g. per plant was given.

Planting

The holes provided on the sides at the bottom of the pots were plugged with glass wool for retaining sand in the pot and at the same time to drain the excess water. The pots were then filled with a measured quantity of sand mixed with basal manures. 150 kg. of sand was added to each pot, sufficient for filling the pot upto 7.5 cm. from the top.

The suckers were planted at the centre of the pot by scooping the sand. The planting was done on 17-11-1962.

Fertilisers

The basal dressing with 13.6 kg. of cattle manure was done for each pot before filling. 6.16 g. of manganese sulphate, 8.8 g. of zinc sulphate, 7.84 g. of copper sulphate, 10 g. of ferrous sulphate, 5.2 g. of boric acid and 1.5 g. of molybdic acid were also mixed with the sand in each pot before filling.

Lime as calcium carbonate was applied to treatments C & E at the rate of 0.5 kg. per plant. The application was done in a circular layer 30 cm. below the surface and away from the

rhizome of the banana sucker. It was applied before planting the suckers.

Magnesium was supplied as magnesium carbonate. It was mixed with the sand before filling in the pot. The dose applied was 56 g. per plant under treatments D & E.

The N.P.K. fertiliser mixture at 2.5 kg. per plant was applied to all the plants, except control, in 3 split doses of 1/3 quantity each time at monthly intervals. The 1st dose was applied on 16-12-1962.

Irrigation

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

Release of aphids

Pentalonia nigronervosa, the banana aphid, is the vector responsible for the transmission of the virus, the causative agent for the "Bunchy Top" disease of bananas.

The aphid vector thrives best in humid conditions and persists on the plant if there is sufficient shade. To provide an optimum condition for the aphids to persist on the plants, a pandal was erected with the object of providing shade. One good rain was received a day prior to the release of aphids and this was helpful in keeping the ground in moist humid condition.

The aphids required for transmission were reared on healthy plants and then allowed to feed on diseased plants for a period of 7 days. The aphids were collected on 10-1-1963 and half-starved for 24 hours. They were released in the leaf sheath of young leaves at 30 numbers for each plant. The release of the aphids was done under the supervision of the Research staff of the Bunchy Top Research Scheme, Agricultural College, Vellayani. The humid condition and shade were maintained for a period of 5 days from the date of release of the aphids. The aphids were released on 11-1-1963.

Characters studied

1. Height of the plant

The height of the plant was measured at weekly intervals. The height was measured in centimeters from the surface of the sand in the pot to the apex of the plant.

2. Number of leaves

The number of leaves emerged and opened on the days of observation were recorded.

3. Length and width of leaves

The length of the leaf was taken from the tip of the leaf to the point where leaf blade ends on the petiole. The width was measured at the middle point of the leaf.

4. Observations on symptoms of disease

The following symptoms of the disease were looked for:

i. Development of chlorotic streaks and dots on the petiole, leaf blade and midrib.

ii. Upright position of leaves, curling of leaf margins, scorching, splitting of leaf blades, brittle nature of leaf.

iii. Shortening of leaf size both in length and width.

iv. Reduction in further growth, elongation of petiole reduced and production of cluster of leaves.

v. Representative leaf samples were drawn from the potted plants under different treatments and analysed for the calcium and magnesium content of the leaves.

## RESULTS

### 1. Soil analysis

#### 1. Soil reaction (pH)

Table I presented below gives the pH values of soils studied.

TABLE I

pH VALUES OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 6.10 | 5.95 | 0.18 | 5.66 | 5.36 | 1.60 |
| Ernakulam | 5.96 | 5.87 | 0.46 | 5.32 | 5.20 | 0.74 |
| Cannanore | 5.48 | - | - | 4.90 | - | - |
| Mean | 5.87 | 5.91 | 0.23 | 5.30 | 5.28 | 0.23 |
| LATERITE | | | | | | |
| Quilon | 5.27 | 4.97 | 0.91 | 5.20 | 4.88 | 2.90+ |
| Ernakulam | 5.39 | 5.29 | 0.60 | 4.88 | 4.78 | 0.43 |
| Cannanore | 5.48 | - | - | 5.36 | - | - |
| Mean | 5.48 | 5.13 | 1.00 | 5.15 | 4.83 | 2.88+ |

\+ Significant at 0.01 level

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

## 2. Organic carbon

The data presented in table II give the organic carbon contents of the soils studied.

TABLE II

ORGANIC CARBON CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as percentage on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.66 | 0.83 | 6.40+ | 0.52 | 0.61 | 2.94+ |
| Ernakulam | 0.70 | 0.87 | 2.36++ | 0.33 | 0.42 | 0.80 |
| Cannanore | 0.81 | - | - | 0.65 | - | - |
| Mean | 0.72 | 0.85 | 3.65+ | 0.50 | 0.53 | 6.4+ |
| LATERITE | | | | | | |
| Quilon | 0.75 | 0.99 | 5.10+ | 0.43 | 0.50 | 2.20+++ |
| Ernakulam | 0.98 | 1.05 | 1.09 | 0.47 | 0.53 | 1.12 |
| Cannanore | 1.15 | - | - | 0.44 | - | - |
| Mean | 0.96 | 1.02 | 1.40 | 0.45 | 0.52 | 2.70++ |

Note: In all tables the asterick mark indicates statistical significance as shown below:

\+ Significant at 0.01 level
++ Significant at 0.05 level
+++ Significant at 0.1 level

The soils from areas of diseased plants had a higher content of organic carbon as compared to those of healthy plants in both the

soil types at the two different depths. The organic carbon content of soils at 12" to 36" depth is found to be lower than that of the 0" to 12" layer. Between the two soils types, the laterite soils have a higher content of organic carbon. The mean values for all the Districts taken together also recorded a higher content of organic carbon in areas of diseased plants.

The higher content of organic carbon in areas of diseased plants is significant statistically in sandy soils of Quilon and Ernakulam districts, and laterite soils of Quilon District at 0" to 12" depth. It is also significant at depth 12" to 36" in respect of sandy and laterite soils of Quilon District. The mean values of organic carbon in diseased areas are 0.89 percent and 1.02 percent in respect of sandy and laterite soils as compared to 0.72 percent and 0.96 percent respectively, in healthy areas.

3. Organic matter

Table III presented on page 45 gives the percentage of organic matter content of the soils studied.

The organic matter content of soils of diseased area is higher than in healthy areas and the higher values are significant for sandy soils of both Quilon and Ernakulam districts at the two depths. It is also significant for laterite soils of Quilon District at the two depths 0" to 12" and 12" to 36". The organic matter content at the lower depth is lower than in the surface sample (0" to 12").

The mean values for these two soil types in the two groups of Districts also recorded a higher content of organic carbon in areas of diseased plants. These higher values are also significant

in the sandy soils at 0" to 12" depth and in the laterite soil at 12" to 36".

TABLE III

ORGANIC MATTER CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as percentage on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 1.14 | 1.43 | $6.20^{+}$ | 0.90 | 1.04 | $6.36^{+}$ |
| Ernakulam | 1.20 | 1.50 | $2.40^{++}$ | 0.56 | 0.72 | $2.9^{++}$ |
| Cannanore | 1.41 | - | - | 1.13 | - | - |
| Mean | 1.25 | 1.46 | $12.00^{+}$ | 0.86 | 0.88 | 0.15 |
| LATERITE | | | | | | |
| Quilon | 1.29 | 1.72 | $5.10^{+}$ | 0.74 | 0.86 | $2.20^{+++}$ |
| Ernakulam | 1.69 | 1.81 | 1.16 | 0.81 | 0.92 | 1.08 |
| Cannanore | 1.99 | - | - | 0.75 | - | - |
| Mean | 1.65 | 1.76 | 1.40 | 0.77 | 0.89 | $2.60^{++}$ |

4. Total Nitrogen

The percentages of total nitrogen in the soils of healthy and diseased areas studied are presented in table IV.

TABLE IV

TOTAL NITROGEN CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as percentage on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.052 | 0.064 | 11.3* | 0.042 | 0.048 | 2.72** |
| Ernakulam | 0.059 | 0.064 | 1.99*** | 0.026 | 0.033 | 2.72** |
| Cannanore | 0.069 | - | - | 0.045 | - | - |
| Mean | 0.060 | 0.064 | 1.59 | 0.038 | 0.040 | 0.05 |
| LATERITE | | | | | | |
| Quilon | 0.059 | 0.072 | 3.70* | 0.038 | 0.042 | 1.40 |
| Ernakulam | 0.079 | 0.083 | 0.67 | 0.043 | 0.044 | 3.40* |
| Cannanore | 0.091 | - | - | 0.037 | - | - |
| Mean | 0.076 | 0.078 | 0.67 | 0.039 | 0.043 | 1.90 |

It can be seen that soils from areas of healthy plants have a lower content of nitrogen as compared to areas of diseased plants at both depths, 0" to 12" and 12" to 36". The higher values of total nitrogen in diseased areas are significantly different from those of healthy areas in sandy soils of both Quilon and Ernakulam districts at both the depths, and laterite soils of Quilon and Ernakulam districts at 0" to 12" and 12" to 36" depths respectively.

## 5. C/N ratio

Values of C/N ratio presented in table V show that in all the diseased areas the ratios are higher as compared to soils of healthy areas.

TABLE V

CARBON/NITROGEN RATIO OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 12.72 | 12.95 | 0.55 | 12.38 | 12.62 | 0.34 |
| Ernakulam | 11.90 | 14.02 | 2.85* | 12.54 | 12.92 | 1.65 |
| Cannanore | 11.82 | - | - | 13.81 | - | - |
| Mean | 12.14 | 13.49 | 3.70* | 12.92 | 12.77 | 0.40 |
| LATERITE | | | | | | |
| Quilon | 12.80 | 13.31 | 1.40 | 11.36 | 11.90 | 1.20 |
| Ernakulam | 12.56 | 12.85 | 0.48 | 10.86 | 11.90 | 1.40 |
| Cannanore | 12.78 | - | - | 11.66 | - | - |
| Mean | 12.71 | 13.08 | 1.20 | 11.30 | 11.90 | 1.20 |

The sandy soils of diseased areas of Ernakulam district have a C/N ratio of 14.02 as against 11.90 in healthy areas and the difference is significant. The mean value for the sandy soils

in the two groups of Districts also showed a significantly higher ratio in diseased areas.

The values of C/N ratio are however not significantly different in other areas. The variation of the C/N ratio at different depths is irregular.

6. Phosphoric acid

Tables VI and VII presented give the data on the total and available phosphoric acid content of soils studied.

TABLE VI

TOTAL PHOSPHORIC ACID CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as Percentage $P_2O_5$ on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.030 | 0.028 | $2.20^{++}$ | 0.023 | 0.021 | $3.20^{++}$ |
| Ernakulam | 0.022 | 0.027 | 1.16 | 0.017 | 0.015 | $2.65^{++}$ |
| Cannanore | 0.036 | - | - | 0.025 | - | - |
| Mean | 0.029 | 0.027 | 1.52 | 0.022 | 0.018 | $2.74^{++}$ |
| LATERITE | | | | | | |
| Quilon | 0.050 | 0.047 | 0.94 | 0.037 | 0.034 | 0.90 |
| Ernakulam | 0.038 | 0.033 | $4.10^{+}$ | 0.026 | 0.015 | $7.00^{+}$ |
| Cannanore | 0.045 | - | - | 0.035 | - | - |
| Mean | 0.045 | 0.040 | $2.30^{++}$ | 0.033 | 0.025 | $2.10^{++}$ |

TABLE VII

AVAILABLE PHOSPHORIC ACID CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as Percentage $P_2O_5$ on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.0047 | 0.0052 | 0.66 | 0.0048 | 0.0059 | 1.90*** |
| Ernakulam | 0.0033 | 0.0035 | 0.40 | 0.0016 | 0.0018 | 0.97 |
| Cannanore | 0.0028 | - | - | 0.0025 | - | - |
| Mean | 0.0036 | 0.0044 | 1.66 | 0.0030 | 0.0039 | 1.04 |
| LATERITE | | | | | | |
| Quilon | 0.0017 | 0.0022 | 1.78*** | 0.0004 | 0.0008 | 1.50 |
| Ernakulam | 0.0008 | 0.0009 | 0.76 | 0.0004 | 0.0003 | 0.62 |
| Cannanore | 0.0015 | - | - | 0.0006 | - | - |
| Mean | 0.0013 | 0.0016 | 0.78 | 0.00045 | 0.00052 | 0.18 |

The total phosphoric acid content is seen to be higher in areas of healthy plants as compared to diseased areas, except in the sandy soils of Ernakulam district where the reverse is the case. The higher values of total $P_2O_5$ are significant only for 0" to 12" depth in the sandy soils of Quilon District and laterite soils of Ernakulam District.

It is also seen that the total $P_2O_5$ content is lower at depth 12" to 36" than at 0" to 12". Between the soil types, laterite soils have a higher content of total $P_2O_5$.

The mean values for the two groups of districts also recorded significantly higher content in healthy areas of laterite soils at 0" to 12" and at 12" to 36" in both soil types.

The soils from areas of diseased plants have a slightly higher concentration of available phosphoric acid. However the higher values are not significant in all the areas except laterite soils of Quilon district at 0" to 12" depth and sandy soils of Quilon district at 12" to 36" depth.

Between the soil types, the laterite soils have a lower content of available phosphoric acid than the sandy soils.

7. Potash

The data presented in table VIII and IX give the total and available potash of the soils studied.

The total potash content is higher in soils studied at both depths in areas of healthy plants as compared to diseased areas in sandy and laterite soils of Quilon. The mean values of total potash are 0.054 percent and 0.050 percent in respect of sandy and laterite soils in areas of healthy plants as compared to 0.036 percent and 0.043 percent in diseased areas respectively. The higher values are significant for sandy and laterite soils of Quilon District at both depths. However the sandy and laterite soils of Ernakulam District have slightly higher content of potash in diseased areas. The mean values for these two

soils in the two groups of districts are higher in healthy areas at both depths, and these are significantly different from diseased areas.

TABLE VIII

TOTAL POTASH CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as percentage $K_2O$ on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.044 | 0.034 | 4.00$^{+}$ | 0.030 | 0.018 | 5.80$^{+}$ |
| Ernakulam | 0.037 | 0.039 | 0.28 | 0.027 | 0.029 | 0.45 |
| Cannanore | 0.081 | - | - | 0.081 | - | - |
| Mean | 0.054 | 0.036 | 4.8$^{+}$ | 0.046 | 0.024 | 2.06$^{+++}$ |
| LATERITE | | | | | | |
| Quilon | 0.055 | 0.043 | 3.50$^{+}$ | 0.037 | 0.030 | 2.6$^{++}$ |
| Ernakulam | 0.037 | 0.044 | 3.15$^{+}$ | 0.030 | 0.029 | 0.091 |
| Cannanore | 0.057 | - | - | 0.066 | - | - |
| Mean | 0.050 | 0.043 | 2.43$^{++}$ | 0.044 | 0.029 | 2.70$^{++}$ |

TABLE IX

AVAILABLE POTASH CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as percentage $K_2O$ on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.00052 | 0.00047 | 0.43 | 0.0005 | 0.0003 | 1.67 |
| Ernakulam | 0.0005 | 0.0003 | 3.2* | 0.0002 | 0.0001 | 0.58 |
| Cannanore | 0.0007 | -- | - | 0.0007 | -- | - |
| Mean | 0.00060 | 0.00040 | 4.00* | 0.0005 | 0.0002 | 2.09** |
| LATERITE | | | | | | |
| Quilon | 0.0009 | 0.0008 | 1.06 | 0.0005 | 0.0003 | 1.90*** |
| Ernakulam | 0.0007 | 0.0006 | 0.94 | 0.00032 | 0.00028 | 0.44 |
| Cannanore | 0.0009 | - | - | 0.0012 | - | - |
| Mean | 0.0008 | 0.0007 | 0.71 | 0.0006 | 0.00050 | 1.05 |

Healthy areas have a higher content of available potash in all soils studied. The healthy areas of Ernakulam District in respect of sandy soils have a significantly higher concentration of available potash at 0" to 12" depth. The mean values for the

sandy soils of the two groups of Districts are higher in healthy areas at both depths.

The healthy areas of the District of Cannanore have higher content of total potash than the diseased areas of Quilon and Ernakulam at both depths.

8. Calcium

The total calcium and exchangeable calcium of the soils from diseased and healthy areas are presented in tables X and XI.

TABLE X

CALCIUM CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as percentage of CaO on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.090 | 0.081 | 1.12 | 0.073 | 0.054 | 1.09 |
| Ernakulam | 0.133 | 0.118 | 1.53 | 0.095 | 0.077 | 2.08$^{+++}$ |
| Cannanore | 0.092 | - | - | 0.078 | - | - |
| Mean | 0.105 | 0.106 | 0.76 | 0.082 | 0.066 | 2.10$^{++}$ |
| LATERITE | | | | | | |
| Quilon | 0.126 | 0.101 | 1.84$^{+++}$ | 0.091 | 0.081 | 1.03 |
| Ernakulam | 0.128 | 0.114 | 0.09 | 0.095 | 0.081 | 2.80$^{++}$ |
| Cannanore | 0.105 | - | - | 0.087 | - | - |
| Mean | 0.120 | 0.108 | 1.32 | 0.091 | 0.081 | 1.64 |

It can be seen from these tables that the HCl-soluble calcium and exchangeable calcium are higher in soils of healthy areas as compared to diseased areas in all soils even though the higher values are not significant in many cases. Significant higher values were obtained in respect of laterite soils of Quilon district at 0" to 12" depth and sandy and laterite soils of Ernakulam district at 12" to 36" depth.

TABLE XI

EXCHANGEABLE CALCIUM CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed in me/100 g. of soil on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 2.03 | 1.99 | 0.41 | 1.48 | 1.26 | 1.31 |
| Ernakulam | 3.28 | 2.71 | 1.52 | 1.30 | 1.16 | 1.12 |
| Cannanore | 2.59 | - | - | 1.96 | - | - |
| Mean | 2.56 | 2.35 | 0.95 | 1.58 | 1.21 | 3.00** |
| LATERITE | | | | | | |
| Quilon | 2.83 | 2.38 | 1.83*** | 1.54 | 1.09 | 2.64** |
| Ernakulam | 2.80 | 2.62 | 0.63 | 1.04 | 0.98 | 0.06 |
| Cannanore | 2.49 | - | - | 1.54 | - | - |
| Mean | 2.70 | 2.50 | 1.20 | 1.37 | 1.04 | 2.97** |

The higher values of exchangeable calcium are significant only in respect of laterite soils of Quilon district at both depths. The mean values for these two soils under the two groups of districts showed higher content of available potash in healthy areas at 12" to 36" depth.

9. Magnesium

The magnesium content and exchangeable magnesium of the soils are presented in tables XII and XIII.

TABLE XII

MAGNESIUM CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed as percentage MgO on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples) | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.074 | 0.065 | 2.03** | 0.065 | 0.060 | 0.94 |
| Ernakulam | 0.092 | 0.079 | 2.29** | 0.060 | 0.059 | 0.30 |
| Cannanore | 0.071 | - | - | 0.060 | - | - |
| Mean | 0.079 | 0.072 | 1.91*** | 0.062 | 0.060 | 0.53 |
| LATERITE | | | | | | |
| Quilon | 0.096 | 0.081 | 1.96*** | 0.054 | 0.047 | 1.26 |
| Ernakulam | 0.110 | 0.094 | 1.89*** | 0.058 | 0.049 | 1.33 |
| Cannanore | 0.059 | - | - | 0.080 | - | - |
| Mean | 0.088 | 0.087 | 0.22 | 0.060 | 0.048 | 2.50** |

The soils from areas of healthy plants had a significantly higher magnesium content in both soil types of Quilon and Ernakulam districts at 0" to 12" depth. The mean value for magnesia with respect to sandy soils under the two groups of districts was also significantly higher for healthy areas. However the higher content of magnesia at 12" to 36" depth is not significant.

TABLE XIII

EXCHANGEABLE MAGNESIUM CONTENT OF SOILS OF HEALTHY AND DISEASED AREAS AT TWO DIFFERENT DEPTHS

(Expressed in me./100 g. of soil on oven dry basis)

| Soil type & District | Depth of soils | | | | | |
|---|---|---|---|---|---|---|
| | 0" to 12" (Mean of 20 samples | | | 12" to 36" (Mean of 5 samples) | | |
| | Healthy | Diseased | t | Healthy | Diseased | t |
| SANDY | | | | | | |
| Quilon | 0.33 | 0.31 | 0.78 | 0.26 | 0.10 | 10.90+ |
| Ernakulam | 0.37 | 0.33 | 0.82 | 0.30 | 0.17 | 4.50+ |
| Cannanore | 0.49 | - | - | 0.43 | - | - |
| Mean | 0.40 | 0.32 | 2.90+ | 0.32 | 0.13 | 4.40+ |
| LATERITE | | | | | | |
| Quilon | 0.42 | 0.39 | 0.66 | 0.30 | 0.29 | 0.42 |
| Ernakulam | 0.59 | 0.50 | 1.94++ | 0.40 | 0.38 | 0.82 |
| Cannanore | 0.47 | - | - | 0.53 | - | - |
| Mean | 0.49 | 0.45 | 1.75 | 0.41 | 0.34 | 2.07++ |

The sandy and laterite soils of healthy areas have a mean

value of 0.079 percent and 0.088 percent of magnesia content as compared to 0.072 percent and 0.087 percent in diseased areas respectively.

Significantly higher values for exchangeable magnesium are seen in respect of laterite soils of Ernakulam district at 0" to 12" depth and sandy soils of both districts at 12" to 36" depth. The healthy areas of Cannanore have higher contents of exchangeable magnesium compared to the soils of the other two districts. The mean values for all the districts taken together show a significantly higher content for healthy areas in sandy soils at both depths and laterite soils at 12" to 36" depth.

## II. Leaf analysis

The results of chemical analysis of healthy and diseased leaf samples collected from the districts are presented in Tables XIV to XIX.

TABLE XIV

NITROGEN CONTENT OF HEALTHY AND DISEASED LEAF SAMPLES

(Expressed as percentage N on oven dry basis)

| Soil type & District | Leaf samples (Mean of 20 samples) | | t |
|---|---|---|---|
| | Healthy | Diseased | |
| SANDY | | | |
| Quilon | 2.10 | 2.21 | $2.50^{++}$ |
| Ernakulam | 2.86 | 2.92 | 0.96 |
| Cannanore | 2.08 | - | - |
| Mean | 2.35 | 2.56 | $2.63^{++}$ |
| LATERITE | | | |
| Quilon | 2.76 | 2.87 | $3.69^{+}$ |
| Ernakulam | 2.78 | 2.88 | $3.40^{+}$ |
| Cannanore | 2.52 | - | - |
| Mean | 2.69 | 2.88 | $6.76^{+}$ |

The data presented in table XIV show a higher content of nitrogen in diseased leaf samples as compared to healthy samples. The higher value is significant in all areas except leaf samples from sandy soil of Ernakulam District. The mean values of nitrogen content of all the Districts taken together also recorded a significant higher content. The nitrogen percentages in diseased samples from sandy and laterite soils are 2.56 percent and 2.88 percent and those of healthy samples are 2.35 percent and 2.69 percent respectively.

2. Phosphoric acid

TABLE XV

PHOSPHOPIC ACID CONTENT OF HEALTHY AND DISEASED LEAF SAMPLES
(Expressed as percentage $P_2O_5$ on dry basis)

| Soil type & District | Leaf samples (Mean of 20 samples) | | t |
|---|---|---|---|
| | Healthy | Diseased | |
| SANDY | | | |
| Quilon | 0.50 | 0.56 | 2.67+ |
| Ernakulam | 0.53 | 0.62 | 5.70+ |
| Cannanore | 0.37 | - | - |
| Mean | 0.47 | 0.59 | 8.90+ |
| LATERITE | | | |
| Quilon | 0.52 | 0.76 | 15.00+ |
| Ernakulam | 0.48 | 0.53 | 6.50+ |
| Cannanore | 0.39 | - | - |
| Mean | 0.46 | 0.65 | 9.70+ |

In the case of phosphoric acid content too, the diseased leaf samples from all the areas have higher values and the difference is significant. The diseased samples have a phosphoric acid content of 0.59 percent and 0.65 percent as compared to 0.47 percent and 0.46 percent in healthy samples from sandy and laterite areas respectively.

3. Potash

TABLE XVI

POTASH CONTENT OF HEALTHY AND DISEASED LEAF SAMPLES

(Expressed as percentage $K_2O$ on dry basis)

| Soil type & District | Leaf samples (Mean of 20 samples) | | t |
|---|---|---|---|
| | Healthy | Diseased | |
| SANDY | | | |
| Quilon | 2.29 | 3.08 | 18.00+ |
| Ernakulam | 3.66 | 4.63 | 6.30+ |
| Cannanore | 2.82 | - | - |
| Mean | 2.92 | 3.86 | 6.00+ |
| LATERITE | | | |
| Quilon | 3.88 | 4.24 | 5.20+ |
| Ernakulam | 3.31 | 3.97 | 5.80+ |
| Cannanore | 2.88 | - | - |
| Mean | 3.36 | 4.10 | 8.5+ |

It is seen from the data presented in table XVI that potash is higher in diseased leaf samples from both soil types.

The higher values are significant. The mean values of potash in diseased samples from sandy and laterite soils are 3.86 percent and 4.10 percent as against 2.92 percent and 3.36 percent in healthy samples respectively.

4. Calcium

TABLE XVII

CALCIUM CONTENT OF HEALTHY AND DISEASED LEAF SAMPLES

(Expressed as percentage CaO on oven dry basis)

| Soil type & District | Leaf samples | | t |
|---|---|---|---|
| | Healthy | Diseased | |
| SANDY | | | |
| Quilon | 0.67 | 0.54 | $2.70^{++}$ |
| Ernakulam | 0.59 | 0.48 | $3.90^{+}$ |
| Cannanore | 0.67 | - | - |
| Mean | 0.64 | 0.51 | $5.10^{+}$ |
| LATERITE | | | |
| Quilon | 0.62 | 0.52 | $3.60^{+}$ |
| Ernakulam | 0.63 | 0.57 | $2.56^{++}$ |
| Cannanore | 0.66 | - | - |
| Mean | 0.64 | 0.54 | $4.30^{+}$ |

Table XVII presents the data on the calcium content of healthy and diseased leaf samples. The calcium content of the diseased leaf samples showed significantly lower values

as compared to that of healthy leaf samples.

5. Magnesium

TABLE XVIII

MAGNESIUM CONTENT OF HEALTHY AND DISEASED LEAF SAMPLES

(Expressed as percentage MgO on oven dry basis)

| Soil type & District | Leaf samples | | t |
|---|---|---|---|
| | Healthy | Diseased | |
| SANDY | | | |
| Quilon | 0.462 | 0.413 | 2.42++ |
| Ernakulam | 0.531 | 0.461 | 3.40+ |
| Cannanore | 0.332 | - | - |
| Mean | 0.442 | 0.437 | 0.30 |
| LATERITE | | | |
| Quilon | 0.459 | 0.403 | 1.60 |
| Ernakulam | 0.461 | 0.432 | 0.50 |
| Cannanore | 0.443 | - | - |
| Mean | 0.455 | 0.417 | 2.38++ |

The magnesium content of leaf samples analysed are presented in Table XVIII. The magnesia content is higher in healthy leaf samples compared to diseased samples. However the difference is not statistically significant in respect of samples from laterite soil.

6. Calcium + Magnesium/Potassium ratio

TABLE XIX

CALCIUM + MAGNESIUM/POTASSIUM RATIO OF HEALTHY AND DISEASED LEAF SAMPLES

| Soil type & District | Leaf samples | | t |
|---|---|---|---|
| | Healthy | Diseased | |
| SANDY | | | |
| Quilon | 0.49 | 0.31 | 7.80+ |
| Ernakulam | 0.32 | 0.20 | 6.30+ |
| Cannanore | 0.35 | - | - |
| Mean | 0.39 | 0.26 | 6.50+ |
| LATERITE | | | |
| Quilon | 0.28 | 0.22 | 5.30+ |
| Ernakulam | 0.34 | 0.25 | 4.80+ |
| Cannanore | 0.38 | - | - |
| Mean | 0.33 | 0.24 | 8.00+ |

The data presented in Table XIX give the calcium + Magnesium/ Potassium ratio. The ratio is seen decreasing from healthy to diseased leaf samples and the difference is statistically significant.

III. Pot experiment

Growth measurements such as height of the plants, number of leaves, length and width of leaves were taken on all the 30 plants

under the five treatments. The time taken for the appearance of symptoms was also recorded.

The data presented in Tables XX and XXI give the growth measurements of plants, namely, height of plants and number of leaves on the day of release of aphids.

TABLE XX

AVERAGE HEIGHT OF PLANTS IN cm. ON THE DAY OF RELEASE OF APHIDS

| Treatment | Average height of plants in cm. |
|---|---|
| A. (Control) | 76.7 |
| B. (N.P.K) | 95.8 |
| C. (N.P.K. + Ca) | 81.3 |
| D. (N.P.K. + Mg) | 87.0 |
| E. (N.P.K. + Ca + Mg) | 91.0 |

Critical difference: 9.99

B E D C A

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

TABLE XXI

AVERAGE NUMBER OF LEAVES ON THE DAY OF RELEASE OF APHIDS

| Treatments | Average No. of leaves |
|---|---|
| A. (Control) | 7.33 |
| B. (N.P.K) | 7.33 |
| C. (N.P.K. + Ca) | 8.50 |
| D. (N.P.K. + Mg) | 8.33 |
| E. (N.P.K. + Ca + Mg) | 8.67 |

Critical difference: 0.91

E C D B A

The plants under treatment E,C and D have more number of leaves as compared to plant under treatments B and A. However there is no significant difference between treatments E,C and D.

Disease symptoms appeared in all the plants under different treatments. However there is variation in time taken between treatments in the appearance of symptoms.

The table XXII presented gives the average number of days taken for the appearance of symptoms after release of aphids.

Of all treatment combinations studied, treatment E, namely N.P.K. + Ca + Mg delayed the incidence of the disease to the greatest extent, i.e., 23 days over N.P.K. treatment. The time taken for appearance of symptoms in treatment E is significantly

different from treatment A, C and B.

TABLE XXII

AVERAGE NUMBER OF DAYS TAKEN FOR APPEARANCE OF SYMPTOMS AFTER RELEASE OF APHIDS

| Treatments | Average number of days taken for appearance of symptoms |
|---|---|
| A. (Control) | 34.30 |
| B. (N.P.K) | 30.00 |
| C. (N.P.K. + Calcium) | 30.20 |
| D. (N.P.K. + Mg) | 42.70 |
| E. (N.P.K. + Ca + Mg) | 53.00 |

Critical difference: 12.82

E D A C B

The plants under treatment D showed delayed appearance of symptoms over treatments A, C, and B, but the delay is however not significant. The difference between the time taken by E and D, although not significant, is approaching significance.

TABLE XXIII

AVERAGE GROWTH MEASUREMENTS OF PLANTS AT TIME OF APPEARANCE OF SYMPTOMS AND AT THE FINAL OBSERVATION

| Treatment | Average growth conditions at the time of noting symptoms | | | | Average growth condition at final observation | | | |
|---|---|---|---|---|---|---|---|---|
| | Height in cm | No. of leaves | Length of leaf in cm | Width of leaf cm | Height of plants cm | No. of leaves | Length of leaves cm | Width of leaves cm |
| A. | 114.0 | 12.2 | 102.3 | 48.8 | 118.8 | 17.7 | 61.8 | 17.3 |
| B. | 139.7 | 11.8 | 118.2 | 52.2 | 142.3 | 18.8 | 57.3 | 15.2 |
| C. | 128.0 | 13.2 | 112.0 | 50.2 | 130.7 | 20.8 | 65.2 | 15.0 |
| D. | 137.0 | 14.2 | 123.3 | 51.8 | 140.5 | 19.8 | 78.3 | 23.0 |
| E. | 161.8 | 16.3 | 135.7 | 58.7 | 162.0 | 20.2 | 96.2 | 31.5 |

From the above data, it can be seen that after the appearance

of the first symptoms, further growth is reduced or almost curtailed, and size of leaf both in length and width was also reduced considerably.

The analysis of leaf samples, from the potted plants under different treatments for calcium and magnesium is presented in tables XXIV and XXV.

TABLE XXIV

CALCIUM CONTENT OF LEAF SAMPLES

(Expressed as percentage on oven dry basis)

| Treatments | Average uptake of calcium as CaO |
|---|---|
| A. (Control) | 1.10 |
| B. (N.P.K.) | 1.24 |
| C. (N.P.K. + Ca) | 1.44 |
| D. (N.P.K. + Mg) | 1.21 |
| E. (N.P.K. + Ca + Mg) | 1.60 |

Critical difference: 0.12

E C B D A

The uptake of calcium in treatments E and C is seen significantly different from that in treatments B,D and A. The difference between E and C is also significant. No significant difference is seen between treatments B and D and between D and A. But

uptake in treatment B is significantly higher than in A.

TABLE XXV

MAGNESIUM CONTENT OF LEAF SAMPLES

(Expressed as percentage on oven dry basis)

| Treatments | Average uptake of Magnesium as MgO |
|---|---|
| A. (Control) | 0.346 |
| B. (N.P.K) | 0.352 |
| C. (N.P.K. + Ca) | 0.404 |
| D. (N.P.K. + Mg) | 0.604 |
| E. (N.P.K. + Ca + Mg) | 0.562 |

Critical difference: 0.093

$\overline{D\ E}\quad \overline{C\ B\ A}$

The leaf analysis under treatments D and E showed significantly higher values for the uptake of magnesium than treatments C, B and A. However there is no significant difference between treatments D and E.

TABLE XXVI

AVERAGE GROWTH MEASUREMENTS AT WEEKLY INTERVALS

| Date of measurements | Treatments | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | | B | | C | | D | | E | |
| | X | Y | X | Y | X | Y | X | Y | X | Y |
| 20-12-62 | 53.5 | 3.7 | 59.3 | 3.3 | 55.8 | 4.3 | 59.5 | 4.3 | 63.7 | 4.3 |
| 27-12-62 | 60.5 | 5.3 | 71.0 | 5.2 | 62.7 | 6.2 | 68.0 | 6.2 | 72.3 | 6.2 |
| 3-1-63 | 68.3 | 6.3 | 83.2 | 6.3 | 72.8 | 7.3 | 78.2 | 7.2 | 80.5 | 7.5 |
| 10-1-63 | 76.7 | 7.3 | 95.8 | 7.3 | 81.3 | 8.5 | 87.2 | 8.3 | 91.0 | 8.7 |
| 17-1-63 | 82.2 | 8.3 | 101.2 | 8.3 | 87.3 | 9.5 | 92.2 | 9.3 | 96.8 | 9.7 |
| 24-1-63 | 91.0 | 9.3 | 112.2 | 9.3 | 98.0 | 10.5 | 104.2 | 9.7 | 108.7 | 10.7 |
| 31-1-63 | 100.0 | 10.3 | 123.5 | 10.3 | 113.7 | 11.7 | 116.0 | 11.3 | 121.8 | 11.5 |
| 7-2-63 | 108.0 | 11.3 | 136.3 | 11.3 | 125.8 | 12.7 | 129.7 | 12.3 | 137.2 | 12.5 |
| 14-2-63 | 114.7 | 12.3 | 139.7 | 12.5 | 129.0 | 13.8 | 134.8 | 13.3 | 145.5 | 13.7 |
| 21-2-63 | 118.8 | 13.3 | 143.3 | 13.5 | 130.3 | 14.8 | 138.2 | 14.3 | 152.3 | 14.7 |
| 28-2-63 | 118.8 | 13.8 | 143.3 | 14.5 | 130.3 | 15.8 | 138.7 | 15.3 | 156.2 | 15.5 |
| 7-3-63 | 118.8 | 14.5 | 143.3 | 15.2 | 130.7 | 16.8 | 139.0 | 16.3 | 158.3 | 16.3 |
| 14-3-63 | 118.8 | 15.3 | 143.3 | 16.0 | 130.7 | 17.8 | 139.3 | 17.0 | 160.3 | 17.3 |
| 21-3-63 | 118.8 | 16.0 | 143.3 | 17.0 | 130.7 | 18.7 | 139.7 | 18.0 | 160.8 | 18.2 |
| 28-3-63 | 118.8 | 17.0 | 143.3 | 18.0 | 130.7 | 19.8 | 140.2 | 18.8 | 161.7 | 19.2 |
| 4-4-63 | 118.8 | 17.7 | 143.3 | 18.8 | 130.7 | 20.8 | 140.5 | 19.8 | 162.0 | 20.2 |

Note: X - Height in cm.

Y - Number of leaves

TABLE XXVI(a)

AVERAGE GROWTH MEASUREMENTS AT WEEKLY INTERVALS

| Date of measurements | Treatments | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | | B | | C | | D | | E | |
| | L | W | L | W | L | W | L | W | L | W |
| 20-12-62 | 48.3 | 25.0 | 52.0 | 27.0 | 52.0 | 26.0 | 55.2 | 27.8 | 59.7 | 29.7 |
| 27-12-62 | 55.7 | 27.2 | 65.3 | 31.8 | 58.2 | 29.2 | 61.3 | 30.0 | 67.3 | 33.0 |
| 3-1-63 | 65.0 | 31.7 | 74.5 | 35.3 | 67.3 | 33.3 | 73.5 | 36.7 | 74.3 | 33.5 |
| 10-1-63 | 75.5 | 38.7 | 86.5 | 44.3 | 78.8 | 38.8 | 83.7 | 42.5 | 85.3 | 44.5 |
| 17-1-63 | 81.0 | 42.0 | 93.7 | 46.0 | 89.0 | 40.3 | 88.2 | 43.7 | 91.7 | 47.5 |
| 24-1-63 | 88.7 | 43.7 | 100.8 | 47.0 | 92.0 | 45.2 | 97.8 | 45.5 | 100.0 | 47.2 |
| 31-1-63 | 96.0 | 45.5 | 109.0 | 49.1 | 102.3 | 49.1 | 108.2 | 48.8 | 113.2 | 51.0 |
| 7-2-63 | 100.8 | 46.8 | 114.3 | 51.3 | 108.2 | 52.3 | 115.5 | 53.0 | 121.0 | 54.2 |
| 14-2-63 | 103.5 | 48.8 | 116.7 | 45.3 | 108.5 | 42.7 | 106.2 | 45.0 | 130.2 | 56.2 |
| 21-2-63 | 92.0 | 39.8 | 95.3 | 31.8 | 87.3 | 30.3 | 110.0 | 42.5 | 136.0 | 60.3 |
| 28-2-63 | 88.9 | 36.0 | 71.0 | 17.0 | 79.0 | 20.2 | 100.3 | 36.0 | 123.0 | 49.8 |
| 7-3-62 | 73.7 | 23.5 | 74.2 | 18.7 | 72.5 | 17.5 | 83.2 | 26.5 | 116.3 | 43.7 |
| 14-3-63 | 67.2 | 19.3 | 65.7 | 16.8 | 70.0 | 17.2 | 82.5 | 26.5 | 113.7 | 40.7 |
| 21-3-63 | 65.5 | 18.9 | 62.2 | 16.5 | 68.7 | 16.7 | 82.0 | 26.0 | 110.3 | 38.8 |
| 28-3-63 | 62.7 | 18.2 | 60.2 | 15.7 | 67.0 | 16.0 | 80.5 | 25.5 | 103.5 | 35.3 |
| 4-4-63 | 61.8 | 17.3 | 57.3 | 15.2 | 65.2 | 15.0 | 78.3 | 23.0 | 96.2 | 30.2 |

Note: L = Length of leaf in cm.

W = Width of leaf in cm.

## DISCUSSION OF RESULTS

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

1. Physical condition of soils in relation to the disease

It was observed during a rapid survey of the areas selected for the collection of soil and leaf samples, that the incidence of the disease is more prevalent in low lying areas subject to water logging. The enquiries made in these areas also showed that banana gardens which have been allowed to continue for several years from the date of planting, are more susceptible to the disease than those that have been retained only for a few years. In fact, the results obtained in the investigations conducted by Bryce (1921) have shown that "Bunchy Top" disease was much more prevalent in banana fields allowed to run on several years from the date of planting.

2. Soil reaction (pH)

The results of study of soil reaction presented in table I indicate that the diseased areas are more acidic compared to healthy areas. In the case of sandy soils, there is no appreciable differences in soil reaction, but the difference is more pronounced

in laterite soils. The acidic reaction of the sites of diseased plants shows that it may have a contributing effect on the incidence of the disease. Similar observations were recorded by Verghese (1934) and Menon (1946-54) in their investigations on the incidence of root and leaf disease of coconuts.

3. Nutrient status of the soils in relation to disease

Nutrient status of soils contributes to a very large extent the orienting factor in many diseases. Adequate nutrition from a favourable root environment would maintain the plant in a healthy state with greater disease resistance. The growth of plants is so profoundly influenced by soil conditions that it can safely be assumed that these also exert a powerful effect on infection by virus diseases. The nutrition of the host plant may affect reaction to infection, susceptibility to infection and in the field, chances of infection, by creating conditions favourable for the activity of vectors.

i. Organic carbon and organic matter

Data on the organic carbon content of the soil from the diseased and healthy regions presented in table II show that diseased areas are richer in organic carbon.

Significantly higher contents of organic carbon and organic matter are noticed in diseased areas in respect of sandy soils of both Quilon and Ernakulam Districts and laterite soils of Quilon District, indicating a possible contributing influence of organic carbon in the incidence of the disease.

Since severe infection has been observed in water logged areas and in gardens in such localities where banana crop is

grown continuously over a period of years, it would appear that the possibility of injurious substances being produced from organic matter and their accumulation in the soil under the poorly drained conditions, may also be a predisposing factor in the incidence of the disease.

ii. Nitrogen

The role of nitrogen in luxuriant vegetative growth is well recognised. The cells become more succulent and pliable and the tissues become more susceptible to attack by organisms causing diseases. Many investigators have reported that excessive nitrogen is a decisive factor in favouring the incidence of many fungus and virus diseases of plants. Jansson (1929), Spencer (1935) and Bawden and Kassanis (1948) have made observations that susceptibility to virus diseases increased in the presence of more nitrogen. The findings of Jansen (1921) showed that increasing nitrogen increased both aphid population and susceptibility of potato plants to infection by leaf roll viruses. The field observations recorded by Wardlaw (1935) on the incidence of "Bunchy Top" disease also clearly reveal the role of high nitrogen in the incidence of this disease.

The data presented in table IV show that the nitrogen contents of the soils taken from infected areas are high in comparison to healthy areas, although the difference is not significant.

iii. Carbon-nitrogen ratio

The results obtained (Table V) reveal that the soil samples from sites of diseased plants have higher carbon-nitrogen ratio compared to sites of healthy plants. However the higher value is

significant only in respect of sandy soils of Ernakulam District at 0" to 12" depth. The mean value for carbon-nitrogen ratio for all the districts taken together was also higher in diseased areas with respect to sandy soil.

iv. Phosphorus

With the possible exception of nitrogen no other element has been found to be so critical for plant growth in the field as phosphorus. Phosphorus, being a major part of the nucleus of cells, becomes an essential element for the multiplication of viruses in host cells and may increase susceptibility to viruses and other disease agents.

Table VII gives the data for available phosphoric acid in the soils. There is a higher content of available phosphoric acid in soils from diseased areas.

This is also true of the values for total phosphoric acid presented in Table VI in respect of sandy soils of Ernakulam District. With regard to laterite soils, however, the reverse is the case.

v. Potash

From the data presented in table VIII it might be seen that the total potash content is higher in soils from sites of healthy plants in sandy and laterite soils of Quilon District. However a higher potash content is noticed in diseased areas of Ernakulam District at 0" to 12" depth. There is a higher concentration of total and available potash in the healthy areas of sandy and laterite soils of Cannanore District. The available potash contents (Table IX) is higher in healthy areas of both soil types studied.

It has been reported by many investigators that potassium is responsible for increasing resistance of certain crops to specific diseases. It is not known definitely whether potassium enables the plants to withstand attacks of organisms or whether organisms become established more easily in potassium deficient plants.

Potassium promotes the development of thicker outer walls in the epidermal cells and firm tissues which are less subject to collapse. More plant diseases have been retarded by the use of potash fertilisers than any other substances.

Haley and Reid (1943), Tisdale and Dick (1942), Hoffer (1949) and Patel and Nair (1936) have reported the role of potassium in reducing the incidency of diseases caused by fungi.

Janssen (1929) reported that deficiency of potash favoured aphid reproduction and spread of virus diseases. The findings of Broadbent (1952) showed that applications of muriate of potash decreased the aphid population. According to Spencer (1935) potassium decreased susceptibility to virus diseases at levels that increased growth. Bawden and Kassanis (1948) found that potash had little effect on resistance to tobacco mosaic virus. Bryce (1921) has stated that "Bunchy Top" disease in Borneo Islands was definitely ascribed to deficiency of potash in the soil and application of potash manures greatly reduced the incidence of the disease.

The finding of Brun (1954) confirmed the conclusion that blue disease of banana is due to an unbalanced potassium-magnesium ratio. Mention has been made in the annual report of Cameroons' Development Corporation (1957) that crown disease and little leaf disease of

oil palms were noticed when potassium was alone applied but this was counter balanced by the addition of magnesium (R.A.M. 1958).

Nair (1961) reported that manuring of rubber severely affected by dieback, with high dosage of potash along with nitrogen suppressed the disease and increased the yield of rubber.

vi. Calcium

Calcium is an essential element in plant tissues and a deficiency of this ion soon disrupts the mechanism of utilisation of all other nutrient ions. A large part of the calcium in most plants is present in leaves. In contrast to phosphorus and potash, older leaves have more calcium than younger leaves, as much of the calcium is permanently fixed in the cell walls as Calcium-pectic components of the middle lamella.

The data presented in Tables X and XI show that the soils from sites of healthy plants in both laterite and sandy areas showed a higher content of total calcium and exchangeable calcium. However the difference is not significant in laterite soils of Ernakulam District and sandy soils of both Ernakulam and Quilon Districts at 0" to 12" depth. The mean values of total calcium and exchangeable calcium for all the districts taken together are higher in healthy areas.

The results obtained in the present study is in conformity with the results reported by Pandalai et al (1938) in respect of root (wilt) disease of coconuts. They reported that the total calcium and exchangeable calcium were lower in diseased areas compared to healthy areas.

vii. Magnesium

The present study revealed (Table XII and XIII) that soils from the sites of healthy plants are higher in total and exchangeable magnesium compared to diseased areas. The surface soils of healthy areas are found to contain significantly higher content of total magnesium. With regard to exchangeable magnesium, significant higher values are seen in laterite soils of Ernakulam District at 0" to 12" depth and sandy soils of both Districts at 12" to 36". The mean values for exchangeable magnesium for all the Districts taken together were also significantly higher in healthy areas at 12" to 36" depth.

Hale (1947) attributed chlorosis and bronzing of oil palms in certain localities of West Africa to the combined effect of potassium and magnesium. The tapering disease of coconuts has been attributed by Cooke (1950) to a possibly localised magnesium deficiency. Pandalai et al (1958) have reported that magnesium content of the soil tends to show that total or exchangeable magnesium has little bearing on the diseased conditions of coconut palms although a major symptom of the root diseased trees is the chlorosis of the leaves. They found that total and exchangeable magnesium content of laterite soils from healthy areas were greater, the position being reverse in the case of sandy soils.

Mariakulandai and John Durairaj (1958) have reported higher magnesium content associated with healthy conditions of trees based on their study of orange decline. Brun and Champion (1954) have reported that blue disease of bananas in French Guinea

is associated with magnesium deficiency and demonstrated the effectiveness of magnesium in any form, but chiefly as dolomite. They have also indicated the importance of combining magnesium with potassium fertilisers.

Nutrient content of leaves

Leaf samples collected from the healthy and diseased plants were analysed for nitrogen, phosphoric acid, potash, calcium and magnesium. The results are presented in tables XIV to XIX.

i. Nitrogen

Comparative leaf analysis (table XIV) indicated that the diseased leaves contained more nitrogen in both soil types. The diseased leaf samples from sandy area and laterite area contained 2.4 to 9 percent and 3.6 to 6.7 percent more nitrogen than the leaves from healthy plants of the respective areas. The higher content of nitrogen in the diseased samples is statistically significant in all cases except for the sandy soils of Ernakulam District. The results are similar to the findings of Verghese (1961) who has reported greater amount of nitrogen, to the extent of 5 to 13 percent, uniformly in all soil types of Kerala State subjected to the incidence of the root wilt disease of coconut.

ii. Phosphoric acid

The data presented in table XV show higher concentration of phosphoric acid in the diseased leaf samples collected from sandy and laterite soils. The difference in phosphoric acid content between diseased and healthy samples is significant.

The diseased leaf samples showed 5.6 to 16.1 percent more phosphoric acid than the healthy samples.

Verghese (1961) reported higher content of phosphoric acid in the diseased leaf samples in relation to the root (wilt) disease of coconuts and the increase reported was 0 to 13 percent over the $P_2O_5$ content in the healthy samples.

iii. Potash

The present study revealed (table XVI) that there is a higher concentration of potash in the diseased leaf samples as compared to healthy samples from sandy and laterite soils of both Quilon and Ernakulam Districts and the higher values are statistically significant. The percentage increase ranges from 26 to 35 percent in samples from sandy soils and from 9 to 21 percent in laterite soils.

Similar studies by Verghese (1961) on root (wilt) disease of coconut showed higher values for potash from 7 to 48 percent in diseased leaf samples. Mariakulandai and John Durairaj (1958) reported higher content of potassium in diseased samples, which increased in increasing order of deterioration, in the case of orange decline.

iv. Lime

Lime content of healthy leaf samples was found to be significantly higher than in the diseased samples in sandy and laterite areas (table XVII). The increase in healthy samples ranges from 18 to 20 percent in sandy soils and from 9 to 17 percent in laterite soils.

v. Magnesium

The data presented in table XVIII show a higher content of magnesium in healthy leaf samples as compared to diseased samples, and the difference is significant. The increase in magnesia content ranges from 1.1 to 13 percent in sandy soils and 6 to 13 percent in laterite soils.

Verghese et al (1961) reported that the values of calcium and magnesium were not consistent in the case of diseased and healthy leaf samples of coconut. Mariakulandai and John Durairaj (1958) found that lime and magnesium content of leaves perceptibily decreased with the increase in the deterioration of orange trees.

The phenomena of accumulation of nutrients in the leaf samples of diseased plants may be due to inadequate translocation or due to impaired physiological functioning. Increased respiration early in infection and alteration of the permeability of cytoplasm resulting in slow diffusion of soluble substances have been reported as a result of virus infection. Increased enzyme activity has also been reported in many cases. Bawden (1935) stated that the necrotic symptoms produced by many viruses have profound effect on the metabolism of their host cells.

vi. Calcium plus Magnesium/Potassium ratio

From table XIX it can be seen that there is significant reduction in the calcium plus magnesium/potassium ratio of diseased leaf samples compared to that of healthy leaf samples. Similar results were also recorded by Mariakulandai and

John Durairaj (1958) in respect of orange decline.

Summarising the results of soil and leaf analysis, the following picture emerges. In the case of nitrogen, the soils of diseased areas as well as the diseased leaf samples contain a greater proportion of this constituent than in healthy areas and healthy leaves. In the case of phosphoric acid, the same general situation holds, with a higher content of $P_2O_5$ both in the soils of diseased areas as well as in the diseased leaf samples. With regard to potash, the soils of healthy areas contain more of this constituent than in diseased areas, and there is considerable accumulation in the diseased leaf samples.

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

These data point to several interesting possibilities. It is to be appreciated that the total contents of nitrogen, phosphoric acid and potash in the soils studied are by no means at a level to be considered high in relation to the fertility status. These low total levels are incapable of contributing any injury due to "excess", and to attribute any relation between the quantities of these elements in the soils studied and the incidence of the disease, will be unwarranted. However, it is very clear that with the incidence of the disease, the translocation of nitrogen, phosphoric acid and potash from the leaves is severly affected, possibly due

to the physiological disturbance occurring as a result of the virus infection. It is also interesting to note that potassium accumulation occurs in the diseased leaves to a much greater extent than nitrogen and phosphoric acid, indicating that this element plays an important role, either before, during or after the incidence of the disease.

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

Experimental Observations

The aphids for the transmission of the virus disease were released in leaf sheath 59 days after planting the banana suckers. The growth characters of the plants such as height, number of leaves and length and width of leaves were measured at weekly intervals. The growth measurements for 16 weeks are presented in table XXVI and XXVI(a). It shows progressive increase in growth characters in all treatments till the symptoms of disease were first noticed.

The data presented in tables XX and XXI reveal the growth condition of plants at the time of release of aphids for transmission of the virus. It is seen from (table XX) that there is no significant difference in the height of plants in treatments B,E and D. Similarly treatments E,D and C showed no significant difference. Treatment B receiving N.P.K. alone showed significant difference in height over treatments C and A.

Table XXI gives the data regarding the average number of leaves as a growth character at the time of releasing the aphids. These data reveal that there is no significant difference in the number of leaves between treatments E,C and D but they are significantly different from treatments B and A.

Thus taking the height of plants and number of leaves produced as growth characters, it can be seen that there was more or less uniform growth in treatments B,C,D and E at the time of release of the aphids and compared to B,C,D and E the growth in treatment A was poor.

Time taken for the appearance of symptoms

The data presented in Table XXII show the time taken for the appearance of symptoms. It can be seen from this table that treatment B recorded early symptoms ie. 30 days after release of aphids. Compared to treatments B and C, there is slight delayed appearance of symptoms in treatment A (ie. control plants). But treatments E and D showed much more delayed appearance of symptoms over to other 3 treatments. Statistically, there is significant difference in the delay in appearance of symptoms in treatment E over treatment A, B and C and is approaching significance over treatment D. Difference between treatment D, A, C and B is not however significant.

The results of work done at the Agricultural College, Vellayani on the time taken for the appearance of symptoms showed a period of 35 to 45 days (Progress report of scheme of research on "Bunchy Top" disease of bananas in Kerala State, 1956-57). The result of the present study is also in agreement with this.

The plants under treatment D and E were as vigorous as the plants under treatment A and C, taking height of plants and number of leaves as growth characters (Tables XX and XXI). Treatments D and E were supplied with magnesium. There is delay in the appearance of symptoms in both these treatments. Treatment E gives significant delay over treatment A, C and B and is approaching significance over D. Thus magnesium alone or in combination with calcium appears to have induced delay in the appearance of symptoms. (In two cases of the replications under E, the symptoms actually appeared 76 and 77 days after the release of aphids).

Symptoms

The data presented in table XXIII give the growth measurement of plants at the time of appearance of symptoms and at the final observation. The first symptom noticed was the development of chlorotic streaks and dots on the leaf petiole, leaf blade and midrib. Premature unfurling of heart leaf, upright position of leaves, curling of leaf margins, splitting of leaf blades, and brittle nature of leaves were the other symptoms noticed. The subsequent leaves produced were reduced in size, both in length and width. The rate of growth was also retarded. The petioles or the leaf stalks of succeeding leaves failed to emerge and the cluster of leaves gave a rosette appearance. The average growth measurements at the final observation showed reduction in growth and leaf size.

Uptake of calcium

Table XXIV gives the data regarding the uptake of calcium by the plants under the different treatments A, B, C, D and E. Treatments E and C receiving calcium plus magnesium, and calcium alone showed increased uptake of calcium as compared to treatment B, D and A and the difference in uptake is significant. The difference between treatments E and C is also significant. However there is no significant difference between B and D; D and A.

Uptake of magnesium

The present study revealed (table XXV) that the uptake of magnesium in treatments D and E is significantly higher than in treatments C, B and A. But the difference in uptake of magnesium between E and D is not significant.

The uptake of magnesium in treatment E is less compared to treatment D and this may be due to the high level of calcium in treatment E. According to Russel (1950) a high level of calcium depresses the uptake of potassium and magnesium (calcium-magnesium antagonism).

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

The soil and leaf analytical data reported earlier, show that the soils of healthy areas contain much higher quantities of calcium and magnesium than the diseased areas and that the healthy leaves contain more of these two constituents than diseased leaves. This fact along with the correlation observed between the calcium-magnesium treatments and the delay in the appearance of the symptoms would indicate that these two elements are vital in any attempt to control or regulate the incidence of the "Bunchy Top" disease. A possibility is indicated of a proper proportion of calcium and magnesium in the soil being able to create conditions

of resistance in the plant, and perhaps a sufficiently long period of resistance, rendering the virus ineffective up to the time of emergence of the bunch. If this can be achieved, it would be an important step towards the solution of this problem.

## SUMMARY AND CONCLUSIONS

Banana plays a very decisive role in the economy of the country. This is more so in the case of Kerala which commands the largest acreage under this crop. Such an economic crop is threatened with annihilation by the deadly disease "Bunchy Top" and the modest estimate of the annual loss is calculated to be about six crores of rupees.

An attempt has been made in the present investigation to find out how far the chemical characteristics of the soil act as a predisposing factor in the incidence of the disease. A survey of the disease in Kerala State revealed that the disease was more severe in water logged areas and localities where banana cultivation was carried on continuously for long number of years. During the survey, representative areas were selected for soil and plant material study. Soil samples were collected from the base of healthy and infected plants, representing the soil types of the region, and analysed for nitrogen, phosphoric acid, potash, calcium and magnesium. Soil reaction and organic carbon were also determined. Leaf samples collected from healthy as well as diseased plants were analysed for nitrogen, phosphoric acid, potash, calcium and magnesium.

In addition to the study of soils and plant materials referred to, an experiment was conducted for the elucidation of the influence of calcium and magnesium singly, and in combination, on the incidence of the disease.

Disease free suckers were planted in the pots and after the

suckers had established, the insect vector previously fed on diseased plants was given free access to the plants in the pots for the transmission of the virus.

Morphological observations like height of plants, number of leaves and length and width of leaves were made periodically and correlated with the time of exhibition of characteristic disease symptoms.

Leaf samples were collected from the plants and analysed for the uptake of calcium and magnesium in order to find out whether there is any characteristic variation in the uptake of these nutrients.

The analysis of soils in general showed that the soils of infected regions are more acidic, higher in organic matter, higher in nitrogen and available phosphoric acid, but lower in total potash, and calcium, and very low in magnesium.

The leaf analysis of healthy and diseased plants revealed a comparatively high amount of nitrogen, phosphoric acid and appreciably high content of potash in the infected leaves.

The plant experiments have revealed that the application of lime in combination with N.P.K. has little effect on the incidence of the disease as measured by the delay in infection, while magnesium alone or in combination with calcium exerts an appreciable influence on the incidence of the disease by delaying the appearance of symptoms.

Conclusions

1. Higher acidity of the soil may be a factor favouring the

incidence of the disease.

2. Organic matter and nitrogen content of the soils from sites of diseased plants are higher.

3. Total phosphoric acid is higher in the healthy areas of laterite soils, but lower in sandy soils.

4. Available phosphoric acid contents of soils of diseased areas are appreciably higher than those of healthy areas.

5. There is an appreciably higher concentration of available and total potassium in healthy areas as compared to diseased areas.

6. The total and exchangeable calcium content of soils in healthy areas are higher.

7. Healthy areas contain higher amounts of total magnesium. This is significant in the case of surface soils of all the types studied.

8. Exchangeable magnesium is found to be appreciably higher in healthy areas.

9. There is a higher concentration of nitrogen, phosphoric acid and potash in diseased leaf samples.

10. Healthy leaf samples on the other hand have a higher content of calcium and magnesium.

11. The calcium plus magnesium/potassium ratio is lower in diseased leaf samples compared to healthy leaf samples.

12. Calcium alone does not appear to have any influence on disease resistance or delayed appearance of symptoms.

13. Magnesium alone or in combination with calcium has remarkable effect in delaying the appearance of disease symptoms

and gives a greater capacity to the plants to resist infection. Compared to N.P.K. alone, the calcium magnesium combination has delayed infection by a significant period of 23 days. In two of the replications, infection was delayed by 46 and 47 days.

The increased uptake of calcium and magnesium by the resistant plants support the above view. Further work in this line is necessary to confirm these findings and to determine the correct dose and proportion of calcium to magnesium to effect a delay in the onset or even complete arrest of the disease. The special role of potassium has also to be further investigated.

# REFERENCES

REFERENCES


ALLINGTON, W.B. and LAIRD, E.F., (1954) The infection of Nicotiana glutenosa with tobacco mosaic virus as affected by potassium nutrition. Phytopathology., 44 : 277-299.

ASANA, R.D., (1959) Decline of Citrus. Proc. Seminar on diseases of Hort. plants., 55-61.

Ann. Rept. of the Cameroons Development Corporation+(1957) R.A.M. 37 : 636, 1958.

Association of Official Agricultural Chemists 1950.

BAIN, F.M., (1934) Bronze leaf wilt of coconut palms. Proc. Agric. Soc., Trinidad and Tobago., 35 : 507-21.

----------., (1937)+ Bronze leaf wilt of coconut palms. Publ. Dept. Agric. Govt. Printing office, Trinidad.

BAWDEN, F.C., (1953)+ Nature. 123 : 168.

----------., KASSANIS, B., and ROBERTS, F.M.+ (1948). Ann. Appl. Biol., 35 : 250.

----------., ----------., (1949) Some effects of host nutrition on the susceptibility of plants to infection by certain viruses., Phytopathology., 37 : 46-57.

----------., (1956) Plant viruses and diseases P. 332. Chronica Botanica Co. U.S.A.

BHATT, S.S., (1945) The 'die back' disease of citrus trees Indian Farming., 6 : 250-53.

BRIERLEY, P. and STUART, N.W.,+ (1946) Phytopathology., 36 : 297.

BROADBENT, L., and MARTINI, C., (1959) Spread of plant viruses. Advances in virus Research. 6 : 93-135

----------+ (1954) Ann. Appl. Biol., 41 : 174.

BRUN, J.,* (1954) Phytopathologie courr chercr off. Rect. Sci. Outre. Mer. 8 : 159-186.

--------, and CHAMPION, J.,* (1955) Le"Bleu" du Bananier Guinéenne rancaire. R...M. 34 : 656.

BRYCE, T., (1921) The "Bunchy Top" plantain disease Dept. Agric. Ceylon Leaflet No. 18 : 2.

CAMPBELL, J.G.C., * (1926) Banana disease. Report by the Govt. Mycologist. Ann. Rept. Fiji Dept. of Agric. for the year 1926. 3-4.

CAPOOR, S.P., (1959). "Bunchy Top" disease of banana. Proc. Seminar on Hort. plants., 163-172.

CHEEMA, G.S., BHATT, B.S. and NAIK, K.C., (1954). Commercial fruits of India p. 442. Macmillan and Co. Ltd. London.

CHOUDHURY, S., (1954) Deficiency disease of citrus in Assam F.A.O. Plant. Prot. Bull. 2: 151-153.

COOK, F.C., (1950). The tapering disease of coconuts. Ceylon Coconut Quart., 1(1): 17-21.

DARNELL SMITH, G.P.,* (1924) "Bunchy Top" disease in bananas Queensland Agric. J., 21 : 169-179.

EVANS, H.J. and TROXLER, R.V., * (1953) Relation of calcium nutrition to the incidence of blossom end rot in tomatoes. Proc. Amer. Soc. Hort. Sci., 61 : 346-56.

FAHMY, T., * (1924). Banana disease caused by a species of Heterodera. Bull. No. 30. Ministry of Agric. Egypt.

GADD, C.H.,*(1926) "Bunchy Top" disease of plantain. Trop. Agriculturist., 86 : (1) 320.

GAMON, N., J.R. et al * (1953) Physical, spectrographic and chemical analysis of some virgin Florida soils. Florida Agri. Exp. Sta. Tech. Bull. 524.

GARDNER, H. ., and GARDNER,R.V., (1953) use of lime in British Agriculture.Farmer and Stock Breeder publication.

GARDNER, W.H., * (1930) Magnesium and calcium requirements of tobacco crop. J. Agric. Res. 40 : 145-163.

GODDARD, C.J., * (1925) "Bunchy Top" in bananas. Queensland Agric. J., 24 : 424-429.

GOVINDA IYER, T.A., and IYENGAR, T.R., (1956) A study of the decline of citrus in Wynad. South Indian Hort., 4(3) : 70-81.

HALE, J.B., * (1947) J. Agric. Sci. 37 : 236.

HALEY, D.E., and REID, J.J., * (1943). Soil Sci., 55 : 79-86.

HILTON, G.P., * (1925) Ann. Rept. Bot. Botanist to Govt. of Bengal for the year 1923-24.

HEWITT, E.J., (1950) Large scale sand culture method for the study of trace element nutrition of plant. Trace elements in Plant Physiology 3 : 13-18.

HOPPER, G.N., and KRANTZ, B.A., * (1949) "Hunger signs of Crops" 69-84. American Soc. Agro. and National Fertiliser Association, Washington.

INNES, R.F. (1949) The manganese content of leaf and inflorescence tissue in relation to the unknown disease of coconut palm in Jamaica. J. Jamaica Agric. Soc., 52 : 88-91.

JACKSON, M.L. (1958) Soil And Chemical Analysis. Constable and Co. Ltd., London.

JANSSEN, J.J., * (1929) Tijdschr plantenziekten., 35 : 119.

KAMAT, M.B., and PATEL, M.K., (1951) Notes on two important plant diseases in Bombay State. Plant Prot. Bull., 3 : 16

KNOWLES, C.H. and JEPSON, F.P., * (1912) The bananas in Fiji. Fiji Exp. Sta. Bull. No. 4.

MAGEE, C.J., (1927) Investigation on the "Bunchy Top" disease of bananas. Council of Sci. and Indust. Res. Australia Bulletin 30 : 63.

----------, (1940) Transmission studies on the banana "Bunchy Top" virus. J. Aust. Inst. Agric. Sci., 6 : 109-110.

MaGAS, C.J., (1953) Presidential address before Royal Society of New South Wales Proc. Roy. Soc. N.S.W., 87 : 3-18.

MARIAMUTHU, A. and JOHN DORAIRAJ, D., (1958) Some chemical aspects of Mandarin orange decline in Wynad. South Indian Hort., 6 : 23-31.

MURUDASAJAN, D., (1949) Deficiencies of minor elements responsible for diseases of crop plants in this province (Madras). Madras Agric. J., 34 : 488-493.

MARTYN, E.B., (1948) Heart end bud rot or the unknown disease of coconut. J. Jamaica Agric. Soc., 52 : 88-91.

MENON, K.P.V., (1946-54) Ann. Rept. of the Central Coconut Research Station, Kayamkulam.

----------, SANKARASUBRAMONEY, H., and PANDALAI, K.M. (1950) Investigations on soil conditions in relation to health and disease of coconut palm. Indian Coconut J., 3 : 81-87; 99-105.

----------, NAIR, U.A., and PANDALAI, K.M., (1952) Influence of water logged soil condition on some fungi parasitic on the roots of coconut palm. Indian Coconut J., 5 : 71-79.

----------, and PANDALAI, K.M., (1960). The coconut palm - A Monograph I.C.C.C. p. 384

----------, (1961). Diseases of undetermined causes with special reference to root (wilt) disease of south India. Paper read at first meeting of I.C.C. Nov-Dec. 1961.

MILLER, E.C., (1938). Plant physiology. McGraw Hill Book Co., New York.

MUKHERJEE, J.N., (1949) Trace element deficiencies in citrus. Sci. and Cult., 15 : 235-237.

NAIK, K.C., (1949) South Indian Fruits and their culture. P. Varadachari & Co., Madras.

NAIR, C.K.N., (1961) Nutritional and fertiliser experiments on young and old rubber. Agric. Res. J. Kerala 1(1) : 79-94.

MANDI, H.K.,* (1941). Rept. Dept. Agric. Assam (1939-40)., 89-130.

NARASIMHA RAO, ., (1948). Note on Mandarin orange decline. Madras Agric. J. 35 : 7.

NICHTIGALL, G.T.,* (1942). Nitrate and carbohydrate reserves in relation to nitrogen metabolism of pineapple. Bot. Gaz., 103 : 403-56.

----------., (1943). Physiological - chemical functions of potassium in crop growth. Soil Sci., 55 : 73.

PADDICK, G. .,* (1940). Sci. Rept. Agric. Res. Inst. New Delhi (1938-39).

PANSE, V.G. and SUKHATME, P.V. (1957). Statistical method for agricultural workers. I.C.A.R.

PANDALAI, K.M., and MENON, K.P.V., (1957). On the use of potash as fertilizer with its effect on yield, quality and disease resistance in coconut palms. Indian Coconut J., 10 : 19-25.

----------., SANKARASUBRAMONIAN, H. and MENON, K.P.V., (1958). Studies on soil condition in relation to root and leaf disease of coconut palms in Travancore-Cochin. Indian Coconut J., 11 : 49-66 and 87-102.

----------, (1959). Mechanical composition of coconut soils in healthy and diseased areas. Indian Coconut J., 12 : 101-113.

----------., (1959). Studies on soil conditions in relation to root and leaf diseases of coconut palm in Travancore-Cochin. Indian Coconut J., 12 : 87-100.

PARR, F., (1932). The effect of drought on coconuts at Puttalam. Trop. Agriculturists., 78 : 11-14.

PATEL, J.S., and RAIN, .P.B., (1936). Natural and anduced resistance to shoot rot on coconut. Proc. Indian Acad. Sci. 3B: 432-37.

PIPER, C.S., (1950). Soil And Plant Analysis. Inter Science Publishers, New York.

PRITCHETT, G.M.,* (1926). Mosaic disease of sugar cane. Sugar Centre and Planters News. 12 : 791-792.

Progress Report of the scheme of Research on "Bunchy Top" disease of Bananas in Kerala State. 1956-57.

Progress Report of the scheme of Research on "Bunchy Top" disease of Bananas in Kerala State. 1957-58.

RAMAKRISHNAN, T.S., (1954). Deterioration of mandarin oranges in Madras. Indian J. Hort. 11(2) : 6-11.

----------., and DAMODARAN, S., (1956). Observation on the wilt disease of the banana. Proc. Indian Acad. Sci., 43(B): 213-222.

RAMANATHA MENON, M., (1959) Bunchy top of Bananas. Proc. Seminar on diseases of Hort. Plants. I.C.A.R. 15 -15 .

RISHBETH, J., (1954). Personal communication to Garret. Quoted by CHOMA, B.L., Proc. Seminar on diseases of Hort. plants. I.C.A.R. (1959). 134-139.

ROSS, A.F., CHUCKA, J.A., and HAWKINS, A.,* (1947). Maine Agric. Expt. Station Bull. 447.

ROY, H.S., and SHARMA, C.,* (1952). Indian J. Hort., 9 : 39.

RUSSEL, E.J., (1956). Soil conditions and plant growth. p. 437 Longmans Green and Co. London.

RUMLEY, G.E., and THOMAS, W.D., (1951). The inactivation of the carnation mosaic virus. Phytopathology. 41 : 301-303.

SANKARASUBRAMONEY, N, PANDALAI, K.M., and MENON, K.P.V. (1954). Investigations on soil conditions in relation to diseases of coconut palms in Travancore-Cochin. Indian Coconut J. 8 : 5-25.

----------., (1955). Studies on soil conditions in relation to root and leaf disease of coconut palms in Travancore-Cochin. Indian Coconut J., 9 : 90-100.

SHEPHERD, R.J., and FOUND, G.S., (1960). Influence of boron nutrition of Nicotiana tabaccum on the multiplication of tobacco mosaic virus. Phytopathology, 50 : 26-30.

SHEPPARD, E.P.S.,* (1927). Bot. Division Ann. Report. Mauritius Dept. of Agric. for the year 1926: 15-18.

SIMMONDS, J.H.,+ (1933). Squirter disease of banana. Queensland Agric. J., 39 : 8.

SINGH, M.P., and SINGH, R.P. (1953). Studies on die back of citrus. Indian J. Hort. 10(1) : 1-8.

SOROKIN, H., and SOMMER, A.L.,+ (1940). Effect of calcium deficiency upon the roots of pisum sativa. Amer. J. Bot., 27 : 308-318.

SPENCER, E.L.,+ (1935). Phytopathology. 25 : 178.

STEINBERG, R.A.,+ (1951). Mineral nutrition of plants. University of Wisconsin Press, Madison, Wisconsin.

TISDALE, H.B., and DICK, J.B.,+ (1942). J. Amer. Soc. Agron. 34 : 405-426.

VANVAMBEKE, A., (1957). Contribution to the study of symptoms of yellowing in oil palms. Bull. Agric. Congo Belge., 48 : 889-904.

VERGHESE, M.K., (1934). Disease of coconut palm. Dept. Agric. and Fisheries, Travancore.

VERGHESE, E.J., (1961). Statement of work done on the chemical aspects of the root wilt disease of Cocoonuts in Travancore-Cochin. Proc. F.A.O. Coconut Research Workers Conference.

WALL, M.E., (1940). The role of potassium in plants. Soil Sci. 49 : 393-408.

WILSON, J.R., (1956). Effect of nutrition and light intensity on symptoms of leaf roll virus infection in the potato plant. Ann. Appl. Biol., 13 : 273-287.

WARDLAW, C.W., (1935). Diseases of banana and manila hemp plants. p. 615. Macmillan & Co. Ltd. London.

+ Originals not seen.

# A P P E N D I C E S

## APPENDIX I

(ANALYSIS OF VARIANCE)

PLANT HEIGHT ON THE DAY OF RELEASE OF APHIDS

| Source | S.S. | D.F. | Variance | F | Inference |
|---|---|---|---|---|---|
| Total | 5042.97 | 29 | - | - | - |
| Blocks | 2281.37 | 5 | 456.27 | 6.63 | |
| Treatments | 1385.47 | 4 | 346.37 | 5.03 | F(4,20) 2.87 Significant |
| Error | 1376.13 | 20 | 68.81 | | |

## APPENDIX II

(ANALYSIS OF VARIANCE)

NO. OF LEAVES ON THE DAY OF RELEASE OF APHIDS

| Source | S.S. | D.F. | Variance | F | Inference |
|---|---|---|---|---|---|
| Total | 24.97 | 29 | - | - | |
| Blocks | 3.37 | 5 | 0.674 | 1.1 | |
| Treatments | 10.17 | 4 | 2.543 | 4.4 | F(4,20) 2.87 Significant |
| Error | 11.43 | 20 | 0.5715 | - | |

## APPENDIX III

(ANALYSIS OF VARIANCE)

TIME TABLE FOR APPEARANCE OF SYMPTOMS AFTER RELEASE OF APHIDS

| Source | S.S. | D.F. | Variance | F. | Inference |
|---|---|---|---|---|---|
| Total | 5936.0 | 29 | - | - | - |
| Blocks | 1350.2 | 5 | 270.04 | 2.38 | |
| Treatments | 2313.5 | 4 | 578.4 | 5.09 | F(4,20) 2.87 Significant |
| Error | 2272.3 | 20 | 113.62 | | |

## APPENDIX IV

(ANALYSIS OF VARIANCE)

UPTAKE OF CALCIUM BY PLANTS

| Source | S.S. | D.F. | Variance | F. | Inference |
|---|---|---|---|---|---|
| Total | 1.33426 | 29 | - | - | - |
| Blocks | 0.20279 | 5 | 0.040558 | 4.06 | |
| Treatments | 0.93181 | 4 | 0.23295 | 23.00 | F(4,20) 2.87 Significant |
| Error | 0.19966 | 20 | 0.009983 | | |

## APPENDIX V

## (ANALYSIS OF VARIANCE)

## UPTAKE OF MAGNESIUM BY PLANTS

| Source | S.S. | D.F. | Variance | F. | Inference |
|---|---|---|---|---|---|
| Total | 0.5456 | 29 | | | |
| Blocks | 0.0789 | 5 | 0.01578 | 2.67 | |
| Treatments | 0.3488 | 4 | 0.0872 | 14.7 | 1(4,20) 2.87 Significant |
| Error | 0.1179 | 20 | 0.0059 | - | - |

## APPENDIX VI

## TIME TAKEN FOR APPEARANCE OF SYMPTOMS AFTER RELEASE OF APHIDS

| | TREATMENTS | | | | |
|---|---|---|---|---|---|
| Replications | A | B | C | D | E |
| I | 27 | 42 | 28 | 78 | 76 |
| II | 37 | 27 | 37 | 42 | 77 |
| III | 37 | 28 | 27 | 38 | 42 |
| IV | 35 | 27 | 31 | 34 | 44 |
| V | 36 | 28 | 31 | 27 | 37 |
| VI | 34 | 28 | 27 | 37 | 42 |
| Mean | 34.33 | 30.00 | 30.16 | 42.67 | 53 |

## APPENDIX VII

NO. OF LEAVES ON THE DAY OF RELEASE OF APHIDS

| | TREATMENTS | | | | |
|---|---|---|---|---|---|
| REPLICATIONS | A | B | C | D | E |
| I | 7 | 8 | 9 | 9 | 8 |
| II | 8 | 7 | 9 | 9 | 10 |
| III | 6 | 8 | 8 | 8 | 9 |
| IV | 8 | 7 | 8 | 7 | 9 |
| V | 8 | 7 | 9 | 8 | 9 |
| VI | 7 | 7 | 8 | 9 | 7 |
| Mean | 7.33 | 7.33 | 8.5 | 8.33 | 8.67 |

## APPENDIX VIII

PLANT HEIGHT ON THE DAY OF RELEASE OF APHIDS

| | TREATMENTS | | | | |
|---|---|---|---|---|---|
| Replications | A | B | C | D | E |
| I | 77 | 115 | 95 | 102 | 118 |
| II | 78 | 96 | 77 | 94 | 86 |
| III | 68 | 107 | 78 | 84 | 89 |
| IV | 90 | 100 | 86 | 88 | 89 |
| V | 77 | 76 | 87 | 78 | 94 |
| VI | 70 | 81 | 65 | 76 | 70 |
| Mean | 76.7 | 95.8 | 81.3 | 91.0 | 95.8 |

APPENDIX IX

CALCIUM UPTAKE BY PLANT.

| | TREATMENTS | | | | |
|---|---|---|---|---|---|
| Replications | A | B | C | D | E |
| I | 1.064 | 1.400 | 1.736 | 1.232 | 1.792 |
| II | 1.232 | 1.176 | 1.400 | 1.064 | 1.624 |
| III | 1.120 | 1.344 | 1.512 | 1.456 | 1.568 |
| IV | 1.120 | 1.176 | 1.344 | 1.288 | 1.624 |
| V | 1.064 | 1.120 | 1.288 | 1.064 | 1.512 |
| VI | 1.008 | 1.232 | 1.344 | 1.176 | 1.456 |
| Mean | 1.101 | 1.241 | 1.437 | 1.213 | 1.596 |

APPENDIX X

MAGNESIUM UPTAKE BY PLANTS

| | TREATMENTS | | | | |
|---|---|---|---|---|---|
| Replications | A | B | C | D | E |
| I | 0.4536 | 0.3672 | 0.4392 | 0.5616 | 0.7344 |
| II | 0.3528 | 0.4032 | 0.4176 | 0.7920 | 0.5976 |
| III | 0.2736 | 0.3528 | 0.4608 | 0.6264 | 0.5184 |
| IV | 0.3816 | 0.2952 | 0.3960 | 0.7560 | 0.5472 |
| V | 0.3024 | 0.3744 | 0.3528 | 0.4176 | 0.4680 |
| VI | 0.3168 | 0.3244 | 0.3600 | 0.4680 | 0.5040 |
| Mean | 0.3468 | 0.35287 | 0.4044 | 0.60365 | 0.5616 |

# FIGURES AND PLATES


## LAYOUT-RANDOMISED BLOCK DESIGN

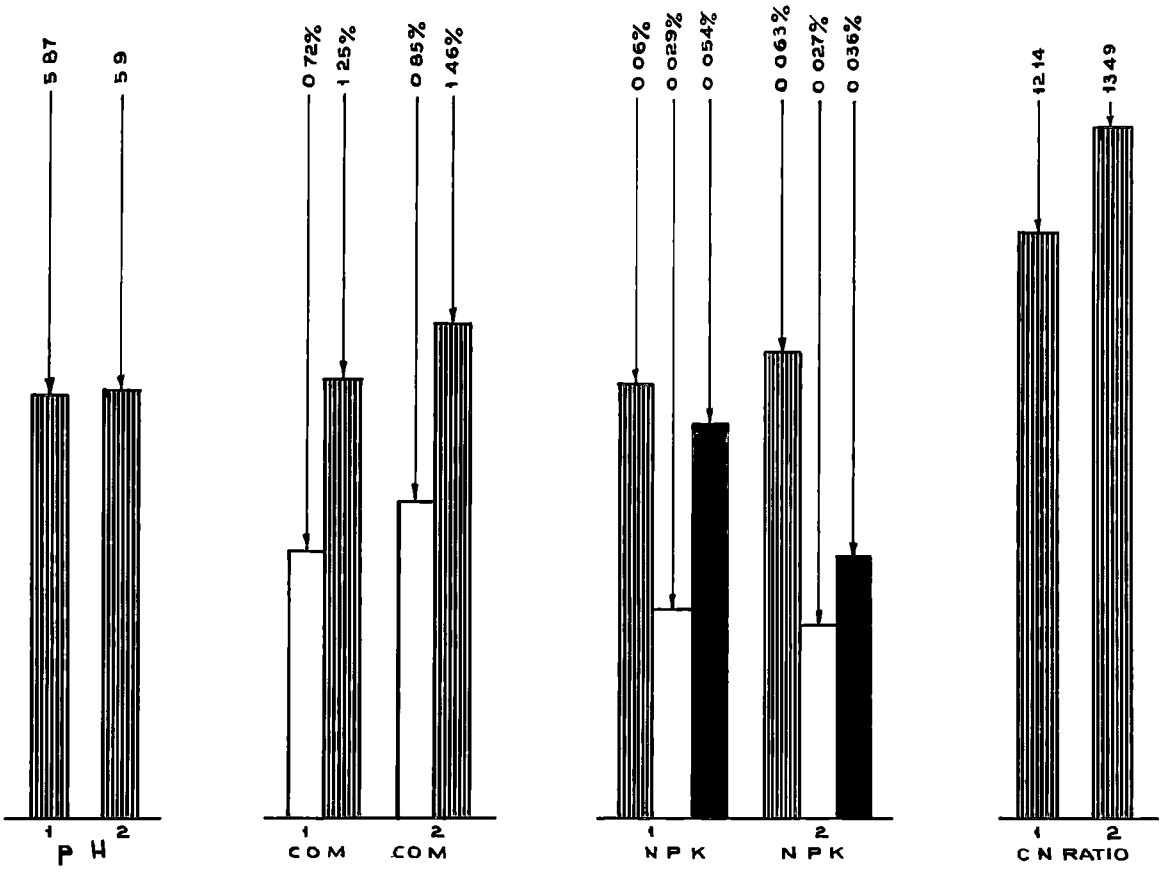
| | | | | | |
|---|---|---|---|---|---|
| R I | D | A | B | E | C |
| R II | B | C | E | A | D |
| R III | D | E | B | C | A |
| R IV | C | A | B | D | E |
| R V | A | E | D | C | B |
| R VI | E | B | C | A | D |

Scale 1 C m = 1 Metre

FIG 1

NUTRIENT STATUS OF SANDY SOILS FROM HEALTHY AND DISEASED AREAS 0' 12" DEPT

(MEAN OF ALL DISTRICTS COMBINED)




1 *Healthy area*
2 *Diseased area*

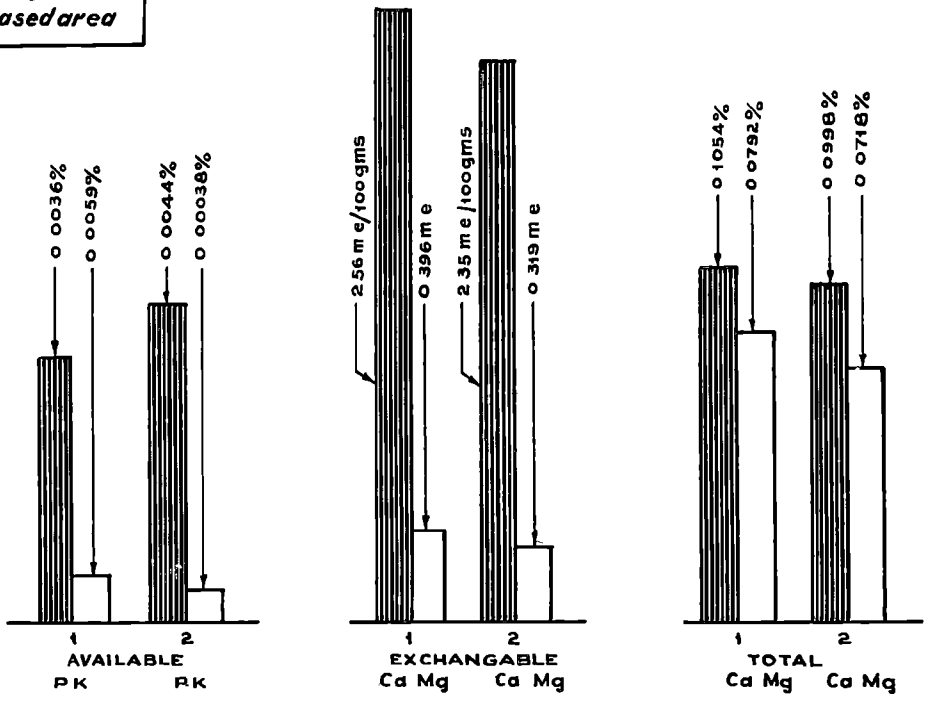
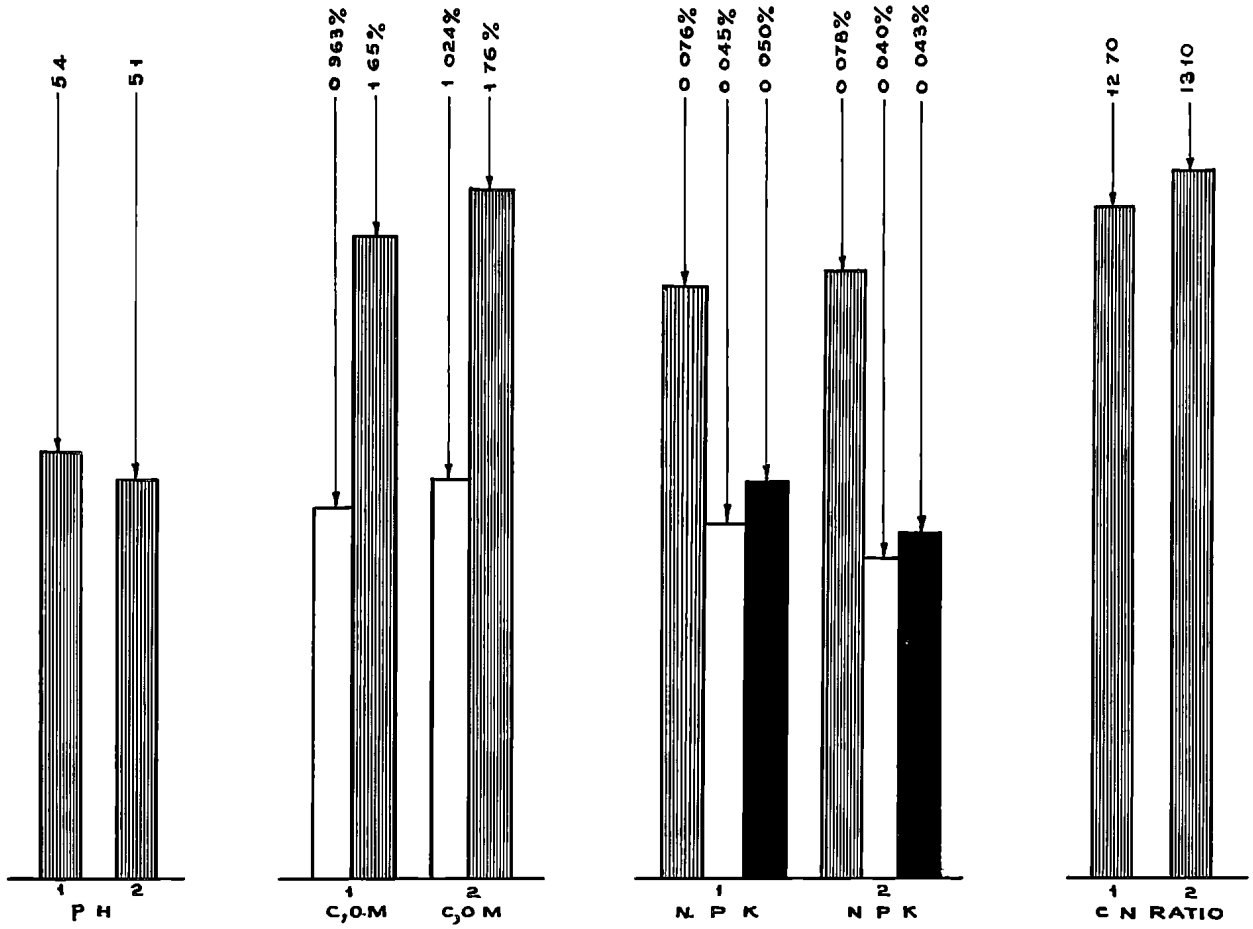



FIG 2

NUTRIENT STATUS OF LATERITE SOIL FROM HEALTHY AND DISEASED AREAS (0"-12" DEP

(MEAN OF ALL DISTRICTS COMBINED)




1 *Healthy area*
2 *Diseased area*

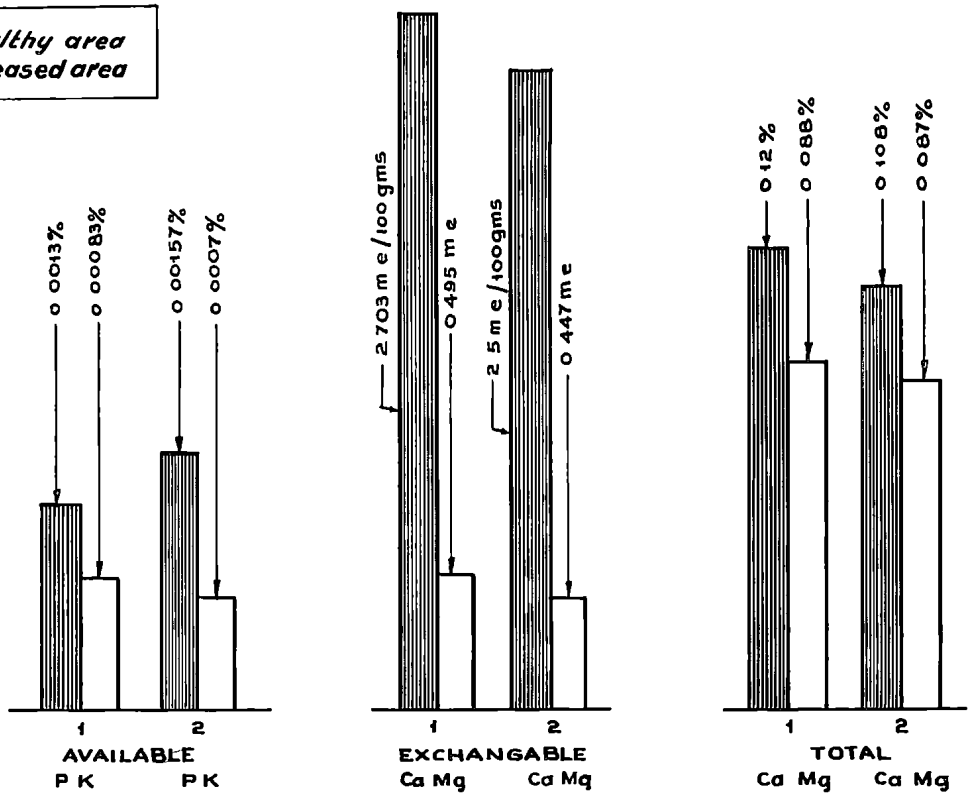
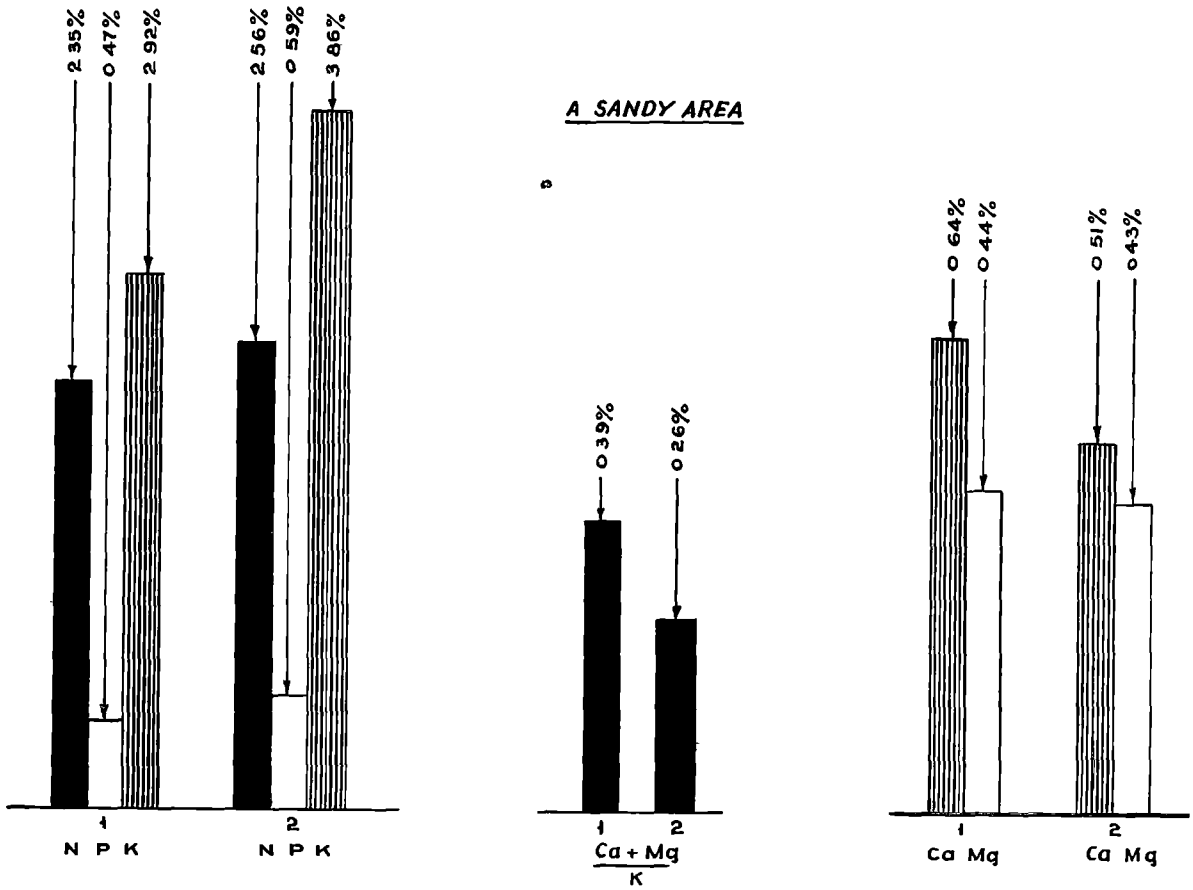



FIG 3

ANALYTICAL DATA OF HEALTHY AND DISEASED LEAF SAMPLES
(MEAN OF ALL DISTRICTS COMBINED)



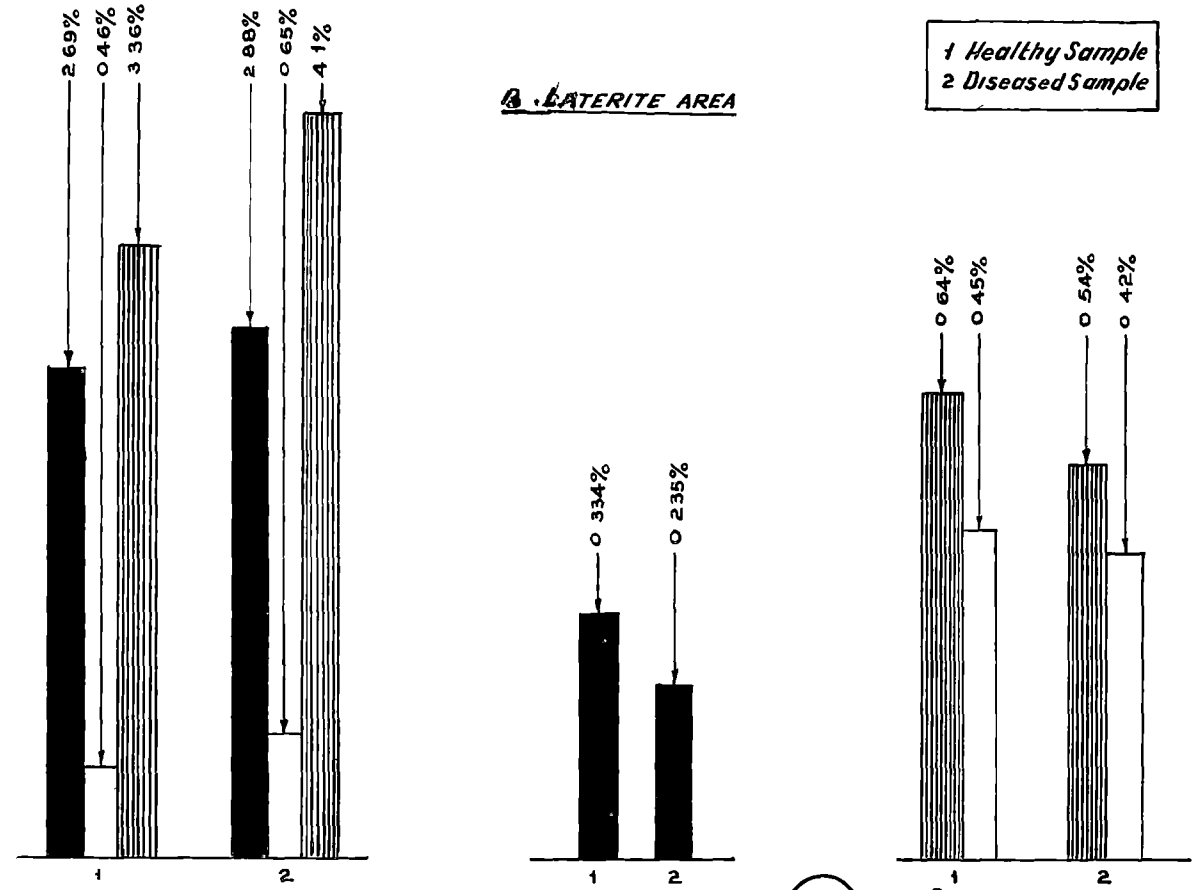




FIG 4

DAYS TAKEN FOR APPEARENCE OF SYMPTOMS

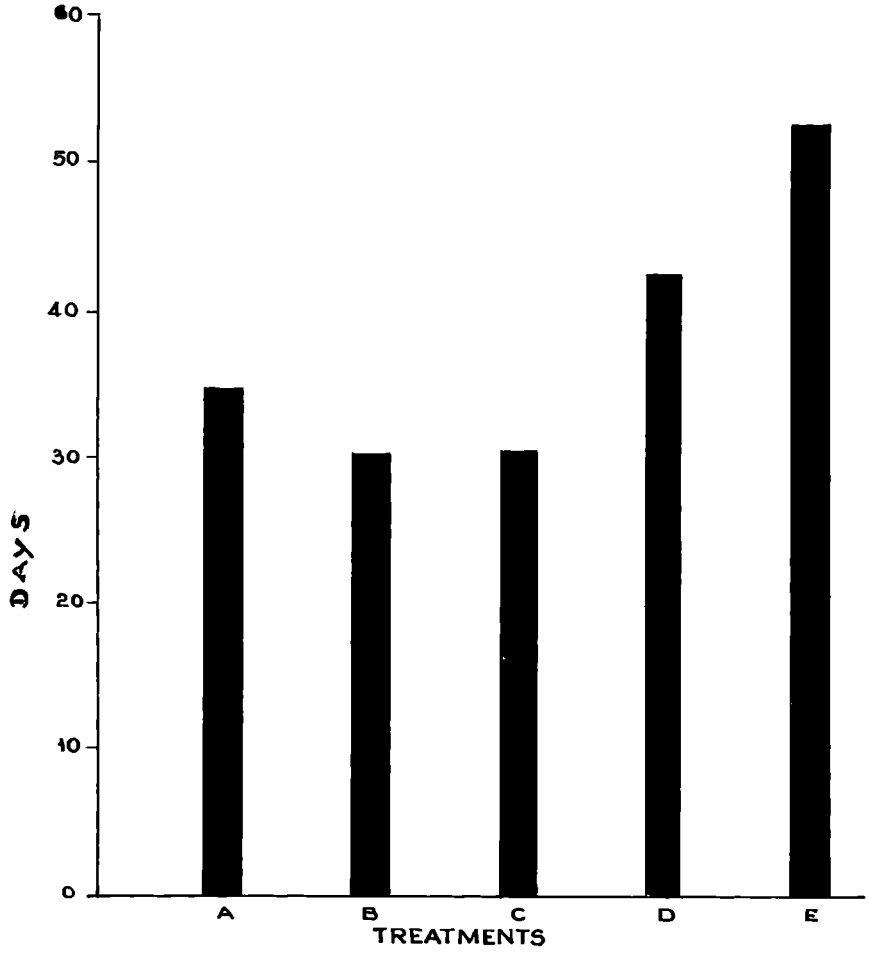



FIG 5

PERCENTAGE UPTAKE OF CALCIUM AND MAGNESIUM BY PLANTS

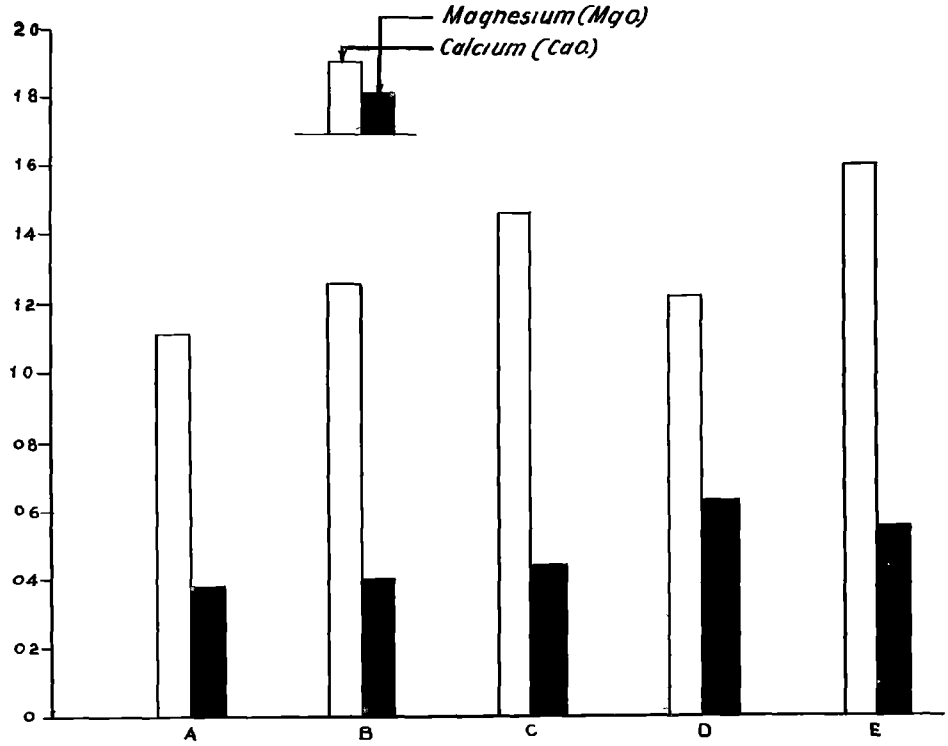



FIG 6

GROWTH CURVES OF PLANTS UNDER DIFFERENT TREATMENTS

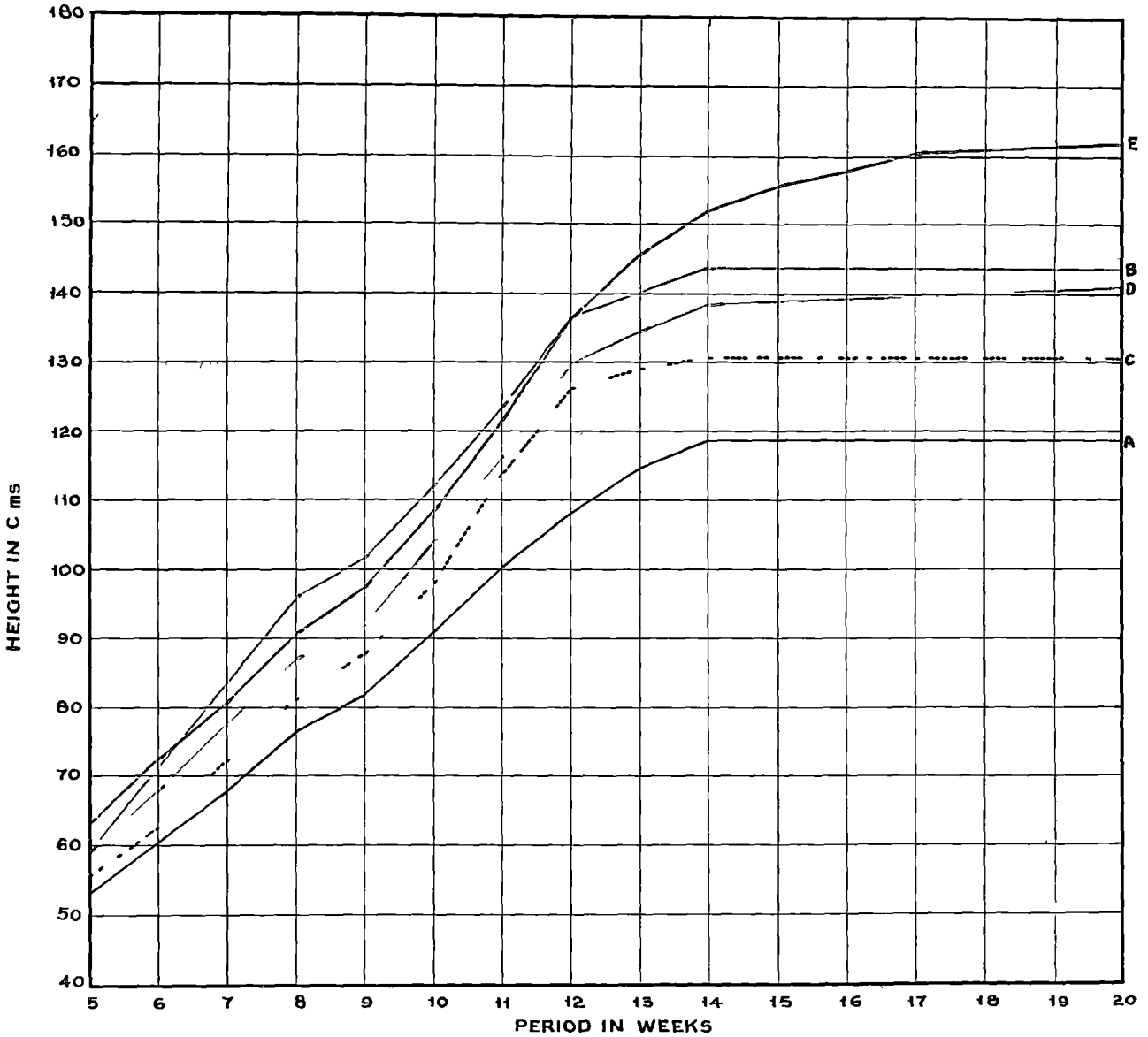
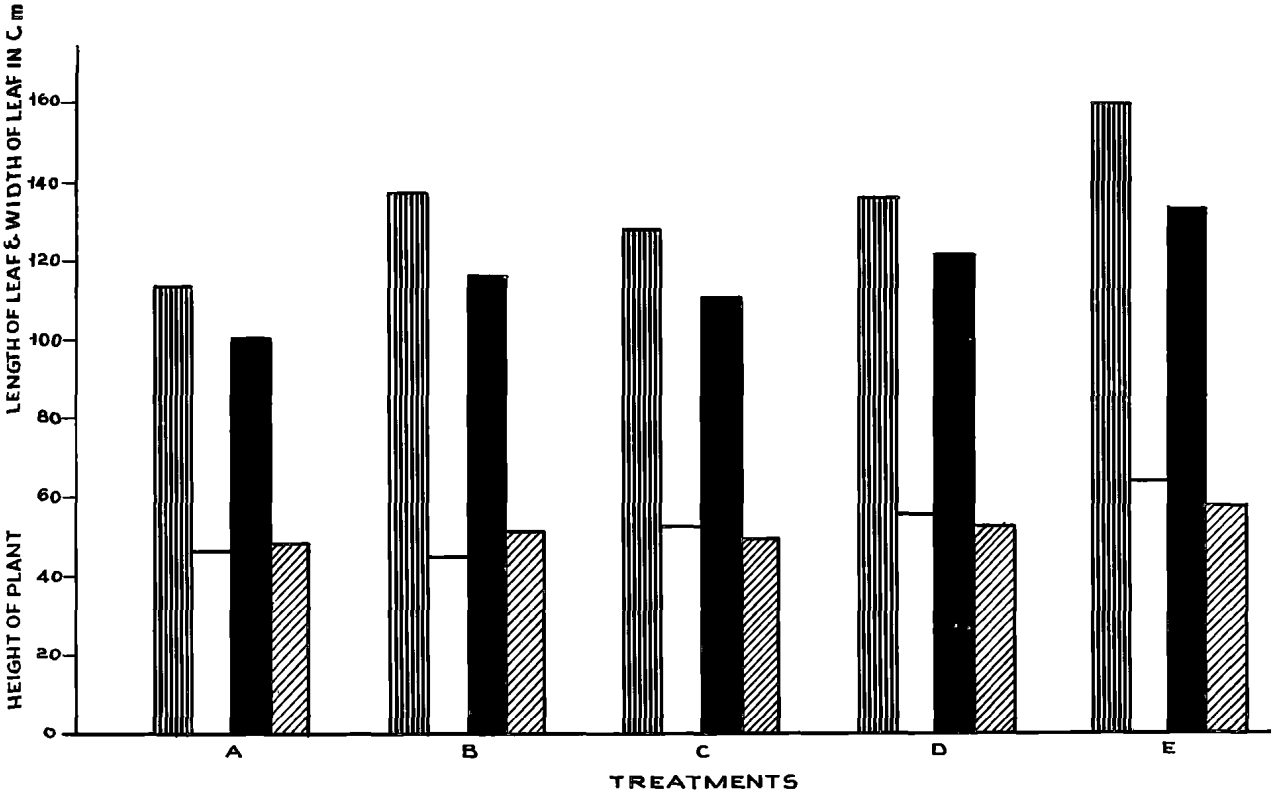
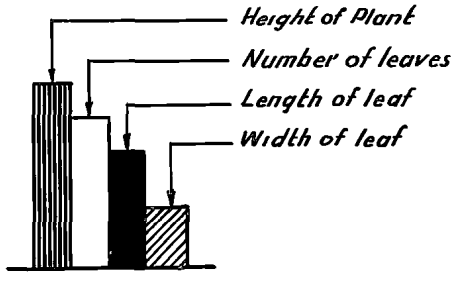



FIG 7

AVERAGE GROWTH MEASUREMENTS AT THE TIME OF APPEARENCE OF SYMPTOMS




AVERAGE GROWTH MEASUREMENTS AT THE FINAL OBSERVATION

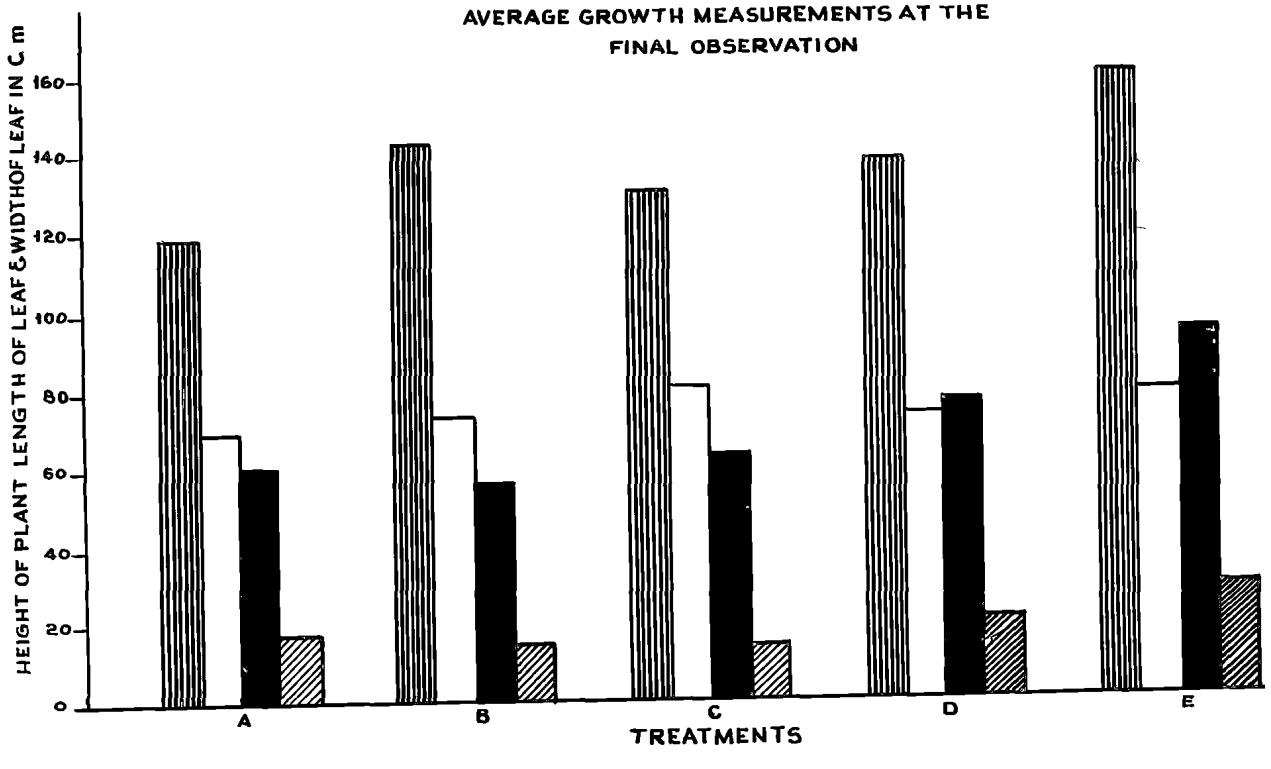


PLATE 1
HEALTHY BANANA PLANTS - GENERAL VIEW
(Before transmission of virus)

PLATE 2
HEALTHY BANANA PLANTS
(Under different treatments)

PLATE 4
DISEASED BANANA PLANTS
(Under different treatments)

PLATE 5
DISEASED BANANA PLANT
(Treatment A)

PLATE 7
DISEASED BANANA PLANT
(Treatment C)

PLATE 8
DISEASED BANANA PLANT
(Treatment D)

PLATE 9
DISEASED BANANA PLANT
(Treatment E)

PLATE 10

A HEALTHY BANANA PLANT UNDER TREATMENT E
(Symptoms appeared 77 days after
transmission of virus)