MAJOR NUTRIENT DISORDERS OF BANANA (var. NENDRAN) IN VAIKOM BLOCK

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"MAJOR NUTRIENT DISORDERS OF BANANA (var. NENDRAN) IN VAIKOM BLOCK"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

%	-	Per cent
@	-	at the rate of
B	-	Boron
BCR	-	Benefit / Cost Ratio
Ca	-	Calcium
CD	-	Critical Difference
CEC	-	Cation Exchange Capacity
Cl	-	Chlorine
cm	-	centimeter
Cu	-	Copper
$dS\ m^{-1}$	-	deci Siemens per meter
EC	-	Electrical Conductivity
et al	-	And Co-workers
Fe	-	Iron
Fig.	-	Figure
g	-	gram
ha^{-1}	-	Per hectare
IFA	-	International Fertiliser Association
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	kilogram
$kg\ ha^{-1}$	-	kilogram per hectare
l	-	litre

m	-	meter
MAP	-	Months After Planting
Mg	-	Magnesium
mg g^{-1}	-	milli gram per gram
mg kg^{-1}	-	milli gram per kilogram
ml	-	milli litre
mm	-	milli meter
mmol g^{-1}	-	milli moles per gram
Mn	-	Manganese
Mo	-	Molybdenum
MT/ha	-	Metric tonnes per hectare
N	-	Nitrogen
P	-	Phosphorus
pH	-	Soil reaction
ppm	-	parts per million
S	-	Sulphur
SE	-	Standard Error
TC	-	Tissue Culture
t ha^{-1}	-	tonnes per hectare
TSS	-	Total Soluble Solids
viz.	-	namely
Zn	-	Zinc

Introduction

1. INTRODUCTION

Banana is a major fruit crop of the country as well as the state, known as "Poor man's fruit" owing to its rich content of carbohydrates, vitamins and minerals and affordable price to the consumers. In Kerala, crop is grown in large area but being an exhaustive crop and since sufficient replenishment of nutrients is not done, the productivity goes low in intensively cultivated areas. Hence deficiency symptoms are quite common. But in most cases these deficiencies are not properly diagnosed and misinterpreted for other reasons. Among the horticultural crops, contribution of banana to Agricultural Gross Domestic Product (AGDP) is the highest (Singh, 2007). Hence achieving and maintaining high productivity in banana is vital to meet the nutritional security of the people. Against this background, this study is done to document the major nutrient disorders of banana and validate the same with respect to soil and leaf nutrient status assumes importance. The study has been focused in Vaikom block of Kottayam district of Kerala where banana cultivation is taken up in large scale. Better nutrient and disease management along with good horticultural practices are the means available for increasing yield.

Nendran is a popular variety of banana extensively cultivated in Vaikom region which is relished as fruit as well as vegetable. Vaikom block is situated in the northwest of Kottayam district in the state of Kerala and the six panchayaths coming under the block are Chembu, Maravanthuruth, Udayanapuram, T. V. Puram, Vechoor and Thalayazham. It is bound by the shores of the Lake Vembanad, and crossed by various distributaries of rivers. *Murinjapuzha* and *Ithipuzha* are two rivers flowing in close proximity to Chembu and Maravanthuruth panchayaths respectively and influence fertility status of soil to an extent.

Banana having a root system spread in the top 60 cm soil, is a heavy feeder of nutrients. Low fertility is one of the major constraints for optimum crop growth and yield. But even when the soil is fertile, there is low productivity. The continuous and imbalanced use of fertilizers adversely affect sustainability of agricultural production.

Nutrient disorders have assumed importance in the Vaikom block due to the following major reasons:-

(i) Reduced use of organic manures
(ii) Imbalanced application of NPK fertilizers
(iii) Non-replacement of exhausted secondary and micronutrients in soil
(iv) Extension of banana cultivation to paddy fields
(v) Cultivation in poorly fertilized lands for years

The unscientific fertilizer application often results in induced micronutrient deficiencies. The lack of awareness about micronutrient disorders, their impact in yield reduction and methods of correction adds up to the situation. Micronutrients are essential for proper growth and efficiency along with other inputs like NPK fertilizers and water to ensure higher productivity. Farmers very often depend on banana crop for a better yield and income. But they are not aware of the status of nutrient imbalances in the soil and nutrient disorders existing in the crop field.

According to Shukla *et al.* (2014) micronutrient deficiencies are severe in India and on an average 43.0, 12.1, 5.4, 5.6 and 18.3 per cent soils are deficient in Zn, Fe, Cu, Mn and B, respectively. Presently, the trend of micronutrient deficiency is changing from single nutrient deficiency to multi-micro nutrient deficiencies due to depletion in soil fertility and this becomes an emerging issue in agriculture, relating to crop as well as human health.

According to recent reports, the deficiency of micronutrients is increasing at an alarming rate. This holds true for Kerala as the fertility status reveals that 59 per cent of the soils are deficient in boron, 15 per cent in copper and 12 per cent in zinc. There is severe reduction in yield and quality of the crops produced in imbalanced soil conditions (Nair *et al.*, 2013). The acidic leaching environment of Kerala soils is not conducive for retention of boron adsorbed by low activity clays, which resulted in widespread deficiency of boron.

To diagnose deficiencies and excess of nutrients using index leaf tissue analysis is appealing. The nutrient content of plant provides reliable information on their nutritional status at the date of sampling, thus giving a guide not only to any supplementary needs of the crop but also to the probable requirements of future crop.

In plant analysis, quantitative analysis of total nutrient content in the plant tissue is carried out. It is based on the fact that amount of nutrients in diagnostic plant parts indicates the soils' ability to supply that nutrient and is directly related to the available nutrient status in the soil. Deficiency or excess of nutrients can cause considerable damage to the plant. For this, the plant index tissue is analyzed and the level of nutrients is found out and compared to its availability in soil. The reason for this difference is expected to be soil acidity, physiography, flooding during monsoon, salt water intrusion during summer, salinity etc. Since it is a heavy nutrient feeder than any other commercially cultivated crop, nutritional deficiencies and disorders often affect the crop growth and yield.

Keeping all these points in view, the present study was undertaken in Vaikom block with the following objectives

- To evaluate the variations in fertility status of banana growing soils, to assess the nutrient status of index tissue of banana with special reference to banana (var. Nendran)
- To catalogue the nutrient disorders of banana in the region
- To document the nutrient management practices in farmers' field

Review of Literature

2. REVIEW OF LITERATURE

Widespread nutrient deficiencies has been found in many countries all over world and their deficiency scenario had changed very much in Indian soils and crops during last 4 decades from 1968 to 2008 (Singh, 2009). The total micronutrient content (zinc, iron, manganese, copper) is adequate in most of the Indian soils, but the micronutrient concentrations in soil solution is insufficient to meet the demand of growing crops (Singh, 1991).

The essential micronutrients are metals (except B and Cl) and its uptake is affected by soil (Lindsay, 1991) , plant (Barber, 1995; Marschner, 1995) microbial and environmental factors (Romheld and Marschner, 1986; Clark and Zeto, 2000).

Micronutrients exist in very small amounts in both soils and plants, but their role is frequently as important as the primary and secondary nutrients. Essential micronutrients include six elements *viz.* zinc, boron, manganese, iron, copper, and molybdenum (Stevenson, 1986). Micronutrients have assumed increasing importance in crop production under present day exploitative agriculture. Intensive cultivation of high yielding varieties and use of high analysis fertilizers and limited use of manures along with restricted recycling of plant residues are some important factors which had led to accelerate exhaustion of soil micronutrients and this in turn limits the crop production. The availability of the essential micronutrients to plants is often poorly related to their total quantity in the soil.

2.1. BANANA

Banana is an important commercial fruit crop in tropical and sub - tropical regions of the world. In India, it is grown in different states under different climatic conditions (Butani *et al.*, 2012). The edible banana is believed to have originated in hot tropical regions of South-East Asia (Spiden, 1926; Suar, 1952). It is in great demand in fresh as well as processed form all over the world and gained commercial popularity in the international fruit trade (Thomas *et al.*,1968).

Among the major producers in the world, India alone accounted for 27.43 per cent of fruits (26.2 million tonnes) followed by Philippines, producing 9.01 million tonnes and China, Brazil and Ecuador, altogether with production ranging from 7.19 to 8.21 million tonnes (FAO Stat, 2011).

Generally, banana is a heavy consumer of nutrients and requires large quantities of nutrients for its growth, development and yield (Hazarika and Ansari, 2010) and so it is considered as an exhaustive or nutrient mining crop.

Among the banana varieties grown in India, the French Plantain cultivar 'Nendran' belonging to the 'Plantain' group (*Musa* AAB) is the most popular variety among growers and consumers, particularly in Tamil Nadu and Kerala for domestic and export markets (Mulagund *et al.*, 2015). The cultivators of Agasthiamalai ranges call this variety as "King of Banana". The shelf life of Nendran banana is high as compared to other cultivars. So, the nendran fruits are exported to European and Arabian countries (Das, 2010).

Venugopal (2008) reported that Nendran banana is mostly cultivated in homesteads and in well-drained rice fields by small and marginal farmers of Kerala. It is the most popular commercial cultivar which is loved much by cultivators and have excellent fruit quality, multiple uses and sustained income. Nendran fruit is used for culinary purposes as well as for processing. Bunch has average of 5-6 hands weighing about 12-15 kg in the popular types. Bananas provide a good source of nutrients for both human and animal consumption. On account of these properties, it is a staple food for millions of people all around the world.

Das (2010) reported that fruit pulp of nendran contains water soluble vitamins like thiamin (Vitamin B_1), riboflavin (Vitamin B_2), niacin (Vitamin B_3), ascorbic acid (Vitamin C), various amino acids, proteins and nutrients in substantial amount which support the daily diet needed for human beings.

2.2. INDEX LEAF TISSUE

Plant analysis, in conjunction with soil testing, becomes highly useful tool not only in diagnosing the nutritional status but also aids in management of decisions for improving the crop nutrition (Rasheed, 2005)

Lopez and Espinosa (2000) reported that it is the third fully opened leaf in banana identified as the index leaf for tissue analysis. According to him the laminar structure of third leaf is sampled by removing a strip of tissue 10 cm wide, on both sides of the central vein, and discarding everything but the tissue that extents from the central vein to the center of the lamina.

Arunachalam *et al.* (1976) showed that adequacy level of nutrients in banana leaf ranged from 3.8 to 3.43, 0.46 to 0.54, 3.36 to 3.76, 2.3 to 2.4 and 0.25 to 0.28 % of nitrogen, phosphorus, potassium, calcium and magnesium respectively.

2.3 SOIL NUTRIENT PARAMETERS

2.3.1. pH

Suresh (1985) obtained a significant correlation between available boron and pH in forest soils of Kerala. Pakrashi and Haldar (1992) observed a significant positive correlation between boron content and pH in some soils of north Bengal. Rajagopal *et al.*(1997) found a significant negative correlation between available iron and pH in Alleppey and Palaghat districts of Kerala

Rajagopal *et al.* (1977) reported that the divalent manganese ions in the soil solution became predominant with increased acidity of the soil and that there was very significant negative correlation between exchangeable manganese and pH in Allepey soils. Pisharody (1965) on studying the manganese and clay fraction in Kerala soils reported that they are highly significant and positively correlated.

Varghese (1971) reported a negative correlation between available zinc and pH in the alluvial soils of Kerala. Valsaji (1972) observed a significant negative correlation between available zinc and pH in surface and subsurface soils of Kerala. Nair (1970) noticed a significant negative correlation between available zinc and clay content in Onattukara soils and a non-significant positive correlation in *Kuttanad* soils.

Nair (1970) observed a significant negative correlation between pH and available copper in *Kuttanad* and *Onattukara* soils. Varghese (1971) noticed a non - significant negative correlation between pH and available copper in the alluvial soils of Kerala.

2.3.2. EC

During monsoon season, rain water and fresh water from the rivers enters the field and attains EC ranging from 6 - 8 dS m^{-1} in pokkali soils (Varghese *et al,* 1970). According to the studies conducted by Mini (2015) the electric conductivity of *Onattukkara* soils ranged from 0.01 to 0.15 dS m^{-1}.

2.3.3 Organic carbon

Sharma and Shukla (1972) found that the available boron significantly increased with increasing organic carbon content of the acid soils of western Rajastan. Suresh (1985) observed a positive correlation between available boron and organic matter in the sandy soils of Kerala. Sheeja *et al.* (1993) noticed a positive correlation between available boron and organic carbon in the cassava growing soils of Tamil Nadu.

Rajagopal *et al.* (1997) reported a positive correlation between organic carbon and available iron content in Trivandrum and Thrissur districts of Kerala. Mariam (1989) observed that available iron was positively and significantly correlated with organic carbon in the lateritic and coastal sandy alluvial soils of Kerala.

Gopalaswamy and Soundararajan (1962) reported that various forms of manganese were significantly correlated with organic carbon. A close relationship between available manganese and organic carbon was observed by Pisharody (1965) also. Rajagopal *et al.*

(1977) noticed a significant positive correlation between organic carbon and manganese in Alleppey district of Kerala.

Mariam (1989) observed a significant positive correlation between available manganese and organic carbon in the Kari soils of Kerala. Similar observations were also made by Kannan and Mathan (1994) and Srivastava (1994). Available (DTPA extractable) manganese ranges from 0.6 to 164 mg kg^{-1} soil in Indian soils with an average of 25 mg kg^{-1}(Gupta, 2005).

Nair (1970) reported a positive but non-significant correlation between organic carbon and zinc content. Varghese (1971) obtained a significant correlation between available zinc and organic matter in alluvial soils of Kerala. Mariam (1989) obtained a significant positive correlation between zinc and organic carbon in Kayal soils of Kerala.

Nair (1970) noticed a positive non-significant correlation between organic carbon and available copper. Praseedom (1970) and Varghese (1971) also obtained similar results in the Kari and alluvial soils of Kerala.

2.3.4. Primary nutrients- N, P, K

Essentiality of primary nutrients

Nitrogen is one of the primary nutrients absorbed by banana roots, preferably in nitrate form and is the chief promotor of growth and induces higher vegetative growth of the pseudostem and leaves giving them desirable healthy green colour. Optimum nirogen fertilization ensured higher content of TSS, sugars and sugar/acid ratio in banana (Murray,1960).

Phosphorus absorbed in the form of orthophosphate ($H_2PO_4^-$) produce healthy rhizome and strong root system. It also influences flower setting and general vegetative growth. It is a component of sugar-phosphates, nucleic acids, nucleotides, coenzymes, phospholipids, phytic acid and more. Deficiency occurs in older leaves and chlorosis and curling up of leaves , petioles break and younger leaves develop deep green colour. (Lopez, 2000).

Due to very high K contents in banana fruit and leaves, potassium is considered as most important plant nutrient in banana production. It catalyses important reactions such as respiration, photosynthesis, chlorophyll formation and water regulation. The role of potassium in the transport and accumulation of sugars inside the plant is particularly important since these processes allow fruit fill and thereby yield increase.

Primary nutrient status in soil

Nitrogen which is one of the primary nutrient in soil is deficient in soils of India as well as Kerala. Higher rates of nitrogen deficiency is Kerala is as a result of heavy leaching to lower horizons due to heavy rainfall in the region (Nair *et al.*, 2013). A study by Mini (2013) found that nitrogen requirement vary with the available N pool of the soil rather than organic carbon per cent of soil with respect to the soils of Kerala.

A work by Conde *et al.*(2014) showed that sufficient P application promoted rice growth and growth of the following crop soyabean was also influenced positively by P supply. The higher phosphorus content in soils induced deficiency of micronutrients in soil of Kerala (Semseer, 2015). Mini (2013) found that 62 percent of the soil samples tested were high in plant available phosphorus in *Onattukara* region. Vig and Dev (1984) reported that acid soils adsorbed more phosphorus as compared with the alkaline soils irrespective of the phosphorus concentration at equilibrium.

According to reports of Nair *et al.* (2013), potassium content in Kerala soils is very low leading to lower yield and productivity. Nair (2013) suggests that the possible reason for low potassium status in soil may be intensive leaching condition brought in by excess runoff or irrigation and the very strong acid condition and low CEC which do not permit any retention and rapid leaching loss of the element.

2.3.5. Secondary nutrients- Calcium, Magnesium and Sulphur

Essentiality of secondary nutrients

Calcium is an important secondary nutrient required for enzyme activation, cell elongation and stability. Deficiency is widely seen in banana crops and reduces fruit quality.

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Calcium deficiency is largely due to low mobility of soil calcium and competition with other nutrients such as ammonium, potassium and magnesium. Calcium deficiency symptoms indicating general dwarfing, reduced leaf length, crinkled leaves and tissue near midrib thickens. Spike leaf symptom was observed in case of severe deficiency.

Magnesium is secondary nutrient absorbed as Mg^{2+}which is required by plants for nitrogen metabolism, photosynthesis, phloem export and root growth. Magnesium deficiency is expressed by yellowish chlorosis of the central zone of leaf lamina while the margins and midrib area remain green. Deficiency results in lower yields, poor plant growth and reduced uptake of potassium and calcium (Prasad, 2007).

Sulphur is also a secondary plant nutrient essential for protein formation. Its required for the formation of chlorophyll and for the activity of ATP-sulfurase. These essential functions permit the production of healthy and productive plants which give higher yield and superior quality fruits. Sulphur deficiency in leaves is observed by chlorotic and reduced size of leaves along with yellowing of entire lamina. (IFA, 1992).

2.3.6. Available Boron

Essentiality of Boron

Boron has been known to be a constituent of plants since 1857 (Tandon, 1989). Warrington (1923) was the first to really prove the essentiality of boron. According to Truog (1940), the importance of boron is spelt as follows, plants will not make growth without boron any more than….without phosphorus or potassium which they require in considerable amounts'.

Boron is essential for plant growth, new cell division in meristematic tissue, translocation of sugar, starch, nitrogen, phosphorus, certain hormones, synthesis of amino acids and protein, regulations of carbohydrate metabolism, development of phloem. In the absence of adequate supply, middle lamella of new cell develops poorly and phloem tubes break down (Edmond *et al.*, 1997). The primary role of B in plants is to improve Ca metabolism and improved solubility and mobility of Ca and helps in absorption of nitrogen.

It also involves in lignification, growth regulatory metabolism, phenol metabolism and integrity of membranes, root elongation, DNA synthesis, pollen formation and pollination (Shukla *et al.*, 2009). Increased B application enhances root elongation in acidic and high aluminium soils (Blevins and Lukaszewski, 1998).

Boron status in soils

Mathur *et al.*(1964) noticed that the total and available boron levels were much greater in irrigated than in unirrigated soils. Panda and Koshy (1982) observed that the water soluble boron was 0.33 mg kg-1 in alluvial acid soils and found that it was nearly twice as much as in ferruginous red soils.

Suresh (1985) on assessing the boron status of the major upland soils of Trivandrum district found that the content was much higher in the forest soils (0.86mg kg^{-1}). In all the other soils it was less compared to forest soils. Jose *et al* (1985) found that hot water extractable boron ranged from 0.11 to 0.79 mg kg^{-1} in the coconut palms growing soils of the reclaimed marshy lands of Kerala.

Sheeja *et al.* (1996) while investigating the micronutrient status found that the available boron ranged between 0.04 and 0.38 mg kg^{-1} in the sweet potato growing sandy soils of Kerala. Hadwari et al (1992) on assessing the boron status found that hot water extractable boron ranged from 0.06 to 1.49 mg kg^{-1} and 0.08 and 1.71 mg kg^{-1} in the Junagadh and Rajkot districts of Gujarat.

The total boron content in Indian soils varied from 7 to 630 mg kg^{-1} of soil (Prasad *et al.*, 2014). The available (hot water soluble – HWS) boron in Indian soils ranged from 0.75 to 8.0 mg B kg^{-1} (Das, 2000; Singh, 2001). Hot water extractable boron ranged from traces to 8.2 mg kg^{-1} in Indian soils (Gupta, 2005).

Gogoi *et al* . (1993) found that the available mean boron content was 1.7 mg kg^{-1} in these soils. Kushawaha and Singh (1981) reported that the hot water soluble boron varied from trace to 0.80 mg kg^{-1} and from 0.11 to 0.88 mg kg^{-1} in surface and subsurface soils of sweet orange orchards in the Agra region in Uttarpradesh.

Sharma and Shukla (1972) found that the available boron significantly increased with increasing organic matter content of the acid soils of western Rajastan. Suresh (1985) observed a positive correlation between available boron and organic matter in the sandy soils of Kerala. Sheeja *et al* .(1993) noticed a positive correlation between available boron and organic carbon in the cassava growing soils of Tamil Nadu.

Suresh (1985) obtained a significant correlation between available boron and pH in forest soils of Kerala. Pakrashi and Haldar (1992) observed a significant positive correlation between boron content and pH in some soils of north Bengal.

2.3.7.Available Iron

Essentiality of Iron

The essentiality of iron (Fe) for plant growth was established by Gris (1843). Iron act as a constituent of various enzymes such as cytochrome oxidase, catalase and nitrogenase. It helps in the synthesis of chlorophyll, about 60 to 80 per cent of the iron content of leaves is found in the chloroplast. Iron is a key element in various redox reactions of respiration, photosynthesis and reduction of nitrates and sulphates (Wallihan *et al.,* 1958; Reddy and Reddi, 2002).

It is a component of flavoprotein like FMN (Flavin Mono Nucleotides) and FAD (Flavin Adinosine Dinucleotide). The leghaemoglobin present in the root nodules of leguminous crops contains iron as an essential constituent (Gupta and Gupta, 2005). Iron is a constituent of a large number of metabolically active compounds like cytochromes, heame and non-heame enzymes and other functional metallo proteins such as ferrodoxin and heamoglobin.

As redox-active metal, it is involved in photosynthesis, mitochondrial respiration, nitrogen assimilation, hormone biosynthesis (ethylene, gibberellic acid, and jasmonic acid), production and scavenging of reactive oxygen species, osmo protection and pathogen defense (Hansch and Mendel, 2009). It may also be associated with organic acid metabolism (citric acid, malic acid and ascorbic acid).

Iron deficiency is common in alkaline soil with typical chlorosis, the young leaves turns yellowish with veins remaining green. Iron application increased the levels of all leaf pigments, but the extent of increase in level depend on the pigment affected (Srivastava and Singh, 2003).

Iron status in soils

Rajagopal *et al* .(1997) found that iron was very much available in Kerala soils and value ranged from 1.6 to 5066mg kg^{-1}. He also reported a positive correlation between organic carbon and available iron content in Trivandrum and Thrissur districts of Kerala. Mariam (1989) observed that available iron was positively and significantly correlated with organic carbon in the lateritic and coastal sandy alluvial soils of Kerala.

Rajagopal *et al* .(1997) found a significant negative correlation between available iron and pH in Alleppey and Palaghat districts of Kerala. Adhikari (1991) observed a positive correlation between the different forms of iron and clay content in some acid soils of Bangladesh. Maji *et al.* (1993) noticed a positive and significant correlation between available iron and clay in some coastal rice soils of West Bengal.

Jose *et al.* (1985) revealed that available iron ranged from 90.40 to 196.06 mg kg^{-1} in the coconut palm soils of the reclaimed marshy lands of Kerala.

2.3.8. Available Manganese

Essentiality of Manganese

The necessity of manganese for the growth of autotrophic and heterotrophic plants was first proposed by Mchargue (1922). Manganese is necessary for chlorophyll formation for photosynthesis, respiration and for the activity of several enzymes like oxidase, peroxidase, dehydrogenase, kinase and decarboxylase. For optimal growth and development plants have to accumulate at least 30 mg Mn kg^{-1} dry weight in tissues regardless of plant species (Marschner, 1995).

Under deficient condition, the concentration of manganese in leaves is less than 15 mg kg^{-1} and in toxic condition it becomes more than 300 mg kg^{-1}. Manganese is involved in the oxygen evolving system in photosynthesis PS II (water oxidizing enzyme complex). It is essential for photolysis of water and also it is involved in nitrogen fixation. It acts as a predominant metal ion in Krebs cycle (Gupta and Gupta, 2005).

Manganese is moderately mobile in plant tissues so symptoms appear on younger leaves first, most often in those leaves just reaching their full size. Manganese availability is reduced in high pH calcareous soils but is often very high in the acid soil commonly chosen for tropical fruit production. Over liming of the soils as well as well drained, poor, coastal sandy soils can induce manganese deficiency. Manganese deficiency causes a light green mottle between the main veins. A dark green band is left bordering the main veins while the interveinal chlorotic areas become pale green or dull yellowish colour (Gupta and Gupta, 2005).

Soil application of manganese can be ineffective due to immobilization especially in heavier soils or soils which have been over limed. Two to three sprays of 0.1 per cent manganese sulphate can be recommended (Gupta and Gupta, 2005).

Manganese status in soils

According to Pisharody (1965) the total and water soluble manganese content of fourteen typical profiles of Kerala ranged from 1.8 to 14.8 mg kg^{-1}. Rajagopalan (1969) observed that the levels of water soluble and exchangeable manganese was maximum in Kari soils (82.5 mg kg^{-1}) and minimum (1.5 mg kg^{-1}) in the laterite soils of Kerala. Rajagopal *et al.* (1977) while investigating the available manganese status of Kerala soils found that it ranged between 0.2 and 220 mg kg^{-1}.

Jose *et al.* (1985) found that available manganese content varies from 1.18 to 12.40 mg kg^{-1} with mean value of 5.02 mg kg^{-1} in coconut growing soils of the reclaimed marshy lands of Kerala. Usha (1996) while investigating the acidity parameters of submerged soils of Kerala, noticed that the DTPA extractable manganese varied between 10 to 37.8 mg kg^{-1},

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17.2 to 80.6 mg kg^{-1} and 25.8 to 299 mg kg^{-1} in Vellayani, Kari and *Karappadam* soil profiles of Kerala.

Gopalaswamy and Soundararajan (1962) reported that various forms of manganese were significantly correlated with organic carbon. A close relationship between available manganese and organic carbon was observed by Pisharody (1965) also. Rajagopal *et al.* (1977) noticed a significant positive correlation between organic carbon and manganese in Alleppey district of Kerala.

Mariam (1989) observed a significant positive correlation between available manganese and organic carbon in the Kari soils of Kerala. Similar observations were also made by Kannan and Mathan (1994) . Available (DTPA extractable) manganese ranged from 0.6 to 164 mg kg^{-1} soil in Indian soils with an average of 25 mg kg^{-1}(Gupta, 2005).

Rajagopal *et al.* (1977) reported that the divalent manganese ions in the soil solution became predominant with increased acidity of the soil and that there was very significant negative correlation between exchangeable manganese and pH in Allepey soils. Pisharody (1965) on studying the manganese and clay fraction in Kerala soils reported that they are highly significant and positively correlated.

2.3.9. Available Zinc

Essentiality of Zinc

Zinc (Zn) was discovered as an essential plant nutrient by Sommer an Lipman (1926). Zinc is essential for proper growth and development of plant. Zinc is now being regarded as the third most important limiting nutrient element in crop production after nitrogen and phosphorus. Synthesis of plant hormones and balancing intake of phosphorus and potassium inside the plant cells are depending upon Zn nutrition.

Zinc is important as a component of enzymes for protein synthesis and energy production and maintains the structural integrity of bio-membranes. Zinc is required for the synthesis of carbohydrate metabolism, protein synthesis, internode elongation for stem growth and in pollen formation (Shukla *et al.*, 2009). It is also vital for the oxidation

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processes in plant cells and helps in the transformation of carbohydrates and regulates sugar in plants.

Under Zn deficient conditions, flowering and fruit development are reduced and maturity is delayed which resulted in lower yield, poor quality and sub-optimal nutrient use efficiency (Gupta, 1995). Zn^{2+} ions at low concentration (0.01 mg kg^{-1}) slightly enhance the activity of tryptophan synthesis leading to biosynthesis of auxin (Horak *et al.*, 1976).

Zinc deficiency in plants resulted in stunted growth, little leaf and fruit sizes which are attributed with IAA metabolism (Marschner, 1995). Application of zinc was found to increase the green pigments of necrotic leaf of plants (Srivastava and Singh, 2003).

Zinc status in soils

Nair (1970) observed that the available zinc ranged between 0.51 to 5.01 mg kg^{-1} in *Onattukara* soils and from 0.5 to 2.47 mg kg^{-1} in Kuttanad soils of Kerala. According to Praseedom (1970) the available zinc ranged from1.75 mg kg^{-1} to 3.85 mg kg^{-1} in alluvial soils and the availability was found to decrease with depth. Aiyer *et al.* (1975) observed that the available zinc content of the acid rice soils of Kuttanad ranged between traces and 2.2 mg kg-1. Studies conducted by Rajagopal *et al* (1977) showed that the available zinc content of Kerala soils varied from 0.32 to 10.5 mg kg^{-1} and 0.3 to 1.2 mg kg^{-1} in Allapuzha and Kottayam respectively.

Sheeja *et al.* (1996) found that the available zinc content ranged between 0.04 to 2.90 mg kg^{-1} and 0.20 to 7.08 mg kg^{-1} in the sweet potato growing sandy and lateritic soils of Kerala and in both the cases the content was found to decrease with depth.

Total Zn content in the normal soils of world ranged between 10–300 mg kg^{-1} with an average of 50 mg kg^{-1}(Mulligan *et al.*, 2001). In Indian soils total Zn ranges from a few mg kg^{-1} to about 1000 mg kg^{-1}. It ranges from 7 mg kg^{-1} in coarse textured alluvial soils (Entisols) to 284 mg kg^{-1} in fine textured vertisols (Ganjir *et al.*, 1973). Available zinc content in Indian soils ranges from 0.08 to 20.5 mg kg^{-1}.

Varghese (1971) reported a negative correlation between available zinc and pH in the alluvial soils of Kerala. Valsaji (1972) observed a significant negative correlation between available zinc and pH in surface and subsurface soils of Kerala.. Nair (1970) noticed a significant negative correlation between available zinc and clay content in *Onattukara* soils and a non-significant positive correlation in *Kuttanad* soils. Rajagopal *et al.* (1977) reported that the availability of zinc decreased in clay content in Kerala soils.

Available zinc in Indian soils ranges from 0.08 mg kg^{-1} to 20.5 mg kg^{-1} soil. Nair (1970) reported a positive but non-significant correlation between organic carbon and zinc content. Varghese (1971) obtained a significant correlation between available zinc and organic matter in alluvial soils of Kerala. Mariam (1989) obtained a significant positive correlation between zinc and *Kayal* soils of Kerala.

2.3.10. Available Copper

Essentiality of copper

Lipman and MacKinney (1931) demonstrated the necessity of copper for the vegetative growth and reproduction of higher plants. Copper is essential for photosynthesis and mitochondrial respiration, carbon and nitrogen metabolism, oxidative stress protection and cell wall synthesis. It acts as a component of phenolase, lactase, tyrosine and ascorbic acid oxidase. The chloroplast possesses a copper containing proteins as plastoquinone and plastocyanin, which are essential for electron carrier in photosynthesis (Gupta and Gupta, 2005).

Copper status in soils

Nair (1970) observed that the available copper content varied from 1.08 to 6.30 mg kg^{-1} in *Onattukara* soils and 0.8 mg kg^{-1} to 3.31 mg kg^{-1} in *Kuttanad* soils. Varghese (1971) noticed that the available copper content ranged between 0.65 mg kg^{-1} to 4.35 mg kg^{-1} in some soil types of Kerala and found that the available copper decreased with depth in alluvial soils of Kerala. Gopinath (1973) found that the available copper varied from 0.40 mg kg^{-1} to 1.80 mg kg^{-1} in the surface layers and 0.30 to 1.60 mg kg^{-1} in the subsurface layers in the acid peat (Kari) soils of Kerala.

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Sheeja *et al.* (1996) noticed that the available copper content ranged between 0.12 and 6.48 mg kg^{-1} and 0.74 and 4.06 mg kg^{-1} in the sweet potato growing sandy and alluvial soils of Kerala and it was found to decrease with depth. Nair (1970) noticed a positive non - significant correlation between organic matter and available copper. Praseedom (1970) and Varghese (1971) also obtained similar results in the Kari and alluvial soils of Kerala.

Nair (1970) observed a significant negative correlation between pH and available copper in *Kuttanad* and *Onattukara* soils. Varghese (1971) noticed a non-significant negative correlation between pH and available copper in the alluvial soils of Kerala. Sheeja *et al.* (1996) got a highly significant correlation between available copper and clay in the sweet potato growing soils of Kerala.

The available (DTPA extractable) copper content of the Indian soils ranges from traces to 32 mg kg^{-1} soil. The highest copper deficiency was observed in soils of Kerala, followed by Uttar Pradesh (Gupta, 2005).

2.4. Extent of micronutrient deficiencies in Indian soils

Singh (2009) reported that Green revolution had significantly increased the food crop production in India, but continuous cultivation of high yielding crop varieties have led to depletion of native micronutrient soil fertility and now most of the soils are showing sign of fatigue for sustaining higher crop production. Besides, this hidden hunger of micronutrients is widely noticed leading to even entire failure of crops and reduced content of micronutrients in plant parts.

Takkar *et al.* (1989) reported that along with N, P and K the wide spread deficiencies of micronutrients are frequently seen in Indian soils. 43 per cent of Indian soils are deficient in Zn. High phosphate content of soils or high fertilization with phosphate may reduce the uptake of zinc and other nutrients (Dadhich and Somani, 2007; Kizilgoz and Sakin, 2010).

Deficiency of micronutrient has become a major constraint to the productivity, stability and sustainability of crops in many Indian soils and may further deteriorate due to global warming (Kumar *et al.*, 2011).Till date, analysis of 3,00,000 soil samples indicated that the average deficiency of Zn, Fe, Mn and Cu in Indian soils are 44, 15, 6 and 8 per cent respectively (Shukla and Behera, 2012). Similarly, the analysis of 50,000 soil samples showed boron and molybdenum deficiencies of 33 and 13 per cent respectively. B deficiency is reported more in acid soils than other parts of the country due to leaching of available B and continuous depletion of total soil reserved boron.

Zinc deficiency is prevalent in the soils having high pH, low organic matter and which are calcareous, sodic, sandy and limed acidic in nature (Rattan and Sharma, 2004). Much of the zinc associated with the solid phase is not available for plant uptake (Lake *et al.*, 1984). It is estimated that 30 per cent of the world's cultivated soils are deficient in zinc (Suzuki *et al.*, 2006).

Boron has emerged as an important micronutrient in Indian agriculture, next only to zinc in the context of the spread of its deficiency (Sathya *et al.*, 2009). In India, boron deficiency was initially reported as two per cent in the year 1980 (Katyal and Vlek, 1985), which has now increased to 52 per cent (Singh, 2012). Deficiencies of B in Indian soils ranged from 2 per cent in alluvial soils (Ustipsamments) of Gujarat, to 68 per cent in red soils (Calciorthhents, Haplustalfs) in Bihar, with a mean of 33 per cent for the whole country (Singh, 1999; Singh, 2006).

Manganese deficiency is emerging very fast, particularly in wheat crops grown after rice in Haryana and Punjab due to continuous leaching of manganese from the surface layers of the coarse textured soils (Shukla *et al.*, 2012).

Now, multi-nutrient deficiencies are emerging in many states of the country. The Zn+Fe in swell-shrink soils, Zn+Mn or Zn+Fe+Mn in alluvial soils of Indo- Gangatic alluvial plains, Zn+Fe, Zn+B, Zn+Fe+B in highly calcareous soils of Bihar, Saurashtra, Zn+B in acid leached alfisols, red and lateritic soils of India are leading to stagnation or a decline in productivity (Shukla and Behera, 2011).

Shukla *et al.* (2012) confirmed that in acid soils of India, most of the soil samples indicated an adequate supply of Cu, Fe and Mn, low deficiencies of Zn (30 %) and higher deficiencies of B (46 %) and Mo (50 %).

Analysis of 20,000 plant samples for Zn, Cu, Fe and Mn indicated deficiencies of 44, 10, 6 and 4 per cent respectively, suggesting that the increasing multi-micronutrient deficiencies in soils and crops also affect animals and humans health along with crop productivity (Shukla *et al.*, 2012).

Iron deficiency is a widespread agricultural problem that decreases plant growth and crop yields. Fe deficiency is a common nutritional disorder in many crop plants, causing chlorosis, poor yields and reduced nutritional quality. Increasing available Fe levels in major staple food crops is an important strategy to reduce Fe deficiency in people (Mori, 1999).

Manganese is a nutrient found in plant tissue at concentrations ranging from 10 to 500 mg kg^{-1}or more. In most plants, it is deficient at less than 10 mg kg^{-1} and toxic when the concentration exceeds about 300 mg kg^{-1} (Sturgul, 2010).

The typical Cu content in plants ranged between 0.08–0.24 mmol g^{-1} dry weight and Cu toxicity generally occurs when the plant tissue level exceeds 0.4 mmol g^{-1} dry weight (Macnicol and Beckett, 1985).

2.5. NUTRIENT STATUS OF KERALA SOILS

Major soils of Kerala, derived from acid igneous rocks are deficient in boron (SSO, 2007). Moreover, being highly mobile in the soil (Tisdale *et al.*, 1985), leaching losses further aggravate B insufficiency in the high rainfall zones of Kerala, frequently leading to development of deficiency symptoms in crop plants.

Recent reports indicate that the deficiency of micronutrients is increasing at an alarming rate. This holds true for Kerala as the fertility status reveals that 59 per cent of the soils are deficient in boron, 15 per cent in copper and 12 per cent in zinc. There is severe reduction in yield and quality of the crops produced in imbalanced soil conditions (Nair *et al.*, 2013).

Fe and Al toxicity is very wide spread disorder in acid sulphate soils of *Kuttanad* region and often leads to declining of crop yield of 50 to 70 per cent (Thampatti *et al.*, 2005). Reports showed that the total Mn content of Kuttanad soils normally ranged between 28 to

350 mg kg^{-1}(Rajendran and Aiyer, 1981; KAU, 1994) and total Fe content ranged from 2.75 to 7.72 per cent.

Investigation on micronutrient status of cardamom- growing soils of Kerala conducted by Srinivasan *et al.* (1993) indicated that available iron ranged from 14.6 mg kg^{-1} to 65.8 mg kg^{-1}, available manganese from 1.3 mg kg^{-1} to 44.8 mg kg^{-1}, available copper from 0.66 mg kg^{-1} to 32.2 mg kg^{-1}, available zinc from 0.01 mg kg^{-1} to 2.71 mg kg^{-1}, available boron from 0.05 mg kg^{-1} to 3.7 mg kg^{-1} and available molybdenum from 0.01 to 11.1 mg kg^{-1}.

Soils of Kerala are high in iron and manganese indicating high sesqui-oxide contents. Toxic levels of these elements are often observed in wetlands and deficiency of these elements has been very rarely reported, except from coastal sands and also the neutral to alkaline soils of Palakkad district. About 31 per cent of copper deficiency is observed in Kerala soils. In case of Zinc, deficiency was observed in Palakkad region. Widespread B deficiency has been observed in most of the districts with characteristic symptoms expressed in banana and coconut (DAO, 2013).

Srinivasan *et al.* (1993) reported that 68 per cent of cardamom - growing areas of Kerala is deficient in zinc, 49 per cent deficient in boron, 28 per cent deficient in molybdenum and 9 per cent deficient in manganese.

Evaluation of Soil fertility status of Kasargod district conducted by Suresh *et al.* (2014) revealed that Kasargod soils are 78 per cent deficient in boron, 8 per cent deficient in zinc and 3 per cent deficient in copper.

2.6. NUTRIENT INTERACTIONS

In crop plants, the nutrient interactions are generally measured in terms of growth response and change in concentration of nutrients. According to Fageria (2006) upon addition of two nutrients, an increase in crop yield that is more than adding only one, the interaction is positive (synergistic). Similarly, if adding the two nutrients together produced less yield as compared to individual ones, the interactions is negative (antagonistic).When there is no change, there is no interaction. All the three interactions among essential plant nutrients have been reported. However, most interactions are complex.

A nutrient interacting simultaneously with more than one nutrients may lead to induced deficiencies, toxicities, modified growth responses, and/or modified nutrient composition. Better understanding of nutrient interactions may be useful in understanding importance of balanced supply of nutrients and consequently improvement in plant growth or yields.

Zinc uptake by plants was reduced by increased phosphorus concentration in the soil. The excessive accumulation of phosphorus, causes zinc induced deficiency (Salimpour *et al.*, 2010; Das *et al.,* 2005; Marschner *et al.*, 1990). Another study by Mousavi (2011) stated that zinc absoption capacity was reduced by high phosphorus utilization. Zinc in plant and soil has an antagonism state with phosphorus and therefore zinc utilization was essential to obtain high yield and quality in crops.

Similar interaction was reported in the case of boron with phosphorus. Gunes and Alpaslan (2000) reported antagonistic relationship between the effects of the application of boron and phosphorus in maize. He reported that increased level of phosphorus in the soil resulted in an increase in both the concentration and uptake of phosphorus in all cultivars, but it resulted in a decreased concentration and uptake of boron.

Barman *et al* .(2014) observed that application of boron (20 mg/kg) and lime (1/3 LR) significantly increased N, P, K, Ca, Mg, S and Zn content in soil while the availability of Cu, Fe, Mn in soil reduced due to application of B and lime. Sandra *et al* (1988) found that boron chemistry in soil and its role in plant differs from other micronutrients such as Zn, Cu, Fe, Mn but its deficiency or excess may affect the solubility of this micronutrient in soil.

Nitrogen appears to affect the zinc status of crop by both promoting plant growth and by changing the pH of the root environment. In many soils, nitrogen is the chief factor limiting growth and yield and therefore not surprisingly, improvements in yield have been found through positive interactions by applying N and Zn fertilisers. Nitrogen promoted growth can cause a dilution in Cu concentration which is then exacerbated by applied zinc.

Nitrogen fertilizers such as ammonium sulphate can have a marked acidifying effect on soils and so lead to an increase in the availability of zinc to crops in soils of relatively high pH status (Kirk *et al.*, 1995).

Several nutrient elements including calcium, magnesium, potassium and sodium are known to inhibit the absorption of zinc by plant roots in solution culture experiments but in soils their main effect seems to be through their influence on soil pH. K , Mg have shown to inhibit zinc absorption in solutions with low levels of Ca, but once the Ca concentration was increased, the effects disappeared. In the dry season, rice in the Phillipines has been found to respond to zinc combined with K at some sites, but only response to K were found in most season (Ramon and Villemin, 1989)

In Zn-Cu interaction can occur through competitive inhibition of absorption (due to copper and zinc sharing a common site for root absorption). Cu nutrition affects the redistribution of zinc within plants. Fe - Zn interactions appear to be just as complex as those between Zn - P, but they have not attracted so much attention. Increasing Zn supplies to plants have been observed to increase iron status. Zinc deficient plants can absorb high concentration of boron in a similar manner to zinc deficiency enhancing phosphorus toxicity in crops and this is probably due to impaired membrane function in the root (Loneragan *et al.*, 1993)

2.7. EFFECT OF NUTRIENTS ON YIELD AND QUALITY

Application of zinc and boron @ 0.4 per cent increased the yield of tomato by 23.1 t ha^{-1} compared to farmers' practice which was only 14.52 t ha^{-1} (Singh *et al.*, 2014). In banana, the yield parameters like bunch weight, number of fingers, number of leaves at bunching stage and quality parameters like TSS, titrable acidity, sugar acid ratio, keeping quality *etc.* was found to have a positive correlation with micronutrient application (Premalatha, 2016).

Application of Fe (0.5 %) + Zn (0.5 %) recorded maximum bunch weight (16.30 kg) in banana (Pathak *et al.*, 2011). Combined foliar spray of $FeSO_4$ (1%), $ZnSO_4$ (1%) and borax (0.5%) , increased number of nuts and copra yield in coconut (Padhiar *et al.*, 2011).

2.8. EFFECT OF NUTRIENTS ON PLANT PEST AND DISEASE CONTROL

Nutrient concentrations in plants are important in host ability to resist or tolerate infectious pathogens. Plant nutrition is an important component of disease control (Huber and Wilhelm, 1988). All the essential nutrients can affect the disease severity (Huber and Graham, 1999) and nutrients availability is the best way to control plant diseases in an integrated pest management system (Graham and Webb, 1991).

Generally, plants with an optimal nutritional status have the highest tolerance to pests and diseases. Susceptibility increases as nutrient concentrations deviate from this optimum. In addition to pest and disease tolerance, abiotic stress management is also influenced by micronutrients. The role of B, Zn and Mn in drought tolerance has been reported by several workers.Zn, Cu and Mn lowers the ROS (Reactive Oxygen Species) generation and protect cells against ROS attack under water stress (Waraich *et al.*, 2011).

Micronutrient disorders of Zn, Mn, B, Cu and Fe are widespread in India and correction of these nutritional disorders resulted in resistance to plant diseases (Agrios, 2005). The effect of micronutrients on reducing severity of diseases can be attributed with physiology and biochemistry of plants (Marschner, 1995).

Boron sufficiency in plants reduces the incidence and severity of diseases, while B deficiency enhances them (Gupta, 1993; Graham and Webb, 1991).

Zinc nutrition is associated with important plant defense pathways against many fungal and bacterial pathogens. Grewal *et al.* (1996) reported that root rot and *Fusarium graminearum* (Schwable) diseases of wheat controlled with soil application of Zn. Zinc reduces the concentration of ROS. This helps the plant to attain drought tolerance and the damages resulting from it.

According to Sanjeev and Eswaran (2008), the mycelial growth of *Fusarium oxysporum f. sp. cubense* causing Banana fusarium wilt was inhibited by *Trichoderma viride* applied with combination with Borax and Zinc sulphate amended medium and also found that Borax at higher concentration maximizes sporulation capacity.

Graham (1983) observed that foliar application of Fe increased the disease resistance of apple and pear to *Sphaeropsis malorum* and cabbage to *Olpidium brassicae*. Rhizosphere microorganisms could able to synthesize siderophores which lowers Fe levels for harmful microorganisms in soil. These iron chelators resulted in suppressing chlamydospores of *Fusarium oxysporum f. sp. cucumerinum*, crown-gall (*Agrobacterium tumefaciens*) and take-all diseases of wheat, soft rot of potato (*Erwinia caratovora*). Proper iron nutrition not only boosts plant vigour and health, it indirectly affects disease in the rhizosphere where its availability may limit the growth of pathogens. Iron reduced the disease severity of rust and smut of wheat, *Colletotrichum musae* of banana (Graham and Webb, 1991; Graham, 1983).

Manganese concentration in host tissue commonly decreases as the incidence of disease increases. Manganese acts as an important cofactor for number of key enzymes involved in lignin synthesis(Graham, 1983). This function of manganese is reported to play a key role in imparting resistance to diseases (Graham, 1983; Webb, 1991). Simoglou and Dordas (2006) revealed that manganese fertilization decreased the pathogenic disease incidence such as powdery mildew and take-all of wheat. Related studies also showed that soil application of manganese reduced common scab of potato (Keinath and Loria, 1996), *Fusarium* wilt of cotton and *Sclerotinia sclerotiorum* in squash (Graham and Webb, 1991; Agrios, 2005). Manganese reduces the concentration of ROS. This helps the plant to attain drought tolerance and the damages resulting from stress (Waraich *et al.*, 2011).

Copper fungicides are widely used for managing several plant diseases which having broad-spectrum activity, acting upon bacteria as well as fungi. Bacterial pustules successfully controlled by two sprays at 45 and 55 days after planting with a mixture of streptocycline (150 g ha^{-1}) + copper sulphate (1 kg ha^{-1}) (Kanniyan and Prasad, 1979). Soil application of Cu reduced downy mildew (*Plasmopara viticola*) of grapes (Evans *et al.*, 2007).

Patil (1981) reported that Molybdenum reduced Ascochyta blight (*Ascochyta* spp) in beans and peas and late blight (*Phytophthora infestans*) of potato. Symptoms of verticillium wilt of tomato reduced with Mo application (Kuti *et al.*, 1989).

Materials and Methods

3. MATERIALS AND METHODS

The study entitled "Major nutrient disorders of Banana (var. Nendran) in Vaikom Block" was carried out in farmers' field. The study has been focused in Vaikom block of Kottayam district of Kerala where banana cultivation is taken up in large scale. As part of the study, preliminary survey, soil analysis and plant analysis were carried out to understand the nutrient imbalances and disorders persisting in the area.

3.1. Preliminary survey

Initial survey was conducted as part of the study to select the major banana growing tracts of the Vaikom block. . The survey was carried out with help of an already prepared questionnaire , according to which data was collected from farmers. Data collected included crops cultivated, frequency of cultivation, history of nutrient management practices and pest and disease incidence. Based on the survey, six panchayaths in entire Vaikom block was selected as six locations for future soil sampling and corresponding plant analysis(Plate 1).

3.2. Selection of samples

Based on the data collected during preliminary survey, area under banana cultivation were identified. Samples were collected from six locations pertaining to six panchayaths of Vaikom block were nutrient imbalances and yield reduction were suspected. This was based on field observation and interaction with farmers. The major banana growing tracts were identified and 20 samples were randomly collected from each of the panchayath during the first month after planting. Initial selection was based on visual symptoms and farm history. From these 120 samples, ninety samples were selected for further soil analysis using standard analytical procedures. Leaf samples were collected from the same area during the fourth month after planting. The number of samples taken from each panchayath varied depending upon the area and occurrence of nutritional imbalances. The details regarding location and number of samples from each panchayath is given in Table 1. Samples are taken from each panchayath, to represent the entire block and interpretation is based on the trends in the entire block.

Table 1. Location details

Location	No: of samples	Sample no:	Panchayath	Areas
1	24	1 – 24	Chembu	Thuruthumma, Chembu
2	18	25 – 42	Maravanthuruth	K. S. Mangalam. Edavattom, Palankadavu, Kochukavala
3	12	43 - 54	Udayanapuram	Vaikkaprayar, Thiruvelikunnu, Padinjarekkara
4	12	55 – 66	T. V. Puram	Chemmanathukara, Moothedathukavu
5	12	67 – 78	Vechoor	Vechoor
6	12	79 – 90	Thalayazham	Thalayazham

3.2. Soil analysis

Soil samples for initial analysis were collected on a random basis from six panchayaths coming under Vaikom Block viz. Chembu, Maravanthuruth, Udayanapuram, T.V. Puram, Vechoor and Thalayazham. More than 120 samples were collected from the block altogether and scrutinized to ninety samples based on previous history of nutrient deficiency in the area. Soil samples were collected from different locations and the air dried soil samples were ground and passed through 2 mm sieve and stored in air tight containers .

The samples were analyzed for soil fertility parameters like pH, EC, organic carbon per cent , available nitrogen(N), phosphorus(P), potassium(K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and boron (B) in soil following the standard analytical procedures as shown in table 2.

3.3. Plant analysis

Index leaf tissue of banana was collected for plant analysis from the study area during the fourth month after planting. The laminar structure of third leaf was sampled by removing a strip of tissue 10 cm wide, on both sides of the central vein, and discarding everything but the tissue that extents from the central vein to the center of the lamina. The sampling procedure of banana leaf (Martin- Prevel, 1987) is depicted in Plate 4.

The collected sample was then cleaned and dried as immediately as possible. The collected leaf samples were washed with 0.1% detergent solution and cleaned with pure water quickly to remove contaminants like dust, soil and other materials. The cleaned samples were then wiped with a towel and placed in a paper bag and transferred to oven for drying. This was dried rapidly to prevent chemical and biological changes to minimum. Drying was carried out conveniently at 50 - 60 °C.

The dried up samples were then ground and packed carefully. The samples were then analyzed for the macro and micronutrient status using standard analytical procedures as given in the table 3.

3.4. Statistical analysis

The data obtained from field experiment was analyzed statistically and tested for its significance using WASP 2.0 software given by ICARGOA.

Plate 1. Location of study

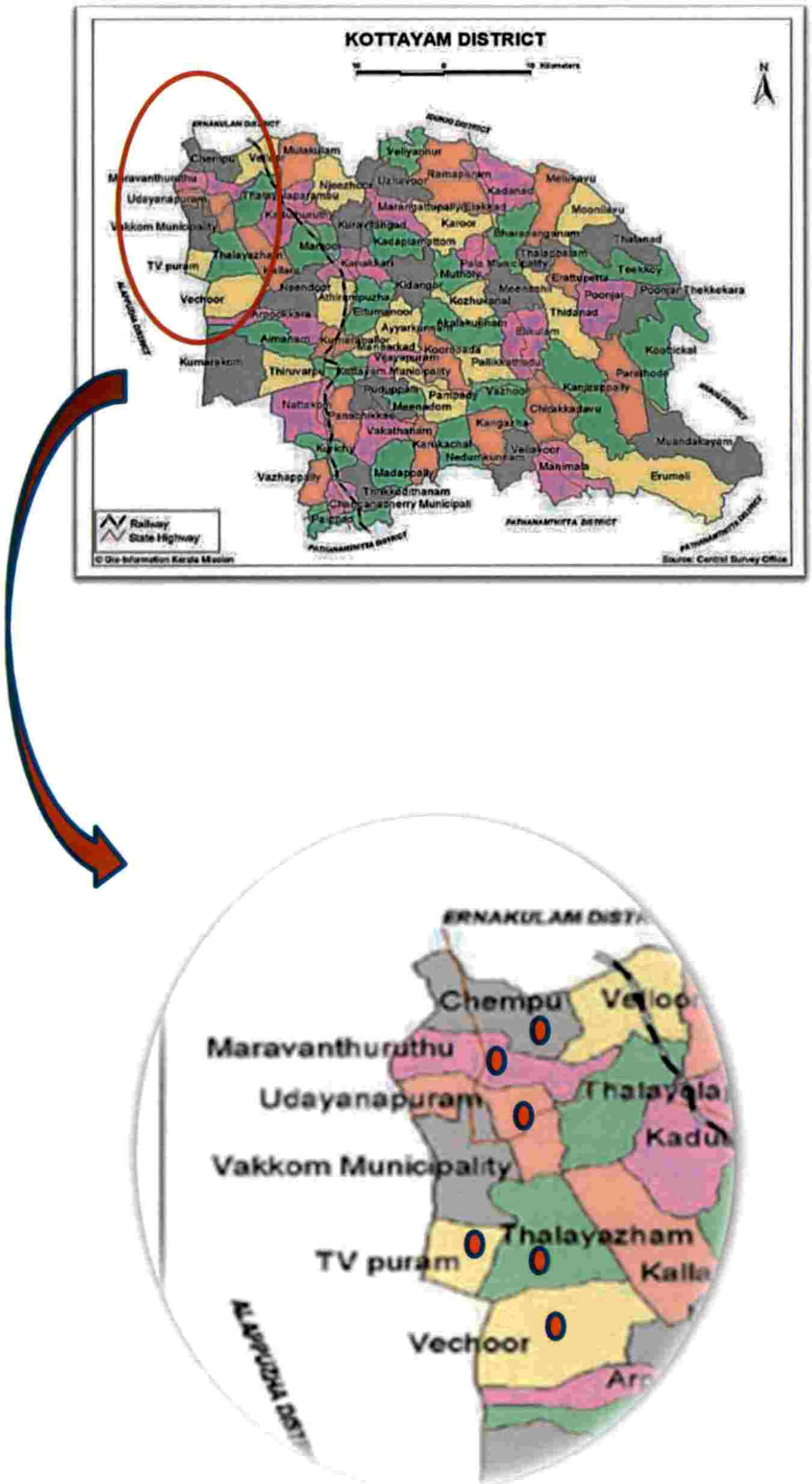

Table 2. Analytical methods followed for soil analysis

Sl. No	Parameter	Method	Reference
1.	pH	Potentiometric method using pH meter in 1: 2.5 soil water suspension	Jackson (1958)
2.	EC	Estimated using conductivity meter in the suspension liquid used for pH determination	Jackson (1958)
3.	Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
4.	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
5.	Available P	Bray extraction and estimated colorimetrically by reduced molybdate ascorbic acid blue colour method	Bray and Kurtz, 1945; Jackson (1958)
6.	Available K	Flame photometry	Pratt (1965)
7.	Available Calcium and Magnesium	Extracted using neutral normal ammonium acetate and extract estimated using Atomic absorption spectroscopy	Jackson (1958)

8.	Available S	Extracted using 0.15 % $CaCl_2$ and estimated by Turbidimetry method	Tabatabai,1982; Massouni and Cornfield, 1963
9.	Available Zn	Inductively coupled plasma optical emission spectrometry (ICP-OES)	Soltanpour and Schwab (1977)
10.	Available B	Hot water extraction method	Berger and Troug, 1939; Gupta ,1972
11.	Available Fe	Inductively coupled plasma optical emission spectrometry (ICP-OES)	Soltanpour and Schwab (1977)
12.	Available Cu	Inductively coupled plasma optical emission spectrometry (ICP-OES)	Soltanpour and Schwab (1977)
13.	Available Mn	Inductively coupled plasma optical emission spectrometry (ICP-OES)	Soltanpour and Schwab (1977)

Table 3. Analytical methods followed for plant analysis

Sl. No	Parameter	Method	Reference
1.	Total N	Modified kjeldhal digestion method	Piper (1966)
2.	Total P	Diacid digestion of plant sample [9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and Vanado molybdate yellow colour method	Piper (1966)
3.	Total K	Diacid digestion of plant sample [9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and Flame photometry	Jackson (1958)
4.	Total Ca	Diacid digestion of plant sample [9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and analysed in Atomic absorption spectroscopy	Issac and Kerber (1971)
5.	Total Mg	Diacid digestion of plant sample [9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and analysed in Atomic absorption spectroscopy	Issac and Kerber (1971)
6.	Total S	Turbidimetric method	Bhargava and Ragupathi (1995)
7.	Total Zn	Diacid digestion of plant sample	Soltanpour and

		[9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and filtrate analysed in Inductively coupled plasma optical emission spectrometry (ICP-OES)	Schwab (1977)
8.	Total B	Diacid digestion of plant sample [9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and Azomethane - H colorimetric method	Bingham (1982)
9.	Total Fe	Diacid digestion of plant sample [9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and filtrate analysed in Inductively coupled plasma optical emission spectrometry (ICP-OES)	Soltanpour and Schwab (1977)
10.	Total Cu	Diacid digestion of plant sample [9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and filtrate analysed in Inductively coupled plasma optical emission spectrometry (ICP-OES)	Soltanpour and Schwab (1977)
11.	Total Mn	Diacid digestion of plant sample [9:4 nitric acid (HNO_3) : perchloric acid ($HClO_4$)] followed by filtration and filtrate analysed in Inductively coupled plasma optical emission spectrometry(ICP-OES)	Soltanpour and Schwab (1977)

Plate 2. Crop stage at soil sample collection (1 MAP)

Plate 3. Soil samples collected from different panchayaths

Plate 4. Sampling procedure for banana leaves (Martin- Prevel, 1987)

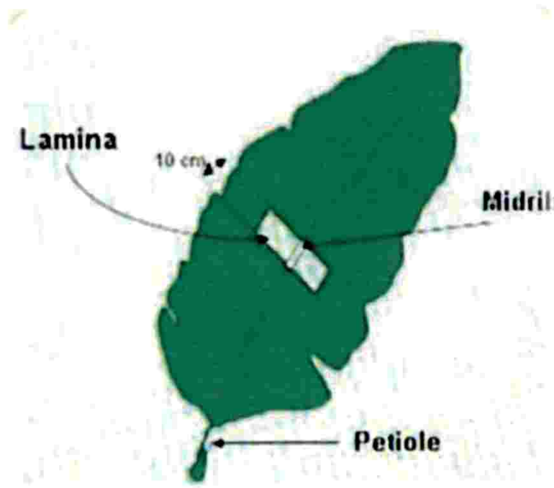

Plate 5. Crop stage at plant sample collection (4 MAP)

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Results

4. RESULTS

The study entitled 'Major nutrient disorders of banana (var. Nendran) in Vaikom Block' was carried out at Vaikom block of Kottayam district during 2016- 2017. As part of the study preliminary survey was conducted in the entire Vaikom block to select plots with previous history of nutrient disorders. Subsequently, from the selected plots of the six panchayaths of Vaikom block soil sampes were collected during the first month after planting before fertiliser application and index leaf samples during the fourth month after planting. All the samples were analysed for major and micronutrients.The nutrient status of soil and plant samples were critically evaluated. General nutrient management practices followed by the banana farmers' and nutrient disorders in the filed were also recorded.

4.1 SOIL ANALYSIS

4.1.1.pH

Analysis of data on soil pH showed that highest acidity was recorded in Chembu panchayath and least acidity was observed in T. V. Puram panchayath. The pH of the samples ranged from 4.38 to 6.2 , 4.93 to 6.32, 5.5 to 6.3, 4.53 to 6.35 , 4.7 to 6.4 and 4.9 to 6.3 in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayaths respectively and the soils were classified as shown in table 4.

Table 4. Classification of soil samples according to soil acidity

Class	Range	Per cent (%)
Very strongly acidic	4.5 – 5.0	13.33
Strongly acidic	5.1 – 5.5	17.78
Moderately acidic	5.6 – 6.0	41.11
Slightly acidic	6.1 – 6.5	27.77

4.1.2. Electrical conductivity (EC)

On analysing the electric conductivity of the soil samples, it was found that there was slight variation in electrical conductivity among the six panchayaths viz. Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayaths. The values obtained are shown in the table 7. The electrical conductivity of the samples was lowest in Thalayazham panchayath (0.005 dS m^{-1}) and highest in the Chembu panchayath (0.1489 dS m^{-1}). Panchayath wise range in electic conductivity is shown in table 5.

Table 5 . Electric conductivity in different locations

Location	Panchayath	Range (dS m^{-1})
1	Chembu	0.010 - 0.149
2	Maravanthuruth	0.009 - 0.083
3	Udayanapuram	0.008 - 0.052
4	T. V. Puram	0.011 - 0.097
5	Vechoor	0.005 - 0.044
6	Thalayazham	0.005 - 0.027

4.1.3. Organic carbon (OC %)

The per cent organic carbon content of the soils ranged from 0.18 to 3.25 %. The lowest organic carbon content was recorded in T.V Puram panchayath and the highest value of 3.27% was recorded in Chembu panchayath of Vaikom block. Among the six panchayaths the organic carbon per cent obtained is shown in table 6.

Table 6. Organic carbon content in different locations

Location	Panchayath	Range (per cent)
1	Chembu	0.75 – 3.27
2	Maravanthuruth	0.36 – 1.83
3	Udayanapuram	0.54 – 1.41
4	T. V. Puram	0.18 – 1.05
5	Vechoor	0.36 – 1.34
6	Thalayazham	0.21 – 1.05

Table 7 : pH, EC, OC content of soil samples

Sample no:	pH	EC (dS m^{-1})	OC (%)
1	5.80	0.021	0.75
2	6.20	0.012	1.23
3	5.84	0.016	0.96
4	6.16	0.015	1.05
5	5.65	0.023	1.05
6	5.20	0.025	1.89
7	5.60	0.020	1.50
8	5.98	0.023	1.44
9	4.81	0.042	2.25
10	5.72	0.032	3.15
11	5.77	0.028	3.24
12	5.12	0.015	2.13
13	5.74	0.011	1.53
14	5.40	0.010	1.23
15	5.34	0.022	2.19
16	4.90	0.031	1.77
17	4.80	0.087	1.83
18	4.88	0.078	2.37
19	4.94	0.143	2.22
20	4.48	0.085	0.96
21	4.46	0.075	3.18
22	4.38	0.087	0.93
23	4.89	0.086	1.77
24	5.70	0.149	3.27
25	6.10	0.017	1.26
26	5.40	0.019	1.41
27	6.25	0.013	1.35
28	5.80	0.009	1.11
29	5.90	0.014	1.13
30	6.32	0.014	0.63

(contd.)

Table 7. pH, EC, OC of soil samples

Sample no:	pH	EC (dS m^{-1})	OC (%)
31	6.20	0.016	1.83
32	5.87	0.019	0.84
33	5.70	0.010	0.81
34	6.07	0.012	0.78
35	5.50	0.021	0.87
36	5.68	0.065	0.36
37	4.93	0.083	0.96
38	5.33	0.012	1.74
39	6.07	0.018	1.02
40	6.30	0.013	0.54
41	6.25	0.009	0.72
42	5.87	0.074	1.26
43	5.50	0.013	0.57
44	5.70	0.019	1.41
45	6.08	0.020	1.17
46	5.85	0.048	0.99
47	5.90	0.024	0.66
48	5.64	0.052	0.69
49	6.14	0.021	0.93
50	6.05	0.008	0.54
51	6.15	0.014	0.59
52	5.75	0.014	0.72
53	5.66	0.015	1.17
54	6.30	0.011	0.96
55	6.10	0.017	0.53
56	5.90	0.013	0.67
57	5.80	0.011	0.54
58	6.02	0.010	0.54
59	6.16	0.039	0.66
60	6.35	0.014	0.18

(contd.)

Table 7. pH, EC, OC of soil samples

Sample no:	pH	EC (dS m^{-1})	OC (%)
61	4.89	0.080	0.61
62	5.01	0.097	0.57
63	4.53	0.077	1.05
64	5.08	0.082	0.82
65	5.14	0.084	0.64
66	5.34	0.069	1.02
67	6.10	0.012	0.66
68	5.60	0.044	0.58
69	6.20	0.007	0.69
70	5.50	0.005	0.62
71	5.80	0.008	0.45
72	5.90	0.019	0.99
73	4.70	0.027	0.68
74	6.10	0.016	0.59
75	5.70	0.022	1.34
76	6.40	0.018	0.98
77	5.50	0.028	1.31
78	6.21	0.025	0.72
79	6.10	0.008	0.53
80	5.60	0.008	0.35
81	5.90	0.01	0.63
82	6.10	0.005	0.48
83	5.50	0.007	0.51
84	5.80	0.012	0.55
85	5.40	0.027	0.96
86	5.80	0.017	0.61
87	6.30	0.013	0.42
88	5.40	0.016	0.87
89	4.90	0.018	0.93
90	5.60	0.025	1.05

4.1.4. Available Nitrogen

Available N content of the soil samples showed a narrow variation. The lowest value was observed in Vechoor panchayath (189 kg ha^{-1}) and the highest recorded in Chembu panchayath (384.3 kg ha^{-1}). All the six panchayaths coming under Vaikom block showed deficiency in most of the areas, it ranged from 277.2 to 384.3 kg ha^{-1}, 258.3 to 379.3 kg ha^{-1}, 208.3 to 375 kg ha^{-1}, 201.6 to 340.2 kg ha^{-1}, 189 to 371.7 kg $ha^{-1}$and 195.3 to 346.5 kg ha^{-1} in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 8).

4.1.5. Available Phosphorus

Available P content of the soil samples collected from Vaikom block showed a wide variation. The lowest value was observed in Maravanthuruth panchayath (15.204 kg ha^{-1}) and the highest recorded in Vechoor panchayath (343.22 kg ha^{-1}). All the six panchayaths coming under Vaikom block showed sufficient levels of P content, it ranged from 17.81 to 220.94 kg ha^{-1}, 15.204 to 334.22 kg ha^{-1}, 32.133 to 209.55 kg ha^{-1}, 41.866 to 277.306 kg ha^{-1}, 71- 343.89 kg $ha^{-1}$and 15.59 to 172.55 kg ha^{-1} in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 8).

4.1.6. Available Potassium

Available K content of the soil samples on analysis showed a wide spread deficiency. The lowest value was observed in T V Puram panchayath (34.16 kg ha^{-1}) and the highest recorded in Maravanthuruth panchayath (430.08 kg ha^{-1}). The values ranged from 49.28 to 262.41 kg ha^{-1}, 62.72 to 430.08 kg ha^{-1}, 42 to 327.04 kg ha^{-1}, 34.16 to 188.61 kg ha^{-1}, 55.44 to 192.64 kg ha^{-1} and 64.232 to 196.84 kg ha^{-1} in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 8).

Table 8. Major nutrient content of soil

Sample no:	N (kg ha $^{-1}$)	P (kg ha^{-1})	K (kg ha $^{-1}$)
1	352.8	91.644	62.832
2	333.9	23.447	141.68
3	352.8	77.896	117.60
4	283.5	29.501	87.360
5	378.0	197.40	124.88
6	289.8	60.536	99.680
7	346.5	93.218	190.96
8	308.7	50.256	262.42
9	340.2	77.924	152.32
10	371.7	44.727	171.36
11	289.8	61.029	99.848
12	346.5	75.841	180.88
13	296.1	210.29	76.160
14	340.2	92.714	49.280
15	321.3	186.18	85.120
16	302.4	45.069	192.08
17	359.1	27.849	241.36
18	384.3	53.659	219.52
19	308.7	7.8020	198.24
20	289.8	187.12	103.60
21	308.7	17.814	127.68
22	327.6	79.335	124.88
23	359.1	74.816	209.44
24	277.2	220.95	198.80
25	315.0	57.226	85.120
26	379.3	197.57	310.80
27	340.2	113.46	285.04
28	270.9	334.22	88.480
29	296.1	251.12	365.68
30	346.5	124.32	132.16

(contd.)

Table 8. Major nutrient content of soil

Sample no:	N (kg ha $^{-1}$)	P(kg ha $^{-1}$)	K (kg ha $^{-1}$)
31	327.6	191.31	366.24
32	258.3	205.22	430.08
33	289.8	274.20	160.16
34	333.9	141.96	66.640
35	346.5	95.155	74.480
36	258.3	84.616	97.440
37	327.6	60.592	271.60
38	289.8	10.005	140.00
39	346.5	149.41	174.72
40	340.2	9.2040	62.720
41	308.7	53.586	196.56
42	340.2	98.504	76.160
43	346.5	174.66	183.68
44	233.1	65.397	144.48
45	371.7	142.48	76.720
46	264.6	91.599	190.96
47	277.2	34.222	187.71
48	327.6	51.150	327.04
49	359.1	209.55	82.880
50	359.1	158.25	136.64
51	352.8	50.400	203.17
52	370.5	32.133	42.000
53	296.1	130.47	53.704
54	201.6	151.39	88.648
55	270.9	67.637	188.61
56	308.7	133.73	63.392
57	270.9	198.62	75.600
58	233.1	54.320	34.160
59	270.9	80.858	121.52
60	333.9	81.530	73.360

(contd.)

Table 8. Major nutrient content of soil

Sample no:	N (kg ha $^{-1}$)	P(kg ha $^{-1}$)	K (kg ha $^{-1}$)
61	264.6	144.41	80.640
62	302.4	130.30	62.160
63	340.2	81.530	74.480
64	208.5	203.06	110.09
65	296.1	41.866	87.920
66	283.5	277.31	93.464
67	359.1	343.89	65.520
68	333.9	306.58	96.880
69	189.0	153.29	93.632
70	308.7	255.47	55.440
71	270.9	211.32	63.280
72	333.9	117.88	103.04
73	371.7	156.80	132.38
74	226.8	71.680	152.88
75	283.5	134.96	96.320
76	327.6	98.000	119.28
77	296.1	165.20	192.64
78	346.5	88.144	135.85
79	327.6	63.762	75.880
80	195.3	9.560	65.632
81	296.1	51.621	81.536
82	258.3	8.6960	76.832
83	346.5	126.05	64.232
84	258.3	88.430	76.608
85	283.5	172.55	171.98
86	315.0	100.12	109.31
87	217.9	146.16	196.84
88	270.9	40.034	161.84
89	220.5	87.864	99.176
90	289.8	93.296	188.83
CD (0.01)	27.525	2.137	8.313
CD (0.05)	20.780	1.613	6.276

Plate 6. Nitrogen deficiency symptom in banana plants (Udayanapuram panchayath)

a) Nitrogen deficient leaf

b) Normal leaf petiole

Plate 7. Potassium deficiency symptom in banana leaf (Maravanthuruth panchayath)

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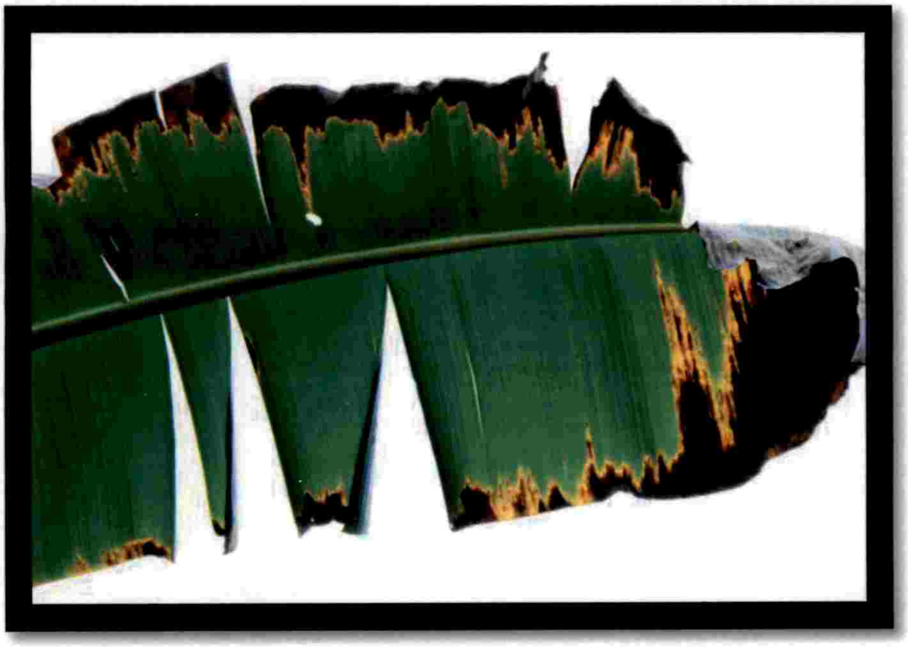
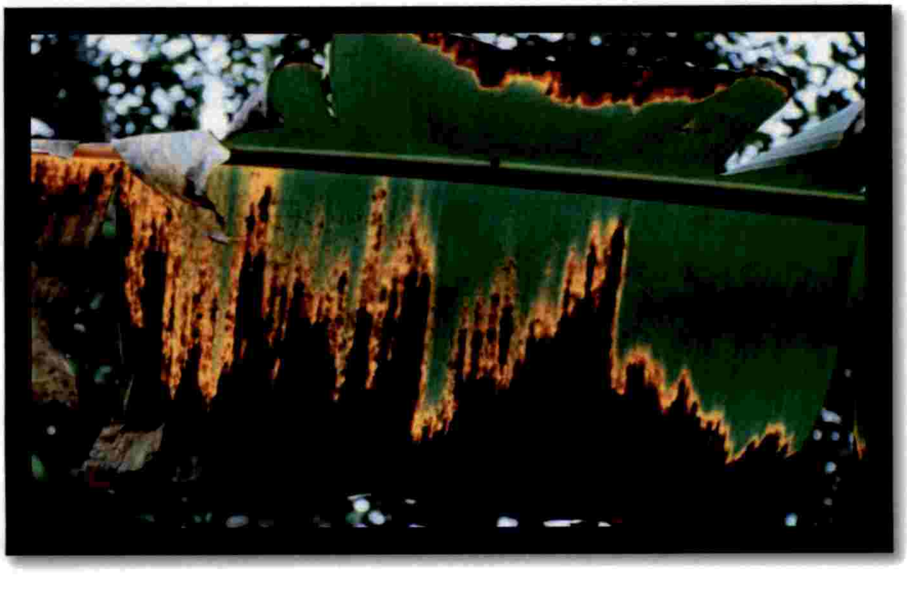
Plate 8. Potassium deficiency symptom in banana leaf (Vechoor panchayath)





4.1.7. Available Calcium

Available Ca ranged from 160 mg kg $^{-1}$ to 616 mg kg $^{-1}$ in Vaikom block and the lowest and highest value was recorded in Thalayazham and T. V. Puram panchayath respectively. Among the panchayaths the Ca content ranged from 243 to 457.5 mg kg $^{-1}$, 267.25 to 391.75 mg kg $^{-1}$, 252.5 to 511.25 mg kg $^{-1}$, 262 to 616 mg kg $^{-1}$, 193 to 360.75 mg kg $^{-1}$, 160 to 317.75 mg kg $^{-1}$ in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 9).

4.1.8. Available Magnesium

Available magnesium content of the soil samples collected from Vaikom block showed a wide spread deficiency and the available Mg ranged from 6.863 mg kg $^{-1}$ to 41.45 mg kg $^{-1}$ in the block. The lowest value was observed in Udayanapuram and the highest recorded in Thalayazham panchayath. However all the samples were below the critical level of 120 mg kg $^{-1}$ (Table 9).

4.1.9. Available Sulphur

Soil analysis from Vaikom block revealed that the available Sulphur content was sufficient in the Vaikom region and the value ranged from 1.889 to 60.328 mg kg $^{-1}$. The values ranged from 9.247 to 53.08 mg kg $^{-1}$, 5.827 to 43.929 mg kg $^{-1}$, 1.889 to 60.328 mg kg $^{-1}$, 7.181 to 41.75 mg kg $^{-1}$, 6.031 to 26.383 mg kg $^{-1}$ and 6.075 to 33.018 mg kg $^{-1}$ in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 9).

Table 9. Secondary nutrient content of soil

Sample no:	Ca (mg kg^{-1})	Mg (mg kg^{-1})	S (mg kg^{-1})
1	260.00	18.79	19.56
2	256.50	9.70	14.59
3	264.00	15.54	20.28
4	322.50	11.63	23.22
5	276.75	30.25	10.52
6	457.50	41.45	13.16
7	276.00	10.36	29.85
8	282.50	21.30	13.03
9	253.75	8.31	29.37
10	346.50	19.29	11.72
11	312.75	10.82	53.09
12	285.75	15.71	15.61
13	273.50	19.46	24.35
14	352.00	11.234	23.11
15	297.50	10.86	38.19
16	301.00	10.81	25.44
17	293.50	18.80	17.09
18	348.75	21.36	10.66
19	348.25	11.32	37.98
20	247.50	8.01	23.33
21	280.75	10.42	10.50
22	243.50	7.95	9.24
23	318.00	10.86	24.40
24	337.90	22.47	19.64
25	311.50	15.59	24.57
26	302.50	10.31	16.01
27	383.25	17.25	26.77
28	391.75	11.0	28.21
29	322.00	10.76	9.37
30	368.00	14.84	23.37

(contd.)

Table 9. Secondary nutrient content of soil

Sample no:	Ca (mg kg^{-1})	Mg (mg kg^{-1})	S (mg kg^{-1})
31	391.15	12.19	26.98
32	372.50	10.83	30.47
33	283.00	18.48	26.86
34	332.50	10.77	3.827
35	267.25	8.31	20.63
36	277.50	10.75	26.56
37	357.75	16.42	35.86
38	322.30	23.64	10.60
39	378.325	11.17	18.34
40	277.75	8.80	43.93
41	279.00	10.76	10.31
42	268.00	31.36	20.50
43	317.25	11.79	21.86
44	403.50	15.72	3.49
45	258.50	8.34	1.88
46	297.75	10.53	6.93
47	334.65	12.34	51.19
48	435.50	21.85	9.46
49	255.50	7.25	60.33
50	271.50	18.34	12.24
51	511.25	12.27	59.20
52	271.75	8.66	59.04
53	252.50	16.86	34.46
54	329.00	10.45	13.83
55	497.25	11.54	23.28
56	383.50	12.52	25.93
57	317.50	24.52	30.36
58	262.00	11.84	7.18
59	379.50	16.96	22.25
60	304.00	10.62	20.56

(contd.)

Table 9. Secondary nutrient content of soil

Sample no:	Ca (mg kg^{-1})	Mg (mg kg^{-1})	S (mg kg^{-1})
61	441.75	8.42	20.72
62	616.00	10.65	41.75
63	336.00	21.33	32.16
64	476.83	11.37	28.21
65	317.25	17.23	9.54
66	300.50	10.72	28.04
67	220.50	7.62	18.45
68	307.75	10.42	26.38
69	289.25	10.58	20.46
70	360.75	18.98	6.03
71	246.25	9.18	23.34
72	223.25	14.51	21.84
73	204.25	11.45	18.42
74	288.00	20.50	22.93
75	193.00	15.28	16.88
76	282.25	8.32	22.10
77	255.75	28.82	14.61
78	271.25	9.87	24.41
79	275.75	17.28	19.17
80	317.75	10.79	33.02
81	196.75	9.09	4.08
82	244.25	10.27	26.88
83	267.25	19.05	23.34
84	207.75	9.12	19.79
85	307.50	11.79	9.344
86	191.25	23.08	15.76
87	267.00	7.63	21.60
88	244.25	10.18	12.05
89	273.00	14.37	19.62
90	160.00	9.53	20.71
CD (0.01)	8.370	1.245	2.531
CD (0.05)	6.319	0.940	1.911

Plate 9. Calcium deficiency symptom in banana leaf – Yellowish white parallel streaks

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Plate 10. Ca- B combined deficiency symptom in banana (Thalayazham panchayath)

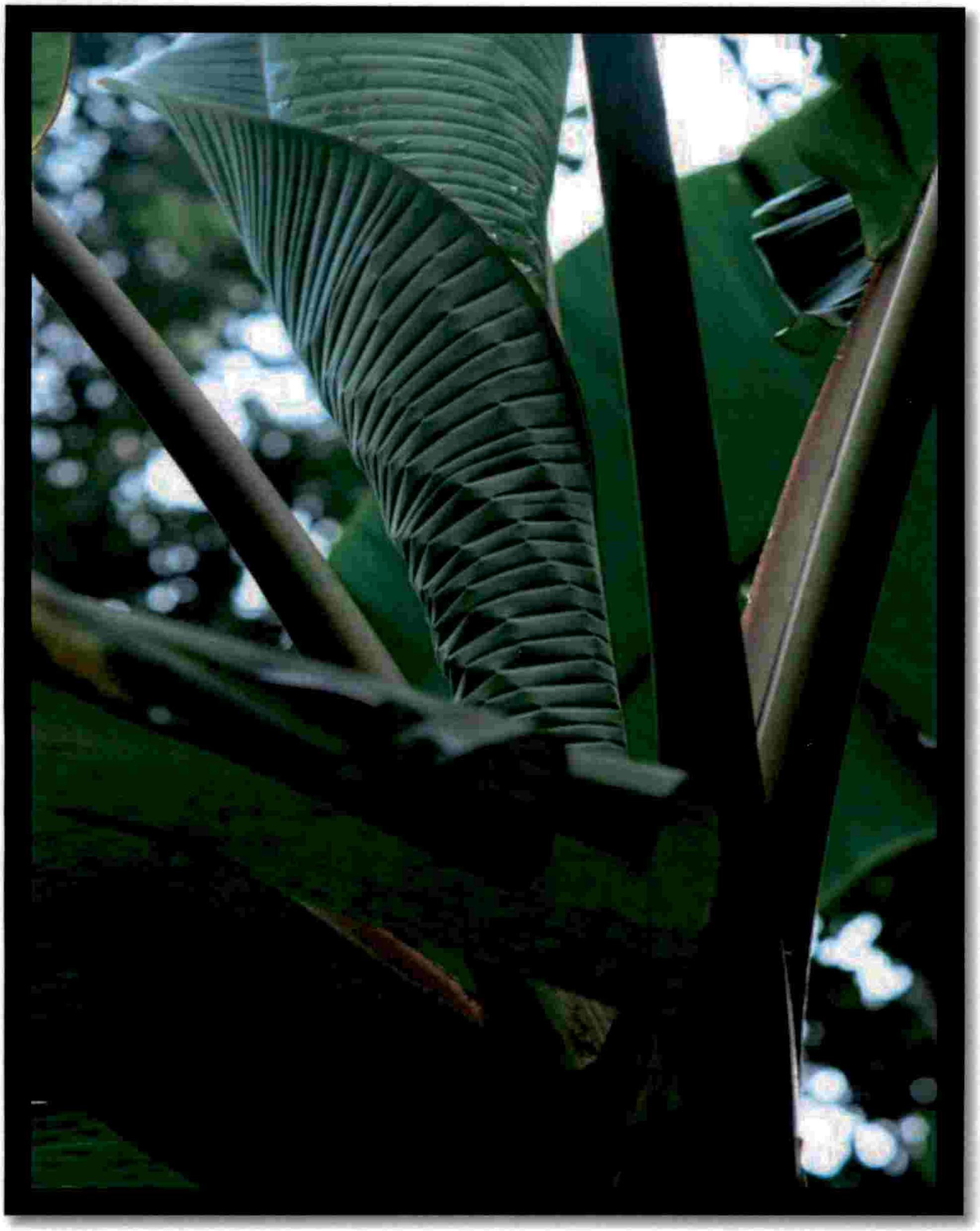


Plate 11. Magnesium deficiency symptom in banana leaf (Maravanthuruth panchayath)

4.1.10. Available Boron (B)

The critical level of boron in the soil is 0.5 mg kg $^{-1}$ and available boron concentration showed a wide spread deficiency. The lowest value was observed in T. V Puram panchayath (0.065 mg kg $^{-1}$) and the highest recorded in Maravanthuruth panchayath (4.802 mg kg $^{-1}$). The values ranged from 0.089 to 3.94 mg kg $^{-1}$, 0.174 to 4.802 mg kg $^{-1}$, 0.274 to 2.09 mg kg $^{-1}$, 0.065 to 2.76 mg kg $^{-1}$, 0.611 to 1.482 mg kg $^{-1}$ and 0.369 to 2.289 mg kg $^{-1}$ in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 10). In Vechoor panchayath the boron content in the soil was found to be sufficient.

4.1.11. Available iron (Fe)

Soil analysis from Vaikom block revealed that the available Fe content was sufficient in the area and the value ranged from 6.1 – 65.435 mg kg $^{-1}$. The highest concentration of Fe was found in Maravanthuruth panchayath. Soil analysis data revealed that iron content was sufficiently high in the Vaikom region as shown in table 10.

4.1.12. Available Manganeese (Mn)

The manganese content of the soil ranged from 1.141 to 8.193 mg kg $^{-1}$ and is suufficiently high in the block as shown in table 10. The critical level of manganese in soil is 1 mg kg $^{-1}$ and all the samples collected from Vaikom region were found to be above the critical level.

4.1.13. Available Zinc (Zn)

Available zinc concentration of soil samples ranged from 0.309- 2.642 mg kg $^{-1}$. The lowest value was observed in Thalayazham panchayath (0.309 mg kg^{-1}) and the highest recorded in Chembu panchayath (2.642 mg kg $^{-1}$). The values ranged from 0.764 to 2.642 mg kg $^{-1}$, 1.089 to 2.23 mg kg $^{-1}$, 0.309 to 1.683 mg kg $^{-1}$, 0.404 to 1.563 mg kg $^{-1}$, 0.33 to 1.434

mg kg $^{-1}$ and 0.309 to 1.743 mg kg $^{-1}$ in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 10).

4.1.14. Available Copper (Cu)

Available Cu content of the soil samples collected from Vaikom block on analysis showed wide spread deficiency. The lowest value was observed in Thalayazham panchayath (0.086 mg kg $^{-1}$) and the highest recorded in Maravanthuruth panchayath (2.23 mg kg $^{-1}$) as shown in table 10. The critical level of copper in the soil is 1 mg kg $^{-1}$ and around more than fifty per cent of the samples were below the critical level.

Table 10. Micronutrient content of soil

Sample no:	B (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
1	1.28	32.79	4.151	1.231	0.871
2	1.27	9.49	1.582	0.848	0.726
3	0.09	15.66	1.745	0.847	0.687
4	0.19	10.51	1.145	1.170	0.846
5	0.48	14.58	3.981	1.157	0.678
6	1.24	17.33	2.163	1.190	0.855
7	0.94	17.54	1.880	1.576	0.974
8	0.15	44.96	2.106	1.278	0.952
9	0.66	36.74	3.502	1.039	1.168
10	3.94	51.82	1.769	1.236	1.137
11	0.22	52.93	2.828	1.165	0.780
12	0.93	28.58	4.585	1.746	1.154
13	0.09	7.82	1.265	1.246	1.072
14	1.32	8.63	1.748	1.688	1.641
15	0.84	37.58	3.662	1.360	1.735
16	1.12	21.73	2.250	1.659	1.348
17	0.31	16.99	2.576	1.174	1.054
18	1.32	43.08	3.325	2.642	1.707
19	3.34	55.55	5.869	1.955	1.772
20	0.66	15.89	1.510	0.764	0.558
21	2.48	27.55	1.277	1.471	1.257
22	1.09	14.07	1.378	0.841	0.563
23	0.53	13.23	1.085	1.158	0.767
24	0.79	15.54	8.076	1.254	0.325
25	0.26	14.60	3.569	1.440	1.515
26	0.21	26.43	3.816	1.910	1.220
27	1.32	47.59	1.543	1.466	1.239
28	0.89	21.63	5.870	1.859	1.431
29	0.61	29.63	2.079	1.452	2.230
30	5.06	21.54	4.861	1.750	1.072

(Contd.)

Table 10. Micronutrient content of soil

Sample no:	B (mg kg^{-1})	Fe (mg kg^{-1})	Mn(mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
31	4.80	48.61	5.483	1.876	1.873
32	0.26	20.03	2.388	1.929	0.360
33	0.75	22.56	1.584	1.856	0.836
34	4.43	65.43	1.900	1.942	0.918
35	2.71	54.53	1.658	1.466	0.859
36	1.08	14.98	3.375	1.089	0.384
37	1.84	10.31	1.717	2.205	0.825
38	3.49	21.66	2.936	2.238	1.591
39	0.65	15.53	6.568	1.670	1.331
40	1.47	8.87	1.759	1.556	0.174
41	0.17	27.12	1.151	1.262	0.624
42	0.28	10.36	2.874	1.717	1.223
43	0.74	40.97	2.052	1.683	1.091
44	1.25	57.43	1.977	1.441	1.578
45	1.69	38.55	1.177	1.226	1.258
46	1.07	6.01	2.356	0.760	0.460
47	0.88	8.04	1.740	0.467	0.359
48	2.09	7.98	1.433	0.309	1.311
49	1.31	23.75	1.449	1.581	0.518
50	1.25	6.30	1.671	0.551	0.342
51	0.31	9.03	4.688	0.544	0.351
52	0.49	13.13	1.670	0.553	0.318
53	0.27	7.73	1.665	0.842	0.512
54	1.55	11.55	2.685	0.682	0.443
55	0.06	50.78	6.714	0.862	0.542
56	1.10	61.79	1.865	1.563	0.350
57	0.51	31.09	2.595	0.862	0.423
58	2.76	33.19	1.343	0.575	0.372
59	0.95	28.05	8.193	0.966	0.533
60	0.33	23.96	2.677	0.933	0.245

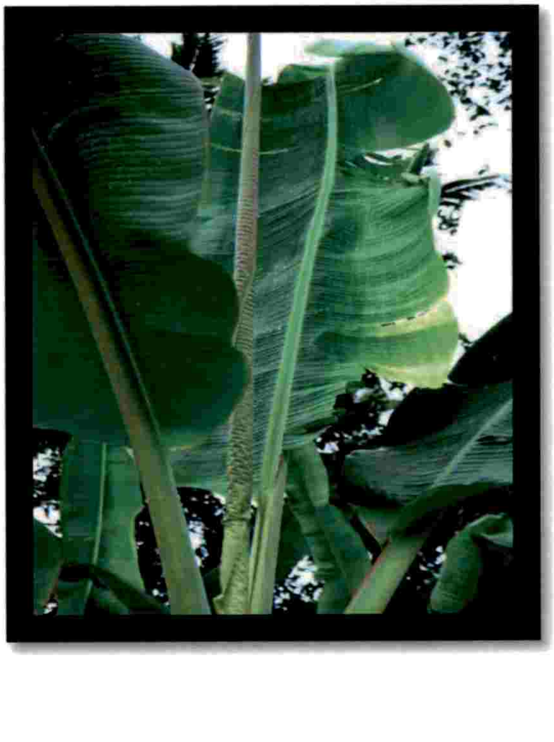
(Contd.)

Table 10. Micronutrient content of soil

Sample no:	B (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
61	0.38	25.54	3.605	0.994	0.651
62	0.07	9.05	1.637	0.452	0.323
63	0.45	30.02	1.734	0.570	0.451
64	1.13	7.20	4.344	0.513	0.246
65	0.14	8.66	1.313	0.404	0.481
66	0.70	14.32	6.363	0.691	0.251
67	0.96	8.61	1.141	0.847	0.351
68	1.48	8.11	1.343	0.646	0.242
69	0.61	17.21	3.255	0.330	0.215
70	1.03	7.51	5.349	0.977	0.283
71	0.63	9.20	1.351	0.543	0.353
72	0.86	11.14	1.371	0.851	0.375
73	1.13	7.50	4.465	0.548	0.734
74	0.96	9.40	1.807	0.727	0.534
75	1.26	7.14	2.165	0.535	0.223
76	0.89	8.49	1.925	0.934	0.196
77	1.11	9.42	2.952	1.434	0.385
78	0.74	7.99	1.740	0.664	0.335
79	2.28	8.81	1.156	0.309	0.137
80	1.64	8.60	4.334	0.439	0.108
81	1.06	11.10	2.835	1.521	0.125
82	0.36	8.82	1.728	0.477	0.086
83	1.73	7.92	1.566	0.559	0.092
84	1.74	16.30	1.843	1.114	0.239
85	1.34	7.85	3.931	1.743	0.152
86	0.69	5.44	5.866	0.665	0.335
87	1.24	9.59	1.571	1.233	0.437
88	1.07	7.13	2.753	0.750	0.253
89	0.87	11.68	1.755	0.975	0.461
90	1.08	9.02	4.508	1.553	0.345
CD (0.01)	0.295	1.244	0.198	0.091	0.042
CD (0.05)	0.223	0.939	0.149	0.068	0.032

Plate 12. Boron deficiency symptom in banana – T. V. Puram panchayath

Plate 13 . Calcium - Boron deficiency symptom – Maravanthuruth panchayath



4.2. PLANT ANALYSIS

4.2.1. Nitrogen (N)

The nitrogen content in leaf tissue ranged from 1.89 per cent to 3.33 per cent whereas the adequacy level of N in banana leaf was 2.3 per cent. As per this critical level, 26.67 per cent leaf samples were found to be deficient in nitrogen. Deficiency symptoms were observed in the area of study. The nitrogen content ranged from 1.89 to 3.22, 1.89 to 3.08, 1.96 to 3.08, 2.1 to 3.09, 1.96 to 3.08, 1.96 to 2.94 in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively(Table 11). Nitrogen deficiency was observed in the farmers' field and about 26.67 per cent of the samples showed deficiency.

4.2.2. Phosphorus (P)

Plant analysis was carried out using the index leaf tissue of banana and the phosphorus content in leaf was in a range of 0.097 to 0.293 %. The lowest P content was seen in samples collected from Thalayazham panchayath. The phosphorus content in leaf ranged from 0.097 to 0.293 per cent and around 79 per cent of the leaf samples were having nutrient content more than the critical level of 0.13 per cent. The deficiency symptoms of phosphorus were not observed in the study area. The phosphorus content ranged from 0.103 to 0.246 %, 0.102 to 0.293 %, 0.098 to 0.268 %, 0.109 to 0.222 %, 0.147 to 0.282 %, 0.097 to 0.182 % in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 11). Phosphorus deficiency was not observed in the study area.

4.2.3. Potassium (K)

Plant analysis was carried out using the index leaf tissue of banana and the potassium content in leaf was in a range of 1.726 to 4.95 % as shown in table 11. The lowest and highest K content was seen in samples collected from Chembu and Maravanthuruth panchayath. Potassium deficiency was very prominent in the fields and about 73.33 per cent of the samples showed severe deficiency in leaf tissue .

Table 11. Major nutrient content in leaf tissue

Sample no:	N (%)	P (%)	K (%)
1	1.89	0.180	2.545
2	2.80	0.107	3.135
3	2.52	0.187	3.303
4	2.87	0.122	2.675
5	2.70	0.194	3.338
6	1.89	0.138	2.758
7	3.27	0.197	3.461
8	2.17	0.121	4.344
9	2.52	0.194	3.733
10	3.15	0.114	2.34
11	2.48	0.144	2.147
12	2.66	0.183	2.77
13	2.87	0.244	2.126
14	2.10	0.178	1.726
15	2.54	0.203	2.525
16	2.31	0.129	3.526
17	2.82	0.147	3.910
18	2.94	0.147	3.742
19	2.12	0.123	3.481
20	2.59	0.208	2.806
21	2.38	0.103	3.012
22	2.83	0.193	2.875
23	2.73	0.198	3.735
24	2.24	0.246	3.602
25	2.59	0.185	3.855
26	3.35	0.157	4.763
27	2.66	0.148	4.928
28	1.89	0.293	2.673
29	2.24	0.236	3.793
30	2.71	0.183	2.950

(contd.)

Table 11. Major nutrient content in leaf tissue

Sample no:	N (%)	P (%)	K (%)
31	2.87	0.157	4.839
32	2.13	0.192	4.950
33	2.38	0.192	3.050
34	3.21	0.153	3.434
35	2.66	0.168	3.643
36	1.96	0.193	2.760
37	2.94	0.108	4.040
38	2.38	0.102	2.790
39	2.82	0.197	3.372
40	2.87	0.174	2.796
41	2.16	0.188	3.321
42	2.59	0.197	3.528
43	2.61	0.229	3.079
44	2.14	0.128	2.923
45	3.32	0.183	2.828
46	2.73	0.148	3.126
47	2.03	0.102	3.208
48	2.38	0.118	4.833
49	2.94	0.268	3.631
50	3.44	0.169	2.979
51	2.59	0.098	3.668
52	3.31	0.106	2.471
53	2.87	0.157	2.508
54	1.96	0.158	3.491
55	2.24	0.142	3.214
56	3.29	0.159	2.828
57	2.87	0.198	2.857
58	2.13	0.143	2.493
59	2.38	0.151	3.031
60	2.77	0.151	2.851

(contd.)

Table 11. Major nutrient content in leaf tissue

Sample no:	N (%)	P (%)	K (%)
61	2.45	0.168	2.830
62	2.80	0.157	2.730
63	3.08	0.156	3.015
64	2.11	0.202	2.878
65	2.45	0.109	2.697
66	2.21	0.222	2.828
67	3.08	0.282	2.829
68	2.87	0.228	2.689
69	1.96	0.178	2.832
70	2.94	0.217	2.690
71	2.24	0.168	2.698
72	2.21	0.157	2.814
73	2.91	0.163	2.889
74	2.17	0.147	2.941
75	2.45	0.152	2.795
76	2.70	0.147	2.869
77	2.59	0.168	2.951
78	2.94	0.154	2.951
79	2.87	0.143	2.740
80	1.96	0.097	2.591
81	2.52	0.138	2.762
82	2.45	0.107	2.719
83	2.94	0.173	2.591
84	2.45	0.152	2.653
85	2.59	0.176	2.942
86	2.80	0.157	2.739
87	1.96	0.182	2.918
88	2.59	0.112	2.883
89	2.10	0.142	2.799
90	2.66	0.148	2.910
CD (0.01)	0.356	0.003	0.241
CD (0.05)	0.269	0.003	0.182

80

4.2.4. Calcium (Ca)

Calcium content in leaf tissue was analysed and found that 55.55 per cent of the samples were deficient and values ranged from 0.437 to 1.322 per cent. Calcium deficiency appeared as yellow-white parallel streaks in the leaf lamina parallel to the midrib accompanied by severe crinkling of leaves. Field symptoms of calcium deficiency were promiment in the region. The lowest content was seen in samples collected from Maravanthuruth panchayaths. The calcium content was 0.639 to 1.322 % , 0.437 to 0.89 %, 0.637 to 0.912 %, 0.656 to 0.924 %, 0.568 to 0.874 % and 0.574 to 0.862 % in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 12).

4.2.5. Magnesium (Mg)

Leaf tissue analysis was carried out and the magnesium content in leaf was in a range of 0.242 to 0.38 per cent. The lowest Mg content was observed in samples collected from Vechoor panchayath. The field symptoms of magnesium deficiency were very prominent in the area of study. Here the older leaves in the plants showed typical yellowing of central part of leaf lamina, while the margin and mid rib still remained green.The magnesium content in leaf ranged from 0.266 to 0.38 %, 0.243 to 0.353 %, 0.244 to 0.293 %, 0.257 to 0.276 %, 0.242 to 0.271 % and 0.243 to 0.278 % in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively (Table 12).

4.2.6. Sulphur (S)

Plant analysis was carried out using the index leaf tissue of banana and the sulphur content in leaf was in a range of 0.07 to 0.291 per cent. Sulphur content in leaf tissue revealed that 12.2 per cent of the samples showed sulphur deficiency though field symptoms were not so prominent. The critical level of sulphur in banana leaf tissue was 0.21 per cent and sulphur content of most of the leaf samples were found to be sufficiently high. The sulphur content was 0.135 to 0.29 %, 0.137 to 0.238 %, 0.07 to 0291 %, 0.129 to 0.245 %, 0.128 to 0.263 % and 0.128 to 0.239 % in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively(Table 12).

Table 12. Secondary nutrient content in index leaf tissue

Sample no:	Ca (%)	Mg (%)	S (%)
1	0.714	0.270	0.285
2	0.722	0.267	0.267
3	0.718	0.270	0.294
4	0.787	0.274	0.289
5	0.746	0.271	0.301
6	1.322	0.271	0.251
7	0.731	0.267	0.268
8	0.748	0.380	0.181
9	0.671	0.298	0.273
10	0.835	0.277	0.255
11	0.795	0.280	0.29
12	0.776	0.273	0.266
13	0.742	0.269	0.168
14	1.203	0.278	0.294
15	0.800	0.268	0.270
16	0.882	0.269	0.319
17	0.771	0.266	0.273
18	0.864	0.273	0.296
19	0.877	0.284	0.261
20	0.641	0.293	0.187
21	0.764	0.339	0.274
22	0.639	0.290	0.259
23	0.764	0.271	0.299
24	0.861	0.274	0.274
25	0.841	0.331	0.316
26	0.877	0.323	0.272
27	0.769	0.272	0.254
28	0.858	0.275	0.277
29	0.691	0.279	0.251
30	0.856	0.282	0.286

(contd.)

Table 12. Secondary nutrient content in index leaf tissue

Sample no:	Ca (%)	Mg (%)	S (%)
31	0.868	0.282	0.272
32	0.859	0.274	0.259
33	0.762	0.342	0.264
34	0.728	0.319	0.168
35	0.562	0.268	0.259
36	0.437	0.243	0.265
37	0.838	0.278	0.289
38	0.843	0.266	0.253
39	0.858	0.273	0.169
40	0.891	0.263	0.251
41	0.567	0.284	0.195
42	0.646	0.283	0.316
43	0.827	0.284	0.289
44	0.868	0.273	0.269
45	0.642	0.258	0.270
46	0.875	0.269	0.163
47	0.902	0.283	0.254
48	0.876	0.271	0.275
49	0.657	0.247	0.252
50	0.649	0.262	0.274
51	0.912	0.313	0.280
52	0.653	0.26	0.291
53	0.637	0.254	0.269
54	0.867	0.274	0.293
55	0.907	0.262	0.302
56	0.878	0.274	0.264
57	0.858	0.272	0.273
58	0.656	0.343	0.269
59	0.872	0.261	0.188
60	0.869	0.266	0.275

(contd.)

Table 12. Secondary nutrient content in index leaf tissue

Sample no:	Ca (%)	Mg (%)	S (%)
61	0.886	0.257	0.272
62	0.924	0.271	0.255
63	0.861	0.264	0.279
64	0.810	0.276	0.252
65	0.860	0.273	0.141
66	0.659	0.268	0.284
67	0.645	0.249	0.264
68	0.853	0.269	0.253
69	0.671	0.314	0.290
70	0.874	0.264	0.268
71	0.633	0.260	0.255
72	0.618	0.267	0.289
73	0.625	0.297	0.137
74	0.659	0.316	0.289
75	0.568	0.262	0.259
76	0.674	0.242	0.261
77	0.676	0.268	0.284
78	0.680	0.262	0.262
79	0.667	0.291	0.273
80	0.862	0.272	0.259
81	0.591	0.263	0.279
82	0.658	0.263	0.326
83	0.658	0.256	0.264
84	0.659	0.261	0.262
85	0.847	0.318	0.258
86	0.590	0.243	0.181
87	0.661	0.256	0.285
88	0.662	0.258	0.253
89	0.659	0.328	0.298
90	0.574	0.255	0.276
CD (0.01)	0.028	0.023	0.014
CD (0.05)	0.021	0.017	0.011

4.2.7. Boron (B)

Analysis of index leaf tissue of banana revealed that the boron content in leaf tissue was found to be in a range of 6.85 to 28.03 mg kg^{-1} (Table 13). Deficiency was severe in T. V. Puram panchayath of Vaikom block. The critical level of boron is 11 mg kg^{-1} (IFA, 1992)and samples below this were classified as deficient. Boron deficiency was observed in 38.89 per cent of the leaf samples and these plants showed delayed unfolding of leaves along with deformation. Uneven and brittle leaf surface with 'ladder like' symptoms were also noticed in these plants where both calcium and boron were deficient. The deficient leaves were found to be pale white in colour. The boron content ranged from 7.47 to 28.03 mg kg^{-1}, 6.985 to 18.55 mg kg^{-1}, 9.3 to 25.5 mg kg^{-1}, 6.85 to 14. 55 mg kg^{-1}, 7.05 to 15.5 mg kg^{-1} and 7.585 to 18.44 mg kg^{-1} in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively .

4.2.8. Iron (Fe)

Plant analysis was carried out using the index leaf tissue of banana and the iron content in leaf was in a range of 105.2 to 550.05 mg kg^{-1}(Table 13) . The iron content in leaf tissue was studied and found that it contained sufficiently high levels iron. The iron content in leaf ranged from 123.5 to 443.9 mg kg^{-1}, 153.9 to 550. 05 mg kg^{-1}, 108.85 to 374.4 mg kg^{-1}, 135.05 to 486.9 mg kg^{-1}, 132.5 to 184.95 mg kg^{-1} and 105.2 to 203.4 mg kg^{-1} in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively.

4.2.9. Manganeese (Mn)

The manganese content in leaf tissue was studied and found that it contained sufficiently high levels manganese. The manganese content in the index leaf tissue of banana was in a range of 101.80 to 985.25 mg kg^{-1}(Table 13) . Deficiency was not observed in the study area. The manganese content ranged from 132.45 to 985.25 mg kg^{-1}, 115.9 to 734.45 mg kg^{-1}, 154.45 to 333.9 mg kg^{-1}, 102.75 to 947.05 mg kg^{-1}, 101.8 to 342.95 mg kg^{-1} and 103.7 to 522.75 mg kg^{-1} in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively.

4.2.10. Zinc (Zn)

On analysis, the zinc content in leaf was in a range of 20.55 to 52.45 mg kg^{-1} with the lowest and highest content recorded in Thalayazham and Maravanthuruth panchayaths respectively as shown in table 13. Leaf analysis data revealed that about 48.89 per cent of the samples were deficient in zinc. But the field symptoms were not so prominent in the area under study. The zinc content was 27.4 to 37.45 mg kg^{-1}, 31.7 to 52.45 mg kg^{-1}, 21.15 to 34.75 mg kg^{-1}, 21.65 to 34.35 mg kg^{-1}, 21.65 to 36.35 mg kg^{-1} and 20.55 to 36.1 mg kg^{-1} in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively.

4.2.11. Copper (Cu)

Plant analysis was carried out using the index leaf tissue of banana and the copper content in leaf was in a range of 4.4 to 40.05 mg kg^{-1} (Table 13). On analysis of leaf tissue, 31.11 per cent of the leaf samples were found to be deficient in copper. According to IFA, the critical level of copper in leaf tissue is 9 mg kg^{-1} and leaf tissues having lower content than critical level were classified as deficient. But the field symptoms were not so prominent in the Vaikom region. The copper content was 9.05 to 28.95 mg kg^{-1}, 5.75 to 40.05 mg kg^{-1}, 4.4 to 24.6 mg kg^{-1}, 5.45 to 14.95 mg kg^{-1}, 13.65 to 17.05 mg kg^{-1} and 5.3 to 16.65 mg kg-1 in Chembu, Maravanthuruth, Udayanapuram, T. V Puram, Vechoor and Thalayazham panchayath respectively.

Table 13. Micronutrient content in index leaf tissue

Sample no:	B (mg kg $^{-1}$)	Fe (mg kg $^{-1}$)	Mn (mg kg $^{-1}$)	Zn (mg kg $^{-1}$)	Cu (mg kg $^{-1}$)
1	18.51	274.35	515.05	31.70	16.65
2	16.88	146.00	175.00	28.60	19.25
3	8.94	175.20	167.90	27.40	15.40
4	9.75	164.00	224.95	31.50	16.75
5	10.27	185.10	165.55	30.65	15.55
6	17.62	197.45	306.95	31.40	17.70
7	14.18	196.35	184.50	35.55	18.30
8	10.77	381.75	333.40	35.70	19.55
9	27.28	287.90	176.00	32.80	24.65
10	28.03	437.25	244.40	32.75	22.90
11	8.72	443.90	367.10	31.05	18.95
12	25.28	222.90	247.10	35.65	28.95
13	9.59	132.55	236.40	32.45	21.40
14	10.52	143.10	286.60	35.45	27.00
15	24.30	287.20	435.50	31.65	28.40
16	18.50	218.40	323.85	32.50	23.40
17	10.34	214.30	334.95	31.25	21.10
18	16.70	355.45	444.35	37.35	25.55
19	17.41	443.70	636.95	35.55	27.85
20	9.18	164.30	186.40	27.50	12.50
21	7.47	257.10	701.95	37.45	24.10
22	12.59	133.10	162.45	28.20	13.45
23	12.60	123.50	215.35	31.45	14.40
24	15.71	154.45	985.25	31.65	9.05
25	18.45	174.05	434.40	33.35	22.90
26	8.19	194.10	456.25	37.40	21.10
27	12.74	344.35	234.55	34.20	21.65
28	10.53	231.55	614.55	36.45	22.90
29	9.52	244.00	304.95	34.60	40.05
30	26.40	232.05	523.50	35.75	21.50

(Contd.)

Table 13. Micronutrient content in index leaf tissue

Sample no:	B (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
31	23.11	356.80	614.25	37.65	25.95
32	7.98	221.70	344.95	38.50	8.35
33	6.98	244.50	263.36	36.05	14.55
34	18.05	550.05	174.90	32.05	19.01
35	17.91	509.00	165.90	52.45	16.40
36	24.73	176.40	176.81	41.60	8.95
37	16.65	153.95	233.65	37.20	18.95
38	17.34	245.80	314.25	36.60	25.65
39	38.55	164.80	734.45	34.45	21.40
40	24.83	179.15	196.60	35.45	5.75
41	17.55	268.00	206.45	31.70	10.50
42	7.49	168.25	376.10	32.61	23.60
43	10.60	331.75	333.90	31.73	20.80
44	21.72	374.40	244.60	34.75	24.61
45	24.73	324.10	254.10	31.63	22.91
46	21.89	108.85	297.20	23.70	6.61
47	12.57	122.95	264.55	24.05	5.75
48	25.51	132.85	233.45	21.15	21.60
49	18.55	232.85	244.00	31.65	6.45
50	17.41	122.90	231.90	26.40	6.65
51	9.30	166.10	194.45	24.12	6.70
52	7.30	185.95	196.10	25.60	4.40
53	12.70	133.15	255.60	28.50	7.45
54	23.72	177.25	164.45	23.95	4.65
55	9.42	443.35	734.60	28.70	7.71
56	14.55	486.90	244.85	34.35	5.45
57	10.79	332.30	354.00	27.55	6.45
58	13.70	334.35	173.25	26.65	9.15
59	7.710	323.65	947.05	30.70	5.50
60	12.20	310.25	162.75	31.70	7.65

(Contd.)

Table 13. Micronutrient content in leaf tissue

Sample no:	B (mg kg $^{-1}$)	Fe (mg kg $^{-1}$)	Mn (mg kg $^{-1}$)	Zn (mg kg $^{-1}$)	Cu (mg kg $^{-1}$)
61	9.715	322.85	432.90	31.45	7.55
62	7.795	184.95	234.25	21.71	6.50
63	12.11	350.45	173.15	25.55	7.71
64	13.70	144.25	169.47	24.55	7.62
65	7.950	135.05	183.25	21.65	14.95
66	6.850	153.75	164.95	26.35	6.42
67	8.380	139.15	192.55	28.45	13.65
68	15.50	144.75	171.80	24.05	14.55
69	8.610	184.95	164.65	21.65	13.45
70	13.55	134.80	177.50	29.11	15.41
71	7.512	153.75	185.60	25.40	6.55
72	9.575	175.05	234.45	27.55	13.55
73	11.55	134.55	194.55	25.25	16.55
74	7.052	167.15	243.00	26.45	7.45
75	11.51	132.50	342.95	23.45	13.65
76	8.350	165.15	243.45	29.61	7.42
77	11.55	184.65	174.60	36.35	15.11
78	7.685	164.15	184.45	26.60	17.05
79	18.44	203.40	163.70	20.55	9.55
80	11.59	155.45	171.90	21.95	5.71
81	11.585	175.90	213.85	36.21	9.31
82	9.560	165.65	187.55	20.80	5.31
83	11.46	144.05	173.00	22.90	5.61
84	11.65	193.95	194.20	32.95	12.41
85	11.57	143.70	255.35	34.55	8.25
86	9.615	105.20	163.38	27.70	13.55
87	11.81	133.90	264.35	32.05	16.65
88	12.70	142.95	327.90	27.65	13.65
89	7.585	192.95	232.40	29.55	16.41
90	11.72	154.25	522.75	35.50	14.61
CD (0.01)	4.697	8.738	5.911	0.860	0.788
CD (0.05)	3.546	6.597	4.463	0.649	0.595

4.3. NUTRIENT DISORDERS OF BANANA IN VAIKOM BLOCK

Disorders due to deficiency of major and micronutrient were widespread in Vaikom block. Among the major nutrient disorders nitrogen and potassium deficiency were prominent in the area. Nitrogen deficiency was observed in 25.55 per cent of the samples collected from Vaikom region. Nitrogen deficiecy occurred even when the organic carbon content in the respective areas were high. Lower nutrient concentration than critical level in soil directly resulted in lower uptake by plants. Deficiency resulted in yellowing of leaves and reduced vegetative growth. Number of leaves were reduced in severely affected areas.

Similar to nitrogen , potassium deficiency was also widespread in Vaikom region. About 48.8 per cent of the soil samples collected from this region were deficient in available potassium. Widespread foliar symptoms were observed in T. V. Puram panchayath of Vaikom block. Yelowing and necrosis of leaves starts at leaf margin and it reaches leaf midrib at time of severe deficiency. In later stages leaf dessicates and typical curling was seen. Severe incidence of pest and diseases were common in potassium deficient soils.

Among the secondary nutrients, calcium deficiency was found to be deficient in 47.78 per cent of the soil samples from Vaikom region. Calcium deficiency was associated with boron deficiency very frequently. While observing the six panchayaths in Vaikom region widespread deficiency of calcium and boron were observed. Either calcium - boron combined deficiency or boron deficiency alone. It was difficult to differentiate between calcium and boron deficiency. Early foliar symptom were seen as yellow stripes parallel to leaf midrib in case of calcium deficiency . Crinkling of leaves and deformation were seen in case of calcium - boron combined deficiency.

Widespread deficiency of magnesium was observed in both soil and leaf tissues of banana. Leaves showed excessive yellowing and chlorosis in the central zone of the lamina while the margins and midrib area remained green. Deficiency in soil resulted in lower uptake by banana and was found to be deficient in plant also. Sulphur deficiency was very rarely observed since available sulphur content in soils was high. Still deficiency was seen in certain fields and the leaves which showed sulphur deficiency had yellowing of the entire lamina especially younger leaves and were reduced in size. But deficiency was not widespraed as in the case of calcium and magnesium.

The boron content in the leaf tissue was below the critical level in more than 30 per cent of the samples. Deficiency observed was of two kinds- actual deficiency and induced deficiency. Deficiency due to low available boron status in soil resulted in lower uptake by plants and resulted in boron deficiency. Phosphorus induced boron deficiency was observed in Vechoor and Thalayazham panchayaths of Vaikom block. In the early stages whitish parallel streaking of the entire width of central part of the lamina. Later stages boron deficiency resulted in severe crinkling of leaves, difficultly in emergence of new leaf and delayed fruit bunch emergence along with malformation of fruits.

Zinc deficiency was observed in 45.55 per cent of the samples collected from Vaikom region. Actual deficiency as well as induced deficiency of zinc was found in the banana growing tracts of Vaikom block. Phosphorus induced zinc deficiency was observed in Chembu and Maravanthuruth panchayath. Symptoms were found in younger leaf and leaves become narrow with yellowish white strips appearing between the secondary veins. A zinc deficient leaf was found to be significantly smaller in size than normal leaf and leaf chlorosis was found in strips or patches.

Copper deficiency in soil was found to be very high but index leaf tissue analysis revealed that range of deficiency was less in the plant samples (72.2 %) compared to soil (31.11 %). Deficient leaves turned yellow in colour and midrib and veins bend backwards in severe cases. Though copper defciency was found in Vaikom region ,it was not as wide spread as boron and zinc deficiency.

4.4. PEST AND DISEASE INCIDENCE

Incidence of pest and diseases were severe in almost all the farmers field studied. Almost all the farmer's field were found to have heavy incidence of pest and diseases. Out of the ninety fields from which soil and plant samlpes were analysed, heavy incidence of pest and diseases were observed in potassium and calcium deficient soils.

The major pest observed in the fields were banana pseudostem weevil (*Odoiporus longicollis*) and rhizome weevil (*Cosmopolites sordidus*). Pseudostem weevil attack started after 4 MAP and common in fields were field sanitation were not carried out. Crop loss were severe in fields and resulted in lodging of plantains due to weak pseudostems. Symptoms of weevil attack were frequently observed, with slimy ooze coming out of the injury as shown in the Plate 15.

Occurrence of disease was also prominent in the fields with nutrient imbalance. Most of the fields were infested with *sigatoka* leaf spot and other viral diseases. In certain pockets of Vaikom region , attack by birds were also seen and the fruit bunches were eaten up by them and resulted in yield loss prior to harvest. Farmers were not following any control measures in case of avian pests.

Plate 14. Pseudostem weevil attack in banana (breaking of stem in severe case)

Plate 15 . Pseudostem weevil attack in banana (ooze coming out of injury)

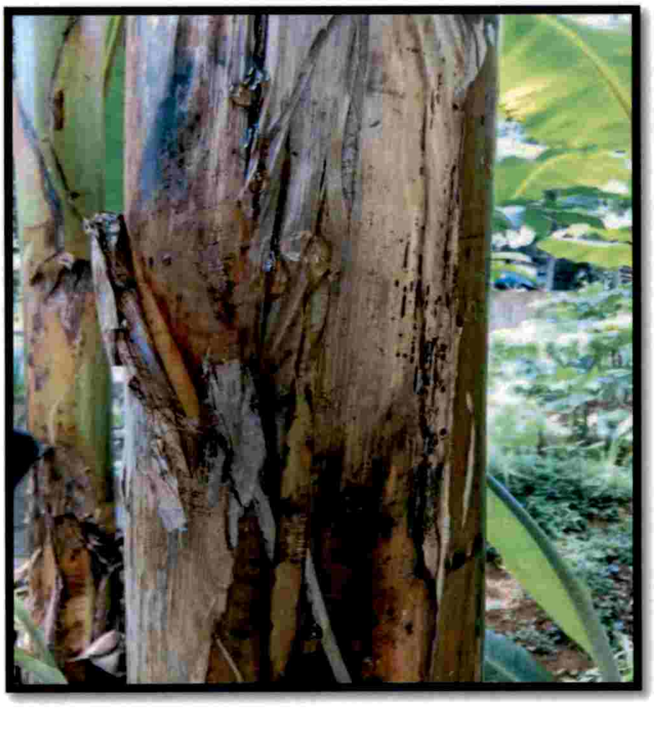


Plate 16. Leaf spot disease in banana –Maravanthuruth panchayath

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4.5. FARMERS' PRACTICE IN VAIKOM BLOCK

Banana is a heavy feeder of nutrients and requires higher concentration of all the essential nutrients for better yield and fruit quality. But farmers in Vaikom block were following unscientific nutrient management practices except few farmers in Maravanthuruth and Chembu region. Even though the soils were acidic, most of the farmers were not following liming practices. Some of the farmers practice lime application, but were not according to the requirement . Soil testing was not done in most of the cases.

. Before planting the material, it is treated with chemicals to prevent rhizome weevil attack. But growing the same crop for a long term over the same piece of land increased the susceptibilty to pest and diseases. Most importantly, recycling and replenishment of soil nutrients was affected as banana is an exhaustive crop. Farmers used to apply poultry manure, in addition to NPK fertilisers. They depended on complex and mixed fertilisers and phosphatic fertilisers like bone meal and Factamphos were applied in higher doses. General trend observed in Vaikom region was application of mixed fertilizers like 8:8:16 or 18:18:18. But rate of application varied among farmers. Fertiliser application was not according to soil test data.

In certain fields where banana was grown organically, they applied cowdung and bonemeal alone. Farmers were unaware of the importance of secondary and micronutrient application and almost totally ignored secondary and micronutrients.According to package of practices, requirement of potassium is almost more than double of phosphorus requirement, but farmers were applying lower doses. This resulted in yield reduction and the average yield obtained by farmers were found to be less than 10 kg per plant. Table 14. shows the comparison of the nutrient management practices with package of practices (KAU, 2011). Observing the farmer practices, it is evident that nurient management practices of the Vaikom region is one of the major reasons for yield reduction.

Table 14. Comparison of Farmer practices with POP Recommendations (KAU, 2011)

Sl no:	Stage of crop	Nutrient practice	Farmer practice	POP recommendation
1	Land preparation	Liming	a) Rarely apply lime b) Sufficient quantity not applied	1 kg per plant
2	At time of Planting	Organic manure application	a) Rarely applied b) Apply large quantities of poultry manure	10 kg/ plant
3	1 MAP	Fertilizer application	a) Application of Bone meal, Factamphos and b) Quantity not based on crop requirement.	40: 65: 60 g/ plant
4	2 MAP		a) Factamphos, potash and mixed fertilizers applied (18: 18: 18) b) Imbalanced fertilizer application - Higher rate of P fertilizers and low level of K application c) Scientific management practices not followed	30: 50: 60 g/ plant
5	3 MAP		a) Fertilizer application mostly mixed fertilizers. b) Unaware of split application (6 Splits)	30: 00: 60 g/ plant
6	4 MAP			30: 00: 60 g/ plant
7	5 MAP			30 :00: 60 g/ plant
8	Bunch emergence stage		No fertilizer application	30 :00: 00 g/ plant Spray K_2SO_4

Discussion

5. DISCUSSION

An investigation was carried out at Vaikom block, to find out the major nutrient disorders of banana cv. Nendran and the comparison of existing farming practices with package of practices (KAU, 2011) are presented in this chapter. The whole investigation comprised of preliminary survey conducted at Vaikom block to identify the major banana growing tracts and later collection of soil and plant samples from the six locations pertaining to six panchayaths *viz.* Chembu, Maravanthuruth, Udayanapuram, T. V. Puram, Vechoor and Thalayazham. Variations in fertility status of these banana growing tracts were related with the existing nutrient management practices followed by the farmers of the region. With the help of this data nutrient disorders existing in the region was documented.

5.1. NUTRIENT STATUS OF SOILS

In general nutrient status of the Vaikom soils revealed that soils were acidic in nature and 13.33 percent of the soils were very strongly acidic, 17.78 per cent strongly acidic, 41.11 per cent were moderately acidic and 27.77 per cent slightly acidic. The acidic nature of soils of Kerala is due to high iron, aluminium and manganese indicating high sesqui-oxide contents. Toxic levels of these elements are often observed in wetlands and deficiency of these elements have been very rarely reported, except from coastal sands and also the neutral to alkaline soils of Palakkad district (DAO, 2013).To an extent the acidic nature of the soil was due to farmers practice followed in the region. Long term use of acidic fertilizers like ammonium sulphate and reduced lime application increase the acidity of soil.

On observing the organic carbon status of the soils it is seen that soils are generally rich in organic carbon and the content ranged from 0.18 to 3.25 per cent. Only 6.7 per cent of the samples were deficient in organic carbon. Out of the six panchayaths coming under Vaikom block, highest organic carbon was recorded in Chembu panchayath, which is due to the physiography of the area. Chembu region is surrounded by river, *Murinjipuzha* and the seasonal inundation of water during rainy season is responsible for the accumulation of organic matter in the soil. Padmanabhan *et al.*(2001) found that seasonal fluctuations of water level together with intermingling of fluviatile and estuarine silts have further modified the chemical and biological characteristics of the soil.

Available nitrogen content of Vaikom block revealed that 25.55 per cent of the samples were deficient and rest were found to be sufficiently high. Though the organic carbon content were sufficiently high in the block, the estimated available N were not in accordance with organic carbon content of the corresponding area. Mini (2013) also found that nutrient requirement vary with the available N pool of the soil rather than organic carbon per cent of soil with respect to the soils of Kerala. Lower nitrogen content in the region is also due to loss of nitrogen by leaching to lower profiles.

On observing the available phosphorus content of the soil samples from Vaikom block, it is very evident that the phosphorus content is very high in the soils. This is due to the unscientific fertilizer application. On the basis of survey conducted in farmers field, it was clear that farmers used to apply high levels of phosphorus fertilizers especially Factamphos and bonemeal throughout the crop season irrespective of soil content and plant requirement.

Banana requires less quantity of phosphorus compared to nitrogen and potassium. But farmers are unaware of these requirements and often apply mixed fertilizers like 8 : 8: 16 and 18 : 18: 18 and complex fertilisers like Factamphos as mentioned in farmers practice which is the reason for higher level of phosphorus content in soil. They also apply bonemeal in higher doses. Vig and Dev (1984) reported that acid soils adsorbed more phosphorus as compared with the alkaline soils irrespective of the phosphorus concentration at equilibrium.

With respect to available potassium, wide spread deficiency were seen in all the six panchayaths *viz.* Chembu, Maravanthuruth, Udayanapuram, T.V. Puram, Vechoor and Thalayazham of Vaikom block. About 48.8 per cent of the samples collected from this area were deficient in potassium. Deficiency is due to climate and physiography of the land and also due to the nutrient management practices followed by farmers over a period. Heavy rainfall and seasonal inundation of water from rivers and estuaries is responsible for the leaching of K from soil pool making it less available to plants. Similar reports given by Mini (2013) states that 62 per cent of the soils of *Onattukara* region has low potassium status. Nair *et al.* (2013) suggests that the possible reason for low potassium status in soil may be intensive leaching condition brought in by excess runoff or irrigation and the very strong acid condition and low CEC which do not permit any retention and rapid leaching loss of the element. Another important reason for lower potassium in soil is the farmer practice followed. Banana is a heavy feeder of potassium and the K requirement is almost double the amount of phosphorus. But farmers often ignore this and apply fertilizers like 18:18: 18 , Factamphos *etc.* in variable quantities which do not provide the adequate amount of potassium for plant growth and metabolism. This practice create nutrient imbalance in soil and plant ultimately leading to nutrient disorders and yield reduction.

Available calcium content showed variation among the panchayaths and deficiency was reported to be more in Thalayazham and Vechoor panchayaths. The calcium content was found to be high in Chembu and Maravanthuruth region. Farmers rarely apply sufficient quantity of calcium fertilizers. The only source of calcium is from lime application which is done once in a season. Farmers of Vaikom block except few from Chembu and Maravanthuruth do not follow scientific fertilizer and lime application based on soil test values. This aggravates the condition of acidity, potassium, calcium deficiency etc. In addition to that the proximity of Chembu panchayath to backwaters also contributes to the physio-chemical properties of the soil in that area. In general 47.78 per cent of the samples were deficient in available calcium. This is also related to the acidic nature of the soil.

A wide spread deficiency for available magnesium was felt in the whole block whereas sulphur content was sufficiently high. As per the farming practices followed in Vaikom region farmers very rarely applied fertilizers like $MgSO_4$ in the fields. The continuous cultivation over the same piece of land without proper nutrient recycling resulted in the lower yields. Farmers seldom applied secondary and micronutrient fertilsers. Acidic soils with low CEC and leaching of basic cations like calcium and magnesium are vulnerable to deficiencies of these elements.

Sulphur deficiency was not so prominent in the area and was observed only in narrow tracts of Vaikom region. Sufficiency level of Sulphur relates to heavy application of phosphatic fertilizers especially factamphos which contain sulphur in addition to nitrogen and phosphorus. Mini (2013) reported that most of the phosphatic fertilizers contain sulphur as an additional constituent and that may be responsible for satisfactory levels of sulphur in soils of high input crop production systems like vegetables and banana. Soils were sufficiently high in available Sulphur because of the retension capacity and organic matter status of the soil. Ion pair interaction was responsible for adsorbing the sulphate ions and retaining them in the soil. A study by Cichota (2009) showed that sulphate ions are specifically adsorbed by clay fraction.

An overview of micronutrient data showed a general trend of high iron and manganese content in the Vaikom block. The availability was high due to the acidic nature of the soils. Rajagopal *et al.* (1997) found a significant negative correlation between available iron and pH in Alleppey and Palaghat districts of Kerala. They also found that availability of iron was very high in Kerala soils and value ranged from 1.6 to 5066 mg kg^{-1}. Rajagopal *et al.* (1997) also reported a positive correlation between organic carbon and available iron content in Trivandrum and Thrissur districts of Kerala and similar reports were also given by Mariam (1989) in lateritic and coastal sandy alluvial soils of Kerala.

Similarly manganese content was also very high in the Vaikom region due to the acidic soil and higher organic carbon content of the soil. Most of the samples were rich in organic carbon content and this is related with the prevailing climatic condition, soil genesis and parent material. Nair and Pillai (1990) suggested the presence of excess quantities of iron and managanese in *Kuttanad* soils. Similar reports were given by Mini (2013) in soils of *Onattukara* region. Reports by Mariam (1989) showed a significant positive correlation between available manganese and organic carbon in Kari soils of Kerala.

The results on soil analysis of Vaikom block revealed that manganese content in soil was positively correlated with organic carbon content and negatively correlated with pH of the soil. Availability of manganese is more in acidic condition. Similar conditions were reported by Rajagopal *et al.* (1977) in Allepey where the divalent manganese ions in the soil solution became predominant with increased acidity of the soil and there was very significant negative correlation between exchangeable manganese and pH.

Boron is another micronutrient which is required in very small quantities by the plant. In the entire Vaikom block only 24.4 per cent of the soil samples showed deficiency of boron. But the deficiency symptoms were widespread and pronounced in the fields. Even though the soils were having sufficient quantities of boron, the plant uptake was hindered due to other reasons. The induced deficiency of boron is due to higher levels of phosphorus in the soil due to anionic competition. Induced deficiency of boron were observed in Vechoor and Thalayazham panchayaths. Mini (2013) found that 82 percent of the soil samples in banana growing areas from *Onattukara* region was deficient in boron. In cases of induced deficiency of boron foliar spary of Borax is found to be effective. Premalatha (2015) found that foliar application of nutrient is effective than soil application when acute deficiency is felt.

On analysis of soil samples from the Vaikom block, a wide spread deficiency of zinc 45.55 per cent was observed. Deficiency was severe in T. V. Puram and Vechoor panchayaths and lowest in Maravanthuruth panchayath. Zinc deficiency was comparatively lower in Chembu and Maravanthuruth panchayaths. This might be due to higher phosphorus application. Though farmers rarely applied micronutrient fertilizers , zinc was found in be available in soil due to higher levels of phosphorus application in Vaikom region. Several studies revealed that heavy input of phosphatic fertilizers might have ensured adequate level of zinc in the soils as zinc occurs as a contaminant in phosphatic fertilizers (Nair *et al.*, 2013)

The available zinc content of Vaikom region showed significant negative correlation with soil pH. Availability increases with decrease in soil pH because ions become more soluble in acidic condition. Similar results were reported earlier by Varghese (1971); Valsaji (1972). Another trend shown in the results was significant correlation with organic carbon content and available zinc in soil. Varghese (1971) reported similar condition in Kerala soils.

As regards copper content in the soils of Vaikom, 72.2 per cent of the soil samples were deficient. Considering the individual panchayaths, deficiency was more pronounced in T. V. Puram, Vechoor and Thalayazham panchayaths. This might be the reason that incidence of fungal diseases was very high in these panchayaths.. It was observed that soil application of copper reduced downy mildew of fruit crops (Evans *et al.,* 2007). This is the reason that copper fungicides are widely used for managing several plant diseases since they have broad spectrum activity controlling bacterial as well as fungal attack.

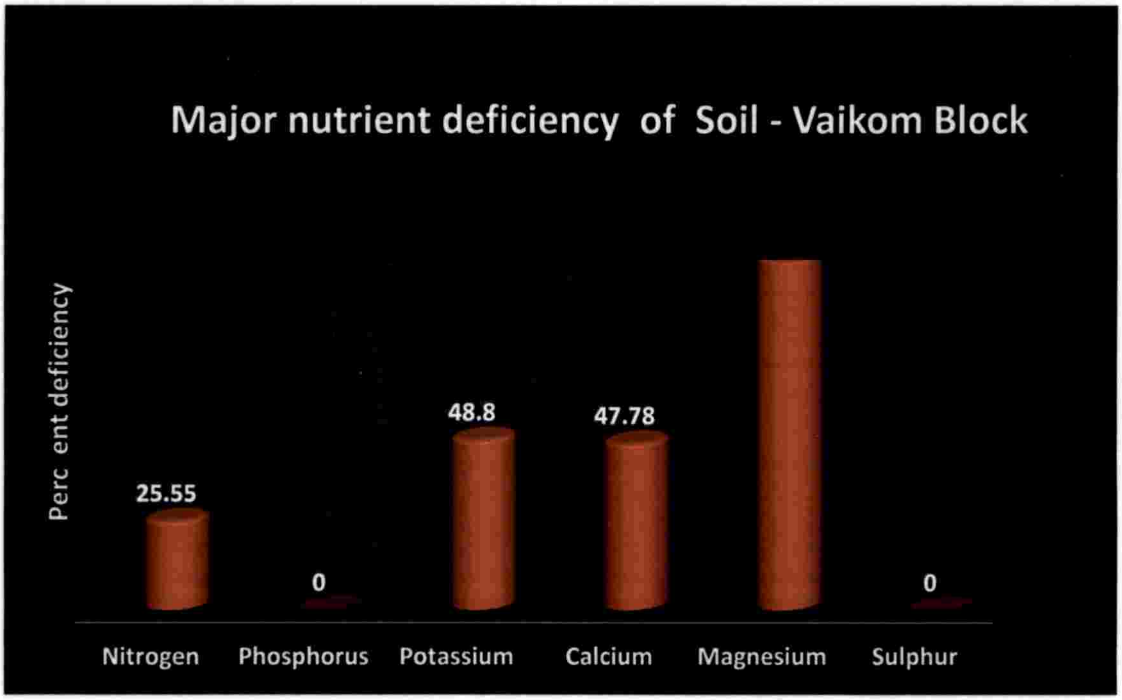

Fig 1. Major nutrient deficiency in banana growing soils

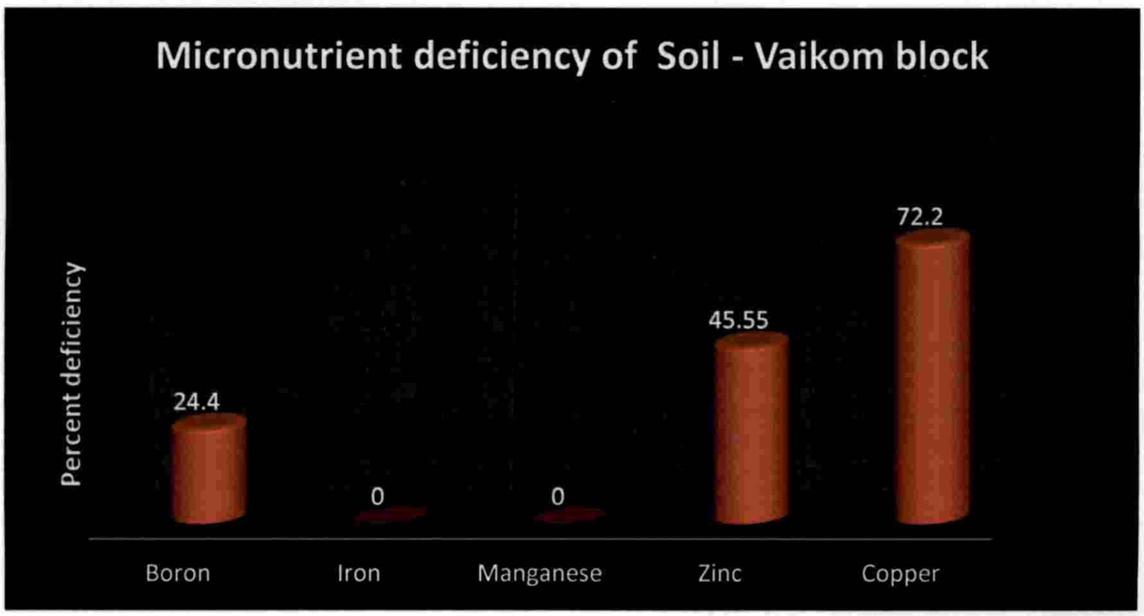

Fig 2. Micro nutrient deficiency in banana growing soils

5.2. NUTRIENT STATUS OF LEAF TISSUE

Index leaf tissue of banana collected during fourth month after planting was analysed. The nutrient content was compared to the respective soil samples collected from Vaikom. As per studies critical level of nitrogen in banana plant is 2.3 per cent (IFA, 1992) and 26.67 per cent samples falls under this lower critical level. The nitrogen content was low which is due to the low available nitrogen content in soil and the values ranged from 1.89 per cent to 3.33 per cent. This again shows that even when organic carbon is high, it must not be taken as a relative measure to estimate available nitrogen in soil pool (Mini , 2013). In Vaikom block the available nitrogen content was lower even when organic carbon content was high at that area.

The phosphorus content in leaf ranged from 0.097 to 0.293 per cent and values were positively and significantly correlated with available phosphorus content of soil. Critical level concentration of phosphorus in leaf tissue is 0.13 per cent (IFA, 1992) and higher than it comes under optimum level. Due to very high phosphorus content in soil the corresponding leaf tissue also had adequate P content. Hence the uptake of P from soil pool was observed to be moderate. But higher levels of phosphorus induced deficiency of other nutrients like boron, zinc and sulphur in banana leaf tissues(Nair *et al.,* 2013).

Potassium content in leaf tissue was very low and about 73.33 per cent of the leaf samples were found to be deficient. Heavy rainfall and seasonal variation in water level results in leaching of potassium from soil and affects the uptake by plants. This was very evident from the field symptoms and the frequency of pest and disease incidence in the field. Extent of deficiency was very high in T.V. Puram, Vechoor and Thalayazham panchayaths of Vaikom block. Banana is a heavy feeder of potassium and the deficiency in soil severely affected the plant nutrient uptake. Similar results have been reported by IFA (1992) that when the potassium supply is limited in soil, a relative reduction in uptake of nutrients was observed. This holds good in the case of calcium, magnesium, zinc and copper.This occurs because the transport of these nutrients is impaired in xylem resulting in subsequent deficiency in leaf tissues.

Calcium content in leaf tissue was analysed and found that 55.55 per cent of the samples were deficient. According to Prevel *et al.*(1986) lower critical values ranges from 0.4 to 0.8 and most of the samples are coming in this lower critical range. Wide spread calcium deficiency resulted in increased susceptibility to pest and diseases due to lower membrane rigidity. Younger leaves and bunch emergence were found to be severely affected due to lower uptake and susceptibility to disease increased due to reduced membrane stability. It was also observed that reduced boron resulted in induced deficiency of calcium (IFA, 1992; Edmond *et al.,* 1997). This is due to the fact that boron is required for calcium uptake and movement from soil pool.

Leaf tissue analysis revealed that magnesium content in leaf tissue was found to be deficient in all the six panchayaths *viz*. Chembu, Maravanthuruth, Udayanapuram, T.V. Puram, Vechoor and Thalayazham panchayaths . The values were lower than the critical level of 0.3 to 0.4 per cent as per the studies of Martin and Prevel (1999). This might be due to higher concentration of manganese in the Vaikom region. According to reports of IFA (1992) higher manganese content in soil reduced the uptake of magnesium by 40 per cent. Acidic soil with low calcium content and leaching nature of the soil also contributed to the severe magnesium deficiency in soil there by reducing plant uptake.

Sulphur deficiency was not so common in Vaikom region and the critical level of sulphur in leaf tissue was 0.21 per cent according to studies by Prevel *et al.*(1986). The soils of Vaikom region was found to have higher content of sulphur due to inherent properties of soil and higher application of Factamphos as mentioned in farmers practice. This might have contributed to sufficient level in soil and thereby enhancing uptake by plants.

On assessing the micronutrient content, it was found that banana leaf tissue contained sufficiently high levels of iron and manganese in the leaf samples collected from Vaikom. According to Prevel *et al.* (1986), the critical level of iron and manganese in index leaf tissue was 100 mg kg^{-1} and 160 mg kg^{-1} respectively. Higher concentration of iron in leaf tissue is because of uninterrupted uptake of ions from soil pool. But higher iron content in soil is responsible for the reduced uptake of other nutrients especially zinc from soil resulting in deficiency in the leaf tissues.

About 72.2 per cent of soils were found to be deficient in copper but this deficiency was not reflected in the plants. This might be mainly because of application of copper based fungicides in banana plants for the control of fungal diseases. Leaf tissue analysis revealed that 31.11 per cent of the samples collected from the Vaikom region were deficient in copper and the critical range of copper in leaf tissue was 9 mg kg^{-1}.

In the case of zinc as well as boron, deficiency was seen in leaf tissue due to reduced uptake by plants. This might be due to lower concentration of zinc in soils of Vaikom block. About 45.55 per cent of the soil samples were found to be deficient and as a result uptake is reduced. Foliar symptoms were found in younger leaf and leaves became narrow with yellow- white strips appearing between the secondary veins. A zinc deficient leaf was found to be significantly smaller in size than normal leaf and leaf chlorosis was found in strips or patches. Another reason for zinc deficiency might be due to higher levels of phosphorus and iron in soil. Higher phosphorus content adversely affects Zn uptake by plants. Soil analysis data of Vaikom block revealed that iron content also inhibits zinc uptake by leaf tissue. Reports by IFA (1992) shows that, there was 20 per cent reduction in zinc uptake by banana due to higher concentration of iron in soil which exhibits antagonistic effect on uptake of other nutrient elements. Similarly high manganese content also reduce uptake of other cationic species.

The critical level of boron in leaf tissue was 11 mg kg^{-1} and more than 30 per cent of the samples falls below this critical level. The crop was affected in both vegetative and reproductive stage and resulted in heavy yield loss. Severe crinkling of leaves were seen and in many cases the leaves failed to emerge out and situation was worst during bunch emergence stage.

In Vechoor and Thalayazham panchayaths boron concentration was optimum in the soils but leaf tissues showed widespread deficiency. This might be due to phosphorus induced boron deficiency. Higher concentration of phosphorus in Vaikom region exhibits a competitive effect as both the nutrients are taken up in anionic form. This competition results in reduced uptake by plants even when the soil has sufficient quantities of available boron in soil pool (Edmond *et al.,* 1997). Thus leaf tissues contain lower boron affecting growth of younger parts and bunch emergence. Since boron is required for root development and plant strength, deficiencies often increase the likelihood of fungal diseases and reduce the plants tolerance to diseases.

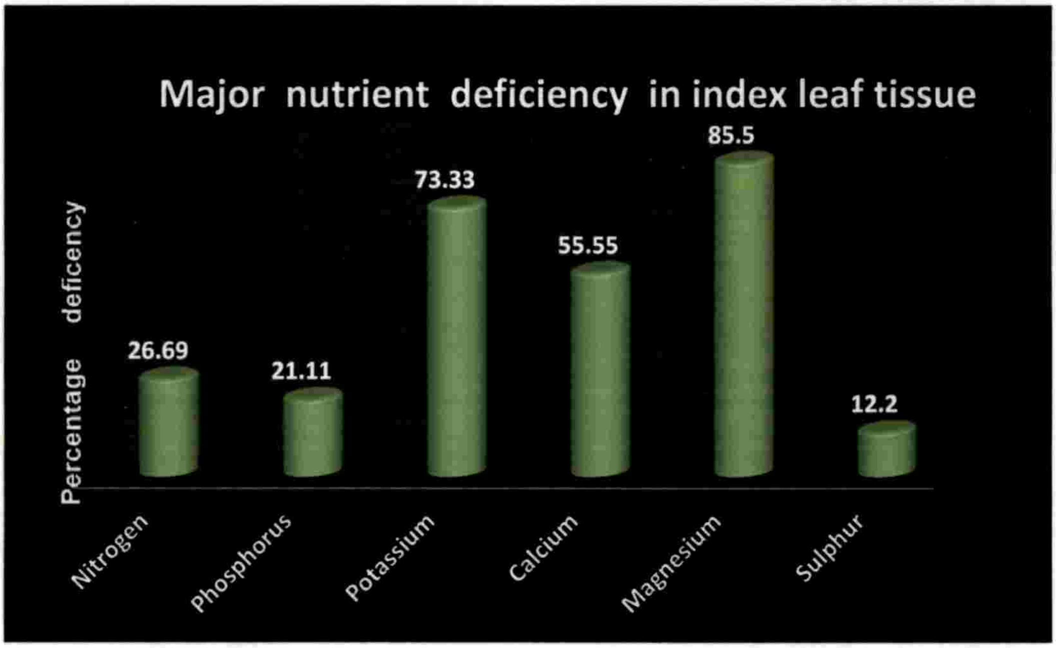

Fig 3. Major nutrient deficiency in banana index leaf tissue

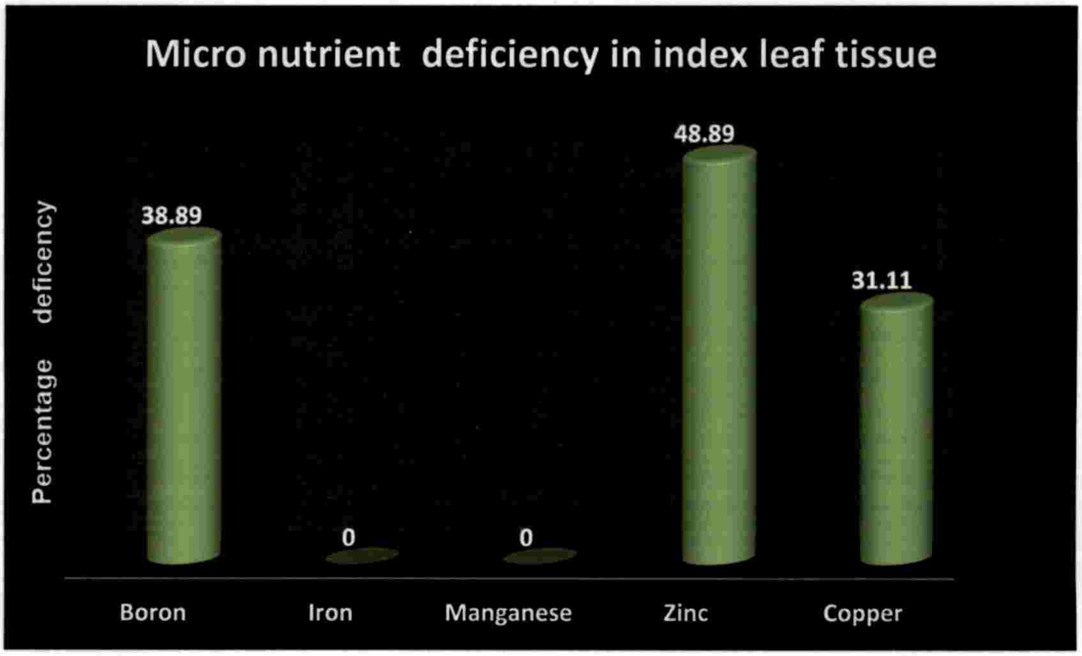

Fig 4. Micro nutrient deficiency in banana index leaf tissue

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5.3. INCIDENCE OF PEST AND DISEASE

Observation on the incidence of pest and disease revealed that the pest and diseases were common in field where severe nutrient imbalances seen. About 87 per cent of the fields showed severe yield loss due to either pest or disease. The major pests reported in the field were banana pseudostem weevil (*Odoiporus longicollis*) and banana rhizome weevil (*Cosmopolites sordidus*). The occurance were severe in fields were potassium, calcium, magnesium, boron, zinc and copper deficiencies were seen. It was either due to individual or multiple deficiency.

Occurance of disease was also significantly correlated with nutrient imbalance observed in Vaikom block. Most of the fields in the block reported the incidence of sigatoka leaf spot and other viral diseases. The combined deficiency of potassium, calcium, magnesium, boron, zinc and copper is found to have an effect in this scenario.

Magnesium deficiency was very severe in Vaikom block and interveinal chlorosis of older leaves was also observed in these areas. The yellowing and low chlorophyll content in diseased and virus affected plants might be due to the lower levels of magnesium in soil pool since magnesium plays a fundamental role in export of photosynthates. Similar trends were observed by Bertamini *et al.* (2003). The relative deficiency would restrict the partitioning of dry matter between roots and shoots to result in accumulation of excessive sugar , starch , amino acids *etc.*in chlorophyll break down and over reduction in the photosynthetic electron transport chain and generation of highly reactive oxygen species (ROS) because of impairment in photosynthetic CO_2 fixation as reported by Cakmak and Kirkby (2008).

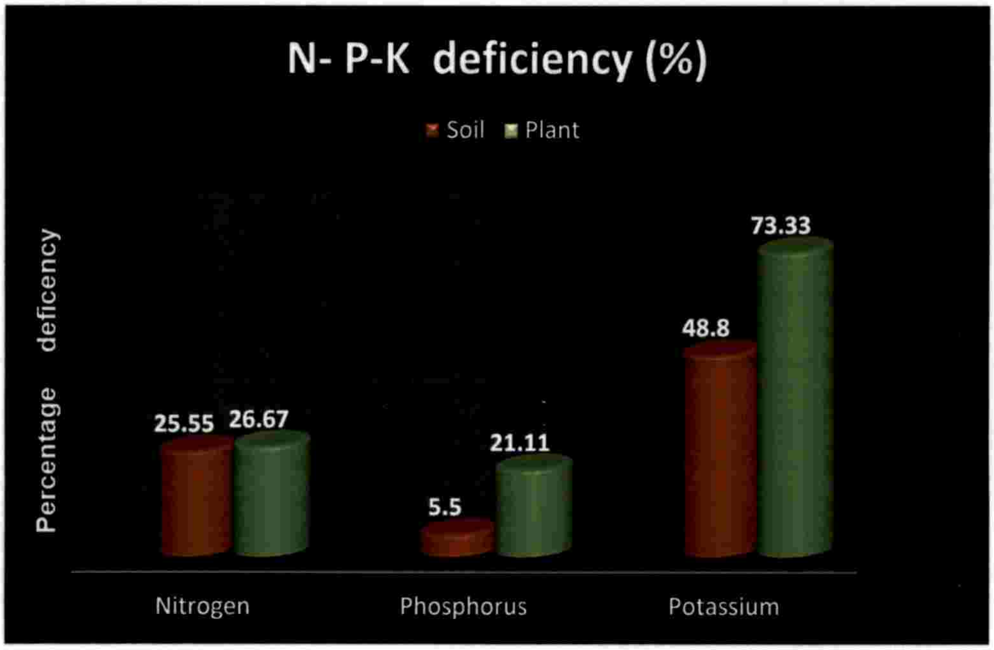

Fig 5. Extent of major nutrient deficiency in soil and plant

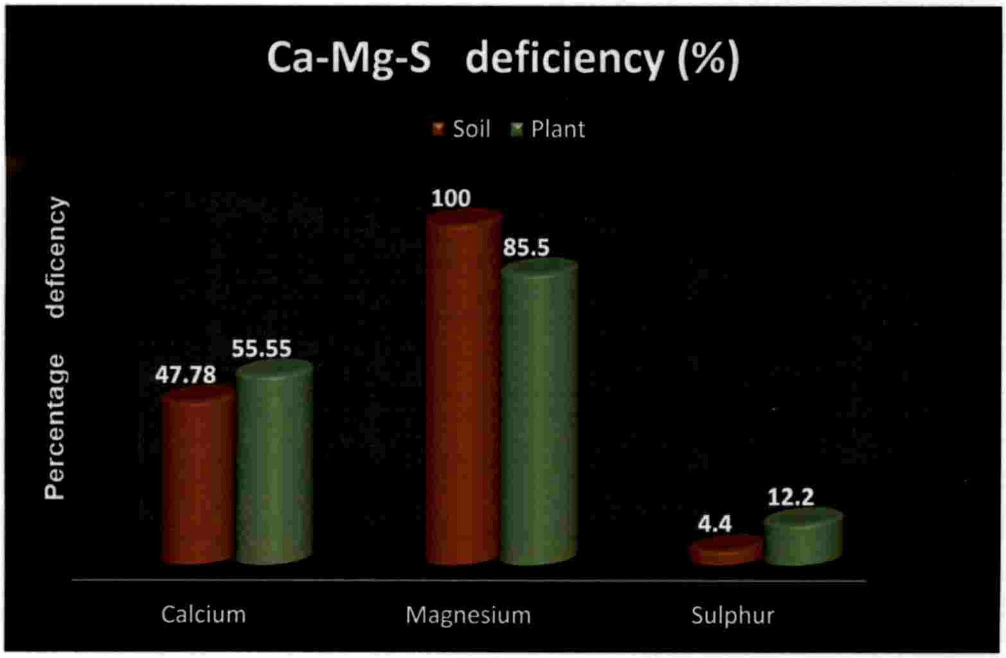

Fig 6. Extent of Secondary nutrient deficiency in soil and plant

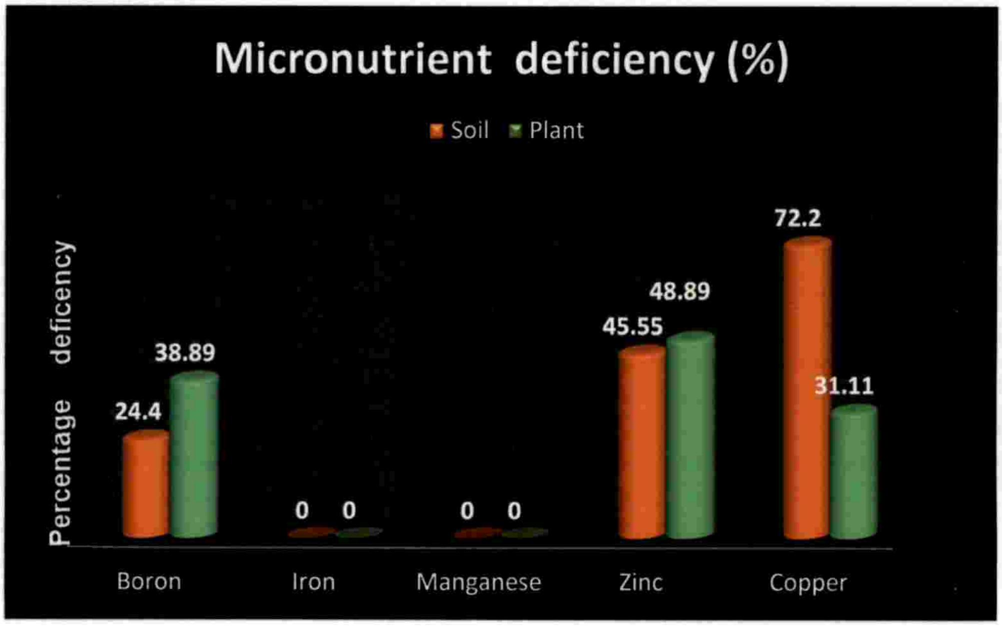

Fig 7. Extent of micro nutrient deficiency in soil and plant

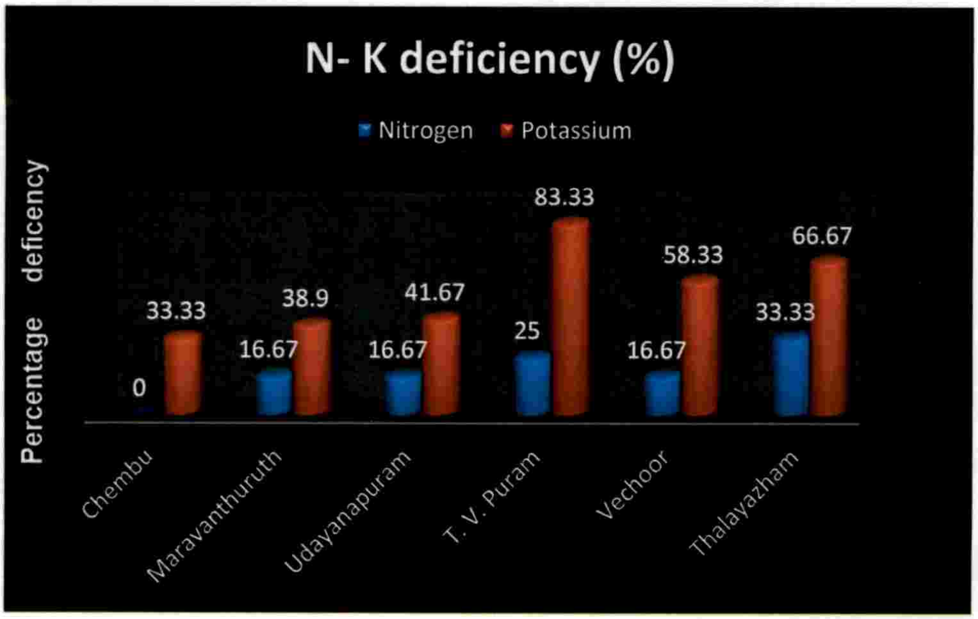

Fig 8. Extent of nitrogen –potassium deficiency

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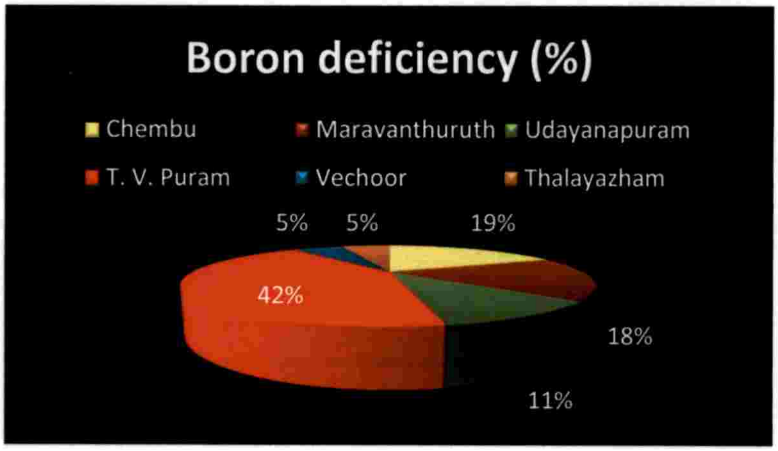

Fig 9. Extent of boron deficiency in Vaikom block

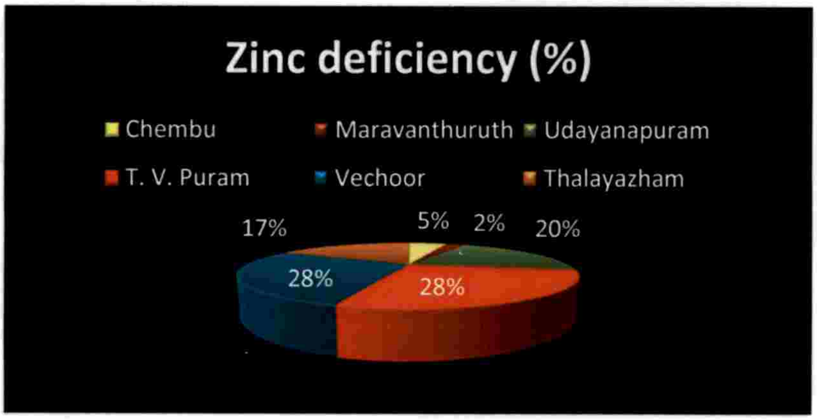

Fig 10. Extent of zinc deficiency in Vaikom block

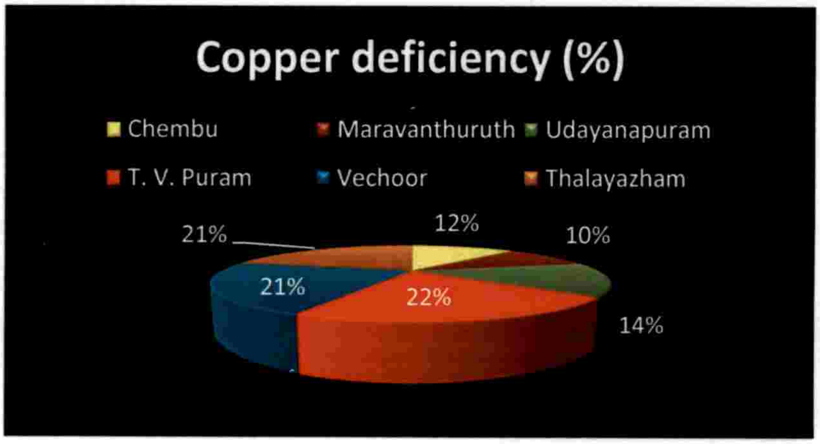

Fig 11. Extent of copper deficiency in Vaikom block

Summary

6. SUMMARY

The salient findings of the present study entitled "Major nutrient disorders of Banana (var. Nendran) in Vaikom Block" are summarized in this chapter.

The study was carried out with the objective of evaluating the variations in fertility status of banana growing soils and to assess the nutrient status of index tissue of banana (var. Nendran). It also aimed to catalogue the nutrient disorders of banana in the region and document the nutrient management practices in farmers' field

As part of the study preliminary survey was conducted in the six locations of Vaikom block. The major banana growing tracts were identified and soil samples for initial analysis were collected on a random basis from six panchayaths coming under Vaikom Block viz. Chembu, Maravanthuruth, Udayanapuram, T. V.Puram, Vechoor and Thalayazham. About 120 samples were collected from the block altogether and scrutinized to ninety samples based on previous history of nutrient deficiency in the area. Leaf samples were also collected from the area of study during the fourth month after planting.

The samples were analyzed for pH, EC, organic carbon, available nutrients such as N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn and B. The index leaf tissues were also analysed for major and micronutrients.

In general nutrient status of the soils under study revealed that soils were acidic in nature with 13.33 per cent of the soils very strongly acidic, 17.78 per cent strongly acidic, 41.11 per cent moderately acidic and 27.77 per cent slightly acidic. The acidic nature of soils of Kerala are due to high in iron, aluminium and manganese indicating high sesqui-oxide contents. Toxic levels of these elements are often observed in wetlands and deficiency of these elements has been very rarely reported.

The organic carbon status of the soil was very high and it ranged from 0.18 to 3.25 per cent. Only 20 per cent of the samples were deficient in organic carbon. Out of the six panchayaths coming under Vaikom block, highest organic carbon content was recorded in Chembu panchayath, which is due to the physiography of the area. It is bounded by the shores of the Lake Vembanad, and is crossed by various distributaries of the river Muvattupuzha.

Available nitrogen content of the study area revealed that 25.55 per cent of the samples were deficient and rest was found to have medium status. Though the organic carbon content was sufficiently high in the block, the estimated available nitrogen was not in accordance with organic carbon content of the corresponding area.

On observing the available phosphorus content of the soil samples from study area , it is very evident that the phosphorus content was very high in the soils. This is due to the fact that farmers used to apply high levels of P fertilizers especially Factamphos and bonemeal throughout the crop season.

The results on available potassium content revealed wide spread deficiency in Vaikom region. About 48.8 per cent of the samples collected from this area were found to be deficient in potassium. Lower application of potash fertilizers and leaching of potassium from soil pool due to rainfall make it less available to plants. The unscientific nutrient management practices by the farmers' aggravate the situation.

Available calcium content showed variation among the panchayaths and deficiency was reported to be more in Thalayazham and Vechoor panchayaths. Almost 50 per cent of the soil samples collected from Vaikom block showed calcium deficiency. A wide spread deficiency for available magnesium was felt in the whole block whereas sulphur content was sufficiently high. This also relates to heavy application of phosphatic fertilizers by the farmers especially factamphos which contain sulphur in addition to nitrogen and phosphorus.

On analyzing the data, the general trend observed was higher levels of iron and manganese content in the soils. The boron status of soil revealed that the extent of deficiency in Vaikom block was 24.4 per cent and maximum deficiency was reported in T. V. Puram panchayath (42%). Induced deficiency was observed in certain regions of Vechoor and

Thalayazham panchayath. The induced deficiency was due to higher levels of phosphorus in the soil.

Wide spread deficiency of 45.55 per cent was observed in case of zinc and was severe in T. V. Puram and Vechoor panchayaths. Zinc deficiency was comparatively lower in Chembu and Maravanthuruth panchayaths. Heavy input of phosphatic fertilizers might have ensured adequate level of zinc in the study area as zinc occurs as a contaminant in phosphatic fertilizers. With regard to copper, 72.2 per cent of the soil samples were deficient and were below the critical level of 1 mg kg^{-1}. Deficiency was more pronounced in T. V. Puram, Vechoor and Thalayazham panchayaths.

The index leaf tissue was analysed for major and micronutrients and among the major nutrients nitrogen and potassium deficiency was very prominent whereas phosphorus was found to be sufficient. The nitrogen content in leaf tissue ranged from 1.89 per cent to 3.33 per cent whereas the adequacy level of N in banana leaf was 2.3 per cent. As per this critical level , 26.67 per cent leaf samples were found to be deficient in nitrogen. Deficiency symptoms were observed in the area of study.

The phosphorus content in leaf ranged from 0.097 to 0.293 per cent and around 79 per cent of the leaf samples were having nutrient content more than the critical level of 0.13 per cent. The deficiency symptoms of phosphorus were not observed in the study area.

Potassium content in leaf tissue was very low and about 73.33 per cent of the leaf samples were found to be deficient. This was very evident from the field symptoms and frequent occurrence of pest and disease in the field. Extent of deficiency was very high in T.V. Puram, Vechoor and Thalayazham panchayaths of Vaikom block. Potassium deficiency was very prominent in the field and yellowing and necrosis of leaves starts at the leaf margin and reaches midrib during severe deficiency. In later stages leaf desiccates and typical curling occurs.

Calcium content in leaf tissue was analysed and found that 55.55 per cent of the samples were deficient. As per the critical levels of IFA, it was evident that these samples were coming under this lower critical range of 0.4 per cent. Wide spread calcium deficiency added to increased susceptibility to pest and diseases due to lower membrane rigidity. Deficiency of calcium was acute in the soils and field symptoms were observed. Calcium deficiency appeared as yellow-white parallel streaks in the leaf lamina parallel to the midrib accompanied by severe crinkling of leaves.

Widespread deficiency of magnesium was observed in entire Vaikom block. The magnesium content in leaf was lower than the lower critical range 0.3 - 0.4 per cent. The field symptoms of magnesium deficiency were very prominent in the area of study. Here the older leaves in the plants showed typical yellowing of central part of leaf lamina, while the margin and mid rib still remained green.

Sulphur content in leaf tissue revealed that 12.2 per cent of the samples showed sulphur deficiency though field symptoms were not so prominent. The critical level of sulphur in banana leaf tissue was 0.21 per cent and sulphur content of most of the leaf samples were found to be sufficiently high.

The micronutrient content was studied and found that banana leaf tissue contained sufficiently high levels of iron and manganese. The critical level of iron and manganese in index leaf tissue was 100 mg kg^{-1} and 160 mg kg^{-1} respectively. Deficiency was not observed in the study area.

Calcium – boron deficiency was wide spread and field symptoms were prominent in the entire Vaikom block. In all the six pachayaths of Vaikom, either individual deficiency of these elements or combined deficiency were observed. The critical level of boron is 11 mg kg^{-1} and samples below this were classified as deficient. Boron deficiency was observed in 38.89 per cent of the leaf samples and these plants showed delayed unfolding of leaves along with deformation. Uneven and brittle leaf surface with 'ladder like' symptoms were also noticed in these plants where both calcium and boron were deficient. The deficient leaves were found to be pale white in colour.

The critical level of zinc is 20 mg kg^{-1} and leaf analysis data revealed that about 48.89 per cent of the samples were deficient in zinc. But the field symptoms were not so prominent in the area under study. On analysis of leaf tissue, 31.11 per cent of the leaf samples were found to be deficient in copper. According to IFA, the critical level of copper in leaf tissue is 9 mg kg^{-1} and leaf tissues having lower content than critical level were classified as deficient. But the field symptoms were not so prominent in the Vaikom region.

The farmers in Vaikom block were following unscientific nutrient management practices except few farmers in Maravanthuruth and Chembu region. Even though the soils were acidic, most of the farmers were not following liming practices. Soil testing was not done in most of the cases. Banana being a nutrient exhaustive crop, long term cultivation over the same piece of land resulted in low fertlity status of the soil. Farmers used to apply poultry manure in addition to NPK fertilisers. They depend on complex and mixed fertilisers with out considering the nutrient status of the soil. General trend observed in Vaikom region was application of mixed fertilizers like 8:8:16 or 18:18:18. They give more thrust to phosphatic fertilisers like Factamphos and bone meal, but quantity applied varied among farmers . The nutrient application were not according to soil test data. The farmers were unaware of the importance of secondary and micronutrients and rarely apply these nutrients.

Investigation of the data revealed that the incidence of pest and diseases were common in field where severe nutrient imbalances were seen. About 87 percent of the fields showed severe yield loss due to either pest or disease. The major pests reported in the fields were banana pseudostem weevil (*Odoiporus longicollis*) and banana rhizome weevil (*Cosmopolites sordidus*). The occurrence were severe in fields were major, secondary and micronutrients were deficient. This is one of the contributing factors for the severe pest and disease incidence in the region. Similarly, occurrence of disease were observed in regions were imbalanced fertilser application were carried out. The incidence of sigatoka leaf spot and leaf blight diseases were also prevalent in the Vaikom block.

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MAJOR NUTRIENT DISORDERS OF BANANA (var. NENDRAN) IN VAIKOM BLOCK

by

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Abstract of the thesis

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ABSTRACT

The research programme entitled "Major nutrient disorders of banana (var. Nendran) in Vaikom block" was carried out in various locations of banana growing areas in Vaikom, during 2015–2017. The study was conducted with the objective of finding out nutrient disorders of banana through a preliminary field survey followed by analysis of soil and plant for nutrient contents. The reasons for low yield and productivity of banana in the area of study were also investigated to identify the nutritional causes behind it.

As part of the study, a survey was conducted to identify the major banana growing tracts of Vaikom region and soil samples were collected randomly from six locations in six panchayats of Vaikom block where visible symptoms were observed and nutrient deficiencies were suspected. Soil samples were collected during the first month after planting before fertilizer application from Chembu, Maravanthuruth, Udayanapuram, T. V. Puram, Vechoor and Thalayazham panchayaths. The samples were analyzed for physicochemical parameters like pH, electrical conductivity, organic carbon, available nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and boron (B). The index leaf tissues of banana were also collected from the study locations during the fourth month after planting and were analyzed for major and micro nutrients.

Results on soil acidity showed that the intensity of acidity varied from very strongly acidic to slightly acidic. About 13.33 per cent soils were very strongly acidic, 17.78 per cent strongly acidic, 41.11 per cent moderately acidic and 27.77 per cent slightly acidic. The electrical conductivity was found to be normal in these tracts at the time of sampling. High organic carbon status was observed in 35.56 per cent of the samples.

Available phosphorus was adequate in the soils, but nitrogen and potassium were found to be deficient. About 48.8 per cent of soil samples were deficient in potassium and visible symptoms were prominent in the fields with necrosis of leaves starting from the leaf margin and extenting towards the midrib. Deficiency of calcium and magnesium was acute in

the soils where field symptoms were observed. Calcium deficiency appeared as yellow-white parallel streaks in the leaf lamina parallel to the midrib accompanied by severe crinkling of leaves. Soil and plant analysis data revealed that micronutrient deficiencies were also widespread in the region. The symptoms of boron deficiency were prominent in the study area where plants showed delayed unfolding of leaves. Uneven and brittle leaf surface with 'ladder like' symptoms were also noticed in these plants.

Nutrient management practices followed by the farmers in Vaikom block influenced the fertility status of soils to a certain extent. Majority of the farmers were unaware of the scientific nutrient management practices and rarely applied secondary and micro nutrients. As banana is a nutrient exhaustive crop and continuous cultivation in the same piece of land resulted in severe nutrient mining. These factors might have led to the poor yields obtained in these areas.

It was concluded that the nutrient disorders observed in field were due to deficiency of both major and micro nutrients. Multi- nutrient deficiencies identified in the banana growing areas might be the major reason for decline in productivity. Scientific nutrient management based on soil and plant health can alleviate the nutrient deficiencies and enhance the crop yield.