# ROLE OF BORON IN PLANT NUTRITION IN KERALA IN RELATION TO ITS CONTENT IN SOILS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Role of boron in plant nutrition in Kerala in relation to its content in soils" is a bonafide record of research work done by me during the course of research and that the thesis has not been 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.

Vellayani,
29th June, 1985.

( SURESH, P.R. )

CERTIFICATE

Certified that this thesis entitled "Role of boron in plant nutrition in Kerala in relation to its content in soils" is a record of research work done independently by Sri. SURESH, P.R. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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# INTRODUCTION

# INTRODUCTION

Boron is one of the four essential elements that occur principally as anions, in soils. It is unique among the essential mineral nutrients because it is the only element that is normally present in soil solution as a non-ionized molecule over the pH range suitable for plant growth as shown by Oertli and Grgurovic (1975). The essentiality of this element was first reported by Maze (1914). Many scientists are of the view that boron in soils generally occur in molecular form ($H_3BO_3$) and it is passively absorbed by plants and distributed through the transpiration stream. So it does not participate in the metabolic activity associated with the ion uptake and accumulation in roots.

Boron deficiency in crops is correlated not only with the amount of boron in the soil, but also with other soil factors, species of crops and fertilizer practice. Because of high solubility of potassium tetraborate, heavy addition of potassium to soils should increase the availability of boron in the soil to the plants.

The original source of boron in most well drained soils is tourmaline. Acid rocks and metamorphosed sediments are the main sources of tourmaline (3 to 4 per cent boron) in soils. Boron can substitute for tetrahedrally co-ordinated silicon in some minerals. It is likely that much of the boron in rocks and soils is dispersed in the silicate minerals in this way and would be available only after long periods of weathering (Norrish, 1975). Most of the boron in soils that is available to the plants is derived from sediments or plant residues (Bowen, 1977). Soils formed from marine sediments are likely to contain more boron than those formed from igneous rocks.

Because of its non ionic nature once boron is released from soil mineral, it is subject to leaching from soil, fairly rapidly. That is why soils in high rainfall areas are often deficient in boron. On the other hand the availability of boron decreases sharply under drought conditions. This has been partly attributed to a lower population of micro organisms that can release boron from parent materials. It is also true that sufficient moisture may not be available to dissolve boron under such conditions and causes its absorption into the plant stream along with water.

Total boron and available boron are the two major fractions of boron present in soils. The total boron content of most soils vary from 20-200 ppm. Hot water soluble boron, which is considered to be the available fraction, varies from 0.38 to 4.67 ppm. Generally less than 5 per cent of the total boron is found to be available to the plants.

In plants boron is not readily translocated from older to meristematic region. So when a deficiency occurs the first visual symptom is the cessation of growth of terminal bud followed shortly by the death of the young leaves. The youngest leaves become pale green, losing colour at the base than at the tip. The basal tissues break down and if growth continues, the leaves present a one sided or twisted appearance. Usually the leaves die and terminal growth ceases. The borate ion has an unusual affinity for polyhydroxyl compounds with ortho configurations. Because of this, plus a wealth of experimental evidence that has accumulated, it has been suggested that boron can account for four distinct roles or regulatory mechanisms in many plants.

1. Translocation of sugars across the membrane.
2. Regulatory effects on oxidation by polyphenolase activity.
3. Modifications of equilibrium in phosphate ester metabolism.
4. Influencing extent of catalytic effects of O-diphenols in cell metabolism, including the inhibition of the activity of indoleacetic acid oxidase and possibly promoting pyridine nucleotide quinnole reductase activity which is especially high in roots.

No systematic investigations regarding the role of boron in plant nutrition, in Kerala, has so far been carried out. The boron content of either the soils or plants of Kerala has never been systematically studied by any author. There has also not been any report of wide spread boron deficiency in any crops in the State. The possibility of a hidden hunger with considerable yield reduction existing in the case of many crops, cannot be ruled out. There are reports that the boron deficiency in coconut results in the failure of unfolding of leaves, and that the condition could be corrected by the application of borax. Whether there is any reduction in yield due to this phenomenon is a question yet to be answered. The present investigation was taken up with a view to assessing the boron status of four major soil types of Trivandrum district and also of two crops namely coconut and banana growing in these soils. This investigation was taken up only as a preliminary step, which may lead to a furthering of the knowledge regarding the boron status of soils and plants, which in turn may help further investigators in formulating corrective measures.

# REVIEW OF LITERATURE

## REVIEW OF LITERATURE

Boron, which was included as an essential nutrient for plants after 1914, is an important micronutrient in many places. Very little work has been done on this element in India. There are many constraints in conducting experiments with this element. The major one being the contamination with boron during analysis wherever borosilicate glasswares are used. Yet, a lot of work has been carried out in many foreign countries, regarding its role, soil content and other factors influencing availability. In the present chapter a brief review of the works done on various aspects such as the role of boron in plant nutrition, in relation to soil content, factors governing availability, individual crop requirement and other plant factors controlling boron uptake is presented.

### 2.1. Role of boron in plant nutrition and deficiency symptoms

The essentiality of boron was first mentioned by Maze (1914) in maize crop.

Harris and Brolmann (1965) reported that in peanuts the boron deficient plants showed stubby leaves which were frequently mottled and they developed dark areas in the internodes. The root also showed malformations. The plants which were given boron amendments were free of these malformations.

Norton (1965) described the early symptoms of boron deficiency in banana as the appearance of scattered slightly chlorotic streaks crossing primary veins in the leaf lamina. In acute cases there were interveinal chlorosis and incomplete leaf formation. Such plants responded rapidly to boron application.

Davis and Pillai (1966) after a fertiliser trial concluded that boron increased yield of root (wilt) affected palms and the leaves of diseased plants contained more boron than those of healthy palms after boron application.

Moley <u>et al</u> (1969) observed an increase in yield of cotton in a boron deficient sandy loam soil when it was applied in combination with nitrogen. They have also observed that increased boron application increased the boron content of the plant tissue.

Sadberry <u>et al</u> (1969) based on their experiment conducted over a period of five years suggested that cotton yields were significantly increased by application of boron at the rate of 1 Kg/ha.

Melyubova and Borozhkina (1970) in a sand culture experiment observed that the deficiency of boron inhibited the movement of sugars from the leaves to the roots and also from the conducting tissues of the roots to the storage tissues. But no deficiency symptoms were observed, which indicated a condition of hidden hunger.

Shatilov and Ikinnikov (1969) reported that the application of boron could decrease the harmful effect of drought on pollen viability and the fat content of seeds in sunflower.

Rajaratnam (1972) studied the destribution of boron in oil palm and observed that older leaves had higher boron than younger leaves which confirms the fact that boron is immobile.

Alagarswamy and Rao (1973) noticed an increased uptake of oxygen by the leaves which led to a decrease in the level of reducing sugars and total carbohydrate when plants were grown in cultures containing 1 ppm boron which was greater than the amount possible in normal soil cultures.

Kalichava and Sherstnev (1974) studied the differences in protein composition of normal and boron deficient plants and suggested that boron plays a role in structural organization of the rhibosomes which is the starting point of protein synthesis.

Merkel (1975) studied the effect of boron on the cation-anion equilibrium in tomato plants. He found that boron deficiency resulted in a decrease in the nitrogen and potassium contents. But it increased citrate and malate concentration and decreased oxalate and pectinate content.

Shkoliniknja and Maevskaya (1977) in an experiment showed that the nature, content and activities of phenolic compounds in plants are the main causes of their different reaction to boron deficiency. Monocots are less sensitive to boron difficiency than dicots. They emphasised the view that monocots having higher poly phenol oxidase activity are more sensitive to boron deficiency.

Singh (1977) based on his trial on mango found out that foliar sprays of boric acid upto 0.8 per cent increased leaf number and dry weight of leaves significantly. Leaf nitrogen was also increased but higher doses reduced leaf nitrogen content.

Smirnov et al (1977) in their experiment observed that boron deficiency led to a decrease in the content of free indole acetic acid in sunflower, bean and corn seedlings.

Silva et al (1979) in their experiment with different doses of boron in cotton plants grown in boron deficient soil observed a positive response to additional boron with respect to plant height, weight of bolls and seeds.

Roth (1981) observed that boron enhances stomatal opening in epidermal strips of Commelina communis. They suggested that boron acts either by reducing potassium leakage or by increasing its uptake thus leading to increased ostmotic potential and as a result of stomatal opening.

2.2. Soil content in relation to plant nutrition

Mathur et al (1964) reported that total and available boron levels were much greater in irrigated soils than in unirrigated soils. In irrigated soils the sub soil contained more available boron than surface layers. They also observed significant negative correlation with pH and available boron in irrigated soils.

Patel and Mehta (1966) based on their experiment on tobacco explained the interaction of calcium and boron and potassium and boron on availability of boron. They could correct the toxicity of boron by increasing the concentration of calcium and potassium.

Klenn and Bergmann (1966) observed significant correlation of available boron to soil type and pH. Soil pH correlated negatively with the available boron content of soil.

Park and Park (1966) suggested that the available boron of the different soil types showed a significant correlation with pH and organic matter content in the soil, pH being correlated negatively and organic matter content positively.

Galezynska (1967) reported that the total boron content of podzolic brown soils, peat soils and black earths were 3.65-33.5, 0.75-37.8 and 1.53-93.5 ppm respectively and the soluble boron contents were 0.02-1.7, 0.1-4.45 and 0.05-0.7 ppm respectively.

Paliwal and Anjaneyulu (1967) studied about the available boron status of alkaline soils. They observed significant positive correlation between exchangeable Sodium and boron, but there was no relationship between boron content and soil pH.

Sims et al (1967) based on their study reported that vermiculite, kaolinite, montmorillonite and hydrobiotite exhibited a marked pH dependant affinity for boron.

Sedberry et al (1969) conducted an investigation on boron nutrition of cotton in Louiseana and found a highly significant positive correlation between hot water soluble boron and boron concentration in leaves.

Zembaezyniski (1969) based on his investigation on the boron content of soils in Zaitona Gora province suggested that water soluble boron showed distinct negative relationship to soil pH. The water soluble boron was more abundant in alluvial soils and Chernozems than in brown soils.

Khan (1970) in a green house study with radish observed boron deficiency when the soils were limed to near neutrality. He concluded that this may be due to the increased calcium content of plants resulting from the higher uptake of calcium.

Nathani et al (1970) based on their studies on Rajastan soils observed a significant negative correlation between water soluble boron and soil pH,

Lodha and Baser (1971) in an investigation attempted to find out the relationship between available boron and pH of different soils of Rajastan, ~~and~~ they could not observe any relationship between the factors like pH, E.C., ~~and~~ potassium and Ca content of soils.

Singh and Bhandari (1971) observed significant positive correlation between available boron and pH in Vindyan soils. The average content of water soluble boron tended to increase with increasing $CaCo_3$ content of soil.

Hadas and Hagin (1972) in an experiment observed a significant adsorption of boron by soils when the soils were potassium saturated prior to the experiment. Langmuir equations indicated a greater strength of adsorption of boron by potassium saturated soils.

Rathore et al (1973) based on their research on Agra soils found out that available boron in soils were positively correlated with pH and negatively correlated with organic matter.

Talati and Agarwal (1974) studied the available boron status of Rajastan soils in relation to other soil factors and they observed significant negative correlation with $C_aCO_3$ and positive correlation with pH.

Khan et al (1979) observed a significant positive correlation between soluble boron in soil and the plant boron in 33 crops in Lebanese soils. Higher content of soluble boron in soils always resulted in higher concentration of boron in plants.

Awad and Mikhael (1980) in a study on Egyptian soils observed significant positive correlation between organic matter and available boron. But they could not observe any correlation between available boron and factors like calcium content and soil pH. They proposed that these may be due to the low amount of calcium found in most of the soils investigated and the highly buffered nature of these soils.

Dudziak and Bednarek (1980) based on their studies on chernozems obtained no significant correlation between available boron and soil factors like pH, calcium and organic carbon content.

## 2.3. Factors governing availability of boron

Maurice and Troeme (1965) from an experiment found that liming of the soil decreases plant availability of boron due to the decrease in the content of water soluble boron in soil after liming.

Buchel and Begmann (1966) reported that boron content of plants decreased with increasing clay content. They also emphasised that negative effect of high pH values on the boron supply to plants decreases with increasing clay content of the soil.

Majewski and Jamiszowske (1966) in an experiment on beet and mustard observed greater uptake of boron at higher soil moisture levels. The uptake of boron was less when lime was applied.

Patel and Mehta (1966) in a experiment on tobacco found that boron deficiency symptoms increased with increasing Ca/B on K/B ratios. The nitrogen content in the leaves was lowest, with higher Ca/B and K/B ratios.

Halcher et al (1967) reported that the surface area over which the aluminium hydroxide is spread is an important factor in the adsorption of boron. In soils having a pH value ranging from 6.3 - 8.3 boron concentration showed a high correlation with surface area and citrate soluble aluminium content. Lime induced boron deficiency, according to them, resulted from the additional absorption by aluminium hydroxide precipitated after liming.

Martens (1968) suggested that boron uptake in maize was best produced by the concentration of water soluble boron in the soil and pH of the soil. He also emphasised that boron bound by soil organic fractions was a sink of water soluble boron.

Goralski (1969) in a study to find the influence of systematic liming of soil on the content of water soluble boron observed an increase of water soluble boron from 0.25 - 0.30ppm in unlimed plots to 0.35 to 0.36 ppm in limed plots.

Cornillon (1970) reported that addition of organic matter such as cellulose caused a rapid initial increase of hot water soluble boron and decreased later. The addition of straw did not produce any effect.

El-Kholi et al (1970) suggested that extractable boron was significantly and positively correlated with total soluble salts, soluble calcium, $CaCO_3$ and organic matter content, but not with silt or clay content.

Gupta (1972) in a study to find the interaction effect of boron and lime on barley observed that higher rates of lime decreased kernel yields at boron levels of 0.5 ppm and increased the yields at 2.0 and 4.0 ppm. The optimum Ca/B ratio was found to be 180.

Stoyanov (1973) reported that boron sorption is closely related to sorption capacity, percentage clay, degree of base saturation and humus content and to a lesser extent to the content of free oxides of iron and aluminium.

El-Damaty et al (1974) reported that fixation of boron was generally greater in fine textured alluvial soils than in calcareous soils. There was a close relationship between boron fixation and surface area and amorphous oxide content of clay minerals. Maximum sorption capacities of boron in calcium saturated soils were 84, 96 and 102 mg for kaolinite, vermiculite and bentonite respectively.

Savic et al (1975) observed large variations in micro-nutrient levels especially manganese, copper and boron in the surface layers of different calcareous soils of Sarajevu. The lowest level of boron was found in samples with 20-50 per cent $CaCO_3$.

Scott et al (1975) emphasised the view that lime increased boron adsorption and boron diffusivity in silt loam soil.

Lime decreased the growth and development of cotton grown and the uptake of boron by cotton decreased until square initiation and then increased.

Peterson and Newman (1976) from an investigation found that availability of boron was relatively uniform with the soil pH in a range of 4.7 to 6.3 with significent reduction in availability at pH 7.4.

Maurice (1977) in an investigation to find the relationship between water extractable boron and pH, organic matter, clay, free iron and free aluminium found that the boron content was positively correlated to soil pH and organic matter content. The relationship with clay content, free iron and free aluminium were not significant.

Gupta (1978) found that the organic matter and clay content of soil appreciably affect the quantity of boron removed by different extractants; calcium chloride seemed to remove most of the boron adsorbed on the clays. None of the extractants was found to remove more than 6.5 per cent of the total soil boron.

Gupta and Mac Leod (1977) were of the view that in the absence of added boron, decrease in boron uptake appeared to be related to increased soil pH rather than the availability of Ca or Mg. In the presence of added boron this effect was not evident. Ca and Mg concentration in plant tissues were not affected by the application of boron.

From an investigation Blameg and Chapman (1979) found that application of lime and gypsum had little effect on the boron concentration in sunflower plant tissues. Liming upto pH 7.0 did not appear to be adversely affecting the uptake and translocation of boron. They concluded that the low boron concentration in seedling tops resulted from the dilution effect due to the benefit of liming.

Gupta and Mc Leod (1981) in a field trial to find out the influence of soil pH and calcium sources on plant and soil observed that boron concentration decreased with the addition of lime. They also reported that plant tissue boron was related to soil pH rather than amount of Ca. They found that liming induced boron deficiency.

## 2.4. Crop requirement and factors influencing Boron availability

Ishihara et al (1965) working on the nutrient balance of citrus plants observed that calcium has got a profound influence on boron content of leaves. They also suggested that by increasing Ca/B ratio the plants could be relieved from boron toxicity.

Mehrotra et al (1966) studied the boron nutrition of bhindi and observed that 0.5 ppm B in nutrient culture is sufficient for normal growth. Plant containing $< 35$ ppm B showed deficiency and plants containing $> 125$ ppm showed toxicity.

Tanaka (1967) observed that boron absorption by plants were markedly reduced with the increase in calcium concentration of the medium, but increasing phosphorus concentration increased boron uptake. He also observed that boron translocation from stem to leaves got inhibited by high calcium status in the stem tissues. The Ca/B ratio in sunflower plants was the best index of assessing boron deficiency according to him.

Keogh and Maples (1969) noticed significant yield increase and alleviation of growth abnormalities when boron was applied to loessial plain soils.

Meley et al (1969) obtained significant yield increase in cotton when boron was applied along with nitrogen. His study also showed that increased potassium application increased boron content of plants.

Overtli and Roth (1969) based on their experiment suggested that there is a wide variation among crops with regard to boron requirements. They also observed significant difference in different species of certain crops.

Tollenaar (1969) conducted studies on boron deficiency in sugarcane and oil palm on volcanic soils of Ecuador and found that the deficiency was not correlated with leaf boron contents, but Ca/B ratio had a greater influence in boron deficiency. He noticed that, with higher Ca/B ratios greater was the chance for boron deficiency.

Henriksen (1970) studied the boron content of various agricultural crops in Denmark and he estimated an annual removal of boron at 42 g/ha in cropped lands from an annual supply of boron at the rate of 156 g/ha supplied through manures, fertilisers and lime.

Tanaka (1972) in an experiment to investigate the behaviour of boron in soil-crop systems observed that application of CaCo3 increased boron adsorption by an acid mineral soil. Desorption occured when boron concentration in the soil solution decreased. The amount of boron released being reduced by lime application and soil drying.

Aduayi and Adeghito (1979) while studying the boron nutrition of okra plants observed that root application of 2 ppm boron, resulted in severe root burn and toxicity whereas in foliar boron application four ppm produced adequate growth. They also observed a significant and positive correlation between boron and phosphorus and boron and potassium. But the correlation of boron with calcium was significantly negative.

Blameg <u>et al</u> (1979) in field trials in South Africa observed yield increase as a result of boron application. He suggested that the critical concentration in the topmost leaf was found to be 32-35 ppm.

Margate et al (1979) in their trial with coconut seedlings of yellow Malayan dwarf x West African tall application of borax 0 1-8 g/seedling did not give any significant influence on seedling girth, leaf production and height. Tip burning increased with increasing borax rates. However they recommended low rates of borax application to prevent abnormal development caused by boron deficiency.

Rosenquist (1980) conducted a fertilizer trial on hybrid coconuts of Mawa (Port Bouet) and observed that all fertilizers applied to the plants reduced boron levels and at higher rates of fertilizer application boron deficiency may be a limiting factor on yield.

Kowalenko (1981) in an experiment studied the interaction of nitrogen and boron on rasp-berries. He observed that leaf boron content increased when boron was applied along with nitrogen. He also suggested that leaf tissue analysis is not suitable for determining the requirement of nitrogen and boron fertilizers because of instability of boron concentration in leaves within and between season.

# MATERIALS AND METHODS

# MATERIALS AND METHODS

The present investigation was undertaken with the main objective of assessing the boron status of major upland soils of Trivandrum district. The study was also aimed at assessing the boron content of two major crops in relation to other nutrients. The suspected boron deficiency symptom in coconut was also marginally investigated under the present investigation, while methods of alleviating the symptoms were nominally attempted. The details regarding the collection of soil and plant samples, experimental procedures, analytical techniques and procedures resorted towards alleviating deficiency symptoms are presented in this chapter.

## 3.1. Selection of site and observational plants

### Site selection

Four different soil types representing the major soil types of Kerala viz. forest soil, laterite soil, sandy soil and red soil were chosen for the present investigation. The areas were located after referring to the soil map of Trivandrum district and adopting suitable statistical methods. The different locations selected in each category are:

a) Forest soil

1. Anad Region
2. Pangode Region
3. Palode Region

b) Laterite Soil

1. Ulloor region

2. Madavoor region

c) Red Soil

1. Thiruvallam region

2. Parassala region

d) Sandy soil

1. Kazhakkootam region

2. Kaniyapuram region

3. Vizhinjam region

The number of samples collected from each of these regions are presented in table 3-1.

3.1.2. Observation of deficiency symptoms

The occurance of suspected boron deficiency in coconut as evidenced by uncleaved leaves was found to be scattered and very sporadic. These symptoms were mainly observed in red soil and sandy soils and rarely in laterite soil and seldom in forest soil tracts.

The boron deficient plants are reported to produce abnormal leaves. The leaflets are all webbed together and fail to unfold even after complete emergence. In some cases the leaves even turned yellow. The photographs of such plants are furnished. An important observation in this respect

Table 3-1. Regions selected for sample collection.

| Soil type | region | No. of samples collected |
|---|---|---|
| Forest soil | Anad | 20 |
| | Pangode | 15 |
| | Palode | 15 |
| Laterite soil | Ulloor | 30 |
| | Madavoor | 20 |
| Red soil | Thiruvallam | 25 |
| | Paressala | 25 |
| Sandy soil | Kazhakkoottam | 20 |
| | Kaniyapuram | 20 |
| | Vizhinjam | 10 |

Plate - 1. Photographs of deficiency suspected palms.

is that in a small region itself the occurance of the above symptoms was stray and not continuous. In some regions the affected plants returned to normalcy by producing normal fronds in rainy months and then reverting back to abnormality during the summer period.

3.2. Collection and preparation of soil and plant samples

3.2.1. Collection of soil samples

Surface soil samples (0-20 cm depth) were alone collected from the above region. Fifty samples each were collected from the four soil types so that a total number of 200 samples were collected and subjected to investigation.

3.2.2. Preparation of soil samples for analysis

The samples were serially numbered after giving necessary identification marks for each category, brought to the laboratory, air dried powdered with a wooden mallet and sieved through a 2 mm nylon mesh and then stored in plastic jars for further analysis.

3.3. Collection of plant samples

Leaf samples of coconut and banana plants were also collected from the 200 sites from which soils were collected. In the case of coconut palms showing suspected boron deficiency symptoms, they were marked separately and proper identification marks were given.

While collecting leaf samples from coconut, four middle leaflets each were taken from the two sides of the index frond.

In banana the upper half of the lamina including the midrib was sampled. The leaves were collected in brown paper envelopes and were serially numbered with the number of the corresponding soil sample.

3.3.1. Preparation of plant samples for analysis

The leaf samples were air dried for two days and then dried to constant weight in an air oven at 70 ± 5° C. These leaf samples were finely chopped, mixed and powdered using a procelain mortar and pestle. Then they were collected in serially numbered polythene covers and kept in moisture free desiccators.

3.4. Analytical procedures.

3.4.1. Methods used for soil analysis

3.4.1.1. Electro chemical properties

a) Soil reaction (pH)

The pH of the soil samples were determined in a 1:2.5 soil-water suspension using a Perkin Elmer pH meter with glass and calomel electrodes (Hesse. 1971).

b) Electrical conductivity (E.C.)

The electrical conductivity of the soils were determined by introducing a conductivity cell into the clear supernatant solution of the same soil suspension used for pH measurement using a direct reading conductivity bridge.

3.4.1.2. Chemical properties

a) Total Nitrogen

The total nitrogen status of the soils were determined by the micro-Kjeldahl digestion and distillation method using Parnas and Wagner apparatus (Jackson, 1973).

b) Available phosphorus

The available phosphorus content of the soil was determined by the chlorostannous reduced phosphomolybdic blue colour method in hydrochloric acid system, after extracting the soil with Bray No.1 reagent (Bray and Kurtz, 1945).

c) Exchangeable potassium

Exchangeable potassium was determined in the neutral normal ammonium acetate extract of the soil after destroying the organic matter by treatment with aqua regia, using an EEL flame photometer (Jackson, 1973).

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d) Exchangeable calcium and magnesium

From an aliquot of the aqua regia treated ammonium acetate extract, calcium and magnesium were determined in a Perkin Elmer 3030 Atomic Absorption Spectrophotometer.

e) Organic carbon

Organic carbon in the soil samples were determined by the method of wet digestion as proposed by Walkely and Black.

f) Exchangeable iron

Exchangeable iron in the soil samples were determined in the D.T.P.A. extract using a Perkin Elmer 3030 Atomic Absorption Spectrophotometer.

g) Available boron

Available boron in soils were extracted by refluxing a 1:2 soil water mixture for five minutes and then filtering the extract. The boron was determined colorimetrically in a Klett Summersion Photoelectric Colorimeter, after developing colour by treating the extract with curcumin then baking and dissolving the residue in alcohol.

3.4.2. Methods for plant analysis

3.4.2.1. Total Nitrogen

Total nitrogen in the plant samples was determined by microkjeldahl digestion distillation procedure as described by Jackson, (1973).

Preparation of plant extract

Triple acid extract was used for the determination of P, K, Ca and Mg in the leaf tissues (Johnson and Ulrich, 1959). For this 500 mg of the powdered leaf sample was digested with 10 ml of triple acid mixture. The digest was made upto 100 ml with distilled water, filtered and used for further analysis.

3.4.2.2. Phosphorus

From an aliquot of the triple acid extract of the plant sample, phosphorus was determined by vandomolybdo phosphoric yellow colour method in nitric acid system (Jackson, 1973).

3.4.2.3. Potassium

The triple acid extract was diluted and the potassium in the extract was estimated using an EEL flame photometer.

3.4.2.4. Calcium and Magnesium

Calcium and Magnesium in the plant extract was determined in a P.E. model 3030 Atomic Absorption Spectrophotometer, after diluting the extract.

3.4.2.5. Plant boron

One gram of the plant material was ashed after the addition of calcium chloride. The residue was extracted with hydrocholoric acid. Boron in the extract was determined colorimetrically using curcumin, the colour being read in Klett Summersion Photoelectric Colorimeter.

3.5. Observations made on the suspected boron deficient plants

The occurence of boron deficiency symptoms were stray. Such plants showed webbing together of the leaflets. In some plants all the leaves showed such symptoms. In others only the young leaves showed deficiency symptoms. Incertain plants the symptoms were pronounced during summer months whereas they reverted back to normalcy during monsoon periods. Samples from such affected plants, were collected for analysis. These plant samples were given proper identification marks enabling comparison with the apparently healthy plants.

3.6. Statistical analysis

The data on the nutritional status of the soil and the plants was subjected to statistical analysis. The available boron of the soil was correlated with pH, EC and other nutrient content of the soils. These analyses were done separately for each group of soils. The boron content in leaf samples were also correlated with the other nutrients, present in the plant tissue. The plant nutrient contents were again correlated with different soil parameters investigated. These analyses were done separately for coconut and banana.

The deficiency symptoms were located in a total number of 18 spots in red, laterite and sandy soils. These samples were taken out from the population and were subjected to the aforesaid correlation studies.

# RESULTS

# RESULTS

The results of physicochemical and statistical analyses of 200 soil samples and 200 each of coconut and banana leaf samples, collected from the sites of soil collection are presented in this chapter. The results of analyses were treated statistically to find out inter-relationships if any between the Physicochemical Properties of these soils and their boron content, physicochemical properties of the soils and boron content of plants growing on them, and also the correlation between the available boron of the soils and boron content of corresponding plant samples. Boron content of the four major soil types studied viz. red, laterite, sandy and forest soils were also compared.

The webbing together of leaflets in coconut is considered to be a sign of boron deficiency. This aspect was given due consideration in the present investigation, by grouping together those samples taken from such palms and working out their correlation with samples taken from apparently healthy samples. The different aspects of analyses, and the corresponding tables are given at the appropriate sections.

## 4.1. Soil analysis

Table 4-1(b) presents the averages of various physicochemical properties obtained from the soil analyses.

The influence of the various soil factors on the available boron content (hot water extractable boron) of the four major soil types found in Trivandrum district were studied separately through regression analysis. The boron content of the four different soil types were also compared by means of analysis of variance.

### 4.1.1. Available boron content (hot water soluble) of different soil types

The hot water soluble boron is taken as an index of available boron in the soil. The variation in boron content among different soils was statistically analysed by analysis of variance technique and the result is given in Table 4-1(a). It was observed that there was significant difference in boron content among the four soil types. The average boron content along with the other soil factors are presented in Table 4-1(b). From this it is clear that the available boron content was higher in the forest soil (0.86 ppm). In all other soils it was significantly low compared to the forest soil.

### 4.1.2. Interrelation of soil boron with other nutrients

The correlation coefficient of boron with other soil factors were determined and the relationship is presented

Table 4-1(a). Analysis of variance.

| Source | D.F. | M.S. | F. |
|---|---|---|---|
| Between soils | 3 | 0.3411 | 7.330 ** |
| Within soils | 196 | 0.0465 | |
| Total | 199 | | |

** Significant at 1 per cent level

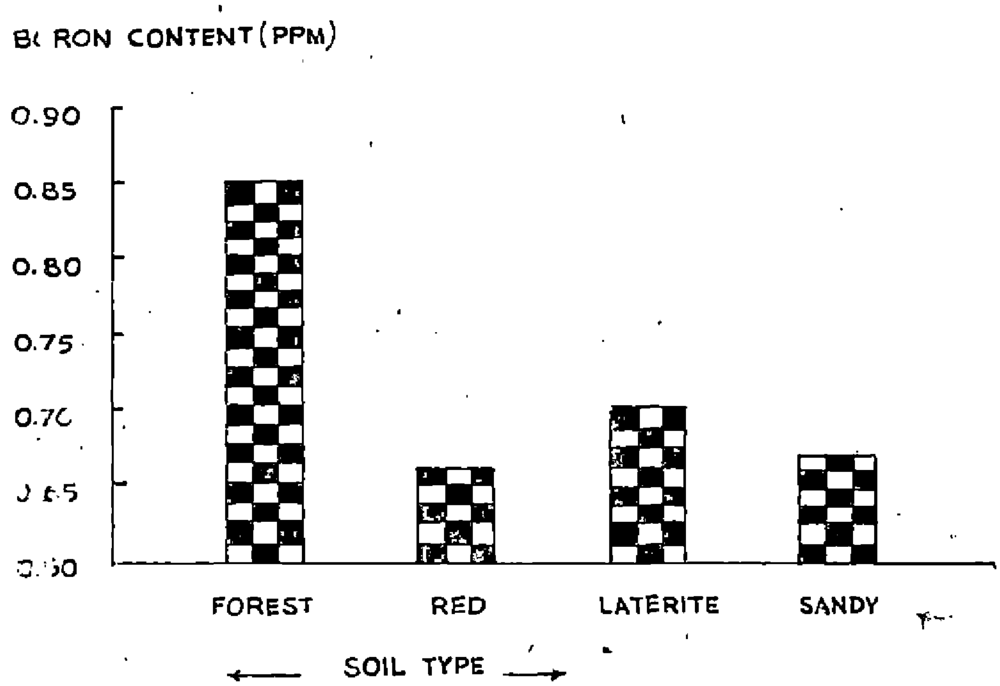
C.D. = 0.0845

Table 4-1(b). Nutrient status of various soil types.

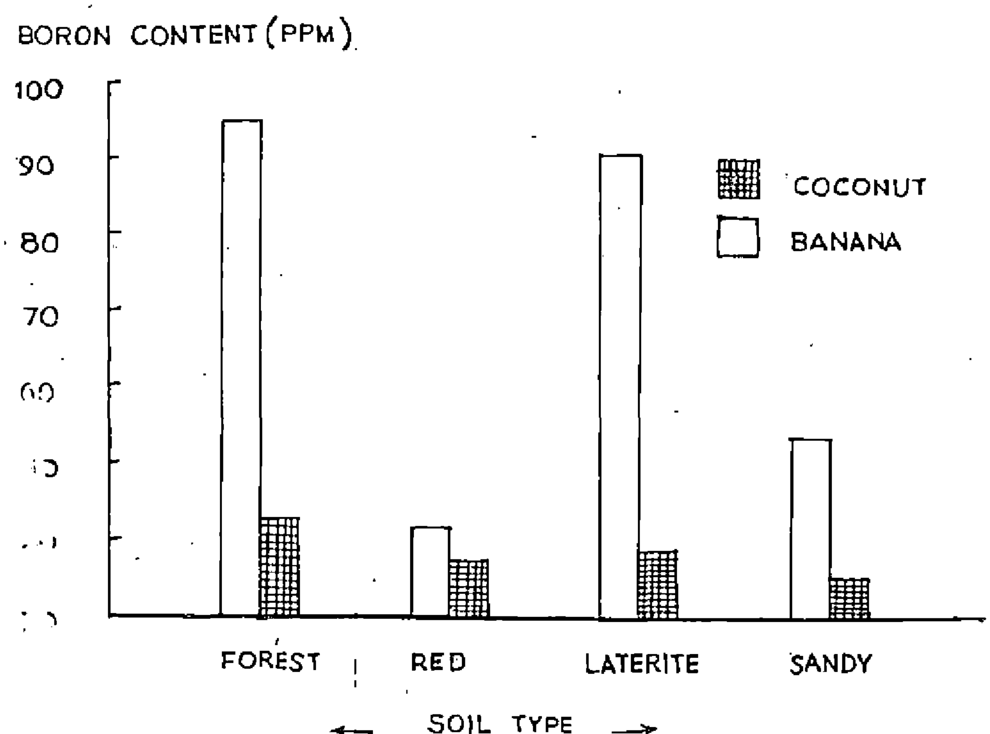
(Available nutrients)

| Soil type | pH | Total N% | $P_2O_5$ Kg/ha | $K_2O$ Kg/ha | Ca Kg/ha | Mg Kg/ha | Org. C. % | B ppm |
|---|---|---|---|---|---|---|---|---|
| Forest soil | 5.30 | 0.155 | 61.731 | 207.605 | 555.012 | 269.120 | 1.530 | 0.856 |
| Red soil | 5.61 | 0.111 | 53.837 | 176.040 | 309.150 | 256.542 | 0.653 | 0.664 |
| Laterite soil | 5.87 | 0.132 | 62.706 | 136.706 | 213.270 | 187.527 | 0.657 | 0.701 |
| Sandy soil | 5.87 | 0.105 | 63.231 | 96.962 | 154.476 | 73.443 | 0.393 | 0.670 |

PLATE - 2




SOIL BORON CONTENT IN DIFFERENT SOIL TYPES




PLANT BORON CONTENT IN DIFFERENT SOIL TYPES in table 4-2. From this table it is evident that in forest soils a significant correlation exist between available boron and soil pH (r=0.34), while all other factors were found to have no influence. In red soil and laterite soil none of these factors showed any relationship with the available boron. But in sandy soils a significant and positive correlation (r=0.36) was observed with organic carbon content of the soil and soil boron, but all the other factors behaved independently.

In taking all the soils together, as a general trend, N, P, K and Ca content of the soil did not show any relationship with the available boron status of these soils.

4.2. <u>Plant analysis</u>

The chemical analysis of the leaf samples of coconut and banana were conducted. The mean values of the various nutrient content are presented in table 4-3. (4.3-a for coconut and 4-3-b for banana)

4.2.1. <u>Boron status in leaves of banana and coconut</u>

The magnitude of boron in leaves of banana and coconut grown in different soil types was investigated. The analysis of variance of the data on 400 leaf samples is presented in Table 4-4(a).

Table 4-2. Correlation of soil boron with soil factors.

| Factors | Forest soil | Red soil | Laterite soil | Sandy soil |
|---|---|---|---|---|
| pH | 0.5527** | 0.0364 | -0.0461 | -0.1628 |
| N | 0.1177 | 0.1508 | -0.1672 | -0.1124 |
| P | -0.2080 | 0.0548 | 0.0623 | -0.1271 |
| K | 0.1600 | 0.0770 | -0.2024 | 0.0166 |
| Ca | 0.0783 | -0.1133 | -0.0824 | -0.1786 |
| Mg | 0.3370* | -0.1159 | -0.1113 | 0.0723 |
| Org.C. | -0.0182 | 0.0579 | -0.2166 | 0.3635* |

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4-3 (a) Nutrient content in Coconut leaves

| Soil type | N % | P % | K % | Ca % | Mg % | B ppm |
|---|---|---|---|---|---|---|
| Forest soil | 1.56 | 0.13 | 1.52 | 0.65 | 0.42 | 42.38 |
| Red Soil | 1.42 | 0.40 | 1.35 | 0.86 | 0.47 | 37.38 |
| Laterite soil | 1.51 | 0.20 | 1.43 | 0.66 | 0.53 | 38.28 |
| Sandy soil | 1.26 | 0.13 | 1.34 | 0.77 | 0.43 | 35.22 |

Table 4-3 (b) Nutrient content in banana leaves

| Soil type | N % | P % | K % | Ca % | Mg % | B ppm |
|---|---|---|---|---|---|---|
| Forest soil | 2.05 | 0.28 | 4.00 | 0.74 | 0.57 | 95.34 |
| Red Soil | 1.77 | 0.28 | 3.59 | 1.30 | 0.67 | 41.14 |
| Laterite Soil | 2.05 | 0.20 | 3.74 | 0.82 | 0.61 | 90.72 |
| Sandy soil | 1.86 | 0.20 | 3.39 | 0.99 | 0.59 | 53.00 |

Table 4-4(a). Analysis of variance.

| Source | D.F. | M.S. | F. |
|---|---|---|---|
| Between soils (S) | 3 | 20733.39 | 109.15** |
| Between crops (C) | 1 | 96809.29 | 509.63** |
| S x C | 3 | 16244.83 | 85.52** |
| Error | 392 | 189.96 | |
| Total | 399 | | |

Table 4-4(b). Boron content in coconut and banana leaves.

| Soil type | Boron content (ppm) | | Mean ppm |
|---|---|---|---|
| | Coconut | Banana | |
| Forest soil | 42.38 | 95.34 | 68.86 |
| Red soil | 37.38 | 41.14 | 39.26 |
| Laterite soil | 38.28 | 90.72 | 64.50 |
| Sandy soil | 35.22 | 53.00 | 44.11 |
| Mean | 38.32 | 70.05 | |

C.D. for comparison of crops = 2.76

C.D. for comparison of soils = 3.90

C.D. for comparison of crops within soils = 5.51.

Significant difference in boron content was observed between coconut and banana leaves. The average boron content was 70.05 ppm in banana leaves while it was only 38.32 in coconut leaves, the difference being about 83 per cent higher in banana compared to coconut (Mean values are presented in Table 4-4(b)).

The difference between the leaf boron contents in different soil types was also significant. Boron content was high in forest soils (68.86 ppm) followed by laterite soils (64.50 ppm) and it was significantly low in red and sandy soils (39.26 and 44.11 ppm respectively).

A significant interaction was observed between plants and soil types. In forest soils, boron content was about 125 per cent more in banana leaves compared to coconut leaves, in laterite soil it was 137 per cent more. This difference was 50 per cent in sandy soils while it was only 10 per cent in red soils. However it was seen that boron content was high in leaves of banana grown in different soil types.

4.2.2. Relationship of soil factors with plant boron.

The correlation coefficients of various soil factors with boron content in plants are presented in table 4-5.

(Table 4-5(a) for coconut and table 4-5(b) for banana).

For the leaf boron content in coconut only soil phosphorus in forest soil showed a significant correlation with plant boron content. All other factors like pH, N, K, Ca, Mg and organic matter content of the soil behaved independently. In red laterite and sandy soils none of the factors were found influence the boron content of the coconut leaves. In the case of banana leaf boron content was found to behave independently of all the factors namely pH, N, P, K, Ca, Mg and organic matter content of the soil in all the four soil types.

4.2.3. Influence of available soil boron on plant boron content

The available boron status of the four different soils were compared with the boron content in coconut and banana leaves. All these correlationships were positive suggesting that the available soil boron (hot water extractable boron) has got a direct influence on the boron content in plants. The correlation coeffecients between soil boron with boron content in coconut leaves and banana leaves in the four soil types are presented in table 4-6. In coconut plants significant and positive correlation was obtained in Red, Laterite and Sandy soils, whereas in forest soil though the correlation was positive, it was not significant at five per cent level.

Table 4-5(a). Correlation of different soil factors with boron content of coconut leaves

| Soil factors | Forest soil | Red soil | Laterite soil | Sandy soil |
|---|---|---|---|---|
| pH | -0.0133 | -0.1135 | -0.1730 | -0.2462 |
| N | 0.1122 | 0.0590 | -0.1388 | 0.025 |
| P | -0.3300* | -0.1950 | -0.1006 | -0.1557 |
| K | -0.1627 | -0.1573 | -0.2254 | -0.1006 |
| Ca | -0.0082 | -0.2559 | 0.0931 | -0.0665 |
| Mg | -0.1673 | -0.2465 | 0.0987 | -0.0306 |
| Org.C | -0.1831 | -0.1445 | -0.1811 | 0.0608 |

* Significant at 5 per cent level

Table 4-5(b). Correlation of soil factors with boron content of banana leaves

| Soil factors | Forest soil | Red soil | Laterite soil | Sandy soil |
|---|---|---|---|---|
| pH | -0.01519 | 0.1420 | 0.1127 | -0.1013 |
| N | 0.0343 | 0.0717 | -0.0274 | 0.0694 |
| P | -0.1497 | 0.2103 | 0.0464 | 0.0213 |
| K | 0.0971 | 0.1020 | 0.1447 | -0.1906 |
| Ca | 0.1126 | -0.0289 | 0.0379 | -0.1906 |
| Mg | 0.2066 | 0.0950 | -0.0665 | 0.0880 |
| Org.C. | -0.0785 | 0.1432 | -0.1803 | -0.0782 |

Table 4-6. Correlation of soil boron with plant boron.

| Soil type | Coconut | Banana |
|---|---|---|
| Forest soil | 0.2490 | 0.3901** |
| Red soil | 0.4031** | 0.2864* |
| Laterite soil | 0.6919** | 0.3953** |
| Sandy soil | 0.6647** | 0.2404 |

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 4-7. Correlation of boron content in coconut and banana levels in different soil types.

| Soil type | Correlation coefficients |
|---|---|
| Forest soil | 0.2517 |
| Red soil | 0.2864* |
| Laterite soil | 0.3584** |
| Sandy soil | 0.4159** |

* Significant at 5 per cent level
** Significant at 1 per cent level

The highest correlation was obtained for laterite soil and sandy soils (r=0.69 and r=0.66 respectively) followed by Red soil and forest soil (r=0.40 and 4=0.25 respectively).

In banana also there was positive correlation between the boron content in leaves and available boron in soils. But the correlation was significant in forest, laterite and red soils, but not in sandy soils. In this plant, the variation among correlation coefficients was much less as compared to coconut. The highest value obtained was for laterite (r=0.40) followed by forest, red and sandy soils (r=0.39, 0.29 and 0.24 respectively).

4.2.4. Inter relationship between boron content in coconut and banana leaves

As presented in table 4-7 the leaf boron content in the two different crops namely coconut and banana showed a positive correlation in all the four soil types. The correlationships were significant in all the soils except for forest soils. The highest correlation was observed in sandy soil (r=0.42) followed by laterite soil (r=0.36), red soil (r=0.29) and forest soil (r=0.25), ~~was~~ the last being not significant at the five per cent level.

4.2.5. Relationship between plant boron and other plant nutrients

a) Coconut

The relationship between boron and N, P, K, Ca or Mg in Coconut leaves was examined using regression techniques. The correlation coefficients for the four different soil types are presented in table 4-8. From the results it was observed that in all the four soil types there was a strong negative correlation between the calcium content and the boron content of the leaves in coconut. As the calcium concentration of the leaves increased the boron concentration showed a decreasing trend.

The highest correlation was observed in red soils (r= -0.79) followed by forest soil (r= -0.76) laterite soil (r= -0.72) and sandy soil (r= -0.54). These correlations were highly significant that the relationship of Ca to the boron content in leaves can be estimated using regression equation. While processing the analytical data the regression equations were found to follow a linear patterns which are presented in table 4-9.

In the sandy soil alone the K content of the plants showed a significant and positive correlation with boron. (r= 0.36). That is an increase in the K content of the coconut leaves was associated with an increase in the boron content. In all other three soil types this relationship was not significant.

Table 4-8. Correlationship between plant boron and other nutrients in coconuts.

| Soil type | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| Forest soil | -0.0088 | -0.1439 | 0.0818 | -0.7585** | -0.0849 |
| Red soil | -0.0819 | -0.1247 | -0.0768 | -0.7093** | -0.0792 |
| Laterite soil | 0.1231 | 0.0532 | 0.1695 | -0.7210** | 0.2633 |
| Sandy soil | -0.2092 | -0.2435 | 0.3563* | -0.5366** | -0.0734 |

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4-9. Regression of boron on calcium in coconut leaves.

| Soil type | Regression equation |
|---|---|
| Forest soil | $Y = 59.710 + (-2.704\ x)$ |
| Red soil | $Y = 50.852 + (-1.585\ x)$ |
| Laterite soil | $Y = 54.052 + (-2.177\ x)$ |
| Sandy soil | $Y = 43.529 + (-1.116\ x)$ |

Y = boron content of leaves in ppm

$x = \frac{\text{Ca concentration of leaves in ppm}}{1000}$

b) Banana

In banana leaves also a significant and negative correlation of Ca with boron was observed, the correlation coefficients being r= -0.89, r= -0.87, r= -0.74, r= -0.75 respectively for forest, red, sandy and laterite soils. The correlation coefficients are presented in table 4-10. Here also the relationship was found to be linear and could be represented by linear equations which are supplied in table 4-11.

In forest soil and sandy soil the plant Nitrogen content was positively correlated with the boron content, the correlation coefficients were r= 0.36 and r= 0.28 respectively. In laterite and sandy soils boron was also found to be influenced by magnesium, that is an increase in magnesium resulting in a decrease in boron content. The correlation coefficients of Mg with boron for these soil are r= 0.31 and r= 0.50 for laterite and sandy soils respectively.

## 4.3 Boron status of soils in areas where deficiency is suspected

All together 20 samples were collected from the four different areas where boron deficiency was suspected, that is in areas where the coconut palms showed webbing together of leaves. In these regions only some of the plants showed the symptoms. The data from soil and plant analysis from these areas are grouped and analysed separately.

Table 4-10. Correlation of boron content in banana leaves to other nutrient concentrations.

| Soil type | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| Forest soil | 0.3578** | 0.1423 | -0.1512 | -0.8877** | 0.0962 |
| Red soil | 0.0907 | 0.0747 | 0.2103 | -0.8716** | 0.2004 |
| Laterite soil | 0.0678 | 0.1699 | 0.1426 | -0.7276** | -0.3061* |
| Sandy soil | 0.2812* | -0.0376 | 0.0954 | -0.7378** | -0.5013** |

* Significant at 5 per cent level

** Significant at 1 per cent level

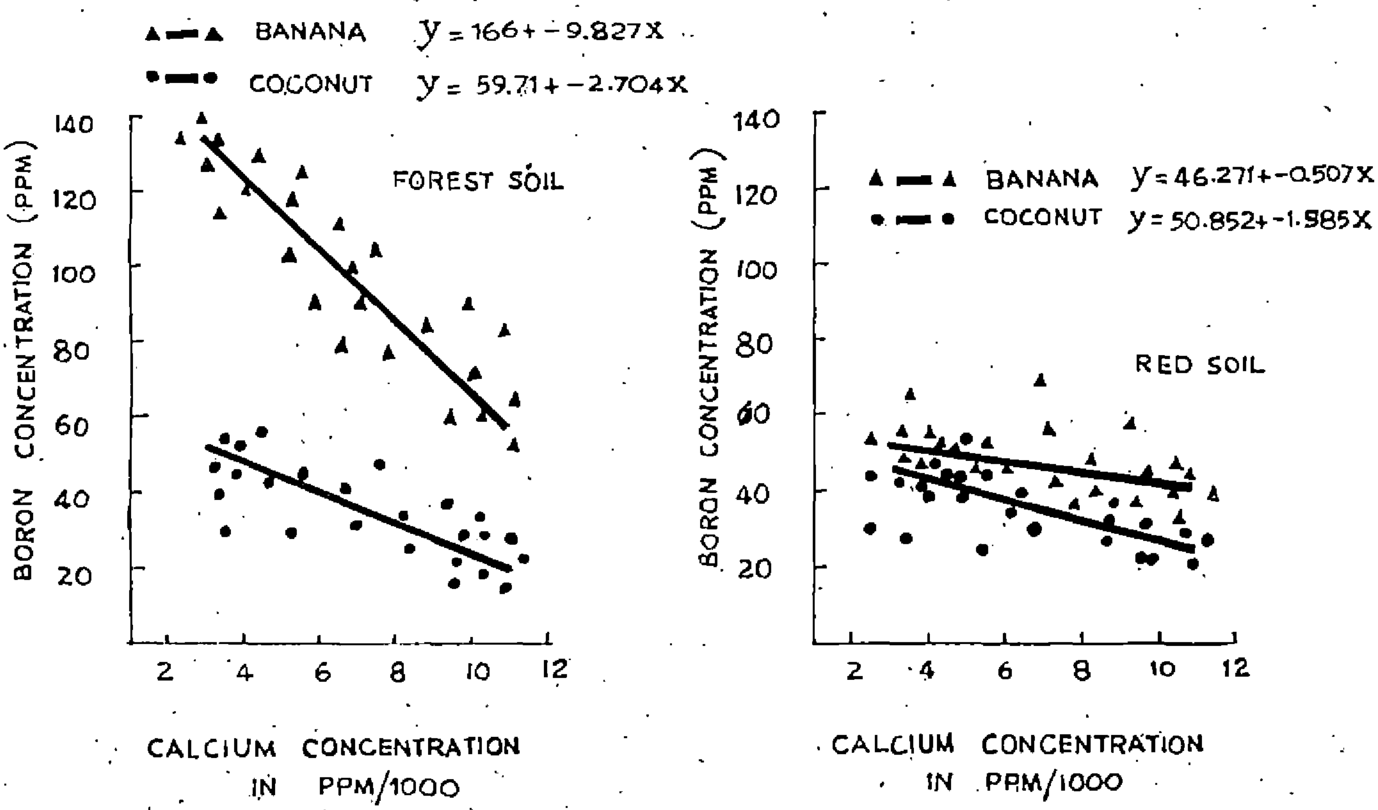
Table 4-11. Regression of boron on calcium in banana leaves.

| Soil type | Regression equations |
|---|---|
| Forest soil | $Y = 166.000 + (-9.8270\ x)$ |
| Red soil | $Y = 46.271 + (-0.5078\ x)$ |
| Laterite soil | $Y = 120.455 + (-3.9960\ x)$ |
| Sandy soil | $Y = 53.260 + (-0.0744\ x)$ |

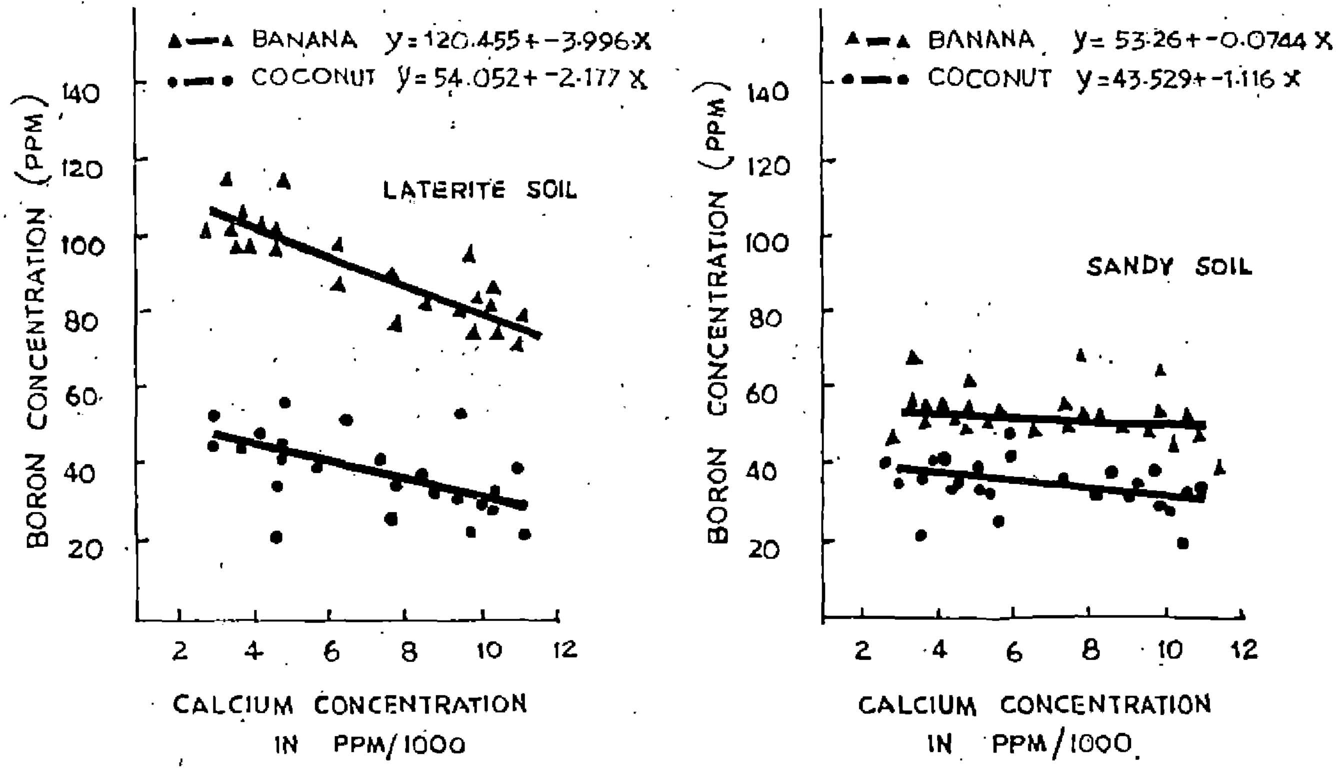
Y = The boron content of leaves in ppm

$x = \frac{\text{Calcium concentration of leaves in ppm}}{1000}$

PLATE - 3




RELATIONSHIP OF PLANT BORON CONTENT TO CALCIUM CONCENTRATION



4.3.1. Soil analysis

The soil was analysed for various factors and the influence of these factors on the available boron status were studied. In these soil samples the soil boron was found to be influenced by soil N, and soil Ca. The correlationships of these factors to boron was observed to be r= 0.36 and 0.37 respectively for soil Nitrogen and calcium content. The correlation with other factors like pH, P, K, Mg or organic carbon were not found to be significant. The correlation coefficients are shown in table 4-12.

4.3.2. Influence of soil factors on B content of banana

The correlation coefficients of different soil factors on leaf boron content of banana are presented in table 4-12. From this it is observed that soil factors like pH, $P_2O_5$, Ca and Mg content of soil had significant correlation with boron status of leaf in banana. pH, $P_2O_5$ content and organic carbon content of the soil showed a positive correlation with boron content of banana leaves (r= 0.53, r= 0.63 and r= 0.41 respectively) while Ca and Mg content of the soil showed a negative relationship with the leaf boron content. This suggests that an increase in those factors decreases the leaf boron content of banana (r= -0.41 and r= -0.45 respectively for Ca and Mg).

Table 4-12. Correlation of soil boron, coconut leaf boron and banana leaf boron with soil factors in boron deficient group.

| | pH | N | $P_2O_5$ | $K_2O$ | Ca | Mg | Org.C |
|---|---|---|---|---|---|---|---|
| Soil | 0.0334 | -0.3608** | 0.0705 | 0.1173 | -0.3788** | 0.2007 | 0.0317 |
| Banana | 0.5311** | -0.1513 | 0.6270** | 0.1843 | -0.4120** | -0.4451** | 0.4642** |
| Coconut | 0.2561 | -0.1025 | 0.4541** | 0.0102 | -0.3684** | -0.3007** | -0.1309 |

** Significant at 1 per cent level

Table - 4.13. Correlation of soil boron to coconut and banana leaf boron.

| Banana | Coconut |
|---|---|
| 0.1401 | -0.0856 |

Table 4-14. Correlation of plant boron to other plant nutrients in deficient region.

| | Coconut | Banana |
|---|---|---|
| N | -0.2232 | 0.1243 |
| P | -0.2813* | -0.1140 |
| K | 0.3630** | 0.1944 |
| Ca | -0.3205* | -0.3790** |
| Mg | -0.2355 | 0.2089 |

* Significant at 5 per cent level

** Significant at 1 per cent level

4.3.3. Influence of soil factors on leaf boron content of coconut palms

The boron content of coconut leaves showed significant correlation with P, Ca and Mg content of the soil. The soil P showed a significant and positive correlation, while the other two showed significant and negative correlation. The correlation coefficients were r=0.45, r= -0.37 and r= -0.31 respectively for P, Ca and Mg. The other factors of soil like pH, N, K and organic matter content behaved independently with respect to the leaf boron content in coconut.

4.3.4. Relationship between soil boron and plant boron

The relationships between soil boron and the boron content in coconut and banana leaves were studied. The correlation coefficients are presented in Table 4-13. The regression analysis showed that there was no significant relationship between soil boron to the leaf boron in banana or coconut, values for correlation coefficients were very low and were negligibly small.

4.3.5. Relationship between coconut and banana boron content

The leaf boron content of coconut and banana were compared using regression analysis and it gave a correlation coefficient, r=0.49. This suggests that in this group also the boron absorption by coconut and banana were identical to that of plants in healthy regions; that is banana leaves contained higher boron than coconut leaves.

### 4.4. Plant analysis

The plant samples collected from these localities (areas of suspected deficiency) were analysed for N, P, K, Ca, Mg and B. The relationship of these different nutrients to the boron content in the leaves were studied.

#### 4.4.1. Relationship of plant boron to other nutrients in deficient plants

The banana leaf samples of the boron deficient region, only the plant calcium content showed significant relationship with the leaf boron content (r=-0.38). The correlation coefficients are presented in Table 4-14. All the other soil factors had no influence on the leaf boron content of banana leaves.

But in the case of coconut palms the leaf boron content showed significant correlationship with that of P, K and calcium content. The factors P and Ca showed significant negative correlation with leaf B content (r= -0.28 and r= -0.32 respectively), while K content of the leaves showed a significant and positive correlation (r= -0.36). The correlation coefficients are presented in table 4-14. The other two factors namely N and Mg content of leaves behaved independently.

4.4.2. Comparison of leaf boron content of coconut and banana growing in soil types deficient in boron.

The leaf boron content of coconut and banana plants from the suspected boron deficient areas of the three soil types namely laterite, red and sandy soils were compared. The analysis of the data are given in table 4-15(a).

Coconut

Result of the analysis of variance indicates that in coconut palms no significant difference in boron content was observed among the zones where the plants showed boron deficiency (Table 4-15(a))

Banana

As in the case of coconut the leaf boron content of the banana leaves in the three deficient zones were compared. From the ANOVA given in table 4-15(a), it is clear that there is a significant difference between the leaf boron contents of the three different soil types where boron deficiency is observed. The banana leaf boron content was significantly lower in red soil when compared to laterite and sandy soils which were on par. The mean values are presented in Table 4-15(c).

4.4.3. Comparison of Ca:B ratio in plants of deficient zones in the three soil types

Table 4-15(a). Abstract of ANOVA (Boron content).

| Source | D.F. | Mean Square | |
|---|---|---|---|
| | | Banana | Coconut |
| Between soils | 2 | 114.56** | 24.39 |
| Within soils | 16 | 13.85 | 7.25 |
| Total | 18 | | |

** Significant at 1 per cent level.

Table 4-15(b). Abstract of ANOVA (Ca/B ratio).

| Source | D.F. | Mean Square | |
|---|---|---|---|
| | | Banana | Coconut |
| Between soils | 2 | 360973.96** | 193066.00 |
| Within soils | 16 | 5449.01 | 88142.61 |
| Total | 18 | | |

** Significant at 1 per cent level.

Table 4-15(c). Average leaf boron content and Ca/B ratios of deficient plants.

| Soil type | Boron content of coconut ppm | Ca/B ratio of coconut | Boron content of banana ppm | Ca/B ratio of banana |
|---|---|---|---|---|
| Laterite | 22.75 | 726.00 | 32.75 | 537.75 |
| Red | 19.43 | 954.43 | 25.00 | 1069.27 |
| Sandy | 22.75 | 637.30 | 31.87 | 900.50 |
| C.D. | | | 4.51 | 283.19 |

Coconut

The Ca/B ratio of the coconut leaves in the three soil types namely red, laterite and sandy were compared. From the ANOVA given in 4-15(b) it is obvious that in coconut palm there is no significant difference in the Ca/B ratios among the three soil types where boron deficiency is suspected.

In the case of banana leaves, there observed a significant difference among the three different soil types. The ANOVA is presented in Table 4-15(b). Based on this result the mean values of Ca/B ratios were compared. The values are presented in table 4-15(c). From that it is observed that the Ca/B ratio of the laterite soil was significantly lower than the Ca/B ratio of red and sandy soils. But the Ca/B ratio in red and sandy soils were on par.

4.4.4. Comparison of leaf boron contents of deficient plants with that of healthy plants

The leaf boron content of the coconut and banana plants of the different zones were compared with that of the healthy groups in the three different soil types respectively. This comparison was made using the student's 'T' test.

Coconut

In coconut plants the deficient plants always showed a significantly lower levels of leaf boron content as compared to the healthy plants in all the three soil types namely laterite, red and sandy soils. The highest difference was noted for laterite soil, followed by red and sandy soils. The mean values of deficient and healthy groups along with the student 't' values are presented in table 4-16.

In the case of banana, a significant difference between samples collected from healthy localities and from areas of suspected deficiency was noticed for leaf boron content in laterite and red soil, while the 't' value was not significant in the case of sandy soils suggesting that in this soil there is no significant difference among the leaf boron status of the deficient and healthy plant groups. The mean values and the student 't' values are presented in table 4-17.

### 4.4.5. Comparison of the Ca/B ratios of the deficient plants with the healthy plants

The Ca/B ratios of boron deficient coconut and banana plants were compared with the healthy plants of three soil types as done for the leaf boron content.

Coconut

In coconut plants there was a significant difference between the Ca/B ratio of the deficient plants and healthy plants in all the three soil types where deficiency was observed.

Table 4-16. Comparison of leaf boron status in healthy and deficient coconut palms.

| Soil type | Boron content of healthy plants ppm | Boron content of deficient plants ppm | t value |
|---|---|---|---|
| Laterite | 39.83 | 22.75 | 3.26* |
| Red | 41.60 | 19.43 | 2.52* |
| Sandy | 37.45 | 22.75 | 2.60* |

* Significant at 5 per cent level.

Table 4-17. Comparison of leaf boron status in healthy plants and plants in deficient locations.

(Banana)

| Soil type | Boron content of healthy plants ppm | Boron content of plants in difficient locations ppm | t value |
|---|---|---|---|
| Laterite | 94.63 | 37.75 | 3.06** |
| Red | 44.74 | 25.00 | 2.54* |
| Sandy | 56.33 | 31.87 | 1.98 |

* Significant 5 per cent level

** Significant 1 per cent level

The mean values and the corresponding student 't' values are presented in Table 4-18. The highest difference was observed for coconut plants of the sandy soil region followed by red and laterite soils.

In the case of banana also a significant difference was noticed among the mean values of Ca/B ratios of the infected and healthy plant groups in all the three soil types. Here also the highest difference was observed in the case of sandy soils, followed by red and laterite soils. The mean values along with the student 't' values are given in Table 4-19.

## 4.5. Results of alleviation studies conducted on the affected plants

Among the ninonteen plants which showed the webbing together of leaves, sixteen plants were selected from each of the four localities as shown below:

| | | |
|---|---|---|
| Agricultural College Campus | (Red loam) | 4 |
| Ambalathara | (Sandy loam) | 4 |
| Parassala | (Laterite) | 4 |
| Kazhakkoottam | (Sandy) | 4 |

These plants were given boron in the form of borax as soil application during May 1984. Then a foliar spray of one per cent boron was given during June.

Table 4.18. Comparison of leaf Ca/B ratios of healthy and deficient coconut palms.

| Soil type | Ca/B ratio of healthy palms | Ca/B ratio of deficient palms | t value |
|---|---|---|---|
| Laterite | 173.23 | 726.00 | 4.61** |
| Red | 170.83 | 954.43 | 4.74** |
| Sandy | 155.52 | 637.50 | 5.68** |

** Significant at 1 per cent level.

Table 4-19. Comparison of leaf Ca/B ratios of healthy plants and plants in deficient locations. (Banana)

| Soil type | Ca/B ratios of healthy plants | Ca/B ratios of plants in deficient locations | t value |
|---|---|---|---|
| Laterite | 96.02 | 537.75 | 3.75** |
| Red | 261.88 | 1069.27 | 4.48** |
| Sandy | 172.52 | 900.50 | 5.81** |

** Significant at 1 per cent level.

These plants were closely watched and the following observations were made. All the treated palms in Agricultural College Campus, Parassala and three out of the four plants in Kazhakkoottam started producing normal leaves after July. But the plants in Ambalathara region did not produce any marked change. The plants which started producing healthy normal leaves, reverted back producing webbed leaves when observed in early January 1983. This showed that the symptoms disappear during monsoon period and reappear during dry spells.

# DISCUSSION

## DISCUSSION

In this chapter the results of the investigations carried out presently are discussed in order to high light the role of boron in crop nutrition with respect to coconut and banana in the four major soil types of Trivandrum district, namely, forest, red, laterite and sandy soils which are scattered at various locations of Trivandrum district. The results obtained from the analyses of leaves of suspected boron deficient coconut palms are also discussed with a view to finding out whether there is any relationship between apparent deficiency symptoms, boron content of plants and also the boron content of the soil in which the palms suspected of boron deficiency are located.

### 5.1. Soil boron

#### 5.1.1. Boron content in four different soil types

The available soil boron status (hot water extractable) of the forest soil was higher than that of the other soils namely, laterite, red and sandy soils. This result is found to be in confirmity with the reports of Bowen (1977), that most of the available boron in soils is derived from sediments of plant materials which is always higher in forest soils. Martens (1968) was also of the view that soil organic matter is a predominant source of water soluble boron. Park and Park (1966), Kerczteng (1968) and Zenbaczymski and Zmigrodzka (1968) were also of the view that the organic matter of the soil has got a great role in the solubilization of boron in the soils. The results of works conducted by Maurice (1977) also had concluded that the hot water soluble boron has a direct correlation with the organic matter content. This report also supports the present finding that the soils of forest region is having a higher content of available boron. But studies on available boron status of soils conducted by Gupta (1978) concluded that the significant correlation of available boron to soil organic matter content is only because hot water extracts more boron from organic matter than from other fractions. Gupta (1979) mentioned that sometimes the higher boron content of organic soils determined colorimetrically may be due to the colour of the extract itself. In the present study the extract was having no colour and hence the higher reading obtained for forest soils cannot be attributed to coloured extracts. Okazaki and Chao (1968) based on their experiments concluded that organic matter is one of the main source of boron in acid soils. So soils having high organic matter should naturally contain high boron. The present investigation confirms the result obtained by the above workers, and it can be said that the higher boron extracted from forest soils, is due to the higher content of organic matter. Berger and Pratt (1963) had suggested that high microbial action on organic matter rich soils, can result in higher hot water extractable boron. This may also be true in the case of forest soils investigated in the present study.

### 5.1.2. Interaction of soil boron with other soil factors and plant nutrients

In the case of forest soil a significant positive correlation was observed with soil pH and magnesium content of the soil. Soil pH is one of the most important factors affecting the availability of boron in soils. Results obtained by Mourice and Troeme (1965), Buchel and Bergmann (1967), Trox (1968) and Khan (1970) suggested that soil pH has got a positive correlation to boron availability in acid soils. Gupta and Mac Leod (1979) obtained similar results in cases where soils were acidic. Studies by Peterson and Newman (1976) and Gupta and Mac Leod (1977) have found a negative correlation between soil pH and available boron when soil pH is greater than 6.3. In the forest soils presently investigated the pH values seldom exceeded 6.0 and therefore a negative relationship with the available boron and soil pH cannot be expected.

In the forest soils subjected to investigation presently the magnesium content of the soil had a positive correlation with the boron content of the soil. This result is contradictory to the reports of Gupta and MacLeod (1977) and Wolf (1940) which states that the boron availability is always negatively correlated with magnesium as in the case of calcium. The possible explanation they gave to this phenomenon is that the increase in concentration of these elements will increase the soil pH probably beyond 6.3, which will in turn reduce the boron availability. In the present investigation results contradictory to this, is obtained. This may be probably due to the fact that the boron availability in these soils is positively correlated with soil pH, since the pH of soils investigated had values less than 6.0.

In red soil and laterite soil none of the soil factors namely, pH, nitrogen, phosphorus, potassium, calcium, magnesium or organic carbon contents were found to influence available born status. It cannot be expected otherwise, since those parameters in these two soil types are not favourable for the higher availability of boron as evidenced by data presented in tables 4-1(b)(low pH, O.C., Ca, Mg etc.). Sims and Bingham (1967) has mentioned that the hydroxy forms of Fe and Al contribute greatly to the retension of boron by soils where such oxides are abundant. In laterite and red soils such oxides are naturally abundant and so boron has to be definitely retained to a great extent by these hydroxy forms and its availability will be independent of soil factors like O.C., pH and Mg content. The findings of Gupta and MacLeod (1977) had revealed that boron uptake is not correlated to pH, Ca and/or Mg as long as the anionic components were the same. This may be another possible explanation for not obtaining significant correlation between boron content in sandy, laterite and red soils with pH, Ca and Mg content of the soil.

In sandy soil the organic matter content of the soil gave positive correlation with the available boron content of the soil. Similar results were reported by Okazuki and Chao (1968) and Gupta (1968). This may be due to the fact that the available boron fraction in such cases are controlled by organic matter as proposed by Berger and Pratt (1963). They also reported that boron in organic matter is largely released in available form through the action of microbes, the population of which is mainly governed by organic matter content of soil. Park and White (1952) had suggested that a complex formation of dihydroxy compounds in soil organic matter is an important mechanism of boron retension. Reisenauer et al. (1973) could get little information from their experiments conducted to study the exact role of soil organic matter and of the influence of microbial activity on the availability of soil boron. Such an attempt was not envisaged in the present investigation.

5.2.1. Comparison of boron content in plants growing in different soils

In forest soil the boron content of banana and coconut was higher than that of other soils. This is most probably due to the higher available boron status in forest soils arising from higher O.M. content. The forest soil contained more hot water extractable boron due to its higher organic matter content as reported by Martens (1968) and Park and Park (1968). A higher amount of hot water extractable boron always results in a greater amount of plant uptake as observed by Buchel and Bergmann (1968). They got such results when the pH values were not so high. Smilde (1970) suggested that there is a close relationship between hot water soluble boron in the soil and boron content in plant leaves. The results of the present investigation fully support the results obtained by these authors.

The banana plant always showed a higher content of boron when compared to coconut plants in all the soil types. This clearly shows the higher demand for boron by banana as compared to coconut.

5.2.2. Relationship of soil factors with plant boron

No significant correlations were observed between the soil factors like pH, N, P, K, Ca, Mg or organic matter content of the soil with leaf B content.

5.2.3. Relationship between plant boron and other plant nutrients

The calcium content of coconut and banana leaf tissues was found to be negatively correlated with leaf boron content as evidenced by the present investigation. The leaf tissue Ca/B ratios have been considered as an indication of the boron status of crops. Gupta (1972 b) and Gupta and Cutcleffe (1972) has reported that higher calcium content in plants is associated with lower levels of boron. Eck and Campbell (1962) found that liming decreases boron uptake when soil boron reserves were low. The reason attributed to this was the antagonistic effects of calcium in boron uptake. Beachamp and Hussain (1974) in their studies on rutabaga found that increased calcium concentration in the leaves was always accompanied by a lower level of boron. So the results of the current investigation confirm the reports of above workers that the boron content of a plant will always be inversely related to the calcium status of the plant. In the present study laterite and sandy soils showed a negative correlation between the leaf boron in banana and its magnesium content. Here also the fact may be due to the antagonistic effect of Mg as in the case of Ca.

Results obtained in the present investigation revealed a positive correlation between potassium and boron in coconut palm leaves. Reeve and Shive (1944) has reported that potassium concentration of the substrate has a definite influence on the accumulation of boron in plant tissues. Nausbum (1947) observed that without added boron low rates of potassium and phosphorus resulted in the exhibition slight boron deficiency symptoms in crop. Kar and Mothiramani (1976) investigating on various soil types from Madhya Pradesh noted a significant positive correlation between exchangeable potassium and boron contents in plants. The results of the present investigation is justified by the findings of the above authors. Reeve and Shive (1944) again observed some toxic effects due to boron when potassium in the growing medium was applied at concentrations in excess of the requirement. This observation cannot be made applicable to the present finding since potassium levels of the sandy soils under study never reached the even the precincts of sufficiency.

5.3. Boron status of soils suspected of deficiency as evidenced by webbed leaves in coconut

The results indicate that in general the soil boron content is negatively correlated with soil nitrogen and calcium content. The importance of nitrogen in enhancing the boron uptake by plants have been discussed by many scientists. Chapmann and Vanselow (1955) were among the pioneers in establishing that liberal nitrogen applications are sometimes beneficial in controlling excess boron in citrus plants. Therefore it is safe to assume that if the boron content of a soil is low, high nitrogen rates in the soil reduces the availability of boron to the crops. In a work by Gupta et al. (1976) increasing rates of nitrogen applied was observed with a slight decrease in available boron, to initially nitrogen deficient soils. In the present investigation it was also observed that the calcium content of soil is having a negative correlation with available boron content of the soils. Similar results were obtained by Gupta and MacLeod (1976). They noticed that the calcium content of the soil is inversely related to the available boron. Other factors like pH, P, K, Mg or organic carbon were not found to be significantly correlated with available boron in the present investigation.

## 5.4. Plant analysis

### 5.4.1. Influence of soil factors on boron content in the plant in areas suspected by boron deficiency

In Banana, soil pH, $P_2O_5$ content and organic carbon content of the soil showed a positive correlation with the plant boron content. About the relationship of soil pH to plant boron availability several workers have observed negative correlation between boron uptake by plants and soil pH (Benett and Mathias, 1973; Bartbelt and Picavelli, 1973; Gupta, 1972 b and wolf, 1940). But the results obtained in the present investigation is contradictory to the findings of the above authors.

Gupta (1972 a, 1977) has reported that there may be variations depending upon crop species. Studies by Peterson and Newman (1976) and Gupta and MacLeod (1977) have shown that a negative relationship between soil pH and plant boron occurs when soil pH levels are greater than 6.3. The availability of boron to plants decreases sharply at higher pH levels, but the relationship between soil pH and plant boron at low pH levels did not show any definite pattern in the present study. The content of soil P is seen positively correlated with the leaf boron content of coconut and banana. This may be possibly due to a substitution of boron by phosphorus in the soil exchange sites and the resultant increased availability of boron. Tanaka (1967) observed that the boron uptake by radish plants increased with increasing phosphorus supply. The reason he suggested is that the increase in phosphorus uptake decreases the calcium absorption which in turn increases the boron absorption. But the findings of Stoyanov (1971) is contradictory to this.

The organic carbon content of the soil has showed a positive correlation with leaf boron content of banana leaves. As already discussed organic matter, being a good reserve of hot water soluble boron will naturally enhance the boron availability to plants and this may be the reason for the increase in plant boron content with increasing organic matter content in the soils investigated presently. The calcium and magnesium content of the soil showed a negative relationship with leaf boron content of coconut and banana. Similar results were obtained from the works of Tanaka (1967), Wolf and Hussain (1974) and Gupta and MacLeod (1977) on various crop they studied.

The factors like pH, nitrogen, potassium and organic matter content of soil did not show any significant correlation with the boron content of coconut and banana leaves. Critical analysis of the data gave no relationship between the leaf boron content of those plants and the soil boron status in areas where coconut palms showed suspected deficiency. But in the case of normal plants, there existed a significant positive correlation between available boron in soils and plant boron contents. The difference between normal soils and group of soils from area of apparently deficient in boron, suggest that some mechanism in the plant is disrupted hindering boron uptake from the soil.

5.4.2. Relationship of plant boron to other nutrients

In the banana and coconut leaf samples from the boron deficient region, the leaf calcium content showed significant negative correlation with the leaf boron content. This result is in conformity with the results obtained by Gupta (1972 b) and

Gupta and Cutcliffe (1972). In the case of coconut leaves the phosphorus content of the leaves was also negatively correlated with boron content of the leaves, whereas the potassium content of leaves showed a positive correlation. This fact may possible be due to increased availability of potassium and boron to plants in the form of readily available potassium tetraborate. This suggest that increased K content in soils is always beneficial for increased boron uptake by coconut palms.

5.4.3. Comparison of leaf boron content of apparently affected plants with that of healthy plants

In coconut plants, leaf boron content of the deficient plants were significantly lower than that of healthy plants in all the three soil types where deficiency is observed. This suggest that the lack of proper boron nutrition in these plants may be one of the factors contributing to the development of webbed leaves. In the case of banana plants such a significant difference between the two groups was evident in the case of laterite and red soils only. In sandy soils the difference was not significant.

5.4.4. Comparison of Ca/B ratios of plants from suspected boron deficient areas with that from normal areas

Highly significant difference in the Ca/B ratios in the leaves were observed both in coconut and banana, between samples collected from normal soils and soils where boron deficiency was suspected as evidenced by the presence of webbed leaves in coconut palms. This was true in all the three soil types namely Red, laterite and sandy soils (Table 4 to 18 and 4 to 19). Gupta and Cutcliffe (1972) and Gupta (1972 b) suggested the importance of such ratios in assessing the deficiency of boron in some temperate vegetable crops. Beachamp and Hussain (1974) stressed the importance of Ca/B ratios in assessing plant deficiency. They pointed out that the use of the Ca/B ratio in assessing boron status of plant should be viewed in relation to the efficiency of other nutrients in the medium. The relative concentration of these two elements (calcium and boron) in the plant have to be considered while considering Ca/B ratio as an index of boron deficiency (Gupta and Cutcliffe, 1972). But in the case of the present study since all the soils were of low pH (average 5.6) and therefore calcium deficient the above argument cannot hold good in the present study. Therefore the results presently obtained (Table 4-18 and 4-19) definitely indicates that Ca/B ratio can be taken as a very good index for assessing boron supplying power (available boron status) of soils.

5.5. Influence of plant genotype on boron deficiency

There is clear evidence that the genotype of a plant can effect the uptake of Ca, Fe and Znin many plant species.

The data on the effect of genotype on the boron uptake is meagre. In some plants susceptibility to boron deficiency is controlled by a single recessive gene (Wall and Andrus, 1962). The reports of other scientists (Brown et al., 1972 and Govsfino et al., 1965) are in support of this theory. If this is true in the case of coconut which is a highly heterozygous and cross pollinated crop there is every likelihood of the sporadic distribution of such recessive gene in the palm by natural crossing. So it may happen that the two recessive genes may get combined in a single plant thereby resulting in a plant having poor capacity for boron uptake. Such plants may readily exhibit deficiency symptoms in soils having low levels of boron, thereby acting as indicator plants. This might be one of the reason why coconut palms with webbed leaves are found scattered in uncontiguous areas. But it is also true that such plants may recover if we continuously supply extra amounts of boron either as foliar spray or as soil application. This may be the reason for the uncertain results obtained in the nominal alleviation attempts conducted during the present investigation.

# SUMMARY

# SUMMARY AND CONCLUSION

Boron is one among the essential micro nutrients in plant nutrition. However little work has been done regarding its presence in the soil medium or its possible role in the nutrition of crops of importance to Kerala. The present investigation was envisaged mainly to elucidate the role of boron in coconut and banana in relation to its content in four major upland soil types of Trivandrum district namely forest, laterite, red and sandy soils.

With this objective in view, a large numbers of soil samples and leaf samples of banana and coconut were collected from different locations and analysed. The results were statistically interpreted. The salient results obtained and the major conclusions drawn are highlighted below:

1. The analysis of soil samples revealed that the four soil types differed significantly with respect to the available boron content which was highest in forest soils (0.86 ppm).

2. The organic matter status of the forest soil was significantly higher compared to others. This indicates that the boron available to the plant is always associated with the organic matter. While, in natural ecosystems of forest this recycling of micronutrients goes on unimpeded, in agricultural ecosystems there

is a need to strengthen the recycling by application of organic matter.

3. The results obtained from the analysis of plant samples lead to the conclusion that the leaf boron content of banana is always higher than that of the coconut, which is a pointer to the fact that the requirement of boron by banana may be higher. The perennial nature of the coconut palm in contrast to the annuality of banana and hence the existance of large reserves of boron for mobilization according to needs in coconut may be another physiological attribute.

4. From the correlation studies it becomes evident that in red and laterite soils the availability of boron is independent of the soil factors while in forest soil pH and magnesium content showed a positive correlation. In the case of sandy soils the organic matter content of the soil correlated positively to boron availability.

5. While studying the influence of soil factors on plant boron content it was observed that none of the soil factors are influencing the leaf boron content of the indicator plants except the phosphorus content of forest

soils which seems to influence the boron content in coconut leaves. Influence of an important major anionic nutrient such as phosphate on another anionic micronutrient such as borate needs further study.

6. The available boron of soil (hot water extractable boron) was significantly correlated with leaf boron content of plants. This suggests the suitability of adopting the hot water extractable boron as an index of boron availability in soils.

7. The leaf boron content of plants were always negatively correlated with calcium content. From this it could be concluded that calcium and boron behave antagonistically in plant systems.

8. While studying the boron status of coconut palms showing symptoms of apprent boron deficiency, it was observed that for these plants the soil boron status was in no way correlated to the leaf boron status. Similar results were also observed for banana plants collected from the deficiency suspected areas.

9. The antagonistic relationship between calcium and boron was more marked in boron deficient plants. Thus the Ca/B ratios

of the healthy plants were significantly different from that of deficient plants.

10. Attempts at alleviating the symptoms by soil and foliar application of boron did not give any conclusive results.

On the basis of the present investigation it can be concluded that the boron availability in soils is mostly governed by the organic matter content of the soils. The leaf calcium content of plants always show antagonistic effects with the leaf boron content. So in areas where liming is a common practice, the risk of boron deficiency cannot be obviated. The deficiency suspected palms showed clear cut differences in their boron status and Ca/B ratios when compared with healthy plants. But the alleviation attempts carried out on these palms did not give conclusive results, probably due to the need for prolonged application. This points to sustained research on alleviating the symptoms by continuous boron application and studying the pattern of uptake and leaf concentration of boron.

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* Originals not seen

# APPENDIX

Basic data-soil and plant boron content (ppm)

| Samples | Forest soil | | | Red Soil | | | Laterite soil | | | Sandy soil | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | C | B | S | C | B | S | C | B | S | C | B |
| 1. | 1.56 | 28 | 128 | 0.24 | 18 | 23 | 0.96 | 48 | 98 | 0.88 | 32 | 60 |
| 2. | 1.08 | 32 | 82 | 0.86 | 46 | 44 | 0.98 | 52 | 85 | 0.42 | 18 | 28 |
| 3. | 0.98 | 41 | 146 | 0.42 | 20 | 26 | 0.97 | 44 | 91 | 0.89 | 34 | 52 |
| 4. | 0.99 | 38 | 118 | 0.76 | 41 | 38 | 0.24 | 18 | 28 | 0.68 | 31 | 55 |
| 5. | 1.06 | 34 | 120 | 0.79 | 45 | 42 | 0.36 | 34 | 106 | 0.87 | 38 | 64 |
| 6. | 1.26 | 40 | 122 | 0.82 | 47 | 32 | 0.84 | 43 | 74 | 0.31 | 21 | 34 |
| 7. | 0.88 | 39 | 84 | 0.32 | 21 | 22 | 0.36 | 36 | 70 | 0.88 | 44 | 66 |
| 8. | 0.72 | 42 | 148 | 0.38 | 41 | 46 | 0.38 | 38 | 102 | 0.51 | 26 | 32 |
| 9. | 0.64 | 48 | 50 | 0.46 | 45 | 52 | 0.47 | 40 | 73 | 0.98 | 40 | 62 |
| 10. | 0.88 | 52 | 112 | 0.88 | 47 | 40 | 0.28 | 26 | 34 | 1.09 | 38 | 44 |
| 11. | 1.05 | 46 | 74 | 0.78 | 44 | 52 | 0.46 | 42 | 118 | 0.98 | 42 | 84 |
| 12. | 0.89 | 36 | 120 | 0.88 | 47 | 36 | 0.52 | 32 | 96 | 1006 | 40 | 75 |
| 13. | 0.72 | 48 | 108 | 0.64 | 46 | 51 | 0.42 | 31 | 83 | 0.98 | 38 | 38 |
| 14. | 0.88 | 49 | 72 | 1.08 | 40 | 54 | 0.28 | 24 | 34 | 0.78 | 36 | 80 |
| 15. | 0.96 | 52 | 120 | 1.58 | 42 | 36 | 0.46 | 36 | 96 | 0.58 | 37 | 40 |
| 16. | 0.88 | 48 | 124 | 0.92 | 16 | 32 | 0.81 | 41 | 78 | 0.69 | 39 | 42 |
| 17. | 0.94 | 56 | 86 | 0.32 | 42 | 54 | 0.82 | 46 | 76 | 0.59 | 36 | 41 |
| 18. | 0.87 | 55 | 110 | 0.41 | 42 | 50 | 0.46 | 38 | 35 | 0.78 | 38 | 48 |
| 19. | 0.48 | 39 | 71 | 0.56 | 46 | 38 | 0.58 | 43 | 68 | 0.87 | 41 | 56 |
| 20. | 0.65 | 44 | 74 | 0.68 | 43 | 36 | 0.64 | 39 | 72 | 0.76 | 32 | 54 |
| 21. | 0.73 | 42 | 68 | 0.64 | 48 | 44 | 0.86 | 46 | 88 | 0.44 | 24 | 28 |
| 22. | 0.93 | 36 | 89 | 0.72 | 40 | 52 | 1.08 | 44 | 114 | 0.88 | 38 | 44 |
| 23. | 0.84 | 32 | 96 | 0.63 | 22 | 22 | 0.76 | 35 | 102 | 1.08 | 40 | 64 |
| 24. | 0.32 | 26 | 66 | 0.21 | 32 | 44 | 0.88 | 38 | 121 | 0.48 | 39 | 86 |
| 25. | 0.42 | 32 | 58 | 0.48 | 45 | 41 | 0.78 | 36 | 138 | 0.58 | 36 | 56 |

| Samples | Forest soil | | | Red Soil | | | Laterite soil | | | Sandy Soil | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | C | B | S | C | B | S | C | B | S | C | B |
| 26. | 0.61 | 41 | 64 | 0.56 | 46 | 56 | 0.86 | 42 | 142 | 0.47 | 32 | 58 |
| 27. | 0.81 | 38 | 108 | 0.81 | 41 | 46 | 0.84 | 40 | 96 | 0.56 | 34 | 40 |
| 28. | 0.32 | 42 | 81 | 0.64 | 32 | 45 | 0.78 | 42 | 93 | 0.41 | 21 | 30 |
| 29. | 0.72 | 44 | 96 | 0.62 | 18 | 47 | 0.41 | 36 | 61 | 0.28 | 32 | 61 |
| 30. | 0.64 | 35 | 85 | 0.32 | 33 | 22 | 0.82 | 23 | 35 | 0.58 | 38 | 68 |
| 31. | 0.82 | 42 | 104 | 0.62 | 58 | 55 | 0.85 | 42 | 86 | 0.86 | 36 | 65 |
| 32. | 0.52 | 37 | 105 | 1.06 | 46 | 46 | 1.01 | 54 | 116 | 0.98 | 41 | 68 |
| 33. | 6.68 | 46 | 82 | 0.96 | 36 | 49 | 0.86 | 48 | 81 | 0.41 | 34 | 54 |
| 34. | 0.72 | 48 | 103 | 0.88 | 35 | 46 | 0.94 | 44 | 103 | 0.41 | 26 | 36 |
| 35. | 6.86 | 42 | 99 | 0.72 | 32 | 50 | 0.96 | 46 | 107 | 1.05 | 42 | 48 |
| 36. | 0.98 | 51 | 66 | 0.84 | 34 | 45 | 0.84 | 40 | 45 | 0.88 | 48 | 64 |
| 37. | 1.04 | 48 | 92 | 0.22 | 32 | 30 | 0.43 | 22 | 91 | 0.96 | 52 | 44 |
| 38. | 0.88 | 42 | 98 | 6.58 | 36 | 56 | 0.72 | 38 | 126 | 0.54 | 24 | 38 |
| 39. | 1.08 | 56 | 48 | 0.66 | 46 | 41 | 0.76 | 39 | 88 | 0.33 | 26 | 63 |
| 40. | 1.02 | 54 | 104 | 0.86 | 64 | 44 | 0.68 | 36 | 102 | 0.86 | 58 | 58 |
| 41. | 0.72 | 36 | 73 | 0.48 | 58 | 39 | 0.66 | 34 | 65 | 0.68 | 43 | 45 |
| 42. | 0.84 | 32 | 95 | 0.31 | 21 | 34 | 0.56 | 35 | 106 | 0.86 | 38 | 43 |
| 43. | 0.96 | 41 | 93 | 0.88 | 56 | 28 | 0.66 | 38 | 103 | 0.30 | 30 | 58 |
| 44. | 0.88 | 38 | 81 | 0.44 | 22 | 43 | 0.82 | 41 | 78 | 0.84 | 36 | 46 |
| 45. | 1.05 | 48 | 96 | 0.86 | 42 | 38 | 0.71 | 34 | 116 | 0.42 | 22 | 28 |
| 46. | 0.72 | 52 | 98 | 0.72 | 34 | 41 | 0.64 | 32 | 107 | 0.64 | 38 | 44 |
| 47. | 0.82 | 35 | 108 | 0.64 | 36 | 43 | 0.66 | 36 | 91 | 0.44 | 28 | 63 |
| 48. | 0.86 | 42 | 96 | 0.54 | 28 | 40 | 0.81 | 41 | 103 | 0.38 | 30 | 68 |
| 49. | 0.86 | 36 | 102 | 0.78 | 31 | 39 | 0.88 | 44 | 78 | 0.31 | 36 | 79 |
| 50. | 0.98 | 48 | 114 | 0.81 | 42 | 27 | 0.81 | 46 | 94 | 0.28 | 32 | 49 |

S - Soil

C - Coconut

B - Banana

# ROLE OF BORON IN PLANT NUTRITION IN KERALA IN RELATION TO ITS CONTENT IN SOILS

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ABSTRACT OF THE THESIS
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ABSTRACT

An investigation was carried out to elucidate the role of boron in crop nutrition, especially in crops of relevance to Kerala in relation to its content in major upland soil types. The work included in the present study is on four main soil types of Trivandrum district namely forest, red, laterite and sandy soil in relation to two major crops namely coconut and banana grown on them.

A critical evaluation of soil in relation to plant boron status of the four soil types revealed that forest soils are having the highest content of available boron as compared to other soil types. The indicator plants in the study also showed a close parallel relationship to soil boron status. Between the indicator plant species chosen in all for soil types the boron content of banana leaves were invariably higher than that of coconut leaves.

The soil factors like N, P, K and Ca content of the soil did not show any correlation with the available boron of the soil. The organic matter content of the soil showed a significant positive correlationship with the available boron status in sandy soils. This suggests the need for using organic manures in such soils where boron deficiency occurs. The hot water extractable boron showed a positive and significant correlation with the leaf boron status of both coconut and banana.

Calcium content in plants found to influence the boron status unfavourably. In the boron deficiency suspected areas the available boron of soils could not be correlated with the plant boron content. In plants grown in such regions significantly lower levels of boron was noticeds in leaves of apparently deficient plants than in those of healthy ones. The Ca/B ratios of these plants were very high compared to the normal plants. From attempts at alleviating deficiency by B application, both soil and foliar, no conclusive results could be obtained during the period of study.