FORMULATION AND EVALUATION OF MICRONUTRIENT MIXTURE FOR FOLIAR APPLICATION IN TC BANANA (*Musa* sp.) var. NENDRAN

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"FORMULATION AND EVALUATION OF MICRONUTRIENT MIXTURE FOR FOLIAR APPLICATION IN TC BANANA (*Musa* sp.) var. NENDRAN"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society

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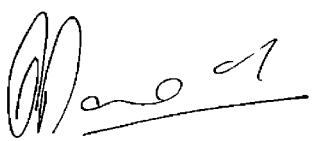

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LIST OF ABBREVIATIONS

%	-	Per cent
@	-	at the rate of
°brix	-	Degree brix
B	-	Boron
BCR	-	Benefit / cost ratio
Ca	-	Calcium
CD	-	Critical difference
CEC	-	Cation exchange capacity
Cl	-	Chlorine
cm	-	Centimeter
Cu	-	Copper
dSm^{1}	-	deci Siemens per meter
EC	-	Electrical conductivity
et al	-	And others
Fe	-	Iron
Fig	-	Figure
g	-	Gram
ha^{1}	-	Per hectare
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	Kilogram
$kg\ ha^{-1}$	-	Kilogram per hectare
l	-	Litre
m	-	Meter
MAP	-	Months after planting
Mg	-	Magnesium

mg g^{1}	-	Mılli gram per gram
mg kg^{1}	-	mılligram per kılogram
ml	-	Mılli lıtre
mm	-	Mılli meter
mmol g^{-1}	-	Mılli moles per gram
Mn	-	Manganese
Mo	-	Molybdenum
MT/ha	-	Metric tonnes per hectare
N	-	Nitrogen
NS	-	Not significant
pH	-	Soil reaction
ppm	-	parts per million
S	-	Sulphur
SE	-	Standard error
Rs ha^{1}	-	Rupees per hectare
TC	-	Tissue culture
t ha^{1}	-	Tonnes per hectare
TSS	-	Total soluble solids
viz	-	namely
Zn	-	Zinc

Introduction

1. INTRODUCTION

Micronutrients are essential for crop growth and are equally important as primary and secondary nutrients Though their requirement is low, they often make a huge variation in yield and difference in quality of crop produce if there is a deficiency Micronutrients have an important role in balanced plant nutrition for the stabilization of crop yield and quality of produce These nutrients play a vital role in regulating the metabolic activities of plants and animals including human beings Micronutrient deficiencies in soils and crops have become prevalent in the recent years due to several factors like intensive croppmg, loss of top soil by erosion, leaching, decreased use of farmyard manure, increased use of high analysis fertilizers and lack of proper liming of acid soils (Singh, 2003, Rattan and Sharma, 2004, De and Rai, 2005) The deficiency of micronutrients has become major constraint to productivity, stability and sustainability of soils (Bell and Dell, 2008)

Systematic soil studies and analysis of more than 2 50 lakh soil samples in 20 states of India by All India Coordinated Research Project indicated the extent of deficiency in zinc (49 %), B (33 %), Fe (13 %), Mo (7 %), Mn (4 %) and Cu (3 %) (Singh, 2009) Another study by Shukla *et al*, 2014 indicated that micronutrient deficiencies are rampant in India and on an average 43 0, 12 1, 5 4, 5 6 and 18 3 per cent soils are deficient in Zn, Fe, Cu, Mn and B, respectively Presently, the trend of micronutrients deficiency is changing from single nutrient deficiency to multi-micro nutrients deficiencies due to depletion in soil fertility and this becomes an emerging issue in agriculture, relating to crop health and human health

According to KSPB (2013), after a detailed study in all 14 districts reported that Kerala soils are deficient in Zn (12 %), Cu (15 %) and B (59 %) The acid leaching environment of Kerala soils is not conducive for retention of boron arrested by highly porous nature dominated by low activity clays, which resulted in

widespread deficiency of B Iron and manganese deficiency is noticed some zones in like Onattukara and coastal sandy tracts Keeping this in view now Government of Kerala had notified the use of zinc, copper and boron for foliar as well as soil application

Banana (*Musa* sp) is the second most important fruit crop of India after mango It is one of the oldest fruit crop known to mankind and it is a rich source of carbohydrates, vitamins and minerals which are essential components of human diet Because of their commercial status, banana and plantains are referred usually as "Poor man's apple"

At present, banana is grown in around 150 countries across the world on an area of 4 84 million ha producing 95 6 million tonnes of fruits (FAO Stat, 2011) Among horticultural crops, contribution of banana to Agricultural Gross Domestic Product (AGDP) is the highest (Singh, H P , 2007) India is world's leading producer of banana with an annual production of 297 24 lakh tonnes which accounts for 33 4 per cent of total fruit production with a productivity of 37 0 MT/ha In Kerala banana is grown in 34 5 lakh ha with a production of 52 8 million tones and productivity of 15 3 t/ha (Saxena, 2015) and the productivity is low

In vitro multiplication is an advanced technology over traditional method of banana propagation with respect to uniformity, vigor, disease-free planting material and true to type plants Tissue culture plants produces 20 per cent higher yield than conventional method due to good quality planting material Nendran is a popular variety of banana extensively cultivated in Kerala which is relished as fruit and vegetable as well as used for processing

Banana requires more nutrients than any other commercially cultivated crop and the various nutritional deficiencies and disorders affect its growth and yield Micronutrients such as Zn, B, Mo and Cu had been reported to be essential for the growth and development of banana plants (Srivastava, 1964a & b) Deficiencies of

Zn, Cu, Fe and Mo affect the growth and production of banana (Charpentier and Martin, 1965) Application of micronutrients in banana increases the growth, yield and quantity of banana (Pathak *et al* , 2011)

Application of essential nutrients in an appropriate balance is fundamental for various physiological processes in plants Primary nutrients play a vital role in promoting the plant vigour and productivity, whereas micronutrients like zinc, boron, copper and molybdenum perform a specific role in the growth and development of plant, quality of produce and uptake of major nutrients

The fertilizers applied through soil are needed in higher quantities because some portion leaches down and some does not become available to the plants due to complex chemical reactions happening in soil or adverse soil conditions hindering uptake The foliar application, therefore, offer a viable alternative way of applying nutrients to fruit plants in such conditions Micronutrients availability can be enhanced by foliar application of the appropriate mineral forms (Alloway, 1986, House and Welch, 1989) Micronutrient content and uptake by plants is better enhanced with foliar application

The multi-micronutrients mixture facilitates the application of wide range of plant nutrients in the correct proportion and to suit the specific requirements of a crop in different stages of growth and are more relevant under site specific nutrient management (Hegde *et al* , 2007)

Multi-nutrient foliar feeding products are the most effective way to correct nutrient deficiencies and disorders and thus resulting in increased crop growth (Mona *et al* , 2012)

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

- To Preparae a micronutrient mixture formulation containing zinc, iron, boron, copper, manganese and molybdenum for foliar spray
- To evaluate stability of formulation and its keeping quality
- To investigate the effect of this formulation on growth, yield and quality of fruits in banana (*Musa* sp) var Nendran

Review of Literature

2. REVIEW OF LITERATURE

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

The micronutrients are essential for the proper biochemical transformations within the plant body, so as to yield the desired end products Zn is essential for protein and auxin production, Cu is a constituent of cytochrome oxidase, Fe helps in photosynthesis while Mn is essential for photosynthesis, carbon assimilation and nitrogen metabolism (Mandavgade *et al*, 2015) Widespread micronutrient deficiencies has been found in many countries all over world and their deficiency scenario had changed very much in Indian soils and crops during last 4 decades from 1968 to 2008 (Singh, 2009)

2 1 BANANA

Banana is an important commercial fruit crop in tropical and sub tropical regions of the world In India, it is grown in different states under different climatic conditions (Butani *et al*, 2012) The edible banana is believed to have originated in hot tropical regions of South-East Asia (Spiden, 1926, Suar, 1952) It comes under family *Musaceae* It is generally harvested when green between 70 to 100 per cent maturity and ripened before consumption (Thomas *et al*, 1968a)

Banana is globally ranked fourth, next to rice, wheat and maize in terms of gross value of production Presently, it has emerged as the major cash-subsistence crop across all parts of the world (Robinson, 1996) as it is a complete fruit-food with delicious taste, necessary energy and health giving nutrients (Anonymous, 1969) along with pleasant flavor On account of these properties, it is a staple food for millions of people all around the world It is in great demand in fresh as well as processed form all over the world and gained commercial popularity in the international fruit trade (Thomas *et al*, 1968b) Bananas provide a good source of nutrients for both human and animal consumption

Among the major producers in the world, India alone accounts for 27 43 per cent of fruits (26 2 million tonnes) followed by Philippines, producing 9 01 million tonnes and China, Brazil and Ecuador, altogether with production ranging from 7 19 to 8 21 million tonnes (FAO Stat, 2011)

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

2.1.1. Tissue culture banana

Traditionally, banana is grown as a perennial crop where the plant is allowed to produce continuous shoots from an underground stem But, the yield falls after three to five years and declines rapidly after ten to fifteen years So the need of shifting to cyclic replacement with a new plantation comprising cycles of one crop and one ratoon has been realized only recently in most Asian countries

Through conventional propagation techniques, there is a difficulty with obtaining large number of uniform disease free plants with high yielding potential which in turn limits the productivity of banana Another important problem faced by the growers is the staggered flowering (variability in time of flowering) Tissue

culture technology enabling the rapid production of a large quantity of uniform disease free plants from a single plant showing good genetic potential is gaining importance in recent days (Sheela and Nair, 2001)

With the increasing demand and vast export potential coupled with the farmer's desire to grow *in-vitro* propagated banana on a large area, it is becoming increasingly important for rapid multiplication of quality planting material (Ray *et al*, 2006)

In micropropagation technique, it is desirable to produce plantlets that can grow better after transplanting into the soil So, acclimatization is the most crucial process during banana micropropagation as the *in vitro* raised plantlets are not readily adapted for *in vivo* conditions (Vasane and Kothari, 2006)

Geetha *et al* (2004) reported that the average bunch weight (12 43 kg) and number of hands per bunch of TC-derived Nendran was 35 per cent higher than that of the conventional suckers

Robinson *et al* (1993) claimed that there was an increase in height and girth of tissue culture plants over the suckers An increase in yield of 25 63 per cent was obtained in tissue culture plants over the plants from suckers (Sheela and Nair, 2001)

2.1.2. Nendran banana

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

Nendran fruit is used for culinary purposes as well as for processing Bunch has average of 5-6 hands weighing about 12-15 kg in the popular types

Venugopal (2008) reported that Nendran banana is mostly cultivated in homesteads and in well-drained rice fields by small and marginal farmers of Kerala It is the most popular commercial cultivar which is loved much by cultivators and fruits have excellent fruit quality, multiple uses and sustained income

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

2 2 ESSENTIALITY OF MICRONUTRIENTS

Micronutrients are required in minute quantities as compared to those of macro nutrients but these nutrients play a vital role in plant metabolism (Benepal, 1967, Katyal, 2004) Also scarcity of these trace elements in soils resulted in poor crop yields (Udode- Haes *et al*, 2012) Micronutrient plays many complex roles in plant nutrition and plant production, as most of micronutrients are specific to functioning of various enzyme systems (Kazi *et al*, 2012) Micronutrients play a catalytic role in nutrient absorption and balancing of other nutrients (Singh and Kalloo, 2000)

The essential micronutrients are metals (except B and Cl) and its uptake is affected by soil (Lindsay, 1991, Lake *et al*, 1984), plant (Barber, 1995, Marschner, 1995) microbial and environmental factors (Romheld and Marschner, 1986, Clark and Zeto, 2000)

2.2.1. Essentiality of Zinc

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

Zinc is important as a component of enzymes for protein synthesis and energy production and maintains the structural integrity of biomembranes Zn is required for the synthesis of carbohydrate metabolism, protein synthesis, internode elongation for stem growth and in pollen formation (Shukla *et al*, 2009) It is also vital for the oxidation processes in plant cells and helps in the transformation of carbohydrates and regulates sugar in plants

Under Zn deficient conditions, flowering and fruit development are reduced and maturity is delayed which resulted in lower yield, poor quality and sub-optimal nutrient use efficiency (Gupta, 1995) Zn^{2+} ions at low concentration (0 01 ppm) slightly enhance the activity of tryptophan synthesis leading to biosynthesis of auxin (Horak *et al*, 1976)

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

2.2.2. Essentiality of Boron

Boron has been known to be a constituent of plants since 1857 (Tandon, 1989) Warrington (1923) was the first to really prove the essentiality of boron According to Truog (1940), the importance of boron is spelt as follows, ' plants

will not make growth without boron any more than without phosphorus or potassium which they require in considerable amounts'

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

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

2.2.3. Essentiality of Iron

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

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

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

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

2.2.4. Essentiality of Manganese

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

Under deficient condition, the concentration of manganese in leaves is less than 15ppm and in toxic condition it becomes more than 300 ppm Mn is involved in the oxygen evolving system in photosynthesis PS II (water oxidizing enzyme complex) It is essential for photolysis of water and also it is involved in nitrogen fixation It acts as a predominant metal ion in Kreb's cycle (Gupta and Gupta, 2005)

Manganese is only moderately mobile in plant tissues so symptoms appear on younger leaves first, most often in those leaves just reaching their full size Mn availability is reduced in high pH calcareous soils but is often very high in the acid soil commonly chosen for tropical fruit production Over liming of the soils as well as well drained, poor, coastal sandy soils can induce Mn deficiency Mn deficiency

causes a light green mottle between the main veins A dark green band is left bordering the main veins while the interveinal chlorotic areas become pale green or dull yellowish colour (Gupta and Gupta, 2005)

Soil application of manganese can be ineffective due to immobilization especially in heavier soils or soils which have been over limed Two to three sprays of 0 1 per cent manganese sulphate can be recommended (Gupta and Gupta, 2005).

2.2.5. Essentiality of Copper

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

2.2.6. Essentiality of Molybdenum

Arnon and Stout (1939) demonstrated for the first time that molybdenum is essential for higher plants The essentiality of molybdenum for plant growth can be understood from the expression of Arnon and Stout (1939) as ' a gram of molybdenum may harness more energy, through greater conversion of sunlight into plant materials, than can be obtained from a gram of uranium ' Mo ions are part of enzymes nitrate reductase and nitrogenase Nitrate reductase is responsible for reduction of nitrate to nitrite during N assimilation in plants Nitrogenase converts nitrogen gas to ammonia in nitrogen-fixing microorganisms

Mo plays a role in breakdown of purines such as adenine and guanine because of its essentiality as part of enzyme xanthin dehydrogenase It is an essential part of oxidase enzyme which converts abscisic acid aldehyde to ABA (Gupta and Gupta,

2005) Mo deficiency is observed in many soils and pasture legumes, vegetables and occasionally in fruits, it is very rare in flower crops

2 3 MICRONUTRIENT DISTRIBUTION IN INDIAN SOILS

Katyal and Sharma (1991) reported that green schist contained the highest concentrations of Zn, Cu, Mn and Fe, while sandstone was the poorest source of these micronutrients Among the sedimentary rocks, Zn content was highest in limestone Shale contained considerably higher content of Fe, Mn and Cu as compared to limestone

Soils developed on flood plain alluvium (Fluvents) and derived largely from silicious sandstone exhibited strikingly lower concentrations of Zn, Cu, Mn and Fe than Chromusterts developed on basaltic alluvium In case of B, sedimentary rocks contain more B than igneous rocks (Gupta and Gupta, 1985)

Molybdenum (Mo) is the least abundant among micronutrients in the lithosphere (Mortvedt, 2000) and its deficiency largely occurs in acid soils and also in the soils formed from parent materials low in Mo, such as sedimentary, basalt and granite Peaty, alkaline and poorly drained soils commonly have high Mo

The total micronutrient content (zinc, iron, manganese, copper) is adequate in most of the Indian soils, but the micronutrients concentrations in soil solution is insufficient to meet the demand of growing crops (Singh, 1991)

Iron is the important micronutrient limiting plant growth Due to the frequent change in its form (Fe^{2+} to Fe^{3+}), its availability to plants is greatly impaired with cropping sequences Available (DTPA extractable) iron varies greatly from traces to 234 mg kg^{-1} in Indian soils Available zinc in Indian soils ranges from 0 08- 20 5 mg kg^{-1} soil

The available (DTPA extractable) copper content of the Indian soils ranges from traces to 32 mg kg^{-1} soil The highest copper deficiency was observed in soils of Kerala, followed by Uttar Pradesh Available (DTPA extractable) manganese ranges from 0 6 to 164 mg kg^{-1} soil in Indian soils with an average of 25 mg kg^{-1} Hot water extractable boron ranged from traces to 8 2 mg kg^{-1} in Indian soils (Gupta, 2005)

The total B contents in Indian soils varied from 7 to 630 mg kg^{-1} of soil (Prasad *et al*, 2014) The available (hot water soluble – HWS) B in Indian soils ranged from 0 75 to 8 0 mg B/kg (Das, 2000, Singh, 2001)

Total Zn content in the normal soils of world ranged between 10–300 ppm with an average of 50 mg kg^{-1} (Mulligan *et al*, 2001) In Indian soils total Zn ranges from a few ppm to about 1000 ppm It ranges from 7 ppm in coarse textured alluvial soils (Entisols) to 284 ppm in fine textured vertisols (Ganjir *et al*, 1973) Available Zn content in Indian soils ranges from 0 08 to 20 5 ppm

2.3.1. Extent of micronutrient deficiencies in Indian soils

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

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

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

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

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

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

Now, multi-nutrient deficiencies are emerging in many states of the country The Zn+Fe in swell-shrink soils, Zn+Mn or Zn+Fe+Mn in alluvial soils of Indo-Gangatic alluvial plains, Zn+Fe, Zn+B, Zn+Fe+B in highly calcareous soils of Bihar,

Saurashtra, Zn+B in acid leached alfisols, red and lateritic soils of India are leading to stagnation or a decline in productivity (Shukla and Behera, 2011)

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

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

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

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

The typical Cu content in plants ranged between 0 08–0 24 mmol g^{1} dry weight and Cu toxicity generally occurs when the plant tissue level exceeds 0 4 mmol g^{1} dry weight (Macnicol and Beckett, 1985)

2 4 STATUS OF MICRONUTRIENTS IN KERALA

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

Investigation on micronutrient status of cardamom- growing soils of Kerala conducted by Srinivasan *et al* (1993) indicated that available iron ranged from 14 6-65 8 ppm, available manganese from 1 3 to 44 8 ppm, available copper from 0 66 to 32 2 ppm, available zinc from 0 01 to 2 71 ppm, available boron from 0 05 to 3 7 ppm and available molybdenum from 0 01 to 11 1 ppm

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

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

Evaluation of Soil fertility status of Kasargod district conducted by Suresh *et al* (2014) revealed that Kasarogod soils are 78 per cent deficient in B, 8 per cent deficient in Zn and 3 per cent deficient in Cu

Fe and Al toxicity is very wide spread disorder in acid sulphate soils of Kuttanad region and often leads to declinmg of crop yield of 50 to 70 per cent (Thampatti *et al*, 2005) The total Mn content of Kuttanad soils normally ranged between 28–350 mg kg^{-1} (Rajendran and Aiyer, 1981, KAU, 1994) and total Fe content ranged from 2 75 to 7 72 per cent

2 5 FOLIAR APPLICATION OF MICRONUTRIENTS

Foliar spray of micronutrients is the most effective way to control nutritional deficiency problems than soil application (Torun *et al*, 2001) Foliar spray of

nutrients is preferred and gives quicker and better results than the soil application (Jamal *et al*, 2006) Generally, foliar application is very fast method for providing required elements in plants because nutrients are absorbing very quickly as compared with absorption that through plant roots (Hashemy *et al*, 1998)

Foliar application of nutrients has become an efficient way to improve yield and quality of crops (Roemheld and El-Fouly, 1999, Sarkar *et al*, 2007) In arid and semiarid regions, foliar application of nutrients is the most suitable option as compared with soil fertilization when the roots were not able to provide necessary nutrients to plants (Kaya *et al*, 2005, Kinaci and Gulmezoglu, 2007, Babaeian *et al*, 2011)

Other advantages are application of smaller quantity and thus, reducing toxicity arises from excessive accumulation of elements and preventing fixation of nutrients in soil (Malakouti and Tehrani, 1999) It may increase the efficacy of fertilizer use (Silberbush, 2002)

Application of fertilizers on leaves of growing plants with suitable concentrations is termed as foliar application Foliar feeding is a relatively new and controversial technique (Bernal *et al*, 2007 and Baloch *et al*, 2008) It is most economical way of fertilization, especially when sink competition for carbohydrates among plant organs take place, while nutrient uptake from the soil is restricted (Kannan, 1986 and Singh, M V, 2007)

In the early of 1950's the commercial production of mixed liquid fertilizers was started in United States and now it has been popularized in many countries (Wiley-VCH and Wiley-VCH, 2007)

For foliar fertilizers to be utilized by the plant for growth, the nutrient must first penetrate the leaf surface prior to entering the cytoplasm of a cell within the leaf

Penetration of foliar nutrients occurs through the cuticle the stomata, leaf hairs and other specialized epidermal cells (Fernandez and Eichert, 2009)

Foliar application of micronutrients resulted in quick absorption of nutrients by leaf epidermis and transported to other plant parts through xylem and phloem vessels (Hasslett *et al* , 2001, Nasiri *et al* , 2010)

Foliar feeding of nutrient promotes root absorption of the same nutrient or other nutrients by enhancing root growth and nutrients movement from terminal leaves to depth roots (El-Fouly and El-Sayed, 1997)

Recently foliar application of nutrients has become an important practice in crop production while soil application of fertilizers is the basic method (Alam *et al* , 2010)

Leaf feeding enhances overall nutrient level in the plant and sugar production during times of stress and it also increases biochemical activities in the leaf by increasing chlorophyll a, b and carotenoids, which presumably favour the photosynthesis Similarly, Shitole and Dhumal (2012) found that foliar application of micro-nutrients increased the primary metabolites like photosynthetic pigments and organic constituents of *Cassia angustifolia*

Foliar feeding was more efficient than soil application in such a way, N- 6 times more efficient, B- 4 times more efficient, Mn- 30 times more efficient, Zn- 20 times more efficient, P- 20 times more efficient and Mo- 14 times more efficient than soil application (Dixon, 2003) Likewise, Liew (1988) advocated that foliar application of micro-nutrients is 6-20 times more efficient than soil application, depending upon various soil types

Foliar spray of zinc, boron and copper has been reported to be equally or even more effective way to overcome micronutrients deficiency in subsoil as compared to soil application (Ali *et al* , 2009, Hussanin *et al* , 2012)

Foliar application micronutrient leads to increase in grain yield components and protein percentage of wheat, maize, rice, barley and sorghum (Boorboori *et al*, 2012)

Foliar application of water soluble iron containing compounds may be applied in alkaline soil conditions to meet out the iron requirement of crops Foliar spray of Ferrous sulphate (0 5 per cent) solution is required repeatedly if chlorosis symptoms persist (Patricia *et al*, 2010)

Moosavi and Ronaghi (2011) found that both soil and foliar application of Fe and Mn notably increased the shoot concentration and uptake in soybean plant However, foliar feeding was found to be efficient than soil application

Copper has been used as a fungicide even before it was recognized as an essential plant nutrient (Graham and Webb, 1991)

Therefore, foliar feeding of nutrients has become an established procedure in crop production to increase yield and quality of crop products (Roemheld and El-Fouly, 1999) and it also minimizes environmental pollution and improves nutrient utilization through reducing the amounts of fertilizers added to the soil (Abou-El-nour, 2002)

2 6 MICRONUTRIENT MIXTURE ON GROWTH AND YIELD OF CROPS

Muthukrishnan and Velu (2011) developed and evaluated a micronutrient formulation for sugarcane and concluded that 92 5 kg MN formulation II as enriched farm yard manure containing 50 kg $FeSO_4$, 5kg $MnSO_4$, 30 kg $ZnSO_4$, 2 5 kg $CuSO_4$ and 5 kg of borax may be recommended for sugarcane for maximizing yield with higher B C ratio Increased cane yield with higher levels of micronutrient mixture maybe attributed to the complementary and supplementary effect of fertilizers and FYM

A multi-micronutrient mixture having a composition of Zn (9 5 %) + B (2 6 %) + Cu (1 2%) + Mg (2 4 %) + N (0 46 %) was developed and found that 0 5 per cent of multi-micronutrient mixture was significantly improved the growth and yield of okra variety Varsha Uphar (Mini, 2015)

Micronutrients play a vital role in enhancing the productivity of crops Optimum fertilization and manuring are prime need for the growth and yield of banana (Simmonds, 1966)

El-Magid *et al* (2000) found that application of NPK with foliar spraying of various micronutrient mixture containing Fe, Mn, Cu, Zn, B, Mg, S and Mo (in the brand names, Satrite SF, Borocol BSF-12 and Micnelf MS-12) increased the grain yield of rice

Shueadshen (1991) reported that foliar application of 0 1 per cent B, Fe, Cu, Co, Zn and Mn at tillering stage has increased number of spikelets per panicle and grain yield and decreased the spikelet sterility

Durairaj (1993) reported that combined foliar application of 20ppm humic acid and 25ppm $ZnSO_4$ gave highest yield of paddy

Modaihsh (1997) found that combined application of micronutrients either in chelated or non-chelated forms resulted in higher biological and grain yields in wheat than the individual application of micronutrients

El-Magid *et al* (2000) reported that foliar spray of micronutrients containing Fe, Cu, Zn and Mn increased the grain and straw yields of wheat

Field experiment on the effect of various micronutrients such as Zn, Cu, Fe, Mn, B and a commercial micronutrient mixture (Brand name- Zarzameen) resulted in maximum grain yield, straw yield and dry matter of wheat (Asad and Rafique, 2002)

According to Patel *et al* (2008), foliar application of 1 per cent micronutrient mixture (containing Fe - 4 %, Mn -1 %, Zn - 6 %, Cu - 0 5 % and B - 0 5 %) at 30, 40, 50 days after sowing recorded highest plant height, number of tillers per plant, shoot weight, grain weight and increased uptake of micronutrients

Foliar spray of micronutrients (containing Fe - 1 %, Mn - 2 %, Zn - 2 %, Cu - 1 %, B - 1 %) on wheat increased the plants height, grains per spike, biological yield, harvest index, 1000-grain weight, straw and grain yield (Khan *et al* , 2010)

Combined foliar spraying of 0 5 per cent $FeSO_4$ and 0 5 per cent $ZnSO_4$ is most effective and increases seed yield by 43 1 per cent in cowpea cultivated oxisols of Kerala (Anitha *et al* , 2005)

Katkar (2005) concluded that 3 sprays of $MgSO_4$ (1 %) + $ZnSO_4$ (0 5 %) at squaring, flowering and boll development stage are recommended to obtain highest yield of cotton

According to Namdco (1992), combined application of recommended NPK rate (120 60 60 kg ha^{-1}) + Foliar spray of one per cent Micnelf MS-16 (consisting of Zn, Cu, Fe, Mn, Mo and B) at 30, 65 and 90 days after sowing resulted in highest seed cotton yield of 8 12 t ha^{-1}

Foliar fertilization of micronutrient mixture (Brand name- Agripower N-180,000 ppm, K- 1000 ppm, Mg- 100 ppm, Zn- 100 ppm, B-100 ppm, Fe- 1000 ppm, Cu- 20 ppm and Mn- 100 ppm) improved the growth and yield paramenters of okra plants such as days to flowering, plant height, number of branches $plant^{-1}$, number of fruits $plant^{-1}$ and fruit length (Abbasi *et al* , 2010)

Patel *et al* (2009) confirmed that green fruit yield of okra significantly improved with foliar application of multi-micronutrient mixture

According to Datir *et al* (2010), application of 2 per cent organically chelated micronutrient mixture containing Zn, Cu, B and Fe on okra increases plant height, leaf area and yield per plant

Suryanarayana and Rao (1981) investigated that foliar application of Fe with Zn, Cu, Mn, Mg, B and Mo in a chelated form (brand name- Agromin) resulted in maximum growth traits of okra

Application of Cu - 20 ppm, Mn - 100 ppm and Zn - 50 to 100 ppm significantly increased the yield parameters like fruit set percentage, number of seeds per pod and total dry bean yield of *Phaseolus vulgaris* cv Giza-3 (Gabal *et al* , 1985)

Yousefi and Zandi (2012) observed that foliar spray of Zn + Mn resulted in highest seed number, fruit yield, seed yield and oil content of pumpkin (*Cucurbita pepo* L)

Yadav *et al* (2009a) reported with three times foliar application of multiplex (0 5 %) gave highest marketable head yield of cabbage with maximum net returns and maximum vegetative growth (number of leaves per plant, more head diameter, higher individual head weight as well as foliage yield)

Kanujia *et al* (2006) found that maximum plant spread, number of non-wrapper leaves, head diameter, head weight and head yield of cabbage var 'Golden Acre' were recorded with foliar application of micronutrient mixture (Zn, Fe, B, Mn, Cu and Mo) @ 100 ppm

Mishra *et al* (2012) reported that maximum number of fruits per plant and yield of tomato cv Utkal Urbasi was obtained with foliar spray of micronutrient mixture containing Zn-100 ppm, B- 100 pmm, Fe- 100 pmm, Mn- 100 ppm, Cu- 100 ppm and Mo- 50 ppm

Naruka *et al* (2000) found that foliar application of Zn and Mo at 0 2, 0 4 and 0 6 % and 30, 60 and 90 ppm respectively significantly increased the plant height, number of fruits, fruit diameter and fruit yield of okra cv Pusa sawani

Studies conducted by Sivaiah *et al* (2013) in tomato (*Lycopersicon esculentum* Mill) reported that foliar application of micronutrients either alone or in combination, enhances plant growth characterstics *viz* plant height, number of primary branches and compound leaves, fruit weight, seed yield and seed weight

Bhatt and Srivastava (2005) claimed that fresh and dry matter weight of tomato fruits, uptake of all the macro and micronutrients has remarkably influenced by the foliar spray of micronutrient mixture (Zn, Fe, B, Cu and Mn as 100 ppm and Mo - 50ppm)

Foliar application of micronutrients recorded higher fruit yields of brinjal than soil application (Selvi and Thiageshwari, 2002)

Al-Jobori and Al-Hadithy (2014) reported that application of full concentration of micronutrient mixture containing 330 g $ZnSO_4$ + 330 g $MnSO_4$ + 150 g $FeSO_4$ + 80 g $CuSO_4$ in 1 litre significantly increased the number of tuber / plant, mean tuber weight, total yield and dry matter percentage of potato (*Solanum tuberosum*)

According to Pal *et al* (2004), foliar application of Boron and Zinc @ 1000 ppm has significantly increases fruit base diameter, fruit weight and pericarp thickness as well as foliar application at 2000 ppm Boron increase quality traits like TSS, ascorbic acid, acidity and carotene content of bell pepper (*Capsicum annuum* L)

Singh and Rajput (1976) found that various combinations of foliar application of Zn (0 1, 0 2 and 0 4 %), Fe (0 1, 0 2 and 0 4 %) and B (0 1, 0 2 and 0 4 %) has

increased the length of terminal shoot, plant height, number of leaves and leaf area per shoot of mango tree

Studies conducted by Ghosh *et al* (1995) revealed that highest yield was obtained in 0 75 per cent brand name Multiplex- Trace elements formulation I with 62 7 kg/plant as compared to control (37 0 kg/plant) and fruit weight was highest in 0 70 per cent brand name Tracel- Trace elements formulation II in Mango cv Himsagar

According to Bhatt *et al* (2012), foliar spray of 0 5 per cent borax on mango trees showed highest fruit yield, fruit weight and fruit volume

Gurjar *et al* (2015) revealed that foliar application of 1 per cent $ZnSO_4$, 1 per cent $FeSO_4$ and 0 5 per cent borax on Alphonso mango (*Mangifera indica* L) increased number of fruits per tree, fruit weight, yield tree^{-1} and decreased the fruit drop

Modi *et al* (2012) revealed that foliar application of $ZnSO_4$ 0 5 per cent and borax 0 3 per cent at 30, 60 and 90 days after transplanting on papaya cv Madhu Bindu exerted great influence on plant height, stem girth, number of leaves, earlier initiation of flower bud, minimum days taken from fruit setting to first harvest, weight of fruit, number of fruit and yield of fruits per plant with maximum yield per hectare

Foliar sprays of Zn 0 5 per cent + B 0 1 per cent at 4th, 8th, 12th and 16th months after planting improved the total number of fruits per tree, fruit characters, fruit and latex yield of papaya (Kavitha *et al* , 2000a)

The monthly spray of $FeSO_4$, $ZnSO_4$ and borax @ 0 1 per cent with or without combination were effective in increasing the plant height and girth of papaya as compared to control (Veena and Lavania, 1998)

Singaram and Prabu (2001) reported that foliar application of $ZnSO_4$ @ 0 5 per cent + borax @ 0 2 per cent resulted in highest shoot length, number of internodes per shoot and number of leaves per shoot of grapes

Foliar application of Zinc (0 6 %), Copper (0 3 %) and Boron (0 3 %) enhanced the growth and vigour of Litchi plant (Babu and Singh, 2002)

Afria *et al* (1999) reported that foliar spray of $ZnSO_4$ + $FeSO_4$ + Borax in pomegranate resulted in maximum number of fruits plant^{-1}, fruit weight and yield plant^{-1}

Bhambota *et al* (1962) found that application of Zinc (0 6 %) + Iron (0 4 %) significantly increased the number of fruits, mean weight of fruit, diameter and volume of each fruits of citrus

Foliar spraymg of Zn and Fe at 0 5 per cent (4 sprays) considerably increased the chlorophyll content of acidlime (Patel and Patel, 1985)

Muthukrishnan and Velu (2011) reported that micornutrient mixture formulation enriched with farmyard manure in sugarcane will largely helps to manage the micronutrient deficiency problems effectively and it clearly reveals that the positive improvement of growth and development due to conjoint use of NPK with organic and micronutrient fertilization

Manimaran *et al* (2009) reported that application recommended dose of fertilizer+ Acetobacter @ 10 kg ha^{-1}+ foliar spraying of 1 per cent micronutrient mixture at 45 and 75 DAR resulted in maximizing single cane weight, cane yield and sugar yield

Foliar spray of micronutrient mixture of EDTA chelated Cu, Zn, Mn and Fe on capsicums cv Vinedale as 5 sprays at 15 days intervals resulted in increased in yield and fruit colour (Navrot and Levin, 1976)

Senthamizhselvi (2000) found that combined application of zinc sulphate - 4 g and ferrous sulphate - 8 g per plant through soil and 0 5 per cent of zinc sulphate and 1 per cent of ferrous sulphate through foliage exerted significant influence on plant height, number of shoots, plant spread and leaf area in *Jasminum sambac*

Katiyar *et al* (2012) reported that foliar application of Zn at 0 5 per cent was effective to increase leaf length, number of leaves, size of spike, thickness of spike and floret of gladiolus plants

Foliar application of micronutrients resulted in increased number of branches, number of leaves per plant, number of blind shoots, vase life of flower, number of flower per plants in rose under polyhouse condition (Jagtap *et al* , 2012)

Balakrishnan (2005) claimed that foliar application of zinc sulphate - 0 5 per cent + ferrous sulphate - 0 5 per cent sprayed at 30 and 45 days after planting in marigold significantly increased stem girth, plant spread, number of branches per plant and dry matter production

Foliar feeding of plants with ferrous sulphate ÷ zinc sulphate + manganese sulphate @ 0 2 per cent each resulted in increasing flower yield per plant, flower diameter and plant height in gerbera (Balakrishnan, 2005)

Ahmad *et al* (2010) revealed that combined application B and Zn in rose plants resulted in increasing plant height, number of leaves branch ^{1}, leaf area, number of flowers plant ^{1}, flower stalk length and leaf Zn contents

2.6.1. Effect of micronutrient mixture on growth and yield of banana

Foliar application of micronutrient mixture (Mg, Fe, Zn, Cu and Mn) resulted in highest bunch weight, number of hands and fingers per bunch, higher numbers of green leaves per plant and decreased bunch shooting period of Hindi banana (*M cavendeshii*) (Abdel-Kader *et al* , 1992)

Das and Mohan (1993) reported that the maximum plant height, leaf area and number of functional leaves were obtained with a combination of B, Zn, Cu and Mn applied at 3 and 5 months after planting of banana cvs 'Chenichampa' (AAB), 'Jahaji' (AAA) and 'Barjahaji' (AAA)

Ghanta and Mitra (1993) found that the combined application of Zn (0 3 %), Cu (0 1 %) and B (0 2 %) showed the best response in plant growth at flowering in terms of height, girth of pseudostem and number of leaves per plant and also it increased the yield parameters such as number of hands per bunch, number of fingers per bunch, bunch weight and yield per hectare in banana cv Giant Governor

Suresh and Savithri (2001) observed that soil application of N, P, K and foliar spray of nutrients (1 % DAP + 1 % MOP + 0 5 % $ZnSO_4$+ 0 3 % $CuSO_4$+ 0 2 % Borax) in addition to liming caused substantial increase in bunch yield of banana

Foliar application of micronutrient mixture ($ZnSO_4$ - 0 5 %, $FeSO_4$ - 0 2 %, $CuSO_4$ - 0 2 % and H_3BO_3 - 0 1 %) at 3, 5 and 7 months after planting of banana increased bunch weight and TSS in ripe fruits (Kumar and Jayakumar, 2001)

Phenotypic correlation analysis of 13 biometric characters of banana cv Nendran showed that bunch length, number of hands and number of fingers had highly significant correlation with yield Plant height exerted the highest direct effect on bunch yield while the pseudostem girth, leaf area and leaf area duration contributed indirectly through their effect on plant height (Kumar, 2001)

Spraying of Zn (1 %) + B (0 5 %) produced the highest plant height, number of functional leaves, petiole length, number of suckers, number of hands per bunch, number of fingers per bunch, hand distance, hand weight, bunch length and bunch weight of dwarf cavendish banana (*Musa*, AAA, sub-group-cavendish, cv Giant Governor) (Mandal *et al* , 2002)

Studies conducted by Yadlod and Kadam (2008a) on the effect micronutrients *(Musa* sp) cv Grand Name revealed that early maturity (98 3 days) and minimum number of days required for ripening were observed with foliar spraymg of micronutrients mixture 1 per cent (two sprays) Maximum length (21 9 cm) and girth (15 5 cm) of fingers, maximum weight of ripe finger (137 5 g) were also recorded

Yadlod and Kadam (2008b) revealed that foliar spraying of micronutrients mixture 1 per cent (two sprays) resulted in maximum weight of bunch (23 8 kg), finger length (23 0 cm), finger girth (17 0 cm) and weight of mature finger (185 6 gm) and minimum number of days required for ripening of banana (*Musa* sp) cv Shrimanti (10 7 days)

Yadlod and Kadam (2008c) claimed that Micronutrients mixture 1 per cent two spray in banana (*Musa* sp) cv Ardhapuri enhanced the plant height (179 2 cm), pseudostem girth (67 3 cm) and number of leaves (14 2) Early maturity (106 0 days), Maximum finger length (22 0 cm) and girth (16 2 cm) and early ripening (9 8 days after harvesting) were also recorded with micronutrient mixture 1 per cent Maximum increase in weight of mature finger was found in two sprays of 1 per cent micronutrients mixture (178 3 g) followed by micronutrients mixture 1 per cent one spray (171 3 g)

Jeyabaskaran and Pandey (2008) reported that under high soil pH condition micronutrient such as Fe, Zn and B applied through foliar spray which resulted in higher pseudostem height, girth, total leaf area and bunch weight, number of fingers per bunch of Karpuravalli banana

Yadav *et al* (2010) reported that the higher level of chelated zinc (Zn-EDTA) with $MnSO_4$, $CuSO_4$, and Borox induced early and vigorous vegetative growth in terms of height and girth of the pseudostem, number of leaves and total leaf area consequently and also induces early inflorescence emergence in the plant and reduced the crop duration Ultimately the treatment with micronutrients produced the plant

with higher bunch weight, number of hands and fingers per bunch, length and girth of finger and yield per hectare It also produced favorable effect on fruit quality in terms of TSS, total sugars and reducing sugars, sugar/acid ratio and acidity percent

Patel *et al* (2010) observed that the foliar application of $ZnSO_4$ (0 5 %) + $FeSO_4$ (0 5 %) of banana cv Basrai at 3rd, 5th and 7th months after planting resulted in highest bunch weight, bunch length, bunch girth, number of hands per bunch and fruit yield

According to Pathak *et al* (2011), the combined application of Fe (0 5 %) and Zn (0 5 %) on banana cv Martaman (AAB, Silk) showed best response to plant height, basal girth of pseudostem, number of leaves, bunch weight, bunch length, bunch breadth, hands per bunch, fingers per bunch, days to shooting days to harvest, finger length, finger breadth, crop duration and days to ripening

Integrated Nutrient Management involving supply of 50 per cent of nutrients by spray on leaf and bunch (0 5 % Urea, 0 5 % SOP, 0 2 % $ZnSO_4$ and 0 1 % Boric Acid) four sprays on leaf from 5th months to 8th months improve quality in banana (IIHR, 2013)

Anjali *et al* (2013) found that foliar spraying of micronutrient mixture containing $ZnSO_4$ (0 5 %) + $FeSO_4$ (0 5 %) + $CuSO_4$ (0 2 %) + H_3BO_3 (0 1 %) increased the growth and yield parameters of banana cv Grand Naine such as plant height, pseudostem girth, number of leaves per plant, leaf area, bunch weight, number of hands per bunch, number of fingers per bunch and yield (t ha^{-1})

2 7 MICRONUTRIENT MIXTURE ON QUALITY OF CROPS

Application of Zn, Fe and Mn at 0 1 and 0 2 per cent resulted in considerable improvement of TSS, sugars and ascorbic acid contents in mango fruit at harvest as well as on ripening as compared to control (Dutta and Dhua, 2002)

Foliar spraying of Zinc @ 0 1 per cent alone or in combination with B @ 0 4 per cent and Cu @ 0 05 per cent increases TSS content of mango fruit cv Langra (Panwar and Singh, 2007)

Foliar spraying of Boric acid 0 02 per cent on mango cv Alphonso significantly increased the total sugars, reducing sugars, non- reducing sugars, TSS, ascorbic acid, carotenoids and sugar acid ratio (Sankar *et al* , 2013)

Kanujia *et al* (2006) found that maximum shelf life of cabbage var 'Golden Acre' was recorded with foliar application of micronutrient mixture (Zn, Fe, B, Mn, Cu and Mo) @ 100 ppm

Foliar spray of Zn, B, and Mo at the rate of 0 2 per cent $ZnSO_4$, 0 4 per cent boric acid and 0 05 per cent ammonium molybdate, singly and in various combination on Guava revealed that maximum TSS, ascorbic acid, reducing and non reducing sugars were obtained with combination of Zn, B and Mo (Singh and Chonkar, 1983)

Foliar spray of Zn @ 0 5 per cent + B @ 0 1 per cent at 4^{th}, 8^{th}, 12^{th} and 16^{th} months after planting in papaya increased total sugars, reducing sugars, non-reducing sugars, ascorbic acid and sugar acid ratio, in association with bio-chemical traits (Kavitha *et al* , 2000b)

Prabu and Singaram (2001) reported that the application of $ZnSO_4$ at 0 5 per cent + borax at 0 2 per cent through foliage increased the TSS, reducing sugars, total sugars and sugar acid ratio and reduced acidity of grapes

Sarkar *et al* (1984) studied that the foliar application of Zn, Cu, B and K on litchi increased the pulp weight, total sugars and TSS over control

Foliar spray of various concentrations of $ZnSO_4$ and borax increased the pulp weight, pulp peel ratio, TSS and sugar acid ratio and significantly decreased the acidity of litchi (Rani and Brahmachari, 2001)

Studies conducted by Dixit *et al* (1977) revealed that the sprays of $ZnSO_4$ and $FeSO_4$ on Kinnow mandarin, improved the juice content, TSS, total and reducing sugar, sugar acid ratio and ascorbic acid content

Haque *et al* (2000) found the maximum total sugar content, reducing sugar content, non-reducing sugar content and ascorbic acid content in fruit juice with spraying of $ZnSO_4$ @ 0 5 per cent in Mandarin orange

Modi *et al* (2012) revealed that foliar application of $ZnSO_4$ 0 5 per cent and borax 0 3 per cent at 30, 60 and 90 days after transplanting on papaya cv Madhu Bindu exerted great influence on ascorbic acid, total soluble solids, reducing sugar, non-reducing sugar and total sugar

Mishra *et al* (2012) reported that maximum TSS and Lycopene content of tomato cv Utkal Urbasi was obtained with foliar application of micronutrient mixture containing Zn-100 ppm, B- 100 pmm, Fe- 100 pmm, Mn- 100 ppm, Cu- 100 ppm and Mo- 50 ppm

2.7.1. Effect of micronutrient mixture on fruit quality of banana

Ghanta and Mitra (1993) observed that TSS, total sugars, reducing sugars, Pulp peel ratio, sugar acid and ascorbic acid content of banana cv Giant Governor were highest with foliar application of 0 3 per cent Zn + 0 I per cent Cu + 0 2 per cent B at 3 and 5 months after planting

Das (1995) reported that the maximum TSS and total sugars were obtained with foliar spraying of B + Zn + Cu at 3 and 5 months after planting of banana cvs 'Chemichampa' (AAB), 'Jahaji' (AAA) and 'Barjahaji' (AAA)

Pertin and Das (1998) revealed that in addition to NPK fertilizers, Zn, Fe, Cu and B were applied separately at 0 5, 0 2, 0 2 and 0 1 per cent, respectively, or in a combination increased the plant growth of banana cv Barjahaji

Foliar application of $ZnSO_4$ (0 5 %) + $FeSO_4$ (0 2 %) + $CuSO_4$ (0 2 %) + H_3BO_3 (0 1 %) at 3, 5 and 7 months after planting increased the pseudostem girth, number of leaves and total chlorophyll content, bunch weight and total soluble solid content of banana (*Musa* AAA) cv Robusta (Kumar and Jayakumar, 2001)

Suresh and Savithri (2001) found that the soil application of N, P and K and foliar spray on nutrients (1 % DAP + 1 % MDP + 0 05 % $ZnSO_4$ + 0 2 % $CuSO_4$ + 0 2 % Borax) in addition to liming had increased the TSS, sugar acid ratio and decreased the titrable acidity of banana

Jeyabaskaran and Pandey (2008) reported that under high soil pH condition micronutrient such as Fe, Zn and B applied through foliar spray which resulted in maximum total soluble solids, acidity and TSS/acid ratio of Karpuravalli banana

Micronutrient mixture 1 per cent at two times spraying in banana cv Grand Naine significantly increases the total sugars, reducing sugars and non-reducing sugar content and minimizes per cent loss in weight during ripening (Yadlod and Kadam, 2008a)

Patel *et al* (2010) observed that the foliar application of $ZnSO_4$ (0 5 %) + $FeSO_4$ (0 5 %) of banana cv Basrai at 3rd, 5th and 7th months after planting resulted in highest ascorbic acid content, reducing sugars and total sugars

According to Pathak *et al* (2011), the combined application of Fe (0 5 %) and Zn (0 5 %) on banana cv Martaman (AAB, Silk) showed maximum sugar acid ratio (47 7), non-reducing sugar (10 0 %) also showed considerable improvement on total soluble solids (25 5 °Brix) and total sugar (17 24 %) content of pulp

Maeda *et al* (2011) confirmed that foliar sprayingof zinc sulfate + citric acid + EDTA + iron sulfate + manganese sulfate + magnesium sulfate (9 4 % S, 5 % Zn, 1 % Fe, 1 % Mn, 1 % Mg, 1 5 % citric acid, and 4 3 % EDTA) has profound to increase TSS, Titratable acidity of pineapple

Yadav *et al* (2011) recorded maximum TSS and other quality parameters of banana cv Grand Naine with Recommended dose of fertilizers (200+90+200 NPK g/plant) + 40 g Zn EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant

According to Bhatt *et al* (2012), foliar spray of 0 5 per cent borax on mango trees showed highest TSS, reducing sugar, non reducing sugar and ascorbic acid content

Bauri *et al* (2014) reported that foliar spraing of Borax (0 1 %) at 5 and 20 days after last hand opening showed maximum total soluble solids (26 7 °Brix), total sugar (14 6 %) and sugar acid ratio (45 5) of banana cv Martaman (*Musa* AAB, Silk)

Ningavva *et al* (2014) found that the maximum pulp weight (147 2 g), peel weight (42 9 g), pulp to peel ratio (3 4), TSS (28 5 °Brix), reducing sugar (16 0 %), non reducing sugar (2 9 %), total sugars (19 0 %), Titrable acidity (0 3 %) and Sugar to acid ratio (65 4) of Ratoon Banana cv Grand Naine were recorded with 100 per cent RDF (100 108 200g NPK/plant) + foliar spray of $ZnSO_4$ (0 5 %) + boron (0 2 %) with double suckers per hill

Paul and Nair (2015) reported that foliar spray of $ZnSO_4$ 1 0 per cent + $FeSO_4$ 0 3 per cent + $CuSO_4$ 0 2 per cent + H_3BO_3 0 2 per cent + $(NH_4)_2MoO_4$ 0 03 per cent recorded highest total sugar (19 4 %) and reducing sugar (16 9 %) and minimum non reducing sugar (2 5 per cent) of banana (*Musa* AAB) Nendran

2 8 EFFECT OF MICRONUTRIENTS ON NUTRIENTS CONTENT IN LEAF

Shueadshen (1991) reported that foliar application of 0 1 per cent B, Fe, Cu, Co, Zn and Mn at tillering stage increased N and P uptake over control in rice Gupta and Gupta (1985) revealed that foliar application of chelated micronutrient mixture enhanced the uptake of Zn, Fe, Mn, Cu, Ca and Mg content in rice

According to Patel *et al* (2008), foliar spray of multi-micronutrient mixture (Fe- 6 %, Mn- 1 %, Zn- 4 %, Cu- 0 3 % and B- 0 5 %) resulted in maximum micronutrient uptake by wheat grain and straw

Spraying with different micronutrients (Zn 0 3 %, Cu 0 1 %, B 0 2 % and Mn 0 05 %) with or without combinations on banana cv Giant Governor significantly increased the leaf nitrogen, phosphorus and potassium content before flowering compared with control (Ghanta and Mitra, 1993)

According to Ray *et al* (2006), leaf content of 2 8 0 52 3 8 per cent NPK at shooting was a good indicator for satisfactory productivity in Robusta banana

Foliar application of $ZnSO_4$ (0 5 %) + $FeSO_4$ (0 2 %) + $CuSO_4$ (0 2 %) + H_3BO_3 (0 1 %) at 3, 5 and 7 months after planting increased the leaf micronutrient status of banana (*Musa* AAA) cv Robusta (Kumar and Jayakumar, 2001)

Jeyabaskaran and Pandey (2008) reported that under high soil pH condition micronutrient such as Fe, Zn and B applied through foliar spray which resulted in higher K, Zn, B, Fe and Mn content of Karpuravalli banana leaves

Foliar spray of micronutrients (Zn as $ZnSO_4$ at 0 3 %, Boron as boric acid 0 1 % , Cu at 0 1 % with 1 % SOP and 1 % Urea) four times at monthly intervals resulted in improving leaf Zn, B and Cu nutrient status of banana cv Ney Poovan (Muthaia and Raja, 2009)

Yadav *et al* (2010) recorded highest Zn content in banana cv Grand Naine leaf with RDF (200+90+200 NPK g/plant) + 40 g Zn EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant While maximum Fe content in leaf noted from RDF + 25 g $FeSO_4$ + 2 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax and RDF + 25 g Fe EDTA + 20 g $MnSO_4$ + 5 g $CuSO_4$ + 10 g Borax/plant, respectively (Yadav *et al* , 2009b)

Dutta and Dhua (2002) reported that the leaf nutrient status of mango increased with application of Zn (0 1 and 0 2 %), Mn (0 1 and 0 2 %) and Fe (0 1 and 0 2 %) Application of Zn improved the leaf N and Zn content while Fe improved P and Fe and Mn improved the Mn and K contents

Foliar spraying of Boric acid 0 02 per cent on mango cv Alphonso significantly increased the N, P, K and B content of leaves (Sankar *et al* , 2013)

Aggarwal *et al* (1975) observed that different combination of $ZnSO_4$ (0 5 %), $CuSO_4$ (0 25 %) and $FeSO_4$ (0 25 %) increased the Zn, Cu and Fe contents in leaf tissues of Thompson seedless grapes over the control

Durgadevi *et al* (1997) reported that the application of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ as foliar spray or soil application or combination of both, significantly increased the N, P, K, Ca and Mg contents in the Sathgudi orange leaves

Patel (2006) revealed that total iron content in leaves increased due to foliar application of iron which recovered iron chlorosis in citrus

Ram and Bose (2000) found that the foliar spray of $MnSO_4$ (2 %), $CuSO_4$ (0 4 %), $ZnSO_4$ (0 5 %), boric acid (0 1 %) and $FeSO_4$ (0 25 %) either singly or in various combinations significantly increased the N, P and K content of the Mandarin orange leaf

Afria *et al* (1999) reported that the foliar application of $FeSO_4$ (0 4 %), $ZnSO_4$ (0 25 %) and borax (0 2 %) on pomegranate increased the Fe, Zn and B content in leaves individually or in combination

Dalal *et al* (2011) found that foliar spraying of zinc sulphate and borax significantly increased the Zn and Mn uptake by ber leaves

Foliar spray of $FeSO_4$ (0 5 %) + $ZnSO_4$ (0 5 %) + Boric acid (0 2 %) resulted in maximum uptake of N and B in okra cv Phule Utkarsha (Satpute *et al*, 2013)

2 9 MICRONUTRIENTS ON PLANT DISEASE CONTROL

All the essential nutrients can affect the disease severity (Huber and Graham, 1999) and nutrients availability is the best way to control plant diseases in an integrated pest management system (Graham and Webb, 1991)

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

Micronutrient concentrations in plants are important in host ability to resist or tolerate infectious pathogens Plant nutrition is an important component of disease control (Huber and Wilhelm, 1988)

Boron sufficiency in plants reduces the incidence and severity of diseases, while B deficiency enhances them (Gupta, 1993, Graham and Webb, 1991) Manganese concentration in host tissue commonly decreases as the incidence of disease increases The severity of parasites on plants is influenced by many micronutrients (Engelhard, 1990, Graham and Webb, 1991, Huber, 1980) The lack of Zn, B, Mn, Mo, Ni, Cu and Fe in plant tissue can enhance various diseases on

plants (Engelhard, 1990; Graham and Webb, 1991, Huber, 1980, Fageria *et al*, 1997, Baligar *et al*, 1998)

Prophylactic treatment of micronutrient solutions as a foliar spray on the upper surface leaves of cucumber plants significantly inhibited powdery mildew development (Reuveni *et al*, 1997)

Simoglou and Dordas (2006) revealed that manganese fertilization decreased the pathogenic disease incidence such as powdery mildew and take-all of wheat Soil application of Mn reduced common scab of potato (Kemath and Loria, 1996), *Fusarium* wilt of cotton and *Sclerotinia sclerotiorum* in squash (Graham and webb, 1991, Agrios, 2005)

Zinc nutrition is associated with important plant defense pathways against many fungal and bacterial pathogens Grewal *et al* (1996) reported that root rot and *Fusarium graminearum* (Schwable) diseases of wheat controlled with soil application of Zn

Proper Fe nutrition not only boosts plant vigour and health, it indirectly affects disease in the rhizosphere where its availability may limit the growth of pathogens Iron reduced the disease severity of rust and smut of wheat, *Colletotrichum musae* of banana (Graham and Webb, 1991, Graham, 1983)

Graham (1983) observed that foliar application of Fe increased the disease resistance of apple and pear to *Sphaeropsis malorum* and cabbage to *Olpidium brassicae* Rhizosphere microorganisms could able to synthesize siderophores which lowers Fe levels for harmful microorganisms in soil These iron chelators resulted in suppressing chlamydospores of *Fusarium oxysporum f sp cucumerinum*, crown-gall (*Agrobacterium tumefaciens*) and take-all diseases of wheat, soft rot of potato (*Erwinia caratovora*)

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

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

Foliar spray of micronutrients (Zn as $ZnSO_4$ at 0 3 %, Boron as boric acid 0 1 % , Cu at 0 1 % with 1 % SOP and 1 % Urea) four times at monthly intervals resulted in improving resistance to Panama wilt of banana cv Ney Poovan The number of affected plants in control plot is 32 per cent whereas in micronutrients sprayed plot 5 per cent only (Muthaia and Raja, 2009)

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

Reuveni *et al* (1998) reported that foliar spray of H_3BO_3, $CuSO_4$, $MnCl_2$ resulted in reduction of powdery mildew disease severity in cucumber

McMillan *et al* (2000) found that KeyPlex 350 (micronutrient preparation) treatment reduced the incidence of Sigatoka leaf spot of banana (*Musa acuminata*) cv Dwarf Cavendish as compared to the untreated control

2 10 MICRONUTIRENT MIXTUE ON ENHANCING ECONOMICS OF CULTIVATION OF CROPS

Yadav and Patel (2013) reported that application of micronutrients ($ZnSO_4$ 40 g + $MnSO_4$ 20 g + $CuSO_4$ 5 g + Borax 10 g) on Grand Naine banana gave the maximum additional net income of Rs 42812 per hectare with the cost benefit ratio of 1 7 17

Patel *et al* (2010) observed that the foliar application of $ZnSO_4$ (0 5 %) + $FeSO_4$ (0 5 %) of banana cv Basrai at 3rd, 5th and 7th months after planting resulted in maximum gross income and net profit with higher cost benefit ratio (1 1 94)

According to Pathak *et al* (2011), the combined application of Fe (0 5 %) and Zn (0 5 %) at 3, 5 and 7 months after planting of banana cv Martaman (AAB, Silk) gave better B C ratio

Bauri *et al* (2014) found that foliar spraing of Borax (0 1 %) and 2,4-dichlorophenoxyacetic acid (30 ppm) at 5 and 20 days after last hand opening showed maximum B C ratio of banana cv Martaman (*Musa* AAB, Silk)

3. MATERIALS AND METHODS

An investigation entitled "Formulation and evaluation of micronutrient mixture for foliar application in TC banana (*Musa* sp) var Nendran" was carried out at College of Agriculture, Padannakkad and Regional Agricultural Research Station (RARS) farm, Nileshwar during November 2014 to March 2016 The objectives of the study were to prepare micronutrient mixture as a liquid formulation and to study the effect of application of this mixture on hardening stage and in the field condition of tissue culture banana var Nendran The whole study was conducted in three steps

Part I Preparation of micronutrient mixture formulation

Part II studies on hardening of TC banana plants using foliar sprays of micronutrients

Part III Field experiment

3 1 PREPARATION OF MICRONUTRIENT MIXTURE FORMULATION

Micronutrient mixture containing zinc, boron, iron, copper, manganese and molybdenum was prepared at different concentrations and evaluated for stability and keeping quality in solution form The different micronutrient salts used were Zinc sulphate, Boric acid, Copper sulphate, Manganous sulphate, Ferrous sulphate and Ammonium molybdate The technique was standardized after trying a series of combinations Finally the micronutrient mixture was formulated and it contains two separate mixtures solution A and solution B Each series of the nutrient solutions were evaluated for their phyto suitability by spraying on leaves and observing the leaves for one week The solutions which produced toxic/ necrotic spots were discarded The prepared nutrient mixture was then, tested with tissue culture Nendran banana as a foliar application in both pot culture and field experiment This work was done as a laboratory trial with the salts containing these nutrients

3 2 POT CULTURE EXPERIMENT

The secondary hardening studies were conducted in mist chamber of Department of Plant Biotechnology, COA, Padannakkad with tissue culture plants of uniform stage multiplied from same genotype The experiment was conducted in completely randomized design with four different levels and three different time of application of micronutrient mixture as a foliar spray There were 12 treatment combinations and one control with three replications each Four plants were maintained in each replication, so that the total number of plants was 156 The potting mixture was prepared uniformly with 1 1 1 ratio of sand, soil and cowdung and the plants were raised in polybags for a period of 20 days in mist chamber (primary hardening stage) The plants were transferred to bigger polybags and then secondary hardening was carried out in partial shade condition for a period of one month and this stage, different spraymgs were given to plants Plate 1 shows the secondary hardening of tissue culture banana var Nendran

3.2.1. Design and Layout

Crop	Tissue culture banana
Variety	Nendran
Design	CRD
Treatments	13
Replication	3

3.2.2. Levels of nutrients

The standardized micronutrient mixture formulation was sprayed at 0 25 per cent, 0 5 per cent, 0 75 per cent and 1 0 per cent foliar sprays The volume of spray solution was 150ml per plant

Concentration	One spray	Two sprays	Three sprays
0 25 %	T_1	T_5	T_9
0 5 %	T_2	T_6	T_{10}
0 75 %	T_3	T_7	T_{11}
1 0 %	T_4	T_8	T_{12}

T_{13} control

3.2.3. Time of application

One spray at immediately after planting, two sprays at immediately and two weeks after planting and three sprays at immediately, two and three weeks after plantmg during secondary hardening stage

3.2.4. Biometric observations

The important biometric observations like plant height, number of leaves, leaf length and leaf breadth were recorded one month after treatment imposition

3.2.4.1. Plant height

The plant height was measured from the base of the pseudostem to the youngest leaf

3.2.4.2. Number of leaves

The number of photosynthetically active leaves was counted

3 2.4 3. Leaf length

Leaf length was measured from petiole to tip of the leaf

3.2.4.4. Leaf breadth

Leaf breadth was measured from the widest portion of the leaf

3 3 FIELD EXPERIMENT

The field experiment was conducted at Regional Agricultural Research Station (RARS) farm, Nileshwar to evaluate the effect of micronutrient mixture as a foliar spray in tissue culture banana var Nendran The experiment was conducted in randomized block design with thirteen treatments and three replications such that four plants were maintained in each replication Nitrogen, phosphorus and potassium application and other cultural practices were followed as per Package of Practices recommendations, KAU (2011) uniformly for all the treatments Plate 2 shows the field view of the experimental plot at RARS farm, Nileshwar

3.3.1. Design and layout

Crop	Tissue culture banana
Variety	Nendran
Design	RBD
Treatments	13
Replication	3

3.3.2. Levels of nutrients

The standardized micronutrient mixture formulation was sprayed at 1 per cent, 2 per cent, 3 per cent and 4 per cent foliar sprays The volume of spray solution was 750ml per plant Package of Practices recommendations were followed for all treatments

Concentration	One spray	Two sprays	Three sprays
1 %	T_1	T_5	T_9
2 %	T_2	T_6	T_{10}
3 %	T_3	T_7	T_{11}
4 %	T_4	T_8	T_{12}

Control-T_{13} was PoP (Package of Practices recommendations)

3.3.3. Time of application

One spray at two months after planting, two sprays at two and four months after planting and three sprays at two, four and six months after planting

3.3.4. Biometric observations

Biometric observations like pseudostem height, pseudostem girth and number of leaves were taken four months after planting and at the time of shooting Days to bunch emergence, incidence of pest and diseases were recorded Days to harvest, number of suckers at harvest, bunch weight, number of hands per bunch, number of fingers per hand, average weight of finger, days to ripening, finger length and finger breadth were recorded at the time of harvesting

3.3.4.1. Pseudostem height

The pseudostem height from the ground level of pseudostem upto the base of youngest leaf at 4 months after planting and upto the base of boot leaf at the time of shooting was measured and it is expressed in meter (m)

3.3.4.2. Pseudostem girth

Girth of pseudostem at 90cm of height from the ground level was measured at four months after plantmg and at the time of shooting and it is expressed in cm

3.3.4.3 Number of leaves

Total number of leaves was recorded at four months after planting and at the time of shooting

Figure 1 Layout of Field experiment

Block I	**Block II**	**Block III**
T_5	T_7	T_2
T_{13}	T_{11}	T_9
T_2	T_1	T_{12}
T_{10}	T_9	T_5
T_8	T_2	T_7
T_4	T_5	T_4
T_7	T_{13}	T_1
T_{12}	T_6	T_{10}
T_3	T_{12}	T_6
T_9	T_{10}	T_{11}
T_6	T_2	T_{13}
T_{11}	T_4	T_8
T_1	T_8	T_3

3.3.4.4. Days to bunch emergence

Number of days to bunch emergence of individual treatments from the date of planting was recorded

3 3.4.5. Incidence of pest and diseases

Incidence of pest and diseases were monitored and necessary control measures also were taken from hardening stage to harvesting

3.3.4 6. Bunch maturity period

Number of days taken from day of bunch emergence to harvest of banana were recorded for individual treatment

3 3.4 7. Days to harvest

Number of days taken from the date of planting to the date of harvest was recorded for individual treatments

3.3.4.8. Number of suckers at harvest

The total number of suckers produced by the plant at the time of harvest was recorded.

3.3.4.9. Weight of male bud

Fresh weight of male bud one month after bunch emergence for individual treatments was recorded

3.3.4.10. Bunch weight

Bunch weight of individual treatment was recorded at the time of harvest

3.3.4.11. Number of hands per bunch

Number of hands in each bunch were counted at the time of harvest

3.3.4.12. Number of fingers per bunch

Total number of fingers in each bunch of all individual plants were counted at the time of harvest

3.3.4.13. Average weight of fingers

Average weight of fingers was calculated for individual bunch by taking weight of fingers from top, middle and bottom of bunch and averaged

3.3.4.14. Days to ripening

Number of days to ripening for individual treatments was recorded from the time of harvest to ripened fruit

3.3.4.15. Finger length

Average length of fingers was calculated by measuring length of finger in topmost, middle and bottom of the bunch and their average was taken

3.3.4.16. Finger breadth

Average breadth of fingers was calculated by measuring breadth of finger in topmost, middle and bottom of the bunch and their average was taken

3 4 FRUIT ANALYSIS

Quality parameters of banana such as Total Soluble Solids, titrable acidity, vitamin C content, total sugar and pulp to peel ratio were analyzed using standard

methods Loss in weight during ripening and keeping quality of fruits in ambient condition was also recorded

3.4.1. Total soluble solids (TSS)

Total soluble solids of the fully ripened banana fruit were analyzed using handheld portable refractometer and it is expressed in terms of °brix

3.4.2. Titrable Acidity

For analyzing titrable acidity of fully ripened banana fruits, 50 g of fruit was ground from which 25 g of pulped material was transferred to a 250 ml beaker In that 100 ml of distilled water was added and boiled for 30 minutes Once it is cooled, transferred to 250 ml standard flask and volume was made up and from that 50ml was taken which was diluted with equal quantity of hot water Titrated against 0 1N NaOH using phenolphthalein indicator till the appearance of light pink colour which was the end point and titrable acidity was worked out and the results are expressed as percentage of maleic acid

3.4.3. Reducing sugar content

Reducing sugar content was determined by titrating fruit juice with Fehling solution A and B as per procedure given by Ranganna (1986) and the results are expressed in percentage

3 4.4. Total sugar content

Total sugar content was determined by titrating fruit juice with Fehling solution A and B and the results are expressed in percentage

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3.4.5. Non-reducing sugars

Non- reducing sugar content was determined by substracting reducing sugars from total sugars content and the results are expressed in percentage

3.4.6. Pulp to peel ratio

Weight of pulp and peel was recorded separately and the relative proportion of pulp to peel was recorded (i e pulp weight divided by the peel weight)

3.4.7. Sugar / acid ratio

Total sugars (%) divided by acidity (%) gave the sugar / acid ratio of ripened fruit

3.4.8. TSS / acid ratio

TSS (°brix) divided by acidity (%) gave the TSS / acid ratio of ripened fruit

3.4.9. Keeping quality of fruits at ambient condition

Keeping quality of fruits was calculated by counting number of days form day of commencement of ripening of fruits to end of saleable life or edible life

3.4.10. Per cent loss in weight during ripening

Per cent loss in weight was calculated form weight of fruits at the time of harvest to weight of ripened fruit and it is expressed in percentage

3 5 SOIL ANALYSIS

3.5.1. Initial soil analysis

Soil samples for initial analysis were collected from the prepared field Soil samples were drawn from surface 15 cm from 10 different places of the field which

was then pooled, reduced to required quantity and air dried The air dried soil samples were ground and passed through 2 mm sieve and stored in air tight containers

The samples were analyzed for bulk density, particle density, porosity, texture, pH, EC, CEC, organic carbon, available nutrients such as N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B and Mo following standard procedures given in table 1 The initial soil properties were given in table 2

3.5.2. Experimental soil analysis

Soil samples for laboratory analysis were collected from all the treatments at the time of harvest The samples were air dried, ground, sieved with 2mm sieve and stored in air tight container They were analyzed for available nutrients such as N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B and Mo as per the standard procedures as given in the table 1

3 6 PLANT ANALYSIS

Plant samples were collected from the index leaf (third fully opened leaf from top) at the time of bunching and at harvest and analyzed for various macro and micronutrient status in it using standard procedures as given in the table 3

3 7 BENEFIT COST RATIO

Cost of cultivation for all the treatments was worked out on the basis of prevailing input cost and market price of fruits, male bud and suckers at the time of experimentation The net income was calculated by deducting the cost of cultivation from the gross return The benefit cost ratio (BCR) was worked out as follows

$$BCR = \frac{\text{Gross return ha}^{-1}\ (Rs)}{\text{Cost of cultivation ha}^{-1}\ (Rs)}$$

3 8 STATISTICAL ANALYSIS

The data obtained from pot culture and field experiment was analyzed statistically and tested for its significance using WASP 2 0 software given by ICARGOA

Table 1 Analytical methods followed for soil analysis

S No	Parameters	Method	Reference
1	pH	pH meter	Jackson (1958)
2	EC	Conductivity meter	Jackson (1958)
3	Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
4	Bulk density	Undisturbed core sample	Black *et al* (1965)
5	Particle density	Pycnometer method	Black *et al* (1965)
6	Porosity	-	Black *et al* (1965)
7	Textural analysis	International pipette method	Robinson (1922)
8	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
9	Available P	Bray extraction and photoelectric colorimetry	Jackson (1958)
10	Available K	Flame photometry	Pratt (1965)
11	Available Ca	Atomic absorption spectroscopy	Jackson (1958)
12	Available Mg	Atomic absorption spectroscopy	Jackson (1958)

13	Available S	Photoelectric colorimetry	Massouni and Comfield (1963)
14	Available Zn	Atomic absorption spectroscopy	Emmel *et al* (1977)
15	Available B	Photoelectric colorimetry	Bingham (1982)
16	Available Fe	Atomic absorption spectroscopy	Sims and Johnson (1991)
17	Available Cu	Atomic absorption spectroscopy	Emmel *et al* (1977)
18	Available Mn	Atomic absorption spectroscopy	Sims and Johnson (1991)
19	Available Mo	Inductively coupled plasma optical emission spectrometry (ICP OES)	Soltanpour and Schwab (1977)

Table 2 Properties of the initial soil sample

S No	Parameter	Value
I Physical properties		
1	Bulk density (g cm ^{3})	1 34
2	Particle density (g cm ^{3})	2 35
3	Pore space (%)	43%
II Mechanical composition		
1	Sand (%)	77 25
2	Silt (%)	19 00

Table 2 Continued

3	Clay (%)	3 75
4	Textural class	Loamy sand
III Chemical properties		
1	pH	5 31
2	EC (dS/m)	0 08
3	Organic carbon (%)	0 40
4	Organic matter (%)	0 69
5	CEC (meq/100g)	7 50
6	Available N (kg/ha)	213 20
7	Available P (kg/ha)	82 69
8	Available K (kg/ha)	184 73
9	Available Ca (mg/kg)	148 25
10	Available Mg (mg/kg)	23 65
11	Available S (mg/kg)	6 25
12	Available Zn (mg/kg)	0 91
13	Available B (mg/kg)	0 26
14	Available Fe (mg/kg)	26 8
15	Available Cu (mg/kg)	2 63
16	Available Mn (mg/kg)	22 10
17	Available Mo (mg/kg)	0 002

Table 3 Analytical methods followed for plant analysis

S.No	Parameter	Method	Reference
1	Total N	Modified kjeldhal digestion method	Jackson (1958)
2	Total P	Vanadomolybdate yellow colour method	Piper (1966)
3	Total K	Flame photometry	Jackson (1958)
4	Total Ca	Atomic absorption spectroscopy	Issac and Kerber (1971)
5	Total Mg	Atomic absorption spectroscopy	Issac and Kerber (1971)
6	Total S	Turbidimetric method	Bhargava and Ragupathi (1995)
7	Total Zn	Atomic absorption spectroscopy	Emmel *et al* (1977)
8	Total B	Azomethane – H colorimetric method	Bingham (1982)
9	Total Fe	Atomic absorption spectroscopy	Piper (1966)
10	Total Cu	Atomic absorption spectroscopy	Emmel *et al* (1977)
11	Total Mn	Atomic absorption spectroscopy	Piper (1966)
12	Total Mo	Inductively coupled plasma optical emission spectrometry (ICP OES)	Soltanpour and Schwab (1977)

Plate 1a Secondary hardening of TC plants (using micronutrient mixture formulation)

Plate 1b Treatment vs Control

Plate 1 Secondary hardening of tissue culture banana var. Nendran (using micronutrient mixture formulation)

Plate 2 a Field view 2 MAP

Plate 2 b Field view 4 MAP

Plate 2 c Field view at bunching stage

Plate 2 Field view of the experimental plot at RARS Farm Nileshwar

Results

4. RESULTS

An investigation was carried out to formulate micronutrient mixture in liquid formulation and to examine the effect of micronutrient mixture in tissue culture banana var Nendran during hardening stage as well as in field The results of biometric observations (taken after hardening stage and in field experiment) and the various soil, leaf and fruit characteristics were statistically analyzed and the results are presented below

4 1 PREPARATION OF MICRONUTRIENT MIXTURE AS A LIQUID FORMULATION

Liquid micronutrient mixture for foliar application was formulated using different micronutrient salts Different combinations were tried and it's keeping quality, stability and compatibility for foliar application was evaluated, finally it is standardized in 2 parts solution A and solution B Solution A consisting of Zinc sulphate, Copper sulphate, Ferrous sulphate, Boric acid, Manganous sulphate and Ammonium molybdate in different proportion Solution B contains 1 per cent humic acid which acts as a natural chelating agent for improving micronutrient use efficiency These two solutions are to be diluted and blended before sprays Plate 3 shows preparation of micronutrient mixture as a liquid formulation

4.1.1. Composition of Solution A (1 litre)

$ZnSO_4$ $7H_2O$ - 100 g
$CuSO_4$ $5H_2O$ - 40 g
$FeSO_4$ $7H_2O$ - 20 g
H_3BO_3 20 g
$MnSO_4$ H_2O - 1 g
$(NH_4)_6Mo_7O_{24}$ $4H_2O$ - 0 5 g

This micronutrient mixture was prepared using these salts but it did not have desired pH for foliar spraying and the its keeping quality and stability were poor The pH of the mixture was 3 4 and there were precipitates in formulation and it was visually not a clear solution

4.1.2. Stability and keeping quality of the formulation

For improving the stability and keeping quality of the micronutrient mixture, various chemicals were tried with solution A and the keeping quality of the mixture was evaluated The different chemicals used were Ammonia (5 %), nitric acid (5 %), tartaric acid (10 %) and citric acid (20 %) Except citric acid other chemicals were forming precipitate with micronutrient mixture which is presented in Plate 3 c When 30 ml of citric acid (20 %) was added to 1 litre of nutrient mixture it became clear liquid, there wass no precipitation of nutrient compounds and its keeping quality was excellent It was further monitored at specific intervals to evaluate its stability and keeping quality Solution A with 30ml/litre of citric acid (20 %) can be kept as such at ambient conditions upto 1 year whereas with nitric acid and ammonia it forms precipitate within a day and with tartaric acid it is stable upto a maximum of one week

Solution B contains 1 per cent humic acid, from solution B 30 ml/litre was uniformly added to final diluted solution of A Both solutions should be mixed thoroughly just before spraying

4.1.3. Properties of micronutrient mixture

The pH of micronutrient mixture was noted just before spraying and it was observed as 5 56 at the desired dilution Colour of Solution A is Green and Solution B is Brown Based on the properties like pH, keeping quality and trail on standing crop, formulated micronutrient mixture was found suitable for foliar application on banana

Plate 3 a Micronutrient mixture with and without citric acid

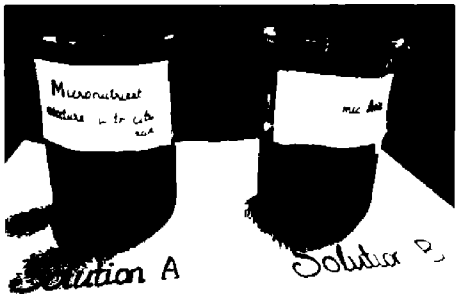


Plate 3 b Micronutrient mixture solution A and solution B

Plate 3 c Keeping quality of solution A with different chemicals

Plate 3 Preparation of Micronutrient mixture as a liquid formulation

4 2 POT CULTURE EXPERIMENT

Tissue culture banana plants of uniform stage multiplied from the same genotype were obtained from Department of Plant Biotechnology, College of Agriculture, Padannakkad The secondary hardening studies were done in the mist chamber with various treatment combinations of micronutrient mixture as foliar spray The treatments consisted of 4 levels of micronutrient mixture sprayed at 3 different intervals The different treatment combinations were T_1, T_5, T_9 at 0 25 per cent (one, two and three sprays), T_2, T_6, T_{10} at 0 50 per cent (one, two and three sprays), T_3, T_7, T_{11} at 0 75 per cent (one, two and three sprays), T_4, T_8, T_{12} at 1 per cent (one, two, three sprays) and T_{13}- control One spray was given at immediately after planting , two sprays at immediately and two weeks after planting and three sprays at immediately, two and three weeks after planting The experiment was intended to evaluate the role of this micronutrient mixture formulation on performance of plants in hardening stage Periodic biometric observations were also made The biometric observations of hardening studies were taken at the end of one month after treatment imposition

4.2.1. Plant height

The results of the effect of micronutrient mixture on biometric characters of TC banana are given in Table 4 All the treatments were found to be superior to the control Among the treatments, T_{10} (0 5 % as three time spraying) recorded highest plant height (20 2 cm) which was on statistically par with treatments T_9 and T_5 whereas the control T_{13} recorded lowest plant height (16 6 cm) which was on par with T_4, T_{12}, T_8 and T_7

Table 4 Foliar application of micronutrient mixture on biometric characters of TC banana

Treatments	Plant height (cm)	Number of leaves	Leaf length (cm)	Leaf breadth (cm)
T_1	18 63	6 58	17 24	6 43
T_2	19 08	6 58	17 95	6 21
T_3	18 81	6 08	18 07	6 83
T_4	16 88	5 83	15 63	5 73
T_5	19 93	6 08	19 58	7 03
T_6	18 68	6 33	18 24	6 49
T_7	17 38	5 42	16 29	6 32
T_8	17 15	5 50	16 66	5 94
T_9	20 04	6 75	18 32	7 33
T_{10}	20 21	6 67	19 33	6 94
T_{11}	17 46	5 75	17 11	6 51
T_{12}	16 98	5 33	16 47	6 10
T_{13}	16 62	5 08	16 68	5 93
SEm (±)	0 369	0 103	0 800	0 199
CD (0 05)	1 019	0 538	1 501	0 749

4.2.2. Number of leaves

Number of leaves was counted and is presented in Table 4 Maximum leaf number was recorded with T_9 (6 8) which was statistically on par with T_{10}, T_1, T_2 and T_6 T_{13} (control) recorded minimum leaf number (5 1)

4.2.3. Leaf length

There was significant difference between treatments with respect to leaf length (Table 4) Leaf length was found to be high in T_5 (0 25 % - two sprays) with 19 6 cm followed by T_{10}, T_9 and T_6 and lowest was T_4 (15 6 cm) which was on par with T_7

4.2.4. Leaf breadth

There was notable difference in leaf breadth between the treatments (Table 4) Leaf breadth found to be maximum in T_9 (0 25 % - three sprays) with 7 3 cm which was statistically on par with T_5 and minimum leaf breadth was found in T_4 (5 7 cm) which was on par with T_{13} and T_8

4 3 FIELD EXPERIMENT

The field experiment was conducted at Regional Agricultural Research Station farm, Nileshwar to study the effect of foliar application of micronutrient mixture in tissue culture banana var Nendran The experiment was conducted in RBD with four different levels and three different time of application of micronutrient mixture as a foliar spray There were 12 treatment combinations and one control with three replications each Four plants were maintained in each replication, so that the total number of plants was 156 The different treatment combinations were T_1, T_5, T_9 at 1 per cent (one, two and three sprays), T_2,T_6,T_{10} at 2 per cent (one, two and three sprays), T_3,T_7,T_{11} at 3 per cent (one, two and three

sprays), T_4, T_8,T_{12} at 4 per cent (one, two and three sprays) and T_{13}- control One spray was given at two months after planting, two sprays at two and four months after planting and three sprays at tow, four and six months after plantmg Periodic growth and yield parameters were recorded, detailed soil, fruit and leaf analysis were carried out and statistically analyzed The salient finding of field experiments are presented below

4.3.1. Effect on vegetative characters

4.3.1.1. Pseudostem height

The pseutostem height was recorded at 4 months after planting and at the time of shooting and the results are presented in table 5 The height of the pseudostem was significantly influenced by the nutrient treatments at 4 months after planting T_{12} recorded maximum plant height of 1 5 m while T_5 recorded lowest height (1 2 m) whereas control T_{13} was recorded with 1 3 m T_{12} was statistically on par with T_{10} (1 4 m), T_1 (1 4 m), and T_8 (1 4 m)

At the time of shooting, there was no notable difference between the treatments on pseudostem height (Table 5) Even though not significant, T_6 recorded maximum pseudostem height (2 9 m) followed by T_{10} and T_{11} (2 8 m) whereas T_4 recorded minimum height of 2 7 m whereas control T_{13} was recorded with 2 7 m

4.3.1.2. Pseudostem girth

Pseudostem girth at 90 cm height was measured at 4 months after planting and at the time of shooting (Table 5) T_{12} (29 6 cm) recorded maximum pseudostem girth at 4 months after planting followed by T_{10} (29 0 cm) and minimum girth was found in T_5 (23 8 cm) However, there was no significant difference between the treatments and control

There was notable difference in pseudostem girth between the treatments at the time of shootmg (Table 5) T_{10} recorded maximum girth of 52 1 m which was

statistically on par with T_6 (51 5 cm), T_1 (51 1 cm), T_5 (50 7 cm) and T_{11} (50 0 cm) and minimum pseudostem girth was found in T_3 (47 7 cm) which was on par with control T_{13} (48 0 cm)

Table 5 Foliar application of micronutrient mixture on pseudostem height and girth of banana

Treatments	Pseudostem height (m)		Pseudostem girth (cm)	
	4 months after planting	At the time of shooting	4 months after planting	At the time of shooting
T_1	1 36	2 75	28 28	51 12
T_2	1 30	2 79	24 70	49 17
T_3	1 24	2 70	24 23	47 67
T_4	1 21	2 68	24 08	48 75
T_5	1 18	2 77	23 75	50 71
T_6	1 24	2 85	26 01	51 54
T_7	1 26	2 69	26 15	48 46
T_8	1 35	2 83	28 23	48 42
T_9	1 25	2 73	26 84	48 89
T_{10}	1 39	2 84	28 96	52 08
T_{11}	1 25	2 84	26 87	49 96
T_{12}	1 47	2 76	29 64	48 50
T_{13}	1 32	2 69	25 07	47 96
SEm (±)	0 006	0 011	8 054	2 579
CD (0 05)	0 130	NS	NS	2 706

4.3.1.3. Number of leaves

Number of leaves at both stages of observation exhibited significant differences among the treatments (Table 6) At 4 months after planting T_6 recorded highest number of leaves (11 7) which was statistically on par with T_1 (11 6), T_9 (11 2), T_3 (11 2), T_{10} (11 0), T_2 (11 0), T_8 (10 9) and the lowest number of leaves was produced in control T_{13} (9 6)

At the time of shooting, T_6 recorded highest number of leaves (12 8) which was on par with T_{11} (12 3), T_1 (11 9), T_4 (11 8) while T_{13} (10 3) recorded lowest number of leaves

4.3.1.4 Number of suckers at harvest

The data on number of suckers at the time of harvest is presented in Table 6 There was no considerable difference between the treatments Even though not significant, T_{10} and T_{12} recorded maximum number of suckers (7 3) followed by T_3 and T_7 (6 8) while T_4 and control T_{13} recorded minimum number of suckers at the time of harvest (5 8)

4.3.2. Effect of yield attributes

4.3.2.1. Weight of male bud

Weight of male bud at the time of detachment was noted and compared (Table 7) There was a significant difference among the treatments with respect to weight of male bud T_5 recorded highest male bud weight (1 5 kg) which was statistically on par with T_{11} (1 5 kg), T_2 (1 4 kg), T_8 (1 4 kg) and lowest male bud weight was found in T_1 (1 1 kg) whereas control T_{13} recorded 1 2 kg

Table 6 Foliar application of micronutrient mixture on number of leaves and suckers at harvest of banana

Treatments	Number of leaves		Number of suckers at harvest
	4 months after planting	At the time of shooting	
T_1	11 58	11 92	6 00
T_2	11 00	11 08	6 08
T_3	11 17	11 33	6 83
T_4	10 58	11 83	5 83
T_5	10 83	11 50	6 33
T_6	11 67	12 75	6 25
T_7	10 83	11 50	6 83
T_8	10 92	11 17	6 42
T_9	11 17	11 42	6 75
T_{10}	11 00	11 25	7 33
T_{11}	10 50	12 25	6 25
T_{12}	10 67	11 08	7 33
T_{13}	9 583	10 25	5 83
SEm (±)	0 216	0 458	0 678
CD (0 05)	0 784	1 140	NS

4.3 2.2. Bunch weight

Bunch weight of plant is the major economic factor considered in banana cultivation There was a significant influence of treatments on bunch weight and the results are presented in Table 7 All the treatments were found to be superior over control on which T_{11} recorded maximum bunch weight (12 8 kg) and control T_{13} recorded minimum bunch weight (8 3 kg) which was on par with T_3 T_{11} was statistically on par with T_{10} (12 7 kg), T_9 (12 2 kg), T_6 (12 2 kg), T_7 (12 1 kg), T_8 (11 9 kg) and T_5 (11 5 kg) Plate 4 shows comparison of bunch weight of selected treatments and control

4.3.2.3. Number of hands per bunch

There was no significant difference between the treatments with respect to number of hands per bunch (Table 7) However T_3, T_6 and T_7 were recorded with 5 4 hands per bunch while T_2 recorded minimum number of hands per bunch (4 8) while control T_{13} was having 5 0 hands per bunch

4.3.2.4. Number of fingers per bunch

The data on total number of fingers per bunch was recorded at the time of harvest and it is presented in Table 8 There was significant difference between the treatments T_9 recorded higher number of fingers per bunch (54 4) and T_{13} recorded lowest number of fingers per bunch (46 7) followed by T_{12} (50 4) All other treatments were on par with T_9 Plate 4 f shows the highest number of fingers per bunch in best treatment

4.3.2.5. Average weight of fingers

The average weight of fingers was calculated by taking the best finger in each hand per bunch and averaged There was notable difference in average weight of fingers between the treatments (Table 8) T_{11} produced maximum average weight of

fingers of 282 6 g whereas minimum was found in T_1 with 222 5 g which was statistically on par with T_5 and control T_{13} T_{11} was on par with T_{10}, T_9, T_6, T_7, T_8, T_4 and T_{12} Plate 5 shows the finger characteristics of treatments and control

Table 7 Foliar application of micronutrient mixture on yield parameters of banana

Treatments	Weight of male bud (kg)	Bunch weight (kg)	No of hands per bunch
T_1	1 12	10 60	5 33
T_2	1 40	10 22	4 83
T_3	1 25	9 55	5 44
T_4	1 35	10 48	4 89
T_5	1 54	11 45	5 17
T_6	1 24	12 19	5 44
T_7	1 35	12 07	5 44
T_8	1 38	11 90	5 33
T_9	1 24	12 23	4 97
T_{10}	1 30	12 73	5 00
T_{11}	1 48	12 76	5 11
T_{12}	1 25	11 02	5 00
T_{13}	1 18	8 32	5 00
SEm (±)	0 007	0 766	0 127
CD (0 05)	0 177	1 475	NS

Table 8 Foliar application of micronutrient mixture on finger characteristics of banana

Treatments	No of fingers per bunch	Average weight of fingers (g)	Average Finger length (cm)	Average finger breadth (cm)
T_1	51 33	222 50	21 15	13 26
T_2	51 08	233 34	20 78	14 68
T_3	53 33	237 38	21 28	14 00
T_4	50 89	247 98	21 11	14 48
T_5	53 89	225 88	20 62	14 38
T_6	53 00	271 65	20 55	14 60
T_7	53 67	268 80	22 38	14 94
T_8	51 67	256 13	22 15	14 15
T_9	54 39	271 75	22 50	13 99
T_{10}	53 94	275 00	22 69	15 25
T_{11}	54 06	282 64	23 05	15 25
T_{12}	50 44	245 06	21 75	14 16
T_{13}	46 68	230 00	17 94	13 02
SEm (±)	4 345	306 077	0 633	0 653
CD (0 05)	3 513	38 122	1 734	NS

4.3.2.6. Average length of fingers

The effect of treatments on average length of fingers is presented in Table 8 T_{11} was recorded with maximum finger length of 23 1 cm while control T_{13} recorded minimum length of 17 9 cm T_{11} was on par with T_{10} (22 7 cm), T_9 (22 5 cm), T_7 (22 4 cm), T_8 (22 2 cm) and T_{12} (21 8 cm)

4.3.2.7. Average breadth of fingers

The effect of treatment application on finger girth is presented in Table 8 Treatment effects on finger breadth at the middle portion was found to be non significant Maximum finger breadth was noticed in T_{11} and T_{10} with 15 3 cm whereas control T_{13} recorded minimum finger breadth of 13 0 cm

4.3.2.8. Days to bunch emergence

Effect of treatment application on the number of days taken from planting to bunch emergence was recorded and presented in Table 9 There was no appreciable difference between the treatments T_{10} produced earliest bunch in 186 days after planting while control T_{13} produced bunch in 198 days after planting which was the late one An average bunch emergence happened between 185-197 days

4.3.2.9. Days to harvest

There was a remarkable difference between the treatments with respect to days to harvest Effect of treatment application on the number of days taken from planting to harvest was recorded and presented in Table 9 T_{13} (control) showed maximum days from planting to harvest (303 days) while T_{11} took minimum of 271 days T_{11} was statistically on par with T_{10} (272 days) and T_9 (274 days)

4.3.2.10. Bunch maturity period

Effect of treatment application on bunch maturity period (from the day of bunch emergence to harvest) was recorded and presented in Table 9 There was a remarkable difference between the treatments T_{11} took minimum maturity period of 82 days which was on par with T_{10} (86 days) and T_9 (88 days) while control T_{13} took maximum days to maturity with 106 days

4.3.2.11. Days to ripening

Effect of treatment application on the number of days taken from harvest to ripening stage of fruit was recorded and presented in Table 9 Treatments found to be non significant in influencing the days to ripening T_4 was recorded with minimum of 4 days to ripening while T_{13} took 6 days

4.3.2.12. Incidence of pest and disease

The banana-leaf caterpillar (*Spodoptera litura*) was prevailed at 2 and 3 months after planting The major disease noticed was sigatoka leaf spot at 4 months after planting caused by *Mycosphaerella musicola* Necessary control measures were taken uniformly for all the plants

Table 9 Foliar application of micronutrient mixture on days to bunch emergence, days to harvest, Bunch maturity period and days to ripening of banana

Treatments	Days to bunch emergence	Days to harvest	Bunch maturity period (days)	Days to ripening
T_1	190 83	283 67	92 83	5 50
T_2	190 67	293 33	102 67	4 83
T_3	194 78	286 67	91 89	5 50
T_4	195 83	289 00	93 17	4 33
T_5	195 67	290 33	94 67	5 83
T_6	191 11	282 67	91 56	6 00
T_7	191 00	283 33	92 33	5 00
T_8	190 67	283 67	93 00	6 07
T_9	185 83	274 00	88 17	4 67
T_{10}	185 72	271 67	85 94	5 65
T_{11}	188 67	270 67	82 00	5 42
T_{12}	191 08	283 33	92 25	5 67
T_{13}	197 67	303 17	105 50	6 00
SEm (±)	22 870	25 982	25 918	1 176
CD (0 05)	NS	8 590	8 580	NS

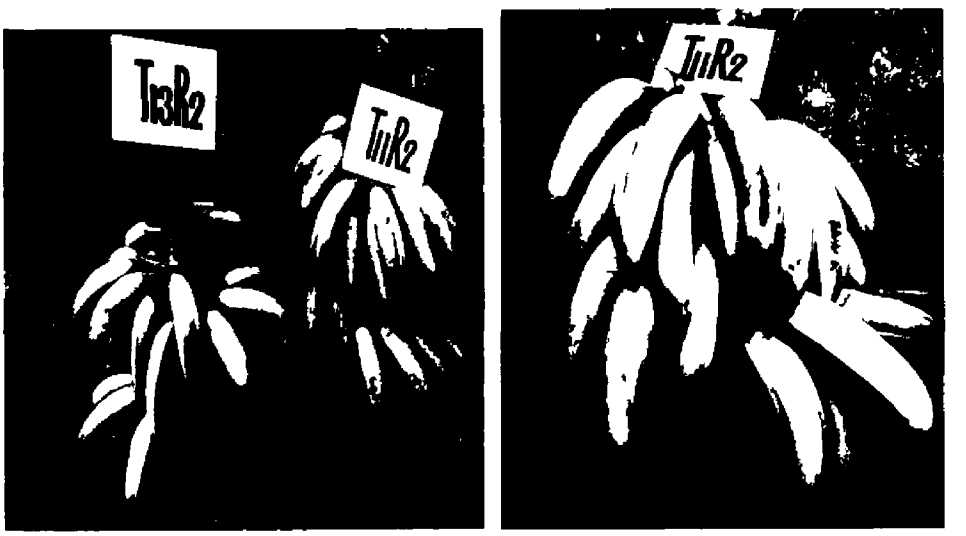


Plate 4 a Best treatment T_{11} (3 % as sprays)

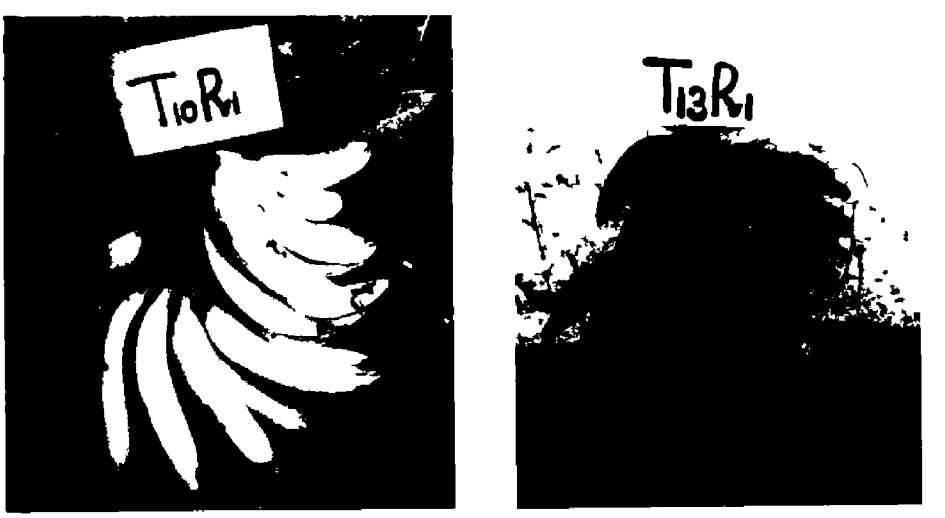


Plate 4 b 2nd best treatment T_{10} (2 % as 3 sprays) Plate 4 c Control T_1

Plate 4 d Highest number of fingers per bunch

Plate 4 Bunches from best treatments vs control

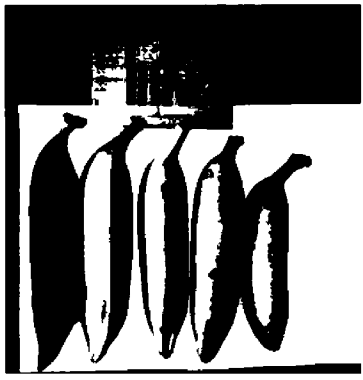


Plate 5 a Highest average weight of fingers T_1 (3 % as 3 sprays)

Plate 5 b Control T

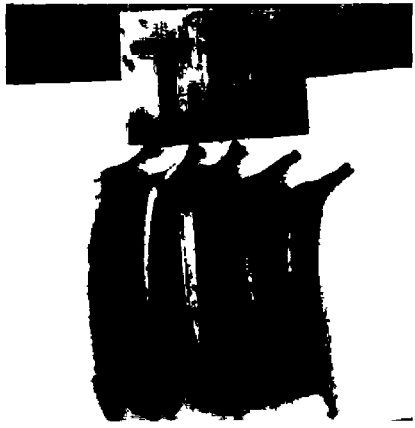


Plate 5 c 2 best treatment I (2 % as 3 sprays)

Plate 5 d Control I

Plate 5 e Finger of best treatment I (2 % as 3 sprays)

Plate 5 Finger characteristics of treatments and control

4 4 FRUIT CHARACTERISTICS

The effect of foliar application of micronutrient mixture on fruit characteristics of banana was examined Various quality parameters like titrable acidity, vitamin C, TSS, reducing sugar content, total sugars, per cent loss in weight during ripening, keeping quality of the fruits at ambient condition and pulp to peel ratio were analyzed and the results are presented below

4.4.1 Titrable acidity

The effect of treatment application on titrable acidity (%) of ripened banana fruits is presented in Table 10 The treatments had notable influence on titrable acidity as compared to control T_{13} was recorded highest acidity of 0 53 % which was on par with T_1 (0 50 %), T_2 (0 45 %) and T_3 (0 43 %) while T_{11} was recorded with minimum acidity of 0 26 % followed by T_{10} (0 27 %) and T_9 (0 28 %)

4.4.2. Total Soluble Solids (TSS)

There was notable difference among the treatments with respect to total soluble solids (Table 10) T_{11} recorded maximum TSS content (30 0 °brix) which was on par with T_{10} (29 9 °brix), T_9 (29 7 °brix) and T_4 (29 5 °brix) Control T_{13} recorded minimum TSS of 26 3 °brix which was statistically on par with T_1 (26 6 °brix)

4.4.3. Pulp to peel ratio

The effect of treatment application on pulp to peel ratio is presented in Table 10 There was significant difference among the treatments T_{12} recorded highest pulp to peel ratio of 3 7 followed by T_{11} (3 6) Lowest ratio was found in T_2 (2 8) which were on par with control T_{13} (2 9) and T_1 (2 9)

Table 10 Foliar application of micronutrient mixture on titrable acidity, TSS and pulp to peel ratio of ripened banana fruit

Treatments	Titrable acidity (%)	TSS (°brix)	Pulp to peel ratio
T_1	0 50	26 60	2 91
T_2	0 45	27 30	2 79
T_3	0 43	27 70	3 13
T_4	0 38	29 50	3 10
T_5	0 36	28 20	3 41
T_6	0 36	28 70	3 37
T_7	0 29	28 40	3 06
T_8	0 39	28 80	3 61
T_9	0 28	29 70	3 52
T_{10}	0 27	29 90	3 48
T_{11}	0 26	30 00	3 64
T_{12}	0 31	27 70	3 70
T_{13}	0 53	26 30	2 88
SEm (±)	0 003	0 121	0 050
CD (0 05)	0 112	0 756	0 488

4.4.4. Total sugars

The influence of treatment application on total sugars percentage of ripened banana fruits are presented in Table 11 Higher sugar content and lower acidity indicates better fruit quality The effect of treatments was found to be statistically significant Maximum total sugars content was recorded in T_{10} with 21 3 % which was statistically on par with T_9 (21 0 %), T_4 (19 7 %) and T_{11} (19 4 %) Control T_{13} recorded minimum of 13 3 % followed by T_1 (14 1 %)

4.4.5. Reducing sugars

The effect of treatment application was highly evident in case of reducing sugar content of fruits and the treatments showed superior and significant differences Among the treatments, T_{10} exhibited highest reducing sugar content of 19 0 per cent which was on par with T_{11} (17 5 %) whereas T_1 recorded lowest reducing sugar content of 9 3 % followed by control T_{13} (9 7 %) The results of treatment application on reducing sugar content of the ripened banana fruits are presented in Table 11

4.4.6. Non-reducing sugars

There was notable difference among the treatments with respect to non-reducing sugar content of ripened banana fruits (Table 11) The highest non-reducing sugar content was found in T_5 with 4 9 per cent while T_{11} recorded lowest non-reducing sugar content (1 9 %) Except T_{11} and T_{10} all other treatments were statistically on par with T_5

4.4.7. Sugar / acid ratio

The influence of treatment application on sugar / acid ratio of ripened banana fruits are presented in Table 11 The effect of treatments was found to be statistically significant Highest sugar / acid ratio were found in T_{10} with 78 7 which were

statistically on par with T_{11}, T_9 and T_7 Control T_{13} recorded lowest sugar / acid ratio of 25 3 which was on par with T_1, T_2 and T_3

4.4.8. TSS / acid ratio

The effect of treatment application was highly evident in case of TSS / acid ratio of fruits and the treatments showed superior and significant differences Highest TSS/ acid ratio indicates better fruit quality Among the treatments, T_{11} exhibited highest TSS / acid ratio of 116 1 whereas control T_{13} reported lowest TSS / acid ratio of 50 2 T_{11} was on par with T_{10}, T_9 and T_7 The results of treatment application on the TSS / acid ratio of the ripened banana fruits are presented in Table 12

4.4.9. Per cent loss in weight during ripening

There was significant difference between treatments with respect to per cent loss in weight during ripening of fruits (Table 12) Per cent loss in weight from day of harvest to ripened fruit was recorded and statistically analyzed Maximum per cent loss in weight was found in T_{13} with 16 7 while minimum loss was recorded in T_{11} (11 9 %) which was on par with T_{10}, T_4, T_{12}, T_3, T_6 and T_2

4.4.10. Keeping quality of fruits at ambient condition

Treatment application on keeping quality of fruits was recorded from the day of ripening to the end of saleable or edible life of fruits Keeping quality of fruits showed notable difference among the treatments which is presented in Table 12 Maximum keeping quality was recorded in T_{10} with 4 40 days which was on par with T_{11} (4 37 days) and T_9 (4 08 days) T_3 was found to the minimum with 3 30 days while control T_{13} was recorded with 3 43 days

Table 11 Foliar application of micronutrient mixture on total sugars, reducing sugars, non-reducing sugars and sugar / acid ratio of ripened banana fruit

Treatments	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Sugar / acid ratio
T_1	14 07	9 33	4 75	28 31
T_2	16 38	12 13	3 88	36 84
T_3	17 04	12 25	4 79	40 12
T_4	19 70	15 45	4 25	52 63
T_5	17 86	12 98	4 89	52 92
T_6	17 80	14 05	3 75	50 12
T_7	17 46	13 29	4 17	62 80
T_8	18 36	13 51	4 85	50 15
T_9	20 95	17 25	3 70	74 12
T_{10}	21 25	19 00	2 25	78 70
T_{11}	19 40	17 50	1 90	75 43
T_{12}	16 41	11 98	4 44	53 40
T_{13}	13 26	9 68	3 58	25 34
SEm (±)	0 798	0 494	0 508	68 512
CD (0 05)	1 946	1 531	1 553	18 036

Table 12 Foliar application of micronutrient mixture on TSS / acid ratio, per cent loss in weight during ripening and keeping quality of fruits at ambient condition

Treatments	TSS / acid ratio	Per cent loss in weight during ripening (%)	Keeping quality of fruits at ambient condition (days)
T_1	53 70	15 00	3 46
T_2	61 33	14 15	3 38
T_3	65 33	13 78	3 30
T_4	78 93	12 50	3 83
T_5	83 56	14 96	3 43
T_6	80 85	13 88	3 75
T_7	102 31	15 96	3 73
T_8	78 90	16 69	3 43
T_9	105 20	16 33	4 08
T_{10}	110 74	12 25	4 40
T_{11}	116 07	11 87	4 37
T_{12}	90 17	13 65	3 75
T_{13}	50 20	16 70	3 43
SEm (±)	133 859	1 892	1 130
CD (0 05)	25 210	2 997	2 316

4 5 SOIL CHARACTERISTICS

4.5.1. pH

There was no considerable difference among the treatments with respect to soil pH (Table 13) T_9 recorded the lowest soil pH value of 4 83 and T_8 had the highest pH 5 52 while control T_{13} recorded pH value of 5 42

4.5.2. EC

Electrical conductivity of the soils was not influenced by the foliar application of micronutrient mixture (Table 13) Even though not significant, highest EC value was found in T_6 (0 27 dS/m) followed by T_{11} (0 25 dS/m) and the lowest EC value was found in T_8 (0 16 dS/m)

4.5.3. Organic carbon content

Treatment application had significant effect on the organic carbon content of soils (Table 13) Highest OC was recorded in T_9 (0 7 %) which was on par with T_{12} (0 7 %), T_{11} (0 6 %), T_8 (0 6 %), T_{10} (0 6 %), T_3 (0 6 %) and minimum OC was found in T_{13} (0 4 %) which was statistically on par with T_4 and T_1

4.5.4. Available N

The results of available N content of soils are presented in Table 14 There was significant difference among the treatments with respect to available N content of soils T_{12} recorded highest available nitrogen content of soil (338 6 kg/ha) followed by T_{11} (263 4 kg/ha) and the lowest available nitrogen content was found in T_3 (175 5 kg/ha) while control T_{13} recorded 219 4 kg/ha

Table 13 Foliar application of micronutrient mixture on soil pH, EC and Organic carbon

Treatments	pH	EC (dS/m)	Organic carbon (%)
T_1	5 04	0 19	0 43
T_2	5 18	0 20	0 51
T_3	5 13	0 20	0 60
T_4	5 05	0 18	0 43
T_5	5 25	0 23	0 51
T_6	5 13	0 27	0 44
T_7	5 12	0 17	0 57
T_8	5 52	0 16	0 62
T_9	4 83	0 24	0 73
T_{10}	5 14	0 18	0 61
T_{11}	5 03	0 25	0 63
T_{12}	4 94	0 24	0 66
T_{13}	5 42	0 17	0 40
SEm (±)	0 277	0 004	0 009
CD (0 05)	NS	NS	0 163

4.5.5. Available P

The effect of treatment application was found to be significant in case of available P content of soils (Table 14) Highest P content was recorded in T_{12} with 110 4 kg/ha whereas T_{11} found to have lowest P content of 80 7 kg/ha T_{12} was

statistically on par with T_5, T_{13}, T_{10} and T_6 Control T_{13} was recorded with 102 8 kg/ha

Table 14· Foliar application of micronutrient mixture on available N, P and K content of soil

Treatments	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	238 20	93 04	412 67
T_2	225 70	88 70	272 33
T_3	175 50	92 31	272 00
T_4	231 90	85 93	373 33
T_5	250 80	110 00	425 00
T_6	250 80	101 29	253 33
T_7	231 90	96 91	348 00
T_8	200 60	90 18	428 67
T_9	231 90	85 26	349 33
T_{10}	238 20	102 52	322 00
T_{11}	263 40	80 65	308 67
T_{12}	338 60	110 39	292 00
T_{13}	219 40	102 84	417 67
SEm (±)	543 185	52 829	214 735
CD (0 05)	50 784	12 249	24 695

4.5.6. Available K

The effect of treatment application was significant in case of available K content of soil which is presented in Table 14 The highest K content was recorded in T_8 with 428 7 kg/ha which was statistically on par with T_5, T_{13} and T_1 while lowest K

content was found in T_6 with 253 3 kg/ha Control T_{13} was found to have 417 7 kg/ha

4.5.7. Available Ca

The effect of treatment application on the available Ca status of soil is presented in Table 15 Available Ca content in the soil was found to be non significant However, maximum Ca content was found in T_5 (533 3 mg/kg) followed by T_4 (501 7 mg/kg) and minimum was found in T_8 with 323 3 mg/kg while control T_{13} was with 456 7 mg/kg

4.5.8. Available Mg

There was a significant influence of treatments on Mg content in soil as shown in Table 15 The highest Mg content was recorded in T_9 (40 7 mg/kg) which was on par with T_5, T_{11}, T_8, T_{10} and T_{13} T_7 recorded the lowest Mg content of 29 5 mg/kg

4.5.9. Available S

The effect of treatment application on the available S content of soil is presented in Table 15 Available S content in the soil were statistically non significant, even then the available S content in treatment plots was higher than control plot T_{11} recorded with highest S content (20 8 mg/kg) while control T_{13} recorded lowest S content of 8 7 mg/kg

4.5.10. Available Zn

The effect of treatment application on available Zn content of soil is presented in Table 16 There was remarkable difference between the treatments T_5 recorded the maximum Zn content of 8 9 mg/kg followed by T_6 (6 0 mg/kg) whereas control T_{13} recorded with minimum Zn content of 0 4 mg/kg

Table 15 Foliar application of micronutrient mixture on available secondary nutrients content of soil

Treatments	Available Ca (mg/kg)	Available Mg (mg/kg)	Available S (mg/kg)
T_1	394 17	29 68	17 29
T_2	351 67	33 98	9 79
T_3	396 67	33 30	7 29
T_4	501 67	32 78	10 54
T_5	533 33	40 30	16 75
T_6	419 50	34 42	7 50
T_7	334 17	29 53	14 58
T_8	323 33	38 63	12 50
T_9	353 33	40 72	19 13
T_{10}	346 67	37 13	11 88
T_{11}	480 00	38 67	20 75
T_{12}	375 00	32 28	10 63
T_{13}	456 67	36 85	8 67
SEm (±)	14690 042	10 079	41 490
CD (0 05)	NS	5 350	NS

4.5.11. Available Fe

The treatments had notable influence on available Fe content of soil (Table 16) T_4 was recorded with highest Fe content of 43 3 mg/kg which was on par with T_3 (39 0 mg/kg) and T_5 (37 2 mg/kg) while control (T_{13}) recorded with lowest Fe content (23 2 mg/kg)

4.5.12. Available Mn

The data on available Mn content of soil is presented in Table 16 The highest Mn content was found in T_{10} (11 4 mg/kg) which was statistically on par with T_1, T_5 and T_3 while T_4 was registered with lowest Mn content of 2 3 mg/kg Control T_{13} was with 4 5 mg/kg

4.5.13. Available Cu

There was no considerable difference in available Cu content of soil between the treatments (Table 16) T_5 was recorded highest Cu content of 3 9 mg/kg while lowest was found in T_2 (2 8 mg/kg)

4.5.14. Available B

The data on available B content of soil is presented in Table 16 Significant difference was found between the treatments The highest B content was recorded in T_4 (0 7 mg/kg) which was statistically on par with T_{11}, T_2 and T_7 All other treatments were on par with control T_{13} was found to have lowest B content of 0 2 mg/kg

4.5.15. Available Mo

The data on available Mo content of soil is presented in Table 16 Significant difference was found between the treatments The highest Mo content was recorded in T_{12} (0 01 mg/kg) which was statistically on par with T_{11} and T_7 whereas control T_{13} was found to have the lowest Mo content of 0 002 mg/kg T_{13} was statistically on par with T_1, T_5, T_2, T_4 and T_3

Table 16 Foliar application of micronutrient mixture on available micronutrients content of soil

Treatments	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	B (mg/kg)	Mo (mg/kg)
T_1	2 61	32 47	10 05	3 16	0 29	0 002
T_2	3 46	30 47	6 57	2 76	0 47	0 003
T_3	4 59	39 03	8 56	3 15	0 37	0 004
T_4	2 30	43 33	2 28	3 19	0 69	0 003
T_5	8 91	37 17	8 89	3 87	0 31	0 002
T_6	5 98	34 43	5 56	2 84	0 29	0 004
T_7	1 91	30 80	3 07	3 20	0 47	0 009
T_8	1 67	29 60	5 56	3 22	0 22	0 007
T_9	0 64	28 47	3 94	3 06	0 24	0 008
T_{10}	1 30	31 47	11 42	3 17	0 40	0 008
T_{11}	2 60	32 47	6 69	3 19	0 52	0 010
T_{12}	1 18	30 13	7 49	3 59	0 27	0 010
T_{13}	0 38	23 23	4 45	3 49	0 19	0 002
SEm (±)	1 394	19 041	5 188	0 194	0 026	0 001
CD (0 05)	1 990	7 354	3 839	NS	0 272	0 002

4 6 NUTRIENT CONCENTRATIONS IN LEAF

Various chemical analysis of banana leaf samples was conducted in order to examine the effect of foliar spraying of micronutrient mixture on leaf nutrient status Leaf samples were collected at bunching stage and at the time of harvest dried in hot air oven, powdered and were analyzed using standard analytical procedures as described in materials and methods

4.6.1. Nitrogen

The effect of treatment application on nitrogen content of banana leaf at bunching stage and at the time of harvest are presented in Table 17 At bunching stage, the treatments found to be non significant with respect to leaf N content However T_7 recorded highest N content of 4 2 per cent and T_{12} recorded lowest N content (2 5 %) while control T_{13} was found to have 2 8 per cent

Leaf N content of banana at the time of harvest found to be non significant However, T_1 and T_7 recorded highest N content of 3 2 per cent whereas T_{12} and T_{13} recorded lowest N content in leaves (2.1 %)

4.6.2. Phosphorus

The effect of treatment application on phosphorus content of banana leaf at bunching stage and at harvest is presented in Table 17 At bunching stage, the treatments found to be non significant with respect to leaf P content T_{11} recorded highest P content of 0 28 per cent whereas control T_{13} recorded lowest P content in leaves (0 15 %)

There was notable difference among the treatments with respect to P content of leaf at the time harvest T_3 and T_7 recorded highest P content of 0 31 per cent which was on par with T_{11}, T_{10} and T_8 Lowest P content was found in T_1 (0 12 %) followed by T_{13} (0 13 %)

Table 17 Foliar application of micronutrient mixture on N, P and K content of banana leaf

Treatments	N (%)		P (%)		K (%)	
	Bunching stage	At harvest	Bunching stage	At harvest	Bunching stage	At harvest
T_1	3 15	3 15	0 25	0 12	3 70	2 50
T_2	3 85	2 80	0 25	0 17	3 65	3 38
T_3	3 50	2 45	0 23	0 31	3 85	3 25
T_4	3 85	2 80	0 23	0 22	3 90	3 50
T_5	3 15	2 45	0 17	0 17	3 75	3 13
T_6	3 50	2 45	0 19	0 18	3 55	3 38
T_7	4 20	3 15	0 21	0 31	3 84	3 38
T_8	3 15	2 45	0 16	0 26	3 25	2 63
T_9	3 15	2 45	0 18	0 18	3 75	3 75
T_{10}	3 50	2 80	0 18	0 26	3 95	3 85
T_{11}	3 85	2 80	0 28	0 28	4 50	3 88
T_{12}	2 45	2 10	0 19	0 20	3 33	3 63
T_{13}	2 80	2 10	0 15	0 13	2 04	1 90
SEm (±)	0 402	0 129	0 001	0 001	0 111	0 150
CD (0 05)	NS	NS	NS	0 076	0 727	0 843

4.6.3. Potassium

The effect of treatment application on potassium content of banana leaf at bunching stage and at harvest is presented in Table 17 At bunching stage, the

treatments had notable difference with respect to K content T_{11} recorded highest K content of 4 5 per cent which was on par with T_{10}, T_4, T_3 and T_7 whereas control T_{13} was found to have lowest K content (2 1 %)

There was significant difference between the treatments with respect to K content of leaf at the time of harvest T_{11} recorded highest K content (3 9 %) whereas control T_{13} recorded the lowest K content of 1 9 per cent Except T_{13}, T_1 and T_8 all other treatments were on par with T_{11}

4.6.4. Calcium

Leaf Ca content at bunching stage and at harvest showed notable difference among the treatments (Table 18) At bunching stage, T_8 recorded highest Ca content of 1 5 per cent which was on par with T_6, T_7 and T_5 The lowest Ca content was found in T_1 (0 7 %) while control T_{13} was with 1 0 per cent

T_{11} recorded highest Ca content of 6 55 per cent at harvest whereas control T_{13} recorded lowest Ca content of 2 2 per cent Except T_{11} and T_7 all other treatments were statistically on par with T_{13} T_{11} was on par with T_7 (6 4 %)

4.6.5. Magnesium

The effect of treatment application on magnesium content of banana leaf at bunching stage and at harvest is presented in Table 18 At bunching stage, significant difference was noticed among the treatments The highest Mg content was observed in T_{10} (0 25 %) which was on par with T_9, T_8, T_{11}, T_{13} and T_{12} except these treatments all other treatments were statistically on par with T_3 T_3 was found to have lowest Mg content of 0 12 per cent

At the time of harvest, there was no appreciable difference found among the treatments with respect to Mg content of banana leaf However, the highest Mg

content was registered in T_7 (0 36 %) while control T_{13} was found to have lowest Mg content of 0 10 per cent

Table 18 Foliar application of micronutrient mixture on Ca, Mg and S content of banana leaf

Treatments	Ca (%)		Mg (%)		S (%)	
	Bunching stage	At harvest	Bunching stage	At harvest	Bunching stage	At harvest
T_1	0 70	2 84	0 13	0 21	0 14	0 10
T_2	0 94	3 24	0 13	0 21	0 14	0 06
T_3	1 01	3 58	0 12	0 22	0 09	0 06
T_4	1 11	3 10	0 13	0 25	0 08	0 08
T_5	1 20	3 35	0 13	0 21	0 15	0 08
T_6	1 43	2 98	0 13	0 19	0 08	0 09
T_7	1 35	6 44	0 19	0 36	0 12	0 25
T_8	1 53	3 45	0 24	0 19	0 11	0 07
T_9	1 15	3 16	0 24	0 17	0 18	0 14
T_{10}	0 73	3 66	0 25	0 15	0 13	0 18
T_{11}	0 77	6 55	0 24	0 15	0 20	0 29
T_{12}	0 98	3 19	0 22	0 19	0 22	0 13
T_{13}	1 00	2 24	0 23	0 10	0 07	0 05
SEm (±)	0 022	0 654	0 001	0 004	0 002	0 03
CD (0 05)	0 325	1 762	0 052	NS	NS	0 121

4.6.6. Sulphur

The effect of treatment application on sulphur content of banana leaf at bunching stage and at harvest are presented in Table 18 At bunching stage, there were no significant differences found among the treatments T_{12} recorded highest S content of 0 22 per cent while control T_{13} recorded lowest S content in leaves (0 07 %)

Leaf S content showed appreciable differences among the treatments at the time of harvest The highest S content of leaf was found in T_{11} with 0 29 per cent whereas lowest was recorded in control T_{13} (0 05 %) T_{11} was statistically on par with T_7 (0 25 %) and T_{10} (0 18 %)

4.6.7. Zinc

The effect of foliar spraying of micronutrient mixture on the Zn content of leaf at bunching stage and at harvest are presented in Table 19 There was significant difference among the treatments in both stages of observation At bunching stage, T_{12} was recorded highest Zn content of 101 0 ppm followed by T_{11}, T_{10} and T_9 The minimum was found in T_{13} (9 0 ppm) which was statistically on par with T_1, T_2, T_3 and T_4

At the time of harvest, T_{11} found to have highest Zn content of 95 7 ppm which was on par with T_{10} (83 3 ppm) whereas control (T_{13}) was found to have lowest Zn content of 3 8 ppm which was on par with T_1, T_2, T_3 and T_4

4.6.8. Iron

The effect of foliar spraying of micronutrient mixture on Fe content of banana leaf at bunching stage and at harvest are presented in Table 19 Fe content of the leaves was significantly influenced by treatment application at bunching stage The

highest Fe was recorded in T_{12} with 415 0 ppm which was statistically on par with T_7 (383 8 ppm) whereas control T_{13} recorded lowest Fe content of 75 0 ppm

Leaf Fe content showed notable differences among the treatments at the time of harvest Highest Fe content was found in T_{12} (945 0 ppm) which was statistically on par with T_4 and T_9 Lowest Fe content was found in T_{13} (398 5 ppm)

Table 19 Foliar application of micronutrient mixture on Zn, Fe and Mn content of banana leaf

Treatments	Zn (ppm)		Fe (ppm)		Mn (ppm)	
	Bunching stage	At harvest	Bunching stage	At harvest	Bunching stage	At harvest
T_1	11 40	5 79	115 00	762 50	2425 00	2175 00
T_2	11 55	11 25	112 50	625 00	2525 00	2550 00
T_3	16 00	14 00	104 75	575 00	2675 00	2525 00
T_4	22 25	14 10	175 60	915 00	3075 00	3250 00
T_5	37 23	36 50	147 50	500 00	2675 00	3575 00
T_6	32 45	27 48	307 25	745 00	3240 00	2050 00
T_7	25 75	28 25	383 75	765 00	3200 00	3560 00
T_8	40 65	32 75	175 00	645 00	3625 00	3775 00
T_9	62 75	70 03	115 00	887 50	3850 00	3375 00
T_{10}	80 13	83 30	227 75	837 50	3825 00	3800 00
T_{11}	82 75	95 74	227 00	695 00	3925 00	3145 00
T_{12}	101 00	48 05	415 00	945 00	4550 00	3300 00
T_{13}	9 00	3 78	75 00	398 50	2450 00	2275 00
SEm (±)	45 436	33 889				
CD (0 05)	14 688	12 685	47 101	79 646	188 271	174 834

4.6.9. Manganese

The effect of foliar spraying of micronutrient mixture on Mn content of banana leaf at bunching stage and at harvest are presented in Table 19 Mn content of the leaves was significantly influenced by treatment application at bunching stage The highest Mn was found in T_{12} with 4550 ppm followed by T_{11}, T_9 and T_{10} whereas T_1 was found to have lowest Mn content of 2425 ppm which was statistically on par with control T_{13} (2450 ppm) and T_2 (2525 ppm)

At the time of harvest also treatment application resulted in appreciable difference among the treatments with respect to Mn content of leaves Highest Mn content was found in T_{10} with 3800 ppm which was on par with T_8 (3775 ppm) whereas T_6 recorded lowest Mn content of 2050 ppm

4.6.10. Copper

The effect of foliar spraying of micronutrient mixture on Cu content of banana leaf at bunching stage and at harvest are presented in Table 20 There was significant difference among the treatments with respect to Cu content of leaves at bunching stage Highest Cu content was found in T_{11} with 129 7 ppm followed by T_{12} and T_{10} whereas T_1 recorded lowest Cu content of 22 2 ppm Except T_{11}, T_{12}, T_{10} and T_9 all other treatments were statistically on par with T_1

At the time of harvest also significant difference found among the treatments with respect to Cu content of banana leaf T_{11} recorded highest Cu content of 105 3 ppm and lowest was found in T_2 with 18 2 ppm T_{11} was statistically on par with T_{12}, T_4 and T_{10}

4.6.11. Boron

The effect of foliar spraying of micronutrient mixture on B content of banana leaf at bunching stage and at harvest are presented in Table 20 At bunching stage,

significant difference was found between the treatments with respect to B content of leaf Highest B content recorded in T_3 with 60 0 ppm which was on par with T_6, T_4, T_7 and T_5 except these treatments all others were on par with T_{12} Lowest B content was found in T_{12} (12 0 ppm) while control T_{13} was with 20 0 ppm

Leaf B content showed significant difference among the treatments at harvest Highest B content was found in T_{12} with 90 ppm which was on par with T_1 (82 5 ppm) whereas T_8 recorded lowest B content of 30 ppm Control T_{13} was found to have 47 5 ppm

4.6.12. Molybdenum

The effect of foliar spraying of micronutrient mixture on Mo content of banana leaf at bunching stage and at harvest are presented in Table 20 At bunching stage, significant difference was found between the treatments with respect to Mo content of leaf Highest Mo content was found in T_{11} and T_{12} with 2 2 ppm which was on par with T_{10} whereas control T_{13} was found to have the lowest Mo content of 0 5 ppm T_{13} was statistically on par with T_1, T_2 and T_3

Leaf Mo content showed significant difference among the treatments at the time of harvest Highest Mo content was found in T_{11} with 2 1 ppm which was on par with T_{12} and T_{10} whereas control T_{13} was found to have the lowest Mo content of 0 4 ppm T_{13} was statistically on par with T_1, T_2, T_3 and T_4

4 7 ECONOMIC ANALYSIS

The data on economics of banana cultivation are given in Table 21 The treatment T_{11} registered the maximum net returns of Rs Rs 6, 94, 964 ha^{-1} and it was on par withT_{10}, T_9, T_6 and T_7 whereas control T_{13} recorded the minimum net returns of Rs 3, 53, 251 ha^{-1}

With regard to benefit-cost ratio, the treatment T_{11} (3 sprays of 3 % micronutrient mixture) recorded the maximum value of 2 3 and was on par with T_{10}, T_9, T_6 and T_7 The lowest Benefit / Cost ratio of 1 6 was recorded by control T_{13}

Table 20 Foliar application of micronutrient mixture on Cu, B and Mo content of banana leaf

Treatments	Cu (ppm)		B (ppm)		Mo (ppm)	
	Bunching stage	At harvest	Bunching stage	At harvest	Bunching stage	At harvest
T_1	22 20	21 75	15 50	82 50	0 65	0 60
T_2	24 50	18 15	29 50	60 00	0 70	0 60
T_3	29 00	23 65	60 00	60 00	0 75	0 68
T_4	26 60	82 65	49 50	42 50	0 93	0 88
T_5	32 70	61 85	47 00	55 00	1 35	1 28
T_6	34 00	31 13	52 50	32 50	1 45	1 40
T_7	45 28	41 15	49 50	47 50	1 40	1 34
T_8	54 12	47 89	18 34	30 00	1 25	1 18
T_9	61 44	50 38	28 50	32 50	1 65	1 47
T_{10}	68 60	75 59	35 00	55 00	1 75	1 68
T_{11}	129 71	105 25	12 50	77 50	2 15	2 08
T_{12}	68 93	86 03	12 00	90 00	2 15	2 02
T_{13}	23 60	22 75	20 00	47 50	0 45	0 40
SEm (±)	252 111	278 782	206 010	31 545	0 038	0 052
CD (0 05)	34 598	36 382	31 275	12 238	0 426	0 0499

Table 21 Foliar application of micronutrient mixture on economics of banana cultivation

Treatments	Cost of cultivation (Rs ha ^{1})	Gross returns (Rs ha ^{1})	Net returns (Rs ha ^{1})	BCR
T_1	537180	1032396	493295 913	1 770
T_2	537255	1002917	467770 667	1 870
T_3	537930	956319 4	414357 593	1 918
T_4	538305	1023528	485357 515	1 901
T_5	537615	1115083	588485 481	2 094
T_6	538365	1177194	637435 920	2 184
T_7	539115	1176042	693185 667	2 286
T_8	539865	1154583	616097 512	2 141
T_9	537877 5	1184653	647935 324	2 190
T_{10}	538815	1216944	641210 987	2 204
T_{11}	539752 5	1230375	694963 583	2 287
T_{12}	530690	1087458	546210 765	2 010
T_{13}	536775	834041 7	353250 657	1 558
SEm (±)			-	0 022
CD (0 05)			128028 716	0 252

Cost of inputs

Nitrogen – Rs 12 kg ^{1}

Phosphorus – Rs 34 kg ^{1}

Potassium – Rs 16 kg ^{1}

FYM – Rs 800 t ^{1}

Lime – Rs 10 kg ^{1}

Calcium	– Rs 9 55 kg ^{1}
Magnesium	– Rs 70 kg ^{1}
Cost of plantıng materıal	– Rs 20 plant ^{1}
Solutıon A	– Rs 150 / lıtre
Solutıon B	–Rs 4 / lıtre
Labour cost	–Rs 600/day

Price of produce

Fruits – Rs 35 kg ^{I}

Malebud – Rs 10 kg ^{1}

Suckers – Rs 5 of each

Discussion

5. DISCUSSION

Discussion of the results on investigation carried out at College of Agriculture, Padannakkad and Regional Agricultural Research Station farm, Nileshwar to formulate micronutrient mixture for foliar spray and to study the effect of micronutrient mixture on growth, yield and quality of fruits of tissue culture banana cv Nendran are presented in this chapter The whole investigation comprised of preparation of micronutrient mixture as liquid formulation, hardening studies of tissue culture banana plants using micronutrient mixture and studying the effect of micronutrient mixture on growth, yield and quality of banana

5 1 MICRONUTRIENT MIXTURE PREPARATION

Preparation of micronutrient mixture as a liquid formulation was tried with the use of different micronutrient salts containing Zn, B, Fe, Mn, Cu and Mo The formulation technique was standardized and it contains two liquids Solution A and Solution B Solution A consisting of $ZnSO_4$ $7H_2O$, $CuSO_4$ $5H_2O$, $FeSO_4$ $7H_2O$, H_3BO_3, $MnSO_4$ H_2O and $(NH_4)_6Mo_7O_{24}$ $4H_2O$ in desired proportion For maintaining stability and keeping quality of solution A, various chemicals were tried Citric acid (20 %) was found best for maintaining keeping quality of solution A which acts as an excellent chelating agent Its stability was periodically monitored at specific intervals and it was found that solution A with 30 ml/litre of citric acid (20 %) can be kept as such at ambient conditions upto 1 year Solution B is prepared as 1 per cent humic acid Humic acid might benefit plant growth by chelating unavailable nutrients and buffering pH Required quantity of this has to be blended with diluted solution A just before spraying The pH of micronutrient mixture was noted just before spraying and it was observed 5 56 at the desired dilution Humic acid plays a key role both in enhancing the bioavailability of nutrients to plants and in reducing the adverse effect of some of the free ions due to its chelate forming capability (Bloom *et al* , 1979)

Muthukrishnan and Velu (2011) developed and evaluated a micronutrient formulation for sugarcane and concluded that 92 5 kg micronutrient mixture formulation II as enriched farm yard manure containing 50 kg $FeSO_4$, 5kg $MnSO_4$, 30 kg $ZnSO_4$, 2 5 kg $CuSO_4$ and 5 kg of borax may be recommended for sugarcane for maximizing yield with higher B C ratio Increased cane yield with higher levels of micronutrient mixture maybe attributed to the complementary and supplementary effect of fertilizers and FYM

A multi-micronutrient mixture having a composition of Zn (9 5 %) + B (2 6 %) + Cu (1 2%) + Mg (2 4 %) + N (0 46 %) was developed and found that 0 5 per cent of multi-micronutrient mixture was enhanced the growth and yield of okra variety Varsha Uphar (Mini, 2015)

5 2 HARDENING STUDIES

Foliar application of micronutrient mixture significantly increased the plant growth characteristics of banana such as plant height, number of leaves, leaf length and leaf breadth (Table 4) This might be due to the beneficial effect of micronutrient on secondary hardening of tissue culture banana since their widespread deficiencies and their relatively low content in soil had been reported (KSPB, 2013)

Increase in growth with foliar fertilization might also be due to the fact that, foliar application of nutrients is readily absorbed by leaves and it enhances the physiological processes Foliar spraying of 0 25 per cent and 0 5 per cent of micronutrient mixture as three sprays at immediately after planting, two weeks and three weeks after planting significantly enhanced all the biometric characters of tissue culture banana cv Nendran

Potarzycki and Grzebisz (2009) reported that zinc exerts a great influence on basic plant life processes, such as (i) nitrogen metabolism- uptake of nitrogen and protein quality (ii) photosynthesis- chlorophyll synthesis which ultimately improved

the number of leaves Boron influences cell development and elongation It is involved in the transport of sugars across cell membranes and in the synthesis of cell wall material Boron also regulates the carbohydrate metabolism in plants and plays a role in amino acid formation and synthesis of proteins Boorboori *et al* (2012) stated that, Iron (Fe) is another micronutrient that is a co-factor for approximately 140 enzymes that catalyze unique biochemical reactions Hence, iron has many essential roles in plant growth and development including chlorophyll synthesis, thylakoid synthesis and chloroplast development Manganese plays an important role in chlorophyll production and its presence is essential in Photo-system II, also involved in cell division and plant growth Copper helps in the utilization of iron during chlorophyll synthesis Mo increased the metabolic pools required for the synthesis of saccharides, along with the enhanced photosynthetic capacity

Earlier, Vasane and Kothari (2006 & 2008) also reported enhanced growth traits such as plant height, girth, leaf length, leaf width and number of leaves were obtained with foliar application of multiplex (commercial micronutrient formulation containing Zn - 3 %, Fe - 2 5 %, Cu - 1 %, Mn - 1 %, B - 0 5 % and Mo - 0 1 %) during secondary hardening in banana cv Grand Naine

Increased plant growth characters by the application of micronutrients may be due to their involvement in chlorophyll formation, which might have helped to favour cell division, synthesis of hormone and proteins, enzymes activity, meristematic activity in apical tissue, expansion of cell and formation of new cell wall (Singh and Maurya, 1979, Havlin *et al* , 2014)

5 3 FIELD EXPERIMENT

Tissue culture hardened plants were planted out in the field and various levels of micronutrient mixture were sprayed on foliage at 2, 4 and 6 months after planting and evaluated It was found that foliar application of micronutrient mixture at concentrations 1, 2, 3 and 4 per cent had significantly enhanced the vegetative

characters like pseudostem height, pseudostem girth and number of leaves at 4 months after planting and at the time of shooting and yield characteristics like days to harvest, bunch weight, number of fingers, average weight of fingers and finer length produced Fruit quality parameters like acidity, TSS, total sugars, reducing sugars, non-reducing sugars, pulp to peel ratio, sugar / acid ratio, TSS / acid ratio, per cent loss in weight during ripening, keeping quality of the fruits at ambient condition also exhibited significant difference among the treatments The quality parameters of fruits were better in plants receiving the micronutrient mixture as foliar application This might be due to the beneficial effect of micronutrients on growth, yield and quality of banana

5.3.1. Effect of treatments on plant growth parameters

The effect of micronutrient mixture on pseudostem height, pseudostem girth and number of leaves were found to be significant It shows that micronutrients could make substantial effect on the above growth parameters of banana cv Nendran Improvement in growth of banana plant might be due to enhancement of photosynthetic and other metabolic activities which lead to an increase in various plant metabolites responsible for cell division and cell elongation

Foliar application of 4 per cent micronutrient mixture as three sprays increased the pseudostem height and girth of banana at 4 months after planting At the time of shooting, three sprays of 2 per cent micronutrient mixture as enhanced the pseudostem girth Ghanta and Mitra (1993) found that foliar spraying of 0 5 per cent $ZnSO_4$, 0 1 per cent $CuSO_4$, 0 2 per cent H_3BO_3 and 0 05 per cent $(NH_4)_2$ MoO_4 at 3 and 5 months after planting enhanced the plant height of banana Anonymous (2005) reported the beneficial effect of micronutrients on height of pseudostem at shooting Mandal *et al* (2002) observed that the beneficial effect of micronutrients and their combination on pseudostem girth over control in banana cv Giant Governor

The beneficial effect of micronutrients on height and girth might be due to micronutrients especially Zn which is the activator of the enzymes involved in protein synthesis and had direct effect on the level of IAA in plants (Ram and Bose, 2000), Copper activates several enzymes in plants and helps chlorophyll synthesis and involve in carbohydrate and protein metabolism (Ram and Bose, 2000) and Boron increases photosynthetic activity and respiration in plants and thus improves the growth (Lal and Rao, 1954)

Foliar spraying of 2 per cent micronutrient mixture as two sprays significantly increased the number of leaves of banana at 4 months after planting and at the time of shooting The synthesis and transport of plant assimilates to the developing banana fruit is greatly affected by the retention of green leaves after the flowering stage, especially when assimilate flow from other plant parts becomes limiting (Kumar and Kumar, 2007) Increase in number of leaves may be due to Zn stimulates photosynthetic activity and its presence is important for protein synthesis which in turn can enhance the rate of leaf production

These results are in harmony with those obtained by Ghanta and Mitra (1993) in banana cv Giant Governor, Haque *et al* (2000) in mandrin orange, Babu and Singh (2002) in litchi, Das and Mohan (1993) in banana cvs Chenichampa, Jahaji and Barjahaji, Anjali *et al* (2013) in banana cv Grand Naine, Yadav and Patel (2013) in banana cv Grand Naine, Yadlod and Kadam (2008c) in banana cv Ardhapuri, Pathak *et al* (2011) in banana cv Martaman (AAB, Silk), Jeyabaskaran and Pandey (2008) in Karpuravalli banana, Mandal *et al* (2002) in banana cv Giant Governor, Subramanian and Pillai (1997) and Kumar and Jayakumar (2001) in banana

In the present study, foliar spraying of micronutrient mixture in banana showed no significant influence on number of suckers at harvest Even though, the higher number of suckers was produced in plants treated with three times foliar

spraying of 2 per cent and 4 per cent micronutrient mixture which was superior than control Similar result was observed in banana cv Grand Naine (Yadav *et al* , 2010)

Increased in vegetative growth of banana due to foliar application of 2 and 4 per cent of micronutrient mixture sprays might be attributed to their stimulatory effect on plant metabolism These results corroborate the findings of Hada *et al* (2014) in guava

5.3.2. Effect of treatments on yield characteristics

Yield of banana is a function of bunch weight and number of plants per hectare Hence, any nutrient management study should aim at producing maximum bunch weight, so that, the productivity could be enhanced reasonably (Kumar and Kumar, 2008)

In the present study, foliar application of micronutrient mixture in tissue culture banana cv Nendran has shown positive and significant influence in the yield characteristics of the crop Increase in yield may be attributed to important role of micronutrients in enhancing cell elongation and division, photosynthetic activity and increased production and accumulation of carbohydrates (Abdel-Kader *et al* , 1992) Treatment application has significantly increased the weight of male bud, bunch weight, number of fingers, average weight of fingers and finger length, which are the traits of paramount importance from the economic point of view

Bunch weight in treated plants was found to be superior to that of control Figure 2 shows the effect of different treatment levels and time of application on bunch weight of banana It was also found that with increasing level of micronutrient mixture and time of application from one sprays to two or three sprays resulted in improvement of bunch weight because of their specific role in improving bunch weight At lower level and time of application the bunch weight of fruits were decreased because of its lower concentration it might not be sufficient for enhancing

yield attributes of banana Three sprays of 3 per cent micronutrient mixture enhanced the bunch weight of banana This may be due to the provision of micronutrients at latter stages of crop, which might have enhanced accumulation of assimilates in fruits and thus resulting in heavier bunch weight The possible reason for increase in bunch weight by the micronutrients might be due to faster loading and mobilization of photo-assimilates to fruits and involvement in cell division and cell expansion which ultimately reflected into more weight of fruit in treated plants

There was no difference between the treatments with respect to number of hands produced per bunch Similar finding was reported by Anjali *et al* (2013) in banana cv Grand Naine with foliar spraying of micronutrients The maximum hands were noted with 2 per cent and 3 per cent micronutrient mixture as foliar sprayed at two and three times, which were on par

Number of fingers per bunch was increased with three sprays of 1 per cent micronutrient mixture Finger length was significantly influenced by treatment application as compared to that of control and the maximum finger length was recorded in 3 sprays of 3 per cent micronutrient mixture Average weight of finger was found to be enhanced with three sprays of 3 per cent micronutrient mixture These results are in line with those obtained by Yadlod and Kadam (2008a) in banana cv Grand Naine, Pathak *et al* (2011) in banana cv Martaman, Suresh and Savithri (2001) in Nendran banana Decrease in average fruit weight may be due to increasing finger number and yield which means the partition of assimilates into a high number of fruit and consequently reduction in individual finger weight and other related characters

Two or three time foliar spraying of micronutrient mixture as 2 per cent and 3 per cent might have helped the crop to increase in chlorophyll content of leaves, photosynthetic efficiency, translocation of metabolites from the source to sink as and

when needed by the crop and it may be responsible for retaining more number of fruits, increase in weight of fruit and productivity as compared to control

The most outstanding effect of micronutrients on yield was reported by Ghanta and Mitra (1993) in banana cv Giant Governor, Suresh and Savithri (2001) in Nendran banana, Yadlod and Kadam (2008b) in banana cv Shrimanti, Haque *et al* (2000) in mandarin, Modi *et al* (2012) in papaya cv Madhu Bindu, Yadav and Patel (2013), Ghanta and Dwivedi (1993), Subramanian and Pillai (1997), Kumar and Jayakumar (2001) in banana, Dutta and Dhua (2002), Dutta (2004) in mango, Gurjar *et al* (2015) in Alphonso mango, Pathak *et al* (2011) in banana cv Martaman (AAB, Silk), Jeyabaskaran and Pandey (2008) in Karpuravalli banana, Yadav *et al* (2010) and Anjali *et al.* (2013) in banana cv Grand Naine

There was significant difference among different treatments regarding total crop duration Total crop duration was significantly altered by the application of micronutrient mixture 1 per cent, 2 per cent and 3 per cent as three sprays Minimum days required from planting to harvesting observed in three times spraying of 3 per cent micronutrient mixture as compared to rest of the treatments Bunch maturity period was found to be minimum in 3 sprays of 3 per cent micronutrient mixture and maximum in control This might be due to reduced flowering and maturity duration which could be attributed to enhancing effect of zinc in enzymatic reaction, cell division as well as in growth (Supriya and Bhattacharyya, 1993, Yadav and Patel, 2013) Similar findings were noted by Ghanta and Mitra (1993) in banana cv Giant Governor, Yadav *et al* (2010) banana cv Grand Naine, Babu and Singh (2002) in mandarin orange, Yadlod and Kadam (2008c) in banana cv Ardhapuri

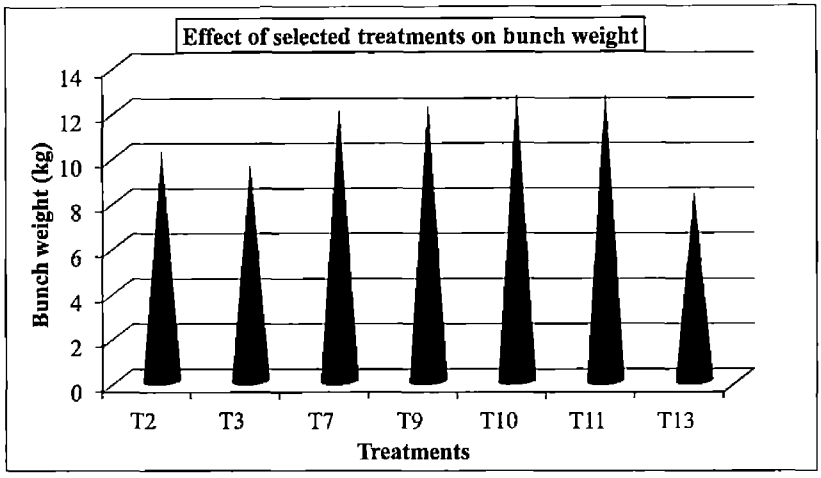


Figure 2 Foliar application of micronutrient mixture on bunch weight of banana

5.3.3. Effect of treatments on fruit characteristics

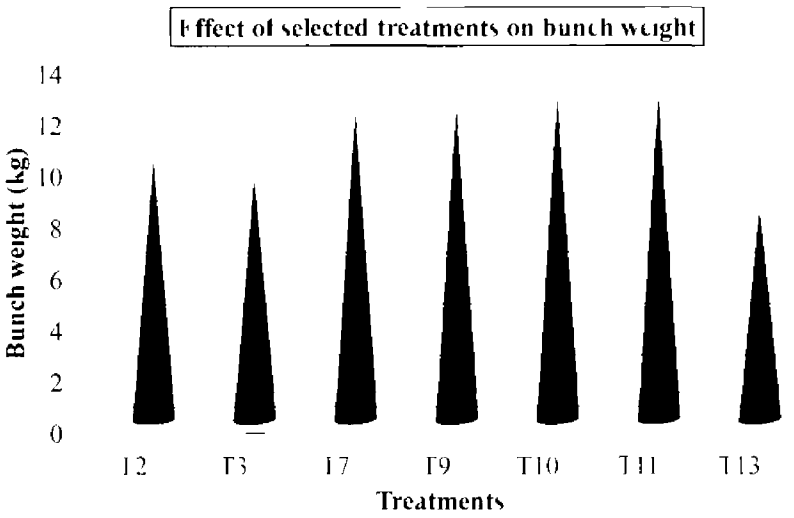
Quality standards have become most important factor for determining monetary yield as well as farmer's income in case of high value crops like banana Any management system should aim to produce quality fruits, besides maximizing productivity (Kumar and Kumar, 2007) Hence, the present investigation reveals that all the quality parameters like titrable acidity, TSS, total sugars, pulp to peel ratio, reducing sugars, non-reducing sugars, sugar / acid ratio, TSS / acid ratio, per cent loss in weight during ripening and keeping quality of the fruits at ambient condition were significantly improved with the foliar application of micronutrients mostly at 1, 2 and 3 per cent in three sprays Increasing the micronutrient mixture levels and time of application might stimulate and activate the biochemical processes in plant, which might improve the fruit quality

Zn and Mn elements have main role in synthesis of proteins, enzyme activation, oxidation and revival reactions, improved the auxin content and

metabolism of carbohydrates Zinc helped other enzymatic reaction like transformation of carbohydrates, activity of hexokinase and formation of cellulose and change in sugar considered due to its action on zymohexose (Dutta and Dhua, 2002) By utilizing of fertilizers contain above elements, performance on quality of crops is increasing and with shortage of this elements due to decline in plant photosynthesis and destroy RNA, amount of solution carbohydrates and synthesis of protein decreased and then performance and quality of crop will be decreased

Treatment application of micronutrients exhibited significant differences in the titrable acidity percentage of the fruits Figure 3 shows the effect of treatment application on titrable acidity of ripened banana fruits Highest acidity percentage was found in control plants and lowest acidity was found in 3 sprays of 1, 2 and 3 per cent of micronutrient mixture A reduction in acidity is usually preferred and here it is found that the treatments have reduced the acidity percentage of fruits as compared to that of control With increasing level and time of application of micronutrient mixture the titrable acidity per cent has been reduced and in case of control it has been increased greatly The reduction of acidity in micronutrient treated fruit juice might be due to their utilization in respiration and rapid metabolic transformation of organic acids into sugars (Brahmachari *et al*, 1997, Ningavva *et al*, 2014) Similar results were also reported by Deolankar and Firake (2001) in banana, Singh *et al* (2003) in pomegranate, Patil and Hiwarale (2004) in acid lime

Total soluble solids (TSS) of fruits exhibited significant differences among the treatments Figure 4 shows the effect of different levels and times of application of nutrients on TSS content of fruits At lower concentration the TSS content was less, whereas with increasing level and time of application of micronutrient mixture, TSS of fruits also increased This is because of the micronutrients were needed in higher quantity for enhancing fruit quality parameters Three sprays of 2 or 3 per cent micronutrient mixture have shown to improve the TSS of ripened fruits The higher TSS was due to the enhanced total sugar content, owing to the increased



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photosynthesis activity, which ultimately leads to efficient translocation of available photosynthates to fruit pulp rather than to other parts (Kulkarni, 2004) Borate ion may be associated with the cell membrane where it could be complex with sugar molecules and facilitates its passage across the membrane that might be the reason of increased total soluble solids (Meena *et al*, 2006) which confirmed the present findings

Figure 5 shows the effect of different levels and times of application of nutrients on pulp to peel ratio The maximum amount of pulp content was recorded in 3 sprays of 1, 3 or 4 per cent micronutrient mixture which might be due to foliar application of micronutrients especially B This might have made rapid synthesis of metabolites particularly carbohydrates and their translocation to the fruits causing relatively greater pulp content Higher pulp weight and lower peel weight might be due to increasing levels and times of application of micronutrient mixture This can also be possible as the complexes of polyhydroxy compounds with B can facilitate transport of carbohydrates within phloem tissue (Hewitt, 1963) These are in agreement with those findings reported by Pathak *et al* (2011) in banana cv Martaman, Yadlod and Kadam (2008a) and Ningavva *et al* (2014) in banana cv Grand Naine

Application of micronutrients found to bring beneficial effect on total sugars, reducing sugars and non-reducing sugar content of ripened banana fruit, sugar / acid ratio, TSS / acid ratio as compared to that of control Figure 6 shows that effect of treatment application on total sugar content of fruits With increasing levels and times of application of micronutrient mixture the total sugar content also increased but it decreased in 3 sprays of 4 per cent micronutrient mixture because of their toxicity effect Total sugar content of ripened banana fruits was found to be maximum in 3 sprays of 2 per cent micronutrient mixture This is due to its action on converting complex substances into simple ones, which enhances the metabolic activity in fruits and it results in increased total sugar of fruit Similar findings were

reported by Paul and Nair (2015) in banana cv Nendran banana, Pathak *et al* (2011) in banana cv Martaman, Yadlod and Kadam (2008b) in banana cv Shrimanti The highest sugar content in juice of sweet orange fruits was observed with foliar application of $ZnSO_4$ (0 5 %) + $FeSO_4$ (0 4 %) + Borax (0 2 %) as reported by Kulkarni (2004)

Increased in reducing sugars with 3 sprays of 2 per cent micronutrient mixture might be due to that formation and translocation of carbohydrate, which improves the fruit quality as reported by Pathak and Mitra (2008) Figure 7 shows the effect of treatment application on reducing sugar content of ripened banana fruits With increasing levels and times of application of micronutrient mixture, the reducing sugar content of ripened fruits also increased because of their necessity in fruit quality attributes At lower level and time of application the reducing sugar content of fruits decreased because its lower concentration may not be enough for enhancing fruit quality attributes The multi-micronutrient mixture comprised of Zn and B and other micronutrients have an important role in sugar metabolism Zinc promotes hydrolysis of starch into sugars and B expedites sugar transport across the membrane by a temporary formation of sugar borate complex (Gauch and Dugger, 1953) Ghanta and Dwivedi (1993) reported the significant effect of micronutrient on reducing sugar content of fruit and the best result (6 99 %) in combined spraying of Zn+Cu+B Similar results were also reported by Aziz and Wahab (1970), Sharma (1976), Paul and Nair (2015) in banana cv Nendran, Yadload and Kadam (2008a) in banana cv Grand Naine

The highest non-reducing sugar content was observed in 2 sprays of 1 per cent micronutrient mixture and lowest was found in 3 sprays of 3 per cent micronutrient mixture Paul and Nair (2015) also found that foliar spraying of micronutrient mixture ($ZnSO_4$ - 1 0 % + $FeSO_4$ - 0 3 % + $CuSO_4$ - 0 2 % + H_3BO_3 - 0 2 % + $(NH_4)_2MoO_4$ - 0 03 %) reduced the non-reducing sugar content of banana cv Nendran

Foliar application of micronutrient mixture 2 and 3 per cent as three sprays significantly increased the sugar / acid ratio and TSS / acid ratio of ripened banana fruit Figure 8 and Figure 9 shows the effect of treatment application on sugar / acid ratio and TSS / acid ratio of ripened banana fruits It might be due to increase in sugar content and decrease in acidity level of fruits by these treatments With increasing levels and times of application of micronutrient mixture the sugar content of ripened fruits has improved greatly and acidity percent has been decreased But in case of lower levels the sugar content decreased and acidity per cent increased which led to reduction in sugar / acid ratio and TSS / acid ratio of ripened banana fruit Similar beneficial effect of foliar application of Zn, Mn B, Cu and Fe on mango, orange, banana and pineapple fruits have been reported by Singh and Rajput (1976) and Nehete *et al* (2011) in mango, Patel *et al* (2010) in banana cv Basrai, Pathak *et al* (2011) in banana cv Martaman, Kavitha *et al* (2000a) in papaya, Yadav and Patel (2013) in banana cv Grand Naine

Per cent loss in weight during ripening and keeping quality of fruits at ambient condition exhibited significant differences among the treatments Figure 10 shows the effect of foliar application of micronutrient mixture on per cent loss in weight of fruits during ripening at ambient condition Foliar spraying of 2 or 3 per cent micronutrient mixture as 3 sprays shown to improve shelf life of ripened fruit as well as minimum loss in weight during ripening With increasing levels and times of application of micronutrient mixture loss in weight during ripening of fruits were reduced Reduction in weight loss might be due to decreased rate of respiration and transpiration, restricting ethylene accumulation and production in fruits during ripening Enhanced shelf life of banana fruits with the application of micronutrient mixture due to their ability to improve the quality of harvested produce These results are in harmony with those obtained by Paul and Nair (2015) in banana cv Nendran, Yadlod and Kadam (2008 b,c) in banana cv Shrimanti and Ardhapuri

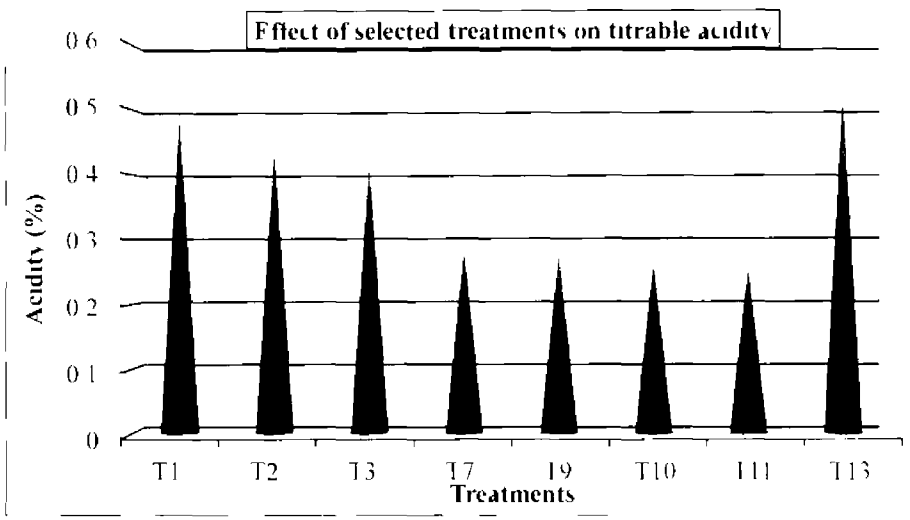

Figure 3 Foliar application of micronutrient mixture on titrable acidity of ripened banana fruits

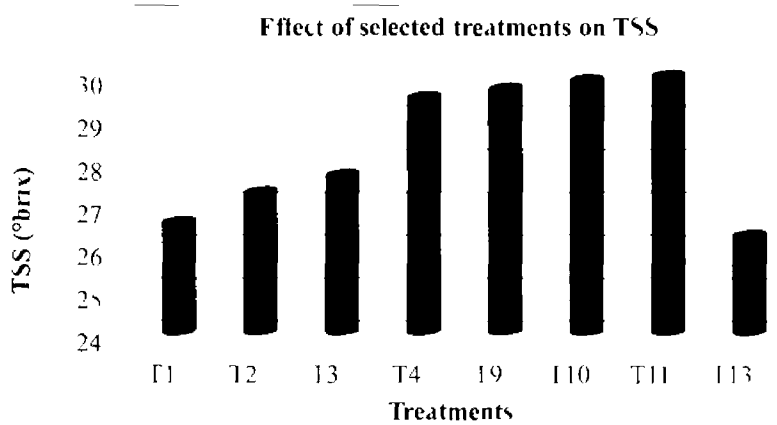

Figure 4 Foliar application of micronutrient mixture on TSS of ripened banana fruits

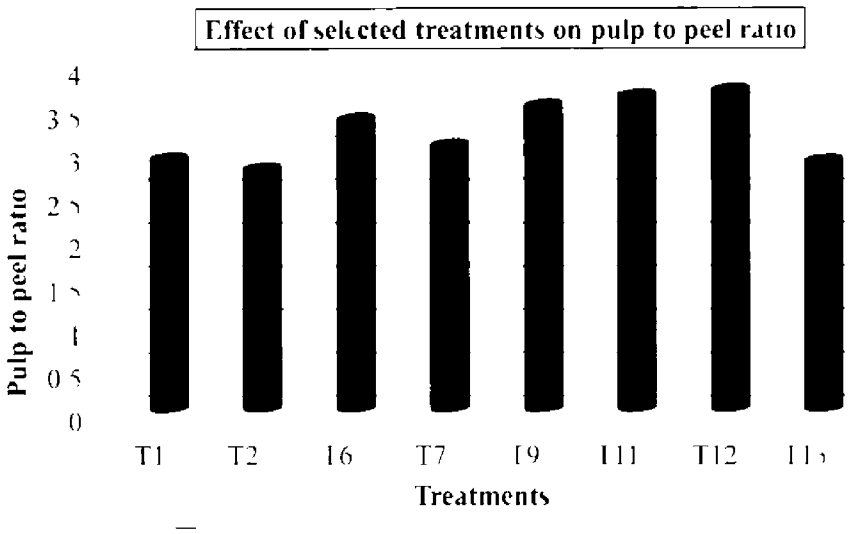

Figure 5 Foliar application of micronutrient mixture on pulp to peel ratio ratio of ripened banana fruits

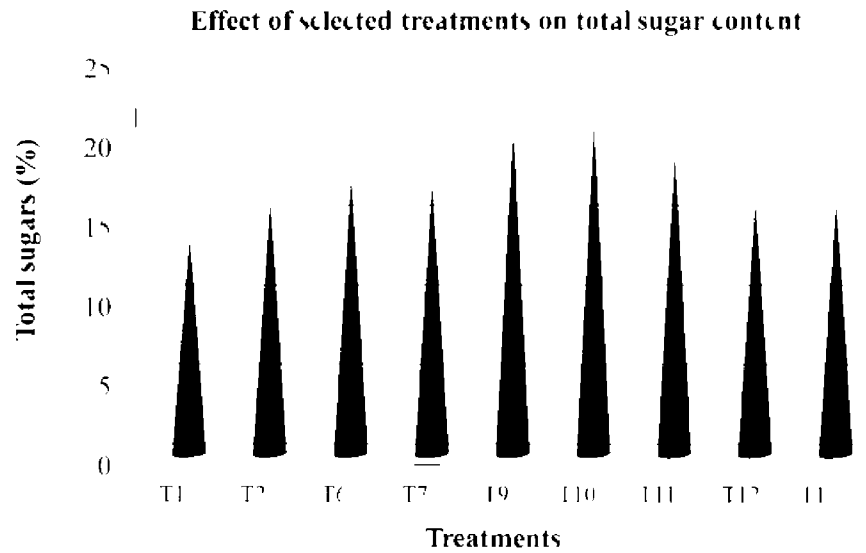

Figure 6 Foliar application of micronutrient mixture on total sugar content of ripened banana fruits

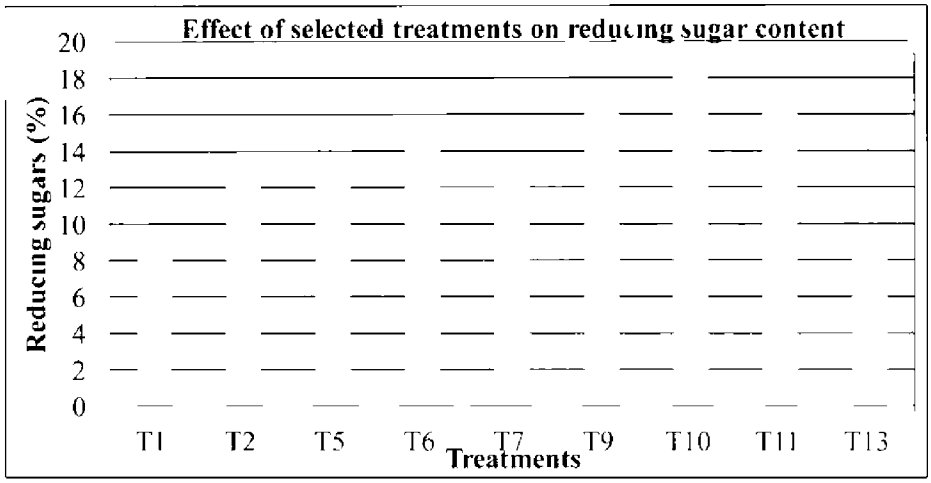

Figure 7 Foliar application of micronutrient mixture on reducing sugar content of ripened banana fruits

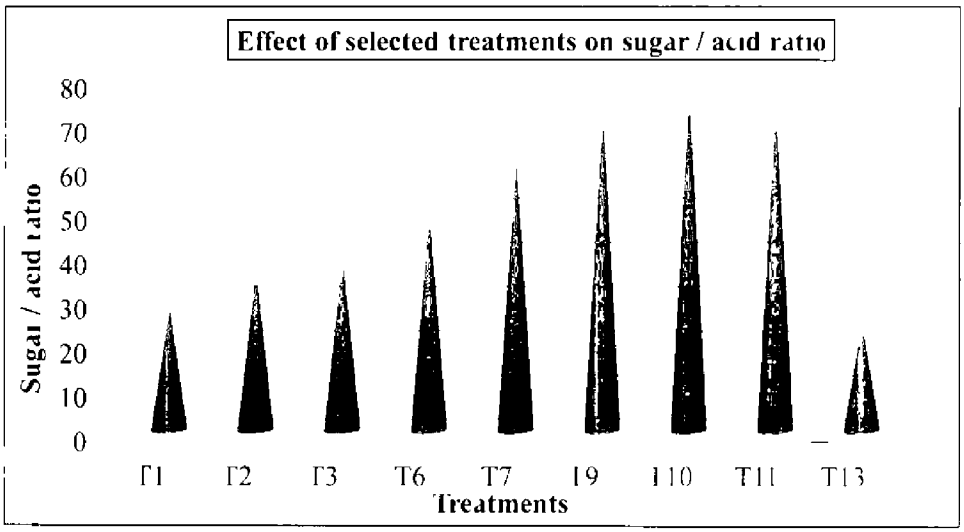

Figure 8 Foliar application of micronutrient mixture on sugar acid ratio of ripened banana fruits

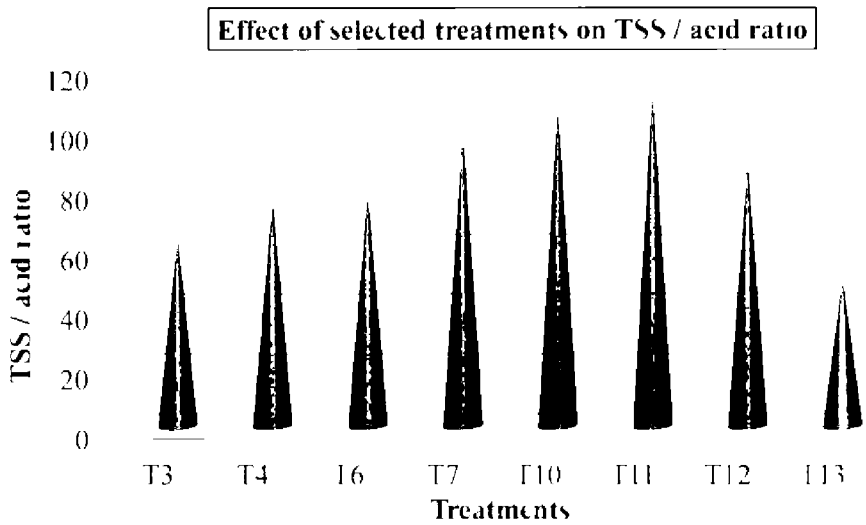

Figure 9 Foliar application of micronutrient mixture on TSS / acid ratio of ripened banana fruits

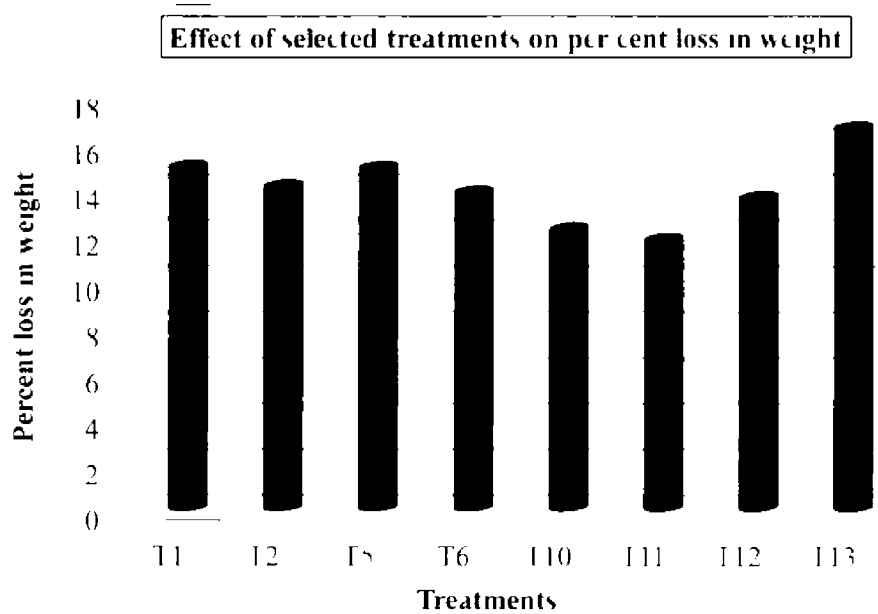

Figure 10 Foliar application of micronutrient mixture on per cent loss in weight during ripening of banana fruits

5.3.4. Effect of treatments on soil nutrient status

The effect of foliar application of micronutrients on soil nutrient status were studied and found that OC, N, P, K, Mg, Zn, B, Fe, B and Mo was found to be significant with treatment application while pH, EC, Ca, S and Cu content soil was found to be non significant

There was no significant effect of treatment application on soil pH and electrical conductivity However average pH of the treatment plots were lower than that of control plot, which in turn enhance the nutrient availability and can bring about a better soil environment for plant growth 3 sprays of 1 per cent micronutrient mixture treated plots were found to have lesser pH of 4 8 Even though non significant, average EC of treatment plots were higher than that of control plot Highest EC value was found in 2 sprays of 2 per cent micronutrient mixture treated plots and lowest EC value was recorded 2 sprays of 4 per cent micronutrient mixture treated plots It might be due to increase in the soluble salt content of the soils

Organic carbon content of the soils was significantly influenced by treatment application 3 sprays of 1 per cent micronutrient mixture treated plots have increased organic carbon content of soil whereas control plot was found to have lowest organic carbon content

Available Nitrogen, phosphorus and potassium content of soil were significantly influenced by treatment application With increasing level of micronutrient mixture the available nitrogen content of soil also increased Highest available N was recorded in 3 sprays of 4 per cent micronutrient mixture treated plots whereas lowest was recorded in one spray of 3 per cent micronutrient mixture treated plots Available P content of soil increased with treatment application as compared to that of control Maximum available P content was found in 3 sprays of 4 per cent micronutrient mixture treated plots and control plot recorded minimum available P content Available K content of soil also improved with treatment application as

compared to that of control Highest available K content of soil was recorded in 2 sprays of 4 per cent micronutrient mixture treated plots while control plot was found to have lowest available K content

Ca and S content of soil was not influenced by treatment application Non significance of nutrients might be due to increased plant uptake and leaching losses Under humid tropical climatic conditions, soils dominated by kaolinitic clay readily leaches out Ca^{2+} (Sims and Ellis, 1983) Mg content of treated plots was increased with increased time of treatment application Highest Mg content was recorded in 3 sprays of 1 per cent micronutrient mixture treated plot

Application of micronutrient mixture brought out significant changes in availability of iron, manganese, zinc, molybdenum and boron in soil Zinc content of the soils exhibited significant difference among the treatments Two sprays of 1 per cent micronutrient mixture treated plot recorded maximum Zn content of soils and control plot recorded the minimum The maximum soil Zn concentration is mainly due to humus-Zn chelating process The mobility and availability of trace elements is controlled by chemical and biochemical processes including precipitation, dissolution, adsorption-desorption, complexation-dissolution and redox processes (Hursthouse, 2001)

Iron content of soil was also significantly influenced by treatment application With increasing level of micronutrient mixture the Fe content of soil has been decreased Maximum Fe content was recorded in one spray of 4 per cent micronutrient mixture treated plot whereas control plot recorded the minimum content

Mn content of soil was significantly influenced by treatment application Highest Mn content was recorded with 3 sprays of 2 per cent micronutrient mixture treated plots When Cu status is considered, treatment application did not influence the Cu content of soils However, highest Cu content was found in 2 sprays of 1 per

cent micronutrient mixture treated plots and lowest was recorded in in one spray of 2 per cent micronutrient mixture treated plots

B content of soil was found to higher in all treated plots as compared to control plot One spray of 4 per cent micronutrient mixture treated plots was found to have highest B content in soil The contribution of foliar fertilization in increasing nutrient content of soils might be due to washing and by draining fertilizer solution from leaves to soil surface (Nomura *et al*, 2011)

Mo content of soil was found to higher in all treated plots as compared to control plot Three sprays of 4 per cent micronutrient mixture treated plots were found to have highest Mo content in soil

5.3.5. Effect of treatments on leaf nutrient contents

The effect of foliar spraying of micronutrient mixture showed significant influences in leaf nutrient contents of banana at bunching stage and at harvest Except nitrogen all other elements like P, K, Ca, Mg, S, Zn, B, Fe, Mn, Mo and Cu content of leaves increased at one or both stage of observation The increased in macro and micronutrient content of leaf might be attributed to fact that the physiological processes of leaves led to rapid absorption and utilization of nutrients for primary metabolic processes Arunachalam *et al* (1976) showed that adequate levels of nutrient in banana leaf ranged from 3 18-3 43, 0 46-0 54, 3 36-3 76, 2 3-2 4 and 0 25-0 28 per cent for N, P, K, Ca and Mg, respectively The results obtained in the present investigation are in line with Arunachalam *et al* (1976) The increased uptake of P, K, Mn and Zn by various crops were reported by Ghanta and Mitra (1993) in banana cv Giant Governor, Durgadevi *et al* (1997) in citrus, Lal *et al* (2000) in guava, Aggarwal *et al* (1975) in grapes, Afria *et al* (1999) in pomegranate, Nehete *et al* (2011) in mango and Yadav *et al* (2009b) in banana cv Grand Naine

Nitrogen content of banana leaves at bunching stage as well as at harvest was not influenced by treatment application Even then, in both stages the N content ranged between 2 10- 4 20 per cent which was sufficient for crop growth Two times foliar spraying of 3 per cent micronutrient mixture was found to have highest N content in leaves and control plants was recorded lowest N content in leaves Hewitt (1955) reported that 2 6 per cent N in the leaf is adequate for banana, while Murray (1962) showed that <1 5 per cent nitrogen is designated as deficient for banana There was gradual decrease in N content from bunching to harvest, because N is the primary element which may be mostly utilized by plants Similar finding was reported by Jeyabaskaran and Pandey (2008) in Karpuravalli banana

Significant differences were noticed in the P content of leaves among the treatments at the time of harvest of banana Highest P content was recorded in 1, 2 and 3 sprays of 3 per cent micronutrient mixture treated plants Control and one spray of 1 per cent micronutrient mixture were found to have lowest P content This might be due to rapid phosphorus uptake by plants, their metabolism and translocation to plant parts Similar findings were reported by Yadav *et al* (2009b) in banana cv Grand Naine, Sankar *et al* (2013) in mango cv Alphonso

Potassium content of leaves was found to be significant at bunching stage as well as at harvest of crop 3 sprays of 3 per cent micronutrient mixture were found to have highest K content of leaves Control plants had lowest K content in leaves This might be due to role of micronutrients especially B in encouragement of potassium absorption from soil rather than utilization in plant tissues Similar report was also obtained by by Yadav *et al* (2009b) in banana cv Grand Naine, Sankar *et al* (2013) in mango cv Alphonso, Jeyabaskaran and Pandey (2008) in Karpuravalli banana and Paul and Nair (2015) in banana cv Nendran The application of micronutrients favoured the accumulation of macronutrients due to their role in activation of enzymes, involved in metabolic processes (Muthukrishnan *et al* , 2014)

Leaf Ca content at bunching stage and at harvest showed notable difference among the treatments At bunching stage 2 sprays of 4 per cent micronutrient mixture and at harvest 3 sprays of 3 per cent micronutrient mixture recorded highest Ca content in leaves Mg content was found highest with 3 sprays of 2 per cent micronutrient mixture at bunching stage Mg content of leaves increased with increasing levels and time of treatment application Sulphur content of leaves also increased with increasing level and time of treatment application Highest S content was found in 3 sprays of 3 per cent micronutrient mixture at the time of harvest

The addition of micronutrients either alone or through mixture, must have exerted its direct effect on its own composition Application of micronutrient mixture brought out significant changes in leaf Zn, Fe, Mn, Cu, B and Mo content at bunching stage and at harvest of banana Similar findings were also observed by Thiyageshwari and Ramanathan (2001), Bhatt and Srivastava (2005), Kumbhar and Deshmukh (1993), Prabha and Singaram (1996)

Treatment application significantly influenced the Zn content of leaves at both stages of observation With increasing level of micronutrient mixture Zn content of leaves also increased At bunching stage, the highest Zn content was recorded in 3 sprays of 4 per cent micronutrient mixture treated plants and at harvest, 3 sprays of 3 per cent micronutrient mixture treated plants recorded the maximum Zn content In both stages, control plants found to have the lowest Zn content This increase in leaf Zn content was due to its maximum absorption from Zn source through foliage and less translocation to other parts of the plant Similar finding was also reported by Yadav *et al* (2009b) in banana cv Grand Naine, Dalal *et al* (2011) in Ber, Hafeez-ur-Rahman and Izhar-ul-Haq (2014) in sweet orange and Lalithya *et al* (2014) in sapota

Application of micronutrients increased the concentration of iron as it was supplied through micronutrient spray Fe concentration of leaves in treated plants

was found to be higher than that of control plants 3 sprays of 4 per cent micronutrient mixture found to have highest Fe content in leaves at both stages whereas control plants recorded the lowest Fe content. The acidic environment in the root vicinity leads the reduction of Fe^{3+} to Fe^{2+} form which is water soluble and available form to plants This results in increase in the Fe content of leaves and might have led to higher Fe uptake The results are in conformity with Lalithya *et al* (2014) in sapota, Yadav *et al.* (2009b) in banana cv Grand Naine, Dalal *et al* (2011) in Ber, Jeyabaskaran and Pandey (2008) in Karpuravalli banana

Significant differences were noticed in the Mn uptake among the treatments However, very high levels of Mn were observed in banana leaves At bunching stage, 3 sprays of 4 per cent micronutrient mixture and at harvest 3 sprays of 2 per cent micronutrient mixture were recorded with highest Mn content of leaves Turner and Barkus (1983) also reported the high Mn concentration in the leaves as a special character of banana Average Mn content of the treated plants was higher than the control plants A concentration upto 2200 ppm is considered as optimum for banana whereas above which it is high under subtropical conditions as reported by Turner and Barkus (1983) Similar findings were obtained by Dalal *et al* (2011) in Ber, Hafeez-ur-Rahman and Izhar-ul-Haq (2014) in sweet orange, Jeyabaskaran and Pandey (2008) in Karpuravalli banana and Hasani *et al* (2012) in pomegranate leaves

Average Cu content of the leaves in treated plants was higher than that of control at bunching stage as well as at harvest of banana 3 sprays of 3 per cent micronutrient mixture found to have highest Cu content Application of micronutrients increased the concentration of copper as it was supplied through foliar spray With increasing level and time of application of micronutrient mixture the Cu content of the leaves also increased Similar findings were also reported by Paul and Nair (2015) in banana cv Nendran, Lalithya *et al* (2014) in sapota and Yadav *et al* (2009b) in banana cv Grand Naine

Significant differences in B concentration of the leaves were noticed at both stages of observation with foliar application of micronutrient mixture This might be due to the presence of boron binding compounds in the cell which might have increased the mechanism of boron uptake, which is thought to be a non-metabolic process determined in plant by the formation of non-exchangeable boron complexes within the cytoplasm and cell wall Similar findings were reported by Brown and Hu (1994) in sunflower, Saran and Kumar (2011) in mango, Asgharzade *et al* (2012) in apple, Sankar *et al* (2013) in mango cv Alphonso

Average Mo content of the leaves in treated plants was higher than that of control at both of stages Three sprays of 3 per cent micronutrient mixture was found to make highest Mo content in leaves Application of micronutrients increased the concentration of molybdenum as it was supplied through foliar spray With increasing level and time of application of micronutrient mixture the Mo content of the leaves also increased

The results of net return and BCR (Table 21) indicated that there exists a significant difference between the treatments The treatment T_{11} (3 sprays of 3 % micronutrient mixture) registered the maximum net return and BCR of Rs 6,94,964 ha^{-1} and 2 29 Foliar spraying of micronutrient mixture enhanced the growth and yield parameters, which in turn gave higher net returns and BCR. This was in accordance with the results of Yadav and Patel (2013) in banana cv Grand Naine, Patel *et al* (2010) in banana cv Basrai, Pathak *et al* (2011) and Bauri *et al* (2014) in banana cv Martaman (AAB, Silk)

Summary

6. SUMMARY

The salient findings of the present study entitled "Formulation and evaluation of micronutrient mixture for foliar application in TC banana (*Musa* sp) var Nendran" are summarized in this chapter

Investigations were carried out at College of Agriculture, Padannakkad and Regional Agricultural Research Station farm, Nileshwar during November 2014 to March 2016, with the objectives of preparation of a micronutrient mixture formulation containing Zinc, Iron, Boron, Copper, Manganese and Molybdenum for foliar spray, to evaluate stability of formulation and its keeping quality and to investigate the effect of this formulation on growth, yield and quality of fruits in banana (*Musa* AAB) Nendran The whole study consisted of three parts – preparation of micronutrient mixture formulation, hardening studies and field experiment

Preparation of micronutrient mixture as a liquid formulation was tried with the use of different micronutrient salts containing Zn, B, Fe, Mn, Cu and Mo The formulation technique was standardized and it contains two liquids Solution A and Solution B Solution A consisting of $ZnSO_4$ $7H_2O$, $CuSO_4$ $5H_2O$, $FeSO_4$ $7H_2O$, H_3BO_3, $MnSO_4$ H_2O and $(NH_4)_6Mo_7O_{24}$ $4H_2O$ in desired proportion For maintaining stability and keeping quality of solution A, various chemicals were tried Citric acid (20 %) was found best for maintaining keeping quality of solution A Its stability was periodically monitored at specific intervals Solution B is prepared as 1 per cent humic acid Required quantity of this has to be blended with diluted solution A just before spraying The second and third part of the experiment was evaluation of this mixture This micronutrient mixture was diluted to different concentrations and applied as foliar spray in tissue culture banana cv Nendran to study the effect of this nutrient mixture on hardening and field experiment

The hardening studies were conducted in the mist chamber, Department of Plant Biotechnology, College of Agriculture, Padannakkad, Kerala with TC plants of uniform size multiplied from same genotype The experiment was carried out in completely randomized design with 12 treatments and one absolute control maintaining 3 replications each and there were 4 plants in each replication The treatments consisted of 4 levels of micronutrient mixture (0 25 %, 0 5 %, 0 75 % and 1 %) sprayed at 3 different intervals The 3 different sprays were one spray was given at immediately after planting, two sprays at immediately and two weeks after planting and three sprays at immediately, two and three weeks after planting during secondary hardening stage Thus there were 12 treatment combinations and one control which were T_1, T_5, T_9 at 0 25 per cent (one, two and three sprays), T_2, T_6, T_{10} at 0 50 per cent (one, two and three sprays), T_3, T_7, T_{11} at 0 75 per cent (one, two and three sprays), T_4, T_8, T_{12} at 1 per cent (one, two and three sprays) and T_{13}- control The important biometric observations such as plant height, number of leaves, leaf length and leaf breadth were recorded at one month after keeping it for hardening The results showed that the application of micronutrient mixture have positive effect on biometric characters of the crop Maximum plant height (20 2 cm) was recorded in T_{10} (0 5% micronutrient mixture as 3 sprays) Highest number of leaves (6 8) and leaf breadth (7 3 cm) was recorded in T_9 (0 25% micronutrient mixture as 3 sprays) and T_5 recorded highest leaf length (19 6 cm)

The field experiment was carried out at Regional Agricultural Research Station farm, Nileshwar to study the effect of foliar application of micronutrient mixture in tissue culture banana cv Nendran One fifty six hardened tissue culture banana plantlets were planted in randomized block design with thirteen treatments and three replications such that four plants were maintained in each replication Nitrogen, Phosphorus and Potassium application and other cultural practices were uniformly followed for all the plants as per Package of Practices, KAU (2011)

The treatments consisted of 4 levels of micronutrient mixture (1 %, 2 %, 3 % and 4 %) sprayed at 3 different intervals The 3 different sprays were one spray was given at two months after planting, two sprays at two and four months after planting and three sprays at two, four and six months after planting Thus there were 12 treatment combinations and one control which were T_1, T_5, T_9 at 1 per cent (one, two and three sprays), T_2,T_6,T_{10} at 2 per cent (one, two and three sprays), T_3,T_7,T_{11} at 3 per cent (one,two and three sprays), T_4, T_8,T_{12} at 4 per cent (one,two,three sprays) and T_{13}- control

The results of the field experiment showed that treatment application significantly enhanced the vegetative characters like pseudostem height, pseudostem girth and number of leaves and yield parameters like bunch weight, number of fingers, average weight of fingers, finger length and minimum days to harvest Maximum pseudostem height was recorded in T_{12} (4 % micronutrient mixture as 3 sprays) at 4 months after planting, pseudostem girth at 90 cm was found to highest in T_{10} (2 % micronutrient mixture as 3 sprays) at the time of shooting, highest number of leaves was recorded in T_6 (2 % micronutrient mixture as 2 sprays) at 4 months after planting as well as at the time of shooting and number of suckers produced at harvest were highest in T_{10} (2 % micronutrient mixture as 3 sprays) and T_{12} (4 % micronutrient mixture as 3 sprays) The highest male bud weight was found in T_5 (1 % micronutrient mixture as 2 sprays) Bunch weight was found to be highest in T_{11} (3 % micronutrient mixture as 3 sprays) with 12 76 kg whereas control T_{13} recorded the lowest bunch weight of 8 32 kg with 53 4 % increases in yield for treatment over control T_9 (1 % micronutrient mixture as 3 sprays) found to have maximum number of fingers, highest average weight of fingers and finger length was found in T_{11} (3 % micronutrient mixture as 3 sprays) Highest breadth was recorded with T_{11} (3 % micronutrient mixture as 3 sprays) and T_{10} (2 % micronutrient mixture as 3 sprays) T_{10} produced the bunch in shortest time of 186 days whereas T_{11} (3 % micronutrient mixture as 3 sprays) took minimum days (271 days) for harvesting as well as

minimum bunch maturity period (82 days) and T_4 (4 % micronutrient mixture as 1 spray) took minimum days for harvesting to ripening of fruits (4 days)

Fruit characteristics like titrable acidity, TSS, pulp to peel ratio, total sugars, reducing sugars, non-reducing sugar content, sugar / acid ratio, TSS / acid ratio, per cent loss in weight during ripening and keeping quality of the fruits at ambient condition were studied All the fruit quality parameters showed significant differences among the treatments Lesser acidity indicates better quality and the lowest titrable acidity was recorded in T_{11} (3 % micronutrient mixture as 3 sprays) whereas control T_{13} recorded the maximum acidity content of fruits Maximum TSS content (30 0 °brix) was found in T_{11} (3 % micronutrient mixture as 3 sprays) whereas T_{12} (4 % micronutrient mixture as 3 sprays) recorded highest pulp to peel ratio of 3 70 The highest total sugar content (21 3 %) and reducing sugar content (19 0 %) was recorded with T_{10} (2 % micronutrient mixture as 3 sprays) and the highest non-reducing sugar content was recorded in T_5 (1 % micronutrient mixture as 2 sprays) whereas T_{11} (3 % micronutrient mixture as 3 sprays) recorded the lowest non-reducing sugar content Highest sugar / acid ratio and keeping quality of the fruits at ambient condition were found in T_{10} (2 % micronutrient mixture as 3 sprays) T_{11} (3 % micronutrient mixture as 3 sprays) was found to have highest TSS / acid ratio and minimum loss in weight of fruits during ripening

The effect of foliar application of micronutrients on soil nutrient status were studied and found that OC, N, P, K, Mg, Zn, B, Fe, B and Mo status were found to be significant with treatment application while pH, EC, Ca, S and Cu content soil was found to be non significant

Lowest pH (4 8) was found in T_9 which receiving 1 per cent micronutrient mixture as 3 sprays, highest EC value was found in T_6 (2 % micronutrient mixture as 2 sprays) treated plots and lowest EC value was recorded T8 (4 % micronutrient mixture as 2 sprays) T_9 (1 % micronutrient mixture as 3 sprays) found to have

highest organic carbon content of soil whereas T_{13} (control) recorded the lowest organic carbon content

Available N content of the soils was significantly influenced by treatment application With increasing levels and times of application of micronutrient mixture, the available nitrogen content of soil also increased Highest available N and available P content were recorded in T_{12} (4 % micronutrient mixture as 3 sprays), whereas control plot recorded the minimum Available K content of soil also improved with treatment application as compared to that of control Highest available K content of soil was recorded in T_8 (4 % micronutrient mixture as 2 sprays), while control plot was found to have the lowest content

Ca and S content of soil was not influenced by treatment application However, maximum Ca content was recorded in T_5 (1 % micronutrient mixture as 2 sprays) and S content in T_{11} (3 % micronutrient mixture as 3 sprays) Mg content of treated plots was increased with increasing time of application Highest Mg content was recorded in T_9 (1 % micronutrient mixture as 3 sprays)

Application of micronutrient mixture brought out significant changes in available Zn, B, Fe, Mo and Mn Highest Zn and Cu content was found in T_5 (1 % micronutrient mixture as 2 sprays) and control plot recorded the minimum With increasing level of micronutrient mixture the Fe content of soil has been decreased Maximum Fe content was recorded in T_4 (4 % micronutrient mixture as one spray) and Mn content was in T_{10} (2 % micronutrient mixture 3 sprays) B content of soil was found to higher in all treated plots as compared to control plot T_4 (4 % micronutrient mixture as one spray) was found to have highest B content in soil Highest Mo content was recorded with T_{12} (4 % micronutrient mixture 3 sprays)

As leaf nutrient concentration of banana is considered, significant influence of treatment application of micronutrient mixture were found in P, K, Ca, Mg, S, Zn, B, Fe, Mn, Mo and Cu content at one or both stage of observation (bunching and at

harvest) Highest N content was found in T_7 (3 % micronutrient mixture 2 sprays) at bunching stage as well as at the time of harvest of banana Highest P content was found in T_3 (3 % micronutrient mixture 1 spray) and T_7 (3 % micronutrient mixture 2 sprays) at harvest Highest K content of leaves was recorded in T_{11} (3 % micronutrient mixture as 3 sprays) at bunching stage and at harvest

At bunching stage T_8 (4 % micronutrient mixture as 2 sprays) and at harvest T_{11} (3 % micronutrient mixture as 3 sprays) recorded highest Ca content in leaves Mg content of leaves increased with increasing levels and time of application Mg content was found highest with T_{10} (2 % micronutrient mixture as 3 sprays) at bunching stage and the highest S content was found in T_{11} (3 % micronutrient mixture as 3 sprays) at harvest

Regarding micronutrient content of leaves there was significant differences between the treatments and the control with respect to Zn, Fe, Mn, Cu, Mo and B content at bunching and at harvest of banana The highest Zn content was recorded in T_{12} (4 % micronutrient mixture as 3 sprays) at bunching stage and T_{11} (3 % micronutrient mixture as 3 sprays) at harvest whereas control plants found to have the lowest Zn content With increasing level of micronutrient mixture Zn content of leaves also increased Fe concentration of leaves in treated plants was found to be higher than that of control plants

At both stages of obesrvation, T_{12} (4 % micronutrient mixture as 3 sprays) found to have highest Fe content in leaves Average Mn content of the treated plants was higher than the control plants Highest Mn content was found in T_{12} (4 % micronutrient mixture as 3 sprays) at bunching stage and T_{10} (2 % micronutrient mixture as three sprays) at harvest Average Cu content of the leaves in treated plants was higher than that of control at bunching stage and at harvest In both stages, T_{11} (3 % micronutrient mixture as 3 sprays) found to have highest Cu content

Highest B content was recorded in T_3 (3 % micronutrient mixture as one spray) at bunching and T_{12} (4 % micronutrient mixture as 3 sprays) at harvest Mo content was found to highest with T_{11} (3 % micronutrient mixture as 3 sprays) in bunching and at harvest

The Highest net return (Rs 6, 94, 964) and benefit cost ratio (2 3) was registered with foliar application of 3 % micronutrient mixture as three sprays (T_{11}) The quantity of spray solution required for best treatment T_{11} on projection to one ha is 56 litres, with an additional cost of Rs 160/ litre for the mixture plus Rs 600 / day as cost of labour for application

The positive effects of the micronutrient foliar spray solution indicate the need of these nutrients on banana This effect can be further evaluated on vegetables and other crops On the basis of the results thus obtained recommendation can be made on adhoc basis

References

7. REFERENCES

Abbasi, F F , Baloch, M A , Zia-ul-hassan, Wagan, K H , Shah, A N , and Rajpar, I 2010 Growth and yield of okra under foliar application of some new multinutrient fertilizer products *Pak J Agric* 26 (2) 11–18

Abdel-Kader, A M M , El-Makhtoun, F M B , and Bastawros, M B 1992 Effect of micro-nutrients foliar application on the vegetative growth and yield of Hindi banana (*M cavendeshii*) *Egyptian J Agric Res* 70 (2) 613– 624

Abou-El-nour, E A A 2002 Can supplemented potassium foliar feeding reduce the recommended soil potassium? *Pak J Biol Sci* 5 259–262

Afria, B S , Pareek, C S , Garg, D K , and Singh, K 1999 Effect of foliar spray of micronutrients and their combinations on yield of Pomegranate *Ann Arid Zone* 38 (2) 189–190

Aggarwal, R K , Panday, S K N , and Pareek, O P 1975 Foliar application of micronutrients on Thompson seedless grape *Ann Arid Zone* 14 (2) 191–193

*Agrios, N G 2005 *Plant pathology* Elseiver-Academic press p 635

Ahmad I , Khan, A M , Qasim, M , Ahmad, R , and Randhawa, A M 2010 Growth, yield and quality of Rosa hybrid L as influenced by various micronutrients *Pak J Agric Sci* 47 (1) 5–12

Alam, S S , Moslehuddin, A Z M , Islam, M R , and Kamal, A M 2010 Soil and foliar application of nitrogen for Boro rice (BRRIdhan 29) *J Bangladesh Agril Univ* 8 (2) 199–202

Ali, S , Shah, A , Arif, M , Mirja, G , Ali, I , Khan, M F A , and Moula, N 2009 An Introduction of Plant Nutrients and Foliar Fertilization A Review *J Agric* 25 1–10

Alloway, W H 1986 Soil-plant-animal and human interrelationships in trace element nutrition In Mertz, W (ed), *Trace elements in Human and Animal nutrition* Academic press, Orlando, San Diego, New York, Austin, London, Montreal, Sydeney, Tokyo, Toronto pp 465–488

Al- Jobori, K M M and Al-Hadithy, S A 2014 Response of Potato (*Solanum tuberosum*) to Foliar Application of Iron , Manganese, Copper and Zinc *Int J Agric Crop Sci* 7 (7) 358–363

Anjali, S , Lenka, P C , Das, S N , and Das, S S 2013 Effect of micronutrients on growth and yield of banana cv Grand Name *Environ Ecol* 31 (4) 1919–1921

Anitha, S , Sreenivasan, E , and Purushothaman 2005 Response of cowpeav (*Vigna unguiculata* L) to foliar nutrition of zinc and iron in the oxisols of Kerala *Legume Res* 28 (4) 294–296

Anonymous 1969 *Medicinal secrets of Yam foods* Pub sec Indo American Hospital, Mahulla, N R Mysore, (1st ed) 183–191

Anonymous 2005 *Annual Reports* AICRP on Tropical fruits, BCKV, Mohanpur centre pp 26–29

Arnon, D I and Stout, P R 1939 Molybdenum as an essential element for higher plants *Plant Physiol* 14 599–602

Arunachalam, A , Ramasawmy, N , and Muthukrishnan, C R 1976 Studies on the nutrient concentration in leaf tissue and fruit yield with nitrogen in leaf for Cavendish clones *Prog Hortic* 8 13–22

Asad, A and Rafique, R 2002 Identification of micronutrient deficiency of wheat in the Peshawar Valley, Pakistan *Commun Soil Sci Plant Anal* 33 (3–4) 349–364

Asgharzade, A , Valizade, G A , and Babaeian, M 2012 Investigating the effect of boron spray on yield, nutrient content, texture and brix index of apple (Sheikh Amir variety) in shirvan region *African J Microbiol Res* 6 (11) 2682–2685

Aziz, A B A and Wahab, F K. 1970 Comparative studies on the different methods of artificial ripening of banana fruits *Curr Sci* 39 552–555

Babaeian, M , Tavassoli, A , Ghanbari, A , Esmaeilian, Y , and Fahimifard, M 2011 Effects of foliar micro-nutrient application on osmotic adjustments, grain yield and yield components in sunflower (Alstar cultivar) under water stress at three stages *Afr J Agric Res* 6 (5) 1204–1208

Babu, N and Singh, A R 2002 Effect of micronutrients spray on fruit cracking of litchi fruits *Haryana J Hortic Sci* 13 (1–2) 18–21

Balakrishnan, V 2005 Effect of micronutrients on flower yield and xanthophylls content of African marigold (*Tagetus erecta* L) M Sc (Ag) thesis, Tamil Nadu Agricultural University, Coimbatore, 114p

Baligar, V C , Fageria, N K., and Elrashidi, M A 1998 Toxicity and nutrient constraints on root growth *Hortic Sci* 33 960–965

Baloch, Q B , Chachar, Q I , and Tareen, M N 2008 Effect of foliar application of macro and micro nutrients on production of green chilies (*Capsicum annuum* L) *J Agric Tech* 4 (2) 177–184

Barber, S A 1995 *Soil Nutrient Bioavailability A Mechanistic Approach* (2nd ed) Wiley, New York 414p

Bauri, F K , De, A , Misra, D K., Bandyopadhyay, B , Debnath, S , Sarkar, S K , and Avani, P 2014 Improving yield and quality of banana cv Martaman (*Musa* AAB, Silk) through micronutrient and growth regulator application *J Crop Weed* 10 (2) 316–319

Bell, R W and Dell, B 2008 *Micronutrients for Sustainable Food, Feed, Fibre and Bioenergy Production* (1st Ed) IFA, Paris, France

Benepal, P S 1967 Influence of micronutrients on growth and yield of potatoes *Am Potato J* 44 363 p

Bernal, M , Cases, R , Picorel, R , and Yruela, I 2007 Foliar and root Cu supply affect differently Fe and Zn-uptake and photosynthetic activity in soybean plants *Environ Exp Botany* 60 145–150

Bhambota, J R , Azad, K C , Kanwar, J S , and Dhingra, D R 1962 Study of the effect of sprays with micronutrients of the chlorosis of citrus *Hortic Adv* 6 168–172

Bhargava, B S and Raghupathi, H B 1995 Analysis of plant material for macro ans micronutrients In Tandon, H L S (ed), *Methods of analysis of soils, plants water and fertilizers* Malhotra publishing house, New Delhi, pp 61–62

Bhatt, L and Srivastava, B K 2005 Effect of foliar application of micronutrients mixture on nutrient uptake in tomato *Veg Sci* 32 (2) 158–161

Bhatt, A , Mishra, N K , Mishra, D S , and C P Singh 2012 Foliar application of potassium, calcium, zinc and boron enhanced yield, quality and shelf life of mango *HortFlora Res Spectrum* 1 (4) 300–305

*Bingham, F T 1982 Boron In Page, A L (ed), *Methods of soil analysis* (2nd ed) *Am Soc of Agron* Madison, USA, 438p

Black, C A , Evans, D D , Ensminger, L E , White, J L , and Clark, F E 1965 Methods of soil analysis *Am Soc Agron* Madison, USA, 156p

Blevins, D G and Lukaszewski, K M 1998 Boron in plant structure and function *Ann Rev Plant Physiol* 49 481–500

Bloom, P R , Mcbride, M B , and Weaver, R M 1979 Aluminium organic matter in acid soil, buffering and solution aluminium activity *Soil Sci Soc Am J* 43 488– 493

Boorboori, M R , Asli, E D , and Tehrani, M 2012 Effect of micronutrient application by different methods on yield, morphological traits and grain protein percentage of barley (*Hordeum vulgare* L) *J Adv Environ Biol* 6 (2) 740

Brahmachari, V.S , Yadav, G S , and Naresh, K 1997 Effect of feeding of calcium, zinc and boron on yield and quality attributes of litchi (*Litchi chinensis* Sonn) *Orissa J Hortic* 25 (1) 49–52

Brown, P H and Hu, H 1994 Boron uptake by sunflower, squash and cultured tobacco cells *Physiol Plant* 91 (3) 435–441

Butani, A M , Chovatia, R S , Patel, K D , Vadaria, K N , and Rankja, N J 2012 Effect of chemical fertilizer and vermi compost on yield and nutrient content and uptake by fruit of banana *Musapar adisiaca* L cv Grand Naine *Asian J Hortic* 7 (2) 594–598

Charpentier, J M and Martin, P 1965 Soil less culture Chronic or temporary deficiencies in major elements Minor element deficiencies in banana *Fruits d' outre Mer* 20 521–557

Clark, R B and Zeto, S K 2000 Mineral acquisition by *Arbuscular mycorrhizal* plants *J Plant Nutr* 23 867–902

Dadhich, S K and Somani, L L 2007 Effect of integrated nutrient management in Soybean-Wheat crop sequence on the yield, micronutrient uptake and post-harvest availability of micronutrients on Typic Ustochrepts soil *Acta Agronomica Hungarica* 55 (2) 205–216

Dalal, R P S , Navjot, Thakur, A , and Brar, J S 2011 Effect of foliar application of nutrients on leaf mineral composition and yield of Ber (*Ziziphus mauritiana* Lamk) under arid conditions *An Arid zones* 50 (1) 53–56

DAO [Department of Agriculture] 2013 *Manual on Soil, Plant and Water Analysis* (Vol 1), (eds) Venugopal, V K , Nair, K M , Vijayan, M R , John, S K , and Kumar, S P 183p

Das, P K and Mohan, N K 1993 Effect of micronutrient on growth and development of banana cvs Chenichampa,Jahaji and Barjahaji *S Indian Hortic* 41 (4) 192–197

Das, P K 1995 Effect of micronutrients on quality of certain banana cultivars *J Agric Sci Soc N E India* 8 (2) 211–215

Das, D K 2000 Boron In *Micronutrients Their Behaviour in Soils and Plants* Kalyani Publishers, Ludhiana, pp 127–155

Das, J L 2010 Medicinal and nutritional values of banana cv Nendran *Asian J Hortic* 5 (1) 11–14

Datir, R B , Laware, S L , and Apparao, B J 2010 Effect of Organically Chelated Micronutrients on Growth and Productivity in Okra *Asian J Exp Biol Sci Spec* 200 115–117

De, N and Rai, M 2005 Micronutrient disorders and management in vegetable crop Review *Veg Sci* 32 (1) 1–10

Deolankar, K P and Firake, N N 2001 Effect of water soluble fertilizers on growth and yield of banana *J Maharashtra Agric Univ* 26 (3) 333–334

Dixit, C K , Yamdagni, R , and Jindal, P C 1977 A note on the effect of micronutrients spray on quality of kinnow- A Mandarin hybrid *Haryana J Hortic Sci* 6 (3–4) 153–154

Dixon, R C 2003 Foliar fertilization improves nutrient use efficiency *Fluid J* pp 1–2

Durairaj, S 1993 Effect of lignite humic acid and zinc on the performance of rice in a coastal saline soil M Sc (Agri) thesis, Annamalai University, Tamilnadu 89p

Durgadevi, D , Srinivasan, P S , and Balakrishna, K 1997 Leaf nutrient composition, chlorosis and yield of Sathgudi orange as affected by micronutrient applications *S Indian Hortic* 45 (1–2) 16–29

Dutta, P and Dhua, R S 2002 Improvement on fruit quality of Himsagar mango through application of zinc, iron and manganese *Hortic J* 15 (2) 1–9

Dutta, P 2004 Effect of foliar boron application on panicle growth, fruit retention and physic-chemical characters of mango cv Himsagar *Indian J Hortic* 61 (3) 265–266

Edmond, J B , Sen, T L , Andrews, F S , and Holfacre, R G 1997 *Fundamentals of Horticulture* (4th Ed) McGraw Hill Book Co , New York

El-Fouly, M M and El-Sayed A A 1997 *Foliar fertilization An environmentally friendly application of fertilizers* Dahlia Greidinger International Symposium on "Fertilization and Environment" 24-27 March, pp 346–357

El-Magid, A A A , Knany, R E , and El-Fotoh, H G A 2000 Effect of foliar application of some micronutrients on wheat yield and quality *J Ann Agric Sci* 1 301–313

Emmel, R H , Solera, J J , and Stux, R L 1977 *Atomic absorption methods manual* Instrumentation Laboratory Inc , Wilmington, pp 67–190

Engelhard, A W 1990 *Soil borne Plant Pathogen, Management of Disease with Macro and Micro Elements* American Phytopathological Society Press, St Paul, MN 217pp

Evans, I , Solberg, E , and Huber, D M 2007 Copper and plant diseases In Dantnoff, L E , Wade, H E , and Huber, D M (eds) Mineral nutrition and plant diseases *Am Phytopathol Soc* pp 177–188

Fageria, N K , Valigar, V C , and Wright, R J 1997 Soil environment and root growth dynamics of field crops *Recent Res Dev Agron* 1 15–58

FAO Stat [Food and Agriculture Oranization of the United Nations] 2011 faostat fao org Available http //www fao org/docrep/018/i3107e/i3107e pdf

Fernandez, V and Eichert, T 2009 Uptake of hydrophilic solutes through plant leaves current state of knowledge and perspectives of foliar fertilization *Crit Rev Plant Sci* 28 36–68

Gabal, M R , Abdellah, I M , Abed, I A , and El-Assiousty, F M 1985 Effect of Cu, Mn and Zn foliar application on common bean growth, flowering and seed yield *Acta Hortic* 158 307–319

Ganjir, H , Abed, I A , and Rutherford, W 1973 Status of micronutrients in Indian soils *Plant Soil* 57 (4) 208–215

Gauch, H G and Dugger, W M 1953 The role of boron in the translocation of sucrose *Physiol Plant* 28 457

Geetha, S , Mahalakshmi, M , and Kannappan, K 2004 Tissue culture banana cv Poovan (AAB) and cv Nendran (AAB) under wetland condition *S Indian Hortic* 52 (6) 310–313

Ghanta, P K and Dwivedi, A K 1993 Effect of some micronutrients on yield and quality of banana cv Giant Governor *Environ Ecol* 11 292–294

Ghanta, P K and Mitra, S K 1993 Effect of micronutrients on growth, flowering, leaf nutrient content and yield of banana cv Giant Governor *Crop Res* 6 (2) 284–287

Ghosh, S N , Hore, J K., and Chattopadhyay, N 1995 Effect of foliar feeding of different commercial micronutrient products on yield and fruit quality of mango cv Himsagar *Hortic J* 8 (1) 85–88

Graham, D R 1983 Effects of nutrients stress on susceptibility of plants to disease with particular reference to the trace elements *Adv Bot Res* 10 221–276

Graham, R B and Webb, M J 1991 Micronutrients and disease resistance and tolerance in plants In Mortvedt, J J , Cox, F R , Shuman, L M , and Welch, R M (eds), *Micronutrients in Agriculture*, (2nd Ed) SSSA, Madison, WI pp 329– 370

Grewal, H S , Graham, R D , and Rengel, D 1996 Genotypic variation in zinc efficiency and resistance to crown rot disease (*Fusarium graminearum*) in wheat *Plant Soil* 186 219–226

Gris, E 1843 Memoir relatif a l' action des composes soluble ferrugineux sur la vegetation *Comptes Rendus de l'Acad Sci* 17 679–686

Gupta, V K and Gupta, S P 1985 Influence of zinc sources on the yield and zinc nutrition on sodic soils *Ann Arid Zones* 24 63–67

Gupta, U C 1993 Factors affecting boron uptake by plants In Gupta, U C (ed), *Boron and its role in crop production*, CRC Press, Boca Raton, FL pp 87–123

Gupta, V K 1995 Micronutrients research In Tandon, H L S (ed), *Micronutrient Research and Agricultural Production* Fertilizer Development and Consultation Organisation, New Delhi, India, pp 132–160

Gupta, A P 2005 Micronutrient status and fertilizer use scenario in India *J Trace Elements Med Biol* 18 325–331

Gupta, N K and Gupta, S 2005 *Plant physiology* Oxford & IBH publishing co pvt ltd 580p

Gurjar, T D , Patel, N L , Panchal, B , and Chaudhar, D 2015 Effect of foliar spray of micronutrients on flowering and fruiting of Alphonso mango (*Mangifera indica* L) *Bioscan* 10 (3) 1053–1056

Hada, T S , Singh, B K , Veer, K , and Singh, S P 2014 Effect of different levels of boron and zinc on flowering, fruiting and growth parameter of winter season guava (*Psidium guajava* L) cv L-49 *Asian J Hortic* 9 (1) 53–56

Hafeez-ur-Rahman and Izhar-ul-Haq 2014 Diagnostic criteria of micronutrients for sweet orange *Soil Environ* 25 (2) 119–127

Hansch, R and Mendel, R R 2009 Physiological functions of mineral micronutrients (Cu, Zn, Mn, Fe, Ni, Mo, B, and Cl) *Curr Opinion Plant Biol* 12 259–266

Haque, R , Roy, A , and Pramanic, M 2000 Response of foliar application of Mg, Zn, Cu and B on improvement of growth, yield and trial quality of Mandarin orange in Darjeeling Hills of West Bengal *Hortic J* 13 (2) 15–20

Hasani, M , Zamani, Z , Savaghebi, G , and Fatahi, R 2012 Effects of zinc and manganese as foliar spray on pomegranate yield, fruit quality and leaf minerals *J Soil Sci Plant Nutr* 12 (3) 471–480

Hashemy, M K., Malakoty, M J , and Tabatabaey, V S J 1998 Effect of foliar application of micronutrients in quality and quantity potato crop in Eastern Azarbyjan Province *J Sci Res Soil Water* 12 44–55

Hasslett, B S , Reid, R J , and Rengel, Z 2001 Zinc mobility in wheat uptake and distribution of zinc applied to leaves or roots *Ann Bot* 87 (3) 379–386

Havlin, J L , Tisdale, S L , Nelson, W L , and Beaton, J D 2014 *Soil fertility and nutrient management An introduction to nutrient management* (8th Ed) Pearson Upper Saddle River, New Jersey U S A 505p

Hazarika, B N and Ansari, S 2010 Effect of integrated nutrient management on growth and yield of banana cv Jahaji *Indian J Hortic* 67 (2) 270–273

Hegde, D M , Babu, S S N , and Murthy I Y L N 2007 Role of customized fertilizers in the improvement of productivity of different crops and cropping systems *In Proceedings of national seminar on "Standards and Technology of Value Added / Fortified / Customized Fertilizers* as a source of plant nutrients" (ICAR- IISS, Bhopal, India)

Hewitt, C W 1955 Leaf analysis as a guide to the nutrition of bananas *Emp J Exp Agric* 23 11–16

*Hewitt, E J 1963 Essential nutrient elements requirements and interactions In Steward, F C (ed), *Plant physiology, A treatise* Academic press, New York, London, pp 137–360

Horak, V , Trcka, I , and Stefl, M 1976 The influence of Zn^{2+} ions on the tryptophan biosynthesis in plants *Biologia Plantarum* 18 (5) 393–396

House, W A and Welch, R M 1989 Bioavailability of and interaction between zinc and selenium in rats fed wheat grain intrinsically labeled with ^{65} Zn and ^{75} Se *J Nutr* 119 916–921

Huber, D M 1980 The role of mineral nutrition in defense In Hosfall, J G and Cowling, E B (eds), *Plant Pathology An Advanced Treatise*, AP, NY pp 381–406

Huber, D M and Wilhelm, N S 1988 The role of manganese in resistance to plant diseases In Graham, R D , Hannam, R , and Uren, N C (eds), *Manganese in Soils and Plant* Kluwer Academic, Dordrecht, The Netherlands pp 155–173

Huber, D M and Graham, R D 1999 The role of nutrition in crop resistance and tolerance to disease In Rengel, Z (ed), *Mineral nutrition of crops fundamental mechanisms and implications* Food product press, New York, pp 205–226

Hursthouse, A S 2001 The relevance of speciation in the remediation of soils and sediments contaminated by metallic elements an overview and examples from

Central Scotland, UK *J Environ Monitoring* 3 46–60

Hussanın, M , Ayaz Khanı, M , Khan, M B , Farooq, M , and Farooq, S 2012 Precısıon Farmıng A New Approach *J Rıce Scı* 19 24–30

IIHR [Indıan Instıtute of Horttıcultural Research] 2013 Mıconutrıent mıxture formulatıon Avaılable http //www ıihr res ın/technologıes20developed html [7 Nov 2014]

*Issac, R A and Kerber, J D 1971 Atomıc absorptıon and flame photometry techniques and uses ın soıl, plant and water analysıs In Walsh, L M (ed), *Instrumental methods for analysis of soil and plant tissue* Soıl Scıence Socıety Amerıca, Madıson, USA, pp 17–37

Jackson, M L 1958 Soıl chemıcal analysıs In Cliffs, E N J (ed), *Soil Sci* Unıversıty of Wısconsın, USA, Madıson, pp 89–102

Jagtap, H D , Golhwar, V J , and Thakre, S A 2012 Effect of foliar applıcatıon of mıcronutrıents on growth and flowerıng of rose under polyhouse condıtıon *Asıan J Horıtic* 7 (1) 25–27

Jamal, Z , Hamayun, M , Ahmad, N , and Chaudhary, M F 2006 Effect of soıl and foliar applıcatıon of dıfferent concentratıons of NPK and foliar applıcatıon of $(NH_4)_2SO_4$ on dıfferent parameters ın wheat *J Agron* 5 (2) 251–256

Jeyabaskaran, K J and Pandey, S D 2008 Effect of foliar spray of mıcronutrıents ın banana under hıgh soıl pH condıtıon *Indıan J Hortıc* 65 (1) 102–105

Kannan, S 1986 Foliar absorptıon and transport ınorganıc nutrıents *Plant Scı J* 341–375

Kanmyan, S and Prasad, N N 1979 Control of sheath blight of rice *Indian Phytopathol* 4 15–21

Kanujia, S P , Ahmed, N , Chattoo, M A , Jabeen, N , and Naryan, S 2006 Effect of micronutrients on growth and yield of cabbage (*Brassica oleracea* var Capitata L) *Appl Biol Res* 8 15–18

Katiyar, P , Chaturvedi, O P , and Katiyar, D 2012 Effect of foliar spray of zinc, calcium and boron on spike production of gladiolus cv Eurovision *HortFlora Res Spectrum* 1 (4) 334–338

Katkar, R N 2005 Foliar nutrition in cotton A review *Crop Res J* 29 186–188

Katyal, J C and Vlek, P L G 1985 Micronutrient problem in tropical Asia *Fertil Res* 7 69–94

Katyal, J C and Sharma, B D 1991 DTPA-extractable and total zinc, copper, manganese and iron in Indian soils and their association with soil properties *Geoderma* 49 165–179

Katyal, J C 2004 *Role of micronutrients in ensuring optimum use of macronutrients* IFA International Symposium on Micronutrients, New Delhi, India pp 3 –17

KAU (Kerala Agricultural University) 1994 A *Glimpse to Problem Soils of Kerala* Kerala Agricultural University, Thrissur, India

KAU (Kerala Agricultural University) 2011 *Package of Practices Recommendations Crops* (14th Ed), Kerala Agricultural University, Thrissur, 360p

Kavitha, M , Kumar, N , and Jeyakumar, P 2000a Effect of zinc and boron on biochemical and quality characters of papaya cv Co 5 *S Indian Hortic* 48 (1–6) 1–5

Kavitha, M , Kumar, N , and Jeyakumar, P 2000b Role of zinc and boron on fruit yield and associated characters in papaya cv Co 5 *S Indian Hortic* 48 (1–6) 6–10

Kaya, M , Atak, M , Mahmood, K K , Ciftci, C Y , and Ozcan, S 2005 Effect of pre-sowing seed treatment with zinc and foliar spray of humic acids on yield of common bean (*Phaseolus vulgaris* L) *Int J Agric Biol* 6 (7) 875–878

Kazi, S S , Ismail S , and Joshi, K G 2012 Effect of multi-micro nutrient on yield and quality attributes of the sweet orange *Afr J Agric Res* 7 (29) 4118–4123

Keinath, P A and Loria, R 1996 Manangement of common scab of potato with plant nutrients In Engelhard, W A (ed), *Management of diseases with macro-and microelements* APS press, Minneapolis, USA, pp 152–166

Khan, M B , Farooq, M , Hussain, M , Shanawaz, and Shabir, G 2010 Foliar application of micronutrients improves the wheat yield and net economic return *Int J Agric Biol* 12 (6) 953–956

Kınacı, E and Gulmezoglu, N 2007 Grain yield and yield components of triticale upon application of different foliar fertilizers *Interciencia* 32 (9) 624–628

Kızılgoz, I and Sakın, E 2010 The effects of increased phosphorus application on shoot dry matter, shoot P and Zn concentrations in wheat (*Triticum durum* L) and maize (*Zea mays* L) grown in a calcareous soil *Afr J Biotechnol* 9 (36) 5893–5896

KSPB [Kerala State Planning Board] 2013 *Fertility of Soils of Kerala* Kerala State Planning Board Thiruvananthapuram, 20p

Kulkarni, N H 2004 Effect of growth regulators and micronutrients on fruit drop, yield and quality in sweet orange (*Citrus sinensis* Osbeck) PhD Thesis, Marathwada Agricultural University, Parbhani, India

Kumar, K S 2001 Character association in banana cv Nendran (*Musa* AAB Group) *Ann Agric Res* 22 (2) 276–277

Kumar, N and Jayakumar, P 2001 Banana nutrition – A review *Plant Nutr* 92 354–355

Kumar, A R and Kumar, N 2007 Sulphate of potash foliar spray effects on yield, quality and post-harvest life of banana *Better crops* 91 (2) 22–24

Kumar, A R and Kumar, N 2008 Studies on the efficacy of sulphate of potash (SOP) on the physiological, yield and quality parameters of banana cv Robusta (Cavendish- AAA) *EurAsia J Biosci* 2 (12) 102–109

Kumar, M , Swarup, A , Patra, A K , and Chandrakala, J U 2011 Micronutrient fertilization under rising atmospheric CO_2 for micronutrient security in India *Indian J Fertil* 7 (7)· 52–60

Kumbhar, V S and Deshmukh, S S 1993 Effect of soil application of ferrous sulphate on the uptake of nutrients, yield and quality of tomato cv Rupali *S Indian Hortic* 41 (3) 144–147

Kuti, J O , Bean, G A , and Macky, W A 1989 Influence of muskmelon cell wall polysaccharides on roridin E production by a pathogenic strain of *Myrothecium roridum Mycopathologia* 108 139–144

Lake, D L , Kisk, P W W , and Lester, J N 1984 Fractionation, characterization and speciation of heavy metals in sewage sludge and sludge-amended soils A reviews *J Environ Qual* 13 175–183

Lal, K.N and Rao, M S 1954 *Micronutrient nutrition of plant* BHU, Press Varanasi, India pp 166–175

Lal, G , Sen, N L , and Jat, R G 2000 Yield and leaf nutrient composition of guava as influenced by nutrients *Indian J Hortic* 57 (2) 130–132

Lalithya, K A , Bhagya, H P , Bharathi, K., and Hipparagi, K 2014 Response of soil and foliar application of silicon and micro nutrients on leaf nutrient status of sapota *Bioscan* 9(1) 159–162

Liew, C S 1988 Foliar fertilizers from Uniroyal and their potential in Pakistan *Proceedings of Seminar on micro-nutrient in soils and crops in Pakistan* 277p

Lindsay, W L 1991 Inorganic equilibria affecting micronutrients in soil In Mortvedt, J J, Cox, F R, Shuman, L M, and Welch, R M (eds), *Micronutrients in Agriculture* (2nd Ed) SSSA, Madison, WI, pp 89–112

Lipman, C B and MacKinney, G 1931 Proof of the essential nature of copper for higher green plants *Plant Physiol* 6 593–599

Macnicol, R D and Beckett, P H T 1985 Critical Tissue Concentrations of Potentially Toxic Elements *Plant Soil* 85 107–129

Maeda, A S, Buzetti, S, and Boliani, A C 2011 Foliar fertilization on pineapple quality and yield *Pesq Agropec Trop* 41(2) 248–253

*Malakouti, M J and Tehrani, M H 1999 *Effect of micronutrients in yield increase and improvement of crops quality* Tarbiat Modarres University Press

Mandal, K.K, Bhattacharya, B, and Singh, D K 2002 Studies on the effect of foliar application of different micronutrients on growth and yield of dwarf cavendish banana (*Musa*, AAA, sub-group-cavendish, Cv Giant Governor) *J Interacademicia* 6 (2) 150–155

Mandavgade, R R, Waikar, S L, Dhamak, A L, and Patil, V D 2015 Evaluation of Micronutrient status of soils and their relation with some chemical properties of soils of Northern Tahsils (Jintur, Selu and Pathri) of Parbhani District *J Agric Vet Sci* 8 (2) 38–41

Manimaran, S, Kalyanasundaram, D, Sudhakar, P, Sivakumar, K, and Venkatakrishnan, D 2009 Biofertilizer (acetobacter) and micronutrient mixture influence on ratoon sugarcane yield *Indian Sugar* 59 (5) 35–38

Marschner, H 1995 *Mineral Nutrition of Higher Plants* Academic Press, San Diego, 889p

Massoumi, A and Comfiled, A H 1963 A rapid method for determination of sulphate in water extracts of soil *Aust J Agric Res* 88 321–322

Mchargue, J S 1922 Role of manganese in plants *J Amer Chem Soc* 44 1592–1598

McMillan, R T , Graves, W , and McLaughlin, H J 2000 Keyplex effect on Sigatoka of banana *Proc Florida State Hort Soc* 112 192–193

Meena, V S , Yadav, P K , and Bhati, B S 2006 Effect of ferrous sulphate and borax on fruit quality of ber *Prog Hortic* 38 (2) 283–285

Mini, V 2015 Assessment and management of micronutrient deficiencies in onatttukara. Ph D thesis, Kerala Agricultural University, Thrissur, 267p

Mishra, B K , Sahoo, C R , and Bhol, R 2012 Effect of foliar application of micronutrients on growth, yield and quality of tomato cv Utkal Urbasi *Environ Ecol* 30 (3) 856–859

Modaihsh, A S 1997 Foliar application of chelated and non-chelated metals for supplying micronutrients to wheat grown on calcareous soils *Expt Agric* 33 237–245

Modi, P K , Varma, L R , Bhalerao, P P , Verma, P , and Khade, A 2012 Micronutrient Spray Effects on Growth, Yield and Quality of Papaya (*Carica papaya* L) cv Madhu Bindu *Madras Agric J* 99 (7–9) 500–502

Mona, E , Eleiwa, Ibrahim, S A , and Mohamed, F 2012 Combined effect of NPK levels and foliar nutritional compounds on growth and yield parameters of potato plants (*Solanum tuberosum* L) *Afr J Micro Res* 6 (24) 5100–5109

Moosavi, A A and Ronaghi, A 2011 Influence of foliar and soil applications of iron and manganese on soybean dry matter yield and iron-manganese relationship in a Calcareous soil *Asian J Crop Sci* 5 (12) 1550–1556

Mori, S 1999 Iron Acquisition by Plants *Curr Opin Plant Biol* 2 250–253

Mortvedt, J J 2000 Bioavailability of micronutrients In Sumner, M E (ed), *Hank book of Soil Science* pp 71-88 CRC Press, Boca Raton, Florida

Mulagund, J , Porika, H , Soorianathasundaram, K , and Deepika, C 2015 Influence of Growth Regulators Combined with Chemicals to Improve Post-harvest Fruit Quality in Banana cv Nendran (*Musa* AAB) *J Food Processing Technol* 6 (3) 1–8

Mulligan, C N , Yong, R N , and Gibbs, B F 2001 Remediation technologies for metal-contaminated soils groundwater An evaluation *Eng Geol* 60 193–207

Murray, D B 1962 Shade and fertilizer relations in the banana *Trop Agric* 38 123–132

*Muthaia, L and Raja, E 2009 Balanced nutrition for preventive management of disease in banana in limited resource situation *Proceedings of the International Plan Nutrition Colloquium XVI UC Davis*

Muthukrishnan, R and Velu, V 2011 Formulations of micronutrient mixture on

yield and quality of sugarcane *Madras Agric J* 98 (10–12) 350–355

Muthukrishnan, R , Velu, V , and Padmavathi, T 2014 Changes in leaf macronutrient concentration under different micronutrient fertilization practices in sugarcane *Int J Farm Sci* 4 (4) 15–25

Namdeo, K N 1992 Foliar Nutrition in Cotton - A Review *Crop Res* 5 451–455

Naruka, I S , Gujar, K D , and Lal, G 2000 Effect of foliar application of zinc and molybdenum on growth and yield of okra (*Abelmoschus esculentus* L Moench) cv Pusa sawani *Haryana J Horitic Sci* 29 (3/4) 266–267

Nasiri, Y , Zehtabe-Salmasi, S , Nasrollahzade, S , Najafi, N , and Ghassemi-Golezani, K 2010 Effect of foliar application of micronutrient (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomila* L) *J Med Plants Res* 4 (17) 1733–1737

Navrot, J and Levin, I 1976 Effect of micronutrients on pepper (*Capsicum annuum*) grown in peat soil under greenhouse and field conditions *Exp Agric* 12 (2) 129–133

Nehete, D S , Padhiar, B V , Shah, N I , Bhalerao, P P , Kolambe, B N , and Bhalerao, R R 2011 Influence of micronutrient spray on flowering, yield, quality and nutrient content in leaf of mango cv Kesar *Asian J Horitic* 6 (1) 63–67

Ningavva, B V , Kulapati, H , Paramappa, M K., and Nadukeri, S 2014 Effect of soil application and foliar spray of zinc and boron on quality of ratoon banana cv Grand Naine under hill zone of Karnataka *Trends Biosci* 7 (20) 3294– 3296

Nomura, E S , Teixeira, L A J , Boaretto, R M , Garcia, V A , Fuzitani, E J , Damatto, J E R , Saes, L A , and Mattos, J D 2011 Boron application in banana plant *Revista Brasileira de Fruticultura* 33 (2). 608–617

Pal, R K , Behera, T K., Sen, T , and Singh, M 2004 Response of bell pepper (*Capsicum annuum* L) cultivars to foliar application of magnesium, boron and zinc *Veg Sci* 31 (1) 40–44

Panwar, R and Singh, C P 2007 Effect of preharvest foliar spray of micronutrients on chemical properties of mango fruit cv Langra *Pantnagar J Res* 5 (1) 56– 61

Patel, B M and Patel, H C 1985 Effect of foliar application of zinc and iron on chlorophyll and micronutrient contents of acidlime (*Citrus aurantifolia* Swingle) *S Indian Hortic* 33 (1) 50–52

*Patel, P C 2006 Effect of foliar application of iron and sulphur in alleviation of iron chlorosis in acid lime (*Citrus aurantifolia*, Swingle) 18th World congress of soil science, Philladelphia, Pennsylvania, USA

Patel, K P , Patel, A K , Patel, A M , Patel, K C , and Patel, V P 2008 Effect of multi-micronutrient mixture on yield and uptake of micronutrients by Wheat (*Triticum aestivum* L) growth on sandy loam soils of North Gujrat. *Asian J Soil Sci* 3 (1) 84–87

Patel, K C , Patel, K P , Ramani, V P , and George, V 2009 Effect of multi-micronutrient mixture on yield of okra (*Abelmoschus esculentus* L) grown on *goradu* soils of kheda district *Veg Sci* 36 (3) 393–394

Patel, A R , Saravaiya, S N , Patel, A N , Desai, K D , Patel, N M , and Patel, K D 2010 Effect of micronutrients on yield and fruit quality of banana (*Musa paradisica* L) cv Basrai under pair row planting method *Asian J Hortic* 5 (1) 245–248

Pathak, P K and Mitra, S K. 2008 Effect of phosphours, potassium, sulphur and boron on litchi *Indian J Hortic* 65 (2) 137–140

Pathak, N L , Bauri, F K , Misra, D K , Bandyopadhyay, B , and Chaigiaborty, K 2011 Application of micronutrients on growth, yield and quality of banana *J Crop Weed* 7 (1) 52–54

Patil, J 1981 Cultural practices and infectious crop diseases *Adv Ser Agric sci* 9 73–189

Patil, M N and Hiwarale, J S 2004 Growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle) as influenced by neem cake and fertilizer *PKV Res J* 28 (1) 50–51

Patricia, M , Rodriguez-Lucena, Hernandez-Apaolaza, L , and Lucena, J J 2010 Comparison of iron chelates and complexes supplied as foliar sprays and in nutrient solution to correct iron chlorosis of soybean *J Plant Nutr Soil Sci* 173 120–126

Paul, A A and Nair, C S J 2015 Effect of foliar application of nutrients on quality characters of banana (*Musa* AAB) Nendran *Int J Appl Pure Sci Agric* 101–104

Pertin, N and Das, R P 1998 Effect of micronutrients on vegetative growth of banana cv Barjahaji (*Musa* AAA group, Cavendish sub group) *J Agric Sci Soc N E India* 9 (2) 166–168

Piper, 1966 Aging of crystalline precipitates *Analyst* 77 1000–1011

Potarzycki, J and Grzebisz, W 2009 Effect of zinc foliar application on grain yield of maize and its yielding components *Plant Soil Environ* 55 (12) 519–527

Prabha, K and Singaram, P 1996 Effect of boron on the content and uptake of nutrient in tomato *Madras Agric J* 83 745–746

Prabu, P C and Singaram, P 2001 Effect of foliar and soil application of zinc and boron on yield and quality of grapes cv Muscat *Madras Agric J* 88 (7–9) 505–507

Prasad, R, Kumar, D, Shivay, Y S, and Rana, D S 2014 Boron in Indian agriculture – A review *Indian J Agron* 59 (4) 511–517

Pratt, P F 1965 Potassium In Black, C A (ed), *Methods of soil analysis* American society of Agronomy, Madison, USA, pp· 1019–1021

Rajendran, P and Aiyer, R S 1981 A comparative study of the efficacy of the different extrants for zinc and manganese in relation to plant availability *Madras Agric J* 68 546–553

Ram, R A and Bose, T K 2000 Effect of foliar application of magnesium and micronutrients on growth, yield and fruit quality of mandarin orange *Indian J Hortic* 57 (3) 215–220

Ranganna, S 1986 Manual of Analysis of Fruits and Vegetable Products Tata McGraw Hill Publishing Company Ltd , New Delhi, 1112p

Rani, R and Brahmachari, V S 2001 Effect of foliar application of calcium, zinc and boron and cracking and physico-chemical composition of litchi *Orissa J Hortic* 29 (1) 50–57

Rattan, R K and Sharma, P D 2004 Main micronutrients available and their method of use *Proceedings IFA International Symposium on Micronutrients* 1–10

Ray, T I , Dutta, P , Saha, S , and Roy, S C 2006 Genetic stability of three economically important micropropagated banana (*Musa spp*) cultivars of lower Indo-Gangetic plains, asassessed by RAPD and ISSR markers *Plant Cell Tissue Organ Cult* 85 11–21

Reddy, Y T and Reddi, S G H 2002 *Principles of Agronomy* Kalyani Publishers, Ludhiana pp 204–206

Reuveni, M , Agapov, V , and Reuveni, R 1997 A foliar spray of micronutrient solutions induces local and systemic protection against powdery mildew (*Sphaerotheca fuliginia*) in cucumber plants *Eur J Plant Pathol* 103 581–588

Reuveni, M , Oppenheim, D , and Reuveni, R 1998 Integrated control of powdery mildew on apple trees by foliar sprays of mono-potassium phosphate fertilizer and sterol inhibiting fungicides *Crop Prot* 17 563–568

Robinson, G W 1922 A new method for the mechanical analysis of soils and other dispersions *J Agric Sci* 12 306–321

Robinson, J C , Eraser, C , and Eckstein, K 1993 A field comparison of conventional suckers with tissue culture banana planting material over three crop cycles *J Hortic Sci* 68 831–836

Robinson, J C 1996 *Bananas and plantains* Institute for tropical and subtropical crops Nelspruit, South Africa 15pp

Roemheld, V and El-Fouly, M M 1999 Foliar nutrient application Challenge and limits in crop production *Proceedings of the 2nd International Workshop on Foliar Fertilization,* Bangkok, Thailand, 4-10 April 1999.

Romheld, V and Marschner, H 1986 Mobilization of iron in the rhizosphere of different plant species *Adv Plant Nutr* 2 155–204

Sanjeev, K.K and Eswaran, A 2008 Efficacy of micro nutrients on *Banana fusarium* wilt (*Fusarium oxysporum* f sp *cubense*) and it's synergistic action with *Trichoderma viride Not Bot Hort Agrobot Cluj* 36 (1) 52–54

Sankar, C , Saraladevi, D , and Parthiban, S 2013 Effect of foliar application of micronutrients and sorbitol on fruit quality and leaf nutrient status of mango cv Alphonso *Asian J Hortic* 8 (2) 714–719

Saran, P L and Kumar, R 2011 Boron deficiency disorders in mango (Mangifera indica) field screening, nutrient composition and amelioration by boron application *Indian J Agric Sci* 81 (6) 506–510

Sarkar, G K , Singh, M M , Misra, R S , and Srivastava, R P 1984 Effect of foliar application of mineral elements on cracking of litchi fruits *Haryana J Hortic Sci* 13 (1–2) 18–21

Sarkar, D , Mandal, B , and Kundu, M C 2007 Increasing use efficiency of boron fertilisers by rescheduling the time and methods of application for crops in India *Plant Soil* 301 77–85

Sathya, S , Pitchai, G J , and Indirani, R 2009 Boron nutrition of crops in relation to yield and quality–a review *Agric Rev* 30 (2) 139–44

Satpute, N R , Suryawanshi, L B , Waghmare, J M , and Jagtap, P B 2013 Response of summer okra (cv Phule Utkarsha) to iron, zinc and boron in inceptisol *Asian J Hortic* 8 (1) 541–546

Saxena, M 2015 *Indian Horticultural Database- 2014* National Horticulutre Board, Ministry of Agriculture, Gurgaon Available http // nhb gov in / area-pro/ NHB_Database_2015 pdf [14 April 2015]

Selvi, D and Thiageshwari, S 2002 Effect of integrated nutrient management on yield of brinjal and bhendi in a mixed black soil (Vertic ustropept) *Madras Agric J* 89 (7–9) 378–382

Senthamizhselvi, B 2000 Studies on the flowering and productivity of Gundumalli (*Jasminum sambac*) as influenced by nutrient management techniques M Sc (Hortic.) dissertation, Tamil Nadu Agricultural University, Coimbatore, India 97p

Sharma, D D 1976 Varietal differences in physic-chemical characteristics of the banana fruits *Indian Agric* 20 (2) 115–119

Sheela, V L and Nair, S R 2001 Growth, flowering and yield potential of tissue culture banana *(Musa* AAB cv Nendran) *J Trop Agric* 39 1–4

Shitole, S M and Dhumal, K N 2012 Influence of foliar applications of micronutrients on photosynthetic pigments and organic constituents of medicinal plant *Cassia angustifolia An Bio Res* 3 (1) 520–526

Shueadshen, A K H 1991 Foliar application of trace elements to rice *Khimizatsya-Sel s Kogo- Khozaistva* 3 46–50

Shukla, A K, Dwivedi, B S, Singh, V K, and Gill, M S 2009 Macro Role of Micronutrients *Indian J Fertil* 5 (5) 11–12, 15–18, 21–24 & 27–30

Shukla, A K and Behera, S K. 2011 Zinc management in Indian Agriculture-Past, present and future *Indian J Fertil* 7 (10) 14–33

Shukla, A K and Behera, S K 2012 Micronutrient fertilizers and higher productivity *Indian J Fertil* 8 (4) 100–117

Shukla, A K, Behera, S K, Shivay, Y S, Singh, P, and Singh, A K 2012 Micronutrients and field crop production in India A review *Indian J Agron* 57 (3) 123–130

Shukla, A K, Pankaj, K, Tiwari, P K, and Prakash, C 2014 Micronutrients Deficiencies vis-a-vis Food and Nutritional Security of India *Indian J Fertil* 10 (12) 94–112

Silberbush, M 2002 Simulation of ion uptake from the soil In Waisel, Y, Eshel, A, and Kafkafi, U (eds), *Plant Roots The Hidden Half* (3rd Ed) Marcel, Dekker New York, 651–661

Simmonds, N W 1966 Planting and management In *Bananas* (2nd Ed) Longman Group Limited, London and New York pp 156–204

Simoglou, K and Dordas, C 2006 Effect of foliar applied boron, manganese and zinc on tan spot in winter durum wheat *Crop Prot* 25 657–663

Sims, J T and Ellis, B G 1983 Adsorption and availability of phosphorus following the application of limestone to an acid, aluminous soil *J Soil Sci Am* 47 888–893

Sims, J R and Johnson, G V 1991 Micronutrient soil tests In Mortvedt, J J (ed), *Micronutrients in Agriculture* (2nd ed) SSSA Book series 4, *Soil Sci Soc Am* Madison, WI, USA pp 427–476

Singaram, P and Prabu, P C 2001 Effect of zinc and boron on growth and quality of grapes cv Muscat *Madras Agric J* 88 (4–6) 233–236

Singh, R R and Rajput, C B S 1976 Effect of various concentrations of zinc on vegetative growth characters, flowering, fruiting and physicochemical composition of fruits in mango cv Chausa, *Haryana J Hortic Sci* 5 (1–2) 10–14

Singh, S S and Maurya, A N 1979 A note on the effect of Zn application on the growth, yield and quality of okra (*Abelmoschus esculentum* L) *Haryana J Hortic Sci* 5 (3–4) 258–259

Singh, P N and Chonkar, V S 1983 Effect of zinc, boron and molybdenum as foliar spray on chemical composition on Guava fruit *Punjab Hortic J* 23 34–37

Singh, M V 1991 *Proceedings of workshop on rice–wheat cropping system Modipuram* Project Directorate Cropping System Research pp 133–144

Singh, M V 1999 Experiences of AICRP on micro and secondary nutrients and pollutant elements in soils and plants *Fertil News* 44 (4) 63–82

Singh, K P and Kalloo, G 2000 Integrated nutrient management (INM) approach for brinjal (*Solanum melongena* L) and other solanaceous vegetables – A review *Fertil News* 45 77–81

Singh, M V 2001 Evaluation of micronutrient status in different agro ecological zones of India *Fertil News* 46 (2) 25–42

Singh, M V 2003 Issues and challenges in promoting safe use of micronutrients in agriculture during new millennium Interface on micronutrients, MCEAR, and pune

Singh, D B , Sharma, B D , and Bhargava, R 2003 Effect of boron and GA3 to control fruit cracking in pomegranate (*Punica granatum*) *Curr Agric* 27 (1–2) 125–127

Singh, M V 2006 *Micro and secondary nutrients and pollutant elements research in India* Progress report, IISS, Bhopal, pp 1–110

Singh, H P 2007 National and International Scenario of Banana and Plantain In Singh, H P and Uma, S (eds), *Banana Technological Advancements* pp 1–19

Singh, M V 2007 Efficiency of seed treatment for ameliorating zinc deficiency in crops *Proceeding of Zinc Crop Conference, Istanbul Turkey*

Singh, M V 2009 Micronutrient nutritional problems in soils of India and improvement for human and animals *Indian J Fertil* 5 (4) 11–16, 19–26 & 56

Singh, M V 2012 *Spread of micro-nutrient deficiencies specially boron in India and response of field crops* "Brain storming workshop on soil test based nutrients including boron and other micro nutrients" Organized by ICRISAT – Agriculture Directorate, Karnataka -Rio Tinto India at Bangaluru, India

Sivaiah, N K , Swain, S K , Raju, B , and Varma, S V 2013 Influence of micronutrients application on growth and seed quality in tomato (*Lycopersicon esculentum* MILL) *Int J Dev Res* 3 (11) 191–195

Soltanpour, P N and Schwab, A P 1977 A new soil test for simultaneous extraction of macro and micro-nutrients in alkaline soils *Comm Soil Sci Plant Anal* 8 195–207

Sommer, A L and Lipman, C B 1926 Evidence on the indispensable nature of zinc and boron for higher green plants *Plant Physiol* 12 (3) 231–249

Spiden 1926 *Bananas by Simmonds* (2nd Ed) Longman Group Ltd , London 429p

Srinivasan, K , Vadiraj, B A , Krishnakumar, V , and Naidu, R 1993 Micronutrients status of cardamom growing soils *J Plant Crops* 21(sup) 67–74

Srivatava, R P 1964a Effect of micronutrient on growth characteristics of banana I-Copper. *Fertil News* 9 (2) 13–26

Srivatava, R P 1964b Effect of micronutrient on growth characteristics of banana II-Zinc *Fertil News* 9 (6) 26–32

Srivastava, A K and Singh 2003 *Citrus nutrition* International books distributing Co , Lucknow 11–17

SSO [Soil Survey Organization] 2007 *Benchmark Soils of Kerala* Agriculture (SC Unit) Department, Govt of Kerala, Thiruvananthapuram, 623p

Stevenson, F J 1986 *Cycles of soil carbon, nitrogen, phosphorus, sulfur and micronutrients* Wiley, New York 448p

Sturgul, S J 2010 Soil Micronutrients From Boron to Zinc *Proceeding of the 2010 Wisconsin Crop Management Conference* pp 49

Suar, 1952 *Bananas by Simmonds* (2nd Ed) Longman Group Ltd , London

Subbaiah, B V and Asija, G L A 1956 A rapid procedure for the estimation of available nitrogen in soil *Curr Sci* 32 325–327

Subramanian, V and Pillai, A A 1997 Studies on the zinc deficiency in banana growing soils of Tamil Nadu *Indian J Agric Res* 31 (3) 105–188

Supriya, L and Bhattacharyya, R K 1993 Effect of foliar application of chelated and non-chelated zinc on growth and yield of Assam lemon *Hortic J* 6 (1) 35–38

Suresh, S and Savithri, P 2001 Yield and quality of wetland banana as influenced by liming and nutrients application in an acid soil *Haryana J Hortic Sci* 30 (122) 12–13

Suresh, P R , Govindan, M , Gladis, R , and Joseph, B 2014 *Soil Fertility status of Kasargod district* College of Agriculture, Padannakad 32p

Suryanarayana, V and Rao, S K V 1981 Effect of growth regulators and nutrient sprays on the yield of okra *Veg Sci* 8 12–14

Suzuki, M , Takahashi, M , Tsukamoto, T , Watanabe, S , Matsuhashi, S , Yazaki, J , Kishimoto, N , Kikuchi, S , Nakanishi, H Mori, S , and Nishizawa, N K 2006 Biosynthesis and secretion of mugineic acid family phytosiderophores in zinc-deficient barley *Plant J* 48 85–97

Takkar, P N , Chibba, I M , and Mehta, S 1989 Twenty years of coordinated research on micronutrients in soils and plants, IISS, Bhopal

Tandon, L S 1989 *Secondary and Micronutrients for soil and crops A guide book* Fertilizer Development and Consultation Organisation, c-110, Greater Kailash-1, New Delhi

Thampatti, K C M , Cherian, S , and Iyer, M S 2005 Managing iron toxicity in acid sulphate soils by integrating genetic tolerance and nutrition *Int Rice Res Notes* 30 37–39

Thiyageshwari, S and Ramanathan, G 2001 Uptake of nutrients as influenced by application of micronutrients and cytozyme to soybean in inceptisol *J Soil Crops* 11 1–6

Thomas, P , Dalal, V B , Pushpa, M C , and Amala, B L 1968a Harvesting, handling, marketing and transporting of banana form export from India *Fd Pckr* 22 (4) 1–6

Thomas, P , Dalal, V B , Pushpa, M C , and Amala, B L 1968b Harvesting, handling, marketing and transporting of banana form export from India *Fd Pckr* 22 16–21

Tisdale, S L , Nelson, W L , and Beaton, J D 1985 *Soil Fertility and Fertilizers* (4th Ed) Mc Millan, New York 754p

Torun, A , Itekin, I G A , Kalayci, M , Yilmaz, A , Eker, S , and Cakmak, I 2001 Effects of zinc fertilization on grain yield and shoot concentrations of zinc, boron and phosphorus of 25 wheat cultivars grown on a zinc-deficient and boron-toxic soil *J Plant Nutr* 2 1817–1829

*Truog 1940 *Soil chemical analysis* Prentice Hall of India Pvt Ltd , New Delhi 230p

Turner, D W and Barkus, B 1983 Long-term nutrient absorption rates and competition between ions in banana in relation to supply of K, Mg and Mn *Fertil Res* 4 127–134

Udode-Haes, H A , Voortman, R L , Bastein, T , Bussink, D W , Rougoor, C W , and Weijden, V W J 2012 Scarcity of Micronutrients in Soil, Feed, Food, and Mineral Reserves - Urgency and Policy Options *Platform Agric Innovation Soc* 2 546–554

Vasane, S R and Kotharı, R M 2006 Optımızatıon of secondary hardenıng process of banana plantlcts (*Musa paradısıaca* L var Grand Name) *Indıan J Bıotechnol* 5 394–399

Vasane, S R and Kotharı, R M 2008 An ıntcgrated approach to prımary and secondary hardenıng of banana var Grand Naınc *Indıan J Bıotechnol* 7 240–245

Veena, P and Lavanıa, M L 1998 Effect of foliar sprays of ıron, zınc and boron on growth and yıeld of papaya *S Indıan Hortıc* 46 (1–2) 1–5

Venugopal, V 2008 Effect of plantıng pattern and ıntercrops on qualıty attrıbutes of banana varıety Nendran *Green farmıng* 1 (6) 29–31

Walkley, A J and Black, I A 1934 Estımatıon of soıl organıc carbon by chromıc acıd and tıtratıon method *Soil Scı* 31 21–38

Wallıhan, E F , Embleton, T W , and Prınty, W 1958 Zınc deficıency m avocado *Calıf Agrıc* 12 (6) 4–5

Warrıngton, K 1923 The effect of borıc acıd and borax on the board bean and certaın other plants *Ann Bot* 37 (4) 629–672

Wıley-VCH and Wıley-VCH, L 2007 *Ullmann's Agrochemıcals lıquıd fertılızers* pp 36

Yadav, B D , Khandelwal R B , and Sharma, Y K 2009a Response of cabbage to foliar applıcatıon of mıcronutrıents *Veg Scı* 36 (1) 47–50

Yadav, M K , Patel, N L , and Hazarika, A 2009b Response to micronutrients on nutritional status in leaf of banana (*Musa paradisiaca* L) Grand Naine *Asian J Soil Sci* 4 (1) 1–3

Yadav, M K , Patel, N L , Parmar, B R , Kirtibardhan, P , and Singh, P 2010 Effect of micronutrients on growth, yield and quality of banana (*Musa paradisiaca* L) cv Grand Naine *Int J Agric Med Plant Res* 1 (1) 1–7

Yadav, M K , Patel, N L , Hazarika, A , and Parmveer, S 2011 Fruit quality and shelf life of Banana cv Grand Naine influenced by chelated and nonchelated micronutrient *Andhara Agric J* 58 (3) 352–354

Yadav, M K and Patel, N L 2013 Economics of Grand Naine banana influenced by Micronutrients *Int J Agric and Med Plants Res* 1 (2) 10–15

Yadlod, S S and Kadam, B A 2008a Effect of plant growth regulators and micronutrients on physical and chemical characters of banana *(Musa* sp) cv Grand Naine *Asian J Hortic* 3 (2) 436–438

Yadlod, S S and Kadam, B A 2008b Effect of plant growth regulators and micronutrients on growth, yield and storage life of banana *(Musa* sp) cv Shrimanti *Asian J Hortic* 3 (2) 409–411

Yadlod, S S and Kadam, B A 2008c Efect of plant growth regulators and micronutrients on growth, yield, and storage life of banana (*Musa* sp) cv Ardhapuri *Agric Sci Digest* 28 (4) 304 – 306

Yousefi, M and Zandı, P 2012 Effect of foliar application of zinc and manganese on yield of pumpkin (*Cucurbita pepo* L) under two irrigation patterns *Electr J Polish Agric Univ* 15 (4) 2–6

* original not seen

FORMULATION AND EVALUATION OF MICRONUTRIENT MIXTURE FOR FOLIAR APPLICATION IN TC BANANA (*Musa* sp.) var. NENDRAN

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ABSTRACT

The experiment entitled "Formulation and evaluation of micronutrient mixture for foliar application in TC banana (*Musa* sp) var Nendran" was carried out with the objectives of preparing a micronutrient mixture formulation for foliar spray, to evaluate stability of formulation and its keeping quality and to investigate the effect of this formulation on growth, yield and quality of fruits in banana (*Musa* sp) Nendran The whole study consisted of three parts – preparation of micronutrient mixture formulation, hardening studies and field experiment The studies were carried out at College of Agriculture, Padannakkad and RARS farm, Nileshwar during 2014–2016

Micronutrient mixture formulation was prepared with the use of different micronutrient salts containing Zn, B, Fe, Mn, Cu and Mo The formulation technique was standardized and it was prepared as two liquids Solution A and Solution B Solution–A consisted of $ZnSO_4$, $CuSO_4$, $FeSO_4$, H_3BO_3, $MnSO_4$ and $(NH_4)_2MoO_4$ in desired proportion For maintaining stability and keeping quality of solution A, addition of citric acid was found to be the best Solution B was prepared as 1 per cent humic acid Required quantity of solution A and B was diluted and blended just before spraying

The hardening studies were conducted in the poly house with TC plants of uniform stage multiplied from same genotype The experiment was carried out in CRD with 12 treatments and one control with 3 replications each and there were 4 plants in each unit The treatments consisted of 4 levels of micronutrient mixture (0 25 %, 0 5 %, 0 75 % and 1 %) sprayed at 3 different intervals The 3 different spray scheduled were one spray- immediately after planting and 2 subsequent sprays given at 2nd and 3rd weeks after planting during secondary hardening stage Thus there were 12 treatment combinations and one control The treatments were T_1, T_2, T_3 and T_4 - one spray, T_5, T_6, T_7 and T_8 - two sprays and T_9, T_{10}, T_{11} and T_{12} - three sprays of 0 25, 0 5, 0 75 and 1 per cent concentrations respectively T_{13} was control

Significant differences among the treatments were observed in the biometric characters of the plants Plant height (20 2 cm) was found to be highest in T_{10} (0 5% as 3 sprays) Highest number of leaves (6 8) and leaf breadth (7 3 cm) was recorded in T_9 (0 25% as 3 sprays) and T_5 recorded highest leaf length (19 6 cm)

The field experiment was carried out at RARS farm, Nileshwar in RBD with 12 treatments and one control with 3 replications each and there were 4 plants in each unit Major nutrients *viz* N, P, K and other cultural practices were uniformly followed for all plants as per PoP, KAU (2011) The treatments consisted of 4 levels of micronutrient mixture (1 %, 2 %, 3 % and 4 %) sprayed at 3 different intervals The 3 different spray scheduled were one spray was given at 2 MAP, two sprays at 2 and 4 MAP and three sprays at 2, 4 and 6 MAP T_1, T_2, T_3 and T_4 - one spray, T_5, T_6, T_7 and T_8 - two sprays and T_9, T_{10}, T_{11} and T_{12} - three sprays of 1, 2, 3 and 4 per cent concentration respectively and T_{13} was control

The results of the field experiment showed that treatment application significantly enhanced the vegetative characters like pseudostem height, pseudostem girth and number of leaves Among the yield characteristics, bunch weight, number of fingers, average weight of fingers, finger length and days to harvest showed significant difference Bunch weight was found to be highest in T_{11} (12 8 kg) with 53 4 % increase in yield over control (8 3 kg) The highest number of fingers was found in T_9 while highest average weight of fingers, finger length was found in T_{11} Minimum days from plantmg to bunch emergence (186 days) was noticed in T_{10} whereas T_{11} took minimum days from planting to harvest (271 days) as well as minimum bunch maturity period of 82 days

Characteristics of fruits like titrable acidity, TSS, pulp to peel ratio, total sugars, reducing sugars, non-reducing sugar content, sugar / acid ratio, TSS / acid ratio, per cent loss in weight during ripening and keeping quality of the fruits at ambient conditions were also found to be influenced by treatments

After harvest, the effect of these treatments on soil nutrient availability was studied The results showed that soil organic carbon status and available nutrient status of N, P, K, Mg, Zn, B, Fe, B and Mo were found to be significant Similarly, leaf nutrient analysis at bunching and at the time of harvest revealed that P, K, Ca, Mg, S, Zn, B, Fe, Mn, Mo and Cu content at one or both stages of observation showed significant difference among the treatments

The results of both the hardening studies and field experiment indicated the beneficial effect of micronutrient mixture on TC banana For hardening studies T_9 - 0 25 per cent and T_{10} - 0 5 per cent given as 3 sprays were noticed better On mature plants T_{10} - 2 per cent and T_{11}- 3 per cent both as 3 sprays were found promising Yield increase was noticed as 53 4 per cent over control with an enhancement of 4 4 kg in bunch weight The benefit cost ratio calculated on projection to one ha is 2 3 with net returns of Rs 6, 94, 964 ha^{-1} in T_{11} (3 % micronutrient mixture as 3 sprays) The quantity of spray solution required for best treatment T_{11} on projection to one ha is 56 litres, with an additional cost of Rs 160 / litre for the mixture plus Rs 600 / day as cost of labour for application