FOLIAR NUTRITION IN *NENDRAN* BANANA USING MULTINUTRIENT WATER SOLUBLE FERTILIZERS

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"FOLIAR NUTRITION IN *NENDRAN* BANANA USING MULTINUTRIENT WATER SOLUBLE FERTILIZERS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

B : C	Benefit Cost ratio
CD	Critical Difference
cm	centimetre
cv	cultivar
D hand^{-1}	per D hand
Fig.	Figure
FYM	Farmyard manure
g	gram
ha	hectare
KAU	Kerala Agricultural University
kg ha^{-1}	kilogram per hectare
L	Litre
LAI	Leaf Area Index
m^2	square metre
MAP	Months After Planting
MOP	Muriate of Potash
NS	Non Significant
NUE	Nutrient Use Efficiency
POP	Package of Practices
plant^{-1}	per plant
Rs ha^{-1}	Rupees per hectare
RDF	Recommended Dose of Fertilizers
RDN	Recommended Dose of Nutrients
SEm	Standard Error of mean
SOP	Sulphate of Potash
t ha^{-1}	tonnes per hectare
TSS	Total Soluble Solids

LIST OF SYMBOLS

@	at the rate of
$^{0}B_{x}$	Degree Brix
^{o}C	Degree Celsius
₹	Rupees
%	per cent

INTRODUCTION

1. INTRODUCTION

Banana regarded as "Apple of Paradise" is one of the major commercial fruit crops grown in the tropics. The crop is popular globally for its nutritional significance as well as economic importance to small and marginal farmers especially those of developing countries. Being excellent sources of vitamins, minerals and dietary fibres, bananas are essential ingredients of a healthy diet. In India, banana is the second important fruit crop next to mango. India is the leading producer of banana in the world and contributes to more than 20 per cent of global production. India produces banana to the tune of 29.73 million tonnes from an area of 0.803 million hectare with an average productivity of 37 t ha^{-1} (NHB, 2015). In Kerala, banana is cultivated in an area of 0.6 lakh ha with a production of 5.36 lakh tons (FIB, 2018). *Nendran* banana belonging to *Musa* AAB group is the most sought after banana variety in Kerala, both for domestic and export markets due to its peculiar taste, nutritive value and varied options for value addition.

Banana is a heavy feeder and requires large amounts of nitrogen and potassium followed by phosphorus (Abdullah *et al.*1999). Being an exhaustive crop, proper scheduling of plant nutrition is especially important for banana in realising potential yield and good quality. As per the Package of Practices of Kerala Agricultural University (KAU, 2016), six top dressings of N and K fertilizers are recommended for *Nendran* banana apart from addition of organics and P fertilizer at initial stages. However, the fertilizers are costly, energy intensive and their continuous use can lead to soil ill health. Hence any measure to bring down the fertilizer levels by means of increasing the NUE of applied fertilizer inputs is always appreciated.

Foliar nutrition, the application of fertilizer material to plant foliage is considered far efficient than the practice of soil application of fertilizers and is gaining importance as an efficient way of supplementing nutrients. Fertilizers when applied to soil suffer various types of losses including leaching, fixation, volatilization etc. and hence may not provide the required nutrient supply.

Because of these reasons, often higher quantities of fertilizers are applied to soil and this eventually leads to environmental pollution. On the other hand, foliar nutrition makes use of fewer quantities of fertilizers only. In this regard, the practice is recognised as an environment friendly agro technique.

Nutrition through foliage facilitates easy absorption and rapid utilisation of nutrients (Swietlik and Faust, 1984, Oosterhuis, 2009). Of late, many types of multinutrient water soluble fertilizers are available in market, suited for foliar application. Malhotra (2016) reported that water soluble multinutrient fertilizers like 19:19:19 when applied as foliar spray could augment the yield of fruit trees and vegetables crops in a positive manner. The use of water soluble fertilizers is fast spreading in many states of India (Chander, 2014). Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala and Gujarat are the major consumers and together account for 75 per cent of the total consumption of these fertilizers.

Micronutrients have a specific role in the growth and yield of crops besides influencing the quality of produce. Micronutrients like boron, copper, iron, manganese, zinc etc are activators of major plant functions and are hence integral part of a well balanced nutrient management strategy. Trials show that plant growth, productive leaf area and consequently yield suffer under conditions of insufficient supply of micronutrients. Reports on wide spread deficiencies of micronutrients in Kerala soils as documented by Kerala State Planning Board (2013) necessitates the supply of required quantity of micronutrients so as to realise full production potential of crops. Several micronutrient formulations suited for foliar spray are available for different crops. Indian Institute of Horticultural Research, Bangalore and National Research Centre for Banana, Trichi have come out with micronutrient formulations for foliar spray named "Banana Special" and "Banana Shakthi" respectively. Paul and Nair (2015) reported improvement in quality characters of *Nendran* banana cultivated in Kerala with foliar application of Banana Special in addition to soil application of fertilizers. The micronutrient fertilizer mixture for banana developed at Kerala Agricultural University (KAU Banana micromix), suited for the Southern region

of Kerala is useful both for soil and foliar application. Mathew (2014) recorded higher yield in *Nendran* banana with the use of this nutrient formulation.

However, research works for standardising a balanced nutrient schedule by means of integrating soil and foliar nutrition is found lacking in banana. Hence, the present study on conjunctive use of soil and foliar nutrition was formulated. The specific objective of the study was

- To assess the feasibility of foliar nutrition in reducing the fertilizer dose of *Nendran* banana and to study its impact on the growth, yield and quality and economics.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Banana is a heavy feeder and requires nutrient addition in a scientific manner for expressing full yield potential. In integrated nutrient management of banana, foliar application of nutrients is becoming an inevitable component. Water soluble fertilizers supplying major and micro nutrients are commonly available these days. Foliar nutrition supplements soil addition of fertilizers and is highly beneficial in improving crop growth, yield, quality, uptake of nutrients and economics as reported by several scientists and are reviewed in this chapter. Reviews on banana are mostly included and wherever literature was found insufficient, reviews on related horticultural crops or else field crops are presented.

2.1 PLANT NUTRITION IN BANANA

Banana exhausts large quantities of nutrients from soil and therefore requires continuous replenishment of nutrients for better growth, yield and quality. Soil application of manures and fertilizers is the conventional method of nourishing plants. Mineral nutrients play an important role in banana nutrition. However, the application of inorganic fertilizers along with organic manures is the best practice for sustained production as the indiscriminate and sole use of inorganic fertilizers deteriorate soil health besides polluting the environment (Hussain *et al.*, 2016). A nutrient management strategy integrating organic manures and inorganic fertilizers is the best alternative for sustainable banana production and maintenance of soil fertility (Purabi, 2017).

Better performance of banana in terms of growth, yield and quality has been scientifically proven by many scientists by practicing crop nutrition at recommended levels of N, P and K nutrients. Athani *et al.* (2000) obtained highest bunch weight in banana cv. Rajapuri (AAB) supplied with major nutrients N, P and K @ 180:108:225g plant^{-1}. Nalina (2002) recommended application of 165:52.5:495 g NPK nutrients plant^{-1} in 4 split doses so as to obtain better growth and yield in Robusta banana. Application of 100 per cent of the recommended

fertilizer in banana improved the growth parameters including pseudostem height, number of leaves and leaf area index along with considerable increase in yield (Kuttimani *et al.*, 2013). Sangeeta *et al.* (2014) reported higher yield of banana cv. Grand Naine nourished with 175:105:220 g of NPK nutrients plant^{-1}. Improvement in quality attributes of banana including TSS, acidity and TSS/Acid ratio was obtained with the application of 100 per cent RDF (Somasundaram *et al.*, 2014). Nayyer *et al.* (2014) reported favourable improvement in TSS, titrable acidity, total sugars and Pulp : Peel ratio of Grand Naine banana with the application of 110:30:330 g NPK plant^{-1}.

An INM package supplying 100:100:150 g of NPK fertilizers plant^{-1} along with 10 kg of poultry manure as organic supplement could realise significantly higher growth and yield of Dwarf Cavendish banana compared to the application of NPK fertilizers only at a rate of 300:200:300 g plant^{-1} (Tirkey *et al.*, 2002) FYM @10 kg as basal followed by soil application of 190:115:300 g of N, P and K fertilizers in six splits and two pre harvest bunch sprays of Sulphate of Potash (3%) is recommended as the scientific nutrient package for *Nendran* banana (KAU, 2016).

Foliar nutrition, the practice of providing nutrient supplements directly to crop canopy in limited amounts has the advantage of rapid crop response, as the nutrients are supplied in a readily absorbable form (Swietlik and Faust, 1984; Oosterhuis, 2009). More efficient utilization of nutrients is associated with foliar nutrition compared to soil application (Fageria *et al.*, 2009). Foliar application of N, P and K fertilizers considerably increases production from crops (Zhang *et al.*, 2012). While foliar nutrition is being used on a wide variety of crops, its economic value is generally deemed greater for horticultural crops than for agronomic crops. For crops with sufficient leaf area, foliar nutrition becomes more effective resulting in higher yields (Ling and Silberbush, 2007; Fageria *et al.*, 2009). Banana crop having larger leaf area (Karuna and Rao, 2016) responds well to foliar application of fertilizers.

Several scientists have reported the benefits of conjunctive application of soil and foliar nutrition in improving production from banana. Karagi (2016) reported that soil application of 75 per cent of RDN along with vermicompost addition and foliar sprays of micronutrient formulation "Arka Banana Special" could register higher yields in banana. Gurjar (2017) studied the effect of foliar sprays of liquid organic fertilizer and micro nutrients supplied in addition to the recommended dose of organic manures and inorganic fertilizers in Grand Naine banana and reported significant improvement in growth, yield and quality.

2.2 EFFECT OF PLANT NUTRITION ON GROWTH CHARACTERS OF NENDRAN BANANA

Well balanced nutrition is the basic factor deciding crop growth as reported by several scientist. Thangaselvabai *et al.* (2009) reported that an INM package inclusive of recommended NPK fertilizers, organic manures and foliar application of micronutrients could significantly improve the growth of banana. In an experiment conducted at TNAU, Krishnamoorthy *et al.* (2017) reported the significant positive influence of integrated application of organic manures, recommended dose of NPK fertilizers and micronutrients (supplied as soil addition or foliar sprays) on the growth characters including pseudostem height, pseudo stem girth, number of leaves, early shooting and leaf area index of Poovan banana.

There are several reports on the benefits of foliar nutrition in influencing crop growth. Kupper (2003) reported that foliar application of major nutrients in banana was beneficial in promoting vegetative growth and size of fruits. Besides soil application of organics and the recommended dose of NPK fertilizers, supplementary foliar spray of major nutrient nitrogen as urea could well improve the growth of banana (Mustafa and Kumar, 2012). In a study conducted at Kerala Agricultural University in *Nendran* banana, Paul (2015) experimented diverse foliar nutrient sprays along with soil application of recommended NPK dose (190:115:300 g plant^{-1}) and reported that application of 3 per cent Potassium

Sulphate at 2, 4 and 6 months of planting in addition to the RDN resulted in significant improvement of growth characters including plant height and girth.

There are several reports on the influence of water soluble NPK fertilizers influencing the growth of other horticultural crops also. Plant nutrition studies by Karpagam *et al.* (2002) conducted at TNAU with test crop hybrid brinjal revealed the positive influence of water soluble foliar fertilizers on crop growth. Reduction in the recommended dose of fertilizers up to the tune of 15 per cent could be achieved in tomato crop (Narayanan *et al.*, 2012) with supplemental foliar sprays of N, P and K nutrients including two sprays of 19:19: 19 fertilizer mixture at vegetative stage, one spray of 0: 52: 34 at flowering stage and one spray of 13:0:45 at fruit development stage, all at two per cent concentration. Devi and Shanthi (2013) reported that the growth attributes with regard to plant height and number of branches in chilli were significantly higher for the treatment which received 5 sprays of water soluble 19:19:19 mixture (1%) in addition to 100 per cent NPK.

Kumar and Jeyakumar (2001) reported the favourable influence of micronutrient foliar sprays (combined spray of $ZnSO_4$ (0.5%), $FeSO_4$ (0.2%), $CuSO_4$ (0.2%) and H_3BO_3 (0.1%) at 3, 5 and 7 months of planting) along with the recommended NPK dose of 110:35: 330 g plant^{-1} for Robusta banana and noticed significant increase in pseudostem girth and number of leaves. Pathak *et al.* (2011) carried out an investigation to evaluate the effect of foliar application of micronutrients viz., Zn, Fe and B singly or in combination on the growth, yield and quality of banana and found that combined application of Fe (0.5%) and Zn (0.5%) had significant positive influence on plant growth in terms of plant height, girth of pseudostem and number of leaves. Anjali *et al.* (2013) assessed the effect of micronutrients on the growth and yield of banana cv. Grand Naine and noticed significant improvement in terms of plant height and pseudostem girth with the use of a combination of micronutrients supplied as $ZnSO_4$ (0.5%), $FeSO_4$ (0.5%), $CuSO_4$ (0.2%) and H_3BO_3 (0.1%). In a field experiment on micronutrient addition for Poovan banana conducted at TNAU,

Balaji *et al.* (2016) recorded higher plant height and more number of leaves at different stages of plant growth in banana with the combined application of Zn (0.5%) and B (0.1%).

2.3 EFFECT OF PLANT NUTRITION ON YIELD ATTRIBUTES AND YIELD OF *NENDRAN* BANANA

Imbalanced nutrition is considered the main reason for low yields in banana. Integrated application of fertilizers and manures to provide the required major and micro nutrients can assure optimum production from the crop (Abro *et al.*, 2008). Among primary nutrients, potassium is considered a major determinant for higher yields in banana. Nitrogen is second only to potassium in terms of quantity needed for crop growth (Lahav, 1995). As early as in 1973, Martin - Prevel reported that low potassium conspicuously restricted fruit yield in banana by way of reduction in the translocation of carbohydrates from leaves to fruits and thereafter, their conversion to starch. According to Fratoni *et al.* (2017), nitrogen and potassium are nutrients of foremost importance for realising higher yields in banana.

Water soluble fertilizers of varying grades are available these days which can be used at different crop stages either alone or in combinations to nourish the crop and improve productivity (Malhotra, 2016).

Fertilizers like urea are of water soluble nature and the nitrogen contained in it is readily available when applied as fertigation. Supply of N in such soluble and readily available forms allows for a reduction in the recommended dose of chemical fertilizers (Patil and Tandel, 2013) with no compromise on yields. In a study conducted at Navsari in Gujrat, Amol (2014) compared conventional fertilizers with water soluble fertilizers and reported possibility of twenty per cent reduction in the recommended dose when supplied as water soluble fertilizers through fertigation. In the study, water soluble fertilizers given at a lower dose maintained better yield and quality for the test crop Grand Naine.

In a study conducted in banana, Vijayaraghavan and Ayyamperumal (2000) reported increased bunch weight with the combined foliar application of water soluble fertilizers urea (1%) and MOP (2%).

In a study conducted in tomato, Narayanan *et al.* (2012), experimented reduction in the recommended dose of NPK up to 15 per cent while supplementing with five foliar sprays of water soluble NPK fertilizers (2%) applied in the vegetative, flowering and fruiting stages. Significant increase in fruit weight per plant, fruit diameter and fruit yield per hectare was observed in the above treatment in comparison with 100 per cent RDN applied to soil. Devi and Shanthi (2013) reported significant improvement in yield attributes and yield of chilli by supplementing 100 per cent RDN with foliar sprays of 19:19:19 (1%) applied five times to crop. Neelgar *et al.* (2013) experimented foliar sprays of water soluble fertilizers 19:19:19 (1%), Fe - EDTA (0.5%) and borax (0.5%) on red chilli and reported highest fruit yield with these fertilizers sprayed twice on crop at 60 and 90 DAP. Manasa *et al.* (2015) studied the effect of integrated soil and foliage nutrition in ground nut and reported that foliar application of NPK grade fertilizers (2%) at 30, 45 and 60 DAS when combined with a reduced NPK dose of 85 per cent could produce comparable yields as that with 100 per cent of the recommended dose.

The recommended dose of potassium fertilizer could be reduced up to 25 per cent when supplemented with foliar nutrition of Potassium Sulphate (2.5%) in faba bean (El - Nour, 2002). Thakur *et al.* (2017) who studied foliar application of water soluble nutrients viz, urea (1%), 19:19:19 (2%) and DAP (2%) applied in addition to the recommended dose of fertilizers in major pulse crops reported significant improvement in yield attributes and yield with such supplemental nutrition.

Soil application of Fe (5 g $FeSO_4$ plant $^{-1}$ at 3 MAP), foliar applications of Zn (0.5 per cent $ZnSO_4$ at 3, 5 and 7 MAP) and B (10 ppm boric acid at 3, 5 and 7 MAP) in addition to the recommended dose of NPK (200: 50: 400 g plant $^{-1}$), produced the highest bunch weight and best quality fruits in Karpuravalli (ABB)

banana (Jeyabaskaran and Pandey, 2008). Pathak *et al.* (2011) reported earliness in shooting as well as increase in finger and bunch weights of banana with the application of micronutrients Zn, Fe and B in addition to the recommended NPK. IIHR (2013) recommended integrated nutrient management in banana involving leaf and bunch sprays of major and micro nutrients (0.5% urea, 0.5% SOP, 0.2% ZnSO4 and 0.1% Boric Acid) from 5^{th} to 8^{th} month of crop stage given in addition to the RDN for 20 per cent yield increase.

Zafar *et al.* (2006) reported that sole application of foliar N, P and K fertilizers resulted in declined yields as leaves alone are not potent enough to fulfil the nutrient needs of crops

Improved dry matter production and more number of suckers were observed in *Nendran* banana with foliar application of 19:19: 19 (0.5%) at 2, 4 and 6 MAP given in addition to full dose of recommended NPK (Shimi, 2014). Paul (2015) experimented seven different foliar sprays (major and micro nutrient mixtures) in *Nendran* banana, in addition to the recommended application of NPK and organics in soil and reported highest yield with foliar spray of potassium sulphate (3%) at 2, 4 and 6 months of planting. The treatment recorded increase in bunch weight to the tune of 50 per cent compared to the nutrient recommendation by KAU. Foliar spray of 19:19:19 fertilizer mixture (2%) at 2, 4 and 6 months of planting was also attempted in addition to the RDN and this recorded nearly nine per cent increase in bunch weight.

2.4 EFFECT OF PLANT NUTRITION ON QUALITY OF NENDRAN BANANA

Plant nutrition has an important role in determining quality of crops. Among major nutrients, potassium is most important in determining quality of fruits (Usher wood, 1985). Micronutrients especially boron are involved in cell wall development, cell division, transport of sugars etc and are directly related to quality of fruits in most crops (Ruby *et al.*, 2001). Lester *et al.* (2005) arrived at the finding that adequate nutrition of potassium is associated with improved shelf

life of many horticultural crops, a major indicator of quality. Kumar *et al.* (2006) opined that potassium is the most important of all nutrients in regulating the quality of fruits as the nutrient is involved in many aspects of plant physiology especially activation of many enzymes of physiological importance.

Additional application of foliar nutrients during plant growth can improve the nutrient content in plants thereby influencing plant physiological mechanisms in a manner leading to improved quality of crop produce (Kolota and Osinska, 2001). Foliar application of micronutrients results in immediate availability of these nutrients thereby positively influencing plant metabolism for quality production (Arun and Kumar, 2014).

Foliar application of 0.3% Zn and 0.1% B given at 3 and 5 MAP in addition to the recommended major nutrients resulted in significant improvement in quality parameters including TSS and total sugar and resulted in a favourable reduction in ascorbic acid in banana cv. Governor (Ghanta and Dwivedi, 1993).

$ZnSO_4$ (0.5%), $FeSO_4$ (0.2%),$CuSO_4$ (0.2%) and H_3BO_3 (0.1%) combinely applied as foliar spray at 3, 5 and 7 months of planting in addition to the recommended NPK nutrients resulted in higher total soluble solids in Robusta banana (Kumar and Jeyakumar, 2001). Higher TSS (22.1%) and total sugar content (21.6%) were obtained in *Nendran* banana with soil addition of recommended NPK + supplemental foliar applications of major (N, P and K) and micro nutrients (Zn, Cu, B) given at 5 and 7 months of planting (Suresh and Savithri, 2001). Foliar spray of SOP (1.5%) given at 3, 5 and 7 months of planting enhanced the quality parameters including TSS (28.9%) and total sugars (22.36 %) in Neypoovan banana (Kumar and Kumar, 2007).

A study conducted by Kumar and Kumar (2008) in Robusta banana revealed enhancement in shelf life of fruits up to 8.70 days with the inclusion of SOP in the fertilizer schedule. Ningavva *et al.* (2014) noticed improvement in quality aspects of Grand Naine banana especially with regard to TSS, total sugars and acidity when 100 per cent of the RDN was supplemented with foliar

application of micronutrients $ZnSO_4$ (0.5%) and B(0.2%). Paul and Nair (2015) reported significant improvement in TSS and lowering of acidity in *Nendran* fruits with the application of SOP (3%) at 2,4 and 6 months of planting given in addition to the recommended dose of fertilizers. In the same study they noticed that RDF when supplemented with micronutrient (Zn, Fe, Cu, B and Mo) foliar sprays, the total sugars attained a higher value of 19.4 per cent. In a study conducted in *Nendran* banana at KAU, Shimi (2014) reported that foliar application of water soluble fertilizer 19:19:19 (0.5%) at 2,4 and 6 months of planting along with the recommended dose of nutrients enhanced the shelf life of fruits up to 11.25 days.

2.5 EFFECT OF PLANT NUTRITION ON THE UPTAKE OF MAJOR NUTRIENTS

Crop uptake of N, P and K nutrients increased when these nutrients were applied at higher levels (Deshpande and Lakdive.,1994 ; Shukla and Naik.,1996). The increased accumulation was therefore attributed to increased availability of the nutrients. According to Dixon (2003), foliar applied N was seven times more efficient than soil applied N. Bhatt and Srivastava (2005) noticed increased uptake of plant nutrients when soil addition of major nutrients was supplemented with foliar spray of micro nutrients B, Zn, Mo, Cu, Fe and Mn in tomato crop. Lalitha *et al.* (2008) reported higher uptake of major nutrients N and P, secondary nutrient S and micronutrient B with foliar application of SOP and boric acid along with the recommended dose of fertilizers in niger. Plant uptake of foliar applied nutrients is rapid as it begins within minutes of application and is completed mostly in 1 to 2 days. On the other hand, soil applied fertilizers are taken up by plants in five to six days only (Fageria *et al.,* 2009). Oosterhuis (2009) noticed that 30 per cent of the foliar applied nitrogen was taken up by cotton crop with in an hour of application and was translocated to the closest boll within 6 to 48 hours. As such, the practice of foliar nutrition was identified far effective in ready supply of nutrients and realisation of higher yields.

In chilli crop, Neelangar (2012) reported higher uptake of NPK nutrients with two foliar sprays of 19:19:19 (1%), Fe-EDTA (0.5%) and borax (0.5%) applied in addition to the recommended dose of fertilizers.

Devi and Shanthi (2013) reported significantly higher uptake of major nutrients in chilli hybrid Sierra with 5 sprays of 19:19:19 polyfeed applied at 1% concentration to foliage in addition to 100% RDN. In a work conducted in *Nendran* banana, Shimi (2014) reported that foliar fertilizer 19:19:19 (0.5%) applied in addition to the recommended NPK at two stages of crop growth i.e., 2 and 4 months of planting could register significantly highest uptake of phosphorous. Taru *et al.* (2014) reported that supplemental foliar sprays of water soluble fertilizers urea (1%) and muriate of potash (0.5%) helped increasing the uptake of N and K nutrients in banana cv. Grand Naine. Manasa *et al.* (2015) studied foliar nutrition as a supplement to the recommended dose of manures and chemical fertilizers in groundnut and reported that RDF when supplemented with foliar spray of water soluble grade fertilizers (2%) could result in higher uptake of N, P and K nutrients.

2.6 EFFECT OF PLANT NUTRITION ON SOIL PROPERTIES

A nutrient management strategy integrating organics as well as soil and foliar nutrition of mineral fertilizers ensured adequate plant nutrients in soil compared to soil addition of recommended fertilizers only (Praharaj and Rajendran, 2007). According to Syers *et al.* (2007) the phosphorous use efficiency of foliar application was as high as 50% compared to soil application (10 to 15%). This could help in reduced fertilizer usage resulting in minimial build up of the nutrient in soil, favouring the environment. In a study conducted in groundnut, Manasa *etal.* (2015) reported higher available status for major nutrients N, P and K, when the crop was sufficiently nourished with 100% RDN and foliar spray of water soluble grade fertilizer 19:19:19 (2%) at 30, 45 and 60 days of sowing. Foliar application of water soluble P fertilizers in wheat crop registered comparable status of available P in soils after the experiment as with soil application of recommended P through SSP (Harshitha *et al.*, 2017).

Gosavi *et al.* (2017) studied the effect of conjunctive soil and foliar nutrition on soil properties in a wheat field. They reported that the soil nutrient status for major nutrients N, P and K after harvest remained statistically comparable under supply of 100 per cent of the RDN and that provided with 75 per cent of the RDN + 3 foliar sprays of 19:19:19 (2%) . The same study also noted that soil organic carbon was maintained on par and the pH levels remained unaffected when the recommended dose of nutrients or else 75% of the recommended dose were supplemented with three foliar sprays of 19:19:19 (2%).

In a study conducted in Neypoovan banana, Hanumanthaaiah *et al.* (2015), experimented supplemental foliar sprays of potassium silicate in addition to the recommended dose of nutrients and noticed better plant growth resulting in higher uptake of potassium from soil. As a result, a decline in the soil balance of the nutrient was registered in comparison to the treatments that supplied the recommended dose of fertilizers only.

Foliar application of micronutrients in a rice - wheat cropping system had no significant effect on post harvest soil nutrient status (Rahman *et al.*, 2002).

2.7 EFFECT OF PLANT NUTRITION ON ECONOMICS OF BANANA

Kumar and Kumar (2007) reported that foliar spraying of SOP (1.5%) at 3, 5 and 7 months of planting given in addition to 100 per cent of the RDN was the most profitable treatment which could double the net income from banana cv. Neypoovan. Foliar nutrition in tomato using water soluble graded fertilizer 19:19:19 at 30 DAT and thereafter at 10 days interval in addition to RDF recorded higher B: C ratio compared with supply of RDF only (Chaurasia *et al.*, 2005). Five foliar sprays of 19:19:19 (1%) supplied in addition to 100 % NPK fertilizers could maximize the yield of hybrid tomato leading to high B: C ratio (Premsekhar *et al.*, 2009).

Higher B: C ratio of 1.94 was obtained in Basrai banana with the combined foliar spray of $ZnSO_4$ (0.5%) + Fe SO_4 (0.5%) given at 3, 5 and 7 months of planting in addition to 100% RDN (Patel *et al.*, 2010).

Narayanan *et al.* (2012) reported that 87.5% of the recommended dose of NPK fertilizers when supplemented with foliar spray of water soluble polyfeed 19:19:19 (2%) two times, first during vegetative stage and the second at flowering stage could record the highest net return and benefit cost ratio in tomato. This suggests that foliar nutrition when included in the fertilizer schedule allows for a reduction in the supply of chemical fertilizers thereby saving cost resulting in improved B: C ratio.

Neelagar (2012) reported higher net income and B: C ratio in chilli when supplied with two foliar sprays of 19:19:19 (1%), Fe-EDTA (0.5%) and borax (0.5%) in addition to the recommended dose of fertilizers. In a trial conducted in Bt cotton, Shivamurthy and Biradar (2014) reported that supplemental foliar sprays of 19:19:19 (1%) and $MgSO_4$ (1%) given in addition to the recommended dose of manures and fertilizers could significantly enhance the net returns from the crop.

Potassium Sulphate (3%) given as foliar application at 2,4 and 6 months of planting in addition to the recommended dose of N, P and K fertilizers gave the highest B: C ratio in *Nendran* banana (Paul, 2015).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "Foliar nutrition in *Nendran* banana using multinutrient water soluble fertilizers" undertaken during the period from 2016 April to 2017 February had the objectives of assessing the feasibility of foliar nutrition in reducing the fertilizer dose of *Nendran* banana and to study its impact on growth, yield, quality and economics. The details of the experimental site, materials used and methods adopted for the study are described below.

3.1 Experimental site

The study was conducted at the Coconut Research Station of Kerala Agricultural University at Balaramapuram, Thiruvananthapuram, Kerala. The experimental site was geographically located at 8^0 22' 53" N latitude and 77^0 1' 47" E longitude and at an altitude of 26 m above mean sea level.

3.1.1 Soil

The soil of the experimental site belonged to the group Alfisols. The texture was sandy loam. A composite soil sample collected from 0 - 15 cm depth before the start of the experiment was analysed for chemical and physical properties (bulk and particle densities) by following standard procedures (Table 1 and 2). The soil was strongly acidic in reaction, low in available nitrogen and potassium and medium in available phosphorous.

Table 1. Physical properties of the soil before the experiment

Particulars	Soil depth	Method adopted
Bulk density	1.48 Mg m^{-3}	Core method (Gupta and Dakshinamoorthi,1980)
Particle density	2.36 Mg m^{-3}	Pycnometer method (Black,1965)

Table 2. Chemical properties of the soil before the experiment

Particulars	Value	Rating	Method adopted
Soil reaction (pH)	5.20	Strongly Acidic	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (dS m^{-1})	0.10	Normal	Digital conductivity meter (Jackson, 1973)
Organic carbon (%)	0.91	High	Walkley and Black rapid titration method(Jackson, 1973)
Available N (kg ha^{-1})	201	Low	Alkaline permanganate method (Subbiah and Asija,1956)
Available P (kg ha^{-1})	26.5	Medium	Bray colorimetric method(Jackson, 1973)
Available K(kg ha^{-1})	200	Low	Ammonium acetate method (Jackson, 1973)
Boron (mg kg^{-1})	Non detectable	Deficient	Hot water soluble extract method (Gupta,1967)
Zinc (mg kg^{-1})	0.98	Deficient	0.1 N HCL method (Jackson, 1973)

3.1.2. Weather conditions

The data on weather parameters (monthly rainfall, evaporation, maximum and minimum temperature) during the period under study is depicted in Fig.1 and given as Appendix I.

3.2 MATERIALS

3.2.1. Crop

The banana variety for the experiment was *Nendran* (*Musa* AAB group), the most sought after banana variety in Kerala because of varied uses as fruit and vegetable. The duration for this variety generally ranges from 10 to 12 months.

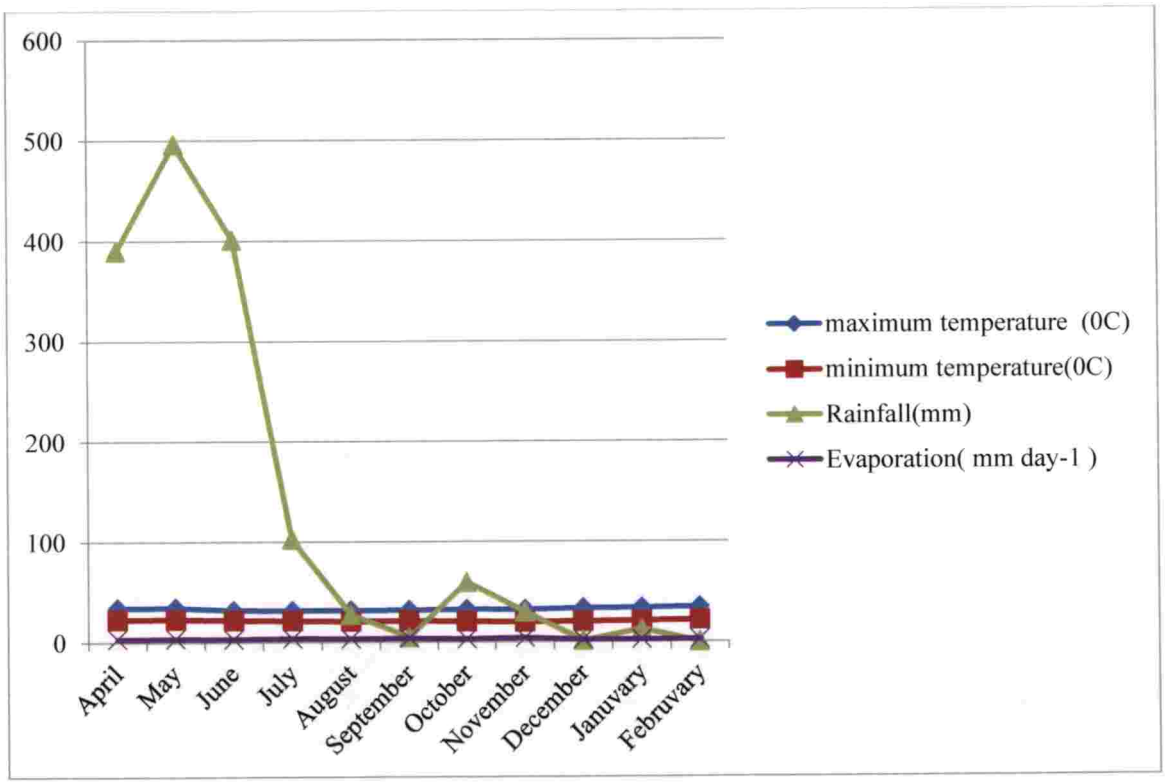


Fig.1. Weather data during the cropping period from 2016 April to 2017 February

The bunch weight of *Nendran* ranges from 12 to 15 kg or even more. Vigorous and disease free sword suckers of uniform age (three months) and size were selected for planting.

3.2.2. Manures and fertilizers

FYM (0.53 per cent N, 0.20 per cent P_2O_5 and 0.48 per cent K_2O) was used as organic manure. Urea (46% N), Rock Phosphate (20% P_2O_5) and Muriate of Potash (60% K_2O) were used as fertilizer sources of N, P and K respectively. Completely water soluble 19:19:19 polyfeed fertilizer was used for foliar application @ 0.5 per cent concentration. Banana micromix, a micronutrient formulation developed by KAU (1% Fe, 2% Mn, 4% Zn, 6% B, and 1% Cu) was foliar sprayed (1%) to supply the micronutrients. Stanowet (1ml litre^{-1}) was used as wetting agent for both these foliar sprays.

3.3 METHODS

3.3.1 Design and Layout

The field experiment was laid out as detailed below in Fig.2

Experimental design	: Randomised Block Design
Number of treatments	: 8
Number of replication	: 3
Number of plants per plot	: 6
Variety	: *Nendran*
Plot size	: 6 m x 4 m

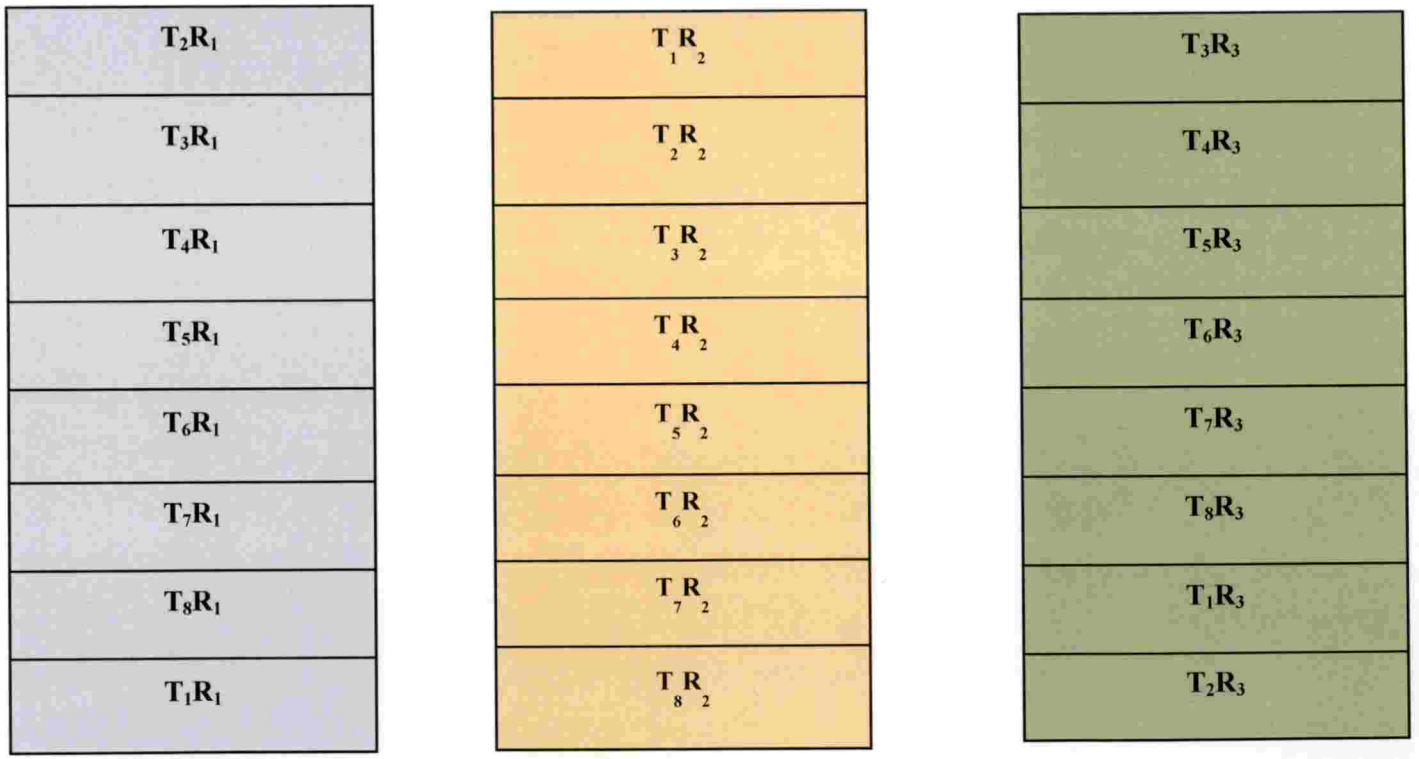
3.3.1.1 Treatments

The eight different treatments under study are detailed below

T_1 - RDN as per POP recommendation of nutrients of KAU

T_2 -75% RDN +19:19:19 (0.5%) foliar spray at 2 and 4 MAP

Fig. 2. Layout of the experiment



T_3- 60% RDN +19:19:19 (0.5%) foliar spray at 2 and 4 MAP

T_4- T_1+ Banana micromix (1%) foliar spray at 3 MAP

T_5- T_2+ Banana micromix (1%) foliar spray at 3 MAP

T_6- T_3+ Banana micromix (1%) foliar spray at 3 MAP

T_7-19:19:19 (0.5%) foliar spray 7 times at monthly interval after planting

T_8- T_7 + Banana micromix (1%) foliar spray at 3 MAP

Recommended Dose of Nutrients (RDN): 190:115:300 g NPK plant $^{-1}$

FYM @10 kg plant^{-1} as recommended in the Package of Practices, KAU was given as basal dose of organic manure common for all treatments. Reduction in the recommended dose of chemical fertilizers up to 25 per cent (Treatments T_2 and T_5) and 40 per cent (T_3 and T_6) were attempted by supplementing with foliar nutrition using 19:19:19 fertilizer (0.5%) at 2 and 4 MAP. Taking into consideration the yield benefits in banana with micronutrient sprays, a foliar spray of banana micromix (1%) was given at 3 months stage in treatments T_4, T_5, T_6 and T_8. The micronutrient mixture had a composition of 1% Fe, 2% Mn, 4% Zn, 6% B, and 1% Cu. Apart from the basal dose of organic manures, treatment T_7 received only foliar sprays of water soluble fertilizer 19:19:19 (0.5%) at monthly intervals up to 7 months. Treatment T_8 received an additional foliar spray of banana micromix (1%) compared to T_7. Pre harvest bunch sprays of Potassium Sulphate (3%) were given twice, first at two weeks and the second at four weeks of bunch emergence, common for all treatments. Potassium Sulphate used for bunch spray had a composition of 41 per cent potassium and 18 per cent sulphur.

3.3.2 CULTIVATION PRACTICES IN BANANA

3.3.2.1 Field preparation and planting

The field was well prepared by deep ploughing and pits of 50 cm ^{3}size were taken at 2 m x 2 m spacing. Lime @ 500 g was applied to each pit at the time of

land preparation. After ten days, suckers were planted in the centre of pits. Planting was done 11- 05 - 2016. The saplings were irrigated till establishment.

3.3.2.2 Application of manures and fertilizers

FYM @ 10 kg plant^{-1} was given uniformly to all treatments as basal dose of organic manure. For treatments receiving full dose of NPK nutrients (190:115:300 g plant^{-1}), N and K were applied in six splits (at 1, 2, 3, 4 and 5 MAP and after bunch emergence) whereas P was supplied in two splits (at 1 and 2 MAP). Foliar application of 19:19:19 water soluble fertilizer (0.5%) was given for treatments T_2, T_3, T_5, and T_6 at 2 and 4 MAP. For treatments T_7 and T_8, apart from the basal dose of organics, foliar nutrition alone was followed using 19:19:19 fertilizer (0.5%) at monthly intervals up to 7 months. Micronutrient mixture Banana micromix (1%) was foliar applied in treatments T_4, T_5, T_6, and T_8 at 3MAP. Two pre harvest bunch sprays of Potassium Sulphate (3%) were provided, first at two weeks and the second at four weeks of complete bunch emergence, common for all treatments.

3.3.3.3 Maintenance of the crop

Two hand weedings were done at 2 and 5 months of planting to check weedy growth. Periodic desuckering was followed up to bunch emergence. The crop was raised as rainfed but uniform irrigation was provided for all treatments for establishment and during dry spells.

3.3.3.4 Plant protection measures

In general, diseases were kept in check by removing and destroying infected leaves. During fourth and fifth months of planting, chlorphyriphos (0.3%) was applied on pseudostem and leaf axils as prophylactic measure against pseudostem weevil.

Plate 1. General view of the experimental field

Plate 2. KAU Banana micromix

Plate 3. Foliar spray of nutrients

3.3.3.5 Propping and harvesting

Banana plants were propped using rope after bunch emergence. Harvest of bunches were carried out from December 2016 to February 2017, based on visual symptoms of maturity.

3.4 MAIN ITEMS OF OBSERVATION

3.4.1 Growth characters

Observations were taken at bimonthly intervals on the following growth characters.

3.4.1.1 Plant height

The plant height was measured in cm from the base of the plant at ground level to the tip of newly emerged leaf.

3.4.1.2 Pseudostem height

The pseudostem height was measured in cm from the base of the plant at ground level to the axil of the youngest unopened leaf.

3.4.1.3 Pseudostem girth

The girth of the pseudostem of banana plants were measured at 10 cm height above the ground level by taking the circumference of the pseudostem and expressed in cm.

3.4.1.4 Time for bunch emergence

The time taken from planting to complete emergence of bunch in each treatment were recorded in days.

3.4.1.5 Leaf area index

Leaf area index (LAI) was determined using the formula suggested by Watson (1947)

$$\text{Leaf Area Index} = \frac{\text{Total functional leaf area plant}^{-1}}{\text{Land area occupied plant}^{-1}}$$

3.4.1.6 Functional leaf area

The third fully opened leaf from the apex was taken as the index leaf. The length of the index leaf was measured from the base of the lamina to the tip and the width was measured at the broadest part of the lamina.

Leaf area was calculated using the equation developed by Murray (1960).

Leaf area of index leaf = Length of lamina x width of lamina x a constant (0.8)

Functional leaf area = Number of functional leaves x Leaf area of index leaf

The functional leaf area was expressed in m^2.

3.4.1.7 Shoot to harvest duration

The number of days taken from shooting to harvest were recorded.

3.4.1.8 Total crop duration

The number of days taken from planting to harvest were recorded.

3.4.1. 9 Number of suckers

Number of suckers from each plant were counted at harvest.

3.4.2 Yield attributes and yield

Bunches were harvested at full maturity as indicated by the disappearance of angles from fingers (Stover and Simmonds,1987). The following observations were made on the bunch characters.

3.4.2.1 Number of hands bunch^{-1}

The number of hands in each bunch of observational plants were noted and their mean values were recorded.

3.4.2.2 Number of fingers bunch $^{-1}$

The total number of fingers in each bunch of the observational plants were counted and the mean values were calculated.

3.4.2.3 Number of fingers in D hand

D hand is the second hand from the top of the bunch (Dadzie and Orchard, 1997). The number of fingers in the D hand were recorded.

3.4.2.4 Weight of D finger

The middle finger in the top row of the D hand is designated as the representative finger or index finger or D finger for studying fruit characters (Gottriech *et al.,* 1964). Fresh weight of index finger was recorded and expressed in g.

3.4.2.5 Length of D finger

The length of D finger was measured from the tip of the finger to the point of attachment at the peduncle (using thread and scale) and was expressed in cm.

3.4.2.6 Girth of D finger

Girth of the index finger was measured at the mid portion of the D finger using thread and scale and expressed in cm.

3.4.2.7 Peduncle length

Peduncle is the stalk that supports the inflorescence. The length measured from the base of the peduncle to the first hand was recorded as peduncle length and expressed in cm.

3.4.2.8 Bunch weight

Weight of the bunch including the portion of the peduncle up to the first scar (exposed outside the plant) was recorded in kg.

3.4.2.9 Yield

The per plant bunch weight recorded in kg was worked out in t ha^{-1} and expressed as total bunch yield.

3.4.2.10 Total dry matter production

Fresh weight of all the plant parts of banana *viz.*, leaves, pseudostem, fruits and rhizome were recorded at harvest. Known weight of these samples were kept separately in oven and dried at 65 ± 5 ^{0} C until constant weight was attained and then expressed in g plant $^{-1}$ and kg ha $^{-1}$.

3.4.3. Quality characters

The index (D) fingers collected from observational plants were used for quality analysis at ripened stage. Known weight of the samples taken from top, middle and bottom portions of these fingers were macerated in a blender and made up to a known volume. Aliquots taken from these samples were used for quality analysis of the fruit.

3.4.3.1 Total soluble solids (TSS)

Total soluble solids were determined using a hand refractometer and mean values were expressed in percentage (Ranganna, 1977).

3.4.3.2 Acidity

Acidity was determined by the procedure suggested by Ranganna (1977). An aliquot from the sample was titrated against 0.1N Sodium Hydroxide solution and the mean values were expressed as per cent Anhydrous citric acid.

3.4.3.3 TSS /Acid ratio

The values of TSS were divided by values of acidity to compute TSS to Acid ratio

3.4.3.4 Total sugars

The total sugar content of the samples was determined by the method given by Ranganna (1977) and expressed as percentage on fresh weight basis.

3.4.3.5 Cracks in fruit peel

The fruits were observed for any crack in peel.

3.4.3.6 Shelf life

Shelf life of banana fruits were recorded as the number of days from harvest to the stage when fruit skin turned black and the fruits lost their edible quality as evident by over softening of pulp.

3.4.3.7 Pulp/ peel ratio

The weight of pulp and peel of index fingers from observational plants were separately determined and the ratio worked out.

3.4.4 Plant analysis and Uptake of major nutrients (at harvest)

Fresh plant samples collected freshly from leaves, rhizome, pseudostem and fruits of observational plants at harvest were chopped and dried in hot air oven at 65 ± 5^0 C till attainment of constant weight. These samples were then powdered and well mixed to prepare a composite plant sample. This sample was further analysed for major plant nutrients N, P and K as per the methods given in Table 3. Table 3. Estimation of nutrient status in plant samples

Particulars	Method used	Reference
N (%)	Modified Micro Kjeldahl method	(Jackson, 1973).
P (%)	Vanado - Molybdo Phosphoric yellow colour method using spectrophotometer	
K (%)	Flame photometry method	

Further, the uptake of nutrients were worked out by multiplying the values of dry matter production (kg ha^{-1}) and nutrient content (%) and expressed as kg ha^{-1}.

3.4.5 Soil analysis

The soil samples drawn from individual plots at the end of the experiment were air dried, powdered, sieved through 2 mm sieve and analysed for soil pH, organic carbon and available N, P and K as per the methods given in Table 2.

3.4.6 Economic analysis

3.4.6.1 Net income

Net income was calculated by subtracting the cost of cultivation from gross income.

3.4.6.2 Benefit Cost Ratio (BCR)

BCR was calculated as the ratio of gross income to cost of cultivation.

$$BCR = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.4.7 Incidence of pest and disease

Pest and disease incidences observed in the experimental field were observed and necessary plant protection measures followed. No pests and diseases were found in magnitudes causing economic injury.

3.4.8 Statistical analysis

The data recorded were analysed statistically and the significance was tested using the technique of analysis of variance (Panse and Sukhatme, 1967), Wherever significance recorded, values of critical differences were calculated for comparing the means.

RESULTS

4. RESULTS

The present investigation entitled "Foliar nutrition in *Nendran* banana using multinutrient water soluble fertilizers" was conducted at Coconut Research Station, Balaramapuram during 2016 April to 2017 February. The main objectives of the study were to assess the feasibility of foliar nutrition in reducing the fertilizer dose of *Nendran* banana and to assess its impact on growth, yield, quality and economics. The results of the study are presented in this chapter.

4.1 EFFECT OF PLANT NUTRITION ON GROWTH CHARACTERS

4.1.1 Plant Height

The effect of treatments on plant height was observed at bimonthly intervals, the results of which are presented in Table 4. Significant differences in plant height were observed among treatments at all the growth stages under study. At 2 MAP, the maximum plant height (325.02 cm) was observed for treatment T_1 (KAU recommended nutrient addition) which was on a par with treatments T_2, T_3, T_4 and T_5. At 4 MAP, T_5 (75 % of KAU recommended nutrients + foliar sprays of 19:19:19 and banana micromix) recorded the highest plant height of 358.05 cm and was comparable to treatment T_4 (100% of KAU recommended nutrient addition + foliar spray of banana micromix). Treatment T_1 (338.30 cm) recorded comparable plant height to T_4 (347.01 cm) at this stage. At later crop stages of 6 and 8 MAP, treatments T_4 and T_5 recorded significantly superior higher plant heights compared to all other treatments. At all stages of observation, plant heights were significantly lower for treatments T_7 and T_8 which received foliar nutrition alone at monthly intervals apart from the basal dose of organics. At 8 MAP, the plant heights recorded by these two treatments were 370.13 cm and 378.51cm respectively whereas T_4 and T_5 recorded respective plant heights of 431.64 cm and 423.45 cm.

Table 4. Effect of treatments on plant height (cm) at bimonthly intervals

Treatments	Plant height (cm)			
	2 MAP	4 MAP	6 MAP	8 MAP
T_1	325.02	338.30	385.56	412.67
T_2	305.63	318.55	368.33	383.96
T_3	298.52	305.33	350.25	370.98
T_4	317.00	347.01	401.27	431.64
T_5	303.40	358.05	399.22	423.45
T_6	286.68	318.56	363.76	379.06
T_7	217.87	283.41	315.66	370.13
T_8	205.51	291.33	325.07	378.51
SEm (±)	10.80	4.781	3.961	3.502
CD (0.05)	30.137	14.510	12.004	10.612

4.1.2 Pseudostem Height

The results of the influence of different treatments on pseudostem height of banana are presented in Table 5. Pseudostem height was recorded at bimonthly intervals from 2 to 8 months of planting. At 2 MAP, no significant differences were noticed among treatments with regard to pseudostem height. At 4, 6 and 8 MAP, T_4 (KAU recommended nutrient addition + banana micromix (1%) at 3MAP) recorded maximum pseudostem heights of 199.8 cm, 231.92 cm and 286.78 cm respectively and was on par with treatment T_5 [75% of KAU recommended nutrients + foliar sprays of 19:19:19 (0.5%) and banana micromix (1%)]. At these three crop stages, T_5 was found comparable to T_1, the KAU recommended nutrient supply. Treatments T_7 and T_8 which received no soil addition of nutrients apart from basal organics, recorded lower and comparable pseudostem heights at crop stages 2, 4 and 8 MAP. At 6 month stage, T_7 registered the significantly inferior pseudostem height of 177.13 cm.

4.1.3 Pseudostem Girth

Observations on pseudostem girth were recorded at bimonthly intervals from 2 to 8 MAP, the results of which are presented in Table 6. At all these stages, treatments T_4, T_5 and T_1 (KAU recommended nutrient addition) registered higher and comparable pseudostem girth. The maximum pseudostem girth of 49.09 cm was recorded with treatment T_5 at 8 MAP and this was on a par with T_4 (48.77 cm) and T_1 (47. 26 cm). In treatments T_7 and T_8 where the plant was nourished with foliar sprays of nutrients alone apart from the basal dose of organics, the pseudostem girth was found significantly reduced compared to all other treatments. At 4 and 6 MAP, treatment T_7 and T_8 registered significantly lower and comparable pseudostem girth. However at 8 months of crop stage, T_7 itself registered the significantly lowest pseudostem girth of 35.50 cm, compared to all other treatments. At this stage T_1, T_4 and T_5 registered comparable and higher pseudostem girth.

Table 5. Effect of treatments on pseudostem height (cm) at bimonthly intervals

Treatments	Pseudostem height (cm)			
	2 MAP	4 MAP	6 MAP	8 MAP
T_1	105.88	176.94	230.64	271.47
T_2	103.19	174.17	219.26	259.64
T_3	109.01	166.38	206.32	244.58
T_4	111.48	199.80	231.92	286.78
T_5	106.08	194.09	231.45	281.07
T_6	101.28	183.45	221.23	275.16
T_7	102.38	158.00	177.13	231.69
T_8	106.68	165.31	189.49	241.30
SEm (±)	4.729	4.308	9.554	7.478
CD (0.05)	NS	13.004	9.340	11.503

Table 6. Effect of treatments on pseudostem girth (cm) at bimonthly intervals

Treatments	Pseudostem girth (cm)			
	2 MAP	4 MAP	6 MAP	8 MAP
T_1	34.23	37.78	42.22	47.26
T_2	32.25	38.37	41.27	46.10
T_3	30.19	34.82	37.67	41.39
T_4	35.86	40.46	44.37	48.77
T_5	36.20	38.39	42.49	49.09
T_6	30.55	33.86	38.85	43.28
T_7	27.31	29.57	32.39	35.50
T_8	25.41	30.35	33.26	39.73
SEm (±)	0.864	0.892	0.827	0.876
CD (0.05)	2.618	2.705	2.336	2.658

4.1.4 Leaf Area Index

Leaf area index, a crucial determinant in crop growth and productivity is closely related to the amount of intercepted radiation and was observed at bimonthly intervals from 2 to 8 MAP (Table 7). The different treatments could significantly influence LAI at all stages except 2 MAP. At 4, 6 and 8 MAP, T_4 (KAU recommended nutrient addition + micronutrient foliar spray) and T_5 [75% of KAU recommended nutrients + foliar sprays of 19:19:19 (0.5%) and banana micromix (1%)] registered significantly superior and comparable LAI. There was a general decline in LAI from 6 to 8 MAP. At 8 MAP, the LAI recorded by T_5 was the maximum (3.03) and was comparable to treatments T_4 (2.89), T_1 (2.67) and T_2 (2.66). LAI was found significantly reduced in T_7 (1.37) at this stage compared to all other treatments.

4.1.5 Functional leaf area

Bimonthly observations recorded on functional leaf area of *Nendran* banana from 2 to 8 MAP are presented in Table 8. The different treatments failed to influence the functional leaf area in a significant manner at 2 MAP. However, at 4 and 6 MAP, T_4 (KAU recommended nutrient addition + micronutrient foliar spray) and T_5 [75% of KAU recommended nutrients + foliar sprays of 19:19:19 (0.5%) and banana micromix (1%)] recorded significantly higher functional leaf area compared to all other treatments. The functional leaf area was highest at the crop stage of 6 MAP with T_4 and T_5 recording higher values of 18.78 and 17.28 respectively. Significantly lower functional leaf area was recorded with treatments T_7 (12.34) and T_8 (13.56) at 6 MAP. Towards the crop stage of 8 MAP, there was a general decline in functional leaf area in all treatments as observed with LAI.

4.1.6 Shoot harvest duration

Shoot harvest duration remained unaffected by the different treatments of the present experiment as per observations made (Table 9).

Table 7. Effect of treatments on leaf area index at bimonthly intervals

Treatments	Leaf area index			
	2MAP	4MAP	6MAP	8MAP
T_1	0.73	2.52	3.98	2.67
T_2	0.61	2.39	3.83	2.66
T_3	0.56	2.27	3.39	2.30
T_4	0.66	3.54	4.69	2.89
T_5	0.63	3.21	4.37	3.03
T_6	0.59	2.64	3.77	2.35
T_7	0.51	2.08	3.07	1.37
T_8	0.54	2.19	3.68	2.30
SEm (±)	0.092	0.157	0.120	0.202
CD (0.05)	NS	0.471	0.371	0.611

Table 8. Effect of treatments on functional leaf area (m^2) at bimonthly intervals

Treatments	Functional leaf area (m^2)			
	2MAP	4MAP	6MAP	8MAP
T_1	2.93	10.58	15.95	10.68
T_2	2.35	10.07	15.35	10.64
T_3	2.24	9.58	14.60	9.20
T_4	2.64	14.05	18.78	11.59
T_5	2.51	12.85	17.28	12.12
T_6	2.37	9.60	14.73	9.40
T_7	2.07	8.34	12.34	5.48
T_8	2.12	9.08	13.56	9.22
SEm (±)	0.369	0.650	0.533	0.887
CD (0.05)	NS	1.972	1.612	2.697

Table 9. Effect of treatments on bunch emergence, shoot harvest duration and total crop duration (days)

Treatments	Time of bunch emergence	Shoot-harvest duration	Total crop duration
T_1	191.00	104.00	277.00
T_2	192.33	107.67	282.00
T_3	192.00	108.00	287.00
T_4	183.33	104.67	270.00
T_5	187.00	105.00	274.00
T_6	192.00	107.00	289.00
T_7	234.33	109.33	324.33
T_8	223.00	108.67	313.67
SEm (±)	2.587	1.786	3.251
CD (0.05)	7.922	NS	9.957

4.1.7 Time of bunch emergence

The time of bunch emergence as observed with different treatments of the study is presented in Table 9. Significant and comparable earliness in bunch emergence were noticed with treatments T_4 (183.33 days), T_5 (187 days) and T_1 (191 days). Bunch emergence was considerably delayed up to 234.33 days in treatment T_7 which was comparable to T_8 (223 days).

4.1.8 Total crop duration

Observations recorded on total crop duration are presented in Table 9. It was noticed that in treatment T_7 (Foliar nutrition using 19:19:19 (0.5%) alone at monthly intervals apart from soil application of basal organics), the crop duration was significantly prolonged up to 324.33 days. The treatment T_8 also registered prolonged duration of 313.67 days. Significant earliness in crop maturation was noticed with treatments T_4 (270 days) which was on a par with T_5 (274days) and T_1 (277 days). T_4 thus had an advantage of one week earliness in crop harvest compared to T_1, the KAU recommended nutrient addition.

4.1.8 Number of suckers

Sucker production plant^{-1} was observed at harvest stage and it ranged between 3 to 4. The eight different treatments could not significantly influence sucker production (Table 10).

4.2 EFFECT OF PLANT NUTRITION ON YIELD ATTRIBUTES AND YIELD

4.2.1 Number of hands bunch^{-1}

Data pertaining to the number of hands bunch^{-1} is presented in Table 11. Comparable and significantly higher number of hands bunch^{-1} were recorded in treatments T_4 (4.33), T_5 (4.11), T_1 (4.0), T_2 (4.0), T_6 (4.0) and T_3 (3.97). The number of hands bunch^{-1} was significantly inferior for treatment T_7 (3.11).

Table10. Effect of treatment on number of suckers

Treatments	Number of suckers
T_1	3.33
T_2	3.67
T_3	3.67
T_4	4.0
T_5	3.67
T_6	3.33
T_7	3.33
T_8	3.33
SEm (±)	0.312
CD (0.05)	NS

Table 11. Effect of treatments on number of hands bunch^{-1}, number of fingers bunch^{-1} and number of fingers in D hand

Treatments	No. of hands bunch^{-1}	No. of fingers bunch^{-1}	No. of fingers in D hand
T_1	4.00	39.11	8.00
T_2	4.00	38.87	8.33
T_3	3.97	37.22	7.67
T_4	4.33	41.66	10.0
T_5	4.11	40.33	10.0
T_6	4.00	37.55	8.67
T_7	3.11	28.55	8.00
T_8	3.66	29.55	8.00
SEm (±)	0.098	1.154	0.689
CD (0.05)	0.354	3.521	NS

4.2.2 Number of fingers bunch^{-1}

The data on the number of fingers bunch^{-1} for *Nendran* banana under the study is presented in Table 11. Treatments T_4 (41.66), T_5 (40.33), T_1 (39.11) and T_2 (38.87) recorded comparable and significantly higher values for number of fingers. The number of finger bunch^{-1} was found significantly lower for the two treatments T_7 (28.55) and T_8 (29.55).

4.2.3 Number of fingers in D hand

The number of fingers in D hand was observed and the data is presented in Table 11. The different treatments failed to produce any significant influence on the number of fingers in D hand.

4.2.4 Weight of D finger

The data on weight of D finger are presented in Table 12. Treatment T_4 recorded the significantly higher finger weight of 245.46 g for D finger and it was comparable to T_5 (233.13 g). KAU recommended nutrient addition (T_1) could record a finger weight of 229.40 g for D finger, comparable to treatment T_5. Significantly lower D finger weights were noticed with two treatments T_7 (185.86 g) and T_8 (193.09 g), which received only foliar nutrition of fertilizers apart from the basal dose of organics.

4.2.5 Length of D finger

Data obtained on the length of D finger for *Nendran* banana is detailed in Table 12. Treatment T_4 recorded significantly longer D fingers (21.81 cm) and it was comparable to treatment T_5 (20.95 cm). T_1 i.e., the treatment which received the KAU recommended nutrients recorded a finger length of 19.36 cm and it was on a par with treatments T_6 , T_2 , T_3 and T_8. Significantly shorter D finger length was noticed with T_7 (16 cm) in comparison to all other treatments.

Table 12. Effect of treatments on weight, length and girth of D finger

Treatments	Weight of D finger (g)	Length of D finger (cm)	Girth of D finger (cm)
T_1	229.40	19.36	12.73
T_2	214.46	18.75	12.17
T_3	210.63	18.30	10.73
T_4	245.46	21.81	14.97
T_5	233.13	20.95	14.61
T_6	214.95	19.33	12.5
T_7	185.86	16.00	8.60
T_8	193.09	17.49	10.62
SEm (±)	4.202	0.638	0.592
CD (0.05)	12.748	1.894	1.795

4.2.6 Girth of D finger

The observations made on the girth of D finger is presented in Table 12. The girth of D finger was significantly superior for treatments T_4 (14.97cm) and T_5 (14.67 cm). The treatment T_1, which received the KAU recommended nutrient addition could record a girth of 12.73 cm for D finger and this was comparable to T_2 (75% of KAU recommended nutrient addition + foliar spray of 19:19:19 (0.5%) at 2 and 4 MAP) and T_6 (60 % of KAU recommended nutrient addition + foliar sprays of 19:19:19 (0.5%) at 2 and 4 MAP + Banana micromix (1%) at 3 MAP). The D finger girth was significantly reduced in treatment T_7 (8.60 cm).

4.2.7 Peduncle length

The data on peduncle length of fruit bunches is presented in Table 13. Significantly shorter peduncle lengths were observed with treatments T_4 (29.83cm) T_1 (30 cm), T_5 (30.6 cm) and T_2 (31.5 cm). For treatments T_7 (35.6cm) and T_8 (35.17 cm), the peduncle lengths were significantly higher compared to all other treatments.

4.2.8 Bunch weight

The average bunch weight plant $^{-1}$ were observed at harvest and the data is presented in Table 13. Significantly higher and comparable bunch weights were observed with treatments T_4 (10.14 kg) and T_5 (9.83kg). This was followed by T_1 (9.0 kg) and T_2 (8.67 kg) which recorded on par yields. Bunch weight was significantly reduced in treatments T_7 (5.62 kg) and T_8 (5.82 kg) compared to all other treatments.

4.2.9 Yield

The yield data was worked out in t ha^{-1} (Table 13). The data followed the same trend as with average bunch weight plant^{-1}. T_4 and T_5 recorded significantly superior and comparable yields of 25.34 t ha^{-1} and 24.58 t ha^{-1} respectively. This was followed by the comparable yields of T_1 (22.50 t ha^{-1}) and T_2 (21.67 t ha^{-1}). Crop yield was significantly reduced in treatments T_7 (14.04 t ha^{-1}) and T_8

Table 13. Effect of treatments on yield characters and yield

Treatments	Total DMP (t ha^{-1})	Peduncle length (cm)	Bunch weight (kg)	Yield (t ha^{-1})
T_1	21.75	30.00	9.00	22.50
T_2	17.78	31.50	8.67	21.67
T_3	17.29	33.00	8.11	20.27
T_4	26.07	29.83	10.14	25.34
T_5	24.78	30.60	9.83	24.58
T_6	18.49	32.00	8.27	20.66
T_7	14.88	35.60	5.62	14.04
T_8	15.33	35.17	5.82	14.54
SEm(±)	1.046	0.564	0.124	0.311
CD (0.05)	3.202	1.690	0.381	0.942

(14.54 t ha^{-1}), inferior to all other treatments. A 13 per cent increase in yield was observed with T_4 in comparison to T_1, the KAU recommended nutrient addition.

4.2.10 Total dry matter production

The data on the influence of different treatments on total dry matter production is presented in Table 13. Total DMP was found significantly higher and comparable for treatments T_4 (26.07 t ha^{-1}) and T_5 (24.78 t ha^{-1}). In T_1 (KAU recommended nutrient addition), the DMP (21.75 t ha^{-1}) was found comparable to that with T_5. Significant reduction in DMP was recorded with treatments T_7 (14.88 t ha^{-1}), T_8 (15.33 t ha^{-1}), T_3 (17.29 t ha^{-1}) and T_2 (17.78 t ha^{-1}).

4.3 EFFECT OF PLANT NUTRITION ON YIELD ATTRIBUTES AND YIELD

4.3.1. TSS

The data on TSS of banana fruits is presented in Table 14. Significantly superior TSS was observed in treatment T_4 (34.67 $^0 B_x$) followed by comparable TSS in treatments T_6 (33.1$^0 B_x$) and T_5 (33$^0 B_x$). The TSS values were the lowest for T_7 (26.37 $^0 B_x$) and this was significantly inferior to all other treatments.

4.3.2. Acidity

The data on acidity of banana fruit is presented in Table 14. Lower acidity is considered good with regard to quality of banana fruit. The treatment T_4 (KAU recommended nutrient addition + micronutrient foliar spray) registered the significantly lowest acidity of 0.31 per cent, superior to all other treatments. This was followed by T_5 (75% POP + foliar spray of 19:19:19 (0.5%) at 2 and 4 MAP+ banana micromix (1%) at 3MAP) which registered lower acidity of 0.32 per cent. Significantly higher acidity (0.70%) was registered with treatment T_7. Acidity of 0.46 per cent was noticed with T_1, the KAU recommended nutrition for banana.

Table 14. Effect of treatments on TSS, Acidity and TSS/Acid ratio

Treatments	TSS (^0B_x)	Acidity (%)	TSS/Acid ratio
T_1	32.13	0.46	69.88
T_2	30.13	0.49	60.47
T_3	29.93	0.63	47.53
T_4	34.67	0.31	114.91
T_5	33.00	0.32	104.73
T_6	33.10	0.51	60.19
T_7	26.37	0.70	40.11
T_8	27.23	0.65	38.68
SEm (±)	0.160	0.002	1.780
CD (0.05)	0 .486	0.003	5.390

4.3.3. TSS/Acid Ratio

The data on TSS/Acid ratio is presented in Table 14. The treatment T_4 which recorded the highest value for TSS and lowest value for acidity registered the highest value for TSS / Acid ratio (114.91), significantly superior to all other treatments. This was followed by T_5 (104.73). The lowest TSS/Acid ratio of 38.68 was recorded by the treatment T_8. The treatment T_1 (KAU recommended nutrient addition) could record a TSS/Acid ratio of 69.88. The highest TSS/Acid ratio recorded by treatment T_4 was 65 per cent higher than that recorded with T_1.

4.3.4. Total sugars

The data on the total sugar content of banana fruit under each treatment are presented in Table 15. The total sugar content was found higher and comparable in two treatments viz., T_4 (19.11 per cent) and T_5 (18.82 per cent). Significantly lowest total sugar content was recorded with T_7 (13.04 per cent). The treatment T_1 (KAU POP recommendation) recorded a total sugar content of 17.92 per cent and was comparable to T_2 [75% of recommended N, P and K + foliar spray of 19:19:19 (0.5%) at 2 and 4MAP] which recorded a sugar content of 17.25 per cent.

4.3.5. Cracks in fruit peel

No cracks in fruit peel were observed in any of the treatments under study.

4.3.6. Shelf life

The effect of different treatments on the shelf life of banana fruits is recorded in Table 15. Significantly enhanced and comparable shelf life of fruits were noticed with the treatments T_5 (8.82 days), T_4 (8.66 days) and T_2 (8.31 days). T_1 (KAU recommended nutrient addition) recorded a shelf life of 8.05 days and was comparable to T_6 (7.59), T_8 (7.56) and T_7 (7.19).

Table15. Effect of treatments on total sugars, shelf life and pulp: peel ratio

Treatments	Total sugars (%)	Shelf life (Days)	Pulp: peel ratio
T_1	17.92	8.05	2.25
T_2	17.25	8.31	2.41
T_3	16.95	7.74	2.38
T_4	19.11	8.66	2.58
T_5	18.82	8.82	2.46
T_6	16.66	7.59	2.36
T_7	13.04	7.19	2.26
T_8	14.21	7.56	2.32
SEm (±)	0.158	0.336	0.044
CD (0.05)	0.473	1.012	0.131

4.3.7 Pulp: peel ratio

The data on pulp : peel ratio of banana fruits recorded under different treatments are given in Table 15. Treatment T_4 (KAU recommended nutrient addition + micronutrient foliar spray) recorded significantly highest pulp : peel ratio of 2.58, comparable to that recorded by T_5 (2.46). This was followed by T_2 (2.41) and T_3 (2.38) recording comparable values for pulp: peel ratio as with T_5. The lowest pulp: peel ratio of 2.25 was recorded by T_7 and it was on par with T_8 (2.26).

4.4 EFFECT OF PLANT NUTRITION ON NUTRIENT UPTAKE

4.4.1. Uptake of Nitrogen, Phosphorus and Potassium

Plant samples collected at harvest stage were analysed for nutrient content and the uptake values were worked out in kg ha^{-1}. Nutrient uptake with regard to the major nutrients N, P and K are presented in Table 16. Significantly higher uptake of nitrogen and phosphorus was recorded by the treatment T_4 (KAU recommended nutrient addition + micronutrient foliar spray) whereas with regard to potassium, T_4 and T_5 recorded higher and comparable uptake of 781.65 and 714.71 kg ha^{-1} respectively. Uptake of all the three major nutrients were lower in treatments T_7 [19:19:19 (0.5%) foliar nutrition alone in addition to soil application of organic manures] and T_8 [T_7 + banana micromix (1%)].

4.5. EFFECT OF PLANT NUTRITION ON SOIL NUTRIENT STATUS

The data on soil analysis with regard to pH, organic carbon and available status of nitrogen, phosphorous and potassium after the experiment are presented in Table 17. None of the treatments could significantly influence the pH and organic carbon status of the soil but significant influence was noticed with the regard to available N and K. Available P however remained unaffected by any of the treatments.

Table 16. Effect of treatments on N, P, and K uptake

Treatments	Uptake (kg ha^{-1})		
	N	P	K
T_1	243.97	22.04	447.02
T_2	206.54	21.48	427.95
T_3	167.51	17.89	374.06
T_4	403.04	48.85	781.65
T_5	334.00	35.04	714.71
T_6	220.22	22.22	525.29
T_7	165.41	10.94	235.12
T_8	183.38	12.89	267.91
SEm (±)	11.614	1.154	0.428
CD (0.05)	35.569	3.498	72.109

Table 17. Effect of treatments on soil pH, organic carbon and available soil nutrients after the experiment

Treatments	Soil pH	Organic carbon (%)	Available soil nutrients (kg ha^{-1})		
			N	P	K
T_1	5.04	0.91	270.38	32.33	255.11
T_2	5.02	0.90	269.23	31.63	252.98
T_3	5.02	0.91	251.18	31.45	251.25
T_4	5.05	0.91	271.99	31.48	257.00
T_5	5.07	0.82	271.02	32.51	252.87
T_6	5.04	0.79	248.78	31.02	240.87
T_7	4.99	0.89	217.35	30.86	193.68
T_8	4.98	0.85	211.55	30.73	196.44
SEm (±)	0.005	0.077	8.479	0.428	11.517
CD (0.05)	NS	NS	24.523	NS	20.491

The status of available N before the start of the experiment was 201 kg ha^{-1}. In all the treatments, the available N status was maintained above the initial level. Among the treatments, T_4 (271.99), T_5 (271.02), T_1 (270.38), T_2 (269.23), T_3 (251.18) and T_6 (248.78) recorded comparable and higher status of available nitrogen after the experiment. The same trend followed for available potassium also with treatments T_4, T_1, T_2, T_5, T_3 and T_6 recording higher status compared to the initial potassium status of 220 kg ha^{-1}. However in treatments T_7 (193.68) and T_8 (196.44) the available potassium status went below the initial level of 220 kg ha^{-1}.

4.6. EFFECT OF PLANT NUTRITION ON ECONOMICS

The data worked out on net returns (Lakh ₹ ha^{-1}) and B: C ratio are presented in Table 18.

4.6.1. Net income

Significantly higher and statistically comparable net income were recorded in treatments T_4 (₹ 5.88 lakhs) and T_5 (5.64 lakhs). T_1 , the KAU recommended nutrient addition recorded a net income of ₹ 4.76 lakhs ha^{-1} and it was on par with the net income of ₹ 4.5 lakhs ha^{-1} generated by T_2 (75% of KAU recommended nutrients + foliar spray of 19:19:19 (0.5%) at 2and 4 MAP). A reduction in the recommended nutrients to the tune of 25 per cent, when supplemented with foliar nutrition thus proved equivalent to 100 per cent of nutrient addition in influencing the net income from *Nendran* banana. The advantage in net income with respect to treatments T_4 and T_5 were 23.53 and 18.49 per cent higher compared to the KAU recommendation of nutrient addition (T_1). The net returns were significantly lower for treatments T_7 and T_8 which generated only ₹ 1.53 lakhs and ₹ 1.7 lakhs respectively on per hectare basis.

4.6.2 B: C ratio

The Benefit : Cost ratios were worked out for each treatment and is presented in Table 18. Significantly higher and comparable B: C ratios of 2.37 and 2.33 were obtained with treatments T_4 (KAU recommended nutrient

addition+ banana micromix (1%) foliar spray) and T_5 (75% POP + foliar spray of 19:19:19 (0.5%) at 2 and 4 MAP + banana micromix (1%) at 3MAP) respectively. This was followed by T_1, the KAU recommended nutrient addition (2.12) which was comparable to T_2 (2.07). Significantly lower and comparable B: C ratios were recorded with treatments T_7 (1.37) and T_8 (1.40) which received lesser dose of nutrients.

Table 18. Effect of treatments on net income and B: C Ratio

Treatments	Net income (lakhs ₹)	B: C ratio
T_1	4.76	2.12
T_2	4.50	2.07
T_3	4.00	1.97
T_4	5.88	2.37
T_5	5.64	2.33
T_6	4.14	1.99
T_7	1.53	1.37
T_8	1.70	1.40
SEm (±)	0.125	0.026
CD (0.05)	0.377	0.081

DISCUSSION

5. DISCUSSION

The investigation on "Foliar nutrition in *Nendran* banana using multinutrient water soluble fertilizers" was conducted at Coconut Research Station, Balaramapuram during 2016 April to 2017 February. The main objectives of the study were to assess the feasibility of foliar nutrition in reducing the fertilizer dose of nendran banana and to assess its impact on growth, yield, quality and economics. The results of the study are discussed in this chapter.

5.1 EFFECT OF PLANT NUTRITION ON GROWTH CHARACTERS

The different treatments on plant nutrition could significantly influence most of the growth characters of the crop at different growth stages. The characters like plant height, pseudostem height, pseudostem girth, leaf area index, functional leaf area etc were found significantly higher for treatments T_4 [100 % of KAU recommended nutrients + banana micro mix (1%)] and T_5 [75% of KAU recommended nutrients + 19:19:19 (0.5%) foliar spray + banana micro mix (1%]. In both these treatments significant decrease in the period for bunch emergence and total crop duration was also observed.

In treatments T_4 and T_5, in addition to the supply of major nutrients in substantial quantities, micronutrient addition also was ensured which could have directly influenced the growth of plants. In T_5 though a reduction was made in the recommended dose of soil applied chemical fertilizers, supplementation of major and micro nutrients was ensured with foliar sprays and it proved as equivalent to full dose of soil applied fertilizers in influencing crop growth. This comparable status of T_4 and T_5 in positively influencing growth could thus be interpreted as the efficiency of foliar application of plant nutrients which allows a reduction in the recommended dose of soil applied fertilizers. Several studies are in agreement with this result. Foliar application of 19:19:19 (0.5%) five times during crop growth stage along with the recommended dose of fertilizers recorded significantly higher plant height in hybrid tomato as reported by Premsanker and Rajashree (2009). They attributed the height increase to increased cell division

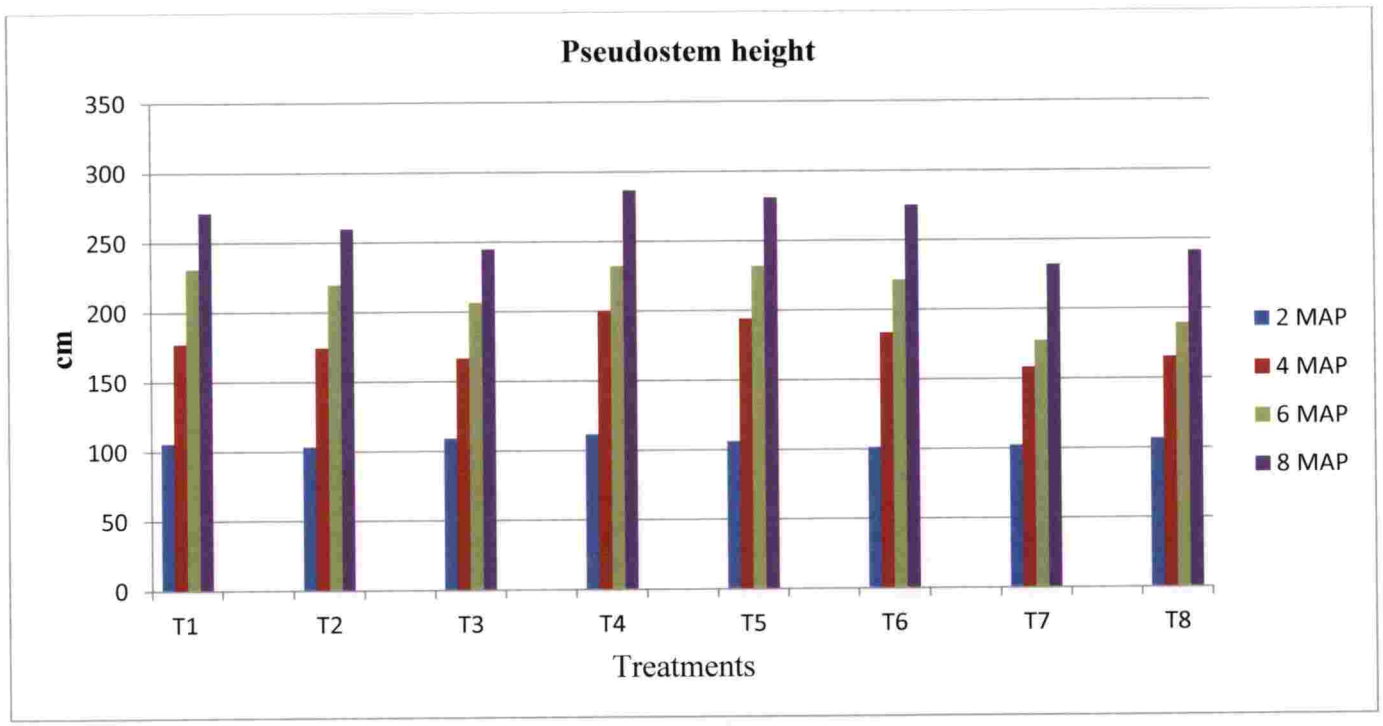


Fig.3. Influence of treatments on pseudostem height at bimonthly interval

and cell elongation at higher levels of nitrogen. The important role of micronutrients in improving cell elongation and cell division promoting better growth of banana has been reported by Kadar *et al.* (1992). The increased availability of plant nutrients in the rhizosphere as ensured with soil addition and the quick entry of nutrients into the plant system as assured with foliar application leading to better plant growth has been reported by several scientists who experimented with soil and foliar nutrition in a conjunctive manner (Mustaffa and Kumar, 2012; Uma and Karthik, 2017).

In the present study, an earliness of one week in the harvest of crop was noticed with T_4 (100 per cent of the recommended dose of fertilizers along with foliar spray of micronutrients) as compared to that of T_1 (KAU recommended nutrient addition). Krishnamoorthy *et al.*, (2017) experimented conjunctive application of recommended dose of fertilizers along with micronutrient mixture Arka banana special (3% Zn, 1.5% B, 1% Mn, 1.5% Fe) developed at IIHR Bangalore and reported significant improvement in growth characters including pseudostem girth, pseudostem height, numbers of leaves and maximum leaf area. They reported an earliness of 13 days with regard to shooting of poovan banana when the recommended dose of fertilizers were supplemented with soil and foliar application of micro nutrients, attributed to balanced plant nutrition.

The role of micro nutrients especially that of zinc in the physiological mechanisms leading to early crop maturity are established by many scientists. Hafeez *et al* (2013) reported delayed maturity and late harvest of many crops under zinc deficient conditions. Hence it could be assumed that the right combination of all essential nutrients as supplied with T_4 had significant favourable influence in the physiology of crop leading to improved growth characters including early maturity.

5.2 EFFECT OF PLANT NUTRITION ON YIELD ATTRIBUTES AND YIELD

As observed with growth characters, T_4 (100 % of KAU recommended nutrients + banana micro mix (1%) at 3MAP) and T_5 (75% POP+ 0.5% foliar

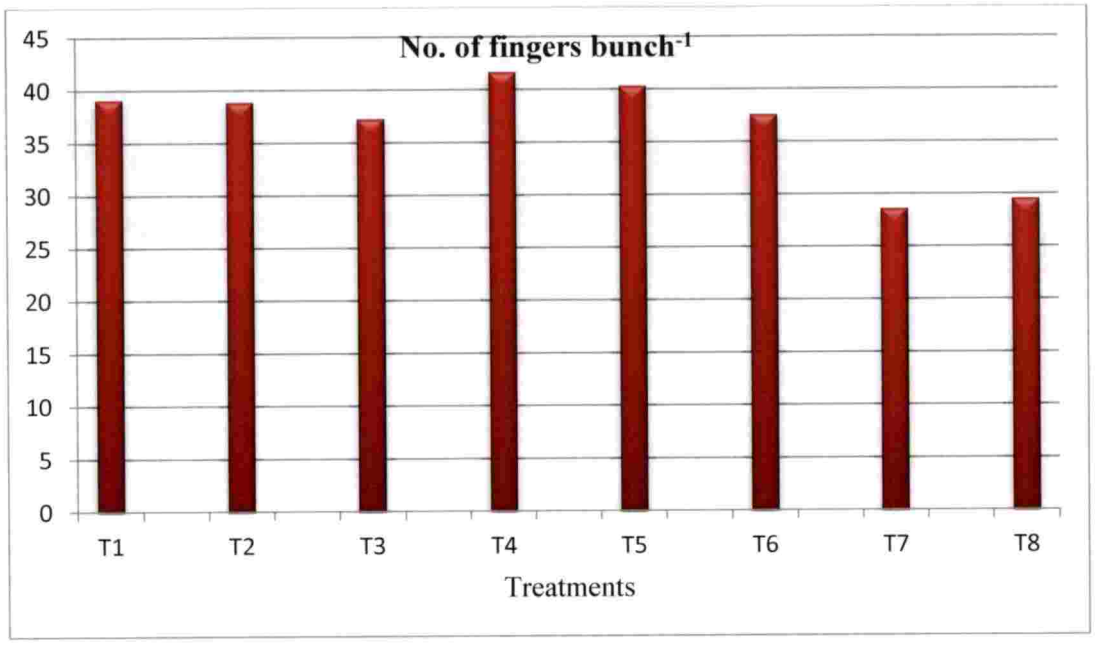


Fig.4 .Effect of treatments on number of fingers bunch^{-1}

spray of 19:19:19 at 2 and 4 MAP + banana micro mix (1%) at 3MAP) recorded significant improvement with regard to yield attributes as well as yield. These treatments received a well balanced supply of major and micro nutrients throughout the growth period which might have increased the photosynthetic efficiency of crop thereby improving the yield attributes and crop yield. A similar report has been made by Devi and Shanthi (2016) on the increased photosynthetic efficiency of chilli when supplemented with five sprays of 19:19:19 (1%) in addition to 100 per cent of the recommended dose of fertilizers. This is further evident from the LAI and functional leaf area.

Leaf area index (LAI) and functional leaf area are measures of photosynthetic efficiency of crops. Increase in LAI results in better utilization of solar energy leading to higher dry matter accumulation through photosynthesis and thereby directly influence crop production. In the present study, treatments T_4 and T_5 recorded significantly higher functional leaf area at active growth stages of 4 and 8MAP, compared to T_1, the POP recommended nutrient package. Leaf area is greatly influenced by plant nutrition. Rahman *et al.* (2014) studied wheat production in relation to LAI and reported progressive enhancement in LAI with increase in N levels up to 120 kg ha^{-1}, resulting in higher yields. Kuttimani *et al* (2013) studied INM in Grand naine banana and reported highest LAI under supply of 100% RDF + organic manure @10 kg $plant^{-1}$, which resulted in maximum yield. Under conditions of reduction in the recommended RDF and organic manure levels, LAI declined and this was reflected as yield reduction. Moreover, the functional leaf area at harvest was more in treatments T_4 and T_5. This again confirms the increased photosynthetic activity at later crop stages leading to better translocation of photosynthates to the fingers leading to higher yield. These observations suggest that the improved LAI as obtained with balanced nutrition in T_4 and T_5 is a major contributor to higher yields. Several scientists have also reported that with sufficient leaf area, foliar nutrition becomes more effective resulting in higher yields (Ling and Silberbush, 2007; Fageria *et al.*, 2009). This also could be related with the yield advantage in treatments T_4 and T_5 which received foliar nutrition.

Dry matter production is considered an indication that nutrients are readily and sufficiently available for crop growth (Kumar and Kumar, 2008). The significantly higher DMP recorded with treatments T_4 and T_5 therefore suggests that the crop was amply nourished with these treatments. Better uptake and translocation of nutrients were recorded by Thippesha *et al.* (2008) under higher levels of N, P and K leading to higher biomass accumulation and hence more DMP in *Robusta* banana. The same justification applies here also.

Significant reduction in yield was noticed with treatments T_7 and T_8 which received only foliar application of fertilizers at monthly intervals and no soil addition. The nutrient contribution through foliar fertilizer 19:19:19 was meagre in these treatments (95 per cent reduction in the supply N, P and K nutrients compared to RDN) which could be related with the yield decline. The reduction in yield in T_7 was up to 37 per cent compared to T_1, which received the recommended dose of nutrients. A similar report was made by Zafar *et al.* (2006) who reported that sole application of foliar N, P and K fertilizers resulted in declined yields , as leaves alone are not potent enough to fulfil the entire nutrient needs of crops. The reduction in yield as noticed with foliar nutrition alone in the present study could be related to the reduced supply of plant nutrients especially potassium. Plant nutrient potassium is highly important with regard to chlorophyll formation, photosynthesis, transport of sugars etc and is having a very important role in determining fruit yields. Under low potassium supply, the translocation of carbohydrates from leaves to fruit is restricted and the conversion of carbohydrates to starch is greatly reduced resulting in lower yields. Mahato *et al.* (2014) reported conspicuously reduced fruit yield in banana under conditions of low potassium with thin and fragile bunches.

The yield advantage observed in the present study with foliar sprays of water soluble fertilizers supplied in addition to the recommended dose of fertilizers is supported by research works of many scientists. Kavino *et al.* (2002) who experimented with banana cv. Robusta (AAA) at Coimbatore reported that soil application of 100% recommended dose of fertilizers along with foliar sprays

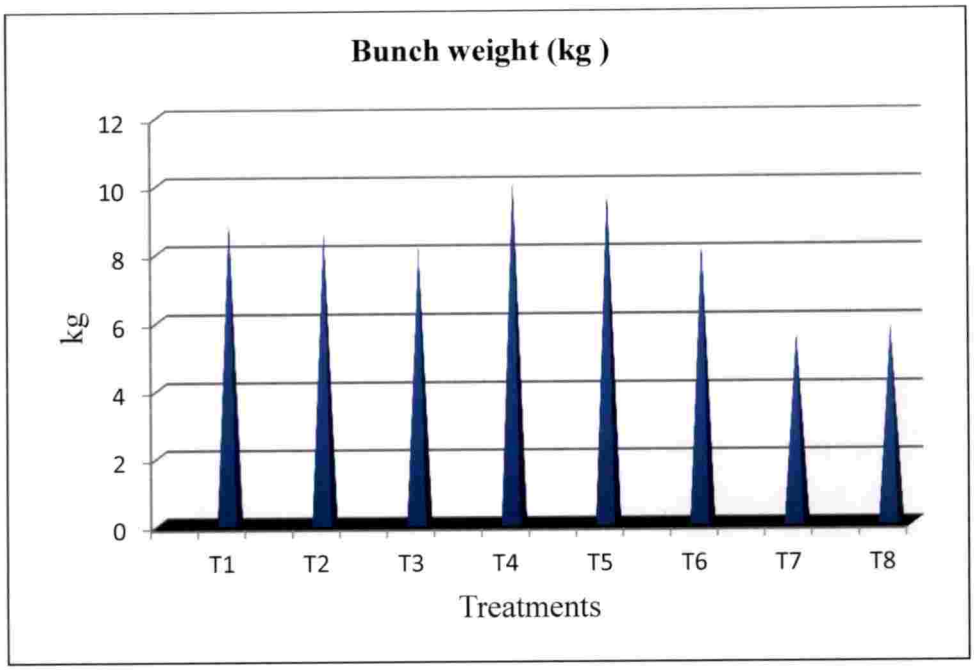


Fig.5. Bunch weight plant^{-1} as influenced by treatments

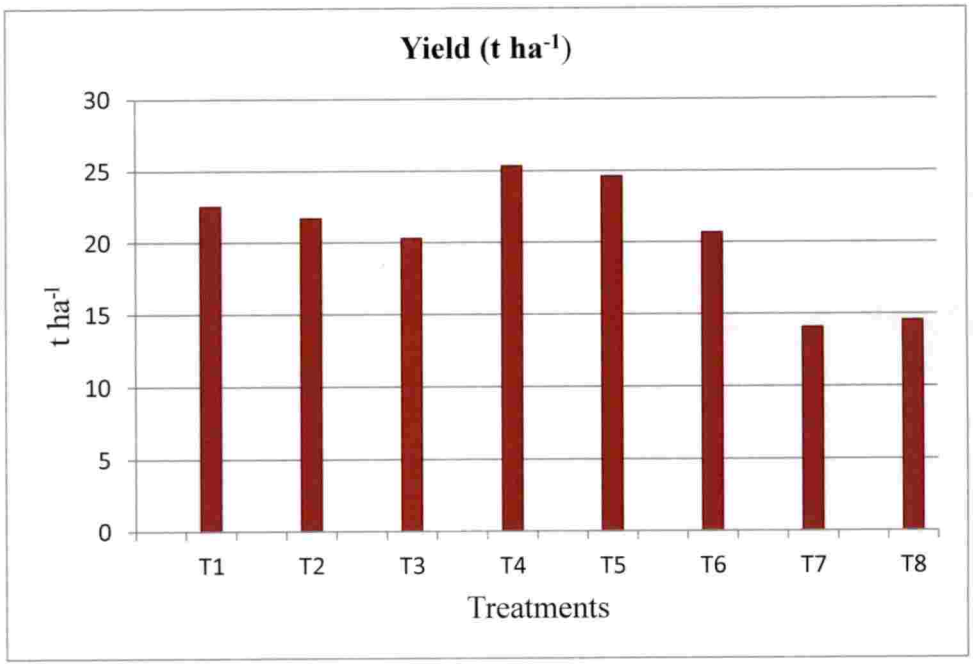


Fig. 6. Effect of treatments on per hectare yield

of water soluble fertilizers - mono ammonium phosphate, Multi - K and urea recorded maximum bunch weight, number of hands bunch^{-1}, number of fingers bunch^{-1}, finger weight and yield. They attributed this to the improved photosynthetic efficiency of crop under well balanced nutrition.

5.3 EFFECT OF PLANT NUTRITION ON QUALITY CHARACTERS

The study revealed that treatments which received well balanced nutrition inclusive of major and micro nutrients (treatments T_4 and T_5) recorded improvement in most of the quality parameters including total soluble solids and total sugars, whereas those which received lower dose nutrients (T_7 and T_8) performed inferior. Nutrition has a significant positive role on plant physiological mechanisms related to quality as established by many researchers. Potassium is the most important major nutrient in regulating the quality of fruits as the nutrient is involved in many aspects of plant physiology especially activation of many enzymes of physiological importance (Malvi, 2011)

Secondary nutrients like Mn activates enzymes involved in conversion of polysaccharides to simple sugars thereby increase TSS; micronutrients like B help translocation of more sugars thereby results in more of total sugars (Babu and Yadav, 2005). In the present study, treatments T_4 and T_5 recorded a favourable reduction in acidity. This could be related with the accumulation of sugars as evident from Tables 15. Patel *et al.* (2010) made a similar report of reduction in acidity in banana fruits with accumulation of more sugars.

Increased level of potassium is also reported to reduce the acidity of fruits (Tisdale and Nelson, 1966; Pattee and Teel, 1967). This occurs due to neutralisation of organic acids under an altered physiological mechanism under high level of potassium. Treatments T_4 and T_5 received sufficient quantities of potassium .The common dose of SOP given as pre harvest bunch spray might have been especially favourable for these treatments as because of synergistic interactions with K and S. Such synergistic interactions between these two nutrients have already been reported by Jat *et al.* (2017). Enhanced quality of

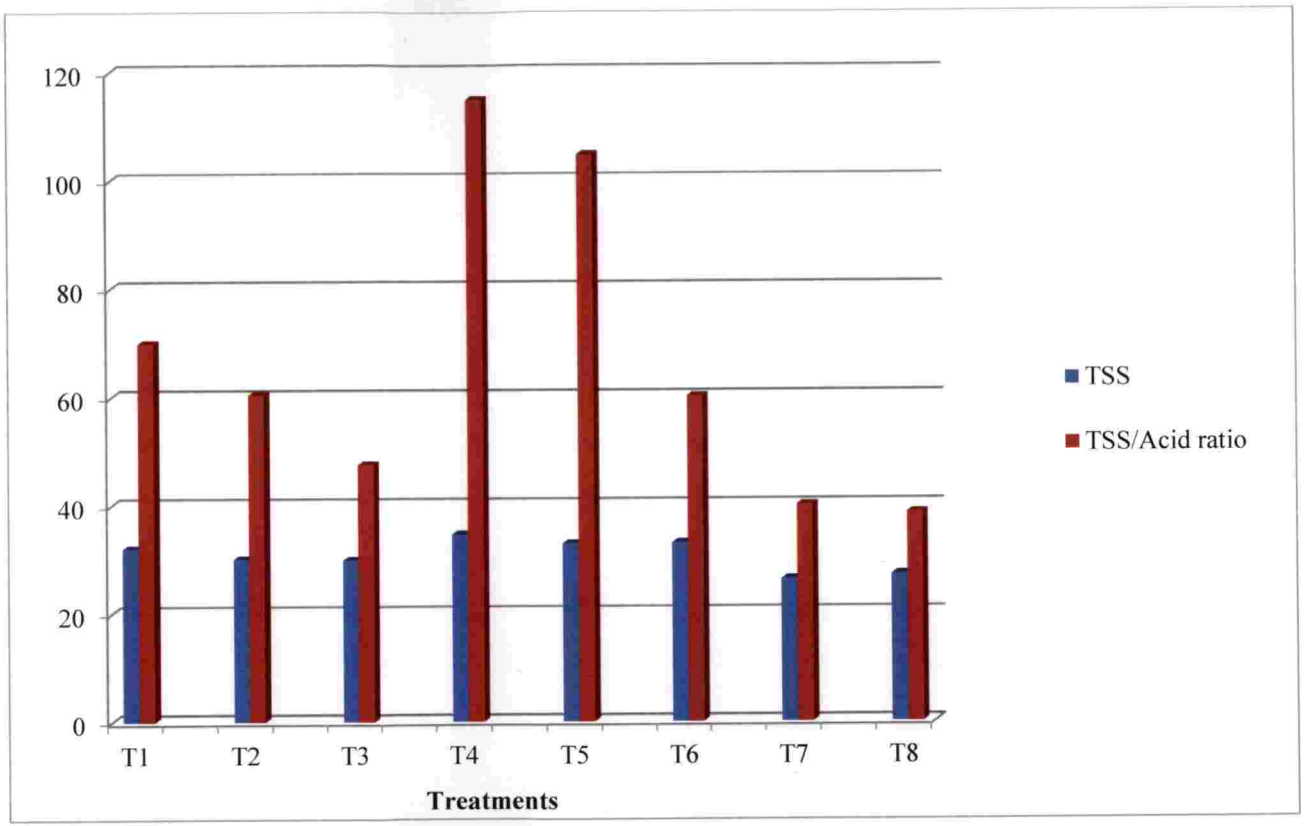


Fig.7. TSS (^{0} B_x) and TSS/acid ratio as influenced by different treatments

T_4

T_5

T_7

Plate.4. D hands from different treatments

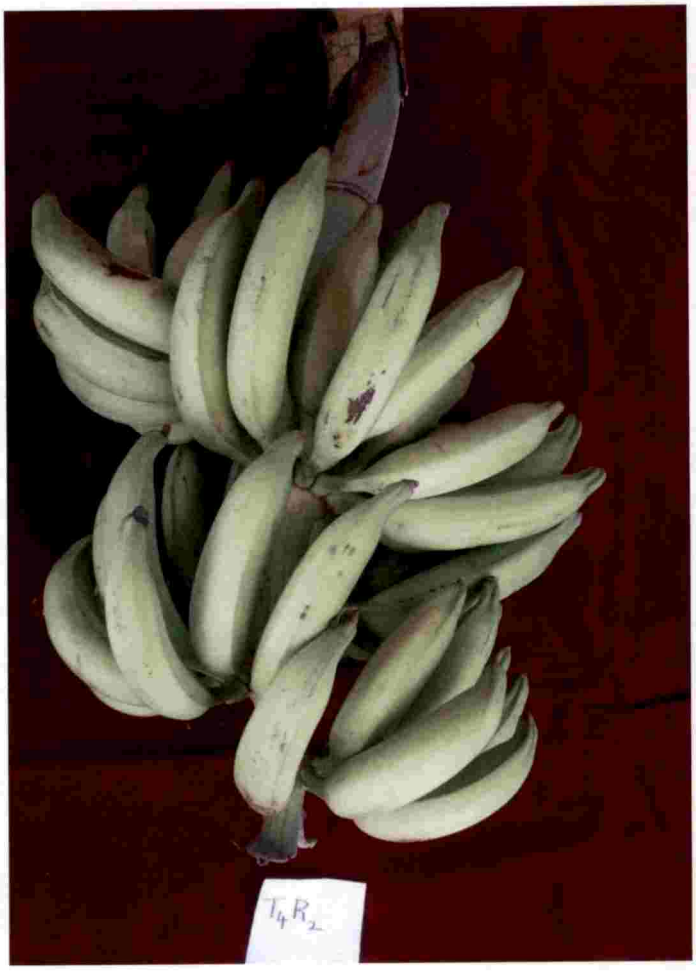


Plate.5. Banana bunch obtained fromT_4

fruits in terms of sugar content could also be due to the role of sulphate ions released from SOP, helping accumulation of highly polymerised carbohydrates which subsequently disintegrates into sugars (Ananthi, 2002).

The present study is in conformity to the findings of Kavino *et al.* (2002) who recorded improvement in quality aspects especially total soluble solids of banana cv. Robusta with 100 % of the recommended dose of fertilizers and additional foliar sprays. Ningavva *et al.* (2014) studied soil addition of fertilizers in conjunction with supply of micronutrients B and Zn as foliar sprays in Grand Naine banana. They reported improved quality of fruits with regard to higher pulp content which was attributed mainly to the role of micronutrients in rapid synthesis of carbohydrates and their translocation to fruits.

Potassium is referred as the "quality element" for crop production (Usherwood, 1985) and it is widely proven that this nutrient plays a crucial role in crop quality parameters including shelf life. The role of potassium in reducing physiological disorders including cracking of fruits and extension of shelf life is well established (Kumar *et al.*, 2006). According to them, potassium is involved in the activation of some 60 enzymes important in plant physiology. The shelf life was more with treatments T_5, T_4 and T1. Ample supply of the major nutrient potassium as ensured with these treatments could be related to the extended shelf life. Potassium improves fruit quality due to suppression of respiration and reduction in ethylene evolution (Hanumanthaiah *et al.*, 2015). All the treatments had received in common, two pre harvest bunch sprays of SOP. This could be related with the absence of fruit crack in all treatments studied. This finds similarity with the report of Patil (2016) who noticed reduced fruit crack in banana with bunch sprays of SOP.

5.4 EFFECT OF PLANT NUTRITION ON UPTAKE OF MAJOR NUTRIENTS

The uptake of major nutrients N, P and K recorded in the present study were significantly higher for treatments T_4 and T_5. Dry matter production was higher (Table 13) with these two treatments and this could be related with

higher nutrient uptake. Pseudostem height, pseudostem girth and leaf area which are contributors to dry matter production were also more with these two treatments towards harvest stage. The improvement in growth attributes could be related with the well balanced supply of major and minor nutrients as provided with treatments T_4 and T_5. This is in accordance with the findings of Thippesha *et al.*(2008) who recorded higher biomass accumulation in Robusta banana with higher levels of nutrient supply (360:250:500 g NPK $hill^{-1}$). According to them, low level of nitrogen and potassium restricted plant growth thereby reducing total dry matter production.

In treatments T_4 and T_5, supply of major nutrients N, P and K and micronutrients was well ensured. This could have resulted in synergistic interrelationships between nutrients resulting in better plant uptake. Especially, the synergism between major nutrients N and K are well established. Potassium is reported to have synergistic relationships with micronutrients Fe and Mn (Malvi, 2011) also. These reports suggest the favourable nutrient interactions in the present study under balanced plant nutrition leading to higher plant uptake.

In treatments T_7 and T_8, apart from the basal dose of organic manure, nutrients were provided only as foliar spray, that too in monthly interval and in limited quantities (0.5% concentration). In these two treatments, the availability of nutrients might have been considerably low attributed to reduced supply of nutrients (95 per cent reduction compared to RDN), which reflected in reduced uptake and poor growth of crop. Banana is a heavy feeder of plant nutrients and absorbs N, P and K nutrients to the average tune of 250, 60 and 1000 kg ha^{-1} respectively (Ganeshamurthy *et al* ., 2011). To replenish this heavy removal and to ensure better growth and yield, supply of sufficient quantities of nutrients are required at different stages of crop growth. The limited supply of major plant nutrients N, P and K through foliar nutrition (5 g of each nutrient per plant) might have been highly insufficient to register better crop growth and yield.

In treatment T_5, soil application was supplemented by foliar sprays of NPK nutrients and this could be result in the better performance of the treatment.

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Foliar applied nutrients enter the plant system in a more rapid manner compared to soil application and evoke early crop response and is considered more nutrient efficient (Oosterhuis and Weir, 2009)

The nutrient use efficiency is reported much high with water soluble fertilizers and this could be related with the better performance of T_5 comparable to T_4. In line with this result, Shimi (2014) reported that 60 per cent of the RDN given as fertigation using water soluble fertilizers in banana was as good as 100 per cent of soil application.

In support to these findings, Deolankar and Firake (1999) reported that 75% of the recommended dose of NPK given as fertigation using water soluble fertilizers was as good as 100% recommended dose of conventional fertilizers in irrigated chilli. Foliar spray of water soluble fertilizers 19:19:19 and KNO_3 both applied to crops at two concentrations (0.5 and 1%) in addition to RDF in chilli crop could well improve the uptake of major nutrients as well as that of secondary nutrient sulphur (Somimol, 2012).

5.5. EFFECT OF PLANT NUTRITION ON SOIL PROPERTIES

Soil pH and organic carbon after the experiment remained unaffected by any of the treatments. This could be related with the fact that organic manure addition was uniformly on (FYM @ 10 kg plant^{-1}) for all the treatments might have resulted through decomposition has occurred during crop growth in similar build up of soil organic carbon. The buffering action provided by the added organic manure might have been sufficient to maintain the pH levels. Also, liming done at the time of land preparation at a common dose which also could be a reason why there was not much fluctuations with soil pH.

The status of N and K in soil was significantly influenced by the treatments as observed in soil analysis after the experiment. The initial status of available N and K nutrients in soil were 201 and 200 kg ha^{-1} respectively. The available N in soil was found maintained above the initial status in all the treatments after the cropping phase. The treatments which supplied nutrients

through soil addition or through soil + foliar applications (T_4, T_5, T_1, T_2, T_3 and T_6) recorded comparable and higher status of available nitrogen after the experiment. It could be assumed that supply of the nutrients through organic manures and soil/foliar fertilizers might have been sufficient enough not to deplete the soil reserves and well maintain soil N. In treatments T_7 and T_8, significant decline in soil available N compared to other treatments was noticed after the cropping phase which could be related with the reduction in the supply of the nutrient.

Similar trend was noticed with soil available potassium also with comparable and higher status of potassium were in treatments T_4, T_5 , T_1, T_2, T_3 and T_6 . Significant decline in soil available K (even below the initial status of 200 kg ha^{-1}) was noticed in treatments T_7 and T_8 (193.68 and 196.44 kg ha^{-1} respectively). Potassium is regarded as a key element in banana nutrition. The crop being a heavy feeder of potassium requires nearly 1500 kg of K_2O ha^{-1} (Bhalerao *et al.*, 2008). Hence an insufficient addition of the nutrient might have resulted in depletion of available soil reserves in treatments T_7 and T_8, after crop harvest. Potassium requirement for *Nendran* banana is regarded as 1.58 times more than nitrogen as evident from the NPK recommendation of 190:115: 300 g plant $^{-1}$ as per KAU (2016). This could be related with the finding that though soil N was not depleted, soil K was.

5.6 EFFECT OF PLANT NUTRITION ON ECONOMICS

The economics of cultivation in terms of net income and B: C ratio was significantly higher for treatments T_4 and T_5. These treatments registered increase in net income to the tune of 24 and 19 per cent over T_1, the nutrient recommendation by KAU. These two treatments received well balanced nutrition including micronutrients and therefore recorded higher yields which contributed to higher net returns and B: C ratios. In treatments T_7 and T_8, though the soil addition of chemical fertilizers were omitted, there was monthly application of water soluble fertilizers, which contributed to a nearly equivalent cost owing to that incurred on water soluble fertilizers and labour cost for application. Besides,

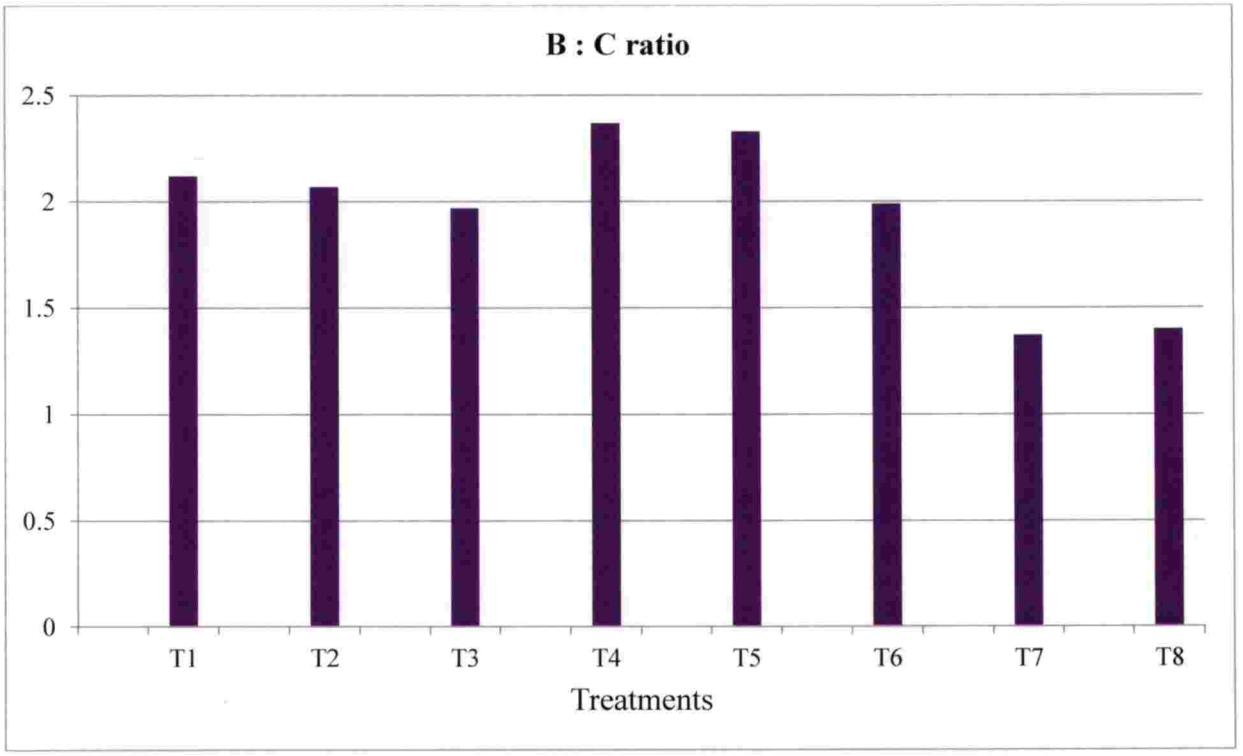

Fig.8. B: C ratio as influenced by different treatments

the yield obtained from these two treatments were low which is attributed to the under nutrition of the crop. These factors led to decline in net returns and B: C ratio from T_7 and T_8.

In treatment T_5, there was a slight reduction in cost of cultivation compared to T_4, (Appendix II) which could be attributed to the saving of chemical fertilizers up to the tune of 25 per cent when supplemented with two foliar sprays of 19:19:19 at a lower dose of 0.5 per cent. Also it could be assumed that foliar nutrition in T_5 was efficient enough to generate comparable yields as that with treatment T_4 and hence both the treatments recorded comparable net returns and B: C ratios. Narayanan *et al.* (2012) observed higher net returns and B : C ratio in tomato when the recommended NPK dose was reduced by 12.5 per cent and supplemented with two foliar sprays of 19:19:19 (2%) at vegetative and flowering stages.

In both T_4 and T_5, micro nutrient supply was ensured which resulted in yield advantage and hence better economic returns. From the nutrition studies in Basrai banana, Patel *et al.* (2010) reported that micronutrients supplied as foliar spray (0.5% Zn SO_4 and 0.5% Fe SO_4) in addition to the RDF at 3, 5 and 7 months of planting could result in the highest B: C ratio of 1.94 whereas supply of 100 per cent RDF alone could achieve a B : C ratio of 1.29 only. A nutrition trial conducted in KAU by Paul (2015) in *Nendran* banana revealed the yield advantage with supplemental foliar sprays. In this study, the net returns were significantly higher when the recommended dose of N, P and K nutrients were supplemented with foliar sprays of micronutrient mixture (Zn, Fe, Cu, B and Mo).

SUMMARY

6. SUMMARY

The investigation entitled "Foliar nutrition in *Nendran* banana using multinutrient water soluble fertilizers" was conducted at the Coconut Research station, Balaramapuram, Kerala Agricultural University during 2016 April - 2017 February. The objective of the experiment was to assess the feasibility of foliar nutrition in reducing the fertilizer dose of *Nendran* banana and also to study its impact on growth, yield, quality and economics. The experiment was laid out in randomised block design with eight treatments and three replications. The treatments were T_1 (KAU - POP recommended dose of nutrients (RDN), T_2 (75% RDN+ foliar spray of 19:19:19 (0.5%) at 2 and 4 months after planting (MAP)), T_3 (60% RDN+ foliar spray of 19:19:19 (0.5%) at 2 and 4 MAP), T_4 (T_1 + foliar spray of micronutrient mixture - KAU banana micromix (1%) at 3 MAP),T_5 (T_2 + foliar spray of KAU banana micromix (1%) at 3 MAP), T_6 (T_3 + foliar spray of KAU banana micromix (1%) at 3 MAP),T_7 (foliar spray of 19:19:19 fertilizer mixture (0.5%) 7 times, at monthly intervals after planting) and T_8 (T_7 + foliar spray of KAU banana micromix (1%) at 3 MAP). Organic manure (10 kg plant $^{-1}$) applied as basal and two pre harvest bunch sprays of Sulphate of Potash (3%) at 2 and 4 weeks after bunch emergence were given uniformly to all treatments. The salient findings of the study are summarised below.

The different treatments on plant nutrition could significantly influence most of the growth characters of the crop in most stages of the study. The characters like plant height, pseudostem height, pseudostem girth, leaf area index and functional leaf area were significantly higher for treatments T_4 (KAU - POP recommended nutrient dose + foliar spray of KAU banana micromix (1%)) at 3 MAP) and T_5 (75 % of RDN along with foliar sprays of 19:19:19 (0.5%) at 2 and 4 MAP and KAU banana micromix (1%) at 3 MAP).

At 4, 6 and 8 MAP, T_4 and T_5 registered significantly higher and comparable LAI. At the active growth stage of 6 months of planting, these treatments registered LAI of 4.69 and 4.37 respectively. The same treatments

also registered significantly higher functional leaf area at growth stages of 4 and 8 MAP in comparison with T_1, the KAU - POP recommended nutrient dose.

Significant and favourable decrease in the time for bunch emergence and total crop duration also were recorded for the treatments T_4 and T_5. For treatment T_7 (addition of basal organic manure along with foliar sprays of 19:19:19 (0.5%) 7 times at monthly intervals), the crop duration was significantly prolonged up to 324.33 days. Treatment T_8 (T_7 + foliar spray of KAU banana micromix (1%) at 3 MAP) also registered a lengthy crop duration of 313.67 days. Among the eight treatments studied, significant earliness in crop duration was noticed with treatment T_4 (270 days) comparable to T_5 (274 days) and T_1 (277 days). Sucker production plant^{-1} was observed at harvest stage and it ranged between 3 to 4. The eight different treatments could not significantly influence the production of suckers.

As observed with growth characters, T_4 and T_5 recorded significant enhancement in yield attributes as well as yield. The number of hands bunch^{-1} and number of fingers bunch^{-1} were significantly higher with these two treatments. T_4 registered significantly superior finger weight (245.46 g), length (21.81 cm) and girth (14.97cm) for the index (D) finger and was comparable to T_5. Significantly shorter peduncles were observed with treatments T_4 (29.83cm) T_1 (30 cm), T_5 (30.6 cm) and T_2 (31.5 cm). For treatments T_7 (35.6cm) and T_8 (35.17 cm), the peduncle lengths were significantly higher compared to all other treatments.

Significantly higher and comparable bunch weight plant^{-1} were observed with treatments T_4 (10.14 kg) and T_5 (9.83 kg). This was followed by T_1 (9.0 kg) and T_2 (8.67 kg) which recorded comparable yields. Bunch weight was significantly reduced in treatments T_7 (5.62 kg) and T_8 (5.82 kg) compared to all other treatments. The same trend followed for per hectare yield of crop recorded in tonnes.

DMP was more with T_4 (26.07 t ha^{-1}) and T_5 (24.78 t ha^{-1}) towards harvest stage. This was followed by T_1, which recorded a DMP of 21.75 t ha^{-1}.

Significant reduction in DMP was recorded with treatments T_7 (14.88 t ha^{-1}), T_8 (15.33 t ha^{-1}), T_3 (17.29 t ha^{-1}) and T_2 (17.78 t ha^{-1}). Higher dry matter production (DMP) obtained with these treatments is related with the higher uptake of plant nutrients. Treatment T_4 which registered the highest DMP recorded the highest uptake of plant nutrients - nitrogen and phosphorus . With regard to potassium, T_4 and T_5 recorded higher and comparable uptake values of 781.65 and 714.71 kg ha^{-1} respectively.

Treatments which received well balanced nutrition of both major and micro nutrients (T_4 and T_5) recorded improvement in most of the quality parameters whereas those which received only lower dose of nutrients (T_7 and T_8) performed inferior. Higher and comparable values for total sugar content (19.11 and 18.82 % respectively) and shelf lives (8.66 and 8.82 days respectively) were recorded with treatments T_4 and T_5. Significantly superior TSS (34.67 ^{0} B_x), TSS/Acid ratio (114.92), Pulp: Peel ratio (2.58) and a favourable reduction in acidity (0.31 per cent) were recorded with treatment T_4.

None of the treatments could significantly influence the pH and organic carbon status of the soil after the experiment. Significant influence was noticed in the available N and K status of soil after the experiment, whereas available P remained unaffected by any of the treatments. In all the treatments, the available N status was maintained above the initial level. Higher status of available nitrogen (kg ha^{-1}) after the experiment was recorded with T_4 (271.99), T_5 (271.02), T_1 (270.38), T_2 (269.23), T_3 (251.18) and T_6 (248.78). These treatments recorded higher status of available potassium also. In treatments T_7 (193.68) and T_8 (196.44), the available potassium status went below the initial level of 220 kg ha^{-1}, related to the reduction in the supply of the nutrient.

Significantly higher and statistically comparable net income were recorded with treatments T_4 (₹.5.88 lakhs) and T_5 (₹ 5.64 lakhs). T_1, the KAU recommended nutrient addition recorded a net income of ₹ 4.76 lakhs ha^{-1} and was comparable to T_2 (₹.4.5 lakhs ha^{-1}). Significantly higher and comparable B: C ratios of 2.37 and 2.33 were obtained with treatments T_4 and T_5 respectively. This was followed by T_1 (2.12). Significantly lower and comparable B: C ratios were

recorded with treatments T_7 (1.37) and T_8 (1.40) which received lesser dose of nutrients.

Future line of work

The study recorded the significant favourable influence of conjunctive soil and foliar nutrition in achieving higher yield and returns from *Nendran* banana. It was also observed that application of foliar fertilizers (19:19:19 mixture at 0.5% concentration) at monthly intervals only (given in addition to the basal dose of organic manures) was found highly insufficient to meet the nutrient demands of a heavy feeder crop like banana. Hence it could be recommended that trials on foliar feeding of banana could be carried out with water soluble fertilizer mixtures like 19:19:19 in higher concentrations and more frequent intervals than what was experimented in the present trial and to standardize the extent to which the chemical fertilizers be substituted by providing supplemental foliar nutrition.

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FOLIAR NUTRITION IN *NENDRAN* BANANA USING MULTINUTRIENT WATER SOLUBLE FERTILIZERS

by

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Abstract of the thesis

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ABSTRACT

The investigation entitled "Foliar nutrition in nendran banana using multinutrient water soluble fertilizers" was conducted at Coconut Research Station, Balaramapuram, Kerala Agricultural University during 2016 April - 2017 February. The objective of the experiment was to assess the feasibility of foliar nutrition in reducing the fertilizer dose of *Nendran banana* and to study the impact of foliar nutrition on growth, yield, quality and economics. The experiment was laid out in randomized block design with eight treatments and three replications. The treatments were T_1 (KAU- POP recommended dose of nutrients (RDN), T_2 (75% RDN+ 19:19:19 (0.5%) foliar spray at 2 and 4 months after planting (MAP), T_3 (60% RDN+ 19:19:19 (0.5%) foliar spray at 2 and 4 MAP), T_4 (T_1 + foliar spray of micronutrient mixture - KAU banana micromix (1%) at 3 MAP),T_5 (T_2 + foliar spray of KAU banana micromix (1%) at 3 MAP),T_6 (T_3 + foliar spray of KAU banana micromix (1%) at 3 MAP),T_7 (foliar spray of 19:19:19 fertilizer mixture (0.5%) 7 times, at monthly intervals after planting) and T_8 (T_7 + foliar spray of KAU banana micromix (1%) at 3 MAP). Organic manure (10 kg plant $^{-1}$) applied as basal and two pre harvest bunch sprays of Sulphate of Potash (3%) at 2 and 4 weeks after bunch emergence were given uniformly to all treatments.

As per the results of the investigation, T_4 (KAU recommended nutrient addition + foliar spray of micronutrient mixture - KAU banana micromix (1%) at 3 MAP) could record significant improvement in growth characters including plant height, pseudostem height, plant girth, leaf area index and functional leaf area and was comparable to T_5 at most of the growth stages. The treatment which received only foliar sprays of nutrients at monthly intervals apart from the basal dose of organics (T_7) recorded significant delay in bunch emergence (234.33 days) and prolonged crop duration up to 324.33 days. Early bunch emergence and shorter crop duration were observed in T_4 and T_5. The treatment T_4 recorded higher values for yield attributes including number of hands bunch^{-1}

(4.33), fingers bunch^{-1} (41.66), weight (245.5g), length (21.81cm) and girth (14.97 cm) of D finger and was comparable to treatment T_5. Bunch weight was significantly higher for T_4 (10.14 kg) and was comparable to T_5 (9.83 kg). An increase in yield of crop to the tune of 13 per cent was observed in T_4 compared to KAU recommended nutrient addition (T_1). Quality attributes like TSS, TSS/acid ratio, total sugars and Pulp Peel ratio were the highest in T_4. The same treatment recorded a favourable reduction in acidity (0.31%). The shelf life of fruits was significantly higher in T_5 (8.82 days) and was comparable to T_4, T_1 and T_2.

Treatment T_4 recorded significantly higher uptake of major nutrients nitrogen, phosphorus and potassium. Available N and K status of soil after the experiment was found higher and comparable for treatments which received soil addition of organic manures and inorganic fertilizers (T_4, T_5, T_1 and T_2), whereas treatments T_7 and T_8 which received only foliar nutrition of water soluble fertilizers apart from basal dose of organic manures recorded only lower status of available N and K.

The treatment T_4 recorded significantly higher net income (₹ 5.88 lakhs ha^{-1}) and B: C ratio (2.37) and was comparable to T_5. Treatment T_1 registered a net income of ₹ 4.76 lakhs ha^{-1} and a B: C ratio of 2.12.

From the results of the study it was inferred that 75 per cent of the RDN when supplemented with foliar sprays of 19: 19:19 (0.5%) at 2 and 4 MAP and KAU banana micromix (1%) at 3 MAP (T_5) resulted in higher yield of *Nendran* banana which was on par with 100 per cent of RDN and foliar spray of KAU banana micromix (1%) at 3 MAP (T_4). The treatment T_5 saved 25 per cent of RDN with distinct advantage in yield and economic returns. Basal application of organic manures and foliar nutrition of 19:19:19 (0.5%) at monthly intervals reduced the crop yield and prolonged the crop duration. The study therefore proves the efficacy of foliar nutrition as a supplement to soil nutrition and not a substitute.

APPENDICES

APPENDIX – I

Weather parameters during the cropping period (Apr. 2016 to Feb. 2017)

Month and year	Temperature (°C)		Rainfall (mm)	Evaporation (mm day^{-1})
	Maximum	Minimum		
April 2016	34	22.47	389.6	3.21
May 2016	34.4	22.71	496	3.53
June 2016	31.7	21.8	400.9	3.07
July 2016	31.38	21.3	102.3	3.6
August 2016	31.56	20.73	27.4	3.3
September 2016	31.82	21.37	4.9	3.8
October 2016	32.56	20.39	59.4	3.02
November 2016	32.23	19.93	29.8	3.93
December 2016	33.4	20.27	1.2	2.2
January 2017	33.83	20.78	12.6	2.2
February 2017	34.5	21.66	0	2.3

APPENDIX – II

Cost of cultivation of banana in different treatments (₹ ha^{-1})

Treatments	Planting materials (₹ ha^{-1})	Manures (₹ ha^{-1})	Fertilizers and SOP (₹ ha^{-1})	Foliar feeds (₹ ha^{-1})	Labour charges (₹ ha^{-1})	Total cost (₹ ha^{-1})
T_1	25000	10000	59760	--	288750	383510
T_2	25000	10000	48476	20000	290250	393726
T_3	25000	10000	41706	20000	290250	386956
T_4	25000	10000	59760	2000	288750	385510
T_5	25000	10000	48476	22000	290250	395726
T_6	25000	10000	41706	22000	290250	388956
T_7	25000	10000	14625	20000	288750	358375
T_8	25000	10000	14625	22000	288750	360375

Price of inputs for working out the cost of cultivation

Items	Price (₹)
Urea	8/kg
Rajphos	20/kg
MOP	18/kg
FYM	10/kg
19:19:19	400/kg
KAU Banana micromix	200/kg
SOP	40/kg

സംഗ്രഹം

നേന്ത്രൻ വാഴയിൽ പത്രപോഷണത്തിന്റെ പ്രാധാന്യം മനസ്സിലാക്കുന്നതിനായുള്ള ഒരു കാർഷിക പരീക്ഷണം 2016 മെയ് മുതൽ 2017 ഫെബ്രുവരി വരെയുള്ള കാലഘട്ടത്തിൽ തിരുവനന്തപുരത്ത് ബാലരാമപുരം തെങ്ങ് ഗവേഷണ കേന്ദ്രത്തിൽ നടത്തുകയുണ്ടായി പത്രപോഷണം നൽകുന്നപക്ഷം മണ്ണിൽ ചേർക്കേണ്ട രാസവളങ്ങളുടെ അളവ് കുറയ്ക്കുവാനാകുമോയെന്നതും വിളവ്, ഗുണമേന്മ, ആദായം എന്നീ ഘടകങ്ങളെ സ്വാധീനിക്കാനാകുമോയെന്നതും പഠനവിധേയമാക്കി.

പത്രപോഷണത്തിന്റെ ഭാഗമായി പ്രധാനസസ്യമൂലകങ്ങൾ പ്രദാനം ചെയ്യുന്ന 19 : 19 :19 എന്ന വളക്കൂട്ട് 0.5% വീര്യത്തിൽ രണ്ട്,നാല് മാസങ്ങളിൽ ഇലകളിൽ തളിച്ചു കൊടുത്തു. കൂടാതെ 1% വീര്യത്തിൽ സൂക്ഷ്മമൂലകമിശ്രിതമായ കെ.എ.യു. ബനാന മൈക്രോമിശ്രിതം മൂന്നാം മാസത്തിൽ ഇലകളിലൂടെ നൽകി. പ്രസ്തുത പരീക്ഷണത്തിൽ റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പഠന രീതിയാണ് അവലംബിച്ചത്. എട്ട് പരിചരണമുറകളാണ് പരീക്ഷിച്ചത്. ഇവ താഴെ പറയും പ്രകാരമാണ്.

T1 - കേരളകാർഷിക സർവ്വകലാശാല (കെ. എ. യു.) നിർദ്ദേശിക്കുന്ന വളപ്രയോഗം

T2 - കെ. എ. യു. നിർദ്ദേശിക്കുന്ന വളത്തിന്റെ 75% അളവ് + 19 : 19 :19 (0.5%) രണ്ട്,നാല് മാസങ്ങളിൽ ഇലകളിലൂടെ.

T3 - കെ. എ. യു. നിർദ്ദേശിക്കുന്ന വളത്തിന്റെ 60% അളവ് + 19 : 19 :19 (0.5%) രണ്ട്, നാല് മാസങ്ങളിൽ ഇലകളിലൂടെ.

T4 - കെ. എ. യു. നിർദ്ദേശിക്കുന്ന വളപ്രയോഗം + കെ.എ.യു. ബനാന മൈക്രോമിശ്രിതം (1%) മൂന്നാം മാസത്തിൽ ഇലകളിലൂടെ.

T5 - കെ. എ. യു. നിർദ്ദേശിക്കുന്ന വളത്തിന്റെ 75% അളവ് + 19 : 19 :19 (0.5%) രണ്ട്, നാല് മാസങ്ങളിൽ ഇലകളിലൂടെ + കെ.എ.യു. ബനാന മൈക്രോമിശ്രിതം (1%) മൂന്നാം മാസത്തിൽ ഇലകളിലൂടെ.

T6 - കെ. എ. യു. നിർദ്ദേശിക്കുന്ന വളത്തിന്റെ 60% അളവ് + 19 : 19 :19 (0.5%) രണ്ട്, നാല് മാസങ്ങളിൽ ഇലകളിലൂടെ.+ കെ.എ.യു. ബനാന മൈക്രോമിശ്രിതം (1%) മൂന്നാം മാസത്തിൽ ഇലകളിലൂടെ.

T7- 19 : 19 :19 (0.5%) വീര്യത്തിൽ മാസത്തിൽ ഒരു തവണയെന്ന കണക്കിൽ ഏഴാം മാസം വരെ ഇലകളിലൂടെ.

T8 - 19 : 19 :19 (0.5%) വീര്യത്തിൽ മാസത്തിൽ ഒരു തവണയെന്ന കണക്കിൽ ഏഴാം മാസം വരെ ഇലകളിലൂടെ + കെ.എ.യു. ബനാന മൈക്രോമിശ്രിതം (1%) മൂന്നാം മാസത്തിൽ ഇലകളിലൂടെ.

മേൽ പറഞ്ഞ എല്ലാ പരിചരണമുറകളിലും വാഴയൊന്നിന് 10 കിലോ ചാണകം വീതം നൽകി. കൂടാതെ കുല വന്നതിനു ശേഷമുള്ള രണ്ട്, നാല് ആഴ്ചകളിൽ 3% വീര്യത്തിൽ പൊട്ടാഷ്യം സൾഫേറ്റ് ലായനി കായ്കളിൽ തളിച്ചു കൊടുക്കുകയും ചെയ്തു.

പ്രസ്തുത പരീക്ഷണത്തിൽ വിളവ്, ഗുണം, ആദായം എന്നിവയിൽ മികച്ചു നിന്നത് T4 (കേരള കാർഷിക സർവ്വകലാശാല നിർദേശിക്കുന്ന വളപ്രയോഗം +കെ.എ.യു. ബനാന മൈക്രോമിശ്രിതം (1%) മൂന്നാം മാസത്തിൽ ഇലകളിലുടെ.), T5 (കെ. എ. യു. നിർദ്ദേശിക്കുന്ന വളത്തിന്റെ 75% അളവ് + 19 : 19 :19 (0.5%) രണ്ട് ,നാല് മാസങ്ങളിൽ ഇലകളിലുടെ +കെ.എ.യു. ബനാന മൈക്രോമിശ്രിതം (1%) മൂന്നാം മാസത്തിൽ ഇലകളിലുടെ) എന്നീ പരിചരണമുറകളാണ്. T5 എന്ന പരിചരണമുറയിൽ രാസവളങ്ങളുടെ അളവ് ശുപാർശയിൽ നിന്ന് 25 ശതമാനം വരെ കുറച്ച് ഒപ്പം പത്രപോഷണവും നൽകി. രാസവളങ്ങളുടെ തോത് കുറയ്ക്കുന്നതിനൊപ്പം വിളവും ആദായവും വർദ്ധിപ്പിക്കുന്ന ഈ പരിചരണരീതിയെ മികച്ചതായി കണക്കാക്കാം.