INPUT MANAGEMENT FOR PRECISION FARMING IN BANANA

SHIMI G. J.
(2011-21-101)

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM – 695 522
KERALA, INDIA

2014

INPUT MANAGEMENT FOR PRECISION FARMING IN BANANA

by

SHIMI G. J.
(2011 - 21 - 101)

THESIS
Submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM – 695 522
KERALA, INDIA

2014

DECLARATION

I, hereby declare that this thesis entitled **"INPUT MANAGEMENT FOR PRECISION FARMING IN BANANA"** 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.

Vellayani, **Shimi G. J.**

Date:10/10/14 (2011-21-101)

CERTIFICATE

Certified that this thesis entitled **"INPUT MANAGEMENT FOR PRECISION FARMING IN BANANA"** is a record of research work done independently by Ms. Shimi G. J. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Dr. Sheela K. R.
(Major Advisor, Advisory Committee)
Professor (Agronomy)
College of Agriculture, Vellayani

Vellayani
Date:10/10/14

CERTIFICATE

We, the undersigned members of the advisory committee of Shimi G. J., a candidate for the degree of **Doctor of Philosophy in Agriculture** with major in Agronomy, agree that the thesis entitled **"INPUT MANAGEMENT FOR PRECISION FARMING IN BANANA"** may be submitted by Ms. Shimi G. J., in partial fulfillment of the requirement for the degree.

Dr. Sheela K. R.
(Chairman, Advisory Committee)
Professor
Department of Agronomy
College of Agriculture, Vellayani

Dr. Babu Mathew P.
(Member, Advisory Committee)
Associate Professor & Head (Agronomy)
Instructional Farm
College of Agriculture, Vellayani

Dr. V. L. Geethakumari
(Member, Advisory Committee)
Professor and Head
Department of Agronomy
College of Agriculture, Vellayani

Dr. J. Arthur Jacob
(Member, Advisory Committee)
Professor and Head (Rtd.)
Instructional Farm
College of Agriculture, Vellayani

Dr. Vijayaraghava Kumar
(Member, Advisory Committee)
Professor and Head
Department of Agricultural Statistics
College of Agriculture, Vellayani

EXTERNAL EXAMINER

Dr. P. Muthukrishnan
Professor (Agronomy)
Tamil Nadu Agricultural University
Coimbatore

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere gratitude to THE ALMIGHTY who guided me and gave me enough confidence to pursue my dream.

There are numerous people without whom this thesis would not have been completed and I am greatly indebted to them.

I am very happy and grateful to express my thanks to my chairma **Dr. Sheela K. R**., Professor, Department of Agronomy for her continuous guidance, patience and diligent assistance throughout the research work. It was her sincerity, dedication and perfectionism both as a teacher and as a human being which influenced me deeply to improve myself in all aspects. I would also thank God for giving me an opportunity to work under her guidance.

Dr. V. L. Geethakumari, Professor and Head, Department of Agronomy for her valuable time, comments and active guidance which facilitated considerable improvements in my work.

Dr. Babu Mathew P., Associate Professor and Head, Instructional farm for his ever willing help and valuable suggestions in the conduct of field experiment and critical scrutiny of the manuscript.

Dr. J. Arthur Jacob, Professor and Head (Rtd.), Instructional farm for valuable advice and support for conducting field work.

Dr. Vijayaraghava Kumar, Professor and Head, Department of Agricultural Statistics for his critical analysis and evaluation of my thesis work and for his valuable suggestions in the analysis of data and its proper interpretation inspite of his busy schedule.

I am greatly thankful to **Dr. Shalini Pillai P**., Associate Professor, Department of Agronomy for her affectionate advice, timely help and valuable suggestions rendered throughout the course of this research work.

I express my gratitude to all the faculty members of Department of Agronomy for their constant encouragement and support throughout my course work.

I wish to place on record my sincere gratitude to Sivadas Sir, Section Officer, KAU., Dr. Nandakumar, Professor, Department of Agricultural Entomology, Dr. Umamaheswaran and Dr. P. J. Joseph, Department of Plant Pathology for their willingness and generous assistance at one stage or the other of the research.

I also thank Laboratory assistants Ramani chechi and Shibu chettan for their help during the lab work.

I would like to thank the Farm supervisor, Farm assistants, labourers of the farm for their great co-operation rendered to me during my field work.

The assistance and the co-operation extended to me by the contract labourers of College of Agriculture, Vellayani are very much appreciated. I thank them sincerely.

I am thankful to Jithu, Rajesh chetan and Sajin chetan in the Print Park, Statue for their neat edition works, printing and binding.

I extend my warm thanks to my batch mate Anita chechi for her co-operation and I would also express my sincere thanks to my senior, Jinsy chechi and juniors Vipitha, Atul, Sheeja chechi, Bindhu chechi, Sharu chechi, Reshma, Athira, Pintu, Sasna, Pavan, Anju, Anjana, Arya, Soumya, Jinu and Surya for their whole hearted support throughout my research work.

I am greatly indebted to Kerala State Council for Science, Technology and Environment for providing me research fellowship which aided greatly in my research work.

I extend my deepest gratitude to my dearest friend Nishan without whom it would be impossible for me to achieve the courage and confidence in all my endeavours.

Last but not the least, I express my loving thanks to my parents, sister and relatives for their affection, prayers and immense support throughout the course of my study.

SHIMI G. J.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

B : C	Benefit Cost ratio
CD	Critical Difference
cfu	colony forming unit
cm	centimetre
DAP	Diammonium Phosphate
EC	Electrical Conductivity
et al.	co –workers/co-authors
FAO	Food and Agriculture Organization
Fig.	Figure
FYM	Farmyard manure
g	gram
ha	hectare
i.e.	That is
K	Potassium
KAU	Kerala Agricultural University
kg ha.mm^{-1}	kilogram per hectare millimetre
kg ha^{-1}	kilogram per hectare
kg	kilogram
L	Litre
LAI	Leaf Area Index
m	metre
m^2	square metre
MAP	Months After Planting
MOP	Muriate of Potash
N	Nitrogen
NS	Non Significant
P	Phosphorus
POP	Package of Practices
plant^{-1}	per plant

RDN	Recommended Dose of Nutrients
RH	Relative Humidity
SEm	Standard Error of mean
SOP	Sulphate of Potash
t ha^{-1}	tonnes per hectare
TSS	Total Soluble Solids
viz.	Namely
WUE	Water Use Efficiency
WP	Water productivity

LIST OF SYMBOLS

@	at the rate of
^{o}C	degree Celsius
%	per cent

INTRODUCTION

1. INTRODUCTION

Banana (*Musa* sp.) referred as 'Kalpatharu' (Plant of virtue) is being cultivated in India from antiquity. It has a great socio-economic significance and is closely interwoven in our national heritage. It is a high calorie tropical fruit rich in health benefitting anti-oxidants (lutein, zea-xanthin, ß and α-carotenes), minerals (Ca, K, Mg, and Mn), vitamins (B6, C), simple sugars and soluble dietary fibres. In India, it contributes to 32.60 per cent of the total fruit production (NHB, 2013). There has been an increase in the area and production of banana to the tune of 66 and 87 per cent, respectively in 2012-2013 compared to 2001-2002. This tremendous increase shows the wide preference and acceptability of the crop among farmers and consumers.

In Kerala, banana is being cultivated in an area of 59,069 ha with a production of 5,14,054 t and the average productivity is estimated to be 8.70 t ha^{-1} in 2013 (FIB, 2014). Nendran is the most popular variety of banana in Kerala due to its wide adaptability, year round availability, affordability, yield stability, taste, high nutritive and medicinal value. The area under this variety has increased during the last ten years owing to its varied uses and consumer demand.

Banana is a shallow rooted crop with high water and nutrient requirement. The plant has low ability to draw water from deeper depths and is highly sensitive to soil water stress. Banana requires a continuous supply of nutrients and water at the proper growth stages for enhanced yield and productivity. The crop is raised traditionally with basin irrigation and application of nutrients to soil in splits. The inefficient crop husbandry practices being adopted by banana farmers lead to poor utilization of nutrients and water resulting in low productivity. Continuous mining of nutrients from the soil due to intensive cultivation and unscientific methods of nutrient and water application have resulted in reduced nutrient use efficiency and degradation of soil health. In this context, efficient and rational use of fertilizers and water is imperative not only for attaining more yield per unit area on a sustainable basis but also to ensure good quality food and conserve the agro ecosystem. There is a need to develop appropriate technologies to ensure this in the most cost effective manner. Precision farming is a viable option to enhance the productivity of banana by improving input use efficiency.

Precision farming refers to the management of each crop production input by recognizing site specific differences within the field and taking management actions accordingly to reduce waste, increase profits and maintain the quality of the environment (Goovaerts, 2000). Deep ploughing and taking raised beds are the improved land management practices adopted in precision farming to ensure better aeration in the root zone, effective drainage during rainy season, developing efficient root system and enhancing moisture retention capacity of the soil. For fertigation, a drip irrigation system can be used, through which crop's nutrient and water requirements can be met accurately (Or and Coelho, 1996). Commercially available water soluble complex fertilizers are being used for fertigation in banana. However, their wide use is limited as they are expensive. Hence, the possibility of replacing them with straight fertilizers needs to be explored. Moreover, information on cost effective fertigation schedule for banana cv. Nendran in Kerala is meagre.

Foliar nutrition is a widely accepted ecofriendly practice for providing nutrient supplements directly to the crop canopy in limited amounts. This practice has multiple advantages of rapid and efficient response to plant needs as the nutrients are provided to the site of absorption in a form which can be readily used by the crop. In addition, post-shoot stage spray of nutrients enhances the yield and quality of fruits (Swietlik and Faust, 1984).

Precision farming practices of improved land management, fertigation and foliar nutrition need to be standardized and popularized among banana growers for enhancing input use efficiency and productivity. It is imperative that the technology generated in this regard should be cost effective and benign to the agro ecosystem.

In the light of the above, the present investigation was undertaken with the following objectives.

- To study the impact of precision land management, fertigation and foliar nutrition on the growth and yield of banana cv. Nendran
- To standardize the nutrient concentration and nutrient sources for fertigation
- To work out the economics of different treatments in banana.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Judicious nutrient and water management is regarded as one of the important aspects to increase the productivity of fruit crops particularly banana. Precision farming is an important approach wherein better land management practices along with improved methods of nutrient and water application result in effective utilization of nutrients and water and reducing their loss to a considerable extent. The literature pertaining to different methods of nutrient and water application are reviewed in this chapter. Wherever sufficient literature on banana is not available, results on related crops and other situations are also reviewed.

2.1 NUTRIENT APPLICATION AND IRRIGATION

2.1.1 Soil Application of Nutrients and Basin Irrigation

Banana is a mesophyte requiring more water at frequent intervals throughout its growth stage. Being a long duration crop, nutrient management involves application of nutrients in several splits to improve its efficiency in utilization. Basin irrigation is the common method of irrigation followed in banana.

Research findings of KAU (1997) standardized the nutrient schedule for different varieties of banana. For sucker planted banana cv. Nendran, a basal application of organic manure @ 10 kg plant^{-1} along with chemical fertilizers @190:115:300 g N, P and K plant^{-1} was recommended. The application of fertilizers has to be done in six splits at monthly intervals starting from the first month onwards. Regarding irrigation method, basin irrigation @ 40 L plant^{-1} in alternate days was found beneficial.

Soil application of recommended dose of nutrients (190:115:300 g NPK plant^{-1}) in six splits in banana cv. Nendran along with basin irrigation increased growth characters like girth, number of leaves and LAI and registered an yield of 9.16 kg plant^{-1}. It was also observed that higher levels of fertilizer application

(400:230:600 or 500:290:750 g NPK plant^{-1}) in six splits were not beneficial in improving growth and yield of banana. The plants with higher level of fertilizer application were observed to be shorter with less girth, number of leaves and LAI compared to recommended dose of nutrients (Thomas, 2001).

Venugopal (2004) reported that in tissue culture Nendran banana, soil application of recommended dose of nutrients (300:115:450 g NPK plant^{-1}) along with conventional basin irrigation @ 40 L plant^{-1}(in alternate days) produced a LAI of 2.29 and 1.60 at 4 MAP and at harvest, respectively. This management package also enhanced the total dry matter production to 21.58 t ha^{-1} which in turn enhanced the weight of D finger (180.33 g), length of D finger (27.22 cm) and girth of D finger (14.00 cm). KAU (2011) recommended soil application of 300:115:450 g NPK plant^{-1} at monthly intervals from 1 to 7 MAP except at 6 MAP along with basin irrigation @ 40 L plant^{-1} in alternate days for yield improvement in tissue culture banana.

2.1.2 Fertigation in Banana

Fertigation is application of fertilizers along with irrigation water directly to the region where most of the plant roots develop. It ensures supply of both nutrients and water in controlled and balanced manner with efficient use of nutrients from 30 to 50 per cent over traditional method. Fertigation also enables substantial saving in fertilizer usage and reduces leaching losses. Moreover, it reduces weed problem and saves labour.

In banana, fertigation has proved to be of great success especially in terms of water and labour saving with increased water use efficiency (Santhanabosu *et al.,* 1995). Prabhu (2006) reported on the farmers' experience of precision farming through drip fertigation implemented by Tamil Nadu Agricultural University in the districts of Krishnagiri and Dharmapuri of Tamil Nadu. The farmers opined that precision farming had helped them to obtain uniform banana bunches with 50 per cent saving of water compared to the conventional system of cultivation. Hasan *et al.* (2010) opined that though water soluble fertilizers were costlier for fertigation, they could contribute to better agronomical and environmental performance when used rationally. Several studies have been documented on fertigation with water soluble fertilizers in various horticulture crops like banana, papaya, pomegranate, musk melon, potato etc. Precision farming practices adopted at Perumatty, Kerala also revealed a saving of 25 per cent in fertilizers and 40 to 60 per cent in irrigation water through drip fertigation. Moreover, it contributed to 45 to 50 per cent more marketable yield compared to conventional system of cultivation (Anon., 2012).

2.1.2.1 Fertigation and Growth

Parikh *et al.* (1994) opined that fertigation treatments could result in early flowering and bunch maturity in banana.

Srinivas *et al.* (2001) noticed increased height, stem girth and number of functional leaves in banana cv. Robusta with increase in N and K through fertigation up to 200 g plant^{-1}. However, the differences beyond 100 g were not significant. Fertigation of N and K at 150 g plant^{-1} increased LAI significantly and the LAI reached a peak at 270 days after planting and declined later. At this fertigation level, leaf area duration also increased gradually up to harvesting.

While providing SOP (Sulphate of Potash) through fertigation in banana cv. Williams, Bakry (2002) found that growth characters like pseudostem height, girth, number of healthy leaves and suckers at bunch shooting responded positively to K fertigation rate. The higher values of the aforesaid characters were obtained at higher dose of K (800 and 1000 g SOP plant^{-1}) while, the lowest values were recorded at lowest dose of K (200 g SOP plant^{-1}).

In a study on fertigation of N and K in banana cv. Williams, Abdel-Khalik *et al.* (2009) reported that increasing rates of N and K through fertigation increased plant height, pseudostem girth and leaf number and reduced the number of days taken for shooting. The uppermost level of N (750 g N plant^{-1} year^{-1}) and K (1200 g plant^{-1}year^{-1}) resulted in improvement in all growth characters.

A study carried out by Kumar *et al.* (2009) on the effect of fertigation on phenological characteristics revealed that treatment with 100 per cent RDN under drip fertigation gave the highest values of plant height, plant girth and number of leaves in banana followed by treatment with 80 per cent RDN. Fertigation of 100 per cent RDN also resulted in earliness of bunch shooting and early harvest.

Results of the study undertaken by Dinesh *et al.* (2012) on banana cv. Monthan showed that maximum pseudostem height (261.50 cm), stem circumference (65.75 cm), total leaf area (19.88 m^2), leaf, fruit and pseudostem dry matter (33.45, 15.27 and 9.98 per cent) were obtained in plots receiving 75 per cent of NPK through fertigation in the ratio of 3:2:1 at vegetative growth stage, 1:3:2 at flowering stage and 2:1:3 at fruit development stage. Compared to soil application, fertigation treatments resulted in an earliness of 12.41 days and 17.91 days for flowering and fruit maturity, respectively.

Experiments conducted by NCPAH INDIA (2012) on the effect of fertigation in banana cv. Basrai for three consecutive years revealed that application of 100 per cent RDN through drip irrigation produced an early flowering and took 17 days less for harvesting as compared to the conventional practice of irrigation and fertilizer application.

Thomas and John (2014) reported that drip fertigation using urea, single super phosphate and MOP (Muriate of Potash) produced taller plants (283.30 cm) with more girth (60.80 cm), higher number of leaves (13.10) and LAI (3.29) in banana cv. Nendran compared to basin method of irrigation and fertilizer application where the irrigation was given once in three days in accordance with evaporation rate and fertilizers were applied in six splits at monthly intervals.

Studies conducted in tomato with different fertilizer sources (urea, single super phosphate and MOP, 12-61-0 and 13-0-45) showed that leaf number was significantly higher with fertigation using 12-61-0 and 13-0-45 at 125 per cent of recommended dose. However, leaf area was enhanced with the application of 12-61-0 at 100 per cent of NPK (98.10 d m^2 $plant^{-1}$). Total dry matter production was the lowest in plots where urea, single super phosphate and MOP were applied as soil application at 75 per cent of recommended NPK (Soumya *et al.*, 2009).

2.1.2.2 Fertigation and Yield

Arscott (1970) reported that urea applied through fertigation was more efficient than broadcasting on soil surface in increasing number of hands bunch^{-1} in banana.

Fertigation studies in banana cv. Robusta planted both under normal and high density planting system, revealed that fertigation with 50 to 75 per cent of recommended NPK (200:30:300 g NPK plant^{-1}) registered the highest bunch weight with more number of hands and fingers (Mahalakshmi *et al.*, 2001).

A study conducted by Thomas *et al.* (2001) in banana cv. Nendran at Kerala Agricultural University revealed that yield of banana could be increased by over 64 per cent by diluting the concentration of fertilizer inputs alone rather than increasing the dose to more than 100 per cent of NPK. They also observed that the yield obtained from soil application of 200:115:300 g NPK plant^{-1} in six splits was comparable with that obtained from drip fertigation at 100:60:150 g NPK plant^{-1}.

Bakry (2002) opined that fertigation at higher levels of SOP (800 and 1000 g plant^{-1}) improved weight, length and girth of fingers in banana cv. Williams.

Reddy *et al.* (2002) found that fruit yield of banana cv. Robusta increased with increase in fertigation levels and was the highest with 200 g N and K, which was on a par with 150 g N and K. Soil application of these nutrients registered the lowest yield in banana.

In Red banana, application of 100 per cent of NPK (110:35:300 g NPK plant^{-1}) through fertigation resulted in more number of fingers (98.92), finger weight (255.36 g) and increased bunch weight (22.55 kg) (Suganthi, 2002).

Application of water soluble fertilizers like 12-61-0, 19-19-19, 13-0-45 and urea at 125 per cent RDN through drip fertigation once in two days resulted in increase in the number of fingers bunch^{-1} (61.20), number of hands bunch^{-1} (5.50), finger weight (275.00 g), higher bunch weight (17.06 kg) and total fruit yield (42. 65 t ha^{-1}) in banana cv. Nendran when compared to surface method of irrigation with soil application of normal fertilizers (Asokaraja, 2004).

Research results in Tamil Nadu revealed that application of complex fertilizers (19-19-19, 13-0-45, 12-61-0, 0-0-50) along with urea in 52 times helped in yield improvement of banana cv. Grand Naine (Vadivel, 2008).

A study conducted to find out the effect of fertigation on yield of banana (Musa AAA cv. Grand Naine) concluded that application of 75 per cent of recommended N and K through drip irrigation at weekly interval in 44 splits up to 300 days and recommended dose of P by soil placement at the time of planting was beneficial in increasing banana yield (Bhalerao *et al.*, 2009).

Kumar *et al.* (2009) obtained the highest yield of 95.20 t ha^{-1} in banana by fertigation with 100 per cent RDN followed by 80 per cent RDN (87.60 t ha^{-1}). Lower yields were obtained with 60 per cent RDN in drip fertigated treatment and 100 per cent RDN under traditional method of fertilizer application. The result also indicated that application of only 60 per cent RDN through fertigation could give the yield at par with conventional cultivation.

Dinesh *et al.* (2012) noticed increase in yield attributes like number of hands and fingers (7.20 and 70.12 plant^{-1} respectively), finger size (20.50 cm × 15.65 cm), finger weight (163.29 g), bunch weight (11.45 kg plant^{-1}) and fruit yield (28.63 t ha^{-1}) in banana cv. Monthan by application of 75 per cent of NPK in the ratio of 3:2:1 at vegetative growth stage, 1:3:2 at flowering stage and 2:1:3 at fruit development stage through drip irrigation.

According to NCPAH INDIA (2012), a higher yield of 83.00 t ha^{-1} was recorded in banana cv. Basrai with 100 per cent RDN through drip fertigation followed by 80 per cent RDN (74.62 t ha^{-1}). These treatments gave 20.46 and 11.02 per cent more yield, respectively in comparison to conventional cultivation of banana.

Pawar and Dingre (2013) reported that 100 per cent RDN through drip fertigation resulted in 46.22 per cent increase in yield (83.62 t ha^{-1}) in banana cv. Grand Naine. However, it was on par with 80 per cent RDN (79.00 t ha^{-1}). The banana under 60 per cent RDN through fertigation also produced 19 per cent more yield (68.00 t ha^{-1}) as compared to conventional fertilizer application through soil (57.40 t ha^{-1}).

The study conducted by Xiao-ping (2013) to evaluate the effect of Suspension Liquid Fertilizer (SLF) on banana growth and yield under drip fertigation revealed that the liquid fertilizer could increase the yield of banana by 2.50 per cent compared to traditional fertilization.

2.1.2.3 Fertigation and Fruit Quality

Pulp, TSS, total sugars and starch per cent in banana cv. Williams grown in sandy soil showed a positive response to increasing level of K supplied as SOP through drip fertigation (Bakry, 2002).

Amilton *et al.* (2004) observed lower acidity in banana fruits from monthly fertigated plots with 100 per cent of N and K than three monthly fertigation.

Dinesh *et al.* (2012) obtained a higher TSS (6.75° brix) by the application of 75 per cent of NPK in splits at various growth stages in the ratio of 3:2:1 at vegetative growth stage, 1:3:2 at flowering stage and 2:1:3 at fruit development stage in banana cv. Monthan. However, the highest pulp-peel ratio (2.68) was recorded with 50 per cent of NPK applied in the same ratio at the same critical growth stages.

Studies on fertigation with water soluble fertilizers in other horticulture crops are reviewed below.

Shivashankar (1995) found that fertigation with water soluble fertilizers at 80 per cent RDN through drip improved the TSS content in blue berries. Shirgure *et al.* (1999) also observed that fertigation with 80 per cent of recommended N gave higher TSS (7.68° brix), juice (49.08 per cent) and acidity (4.10 per cent) than other levels of N fertigation in acid lime.

From a study conducted by Ramachandrappa *et al.* (2010) to assess the effect of fertigation with different sources and levels of fertilizers on quality aspects of green chillies, it was observed that application of fertilizer sources like 12-61-0 and 13-0-45 through fertigation at 125 per cent RDN significantly increased TSS (4.13°, 4.32° and 3.98° brix) at 3rd, 6th and 9th harvest, respectively. Ascorbic acid content (142.31 mg 100 g^{-1}) was also found to be improved by these sources through fertigation. Lower values of the aforesaid quality parameters were recorded in the treatment receiving 75 per cent RDN as urea, single super phosphate and MOP in soil application.

Fruit quality of grapes was greatly improved (high TSS and total sugar and low acidity) by drip fertigation once in three days using water soluble fertilizers (mono ammonium phosphate, SOP, 19-19-19 and 13-0-45) followed by normal fertilizers (urea, phosphoric acid and MOP) (Asokaraja, 2011).

2.1.2.4 Fertigation and Water Use Efficiency

Pawar *et al.* (2000) opined that water saving to the extent of 50 per cent could be achieved in banana under drip irrigation as compared to surface method of irrigation.

Baskar (2002) recorded the highest banana yield with maximum water use efficiency of 2.18 kg $ha.cm^{-1}$ in drip fertigation at 75 per cent of NPK compared to drip fertigation at 100 and 50 per cent of NPK.

Compared to 100 per cent RDN applied through drip fertigation once in two days, water productivity was higher (36.97 kg ha.mm^{-1} and 35.18 kg ha.mm^{-1} for first and second crop of banana cv. Nendran, respectively) with water soluble fertilizers like 12-61-0, 19-19-19, 13-0-45 and urea at 125 per cent RDN (Asokaraja, 2004).

Kumar *et al.* (2009) noticed that the water use efficiency was about 25 per cent higher for drip fertigated plots in comparison to check basin method of irrigation.

Fertigation of 80 and 75 per cent of recommended NPK in banana resulted in water saving of 20 and 25 per cent respectively (Anon., 2011). The water use efficiency was found maximum in 100 per cent recommended NPK through fertigation followed by 80 per cent recommended NPK compared to conventional soil application in banana (NCPAH INDIA, 2012).

Pawar and Dingre (2013) obtained a higher water use efficiency of 69.50 kg ha.mm^{-1} when 100 per cent RDN was applied as water soluble fertilizers through drip fertigation in banana cv. Grand Naine.

2.1.2.5 Fertigation and Nutrient Use Efficiency

Kadam *et al.* (1993) opined that increasing the frequency of drip fertigation could result in better nutrient use efficiency. Fertigation could save soluble fertilizers like urea and SOP to the tune of 25 per cent (Srinivas, 1998). Thomas (2001) also observed a better efficiency of fertilizers applied to Nendran banana by drip fertigation.

Compared to surface irrigation and soil application, drip fertigation resulted in 50 per cent saving in fertilizer for banana (Baskar, 2002). Asokaraja (2004) noticed that highest fertilizer productivity (34.64 and 33.72 kg fruit kg^{-1} NPK ha^{-1} for first crop and second crop, respectively) was associated with drip fertigation once in two days using water soluble fertilizers (12-61-0, 19-19-19, 13-0-45 and urea) at 75 per cent of recommended NPK.

Fertigation could result in 20 to 50 per cent saving of fertilizers with improved yield and quality as compared with the common methods of fertilizer application (Malakouti, 2004).

Kumar *et al.* (2009) observed that fertilizer use efficiency was about 25 per cent higher for drip fertigated banana compared to soil application. Martins and Novias (2011) noticed an increased nutrient use efficiency in fertigation treatments when compared to conventional fertilization under rainfed conditions in banana cv. Williams.

Teixeira *et al.* (2011) reported that fertigation promoted an increase in nutrient use efficiency of 36 per cent over conventional fertilization in banana. As per the reports of NCPAH INDIA (2012), fertigation resulted in a saving of 35 per cent fertilizers in banana cv. Basrai.

A fertilizer saving of 40 per cent was observed in banana cv. Grand Naine plots receiving fertigation with 60 per cent RDN (Pawar and Dingre, 2013). Thomas and John (2014) observed a higher fertilizer use efficiency of 75.80, 127.90 and 50.60 kg kg^{-1} for N, P and K, respectively for drip fertigation compared to basin method of irrigation (70.60, 118.90 and 47.10 kg kg^{-1}) in banana cv. Nendran.

2.1.2.6 Fertigation and Nutrient Uptake

Haynes (1988) reported better absorption of nutrients by banana under drip fertigation. Parikh *et al.* (1994) observed that N uptake by banana finger was significantly improved by fertigation with 100 and 80 per cent of N but it was on par with lower levels of 60 and 40 per cent of N through fertigation.

Srinivas *et al.* (2001) noticed higher N uptake in banana cv. Robusta leaves followed by fruits and stems. The P uptake was highest in fruits. He also observed no variation on nutrient uptake by increasing N and K ratios. According to Thomas (2001) better nutrient uptake was possible under drip fertigation in more frequencies.

Bhalerao *et al.* (2009) observed that nutrient uptake was increased in the fertigation treatments when compared to the conventional method of fertilizer application in banana cv. Grand Naine.

From an experiment to compare the effect of conventional phosphate fertilization and fertigation on P uptake in banana, it was observed that fertigation in seedlings increased the concentration of available P by 108 per cent and decreased the P sorption index by 31 per cent in the 0 to 8 cm surface soil of banana roots compared to conventional fertilization (Pan *et al.*, 2011).

2.1.2.7 Fertigation and Economics

Normal planting of banana with fertigation of 100 per cent of N as straight fertilizer improved the net returns and B : C ratio (Baskar, 2002).

Asokaraja (2004) recorded the highest net income of ` 2,41,393 ha^{-1} in banana cv. Nendran through drip fertigation once in two days with water soluble fertilizers (12-61-0, 19-19-19, 13-0-45 and urea) at 125 per cent RDN. This was followed by 100 per cent and 75 per cent RDN respectively. However, marginal B : C ratio analysis showed that drip fertigation at lower dose of 75 per RDN had registered a higher extra income per extra rupee invested (4.67 and 4.75 for first crop and second crop, respectively).

Compared to costlier water soluble fertilizers, fertigation with conventional fertilizers at 100 and 75 per cent RDN significantly enhanced B : C ratio (3.32 and 2.65) in banana cv. Robusta (Kavino *et al.*, 2004).

Asokaraja (2011) registered higher B : C ratio ranging from 1.92 to 2.36 per rupee invested in grapes through drip fertigation once in three days with normal fertilizers (urea, phosphoric acid and MOP) as compared to water soluble fertilizers (12-61-0, SOP, 19-19-19 and 13-0-45). Similar study by Rane (2011) showed that a marginal B : C ratio of 9:1 could be obtained by adopting fertigation in grapes.

Review of fertigation studies carried out in banana showed that biometric parameters like height and girth of pseudostem, number of functional leaves and dry matter production could be increased by drip fertigation compared to conventional method of soil application. The superiority of weekly fertigation on early flowering and bunch maturity was also indicated. Fertigation resulted in improved yield attributes and yield. Quality attributes like TSS and sugar content were also enhanced by fertigation with water soluble complex fertilizers. Moreover, fertigation enabled better nutrient and water uptake with a saving of 20 to 50 per cent in water and nutrients resulting in higher fertilizer and water use efficiency. Though fertigation with water soluble fertilizers produced higher yield, normal straight fertilizers improved the B : C ratio owing to its low cost and easy market availability.

2.1.3 Foliar Nutrition in Banana

Foliar fertilization (foliar nutrition) is a widely used environmental friendly method for providing supplemental dose of major and minor nutrients, plant hormones, stimulants and other beneficial substances on the canopy. It aims at improving the yield and quality of crops with reduced environmental impacts associated with soil fertilization. Many reports also have indicated the usefulness of post-shoot stage spray of various nutrients in influencing yield, shelf life, and quality of fruits (Swietlik and Faust, 1984). Kuepper (2003) also reported that foliar application of major nutrients was beneficial for promoting vegetative growth and size of fruits.

Foliar nutrition has multiple advantages like low cost, quick plant response, lack of soil fixation, use of limited quantities of fertilizers and ability to combine with other agrochemicals in a single application (Oosterhuis, 2009). Crop response to foliar application depends on species, fertilizer form, concentration and frequency of application as well as the stages of plant growth. Though foliar application is adopted on a wide variety of crops, its economic value is deemed greater for horticultural than field crops.

2.1.3.1 Foliar Nutrition and Growth

Kumar and Jeyakumar (2002) noticed an increase in pseudostem girth and number of leaves with foliar application of micronutrients either in individual or combination spray of $ZnSO_4$ (0.50 per cent), $FeSO_4$ (0.20 per cent), $CuSO_4$ (0.20 per cent) and H_3BO_3 (0.10 per cent) at 3, 5 and 7 MAP in banana cv. Robusta.

Kumar and Kumar (2007) reported that foliar spray of SOP @ 1.50 per cent concentration significantly increased the number of leaves at harvest in banana cv. Neypoovan.

In banana cv. Robusta, post shooting spray of SOP @ 1.50 per cent concentration significantly reduced the maturity days and it was on par with one per cent SOP (Kumar *et al.,* 2008).

A study conducted by Torres-Guy (2011) proved that application of Hyfer (foliar fertilizer) at the rate of 3.50 ml L^{-1} water $plant^{-1}$ or 60 ml for 16 L in addition to chemical fertilizer could increase banana plant height. The same trend was observed for leaf length, stem circumference and LAI when Hyfer was added to chemical fertilizers. However, foliar application of Hyfer had no influence on leaf diameter.

From a study on foliar nutrition with 19-09-19 and 19-19-19 in tomato, it was observed that application of NPK (19-09-19) as foliar spray significantly increased the plant height (125.40 cm) and number of branches (4.20) (Chaurasia *et al*., 2005).

2.1.3.2 Foliar Nutrition and Yield

Spraying SOP (1.50 per cent) initially after the opening of last hand and 30 days later significantly increased number of hands (13.00), fingers (233.30), finger length (14.37 cm), finger girth (13.77 cm), finger weight (75.10 g) and bunch weight (14.27 kg) in banana cv. Neypoovan (Kumar and Kumar, 2007).

Kumar *et al.* (2008) obtained similar result on the number of hands (10.00), fingers (188.70), finger weight (167.30 g) and bunch weight (31.97 kg) in banana cv. Robusta by adopting bunch spray of SOP (1.50 per cent).

Foliar application of micronutrients like $ZnSO_4$ (0.50 per cent) and $FeSO_4$ (0.50 per cent) was observed to be the best for increasing bunch length (93.50 cm), bunch girth (114.00 cm), number of hands bunch^{-1} (11.70) and yield (149.07 t ha^{-1}) in banana cv. Basrai (Patel *et al.*, 2010).

Research results by KAU (2011) recommended pre harvest bunch spray of 3 per cent SOP at two weeks after bunch emergence and four weeks after bunch emergence for getting higher fruit yield.

Application of Hyfer (foliar fertilizer) at the rate of 3.50 ml L^{-1} water plant^{-1} or 60 ml for 16 L along with half the dose of chemical fertilizer was found beneficial in increasing yield parameters of banana like number of hands and weight of hands bunch^{-1} (Torres-Guy, 2011).

An increase in fruit length (4.90 cm), fruit diameter (4.51 cm) and number of fruits (24.6) was observed in tomato by foliar sprays of NPK (19-09-19 and 19-19-19) applied five times (Chaurasia *et al.*, 2005).

2.1.3.3 Foliar Nutrition and Fruit Quality

Venkatarayappa *et al.* (1979) obtained better quality parameters in banana by application of K fertilizers. Bunch spray of SOP was effective in enhancing various quality parameters such as TSS, reducing sugars, non-reducing sugars, total sugars and acidity in banana cv. Neypoovan (Kumar and Kumar, 2007).

Kumar *et al.* (2008) reported increase in TSS (22.62 per cent), reducing sugars (17.62 per cent), non-reducing sugars (2.18 per cent), total sugars (19.80 per cent), acidity (0.16 per cent) and sugar : acid ratio (123.75) by bunch spray of SOP (1.50 per cent) in banana cv. Robusta. A higher pulp : peel ratio of 5.32 was also recorded by the same treatment compared to control (4.59).

Patel *et al.* (2010) noticed that ascorbic acid content (25.00 mg 100 g^{-1}) and TSS (22.03 per cent) in banana cv. Basrai fruits were enhanced by foliar application of $ZnSO_4$ (0.50 per cent) and $FeSO_4$ (0.50 per cent).

While evaluating the effect of foliar applied K sources (KCl, KNO_3, MKP and K_2SO_4) on fruit quality parameters of field grown musk melon, Jifon and Lester (2011) noticed that plots receiving supplemental foliar K had higher external and internal fruit tissue firmness than control and this was associated with higher soluble solids concentrations. All the K sources studied had positive effect on fruit quality parameters except for KNO_3 which tended to result in less firm fruit with lower soluble solids concentration values.

The effect of K compounds on TSS and ascorbic acid were found to be significant with two per cent bunch spray of SOP as compared to other K compounds in fruits of ber (*Zizyphus mauritiana*). The highest TSS (16.50 per cent) and ascorbic acid content (127.48 mg 100 g^{-1}) were registered at two per cent bunch spray with SOP. However, the acidity of the fruits was maximum (0.25 per cent) in control (water spray) (Yadav *et al.*, 2014).

2.1.3.4 Foliar Nutrition and Shelf life

The study conducted by Kumar and Kumar (2007) revealed that shelf life of fruits was significantly lengthened by a maximum of 8.70 days by bunch spray with SOP over control in banana cv. Neypoovan.

Similar enhancement in shelf life period by bunch spray with SOP was also obtained by Kumar *et al.* (2008) in banana cv. Robusta.

2.1.3.5 Foliar Nutrition and Nutrient Uptake

According to Dixon (2003), foliar applied N was seven times more efficient than soil applied N.

Bhatt and Srivastava (2005) noticed that micronutrients *viz*., B, Zn, Mo, Cu, Fe, Mn as foliar spray caused an increase in uptake of nutrients like N, P, K, S, Zn, Fe, Cu, Mn and B in fruits and shoots of tomato.

2.1.3.6 Foliar Nutrition and Economics

Kumar and Kumar (2007) obtained an increased net income of ` 79,410 $ha^{-1}$ by foliar spray of SOP (1.50 per cent) in banana cv. Neypoovan compared to control (` 39,600 ha^{-1}).

Bunch spray with SOP @ 1.50 per cent gave the highest B : C ratio of 4.19 compared to water spray in banana cv. Robusta (Kumar *et al*., 2008). The B : C ratio obtained by different concentrations was in the order of 1.50 > 1.00 > 0.50 > 0.00 per cent which denoted the efficacy of SOP spray in terms of economics.

A higher B : C ratio of 1.94:1 in banana cv. Basrai by foliar application of $ZnSO_4$ (0.50 per cent) and $FeSO_4$ (0.50 per cent) was also reported by Patel *et al*. (2010).

Studies on foliar nutrition with 19-19-19 and 19-09-19 in tomato showed that the highest B : C ratio of 4.12:1 was obtained by five foliar sprays of NPK (19-09-19) followed by NPK (19-19-19) compared to control (2.83:1) (Chaurasia *et al*., 2005).

Experiments conducted on banana with foliar spray of nutrients revealed that foliar nutrition especially the bunch spray was beneficial in increasing yield parameters like length of finger, girth of finger and weight of finger. Post shoot spraying of nutrients especially K was found to enhance the bunch weight and quality attributes. It also increased the shelf life period of banana fruits. The economic analysis also confirmed the beneficial effects of foliar nutrition.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "Input management for precision farming in banana" was carried out during February 2012 to November 2013. The objectives of the experiment were to study the impact of precision land management, fertigation and foliar nutrition on the growth and yield of banana, to standardize the nutrient concentration and sources for fertigation and to work out the economics of different treatments in banana. The experimental site, season and weather conditions, materials used and methods adopted for the study are detailed below.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The experiment was laid out in the Instructional Farm attached to the College of Agriculture, Vellayani. The field was located at 8^{o} 25' 46''N latitude and 76^{o} 59'24'' E longitude (Plate 1) and at an altitude of 19 m above mean sea level.

3.1.2 Soil

The soil of the experimental site is sandy clay loam which belongs to the order oxisols, Vellayani series. Mechanical composition, moisture characteristics and chemical properties of the soil are summarized in Tables 1 and 2.

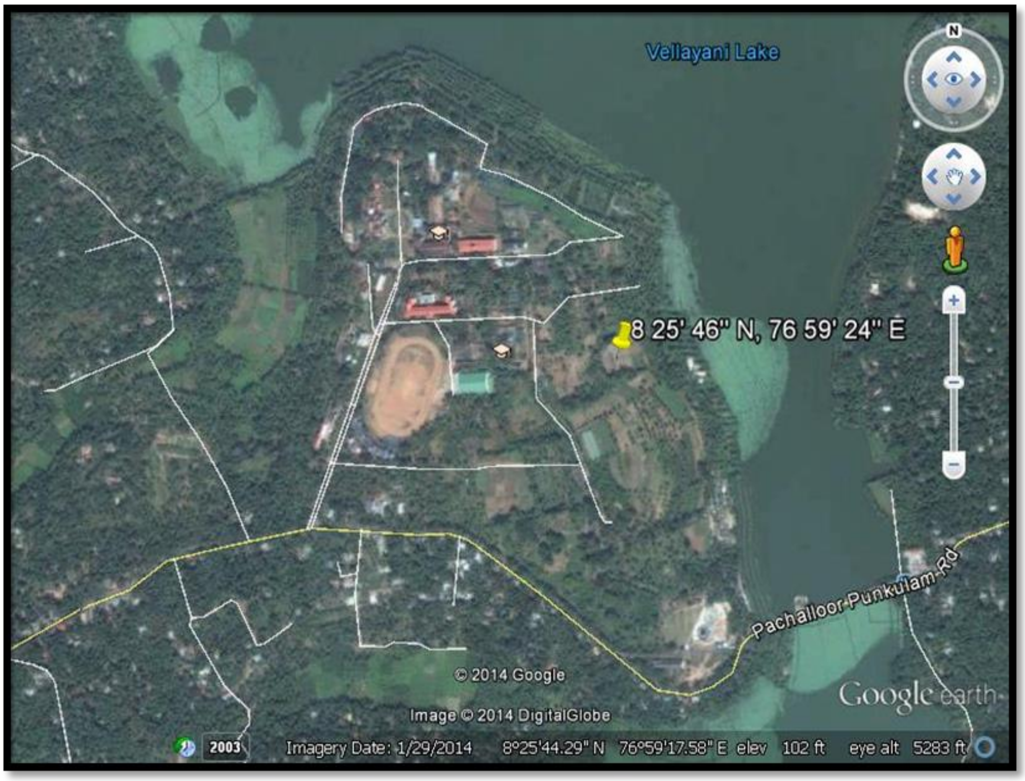


Plate 1. Location of the experimental field

Table 1. Mechanical composition and moisture characteristics of the soil

Particulars	Value	Method used
A. Mechanical composition		
Coarse sand (%)	16.30	International pipette method (Piper, 1967)
Fine sand (%)	30.50	
Silt (%)	25.80	
Clay (%)	26.10	
Textural class	Sandy clay loam	
B. Soil moisture characteristics		
Particle density (g cc^{-1})	2.30	Pycnometer method (Black, 1965)
Bulk density (g cc^{-1})	1.40	Core method (Gupta and Dakshinamoorthi, 1980)
Maximum water holding capacity (%)	23.70	
Porosity (%)	31.10	
Field capacity (%)	21.90	Pressure membrane apparatus (Dastane, 1967)
Permanent wilting point (%)	9.10	

Table 2. Chemical characteristics of soil prior to experiment

Particulars	Value	Method used
Organic C (%)	1.50 (high)	Walkley and Black rapid titration method (Jackson, 1973)
Available N (kg ha^{-1})	260.00 (medium)	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	18.50 (medium)	Bray's colorimetric method (Jackson, 1973)
Available K (kg ha^{-1})	236.50 (medium)	Ammonium acetate method (Jackson, 1973)
Available Ca (ppm)	200.00 (low)	EDTA titration method (Jackson, 1973)
Available Mg (ppm)	100.00 (low)	
Available S (ppm)	10.00 (medium)	$CaCl_2$ extraction method (Tabatabai, 1982)
Fe (ppm)	51.23 (high)	DTPA extraction method (Lindsay and Norwell, 1978)
Zn (ppm)	4.74 (adequate)	
Mn (ppm)	11.76 (adequate)	
Cu (ppm)	3.32 (adequate)	
B (ppm)	1.70 (adequate)	Hot water extraction method (Gupta, 1967)
Soil reaction (pH)	4.60 (very strongly acidic)	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (d S m^{-1})	0.10 (low)	Digital conductivity meter (Jackson, 1973)

Microbial population in the soil prior to the experiment was analysed by serial dilution and plate technique using appropriate medium. Nutrient agar medium was used for growing bacteria, Kenknight's agar medium for actinomycetes and Martin's Rose Bengal agar medium for fungi. Table 3 depicts the soil microbial population prior to experiment at different dilutions. The details of media composition are furnished in Appendix I.

Table 3. Soil microbial population prior to experiment

Microbial population	Count (cfu g^{-1} soil)	Method used
Bacteria	80 x 10^6 75 x 10^7	Nutrient agar medium (Timonin, 1940)
Fungi	88 x 10^3 22 x 10^4	Martin's Rose Bengal agar medium (Martin, 1950)
Actinomycetes	18 x 10^3 14 x 10^4	Kenknight's agar medium (Timonin, 1940)

3.1.3 Irrigation Water

The water used for irrigation was analysed for electrical conductivity and pH and the values are presented in Table 4.

Table 4. Electrical Conductivity (EC) and pH of irrigation water

Particulars	Value	Method used
pH	5.50 (safe)	pH meter with glass electrode (Jackson, 1973)
EC (d S m^{-1})	0.40 (safe)	Digital conductivity meter (Jackson, 1973)

3.2 SEASON AND WEATHER CONDITIONS

The field experiment was conducted for two consecutive seasons from February to December 2012 and January to November 2013. The data on weather parameters (monthly rainfall, number of rainy days per month, maximum temperature, minimum temperature, relative humidity, evaporation and sunshine hours) during the cropping period are presented in Fig.1 a and Fig.1 b and in Appendix II.

3.3 PLANTING MATERIAL

Tissue culture plantlets were used for planting to ensure maximum homogeneity in physiological maturity. The plantlets of tissue culture banana (Musa AAB cv. Nendran) were obtained from the Biotechnology and Model Floriculture Centre, Kazhakkoottam, Thiruvananthapuram, Kerala.

3.4 EXPERIMENTAL DESIGN AND LAYOUT

PART I

3.4.1 Standardization of Concentrations of Nutrient Sources for Fertigation

The experiment was undertaken to assess the effect of different concentrations of nutrient sources on banana and to arrive at a concentration level which will not cause any phytotoxicity in plants. The treatments included six nutrient sources and four concentrations which were laid out in factorial CRD (treatments-24 and replications-3).

3.4.1.1 Treatments

1. **Nutrient Sources (n)**

   n_1 –Urea

   n_2 –Muriate of Potash (MOP)

   n_3 -10-10-10 (N, P, K)

   n_4 - 13-0-45 (Potassium Nitrate) (N and K)

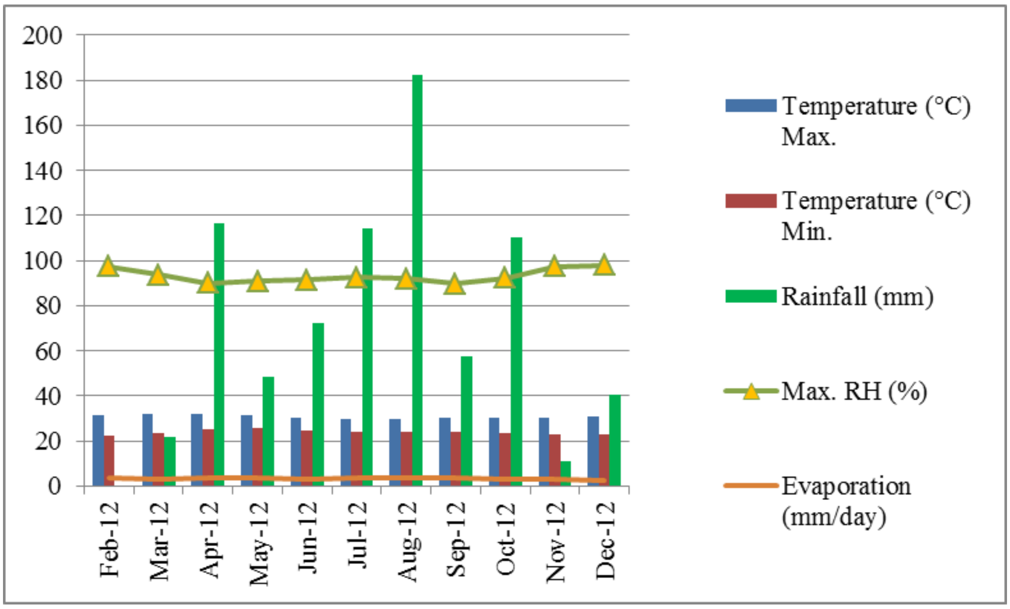


Fig. 1 a. Weather parameters during the cropping period (Feb. to Dec. 2012)

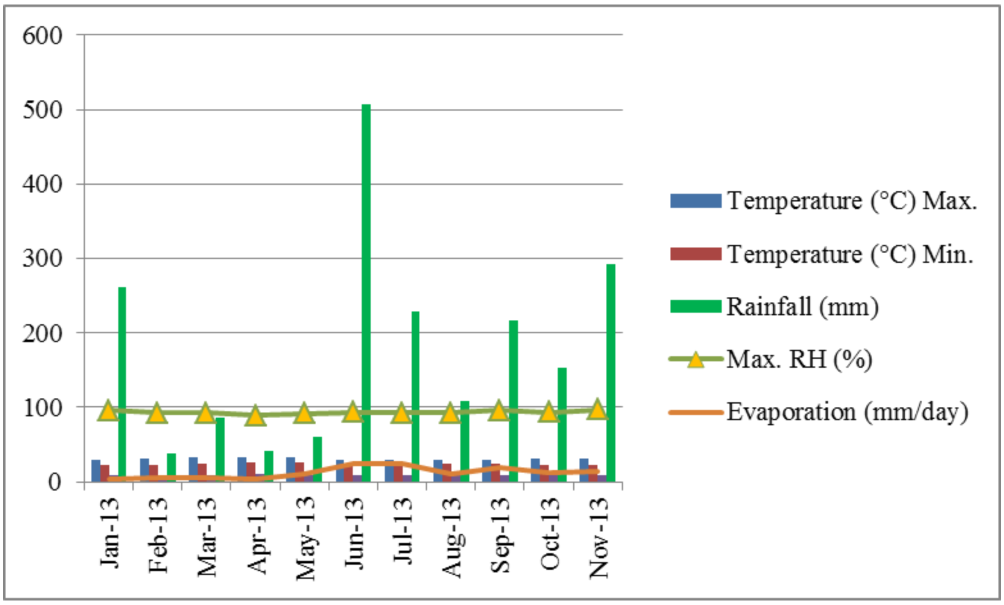


Fig. 1 b. Weather parameters during the cropping period (Jan. to Nov. 2013)

n_5 -0-0-50 (Sulphate of Potash) (SOP)

n_6 - DAP (Diammonium Phosphate)

2. **Concentrations (c)**

c_1 -0.25 %

c_2 - 0.50 %

c_3 - 0.75 %

c_4 -1.00 %

3.4.1.2 Treatment Combinations (6 x 4)

$n_1 c_1$	$n_1 c_2$	$n_1 c_3$	$n_1 c_4$
$n_2 c_1$	$n_2 c_2$	$n_2 c_3$	$n_2 c_4$
$n_3 c_1$	$n_3 c_2$	$n_3 c_3$	$n_3 c_4$
$n_4 c_1$	$n_4 c_2$	$n_4 c_3$	$n_4 c_4$
$n_5 c_1$	$n_5 c_2$	$n_5 c_3$	$n_5 c_4$
$n_6 c_1$	$n_6 c_2$	$n_6 c_3$	$n_6 c_4$

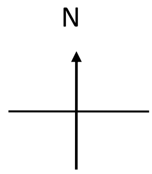
Layout of the experiment is depicted in Fig. 2.

PART II

3.4.2 Nutrient Scheduling through Fertigation and Foliar Application

The experiment was undertaken to standardize the fertigation schedule and the foliar nutrition for banana

Design	:	Split plot
Main plots	:	6
Sub-plots	:	3
Replications	:	3
Gross plot size	:	24 m^2



n_2c_2	n_3c_1	n_6c_1	n_1c_1	n_3c_2	n_5c_2	n_1c_2	n_4c_1	n_2c_2
n_6c_2	n_5c_1	n_4c_1	n_6c_3	n_4c_1	n_1c_4	n_2c_3	n_3c_2	n_3c_4
n_1c_4	n_6c_4	n_2c_1	n_5c_3	n_2c_1	n_3c_3	n_4c_2	n_6c_3	n_1c_4
n_2c_3	n_1c_1	n_6c_3	n_4c_2	n_6c_2	n_4c_3	n_6c_2	n_5c_1	n_3c_1
n_5c_2	n_4c_2	n_2c_4	n_2c_2	n_1c_2	n_5c_4	n_3c_3	n_1c_3	n_4c_3
n_3c_2	n_4c_4	n_1c_2	n_3c_4	n_2c_3	n_4c_4	n_5c_2	n_6c_1	n_5c_4
n_3c_4	n_1c_3	n_3c_3	n_1c_3	n_6c_1	n_2c_4	n_2c_1	n_4c_4	n_1c_1
n_5c_4	n_4c_3	n_5c_3	n_3c_1	n_5c_1	n_6c_4	n_6c_4	n_5c_3	n_2c_4

Replication I | **Replication II** | **Replication III**

Fig. 2. Layout of the experiment (Part I)

3.4.2.1 Treatments

1) **Main plot :- Nutrient Sources (n) for Fertigation**

n_1- Nutrients as per POP (soil application) with basin irrigation

n_2- Nutrients as per POP (soil application) with drip irrigation

n_3- Drip irrigation alone without fertilizer

n_4- Soil application of rock phosphate + fertigation with urea and Muriate of Potash (MOP)

n_5- Fertigation with 10-10-10, urea and Sulphate of Potash (SOP)

n_6- Fertigation with 13-0-45, 0-0-50 (SOP) and Diammonium Phosphate (DAP)

2) **Sub-plot :- Foliar Nutrition (s)**

s_1- Water spray

s_2- New generation foliar fertilizer (19-19-19) (0.50 per cent) with non-ionic spray adjuvant (stanowet) (2^{nd}, 4^{th} and 6^{th} MAP)

s_3- Sulphate of Potash (SOP) @ 2 per cent (after complete bunch emergence and three weeks after first application)

* Fertigation treatments (n_4, n_5 and n_6) – 60 per cent RDN was used

3.4.2.2 Treatment Combinations (6 x 3)

n_1s_1	n_1s_2	n_1s_3
n_2s_1	n_2s_2	n_2s_3
n_3s_1	n_3s_2	n_3s_3
n_4s_1	n_4s_2	n_4s_3
n_5s_1	n_5s_2	n_5s_3
n_6s_1	n_6 s_2	n_6s_3

3.4.2.3 Design and Layout of Drip Fertigation System

The layout plan of the main experiment is given in Fig. 3.

The water for irrigation was diverted with pump from Vellayani lake. Disc filter and screen filter were used for removing the impurities in water.

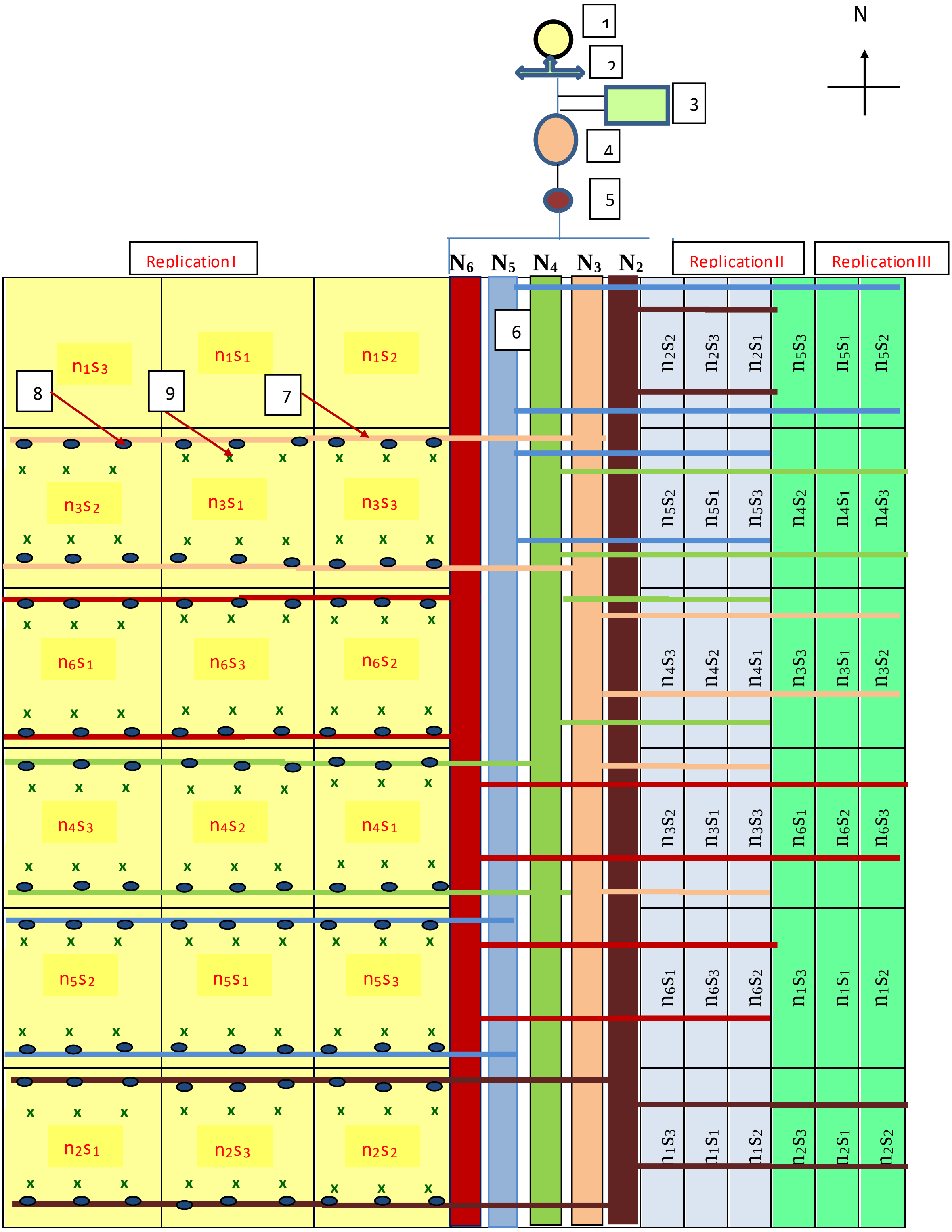


Fig. 3. Layout plan of the main experiment (Part II)

1.Source 2.Control valve 3.Ventury assembly 4.Screen filter 5.Disc filter 6.Submains 7.Laterals 8.Drippers 9.Banana Plant

Ventury assembly was also provided for fertigation. To deliver water and fertilizer to the respective plots, five submains were laid out in the field. From each submain, two laterals were connected to the respective plots. On the laterals, drippers (pressure compensating) with a discharge rate of 8 litres $hour^{-1}$ were connected to deliver water to individual plots. The submains and laterals were provided with flushing devices to remove water and fertilizer after each application.

3.4.2.4 Drip Irrigation Scheduling

Uniform irrigation was given to banana up to three weeks after planting. Irrigation schedule was started from the third week onwards. Drip irrigation was scheduled daily to meet the crop water requirement.

Based on the pan evaporation data, irrigation water requirement through drip (volume in liters $plant^{-1}day^{-1}$) was computed using the following relationship.

IR = Epan x Kp x Kc x spacing x wetted area, where

IR = Irrigation requirement (mm)

Epan = Pan evaporation rate (mm) from U.S class A open pan evaporimeter

Kp = Pan co-efficient (0.75)

Kc = Crop co-efficient (initial stage- 0.50; mid stage – 1.10; late stage – 1.00) (FAO, 1998)

Spacing = 2 m x 2 m (4 m^2)

Wetted area = 0.70 m^2 (Reddy and Reddi, 2011)

3.4.2.5 Fertigation Scheduling

Initial soil samples were collected from different parts of the field after land preparation and analysed for major, secondary and micronutrients. Since the analysis revealed a medium status of the major nutrients in the soil, a lower dose of 60 per cent of the nutrient recommendation was tried for fertigation. Fertigation was done at weekly interval and a total of 24 fertigations were given from one month after planting to one month after complete bunch emergence.

Urea (46 % N) and MOP (60 % K) were the sources of N and K for fertigation in n_4 treatment whereas in n_5 treatment, 10-10-10 (10 % N, 10 % P and 10 % K), urea (46 % N) and SOP (50 % K) were the sources. DAP (18 % N, 46 % P), SOP (50 % K) and 13-0-45 (13 % N and 45 % K) were used in n_6 treatment for fertigation. Quantity of different fertilizers used in the experiment and their cost are furnished in Appendix III.

Nutrient solution for fertigation was prepared by dissolving required quantity of fertilizers. The tube attached to the ventury unit was immersed in the nutrient solution and the system was operated to supply the nutrients along with irrigation water. Flushing of sub mains and laterals were done before the start of fertigation. After every fertigation, drip irrigation was continued for five to ten minutes. Cleaning of disc filter and screen filter were also being carried out once in three days.

The range of concentration of different nutrient sources used for fertigation are furnished in Appendix IV.

3.5 CULTIVATION PRACTICES OF BANANA

3.5.1 Field Preparation and Planting

Deep ploughing up to 50 cm depth was done with JCB. Raised beds of 30 cm height and 3 m width were taken with channels of 1 m width in between beds for proper drainage and to prevent capillary movement of water to the adjacent plots. Pits of 50 cm x 50 cm x 50 cm size were taken at 2 m x 2 m spacing and lime @ 500 g plant^{-1} was applied to these pits. Tissue culture plants of uniform age were planted in the centre of the pits. Irrigation and shading were given to the plants for three weeks to ensure proper establishment of plantlets.

3.5.2 Application of Fertilizers

The schedule of nutrient application followed in the main plots is given in Table 5 a and 5 b.

Plate 2. Land preparation (deep ploughing)

Plate 3. Land preparation (taking raised beds and pits)

Table 5 a. Schedule of nutrient application in the non-fertigation treatments

Treatments	Organic manure (kg plant^{-1})	Nutrients added (g plant^{-1})			Method of application	Sources
		N	P	K		
n_1	15	300	115	450	soil in 6 splits	urea, rock phosphate, MOP
n_2	15	300	115	450	soil in 6 splits	urea, rock phosphate, MOP
n_3	15	0	0	0	basal application	-

FYM @ 15 kg plant^{-1} was applied uniformly as basal for all treatments. For the main plot treatments, n_1 and n_2, the nutrients were given as per POP recommendation of KAU (2011). The full recommended dose of nutrients (300:115:450 g plant^{-1}year^{-1}) were applied in six splits as soil application. Urea (46 %), rock phosphate (20 %) and MOP (60 %) were used as the sources of N, P and K respectively. N and K were given in six splits (1, 2, 3, 4, 5 MAP and after bunch emergence) and P in two splits (1 and 3 MAP). In the main plot treatment of n_4, P was given as soil application as per POP recommendation of KAU using rock phosphate (20 %) and 60 per cent of recommended dose of N and K were supplied as urea and MOP, respectively through fertigation. Fertilizers like 10-10-10, urea and SOP (n_5) and DAP, SOP and 13-0-45 (n_6) were supplied through fertigation.

Table 5 b. Weekly fertigation schedule in the fertigation treatments

Treat-ments	Sources	Application			No. of fertigations
		Time	Quantity of fertilizers (plant^{-1})	Method	
n_4	Rock phosphate	1 MAP 3 MAP	325.00 g 250.00 g	soil	0 0
	Urea	1-5 MAP After complete bunch emergence	16.30 g 16.30 g	fertigation	20 4
	MOP	1-5 MAP After complete bunch emergence	16.25 g 31.25 g	fertigation	20 4
n_5	10-10-10	1 MAP 3 MAP	97.50 ml 97.50 ml	fertigation	4 4
	Urea	2, 4, 5 MAP After complete bunch emergence	16.30 g 16.30 g	fertigation	12 4
	SOP	2, 4, 5 MAP After complete bunch emergence	19.50 g 37.50 g	fertigation	12 4
n_6	DAP	1 MAP 3 MAP	21.20 g 16.30 g	fertigation	4 4
	13-0-45	2, 4, 5 MAP After complete bunch emergence	21.70 g 41.70 g	fertigation	12 4
	SOP	1 MAP 3 MAP	19.50 g 19.50 g	fertigation	4 4

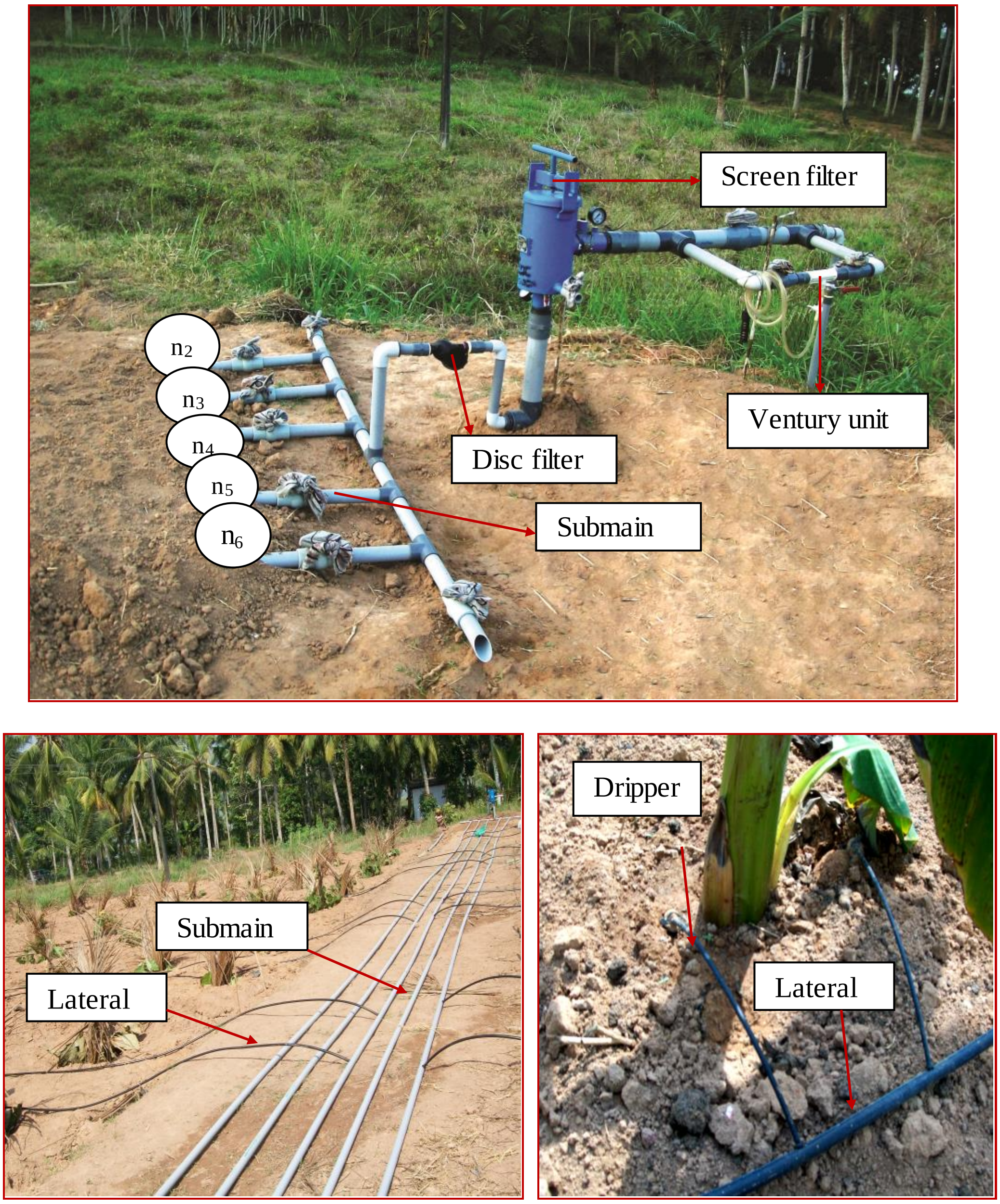


Plate 4. Design and layout of drip fertigation system

Plate 5. Fertigation using ventury

Foliar nutrition was allocated to the subplots. New generation foliar fertilizer (19-19-19) @ 0.50 per cent with non-ionic spray adjuvant (stanowet) @ 1 ml L^{-1} was given as foliar spray during 2^{nd}, 4^{th} and 6^{th} MAP. Two bunch sprays of Sulphate of Potash (SOP) @ 2 per cent were given to the bunches after complete bunch emergence and three weeks after first application.

3.5.3 Maintenance of the Crop

All the management practices except nutrient application and irrigation were carried out according to the need of the crop. In general, two hand weedings and one earthing up at 4 MAP were provided. Periodic desuckering was followed up to bunch emergence. In those plots receiving treatments as basin irrigation, uniform irrigation was given @ 5 L $plant^{-1}$ daily up to 1 MAP, @ 20 L $plant^{-1}$ at 2^{nd} and 3^{rd} MAP and @ 40 L $plant^{-1}$ from 4 MAP to two weeks before harvesting on alternate days.

3.5.4 Plant Protection Measures

Leaf eating caterpillar *Spodoptera* sp. was observed as the major pest in the field in the early stages. It was effectively controlled by spraying chlorpyriphos @ 0.03 per cent. During fourth and fifth months of planting, chlorpyriphos @ 0.03 per cent was applied over the pseudostem and leaf axils as a prophylactic measure against banana pseudostem weevil. Sigatoka leaf spot disease was also controlled by taking prophylactic measures of removing and destroying infected leaves and spraying of propiconazole @ 0.10 per cent.

3.5.5 Propping and Harvesting

Banana plants were propped using rope to protect against wind soon after the emergence of the bunch. Each plant was tied to the sucker of the plant in opposite lines. Harvest of the bunches was done at maturity, the stage was judged by visual observations.

Plate 6. General view of the experimental field-early stage

Plate 7. General view of the experimental field- active growth stage

3.6 OBSERVATIONS - PART I

3.6.1 pH of Nutrient Solution for Fertigation

pH and EC of the nutrient solution at different concentrations were noted using pH meter with glass electrode (Jackson, 1973) and digital conductivity meter, respectively.

3.6.2 Crop Response to Application of Nutrient Solution

Crop response to application of nutrient solutions of different concentrations was observed by visual symptoms (up to 2 MAP). Phytotoxicity symptoms of yellowing and browning of the plant parts especially on leaves and pseudostem were observed to assess the crop response.

PART II

3.6.3. Growth Attributes

3.6.3.1 Height of the Pseudostem

The height of pseudostem was measured from the base of the plant to the axil of the youngest leaf at bimonthly intervals up to bunch emergence and recorded in centimetres.

3.6.3.2 Girth of the Pseudostem

The girth of the pseudostem at 10 cm height above the ground level was measured using a flexible measuring tape at bimonthly intervals up to bunch emergence and recorded in centimetres.

3.6.3.3 Number of Functional Leaves

The total number of fully opened functional leaves retained by the plant at bimonthly intervals and at harvest were recorded.

3.6.3.4 Total Functional Leaf Area (m^2)

Leaf area was calculated using the equation developed by Murray (1960) at bimonthly intervals and at harvest.

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

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

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

3.6.3.5 Leaf Area Index

Leaf area index was calculated at bimonthly intervals and at harvest by the formula.

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

3.6.3.6 Duration of Bunch Emergence

Number of days taken from planting till opening of all bracts just after shooting were recorded.

3.6.3.7 Crop Duration

Number of days taken from planting to harvest were recorded.

3.6.3.8 Sucker Production after Bunch Emergence

Number of suckers from each plant were counted after the emergence of bunches.

3.6.3.9 Total Dry Matter Production

Fresh weight of all the plant parts of banana at harvest was recorded. Samples of leaves, pseudostem, fruit and rhizome were separately dried in oven at 70^{o}C till constant weight and dry weight expressed in t ha^{-1}.

3.6.4 Index Leaf Analysis for Primary, Secondary and Micronutrients

Leaf lamina of third leaf at 4 MAP (index leaf) was sampled by removing a strip of tissue 10 cm wide, on both sides of the central vein (Lopez and Espinosa, 2000). The plant samples were dried in a hot air oven at 70^{0}C till constant weight was obtained. The required quantity of powdered samples were then weighed out accurately and analysed for primary, secondary and micronutrients. The methods adopted for the chemical analysis are given in Table 6 and the values were compared with critical levels of nutrients as suggested in the Table 7.

Table 6. Plant nutrient status estimation

Particulars	Method used
N (%)	Microkjeldahl method (Jackson, 1973)
P (%)	Single acid digestion & colorimetry (Piper, 1967)
K (%)	Single acid digestion & flame photometer (Piper, 1967)
Ca (%)	Nitric acid : Perchloric acid : Sulphuric acid (10 : 4 : 1) & Atomic Absorption Spectrophotometry (Piper, 1967)
Mg (%)	
S (%)	Turbidimetric method (Chesnin and Yien, 1950)
Fe (ppm)	Nitric acid : Perchloric acid : Sulphuric acid (10 : 4 : 1) & Atomic Absorption Spectrophotometry (Piper, 1967)
Zn (ppm)	
Mn (ppm)	
Cu (ppm)	

Table 7. Suggested critical levels of nutrients in index leaf of banana (Lahav and Turner, 1992)

Sl. No.	Nutrient	Content
1	N (%)	2.60
2	P (%)	0.20
3	K (%)	3.00
4	Ca (%)	0.50
5	Mg (%)	0.30
6	S (%)	0.23
7	Mn (mg kg^{-1})	25.00
8	Fe (mg kg^{-1})	80.00
9	Zn (mg kg^{-1})	18.00
10	B (mg kg^{-1})	11.00
11	Cu (mg kg^{-1})	9.00
12	Mo (mg kg^{-1})	1.50-3.20

3.6.5 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.

3.6.5.1 Number of Hands per Bunch

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

3.6.5.2 Number of Fingers per Bunch

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

3.6.5.3 Number of Fingers in the D hand

The second hand from the top of the bunch is regarded as D hand. The number of fingers in the D hand was recorded.

3.6.5.4 Weight of the Finger

The middle finger in the top row of the second hand (from the base of the bunch) was designated as the representative finger or index finger or D finger for studying the fruit characters (Gottriech *et al.*, 1964). The weight of the index finger was taken as the mean finger weight and expressed in grams.

3.6.5.5 Length of Finger

Length of finger was measured from the tip of the D finger to the point of attachment of the peduncle using a thread and scale and expressed in cm.

3.6.5.6 Girth of Finger

Girth of the D finger was measured at the middle portion of the fruit using a thread and scale and expressed in cm.

3.6.5.7 Weight of the Bunch

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

3.6.5.8 Yield

Weight of the bunch including the portion of the peduncle up to the first scar (exposed outside the plant) was recorded in kilograms and total bunch yield was worked out in t ha^{-1}.

3.6.6 Scoring of Pests and Diseases

Pest and diseases observed in the field were recorded and scoring of them were done following the method adopted by Saji (1993) and Anitha (2000).

3.6.7 Quality Characters of Ripe Fruit

The fully ripe index finger selected for recording the observations was used for quality analysis. Known weight of samples taken from three portions *viz.*, top, middle and bottom of the sample fruit were macerated in a blender and made up to a known volume. Aliquots taken from these samples were used for the quality analysis of the fruit.

3.6.7.1 Total Soluble Solids

TSS was determined using a hand refractometer and expressed in per cent (Ranganna, 1977).

3.6.7.2 Acidity

Acidity was measured using titration method suggested by Ranganna (1977) and was expressed as per cent.

3.6.7.3 Total Sugars

Total sugar content was determined as per the method described by Ranganna (1977). The results were expressed as per cent on fresh weight basis.

3.6.7.4 Reducing Sugars

Reducing sugar of the samples were determined as per the method suggested by Ranganna (1977) and presented as per cent on fresh weight basis.

3.6.7.5 Non-Reducing Sugars

Non-reducing sugar was computed using the following formula (Ranganna, 1977).

Non- reducing sugars = Total sugars – Reducing sugars

3.6.7.6 Sugar : Acid Ratio

Sugar acid ratio was arrived at by dividing the value for total sugars with the value for titrable acidity of the corresponding sample.

3.6.7.7 Ascorbic Acid

Ascorbic acid was estimated as per the method developed by Ranganna (1977) and expressed in mg 100 g^{-1} of the fruit.

3.6.7.8 Pulp : Peel Ratio

The weight of pulp and peel of ripe fruits were recorded separately and the ratio was worked out.

3.6.7.9 Shelf Life

The number of days taken from harvest of the fruit to the development of black spots on the peel were recorded to determine the shelf life of the fruit at room temperature (Stover and Simmonds, 1987).

3.6.8 Total Water Requirement, Water Use Efficiency and Water Productivity

Details of irrigation given during the first year and second year of experimentation are summarized in Appendix V.

Total water requirement in each treatment was estimated directly by adding up the quantity of water required for irrigation with the quantity of effective rainfall and moisture contribution from soil profile. Moisture contribution from soil profile was not considered in the present calculation as this was negligible.

Total water requirement = Irrigation requirement + Effective rainfall

Effective rainfall = 70 per cent of total seasonal rainfall (Dastane, 1974)

Water use efficiency was worked out using the following formula and expressed as kg ha.mm^{-1}.

$$\text{FWUE (Field Water Use Efficiency)} = \frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Total water requirement (mm)}}$$

Water productivity was estimated using the formula proposed by Kijne *et al.* (2003) and expressed as kg ha.mm^{-1}.

$$\text{Water Productivity (WP)} = \frac{\text{Total biomass (kg ha}^{-1}\text{)}}{\text{Total water utilized (mm)}}$$

3.6.9 Nutrient Uptake Studies

Uptake of nutrients by each plant parts (leaf, fruit, pseudostem and rhizome) at harvest was calculated from the values of dry matter production and per cent nutrient content of each plant part. Nutrient uptake was calculated by multiplying percentage nutrient content with total dry matter production and expressed in kg ha^{-1}.

3.6.10 Nutrient Use Efficiency (NUE)

NUE was calculated using the following formula

Nutrient Use Efficiency = Physiological efficiency x Apparent recovery efficiency (Goodroad and Jellum, 1988 and Craswell and Godwin, 1984)

$$\text{Physiological efficiency (kg kg}^{-1}) = \frac{\begin{matrix}\text{Total dry matter yield} \\ \text{of fertilized crop (kg)}\end{matrix} - \begin{matrix}\text{Total dry matter yield} \\ \text{of unfertilized crop (kg)}\end{matrix}}{\begin{matrix}\text{Nutrient uptake by} \\ \text{fertilized crop (kg)}\end{matrix} - \begin{matrix}\text{Nutrient uptake by} \\ \text{unfertilized crop (kg)}\end{matrix}}$$

$$\text{Apparent recovery efficiency (\%)} = \frac{\begin{matrix}\text{Nutrient uptake by} \\ \text{fertilized crop (kg)}\end{matrix} - \begin{matrix}\text{Nutrient uptake by} \\ \text{unfertilized crop (kg)}\end{matrix}}{\text{Quantity of nutrients added (kg)}} \times 100$$

Agronomic efficiency was also calculated using the formula suggested by (Craswell and Godwin, 1984)

$$\text{Agronomic efficiency (kg kg}^{-1}) = \frac{\begin{matrix}\text{Yield} \\ \text{of fertilized crop (kg)}\end{matrix} - \begin{matrix}\text{Yield} \\ \text{of unfertilized crop (kg)}\end{matrix}}{\text{Quantity of nutrients added (kg)}}$$

Details regarding quantity of nutrients added are shown in Appendix VI.

3.6.11 Soil Analysis after the Experiment

Soil samples were collected after first and second crop of banana from individual plots of the experimental area. The composite samples drawn from the individual plots were air dried, powdered, sieved through 2 mm sieve and analysed for N, P and K as per the methods mentioned in Table 2.

3.6.12 Soil Microbial Analysis after the Experiment

Microbial population of the experimental plots after the experiment were analysed by serial dilution and plate technique using appropriate medium. The study was carried out at room temperature in the laboratory. Nutrient agar medium was used for growing bacteria, Kenknight's agar medium for actinomycetes and Martin's Rose Bengal agar medium for fungi. The microbes were grown in petri dishes containing the respective media and the count were expressed in cfu g^{-1} soil.

3.6.13 Economic Analysis

3.6.13.1 Cost of Cultivation

The cost of the inputs that were prevailing at the time of their purchase were considered for working out cost of cultivation. Cost of cultivation under different nutrient sources and fertigation are presented in Appendix VII.

3.6.13.2 Gross Income

Gross income $hectare^{-1}$ was calculated by taking into consideration the market price of the products that were prevailing during the investigation period and expressed as ` ha^{-1}. Market price of the produce is shown in Appendix VIII.

3.6.13.3 Net Income

The net income were calculated by subtracting cost of cultivation from gross income and expressed in ` ha^{-1}.

3.6.13.4 B : C Ratio

B : C ratio was worked out as the ratio of gross income to cost of cultivation.

$$\text{B : C ratio} = \frac{\text{Gross income (` ha}^{-1}\text{)}}{\text{Cost of cultivation (` ha}^{-1}\text{)}}$$

While calculating cost of cultivation, drip installation cost was distributed over eight years by amortization.

3.6.14 Statistical Analysis

The data was analysed statistically by applying the techniques of analysis of variance (Panse and Sukhatme, 1985). Wherever the effects were found to be significant, CD values were calculated by using standard technique.

RESULTS

4. RESULTS

The present experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani during February 2012 to November 2013 to study the impact of improved land management practices, fertigation and foliar nutrition on the growth and yield of banana (Musa AAB cv. Nendran). The experimental data collected were analysed statistically and the results are presented below.

4.1 PART I

STANDARDIZATION OF CONCENTRATIONS OF NUTRIENT SOURCES FOR FERTIGATION

4.1.1 pH of Nutrient Solution at Different Concentrations

Data on pH values of nutrient solutions for fertigation at different concentrations are given in Table 8. The pH recorded by different sources (urea, MOP, 10-10-10, SOP, DAP, 13-0-45) was found to be safe for plant growth and it ranged from 5.76 to 8.28. It was observed that in general, the pH increased with increase in concentrations. The sources, 10-10-10 (n_3) and 13-0-45 (n_4) at higher concentration (one per cent) registered high pH values of 9.09 and 9.01, respectively. Whereas, urea, (n_1) recorded low values at different concentrations.

4.1.2 Crop Response to Different Concentrations of Nutrient Solutions

Effect of six nutrient sources (urea, MOP, 10-10-10, 13-0-45, SOP, DAP) at four concentrations (0.25, 0.50, 0.75 and 1.00 per cent) were studied by soil application of the fertilizer solutions of different concentrations on tissue culture plants at one month stage. Observations were made on yellowing and necrosis and it was noticed that the various nutrient sources at different concentrations up to one per cent did not cause any phytotoxicity in tissue culture plants.

Table 8. pH of nutrient solutions as influenced by nutrient sources and concentrations

Treatments	pH
Nutrient sources	
n_1 (Urea)	5.76
n_2 (MOP)	6.52
n_3 (10-10-10)	6.48
n_4 (13-0-45)	8.28
n_5 (SOP)	7.62
n_6 (DAP)	7.31
SEm (±)	0.025
CD (0.05)	0.071
Concentrations	
c_1 (0.25 %)	6.46
c_2 (0.50 %)	6.89
c_3 (0.75 %)	7.08
c_4 (1.00 %)	7.54
SEm (±)	0.021
CD (0.05)	0.058
Interaction	
n_1c_1	5.54
n_1c_2	5.71
n_1c_3	5.78
n_1c_4	6.01
n_2c_1	5.93
n_2c_2	6.48
n_2c_3	6.60
n_2c_4	7.08
n_3c_1	6.64
n_3c_2	7.22
n_3c_3	7.55
n_3c_4	9.09
n_4c_1	7.13
n_4c_2	8.28
n_4c_3	8.70
n_4c_4	9.01
n_5c_1	7.17
n_5c_2	7.20
n_5c_3	7.45
n_5c_4	7.45
n_6c_1	6.39
n_6c_2	6.46
n_6c_3	6.42
n_6c_4	6.64
SEm (±)	0.052
CD (0.05)	0.146

4.2 PART II

NUTRIENT SCHEDULING THROUGH FERTIGATION AND FOLIAR APPLICATION - FIRST YEAR OF INVESTIGATION

4.2.1 Growth Attributes

4.2.1.1 Pseudostem Height (cm)

Data on pseudostem height at 2, 4 and 6 MAP as influenced by treatments are presented in Table 9.

Soil application of full dose of nutrients with basin irrigation (n_1) registered significantly highest plant height at all stages of observations and it was on par with all other nutrient sources at 2 MAP. At 4 MAP, n_1 was significantly superior to other sources and at 6 MAP, n_1 was on par with soil application of full dose of nutrients with drip irrigation (n_2), fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) and soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4). At all stages, drip irrigation alone without any fertilizer (n_3) registered the lowest pseudostem height.

The influence of foliar nutrition was evident only at 4 MAP and foliar application of 19-19-19 (s_2) recorded significantly highest plant height (191.13 cm).

Interaction between main and sub-plots had significant influence on pseudostem height only at 4 MAP. It was noticed that n_1s_2 significantly improved the plant height (232.16 cm) over other treatments.

4.2.1.2 Girth of the Pseudostem (cm)

Data on pseudostem girth recorded at different intervals are presented in Table 10.

Table 9. Effect of nutrient sources, irrigation and foliar nutrition on pseudostem height (first crop), cm

Treatments	2 MAP	4 MAP	6 MAP
Nutrient sources & irrigation			
n_1	78.14	215.61	315.05
n_2	75.13	176.00	312.03
n_3	59.33	152.05	268.62
n_4	76.46	181.27	299.34
n_5	77.85	175.45	304.50
n_6	72.55	185.88	297.22
SEm (±)	3.031	3.160	5.038
CD (0.05)	9.552	9.958	15.875
Foliar nutrition			
s_1	69.48	175.03	299.61
s_2	75.90	191.13	299.46
s_3	74.35	176.97	299.30
SEm (±)	1.889	1.483	3.161
CD (0.05)	NS	4.329	NS
Interaction			
n_1s_1	72.91	200.16	308.66
n_1s_2	82.37	232.16	321.66
n_1s_3	79.14	214.50	314.83
n_2s_1	76.33	175.33	311.00
n_2s_2	72.95	187.00	311.76
n_2s_3	76.12	165.66	313.33
n_3s_1	57.33	147.00	263.00
n_3s_2	60.33	157.83	263.38
n_3s_3	60.33	151.33	279.50
n_4s_1	68.66	165.33	305.36
n_4s_2	85.22	193.66	293.33
n_4s_3	75.50	184.83	299.33
n_5s_1	71.66	176.53	306.50
n_5s_2	79.22	180.16	299.66
n_5s_3	82.68	169.66	307.33
n_6s_1	70.00	185.83	303.16
n_6s_2	75.33	196.00	307.00
n_6s_3	72.33	175.83	281.50
SEm (±)	4.628	3.633	7.743
CD (0.05)	NS	10.604	NS

MAP-Months After Planting

Table 10. Effect of nutrient sources, irrigation and foliar nutrition on pseudostem girth (first crop), cm

Treatments	2 MAP	4 MAP	6 MAP
Nutrient sources & irrigation			
n_1	14.69	54.22	67.05
n_2	14.83	48.11	64.91
n_3	10.64	41.30	54.51
n_4	15.20	48.97	59.08
n_5	16.14	47.05	61.16
n_6	14.89	45.77	58.96
SEm (±)	0.209	1.175	0.806
CD (0.05)	0.661	3.703	2.541
Foliar nutrition			
s_1	14.09	47.27	60.09
s_2	14.56	48.48	62.31
s_3	14.54	46.95	60.44
SEm (±)	0.218	0.689	0.599
CD (0.05)	NS	NS	1.749
Interaction			
n_1s_1	13.83	55.50	65.16
n_1s_2	16.08	55.83	69.16
n_1s_3	14.18	51.33	66.83
n_2s_1	13.49	49.00	65.58
n_2s_2	15.86	47.83	65.50
n_2s_3	15.14	47.50	63.66
n_3s_1	10.53	40.66	53.07
n_3s_2	10.43	42.50	56.78
n_3s_3	10.95	40.75	53.69
n_4s_1	14.06	47.91	57.77
n_4s_2	15.56	48.83	61.26
n_4s_3	16.00	50.16	58.20
n_5s_1	17.41	45.08	60.52
n_5s_2	15.08	49.99	62.16
n_5s_3	15.93	46.08	60.80
n_6s_1	15.24	45.49	58.43
n_6s_2	14.37	45.91	59.00
n_6s_3	15.06	45.91	59.46
SEm (±)	0.535	1.688	1.468
CD (0.05)	1.563	NS	NS

MAP-Months After Planting

At 2 MAP, fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) resulted in significant increase in pseudostem girth (16.14 cm). However, at 4 and 6 MAP, soil application of full dose of nutrients with basin irrigation (n_1) was found to be superior to all other treatments.

Foliar application of 19-19-19 (s_2) recorded significantly higher pseudostem girth (62.31 cm) at 6 MAP and its influence on pseudostem girth was not significant at early growth stages.

Though interaction effect had no significant influence on pseudostem girth at 4 and 6 MAP, it exerted significant influence at 2 MAP. Fertigation of 60 per cent RDN as 10-10-10, urea and SOP along with water spray (n_5s_1) registered significantly highest girth which was on par with n_1s_2, n_4s_3, n_5s_3 and n_2s_2.

4.2.1.3 Number of Functional Leaves

Observations on number of functional leaves recorded at 2, 4, 6 MAP and at harvest are presented in Table 11.

Significant increase in the number of functional leaves plant^{-1} was observed in soil application of full dose of nutrients with basin irrigation (n_1) which was on par with soil application of full dose of nutrients with drip irrigation (n_2), soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4), fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) and fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) at 2 MAP and n_2, n_4 and n_5 at 4 MAP. But at harvest, n_1 was found to be superior to all other treatments.

Though foliar nutrition did not show any significant influence on the number of functional leaves at 2 MAP and at harvest stage, foliar application of 19-19-19 (s_2) significantly increased the number of functional leaves plant^{-1} at 4 and 6 MAP compared to water spray (s_1). Among the interactions, n_1s_1 was

Table 11. Effect of nutrient sources, irrigation and foliar nutrition on number of functional leaves (first crop), leaves plant^{-1}

Treatments	2 MAP	4 MAP	6 MAP	At harvest
Nutrient sources & irrigation				
n_1	10.00	10.85	10.55	4.22
n_2	9.67	10.74	10.55	3.29
n_3	8.00	9.96	9.77	2.68
n_4	9.67	10.74	10.33	3.27
n_5	9.56	10.52	10.44	3.30
n_6	9.67	10.18	10.66	3.72
SEm (±)	0.163	0.155	0.207	0.105
CD (0.05)	0.515	0.490	NS	0.331
Foliar nutrition				
s_1	9.39	10.22	10.22	3.18
s_2	9.61	10.88	10.88	3.54
s_3	9.28	10.40	10.04	3.51
SEm (±)	0.122	0.137	0.122	0.113
CD (0.05)	NS	0.402	0.356	NS
Interaction				
n_1s_1	11.00	10.00	10.00	3.58
n_1s_2	10.00	11.66	11.66	4.33
n_1s_3	9.00	10.90	9.99	4.75
n_2s_1	9.67	10.66	10.66	3.16
n_2s_2	9.33	11.00	11.00	3.50
n_2s_3	10.00	10.56	9.99	3.22
n_3s_1	7.00	10.00	10.00	2.50
n_3s_2	9.33	10.00	10.00	2.72
n_3s_3	7.67	9.90	9.32	2.83
n_4s_1	10.00	10.66	10.66	3.05
n_4s_2	9.67	11.00	11.00	3.66
n_4s_3	9.33	10.56	9.32	3.11
n_5s_1	9.00	10.00	10.00	3.50
n_5s_2	9.33	11.00	11.00	3.25
n_5s_3	10.33	10.56	10.32	3.16
n_6s_1	9.67	10.00	10.00	3.33
n_6s_2	10.00	10.66	10.66	3.83
n_6s_3	9.33	9.90	11.32	4.00
SEm (±)	0.299	0.337	0.299	0.278
CD (0.05)	0.873	NS	0.873	NS

MAP-Months After Planting

found superior with 11.00 functional leaves plant^{-1} at 2 MAP and was on par with n_5s_3 (10.33). However, at 6 MAP, n_1s_2 recorded significantly highest number of functional leaves (11.66) which was on par with n_6s_3, n_5s_2, n_4s_2 and n_2s_2.

4.2.1.4 Total Functional Leaf Area (m^2)

Table 12 depicts the total functional leaf area as influenced by nutrient sources, irrigation and foliar nutrition.

At all growth stages, soil application of full dose of nutrients with basin irrigation (n_1) and soil application of full dose of nutrients with drip irrigation (n_2) were found to be significantly superior to other treatments in improving total functional leaf area. Soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4), fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) were on par with these treatments (n_1 and n_2) at 2 MAP and 4 MAP respectively. Irrespective of growth stages, drip irrigation alone without any fertilizer (n_3) registered the lowest functional leaf area.

Foliar application of 19-19-19 (s_2) exerted a significant influence on increasing the total functional leaf area at all growth stages except at 2 MAP. While at harvest, bunch spray of SOP (s_3) and s_2 were observed to be on par and significantly superior to water spray (s_1).

Interaction was significant only at harvest stage wherein n_2s_2 significantly increased total functional leaf area (5.04 m^2) and was on par with n_1s_2, n_4s_3 and n_2s_3.

4.2.1.5 Leaf Area Index (LAI)

Mean values of LAI recorded at 2, 4, 6 MAP and at harvest are presented in Table 13.

The main plot treatments imparted a significant influence on LAI of banana. All sources except drip irrigation alone without any fertilizer (n_3) were

Table 12. Effect of nutrient sources, irrigation and foliar nutrition on total functional leaf area (first crop), m^2

Treatments	2 MAP	4 MAP	6 MAP	At harvest
Nutrient sources & irrigation				
n_1	1.24	4.50	11.84	4.42
n_2	1.20	4.49	12.09	4.25
n_3	1.02	3.24	7.55	2.39
n_4	1.26	4.32	10.59	3.93
n_5	1.13	4.12	10.02	3.59
n_6	1.14	4.19	9.40	3.41
SEm (±)	0.028	0.106	0.361	0.193
CD (0.05)	0.089	0.335	1.140	0.609
Foliar nutrition				
s_1	1.16	3.99	9.54	3.30
s_2	1.17	4.36	11.06	3.92
s_3	1.16	4.08	10.14	3.78
SEm (±)	0.019	0.093	0.315	0.099
CD (0.05)	NS	0.272	0.919	0.291
Interaction				
n_1s_1	1.25	4.73	12.74	4.13
n_1s_2	1.22	4.59	11.94	4.98
n_1s_3	1.25	4.20	10.84	4.14
n_2s_1	1.23	4.30	10.79	3.36
n_2s_2	1.20	4.86	12.31	5.04
n_2s_3	1.18	4.31	13.16	4.37
n_3s_1	1.02	2.87	6.44	2.02
n_3s_2	1.00	3.15	8.88	2.69
n_3s_3	1.04	3.70	7.34	2.48
n_4s_1	1.29	4.10	9.33	3.89
n_4s_2	1.23	4.74	11.39	3.50
n_4s_3	1.26	4.13	11.05	4.39
n_5s_1	1.05	4.09	9.83	3.32
n_5s_2	1.21	4.26	10.48	3.64
n_5s_3	1.14	4.00	9.74	3.81
n_6s_1	1.14	3.85	8.13	3.07
n_6s_2	1.15	4.57	11.37	3.64
n_6s_3	1.13	4.15	8.70	3.53
SEm (±)	0.046	0.228	0.771	0.244
CD (0.05)	NS	NS	NS	0.714

MAP-Months After Planting

Table 13. Effect of nutrient sources, irrigation and foliar nutrition on leaf area index (first crop)

Treatments	2 MAP	4 MAP	6 MAP	At harvest
Nutrient sources & irrigation				
n_1	0.31	1.12	2.96	1.10
n_2	0.30	1.12	3.02	1.06
n_3	0.25	0.81	1.88	0.59
n_4	0.31	1.08	2.64	0.97
n_5	0.28	1.03	2.50	0.89
n_6	0.28	1.04	2.35	0.85
SEm (±)	0.007	0.026	0.090	0.048
CD (0.05)	0.022	0.083	0.285	0.152
Foliar nutrition				
s_1	0.29	0.99	2.38	0.82
s_2	0.29	1.09	2.76	0.97
s_3	0.29	1.02	2.53	0.94
SEm (±)	0.004	0.023	0.078	0.025
CD (0.05)	NS	0.068	0.230	0.073
Interaction				
n_1s_1	0.31	1.18	3.18	1.03
n_1s_2	0.30	1.14	2.98	1.24
n_1s_3	0.31	1.05	2.71	1.03
n_2s_1	0.30	1.07	2.69	0.83
n_2s_2	0.30	1.21	3.07	1.25
n_2s_3	0.29	1.07	3.29	1.09
n_3s_1	0.25	0.71	1.61	0.50
n_3s_2	0.25	0.78	2.22	0.67
n_3s_3	0.26	0.92	1.83	0.61
n_4s_1	0.32	1.02	2.33	0.97
n_4s_2	0.30	1.18	2.84	0.87
n_4s_3	0.31	1.03	2.76	1.09
n_5s_1	0.26	1.02	2.45	0.83
n_5s_2	0.30	1.06	2.62	0.91
n_5s_3	0.28	1.00	2.43	0.95
n_6s_1	0.28	0.96	2.03	0.76
n_6s_2	0.28	1.14	2.84	0.90
n_6s_3	0.28	1.03	2.17	0.88
SEm (±)	0.011	0.057	0.193	0.061
CD (0.05)	NS	NS	NS	0.179

MAP-Months After Planting

on par at 2 MAP. Soil application of full dose of nutrients with basin irrigation (n_1), soil application of full dose of nutrients with drip irrigation (n_2), soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) and fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) were on par and superior to other two sources at 4 MAP. But at 6 MAP, n_2 and n_1 were on par and significantly superior to other treatments.

Foliar application of 19-19-19 (s_2) recorded significantly higher LAI at 4 MAP (1.09) and 6 MAP (2.76) compared to water spray (s_1). LAI at harvest was increased significantly by bunch spray of SOP (s_3) and s_2 which were on par.

Interaction effect had no significant influence on leaf area index at all growth stages except at harvest. At harvest, n_2s_2 registered the highest LAI of 1.25 and was on par with n_1s_2, n_4s_3 and n_2s_3.

4.2.1.6 Bunch Emergence Duration (days), Crop Duration (days) and Sucker Production after Bunch Emergence

Data on bunch emergence duration, crop duration and sucker production after bunch emergence are presented in Table 14.

Though nutrient sources and irrigation had significant influence on bunch emergence duration and crop duration, foliar nutrition and its interaction with nutrient sources didn't exert any significant influence. The shortest bunch emergence and crop duration period of 179.80 days and 258.77 days respectively were observed in the treatment where drip irrigation alone was given without any fertilizer. However, this treatment was on par with n_6, n_5 and n_4 on crop duration. The longest duration for bunch emergence (212.11 days) and crop duration (292.61 days) were registered by soil application of full dose of nutrients with basin irrigation (n_1) which was significantly superior to all other treatments.

Sucker production after bunch emergence was significantly influenced by the treatments. Soil application of full dose of nutrients with drip irrigation (n_2)

Table 14. Effect of nutrient sources, irrigation and foliar nutrition on bunch emergence duration, crop duration and sucker production after bunch emergence (first crop)

Treatments	Bunch emergence duration (days)	Crop duration (days)	Sucker production after bunch emergence
Nutrient sources & irrigation			
n_1	212.11	292.61	9.00
n_2	200.11	276.11	11.22
n_3	179.80	258.77	10.11
n_4	189.13	262.33	10.11
n_5	190.61	261.50	9.44
n_6	190.27	260.83	11.00
SEm (±)	2.434	3.607	0.221
CD (0.05)	7.669	11.365	0.697
Foliar nutrition			
s_1	193.55	266.16	9.55
s_2	193.01	267.36	10.77
s_3	194.45	272.55	10.11
SEm (±)	1.891	1.916	0.592
CD (0.05)	NS	NS	0.202
Interaction			
n_1s_1	214.75	287.50	8.00
n_1s_2	209.50	292.66	10.00
n_1s_3	212.08	297.66	9.00
n_2s_1	195.66	271.50	9.66
n_2s_2	203.83	273.00	13.33
n_2s_3	200.83	283.83	10.66
n_3s_1	174.33	256.00	10.00
n_3s_2	183.08	256.33	10.66
n_3s_3	182.00	264.00	9.66
n_4s_1	189.66	264.00	9.66
n_4s_2	183.00	263.66	10.00
n_4s_3	194.75	259.33	10.66
n_5s_1	190.25	259.00	9.00
n_5s_2	191.83	261.00	9.66
n_5s_3	189.75	264.50	9.66
n_6s_1	196.66	259.00	11.00
n_6s_2	186.83	257.50	11.00
n_6s_3	187.33	266.00	11.00
SEm (±)	4.644	4.695	0.496
CD (0.05)	NS	NS	1.450

registered the highest sucker number of 11.22 which was on par with fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6). The lowest sucker production (9.00) was recorded in soil application of full dose of nutrients with basin irrigation (n_1). It was observed that foliar application of 19-19-19 (s_2) significantly improved sucker production (10.77) over water spray (s_1) (9.55).

Among the treatment combinations, n_2s_2 significantly enhanced sucker production (13.33) over other treatments and the lowest number of sucker was produced by n_1s_1.

4.2.1.7 Dry Matter Production (t ha^{-1})

Data on dry matter production are presented in Table 15.

Significant increase on leaf, pseudostem, fruit and total dry matter production were noticed by soil application of full dose of nutrients with basin irrigation (n_1) and soil application of full dose of nutrients with drip irrigation (n_2). Fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) was observed to be on par with n_1 and n_2 on pseudostem dry matter production. On leaf dry matter production, n_1 was observed to be on par with n_2, n_5 and n_4. n_2 recorded the highest values of 6.20 t ha^{-1} and 24.71 t ha^{-1} for rhizome and total dry matter production, respectively which was on par with n_1.

Leaf, pseudostem, fruit and total dry matter production were significantly influenced by foliar nutrition. Foliar application of 19-19-19 (s_2) and bunch spray of SOP (s_3) were on par for leaf, pseudostem, and total dry matter production. Regarding fruit dry matter production, s_3 was found to be superior to other treatments. However, foliar nutrition had no significant effect on rhizome dry matter production.

Though interaction effect did not show any significant influence on pseudostem, rhizome and total dry matter production, it had significant influence

Table 15. Effect of nutrient sources, irrigation and foliar nutrition on dry matter production of different plant parts (first crop), t ha^{-1}

Treatments	Leaf	Pseudostem	Fruit	Rhizome	Total
Nutrient sources & irrigation					
n_1	2.80	4.76	11.08	5.91	24.57
n_2	2.75	4.73	11.01	6.20	24.71
n_3	1.62	3.25	7.46	3.29	15.63
n_4	2.50	4.08	10.88	5.25	22.71
n_5	2.55	4.55	10.66	4.79	22.56
n_6	1.96	3.90	9.91	4.58	20.36
SEm (±)	0.127	0.137	0.158	0.209	0.355
CD (0.05)	0.401	0.433	0.499	0.658	1.120
Foliar nutrition					
s_1	2.23	3.85	9.38	5.18	20.65
s_2	2.48	4.52	10.33	4.87	22.22
s_3	2.38	4.26	10.79	4.95	22.40
SEm (±)	0.068	0.145	0.109	0.147	0.275
CD (0.05)	0.199	0.424	0.320	NS	0.804
Interaction					
n_1s_1	2.53	4.62	10.50	5.37	23.02
n_1s_2	2.86	4.68	10.93	6.12	24.60
n_1s_3	3.02	4.99	11.81	6.25	26.08
n_2s_1	2.53	4.50	10.82	6.75	24.60
n_2s_2	2.86	4.87	10.93	5.75	24.42
n_2s_3	2.86	4.84	11.30	6.12	25.13
n_3s_1	1.35	2.79	7.04	3.25	14.43
n_3s_2	1.85	3.52	7.58	3.37	16.32
n_3s_3	1.68	3.46	7.76	3.25	16.15
n_4s_1	2.95	3.62	9.48	5.37	21.43
n_4s_2	2.19	4.56	11.59	5.25	23.59
n_4s_3	2.36	4.06	11.59	5.12	23.13
n_5s_1	2.19	4.09	9.04	5.37	20.69
n_5s_2	3.11	4.87	11.15	4.37	23.51
n_5s_3	2.36	4.69	11.81	4.62	23.48
n_6s_1	1.85	3.52	9.40	5.00	19.77
n_6s_2	2.02	4.65	9.84	4.37	20.89
n_6s_3	2.02	3.52	10.50	4.37	20.42
SEm (±)	0.167	0.356	0.268	0.361	0.674
CD (0.05)	0.489	NS	0.784	NS	NS

on fruit and leaf dry matter production. Treatment combinations of n_5s_3, n_1s_3, n_4s_3, n_4s_2, n_2s_3 and n_5s_2 were on par and superior to other sources on fruit dry matter production. The highest leaf dry matter production was recorded by n_5s_2 which was on par with n_1s_3, n_4s_1, n_2s_3, n_2s_2 and n_1s_2.

4.2.2 Index Leaf Nutrient Status

4.2.2.1 Primary Nutrient Content in Index Leaf (per cent)

Data on primary nutrient content in index leaf at 4 MAP are presented in Table 16.

N content in index leaf was significantly increased by soil application of full dose of nutrients with basin irrigation (n_1) which was on par with soil application of full dose of nutrients with drip irrigation (n_2), fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) and fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6). The P and K content were observed to be significantly high under n_1 which was on par with soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) and n_2.

Foliar application of 19-19-19 (s_2) was found to be significantly superior to others in increasing the N and K content of index leaf and it was on par with bunch spray of SOP for enhancing K content. However, P content was not influenced by foliar nutrition.

Primary nutrient content in index leaf at 4 MAP was not significantly influenced by combined effect of fertigation and foliar nutrition.

4.2.2.2 Secondary Nutrient Content in Index Leaf (per cent)

Data on secondary nutrient content in index leaf at 4 MAP are presented in Table 17.

Table 16. Effect of nutrient sources, irrigation and foliar nutrition on primary nutrient content in index leaf at 4 MAP (first crop), per cent

Treatments	N	P	K
Nutrient sources & irrigation			
n_1	3.20	0.19	4.10
n_2	3.12	0.17	3.73
n_3	2.56	0.12	3.24
n_4	2.76	0.18	3.75
n_5	3.02	0.15	3.42
n_6	3.01	0.16	3.41
SEm (±)	0.091	0.006	0.115
CD (0.05)	0.286	0.020	0.364
Foliar nutrition			
s_1	2.76	0.15	3.35
s_2	3.16	0.17	3.79
s_3	2.91	0.16	3.68
SEm (±)	0.088	0.004	0.100
CD (0.05)	0.259	NS	0.292
Interaction			
n_1s_1	3.90	0.17	4.98
n_1s_2	3.07	0.20	4.51
n_1s_3	2.88	0.20	3.64
n_2s_1	2.99	0.17	4.35
n_2s_2	3.49	0.17	3.21
n_2s_3	2.54	0.17	3.26
n_3s_1	2.60	0.11	3.50
n_3s_2	2.54	0.12	2.97
n_3s_3	2.90	0.12	3.88
n_4s_1	2.68	0.16	3.29
n_4s_2	2.71	0.18	4.08
n_4s_3	2.96	0.19	2.94
n_5s_1	3.21	0.15	3.39
n_5s_2	2.91	0.16	3.94
n_5s_3	2.68	0.15	3.58
n_6s_1	3.60	0.16	3.26
n_6s_2	2.74	0.18	3.41
n_6s_3	0.21	0.16	0.24
SEm (±)	0.635	0.010	0.715
CD (0.05)	NS	NS	NS

Table 17. Effect of nutrient sources, irrigation and foliar nutrition on secondary nutrient content in index leaf at 4 MAP (first crop), per cent

Treatments	Ca	Mg	S
Nutrient sources & irrigation			
n_1	0.79	0.56	0.17
n_2	0.73	0.57	0.18
n_3	0.72	0.46	0.17
n_4	0.75	0.51	0.17
n_5	0.75	0.57	0.26
n_6	0.74	0.52	0.29
SEm (±)	0.018	0.025	0.015
CD (0.05)	NS	NS	0.047
Foliar nutrition			
s_1	0.73	0.53	0.21
s_2	0.76	0.57	0.19
s_3	0.75	0.50	0.22
SEm (±)	0.019	0.025	0.007
CD (0.05)	NS	NS	NS
Interaction			
n_1s_1	0.76	0.67	0.18
n_1s_2	0.83	0.51	0.15
n_1s_3	0.78	0.50	0.18
n_2s_1	0.73	0.61	0.18
n_2s_2	0.72	0.66	0.16
n_2s_3	0.75	0.46	0.21
n_3s_1	0.65	0.40	0.22
n_3s_2	0.83	0.53	0.15
n_3s_3	0.68	0.45	0.14
n_4s_1	0.76	0.52	0.14
n_4s_2	0.71	0.43	0.17
n_4s_3	0.79	0.60	0.21
n_5s_1	0.71	0.48	0.31
n_5s_2	0.74	0.65	0.22
n_5s_3	0.79	0.60	0.24
n_6s_1	0.76	0.50	0.25
n_6s_2	0.74	0.65	0.32
n_6s_3	0.71	0.43	0.32
SEm (±)	0.047	0.063	0.018
CD (0.05)	NS	NS	0.054

It was observed that fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) significantly increased S content in index leaf and was on par with fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5). While the Ca and Mg content were not influenced by the treatments.

Foliar nutrition also had no influence on secondary nutrient content in index leaf at 4 MAP.

Combined effect of fertigation and foliar nutrition did not exert any significant influence on the Ca and Mg content. A significantly higher S content of 0.32 per cent was recorded by fertigation of 60 per cent RDN as 13-0-45, SOP and DAP along with 19-19-19 foliar spray (n_6s_2) which was on par with fertigation of 60 per cent RDN as 13-0-45, SOP and DAP along with SOP bunch spray (n_6s_3).

4.2.2.3 Micronutrient Content in Index Leaf (ppm)

Data on micronutrient content in index leaf at 4 MAP are furnished in Table 18.

Nutrient sources and irrigation, foliar nutrition and their interaction had no significant influence on micronutrient content in index leaf at 4 MAP.

4.2.3 Yield Attributes and Yield

4.2.3.1 Bunch and Hand Characteristics

Data on bunch and hand characteristics are presented in Table 19.

The bunch and hand characteristics were significantly influenced by nutrient sources and irrigation. Except the treatment receiving no fertilizer (n_3), all other nutrient sources were on par on number of hands bunch^{-1} and number of fingers in D hand. Regarding the number of fingers bunch^{-1}, soil application of full dose of nutrients with basin irrigation (n_1) registered the highest number (57.91) which was on par with n_2, n_4 and n_5.

Table 18. Effect of nutrient sources, irrigation and foliar nutrition on micronutrient content in index leaf at 4 MAP (first crop), ppm

Treatments	Fe	Zn	Mn	Cu	B
Nutrient sources & irrigation					
n_1	146.33	18.66	339.00	15.63	23.66
n_2	148.50	19.83	337.00	15.78	26.50
n_3	144.16	16.33	342.27	15.66	24.66
n_4	144.83	18.00	338.27	16.83	23.83
n_5	147.50	18.16	342.77	14.22	23.66
n_6	144.83	17.50	333.77	15.33	23.16
SEm (±)	2.023	0.766	5.186	0.529	0.961
CD (0.05)	NS	NS	NS	NS	NS
Foliar nutrition					
s_1	146.25	17.41	338.77	15.14	23.66
s_2	145.25	18.25	341.63	15.88	25.08
s_3	146.58	18.58	336.13	15.70	24.00
SEm (±)	1.946	0.646	1.878	0.379	0.513
CD (0.05)	NS	NS	NS	NS	NS
Interaction					
n_1s_1	147.50	17.00	336.50	15.50	23.00
n_1s_2	147.50	18.00	345.00	15.50	25.00
n_1s_3	144.00	21.00	335.50	15.90	23.00
n_2s_1	147.50	19.00	332.50	13.85	28.00
n_2s_2	142.00	21.50	336.50	17.00	26.00
n_2s_3	156.00	19.00	342.00	16.50	25.50
n_3s_1	140.50	15.50	345.83	14.00	25.00
n_3s_2	141.00	18.00	344.00	16.50	25.50
n_3s_3	151.00	15.50	337.00	16.50	23.50
n_4s_1	144.00	17.50	336.50	17.00	21.50
n_4s_2	144.00	19.00	343.66	17.00	24.50
n_4s_3	146.50	17.50	334.66	16.50	25.50
n_5s_1	159.00	17.00	348.00	13.83	23.50
n_5s_2	146.00	19.00	347.00	15.33	26.00
n_5s_3	137.50	18.50	333.33	13.50	21.50
n_6s_1	139.00	18.50	333.33	16.66	21.00
n_6s_2	151.00	14.00	333.66	14.00	23.50
n_6s_3	144.50	20.00	334.33	15.33	25.00
SEm (±)	4.767	1.582	4.602	0.929	1.258
CD (0.05)	NS	NS	NS	NS	NS

Table 19. Effect of nutrient sources, irrigation and foliar nutrition on bunch and hand characteristics (first crop)

Treatments	Number of hands bunch^{-1}	Number of fingers bunch^{-1}	Number of fingers in D hand
Nutrient sources & irrigation			
n_1	5.77	57.91	12.22
n_2	5.77	57.83	12.11
n_3	4.55	40.83	9.44
n_4	5.77	54.66	11.77
n_5	5.55	54.63	11.55
n_6	5.33	54.16	11.77
SEm (±)	0.155	1.063	0.221
CD (0.05)	0.490	3.352	0.697
Foliar nutrition			
s_1	5.11	49.41	10.83
s_2	5.77	53.69	11.55
s_3	5.50	56.91	12.05
SEm (±)	0.090	0.712	0.111
CD (0.05)	0.264	2.080	0.324
Interaction			
n_1s_1	5.33	53.50	12.00
n_1s_2	6.00	56.25	12.00
n_1s_3	6.00	64.00	12.66
n_2s_1	5.33	54.50	11.66
n_2s_2	6.00	56.50	12.00
n_2s_3	6.00	62.50	12.66
n_3s_1	4.00	39.00	9.00
n_3s_2	5.00	41.50	9.66
n_3s_3	4.66	42.00	9.66
n_4s_1	5.66	47.75	10.66
n_4s_2	6.00	57.75	12.00
n_4s_3	5.66	58.50	12.66
n_5s_1	5.33	48.25	11.00
n_5s_2	6.00	57.15	11.66
n_5s_3	5.33	58.50	12.00
n_6s_1	5.00	53.50	10.66
n_6s_2	5.66	53.00	12.00
n_6s_3	5.33	56.00	12.66
SEm (±)	0.222	1.745	0.272
CD (0.05)	NS	5.096	NS

Foliar application of 19-19-19 (s_2) significantly increased number of hands bunch^{-1} (5.77) and bunch spray of SOP (s_3) registered the highest number of fingers bunch^{-1} (56.91) and number of fingers in D hand (12.05).

Among the treatment combinations, n_1s_3 significantly increased number of fingers bunch^{-1} which was on par with n_2s_3. However, the interaction effect did not show any significant influence on number of hands bunch^{-1} and number of fingers in D hand.

4.2.3.2 Finger Characteristics

Data on finger characteristics of banana are given in Table 20.

Weight of D finger was significantly increased by soil application of full dose of nutrients with basin irrigation (n_1) (226.27 g) which was on par with soil application of full dose of nutrients with drip irrigation (n_2) and soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4). Similarly, fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) significantly increased length of D finger (27.69 cm) which was on par with all other nutrient sources except n_3. However, nutrient sources and irrigation did not impart any significant influence on girth of D finger.

Bunch spray of SOP (s_3) significantly enhanced the weight of D finger (226.01 g) and girth of D finger (14.32 cm). Foliar application of 19-19-19 (s_2) registered finger girth values on par with s_3. However, the length of D finger was not significantly influenced by foliar nutrition.

Though interaction had no significant effect on length and girth of D finger, weight of D finger was significantly increased by n_2s_3 which was on par with n_1s_3, n_5s_3, n_4s_3, n_6s_3 and n_1s_2.

Table 20. Effect of nutrient sources, irrigation and foliar nutrition on finger characteristics (first crop)

Treatments	Weight of D finger (g)	Length of D finger (cm)	Girth of D finger (cm)
Nutrient sources & irrigation			
n_1	226.27	27.29	14.42
n_2	224.65	27.67	14.42
n_3	185.89	25.51	13.78
n_4	216.83	27.60	14.13
n_5	216.17	27.69	14.10
n_6	212.43	27.45	14.10
SEm (±)	3.158	0.375	0.142
CD (0.05)	9.951	1.182	NS
Foliar nutrition			
s_1	200.44	26.83	13.98
s_2	214.66	27.23	14.18
s_3	226.01	27.53	14.32
SEm (±)	1.891	0.220	0.083
CD (0.05)	5.520	NS	0.243
Interaction			
n_1s_1	216.08	26.89	14.27
n_1s_2	225.00	26.45	14.46
n_1s_3	237.75	28.51	14.53
n_2s_1	211.63	27.25	14.20
n_2s_2	224.00	28.00	14.41
n_2s_3	238.33	27.77	14.66
n_3s_1	183.76	25.06	13.50
n_3s_2	188.41	25.33	13.86
n_3s_3	185.50	26.13	14.00
n_4s_1	204.50	27.03	14.10
n_4s_2	215.83	27.79	14.11
n_4s_3	230.16	27.98	14.18
n_5s_1	192.40	27.61	13.96
n_5s_2	221.41	27.86	14.06
n_5s_3	234.70	27.59	14.28
n_6s_1	194.30	27.16	13.86
n_6s_2	213.33	27.96	14.18
n_6s_3	229.66	27.24	14.26
SEm (±)	4.632	0.539	0.204
CD (0.05)	13.521	NS	NS

4.2.3.3 Bunch Weight (kg plant^{-1}) and Yield (t ha^{-1})

Results on bunch weight and yield of banana as influenced by nutrient sources, irrigation and foliar nutrition are presented in Table 21.

Soil application of full dose of nutrients with basin irrigation (n_1) registered significantly highest bunch weight (12.66 kg plant^{-1}) and total yield (31.66 t ha^{-1}) which was on par with soil application of full dose of nutrients with drip irrigation (n_2), soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) and fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5).

Bunch spray of SOP (s_3) was found to be superior to other treatments in enhancing bunch weight (12.34 kg plant^{-1}) and total banana yield (30.85 t ha^{-1}).

Among the interactions, n_1s_3 recorded significantly highest bunch weight (13.50 kg plant^{-1}) and total yield (33.75 t ha^{-1}) which was on par with n_5s_3, n_4s_3, n_4s_2, n_2s_3 and n_5s_2.

4.2.4 Scoring of Pests and Diseases

Though the incidence of pseudostem weevil and sigatoka leaf spot disease were there in the first year of experimentation, there was no significant variation among the treatments. Hence a uniform score of one was given as depicted in the score charts presented in Appendix IX and Appendix X.

4.2.5 Quality Attributes

Data on quality attributes and shelf life are presented in Tables 22 and 23.

The different nutrient sources and irrigation had significant influence on all quality attributes except TSS and ascorbic acid content in banana fruits. Treatment receiving no fertilizer with drip irrigation alone (n_3) recorded the highest acidity (0.33 per cent) and it was on par with n_4, n_5, n_6 and n_2. Fertigation

Table 21. Effect of nutrient sources, irrigation and foliar nutrition on bunch weight and yield (first crop)

Treatments	Bunch weight (kg plant^{-1})	Yield (t ha^{-1})
Nutrient sources & irrigation		
n_1	12.66	31.66
n_2	12.59	31.49
n_3	8.53	21.32
n_4	12.44	31.11
n_5	12.19	30.48
n_6	11.33	28.33
SEm (±)	0.180	0.450
CD (0.05)	0.568	1.419
Foliar nutrition		
s_1	10.72	26.81
s_2	11.82	29.54
s_3	12.34	30.85
SEm (±)	0.125	0.313
CD (0.05)	0.365	0.914
Interaction		
n_1s_1	12.00	30.00
n_1s_2	12.50	31.25
n_1s_3	13.50	33.75
n_2s_1	12.37	30.93
n_2s_2	12.50	31.25
n_2s_3	12.92	32.31
n_3s_1	8.05	20.13
n_3s_2	8.67	21.67
n_3s_3	8.87	22.17
n_4s_1	10.84	27.11
n_4s_2	13.25	33.12
n_4s_3	13.25	33.12
n_5s_1	10.33	25.83
n_5s_2	12.75	31.87
n_5s_3	13.50	33.75
n_6s_1	10.75	26.87
n_6s_2	11.25	28.12
n_6s_3	12.00	30.00
SEm (±)	0.306	0.767
CD (0.05)	0.896	2.239

Table 22. Effect of nutrient sources, irrigation and foliar nutrition on quality attributes (first crop)

Treatments	TSS (%)	Ascorbic acid (mg 100g^{-1})	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Sugar: acid ratio
Nutrient sources & irrigation							
n_1	31.66	14.08	0.25	20.61	18.02	2.58	81.64
n_2	31.72	14.82	0.30	21.06	18.76	2.29	70.73
n_3	31.33	13.02	0.33	19.32	17.12	2.20	59.44
n_4	31.61	13.85	0.31	20.30	17.86	2.43	67.08
n_5	32.08	12.84	0.31	20.37	17.22	3.15	64.18
n_6	30.94	14.56	0.31	21.57	17.99	3.57	70.53
SEm (±)	0.448	0.560	0.013	0.282	0.271	0.186	3.947
CD (0.05)	NS	NS	0.043	0.889	0.856	0.588	12.439
Foliar nutrition							
s_1	31.54	12.82	0.32	19.36	17.02	2.33	63.52
s_2	31.33	14.13	0.30	20.66	17.81	2.84	67.70
s_3	31.80	14.63	0.29	21.60	18.66	2.94	75.58
SEm (±)	0.261	0.302	0.008	0.206	0.225	0.154	2.515
CD (0.05)	NS	0.882	NS	0.603	0.657	0.449	7.343
Interaction							
n_1s_1	32.00	12.91	0.23	18.75	16.89	1.86	84.95
n_1s_2	31.00	14.40	0.29	20.91	17.99	2.92	71.45
n_1s_3	32.00	14.95	0.25	22.17	19.20	2.97	88.50
n_2s_1	31.50	13.30	0.28	19.96	18.06	1.90	72.87
n_2s_2	32.00	14.56	0.29	20.67	18.21	2.46	70.21
n_2s_3	31.66	16.60	0.32	22.54	20.01	2.53	69.10
n_3s_1	31.00	13.30	0.38	17.78	15.60	2.18	46.52
n_3s_2	31.00	12.15	0.32	19.67	17.52	2.15	61.27
n_3s_3	32.00	13.63	0.30	20.52	18.25	2.27	70.52
n_4s_1	32.16	13.30	0.35	20.08	17.92	2.15	56.36
n_4s_2	31.00	14.95	0.30	19.92	17.42	2.50	65.50
n_4s_3	31.67	13.30	0.26	20.90	18.25	2.65	79.39
n_5s_1	31.26	11.98	0.31	18.62	16.16	2.46	59.23
n_5s_2	32.00	13.80	0.33	21.10	17.75	3.35	64.09
n_5s_3	33.00	12.75	0.30	21.38	17.75	3.63	69.22
n_6s_1	31.33	12.15	0.34	20.97	17.50	3.47	61.17
n_6s_2	31.00	14.95	0.29	21.67	17.99	3.67	73.69
n_6s_3	30.50	16.60	0.28	22.08	18.50	3.58	76.71
SEm (±)	0.640	0.740	0.021	0.506	0.551	0.377	6.162
CD (0.05)	NS	NS	0.061	NS	NS	NS	NS

Table 23. Effect of nutrient sources, irrigation and foliar nutrition on pulp : peel ratio and shelf life (first crop)

Treatments	Pulp : peel ratio	Shelf life (days)
Nutrient sources & irrigation		
n_1	3.58	10.77
n_2	3.55	11.88
n_3	2.87	10.94
n_4	3.23	11.44
n_5	3.30	12.33
n_6	3.42	11.55
SEm (±)	0.109	0.177
CD (0.05)	0.345	0.558
Foliar nutrition		
s_1	3.10	11.05
s_2	3.15	11.44
s_3	3.73	11.97
SEm (±)	0.067	0.116
CD (0.05)	0.196	0.340
Interaction		
n_1s_1	3.63	10.50
n_1s_2	3.28	10.50
n_1s_3	3.84	11.33
n_2s_1	3.26	10.66
n_2s_2	3.65	12.50
n_2s_3	3.74	12.50
n_3s_1	2.54	10.50
n_3s_2	2.80	10.83
n_3s_3	3.29	11.50
n_4s_1	2.62	11.50
n_4s_2	3.08	11.33
n_4s_3	3.99	11.50
n_5s_1	3.19	12.50
n_5s_2	2.97	12.00
n_5s_3	3.75	12.50
n_6s_1	3.35	10.66
n_6s_2	3.16	11.50
n_6s_3	3.77	12.50
SEm (±)	0.164	0.285
CD (0.05)	NS	0.834

of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) enhanced the total sugar (21.57 per cent) which was on par with n_2. Soil application of full dose of nutrients with drip irrigation (n_2) registered the highest value for reducing sugar (18.76 per cent) which was on par with n_1 and n_6. Fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) registered the highest value for non-reducing sugar (3.57 per cent) which was on par with n_5. Sugar : acid ratio was significantly higher in n_1 (81.64) and was on par with n_2 and n_6. The highest pulp : peel ratio of 3.58 was recorded by n_1 which was on par with n_2, n_6 and n_5. In the case of shelf life, the longest shelf life period of 12.33 days was registered by fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) and was on par with n_2.

Bunch spray of SOP (s_3) significantly increased quality attributes like ascorbic acid, total sugar, reducing sugar, non-reducing sugar and sugar : acid ratio and it was on par with foliar application of 19-19-19 (s_2) in ascorbic acid and non-reducing sugar content. Pulp : peel ratio was found to be significantly increased by bunch spray with SOP (s_3) compared to water spray (s_1). Bunch spray was also effective in enhancing the shelf life period (11.97 days).

Interaction effect had significant influence only on acidity and shelf life of fruits. The highest acidity of 0.38 per cent was registered by n_3s_1 and it was on par with n_4s_1, n_6s_1, n_5s_2 and n_3s_2. Whereas in shelf life, the longest period of 12.50 days was recorded by n_2s_2, n_2s_3, n_5s_1, n_5s_3 and n_6s_3. The interaction effect had no significant influence on pulp : peel ratio.

4.2.6 Water Requirement, Water Use Efficiency and Water Productivity

Data on total water requirement, water use efficiency and water productivity as influenced by nutrient sources, irrigation and foliar nutrition are presented in Appendix V and in Table 24.

In the first year of experimentation, total water requirement was computed to be 1387 mm in basin irrigation and 782.82 mm in drip irrigation resulting in 44 per cent reduction in water requirement in drip irrigation compared to basin

Table 24. Effect of nutrient sources, irrigation and foliar nutrition on water productivity and water use efficiency (first crop), kg ha.mm^{-1}

Treatments	Water productivity	Water use efficiency
Nutrient sources & irrigation		
n_1	17.71	22.83
n_2	31.57	40.23
n_3	19.97	27.24
n_4	29.02	39.75
n_5	28.82	38.94
n_6	26.01	36.19
SEm (±)	0.454	0.575
CD (0.05)	1.433	1.813
Foliar nutrition		
s_1	24.25	31.47
s_2	26.10	34.84
s_3	26.20	36.27
SEm (±)	0.313	0.379
CD (0.05)	0.914	1.107
Interaction		
n_1s_1	16.60	21.62
n_1s_2	17.73	22.53
n_1s_3	18.80	24.33
n_2s_1	31.42	39.51
n_2s_2	31.19	39.91
n_2s_3	32.10	41.27
n_3s_1	18.43	25.71
n_3s_2	20.85	27.68
n_3s_3	20.63	28.32
n_4s_1	27.37	34.63
n_4s_2	30.13	42.31
n_4s_3	29.55	42.31
n_5s_1	26.43	33.00
n_5s_2	30.03	40.71
n_5s_3	30.00	43.11
n_6s_1	25.25	34.32
n_6s_2	26.68	35.92
n_6s_3	26.09	38.32
SEm (±)	0.767	0.929
CD (0.05)	NS	2.713

irrigation. Whereas, irrigation requirement was computed to be 845 mm in basin irrigation and 240.82 mm in drip irrigation treatments.

Water use efficiency and water productivity were significantly influenced by the treatments. Among the nutrient sources and irrigation, soil application of full dose of nutrients with drip irrigation (n_2) recorded significantly highest water productivity of 31.57 kg ha.mm^{-1}. Bunch spray of SOP (s_3) registered significantly a higher water productivity of 26.20 kg ha.mm^{-1} which was on par with foliar application of 19-19-19 (s_2). Interaction effect had no significant influence on water productivity. In water use efficiency, though n_2 registered the highest value (40.23 kg ha.mm^{-1}), it was on par with n_4 and n_5. The highest water use efficiency of 36.27 kg ha.mm^{-1} was recorded by s_3 which was followed by s_2.

Among the treatment combinations, n_5s_3 registered significantly highest water use efficiency of 43.11 kg ha.mm^{-1} which was on par with n_4s_3, n_4s_2, n_2s_3 and n_5s_2.

4.2.7 Nutrient Uptake (kg ha^{-1})

Nutrient uptake by different parts of banana at harvest as influenced by nutrient sources, irrigation and foliar nutrition are given in Tables 25, 26 and 27.

4.2.7.1 N Uptake (kg ha^{-1})

Soil application of full dose of nutrients with basin irrigation (n_1) and drip irrigation (n_2) had significant influence in improving the N uptake by different parts of banana at harvest.

Bunch spray of SOP (s_3) and foliar application of 19-19-19 (s_2) were observed to be on par and significantly increased fruit, pseudostem and total N uptake. The Leaf N uptake was significantly improved by s_2 while rhizome N uptake was not influenced by foliar nutrition.

Fruit, leaf, rhizome and total N uptake were influenced by the interaction effect of nutrient sources and foliar application. The highest fruit N uptake was noticed in n_5s_2 which was on par with n_1s_3, n_2s_3 and n_5s_3. The N uptake by leaf and rhizome were highest in n_1s_2 (84.30 kg ha^{-1}) and (126.47 kg ha^{-1}) respectively. The total N uptake was also found to be high in n_1s_2 (434.71 kg ha^{-1}) which was on par with n_1s_3 (414.93 kg ha^{-1}).

4.2.7.2 P Uptake (kg ha^{-1})

Results presented in Table 26 revealed that leaf, rhizome and total plant P uptake were significantly increased by soil application of full dose of nutrients with drip irrigation (n_2) and it was on par with n_1 and n_5 on leaf P uptake. Regarding the fruit P uptake, soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) registered significantly higher value (16.24 kg ha^{-1}) and was on par with n_5 and n_2. The P uptake by pseudostem was significantly increased by fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5).

Foliar nutrition significantly influenced P uptake by various plant parts. Bunch spray of SOP (s_3) registered the highest P uptake by fruits and it was on par with foliar application of 19-19-19 (s_2). Both these treatments were on par and registered higher P uptake by pseudostem. However, leaf, rhizome and total P uptake were significantly superior in s_2.

The interaction effect was significant only for fruit, leaf and rhizome P uptake. The highest P uptake by fruit (18.90 kg ha^{-1}) was recorded by n_5s_3 which was on par with n_4s_2, n_4s_3, n_5s_2 and n_2s_2. Though n_2s_2 registered the highest leaf uptake (9.23 kg ha^{-1}), it was on par with n_1s_2 (9.03 kg ha^{-1}). P uptake values by the rhizome was significantly higher in n_2s_1 (27.16 kg ha^{-1}) which was on par with n_1s_2, n_2s_3 and n_2s_2. The pseudostem and total P uptake were unaffected by treatment combinations.

4.2.7.3 K Uptake (kg ha^{-1})

K uptake values by different plant parts of banana is presented in Table 27.

Table 25. Effect of nutrient sources, irrigation and foliar nutrition on N uptake by different parts at harvest (first crop), kg ha^{-1}

Treatments	Leaf	Pseudostem	Fruit	Rhizome	Total
Nutrient sources & irrigation					
n_1	69.37	64.42	157.57	100.86	392.25
n_2	71.34	66.71	161.76	92.27	392.10
n_3	28.29	34.72	72.88	36.83	172.74
n_4	54.49	53.88	132.87	75.07	316.34
n_5	57.26	59.00	153.09	62.28	331.65
n_6	43.50	52.92	124.87	61.18	282.48
SEm (±)	3.556	1.528	2.579	4.986	5.180
CD (0.05)	11.206	4.814	8.127	15.710	16.322
Foliar nutrition					
s_1	47.50	49.32	116.34	67.28	280.46
s_2	61.41	61.48	140.22	76.40	339.52
s_3	53.22	55.03	144.97	70.56	323.79
SEm (±)	1.749	2.486	2.172	3.157	5.446
CD (0.05)	5.106	7.259	6.342	NS	15.896
Interaction					
n_1s_1	52.59	61.49	145.95	67.06	327.10
n_1s_2	84.30	67.08	156.83	126.47	434.71
n_1s_3	71.23	64.70	169.94	109.05	414.93
n_2s_1	65.66	64.08	162.64	97.80	390.20
n_2s_2	76.68	70.84	153.12	89.87	390.52
n_2s_3	71.69	65.22	169.52	89.13	395.57
n_3s_1	22.14	28.25	59.18	36.49	146.08
n_3s_2	33.41	38.84	81.16	38.25	191.67
n_3s_3	29.32	37.06	78.32	35.76	180.48
n_4s_1	62.55	48.53	105.84	72.29	289.22
n_4s_2	49.91	59.43	143.72	79.10	332.18
n_4s_3	51.02	53.68	149.06	73.83	327.61
n_5s_1	43.55	50.62	113.43	64.41	272.03
n_5s_2	77.15	65.91	178.32	64.60	386.00
n_5s_3	51.08	60.46	167.52	57.84	336.92
n_6s_1	38.49	42.97	111.00	65.66	258.14
n_6s_2	47.00	66.77	128.18	60.10	302.06
n_6s_3	45.00	49.04	135.45	57.76	287.25
SEm (±)	4.284	6.091	5.322	7.735	13.340
CD (0.05)	12.507	NS	15.535	22.578	38.939

Table 26. Effect of nutrient sources, irrigation and foliar nutrition on P uptake by different parts at harvest (first crop), kg ha^{-1}

Treatments	Leaf	Pseudostem	Fruit	Rhizome	Total
Nutrient sources & irrigation					
n_1	6.94	6.51	14.16	20.00	47.62
n_2	7.12	7.95	15.41	26.05	56.57
n_3	3.13	3.15	6.77	4.04	17.11
n_4	5.98	6.47	16.24	8.32	37.03
n_5	6.04	15.53	15.92	8.25	45.75
n_6	4.47	11.37	13.90	6.73	36.48
SEm (±)	0.353	0.533	0.399	1.103	1.315
CD (0.05)	1.114	1.682	1.257	3.475	4.144
Foliar nutrition					
s_1	4.87	7.47	11.67	11.05	35.07
s_2	6.52	9.53	14.55	13.53	44.15
s_3	5.45	8.49	14.98	12.12	41.06
SEm (±)	0.175	0.426	0.310	0.435	0.772
CD (0.05)	0.511	1.244	0.906	1.271	2.254
Interaction					
n_1s_1	5.32	6.06	13.65	12.96	38.00
n_1s_2	9.03	7.00	13.08	26.92	56.05
n_1s_3	6.46	6.46	15.74	20.13	48.81
n_2s_1	5.80	7.30	14.05	27.16	54.33
n_2s_2	9.23	7.82	16.73	25.38	59.17
n_2s_3	6.34	8.74	15.47	25.60	56.20
n_3s_1	2.16	2.04	4.74	3.73	12.68
n_3s_2	3.77	3.62	8.63	4.39	20.43
n_3s_3	3.45	3.81	6.94	4.01	18.23
n_4s_1	6.76	5.80	13.60	7.15	33.32
n_4s_2	5.32	7.00	17.70	9.11	39.15
n_4s_3	5.87	6.61	17.42	8.71	38.63
n_5s_1	5.06	13.97	11.77	8.79	39.62
n_5s_2	7.14	17.64	17.07	7.95	49.82
n_5s_3	5.92	14.99	18.90	8.00	47.83
n_6s_1	4.12	9.64	12.23	6.50	32.50
n_6s_2	4.64	14.13	14.09	7.42	40.31
n_6s_3	4.64	10.34	15.40	6.26	36.65
SEm (±)	0.429	1.044	0.760	1.066	1.892
CD (0.05)	1.254	NS	2.219	3.113	NS

The total K uptake and K uptake by fruit, pseudostem and rhizome were significantly higher in soil application of full dose of nutrients with drip irrigation (n_2). This was on par with n_1, n_4 and n_5 on fruit K uptake, with n_1 on pseudostem, rhizome and total K uptake. Soil application of full dose of nutrients with basin irrigation (n_1) registered the highest leaf K uptake (76.08 kg ha^{-1}) which was on par with n_2.

Bunch spray of SOP (s_3) significantly enhanced the fruit and total K uptake and it was on par with foliar application of 19-19-19 (s_2) on total K uptake. K uptake values by leaf and pseudostem were higher for s_2. Foliar nutrition did not show any significant influence on rhizome K uptake.

Interaction effect also had significant influence on K uptake. The highest K uptake by fruits was recorded by n_2s_3 which was on par with n_5s_3, n_4s_3 and n_1s_3. Leaf K uptake values were significantly higher for n_1s_2 which was on par with n_2s_2, n_1s_3, n_5s_2 and n_2s_3. Regarding the K uptake by rhizome, n_2s_1 showed the highest value which was on par with n_1s_2, n_1s_3 and n_2s_3. The total K uptake as well as K uptake by pseudostem were not affected by treatment combinations.

4.2.8 Nutrient Use Efficiency

Data on physiological efficiency, apparent recovery, nutrient use efficiency of major nutrients and agronomic efficiency as influenced by nutrient sources, irrigation and foliar nutrition are presented in Tables 28, 29 and 30.

4.2.8.1 Physiological Efficiency of Major Nutrients (kg kg^{-1})

Physiological efficiency of major nutrients was found to be significantly influenced by nutrient sources and irrigation. Soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) recorded a significantly higher physiological efficiency of 48.05 kg kg^{-1} for N. The same treatment registered a significantly higher physiological efficiency for P and was on par with soil application of full dose of nutrients with basin irrigation(n_1). In the case of K, fertigation of 60 per cent RDN as 13-0-45, SOP

Table 27. Effect of nutrient sources, irrigation and foliar nutrition on K uptake by different parts at harvest (first crop), kg ha^{-1}

Treatments	Leaf	Pseudostem	Fruit	Rhizome	Total
Nutrient sources & irrigation					
n_1	76.08	234.31	205.12	359.01	874.55
n_2	75.14	240.00	209.78	380.07	905.00
n_3	30.37	118.19	116.30	153.42	418.30
n_4	61.89	177.96	204.50	295.65	740.01
n_5	59.61	204.70	190.78	257.58	712.69
n_6	40.47	159.00	169.63	232.76	601.88
SEm (±)	2.845	5.854	8.294	15.663	23.320
CD (0.05)	8.965	18.447	26.134	49.353	73.480
Foliar nutrition					
s_1	48.57	166.32	160.58	278.85	654.33
s_2	66.18	210.74	181.20	273.69	731.83
s_3	57.03	190.02	206.28	286.71	740.05
SEm (±)	1.797	7.164	3.495	9.508	15.304
CD (0.05)	5.246	20.913	10.202	NS	44.672
Interaction					
n_1s_1	56.49	216.53	190.05	268.73	731.81
n_1s_2	87.47	240.63	203.24	425.28	956.63
n_1s_3	84.29	245.78	222.08	383.03	935.20
n_2s_1	62.15	190.48	186.40	432.25	871.29
n_2s_2	86.08	301.57	198.50	328.80	914.97
n_2s_3	77.20	227.95	244.44	379.16	928.75
n_3s_1	23.62	87.94	108.19	148.75	368.52
n_3s_2	35.26	138.82	116.93	161.41	452.44
n_3s_3	32.25	127.79	123.79	150.10	433.94
n_4s_1	65.52	168.52	170.90	293.25	698.20
n_4s_2	64.82	186.83	216.39	271.88	739.93
n_4s_3	55.34	178.52	226.22	321.81	781.91
n_5s_1	45.94	189.96	147.99	284.95	668.86
n_5s_2	81.54	209.12	189.40	237.79	717.86
n_5s_3	51.34	215.03	234.96	250.00	751.34
n_6s_1	37.68	144.48	159.94	245.16	587.28
n_6s_2	41.95	187.46	162.76	216.97	609.16
n_6s_3	41.78	145.05	186.20	236.16	609.20
SEm (±)	4.402	17.549	8.561	23.291	37.487
CD (0.05)	12.851	NS	24.990	67.985	NS

Table 28. Effect of nutrient sources, irrigation and foliar nutrition on physiological efficiency of major nutrients (first crop), kg kg^{-1}

Treatments	N	P	K
Nutrient sources & irrigation			
n_1	41.77	298.99	20.52
n_2	41.42	232.92	19.03
n_4	48.05	337.19	22.37
n_5	44.59	244.79	23.43
n_6	43.62	267.39	25.20
SEm (±)	0.974	13.388	0.572
CD (0.05)	3.178	43.664	1.865
Foliar nutrition			
s_1	46.45	284.00	21.85
s_2	40.71	259.17	22.65
s_3	44.51	285.60	21.83
SEm (±)	0.732	7.314	0.395
CD (0.05)	2.161	21.578	NS
Interaction			
n_1s_1	46.57	335.71	23.42
n_1s_2	35.57	238.56	17.63
n_1s_3	43.16	322.69	20.51
n_2s_1	41.73	244.37	20.21
n_2s_2	39.81	210.30	17.82
n_2s_3	42.72	244.09	19.07
n_4s_1	48.47	338.91	21.08
n_4s_2	48.72	344.25	25.08
n_4s_3	46.97	328.40	20.93
n_5s_1	48.59	230.98	20.37
n_5s_2	38.16	249.21	26.15
n_5s_3	47.03	254.17	23.78
n_6s_1	46.89	269.98	24.18
n_6s_2	41.30	253.51	26.56
n_6s_3	42.66	278.66	24.87
SEm (±)	1.638	16.356	0.883
CD (0.05)	4.832	NS	2.605

and DAP (n_6) registered the highest physiological efficiency of 25.20 kg kg^{-1} which was on par with n_5.

Foliar nutrition had significant effect on physiological efficiency of major nutrients except K. Physiological efficiency of N was significantly enhanced with water spray (s_1) and was on par with bunch spray of SOP (s_3). Whereas, s_3 recorded the highest value of 285.60 kg kg^{-1} for P which was on par with s_1.

Interaction effect exerted significant influence on physiological efficiency of N and K. Among the interactions, n_4s_2 recorded the highest value for N (48.72 kg kg^{-1}) which was on par with n_5s_1, n_4s_1, n_5s_3, n_4s_3, n_6s_1 and n_1s_1. Whereas, physiological efficiency of K was significantly superior in n_6s_2 which was on par with n_5s_2, n_4s_2, n_6s_3 and n_6s_1.

4.2.8.2 Apparent Recovery of Major Nutrients (per cent)

Results presented in Table 29 revealed that fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) had significantly higher apparent recovery of N (41.17 per cent) which was on par with soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4). In the case of P, n_5 was found to be significantly superior (19.10 per cent) to all other treatments. Significantly highest apparent recovery of K (54.91 per cent) was recorded by n_4 which was on par with n_5, n_2, and n_1.

Apparent recovery of N and P was significantly increased by foliar application of 19-19-19 (s_2). For K, bunch spray of SOP (s_3) registered significantly the highest value which was on par with s_2. Apparent recovery of P and K were not significantly influenced by interaction effect. However, for N, n_5s_2 recorded a significantly higher value of 53.11 per cent.

Table 29. Effect of nutrient sources, irrigation and foliar nutrition on apparent recovery of major nutrients (first crop), per cent

Treatments	N	P	K
Nutrient sources & irrigation			
n_1	32.79	12.12	44.91
n_2	32.77	15.23	47.62
n_4	37.78	8.45	54.91
n_5	41.17	19.10	50.87
n_6	30.27	13.74	34.49
SEm (±)	1.165	0.525	3.451
CD (0.05)	3.801	1.712	11.255
Foliar nutrition			
s_1	28.27	11.51	40.54
s_2	39.95	15.48	48.55
s_3	36.64	14.19	50.59
SEm (±)	1.045	0.404	2.054
CD (0.05)	3.083	1.191	6.061
Interaction			
n_1s_1	24.13	8.80	32.29
n_1s_2	38.39	14.99	52.19
n_1s_3	35.84	12.56	50.25
n_2s_1	32.54	14.48	44.69
n_2s_2	32.52	16.07	48.50
n_2s_3	33.26	15.13	49.68
n_4s_1	31.80	7.17	48.84
n_4s_2	41.20	9.15	54.88
n_4s_3	40.34	9.02	61.01
n_5s_1	27.98	15.61	44.49
n_5s_2	53.11	21.32	51.62
n_5s_3	42.40	20.37	56.50
n_6s_1	24.90	11.48	32.40
n_6s_2	34.53	15.86	35.56
n_6s_3	31.37	13.89	35.52
SEm (±)	2.337	0.903	4.594
CD (0.05)	6.895	NS	NS

4.2.8.3 Nutrient Use Efficiency of Major Nutrients (kg kg^{-1})

Nutrient use efficiency of major nutrients (Table 30) was significantly influenced by nutrient sources and irrigation. The highest nutrient use efficiency of N and K (18.38 kg kg^{-1} and 12.24 kg kg^{-1}, respectively) were recorded by soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) which was on par with fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5). While, the highest P use efficiency (46.97 kg kg^{-1}) was registered by n_5.

Bunch spray of SOP (s_3) was on par with foliar application of 19-19-19 (s_2) and significantly increased nutrient use efficiency of major nutrients.

Interaction effect did not exert any significant effect on nutrient use efficiency of any of the major nutrients.

4.2.8.4 Agronomic Efficiency (kg kg^{-1})

Agronomic efficiency of major nutrients (Table 30) was observed to be significantly improved by soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) for N and K and it was on par with fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5). n_5 recorded the highest P agronomic efficiency of 59.79 kg kg^{-1}.

Bunch spray of SOP (s_3) was significantly superior to other treatments in improving the agronomic efficiency of major nutrients.

Among the treatment combinations, n_5s_3 significantly increased agronomic efficiency of N and K which was on par with n_4s_3 and n_4s_2. The same treatment recorded significantly highest agronomic P use efficiency of 78.93 kg kg^{-1}.

Table 30. Effect of nutrient sources, irrigation and foliar nutrition on nutrient use efficiency of major nutrients and agronomic efficiency (first crop), kg kg^{-1}

Treatments	Nutrient use efficiency			Agronomic efficiency		
	N	P	K	N	P	K
Nutrient sources & irrigation						
n_1	13.50	35.19	8.99	15.36	40.04	10.23
n_2	13.70	35.70	9.13	15.14	39.45	10.08
n_4	18.38	28.75	12.24	24.37	38.12	16.23
n_5	18.04	46.97	12.02	22.97	59.79	15.29
n_6	13.15	36.65	8.76	18.19	47.38	12.11
SEm (±)	0.862	1.949	0.574	1.388	2.067	0.924
CD (0.05)	2.814	6.358	1.872	4.526	6.743	3.013
Foliar nutrition						
s_1	13.26	31.36	8.84	14.14	33.65	9.42
s_2	16.29	38.76	10.87	20.40	47.01	13.61
s_3	16.51	39.84	10.97	23.08	54.20	15.34
SEm (±)	0.510	1.424	0.339	0.490	1.237	0.327
CD (0.05)	1.507	4.201	1.002	1.445	3.651	0.965
Interaction						
n_1s_1	11.46	29.89	7.64	13.15	34.31	8.77
n_1s_2	13.52	35.16	9.02	14.78	38.44	9.86
n_1s_3	15.53	40.52	10.33	18.15	47.36	12.07
n_2s_1	13.55	35.36	9.03	14.40	37.56	9.60
n_2s_2	13.28	34.54	8.86	14.78	38.44	9.86
n_2s_3	14.26	37.22	9.49	16.23	42.35	10.79
n_4s_1	15.55	24.34	10.36	15.50	24.26	10.33
n_4s_2	20.27	31.66	13.53	28.76	44.92	19.19
n_4s_3	19.33	30.26	12.84	28.86	45.18	19.17
n_5s_1	13.91	36.29	9.27	12.66	33.04	8.44
n_5s_2	20.10	52.14	13.42	25.99	67.40	17.34
n_5s_3	20.12	52.49	13.36	30.25	78.93	20.09
n_6s_1	11.85	30.93	7.90	14.97	39.07	9.98
n_6s_2	14.29	40.30	9.54	17.69	45.87	11.80
n_6s_3	13.31	38.72	8.84	21.92	57.19	14.56
SEm (±)	1.142	3.184	0.760	1.096	2.767	0.731
CD (0.05)	NS	NS	NS	3.233	8.164	2.158

4.2.9 Soil Nutrient Status after First Year of Experimentation

Results in Table 31 revealed that the different nutrient sources and irrigation significantly influenced the soil N, P and K status after the first banana crop.

Soil application of full dose of nutrients with basin irrigation (n_1) and soil application of full dose of nutrients with drip irrigation (n_2) were on par and registered the highest soil N and K status. Whereas, P status of the soil was found to be significantly high under soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4), which was on par with n_2 and n_1.

Foliar nutrition and its interaction with nutrient sources and irrigation did not exert any significant effect on nutrient status of the soil.

4.2.10 Soil Microbial Status after First Year of Experimentation

Data on microbial status in the soil after the experiment as influenced by nutrient sources, irrigation and foliar nutrition are presented in Table 32.

Bacteria and actinomycetes count in the soil after the experiment were observed to be significantly high at both the dilutions in treatment receiving drip irrigation alone without any fertilizer (n_3). The count of bacteria and actinomycetes were the lowest in soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4), and soil application of full dose of nutrients with drip irrigation (n_2), respectively. When n_4 registered significantly higher fungi count at 10^{-3} dilution, n_2 recorded significantly higher fungi count at 10^{-4} dilution.

Microbial count was not at all significantly influenced by foliar nutrition.

Interaction also showed significant influence on microbial status in the soil after the experiment. It was observed that n_3s_3 had significantly higher bacterial count at both the dilutions. Fungi count was observed to be higher in n_4s_2 at 10^{-3}

Table 31. Effect of nutrient sources, irrigation and foliar nutrition on soil nutrient status after the experiment (first crop), kg ha^{-1}

Treatments	Available N	Available P	Available K
Nutrient sources & irrigation			
n_1	317.77	134.86	242.71
n_2	317.44	143.05	253.05
n_3	258.22	117.51	156.87
n_4	265.88	143.22	224.33
n_5	268.55	125.00	218.94
n_6	263.11	124.50	225.40
SEm (±)	9.952	5.620	6.708
CD (0.05)	31.357	17.708	21.136
Foliar nutrition			
s_1	283.83	128.77	221.32
s_2	280.88	133.11	218.69
s_3	280.77	132.69	220.63
SEm (±)	2.167	1.458	2.084
CD (0.05)	NS	NS	NS
Interaction			
n_1s_1	320.66	132.10	240.30
n_1s_2	317.33	140.50	250.50
n_1s_3	314.33	132.00	237.33
n_2s_1	322.33	143.66	253.66
n_2s_2	320.66	143.50	253.50
n_2s_3	310.33	142.00	252.00
n_3s_1	260.00	115.70	161.11
n_3s_2	255.33	118.66	154.00
n_3s_3	259.33	118.16	155.50
n_4s_1	270.00	143.66	226.99
n_4s_2	262.66	137.50	217.50
n_4s_3	265.00	148.50	228.50
n_5s_1	268.66	121.00	223.00
n_5s_2	268.00	130.00	212.00
n_5s_3	269.00	127.00	221.83
n_6s_1	261.33	116.50	222.88
n_6s_2	261.33	128.50	224.66
n_6s_3	266.66	128.50	228.66
SEm (±)	5.309	3.572	5.104
CD (0.05)	NS	NS	NS

Table 32. Effect of nutrient sources, irrigation and foliar nutrition on soil microbial count after the experiment (first crop), cfu g^{-1} soil

Treatments	Bacteria		Fungi		Actinomycetes	
	x 10^6	x 10^7	x 10^3	x 10^4	x 10^2	x 10^3
Nutrient sources & irrigation						
n_1	6.88	1.66	12.44	3.11	50.88	41.44
n_2	7.66	6.77	11.11	4.11	32.33	30.22
n_3	13.77	7.44	14.55	2.77	77.11	70.00
n_4	3.66	1.77	23.44	3.11	41.77	41.33
n_5	4.22	3.11	17.33	3.11	44.44	41.55
n_6	8.22	3.11	9.55	3.22	48.77	36.22
SEm (±)	0.247	0.097	0.289	0.147	0.952	0.942
CD (0.05)	0.780	0.306	0.910	0.465	3.001	2.969
Foliar nutrition						
s_1	7.22	3.83	14.16	3.38	50.00	43.50
s_2	7.33	4.16	15.27	3.27	49.16	43.11
s_3	7.66	3.94	14.77	3.05	48.50	43.77
SEm (±)	0.169	0.126	0.317	0.117	0.584	0.541
CD (0.05)	NS	NS	NS	NS	NS	NS
Interaction						
n_1s_1	7.00	1.66	12.00	3.00	50.33	40.66
n_1s_2	6.66	1.66	13.66	3.66	51.00	40.66
n_1s_3	7.00	1.66	11.66	2.66	51.33	43.00
n_2s_1	6.66	6.00	9.00	4.66	32.00	30.00
n_2s_2	8.66	6.66	11.66	3.66	32.00	30.66
n_2s_3	7.66	7.66	12.66	4.00	33.00	30.00
n_3s_1	14.00	6.00	14.66	2.66	77.33	70.00
n_3s_2	13.33	8.66	13.00	3.00	77.33	69.66
n_3s_3	14.00	7.66	16.00	2.66	76.66	70.33
n_4s_1	3.66	2.66	21.66	3.66	45.66	41.66
n_4s_2	2.66	1.66	24.66	2.66	40.00	40.00
n_4s_3	4.66	1.00	24.00	3.00	39.66	42.33
n_5s_1	4.00	3.00	19.66	2.66	45.00	41.66
n_5s_2	4.00	3.66	16.66	3.66	46.66	43.00
n_5s_3	4.66	2.66	15.66	3.00	41.66	40.00
n_6s_1	8.00	3.66	8.00	3.66	49.66	37.00
n_6s_2	8.66	2.66	12.00	3.00	48.00	34.66
n_6s_3	8.00	3.00	8.66	3.00	48.66	37.00
SEm (±)	0.415	0.309	0.777	0.288	1.431	1.325
CD (0.05)	1.213	0.902	2.270	0.842	NS	NS

dilution and was on par with n_4s_3. At 10^{-4} dilution, significantly higher fungi count was recorded by n_2s_1. However, actinomycetes count in the soil after the experiment was not significantly influenced by any of the treatment combinations.

4.2.11 Economic Analysis

The gross income, net income and B : C ratio are presented in Table 33.

Gross income was significantly higher in soil application of full dose of nutrients with basin irrigation (n_1) but it was on par with soil application of full dose of nutrients with drip irrigation (n_2), soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP respectively (n_4) and fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5). The highest net income of ` 8,67,172 ha^{-1} was registered by n_4 and it was on par with n_2 and n_1. The same treatment (n_4) recorded the highest B : C ratio of 5.01 and was found significantly superior to all other treatments.

Bunch spray of SOP (s_3) was significantly superior to all other treatments on gross income (` 10,65,215 $ha^{-1}$), net income (` 7,44,809 ha^{-1}) and B : C ratio (3.91).

Among the interactions, n_5s_3 recorded significantly highest gross income of ` 11,75,000 ha^{-1} and was on par with n_1s_3, n_4s_3, n_4s_2, n_2s_3 and n_5s_2. Whereas, the net income was significantly higher in n_4s_3 which was on par with n_4s_2, n_1s_3 and n_2s_3. The highest B : C ratio of 5.37 was recorded by n_4s_3 and it was on par with n_4s_2.

Table 33. Effect of nutrient sources, irrigation and foliar nutrition on economics of banana cultivation (first crop)

Treatments	Gross income (` ha^{-1})	Net income (` ha^{-1})	B : C ratio
Nutrient sources & irrigation			
n_1	1102083	843292	4.25
n_2	1096201	847329	4.40
n_3	690222	504229	3.71
n_4	1082931	867172	5.01
n_5	1060764	344633	1.48
n_6	985416	680203	3.22
SEm (±)	15780.679	15780.679	0.076
CD (0.05)	49722.835	49722.835	0.239
Foliar nutrition			
s_1	923927	602096	3.42
s_2	1019667	696523	3.72
s_3	1065215	744809	3.91
SEm (±)	10965.694	10965.694	0.048
CD (0.05)	32008.168	32008.168	0.141
Interaction			
n_1s_1	1043750	784921	4.03
n_1s_2	1087500	827358	4.18
n_1s_3	1175000	917596	4.56
n_2s_1	1076563	827653	4.32
n_2s_2	1087500	837278	4.34
n_2s_3	1124542	877057	4.54
n_3s_1	648416	462386	3.48
n_3s_2	702375	515032	3.74
n_3s_3	719875	535269	3.89
n_4s_1	942541	726745	4.36
n_4s_2	1153125	936016	5.31
n_4s_3	1153125	938754	5.37
n_5s_1	897916	181748	1.25
n_5s_2	1109375	391894	1.54
n_5s_3	1175000	460256	1.64
n_6s_1	934375	629124	3.06
n_6s_2	978125	671562	3.19
n_6s_3	1043750	739924	3.43
SEm (±)	26860.355	26860.355	0.118
CD (0.05)	78403.679	78403.679	0.346

4.3 PART II

NUTRIENT SCHEDULING THROUGH FERTIGATION AND FOLIAR APPLICATION - SECOND YEAR OF INVESTIGATION

4.3.1 Growth Attributes

4.3.1.1 Pseudostem Height (cm)

Data on pseudostem height at 2, 4 and 6 MAP as influenced by nutrient sources, irrigation and foliar nutrition are presented in Table 34.

Significant increase on pseudostem height was observed at all growth stages of banana by soil application of full dose of nutrients with basin irrigation (n_1). Fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) and soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) which were on par also contributed a significant effect on pseudostem height at 2 MAP. At 6 MAP, n_1 was on par with n_2, n_5 and n_4.

Though foliar nutrition did not show any significant influence on pseudostem height at 2 and 6 MAP, foliar application of 19-19-19 (s_2) showed a significant improvement on pseudostem height compared to water spray (s_1) at 4 MAP.

Though the interaction was not significant on 2 and 4 MAP, it had significant influence on pseudostem height at 6 MAP. At 6 MAP, n_1s_2 registered the highest values of height (330.50 cm) which was on par with n_1s_3, n_2s_2, n_6s_2, n_4s_1 and n_5s_1.

4.3.1.2 Girth of the Pseudostem (cm)

From the results on pseudostem girth presented in Table 35, it was observed that soil application of full dose of nutrients with basin irrigation (n_1) exerted a significant improvement on pseudostem girth at all growth stages.

Table 34. Effect of nutrient sources, irrigation and foliar nutrition on pseudostem height (second crop), cm

Treatments	2 MAP	4 MAP	6 MAP
Nutrient sources & irrigation			
n_1	84.38	215.88	318.33
n_2	78.43	179.08	309.42
n_3	69.57	159.33	268.63
n_4	80.94	186.35	304.01
n_5	82.36	189.08	304.83
n_6	77.08	196.05	299.10
SEm (±)	1.780	3.515	5.712
CD (0.05)	5.609	11.077	18.001
Foliar nutrition			
s_1	73.41	175.15	299.76
s_2	81.78	198.75	301.80
s_3	81.18	188.98	300.75
SEm (±)	1.667	1.833	2.749
CD (0.05)	NS	5.351	NS
Interaction			
n_1s_1	82.15	202.15	307.65
n_1s_2	87.50	223.00	330.50
n_1s_3	83.50	222.50	317.75
n_2s_1	73.65	172.00	301.33
n_2s_2	90.15	189.25	317.15
n_2s_3	71.50	176.00	309.80
n_3s_1	65.75	149.25	263.75
n_3s_2	67.66	167.60	261.15
n_3s_3	75.30	161.15	281.00
n_4s_1	73.16	166.50	313.55
n_4s_2	84.66	200.55	294.50
n_4s_3	85.00	192.00	304.00
n_5s_1	76.75	179.00	312.50
n_5s_2	83.00	199.00	293.00
n_5s_3	87.33	189.25	309.00
n_6s_1	69.00	182.00	299.80
n_6s_2	77.75	213.15	314.50
n_6s_3	84.50	193.00	283.00
SEm (±)	4.083	4.490	6.735
CD (0.05)	NS	NS	19.659

MAP-Months After Planting

Table 35. Effect of nutrient sources, irrigation and foliar nutrition on pseudostem girth (second crop), cm

Treatments	2 MAP	4 MAP	6 MAP
Nutrient sources & irrigation			
n_1	25.05	55.02	65.77
n_2	24.08	48.31	64.44
n_3	20.46	42.10	54.00
n_4	23.01	51.88	61.11
n_5	23.16	49.77	62.44
n_6	24.30	49.44	60.33
SEm (±)	0.465	0.826	1.111
CD (0.05)	1.465	2.604	3.502
Foliar nutrition			
s_1	22.28	48.13	60.72
s_2	24.31	50.30	61.77
s_3	23.44	49.83	61.55
SEm (±)	0.624	0.582	0.541
CD (0.05)	NS	1.700	NS
Interaction			
n_1s_1	24.65	55.50	65.66
n_1s_2	26.50	55.58	65.33
n_1s_3	24.00	54.00	66.33
n_2s_1	23.50	46.10	63.33
n_2s_2	26.35	49.83	66.00
n_2s_3	22.40	49.00	64.00
n_3s_1	20.00	40.86	53.00
n_3s_2	21.00	43.43	53.00
n_3s_3	20.40	42.00	56.00
n_4s_1	21.25	50.66	60.33
n_4s_2	23.30	52.00	62.33
n_4s_3	24.50	53.00	60.66
n_5s_1	22.00	51.33	62.00
n_5s_2	24.50	49.00	63.00
n_5s_3	23.00	49.00	62.33
n_6s_1	22.30	44.33	60.00
n_6s_2	24.25	52.00	61.00
n_6s_3	26.37	52.00	60.00
SEm (±)	1.530	1.427	1.325
CD (0.05)	NS	NS	NS

MAP-Months After Planting

However, it was on par with fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) and soil application of full dose of nutrients with drip irrigation (n_2) at 2 MAP and was on par with n_2 and n_5 (fertigation of 60 per cent RDN as 10-10-10, urea and SOP) at 6 MAP.

Foliar nutrition showed significant influence on pseudostem girth only at 4 MAP where foliar application of 19-19-19 (s_2) registered the highest girth of 50.30 cm which was on par with bunch spray of SOP (s_3).

The interaction effect had no significant influence on pseudostem girth.

4.3.1.3 Number of Functional Leaves

Table 36 represents the data on number of functional leaves plant^{-1} at 2, 4, 6 MAP and at harvest.

At 2 MAP, soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) registered significantly highest leaf number of 10.11 which was on par with soil application of full dose of nutrients with basin irrigation (n_1), fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) and soil application of full dose of nutrients with drip irrigation (n_2). However, at 4 MAP, n_1 differed significantly from all other treatments in producing a higher number of functional leaves (13.22). At 6 MAP and at harvest, n_6 was on par with n_2, n_5 (fertigation of 60 per cent RDN as 10-10-10, urea and SOP), n_1 and n_4 and significantly enhanced the number of functional leaves plant^{-1}.

Foliar application of 19-19-19 (s_2) significantly increased the number of functional leaves at all growth stages except at 2 MAP. At 4 MAP, it was on par with s_3.

The interaction of nutrient sources with foliar nutrition was significant only at 6 MAP where n_6s_2 registered the highest value of 11.50 and was on par with n_5s_2.

Table 36. Effect of nutrient sources, irrigation and foliar nutrition on number of functional leaves (second crop), leaves plant^{-1}

Treatments	2 MAP	4 MAP	6 MAP	At harvest
Nutrient sources & irrigation				
n_1	10.11	13.22	10.22	4.33
n_2	9.77	12.00	10.66	4.11
n_3	8.66	10.88	9.55	3.00
n_4	10.11	12.16	10.11	3.77
n_5	9.33	12.11	10.44	4.00
n_6	9.77	12.16	10.66	4.11
SEm (±)	0.221	0.143	0.195	0.207
CD (0.05)	0.697	0.451	0.616	0.654
Foliar nutrition				
s_1	9.77	11.63	10.11	3.61
s_2	9.50	12.52	10.58	4.16
s_3	9.61	12.11	10.13	3.88
SEm (±)	0.150	0.157	0.089	0.087
CD (0.05)	NS	0.458	0.260	0.256
Interaction				
n_1s_1	10.33	12.66	10.00	3.66
n_1s_2	10.33	14.00	10.66	4.66
n_1s_3	9.66	13.00	10.00	4.66
n_2s_1	10.00	12.00	10.66	3.66
n_2s_2	9.66	12.00	10.66	4.66
n_2s_3	9.66	12.00	10.66	4.00
n_3s_1	8.33	10.33	9.33	3.00
n_3s_2	8.66	11.00	9.66	3.00
n_3s_3	9.00	11.33	9.66	3.00
n_4s_1	10.66	11.66	10.33	3.66
n_4s_2	9.66	12.50	10.00	4.00
n_4s_3	10.00	12.33	10.00	3.66
n_5s_1	9.66	11.66	10.33	4.00
n_5s_2	9.00	12.66	11.00	4.00
n_5s_3	9.33	12.00	10.00	4.00
n_6s_1	9.66	11.50	10.00	3.66
n_6s_2	9.66	13.00	11.50	4.66
n_6s_3	10.00	12.00	10.50	4.00
SEm (±)	0.368	0.384	0.218	0.215
CD (0.05)	NS	NS	0.638	NS

MAP-Months After Planting

4.3.1.4 Total Functional Leaf Area (m^2)

Data on total functional leaf area as influenced by nutrient sources, irrigation and foliar nutrition at 2, 4, 6 MAP and at harvest are presented in Table 37.

Different nutrient sources and irrigation had significant influence on total functional leaf area at all growth stages. At 2 MAP, soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) registered the highest total functional leaf area (1.38 m^2) which was on par with soil application of full dose of nutrients with basin irrigation (n_1) and fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6). However, at 4 MAP, n_1 was found to be superior to all other treatments. At 6 MAP, though n_1 registered the highest functional leaf area, it was on par with soil application of fertilizers with drip irrigation (n_2), n_4, n_5 and n_6. At harvest also, n_1 recorded the highest total functional leaf area (4.57 m^2) but it was on par with n_4 and n_2.

It was observed that foliar application of 19-19-19 (s_2) resulted in significantly higher total functional leaf area of 5.47 m^2 and 4.41 m^2, respectively at 4 MAP and at harvest. However, it had no significant effect at 2 and 6 MAP.

The total functional leaf area was not influenced by interaction at different growth stages of banana except at 4 MAP. At 4 MAP, n_2s_2 recorded the highest value of 7.80 m^2 which was on par with n_1s_2.

4.3.1.5 Leaf Area Index (LAI)

Data presented in Table 38 represents the LAI values at 2, 4, 6 MAP and at harvest.

Different nutrient sources and irrigation had significant influence on LAI at all growth stages. At 2 MAP, soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) recorded the highest value of 0.34 which was on par with other sources except n_3.

Table 37. Effect of nutrient sources, irrigation and foliar nutrition on total functional leaf area (second crop), m^2

Treatments	2 MAP	4 MAP	6 MAP	At harvest
Nutrient sources & irrigation				
n_1	1.31	6.25	12.52	4.57
n_2	1.24	5.29	12.48	4.24
n_3	1.09	3.72	9.56	2.78
n_4	1.38	5.17	11.68	4.29
n_5	1.25	4.56	11.60	4.03
n_6	1.28	4.43	11.08	3.93
SEm (±)	0.039	0.200	0.491	0.148
CD (0.05)	0.125	0.631	1.548	0.467
Foliar nutrition				
s_1	1.24	4.37	11.12	3.57
s_2	1.29	5.47	11.89	4.41
s_3	1.25	4.87	11.45	3.94
SEm (±)	0.026	0.128	0.283	0.081
CD (0.05)	NS	0.375	NS	0.238
Interaction				
n_1s_1	1.31	5.00	12.43	4.11
n_1s_2	1.34	6.93	12.18	5.03
n_1s_3	1.30	6.82	12.97	4.58
n_2s_1	1.23	4.06	12.50	3.44
n_2s_2	1.25	7.80	11.76	5.06
n_2s_3	1.23	4.02	13.18	4.21
n_3s_1	1.07	3.16	8.49	2.41
n_3s_2	1.12	4.01	9.86	3.28
n_3s_3	1.08	4.01	10.35	2.65
n_4s_1	1.37	5.24	11.81	4.21
n_4s_2	1.40	5.14	12.47	4.58
n_4s_3	1.38	5.13	10.76	4.08
n_5s_1	1.20	4.40	11.10	3.64
n_5s_2	1.29	4.65	13.28	4.42
n_5s_3	1.25	4.63	10.41	4.03
n_6s_1	1.24	4.40	10.38	3.61
n_6s_2	1.34	4.29	11.79	4.10
n_6s_3	1.26	4.61	11.07	4.08
SEm (±)	0.064	0.314	0.694	0.200
CD (0.05)	NS	0.918	NS	NS

MAP-Months After Planting

Table 38. Effect of nutrient sources, irrigation and foliar nutrition on leaf area index (second crop)

Treatments	2 MAP	4 MAP	6 MAP	At harvest
Nutrient sources & irrigation				
n_1	0.32	1.56	3.12	1.14
n_2	0.31	1.32	3.11	1.05
n_3	0.27	0.93	2.38	0.69
n_4	0.34	1.29	2.92	1.07
n_5	0.31	1.14	2.89	1.00
n_6	0.32	1.10	2.76	0.97
SEm (±)	0.009	0.050	0.123	0.037
CD (0.05)	0.031	0.157	0.388	0.117
Foliar nutrition				
s_1	0.31	1.09	2.77	0.88
s_2	0.32	1.36	2.97	1.10
s_3	0.31	1.21	2.86	0.98
SEm (±)	0.006	0.032	0.071	0.020
CD (0.05)	NS	0.093	NS	0.058
Interaction				
n_1s_1	0.32	1.25	3.10	1.02
n_1s_2	0.33	1.73	3.04	1.25
n_1s_3	0.32	1.70	3.24	1.14
n_2s_1	0.30	1.01	3.12	0.85
n_2s_2	0.31	1.95	2.94	1.26
n_2s_3	0.30	1.00	3.29	1.05
n_3s_1	0.26	0.79	2.12	0.60
n_3s_2	0.28	1.00	2.46	0.81
n_3s_3	0.27	1.00	2.58	0.66
n_4s_1	0.34	1.31	2.95	1.05
n_4s_2	0.35	1.28	3.11	1.14
n_4s_3	0.34	1.28	2.69	1.02
n_5s_1	0.30	1.10	2.77	0.90
n_5s_2	0.32	1.16	3.32	1.10
n_5s_3	0.31	1.15	2.60	1.00
n_6s_1	0.31	1.10	2.59	0.89
n_6s_2	0.33	1.07	2.94	1.02
n_6s_3	0.31	1.15	2.76	1.01
SEm (±)	0.016	0.078	0.174	0.049
CD (0.05)	NS	0.229	NS	NS

MAP-Months After Planting

Whereas, at 4 MAP, soil application of full dose of nutrients with basin irrigation, (n_1) differed significantly from all other treatments and recorded the highest LAI of 1.56. At 6 MAP also, n_1 gave the highest LAI and was on par with n_2, n_4, n_5 and n_6. At harvest also, n_1 registered the highest LAI of 1.14 and was on par with n_4 and n_2.

Foliar application of 19-19-19 (s_2) recorded significantly higher values of LAI at 4 MAP (1.36) and at harvest (1.10), respectively.

Nutrient sources vs foliar nutrition interaction had significant influence on LAI only at 4 MAP. At this stage n_2s_2 gave the highest value of LAI and it was on par with n_1s_2.

4.3.1.6 Bunch Emergence Duration (days), Crop Duration (days) and Sucker Production after Bunch Emergence

Data on bunch emergence duration, crop duration and sucker production after bunch emergence as influenced by nutrient sources, irrigation and foliar nutrition are presented in Table 39.

Though the different nutrient sources and irrigation had no significant influence on bunch emergence duration, crop duration was significantly influenced by the treatments. Among the fertigation treatments, fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) recorded the shortest crop duration of 278.66 days which was on par with soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) and fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5). Both bunch emergence duration and crop duration were also significantly influenced by foliar nutrition where bunch spray of SOP (s_3) registered the longest crop duration of 283.38 days and was on par with foliar application of 19-19-19 (s_2) on bunch emergence duration. Water spray (s_1) recorded the shortest bunch emergence and crop duration. Interaction effect also had significant influence on these parameters.

Table 39. Effect of nutrient sources, irrigation and foliar nutrition on bunch emergence duration, crop duration and sucker production after bunch emergence (second crop)

Treatments	Bunch emergence duration (days)	Crop duration (days)	Sucker production after bunch emergence
Nutrient sources & irrigation			
n_1	197.77	290.55	10.00
n_2	196.00	283.00	8.88
n_3	190.38	264.33	7.22
n_4	194.11	278.88	8.88
n_5	194.44	279.11	8.77
n_6	194.44	278.66	9.22
SEm (±)	2.612	3.785	0.204
CD (0.05)	NS	11.927	0.645
Foliar nutrition			
s_1	189.86	276.66	8.88
s_2	194.80	277.22	8.94
s_3	198.91	283.38	8.66
SEm (±)	1.633	1.501	0.172
CD (0.05)	4.767	4.380	NS
Interaction			
n_1s_1	193.50	296.66	11.00
n_1s_2	190.33	280.66	10.00
n_1s_3	209.50	294.33	9.00
n_2s_1	196.00	278.00	8.66
n_2s_2	190.50	276.00	9.00
n_2s_3	201.50	295.00	9.00
n_3s_1	185.66	258.33	7.66
n_3s_2	193.50	264.00	7.00
n_3s_3	192.00	270.66	7.00
n_4s_1	179.00	269.66	9.00
n_4s_2	202.00	289.00	9.00
n_4s_3	201.33	278.00	8.66
n_5s_1	192.33	278.00	8.00
n_5s_2	196.50	278.00	8.66
n_5s_3	194.50	281.33	9.66
n_6s_1	192.66	279.33	9.00
n_6s_2	196.00	275.66	10.00
n_6s_3	194.66	281.00	8.66
SEm (±)	4.001	3.676	0.423
CD (0.05)	11.678	10.732	1.234

The treatment, n_3s_1 registered the shortest period for bunch emergence (185.66 days) and crop duration (258.33 days).

Both main effect (n) and its interactions (ns) had significant influence on sucker production after bunch emergence. It was observed that n_1 recorded the highest number of suckers (10.00) which was significantly superior to all other treatments. Among the treatment combinations, n_1s_1 produced the highest sucker count of 11.00 which was on par with n_1s_2 and n_6s_2. However, sucker production after bunch emergence was not at all influenced by foliar nutrition.

4.3.1.7 Dry Matter Production (t ha^{-1})

Influence of treatments on dry matter production of different plant parts of banana is given in Table 40.

Rhizome and total dry matter production were observed to be significantly superior in soil application of full dose of nutrients with basin irrigation (n_1) and was on par with soil application of full dose of nutrients with drip irrigation (n_2). Fruit and leaf dry matter production were significantly higher in n_1 which was on par with soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4), soil application of full dose of nutrients with drip irrigation (n_2) and fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5). Though pseudostem dry matter production was significantly higher in n_2, it was on par with n_1.

Bunch spray of SOP (s_3) significantly enhanced fruit, pseudostem, rhizome and total dry matter production. Foliar application of 19-19-19 (s_2) also exerted significant influence on enhancing rhizome dry matter production. However, foliar nutrition had no significant effect on leaf dry matter production.

Interaction effect showed significant influence on dry matter production

Table 40. Effect of nutrient sources, irrigation and foliar nutrition on dry matter production of different plant parts (second crop), t ha^{-1}

Treatments	Leaf	Pseudostem	Fruit	Rhizome	Total
Nutrient sources & irrigation					
n_1	2.39	4.39	11.70	6.29	24.77
n_2	2.34	4.56	11.15	5.99	24.06
n_3	1.66	2.21	7.58	3.83	15.29
n_4	2.28	4.11	11.21	5.37	22.99
n_5	2.13	3.99	11.13	5.12	22.38
n_6	1.81	3.59	10.95	5.04	21.40
SEm (±)	0.116	0.054	0.207	0.115	0.419
CD (0.05)	0.367	0.170	0.654	0.365	1.322
Foliar nutrition					
s_1	2.10	3.59	9.86	5.02	20.59
s_2	2.18	3.84	10.69	5.39	22.12
s_3	2.02	3.99	11.31	5.41	22.74
SEm (±)	0.056	0.049	0.100	0.058	0.149
CD (0.05)	NS	0.143	0.294	0.171	0.435
Interaction					
n_1s_1	2.65	4.70	10.65	6.12	24.13
n_1s_2	2.18	4.65	11.89	6.25	24.98
n_1s_3	2.34	3.82	12.55	6.50	25.21
n_2s_1	2.65	4.36	10.76	5.62	23.41
n_2s_2	2.49	4.62	10.89	6.25	24.26
n_2s_3	1.87	4.71	11.81	6.12	24.52
n_3s_1	1.56	2.00	7.17	3.37	14.11
n_3s_2	1.71	2.02	7.57	4.25	15.56
n_3s_3	1.71	2.62	8.00	3.87	16.21
n_4s_1	2.49	3.97	10.20	5.12	21.80
n_4s_2	2.34	4.10	11.68	5.37	23.50
n_4s_3	2.02	4.27	11.75	5.62	23.67
n_5s_1	1.71	3.27	10.67	5.13	20.79
n_5s_2	2.34	4.22	10.70	5.00	22.27
n_5s_3	2.34	4.47	12.03	5.25	24.09
n_6s_1	1.56	3.27	9.73	4.75	19.32
n_6s_2	2.02	3.47	11.40	5.25	22.15
n_6s_3	1.87	4.05	11.71	5.12	22.75
SEm (±)	0.139	0.120	0.247	0.143	0.365
CD (0.05)	0.406	0.350	0.721	NS	1.066

by different plant parts except rhizome. n_1s_3 recorded the highest fruit dry matter production of 12.55 t ha^{-1} which was on par with n_5s_3 and n_1s_2. Whereas, n_1s_1 recorded the highest leaf dry matter production and was on par with n_2s_1, n_4s_1, n_2s_2, n_5s_3, n_5s_2, n_4s_2 and n_1s_3. Significantly high values of pseudostem dry matter production was also observed in n_2s_3 which was on par with n_1s_1, n_1s_2, n_2s_2, n_5s_3 and n_2s_1. The total dry matter production was highest in n_1s_3 (25.21 t ha^{-1}) and it was on par with n_1s_2, n_2s_3 and n_2s_2.

4.3.2 Index Leaf Nutrient Status

4.3.2.1 Primary Nutrient Content in Index Leaf (per cent)

Results on nutrient analysis in Table 41 revealed that the different nutrient sources and irrigation had significant effect on primary nutrient content in index leaf at 4 MAP. The N content in index leaf (3.28 per cent) was significantly increased by fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) which was on par with soil application of full dose of nutrients with drip irrigation (n_2), soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4), soil application of full dose of nutrients with basin irrigation (n_1) and fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6). Regarding P, n_1 registered significantly highest value of 0.40 per cent which was on par with n_2. In the case of K, n_4 exhibited a significantly higher value of 4.30 per cent which was on par with n_1.

Foliar application of 19-19-19 (s_2) was found to be significantly superior to all other treatments in enhancing the N and K content in index leaf. However, the P content was not influenced by foliar nutrition.

The N and K content in index leaf were also significantly influenced by the interaction effect of fertigation and foliar nutrition. The highest N content in index leaf (3.76 per cent) was observed by n_6s_2 which was on par with n_1s_2, n_4s_3, n_5s_2 and n_2s_3. Whereas, the K content in index leaf was highest in n_1s_2 (4.80 per cent) which was on par with n_1s_3.

Table 41. Effect of nutrient sources, irrigation and foliar nutrition on primary nutrient content in index leaf at 4 MAP (second crop), per cent

Treatments	N	P	K
Nutrient sources & irrigation			
n_1	3.22	0.40	4.23
n_2	3.23	0.39	3.71
n_3	2.50	0.14	2.93
n_4	3.22	0.33	4.30
n_5	3.28	0.31	3.88
n_6	3.16	0.31	3.74
SEm (±)	0.085	0.008	0.073
CD (0.05)	0.268	0.025	0.230
Foliar nutrition			
s_1	2.87	0.31	3.50
s_2	3.31	0.32	4.12
s_3	3.18	0.31	3.78
SEm (±)	0.020	0.005	0.037
CD (0.05)	0.125	NS	0.110
Interaction			
n_1s_1	2.80	0.39	3.35
n_1s_2	3.70	0.41	4.80
n_1s_3	3.17	0.41	4.55
n_2s_1	3.09	0.37	3.50
n_2s_2	3.11	0.40	4.30
n_2s_3	3.49	0.39	3.35
n_3s_1	2.56	0.13	2.84
n_3s_2	2.65	0.14	3.00
n_3s_3	2.59	0.14	2.95
n_4s_1	2.98	0.33	4.20
n_4s_2	3.09	0.32	4.50
n_4s_3	3.59	0.35	4.21
n_5s_1	3.06	0.31	3.60
n_5s_2	3.53	0.34	3.91
n_5s_3	3.26	0.30	4.15
n_6s_1	2.76	0.31	3.54
n_6s_2	3.76	0.33	4.22
n_6s_3	2.95	0.31	3.47
SEm (±)	0.105	0.013	0.092
CD (0.05)	0.308	NS	0.270

4.3.2.2 Secondary Nutrient Content in Index Leaf (per cent)

From the data presented in Table 42, it was observed that the Ca and Mg content were not influenced by the treatments. However, S content showed variation and the highest content was noticed in n_5 which was on par with n_6.

Foliar nutrition and its interaction with nutrient sources did not influence the secondary nutrient content of index leaf.

4.3.2.3 Micronutrient Content in Index Leaf (ppm)

Data presented in Table 43 indicated that micronutrient content in index leaf was not at all influenced by nutrient sources and irrigation, foliar nutrition and their interaction.

4.3.3 Yield Attributes and Yield

4.3.3.1 Bunch and Hand Characteristics

Data on bunch and hand characteristics of banana as influenced by nutrient sources, irrigation and foliar nutrition are presented in Table 44.

Among the nutrient sources and irrigation, n_1 registered significantly highest values for number of hands bunch^{-1} (5.77) and number of fingers bunch^{-1} (59.22) and was on par with soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4), soil application of full dose of nutrients with drip irrigation (n_2) and fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) on number of hands and n_4, n_2, n_5 and n_6 on number of fingers bunch^{-1}.

Regarding number of fingers in D hand, n_5 registered significantly higher value of 12.33 which was on par with other nutrient sources except n_3.

Significant variation on bunch and hand characteristics by foliar nutrition were observed. Foliar application of 19-19-19 (s_2) significantly enhanced the

Table 42. Effect of nutrient sources, irrigation and foliar nutrition on secondary nutrient content in index leaf at 4 MAP (second crop), per cent

Treatments	Ca	Mg	S
Nutrient sources & irrigation			
n_1	0.77	0.50	0.17
n_2	0.73	0.53	0.18
n_3	0.72	0.43	0.17
n_4	0.75	0.52	0.17
n_5	0.75	0.53	0.27
n_6	0.82	0.49	0.27
SEm (±)	0.022	0.029	0.012
CD (0.05)	NS	NS	0.040
Foliar nutrition			
s_1	0.74	0.49	0.21
s_2	0.76	0.52	0.20
s_3	0.76	0.49	0.21
SEm (±)	0.017	0.014	0.006
CD (0.05)	NS	NS	NS
Interaction			
n_1s_1	0.76	0.49	0.18
n_1s_2	0.83	0.48	0.16
n_1s_3	0.72	0.54	0.16
n_2s_1	0.73	0.46	0.16
n_2s_2	0.72	0.58	0.17
n_2s_3	0.75	0.54	0.22
n_3s_1	0.65	0.41	0.20
n_3s_2	0.83	0.45	0.16
n_3s_3	0.68	0.42	0.15
n_4s_1	0.76	0.51	0.15
n_4s_2	0.71	0.51	0.17
n_4s_3	0.79	0.54	0.19
n_5s_1	0.71	0.53	0.28
n_5s_2	0.74	0.55	0.27
n_5s_3	0.79	0.51	0.26
n_6s_1	0.86	0.53	0.26
n_6s_2	0.74	0.56	0.27
n_6s_3	0.87	0.38	0.28
SEm (±)	0.043	0.035	0.016
CD (0.05)	NS	NS	NS

Table 43. Effect of nutrient sources, irrigation and foliar nutrition on micronutrient content in index leaf at 4 MAP (second crop), ppm

Treatments	Fe	Zn	Mn	Cu	B
Nutrient sources & irrigation					
n_1	139.00	14.66	321.16	13.50	23.66
n_2	140.16	14.83	315.50	13.33	26.50
n_3	128.83	11.66	308.83	12.50	24.66
n_4	136.50	12.83	321.00	13.00	23.83
n_5	141.00	13.50	320.50	12.33	23.66
n_6	135.33	12.61	314.66	12.50	23.16
SEm (±)	2.835	0.681	2.832	0.290	0.961
CD (0.05)	NS	NS	NS	NS	NS
Foliar nutrition					
s_1	137.91	12.91	315.25	12.75	23.66
s_2	135.66	13.33	318.00	12.83	25.08
s_3	136.83	13.80	317.58	13.00	24.00
SEm (±)	1.281	0.432	1.793	0.184	0.513
CD (0.05)	NS	NS	NS	NS	NS
Interaction					
n_1s_1	139.50	14.00	316.00	14.00	23.00
n_1s_2	141.00	14.50	324.50	13.00	25.00
n_1s_3	136.50	15.50	323.00	13.50	23.00
n_2s_1	142.00	14.00	314.50	12.50	28.00
n_2s_2	132.50	14.50	315.00	13.50	26.00
n_2s_3	146.00	16.00	317.00	14.00	25.50
n_3s_1	127.50	11.00	302.50	12.00	25.00
n_3s_2	130.50	12.50	309.50	12.50	25.50
n_3s_3	128.50	11.50	314.50	13.00	23.50
n_4s_1	138.00	13.00	316.50	13.00	21.50
n_4s_2	136.00	12.00	325.00	13.00	24.50
n_4s_3	135.50	13.50	321.50	13.00	25.50
n_5s_1	148.50	12.50	320.50	12.50	23.50
n_5s_2	137.00	14.50	326.00	12.50	26.00
n_5s_3	137.50	13.50	315.00	12.00	21.50
n_6s_1	132.00	13.00	321.50	12.50	21.00
n_6s_2	137.00	12.00	308.00	12.50	23.50
n_6s_3	137.00	12.83	314.50	12.50	25.00
SEm (±)	3.140	1.059	4.394	0.451	1.258
CD (0.05)	NS	NS	NS	NS	NS

Table 44. Effect of nutrient sources, irrigation and foliar nutrition on bunch and hand characteristics (second crop)

Treatments	Number of hands bunch^{-1}	Number of fingers bunch^{-1}	Number of fingers in D hand
Nutrient sources & irrigation			
n_1	5.77	59.22	12.33
n_2	5.66	58.55	12.11
n_3	4.33	42.00	9.33
n_4	5.66	58.88	12.22
n_5	5.44	58.22	12.33
n_6	5.00	55.55	11.88
SEm (±)	0.143	1.628	0.240
CD (0.05)	0.451	5.130	0.756
Foliar nutrition			
s_1	4.77	52.66	11.11
s_2	5.83	55.72	11.77
s_3	5.33	57.83	12.22
SEm (±)	0.126	0.821	0.260
CD (0.05)	0.368	2.397	0.760
Interaction			
n_1s_1	5.33	55.00	12.00
n_1s_2	6.33	59.33	12.00
n_1s_3	5.66	63.33	13.00
n_2s_1	5.33	59.66	11.66
n_2s_2	6.00	58.00	12.00
n_2s_3	5.66	58.00	12.66
n_3s_1	4.00	40.66	8.66
n_3s_2	4.66	42.00	9.66
n_3s_3	4.33	43.33	9.66
n_4s_1	4.66	58.33	12.00
n_4s_2	6.33	57.00	12.00
n_4s_3	6.00	61.33	12.66
n_5s_1	4.66	53.66	11.33
n_5s_2	6.33	59.33	12.66
n_5s_3	5.33	61.66	13.00
n_6s_1	4.66	48.66	11.00
n_6s_2	5.33	58.66	12.33
n_6s_3	5.00	59.33	12.33
SEm (±)	0.309	2.012	0.638
CD (0.05)	NS	NS	NS

number of hands bunch^{-1} (5.83). Regarding number of fingers bunch^{-1} and number of fingers in D hand, bunch spray of SOP (s_3) and s_2 were on par and significantly superior to water spray (s_1).

However, the interaction effect had no significant influence on bunch and hand characteristics.

4.3.3.2 Finger Characteristics

Finger characteristics of banana are presented in Table 45.

Though soil application of full dose of nutrients with drip irrigation (n_2) registered significantly higher values for weight of D finger (223.50 g), it was on par with n_4, n_5, n_1 and n_6. Length of D finger was significantly higher (28.14 cm) in soil application of full dose of nutrients with basin irrigation (n_1) and it was on par with n_2, n_4, n_5 and n_6. All nutrient sources except drip irrigation alone without any fertilizer (n_3) were on par on girth of D finger.

Finger characteristics (weight of D finger and length of D finger) were significantly improved by bunch spray of SOP (s_3) which was on par with foliar application of 19-19-19 (s_2).

Interaction had no significant effect on any of the finger characteristics of banana.

4.3.3.3 Bunch Weight (kg plant^{-1}) and Yield (t ha^{-1})

Data on bunch weight and yield of banana shown in Table 46 revealed that soil application of full dose of nutrients with basin irrigation (n_1) registered significantly highest bunch weight (13.37 kg plant^{-1}) and total yield (33.44 t ha^{-1}) which was on par with soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4), soil application of full dose of nutrients with drip irrigation (n_2) and fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5).

Table 45. Effect of nutrient sources, irrigation and foliar nutrition on finger characteristics (second crop)

Treatments	Weight of D finger (g)	Length of D finger (cm)	Girth of D finger (cm)
Nutrient sources & irrigation			
n_1	220.66	28.14	14.48
n_2	223.50	28.13	14.51
n_3	186.11	25.94	13.67
n_4	223.05	27.62	14.33
n_5	221.50	27.51	14.30
n_6	218.66	27.47	14.23
SEm (±)	3.256	0.371	0.156
CD (0.05)	10.261	1.169	0.491
Foliar nutrition			
s_1	208.05	26.72	14.11
s_2	218.38	27.52	14.24
s_3	220.30	28.16	14.41
SEm (±)	2.025	0.230	0.101
CD (0.05)	5.911	0.672	NS
Interaction			
n_1s_1	213.50	27.33	14.33
n_1s_2	222.16	28.00	14.50
n_1s_3	226.33	29.10	14.63
n_2s_1	216.25	27.26	14.40
n_2s_2	228.25	28.40	14.45
n_2s_3	226.00	28.73	14.70
n_3s_1	181.66	25.03	13.45
n_3s_2	188.33	25.83	13.66
n_3s_3	188.33	26.96	13.90
n_4s_1	216.83	26.96	14.30
n_4s_2	225.33	27.70	14.31
n_4s_3	227.00	28.20	14.38
n_5s_1	210.50	27.40	14.16
n_5s_2	226.00	27.20	14.26
n_5s_3	228.00	27.93	14.48
n_6s_1	209.58	26.33	14.06
n_6s_2	220.25	28.03	14.28
n_6s_3	226.16	28.06	14.36
SEm (±)	4.961	0.564	0.249
CD (0.05)	NS	NS	NS

Table 46. Effect of nutrient sources, irrigation and foliar nutrition on bunch weight and yield (second crop)

Treatments	Bunch weight (kg plant^{-1})	Yield (t ha^{-1})
Nutrient sources & irrigation		
n_1	13.37	33.44
n_2	12.75	31.89
n_3	8.67	21.68
n_4	12.82	32.05
n_5	12.73	31.82
n_6	12.51	31.29
SEm (±)	0.237	0.593
CD (0.05)	0.748	1.871
Foliar nutrition		
s_1	11.28	28.21
s_2	12.22	30.55
s_3	12.93	32.33
SEm (±)	0.115	0.288
CD (0.05)	0.336	0.840
Interaction		
n_1s_1	12.18	30.45
n_1s_2	13.60	34.00
n_1s_3	14.35	35.87
n_2s_1	12.31	30.78
n_2s_2	12.45	31.12
n_2s_3	13.51	33.77
n_3s_1	8.20	20.51
n_3s_2	8.66	21.65
n_3s_3	9.16	22.90
n_4s_1	11.67	29.17
n_4s_2	13.36	33.40
n_4s_3	13.43	33.58
n_5s_1	12.20	30.50
n_5s_2	12.24	30.60
n_5s_3	13.75	34.38
n_6s_1	11.13	27.83
n_6s_2	13.03	32.57
n_6s_3	13.39	33.47
SEm (±)	0.282	0.705
CD (0.05)	0.823	2.059

It was noticed that bunch spray of SOP (s_3) was significantly superior to others in producing higher bunch weight (12.93 kg $plant^{-1}$) and banana yield (32.33 t ha^{-1}).

Interaction effect also showed significant influence on bunch weight and yield of banana. Among the interactions, n_1s_3 significantly increased bunch weight (14.35 kg $plant^{-1}$) and yield of banana (35.87 t ha^{-1}) which was on par with n_5s_3 and n_1s_2.

4.3.3.4 Pooled Yield (t ha^{-1})

Data on pooled yield of banana (Table 47) revealed that the different nutrient sources, irrigation and foliar nutrition significantly enhanced the yield of banana. Among the nutrient sources and irrigation, soil application of full dose of nutrients with basin irrigation (n_1) produced a higher yield which was on par with n_2 and n_4. In foliar nutrition, bunch spray of SOP (s_3) was found to be significantly superior to other treatments in producing a higher yield during both the years. It was also observed that there was significant variation in the yield between two years of experimentation. Second year was found to contribute significantly higher yield compared to first year.

Data on interaction effect of treatments on pooled yield of banana are presented in Tables 48, 49, 50 and 51.

The interaction of nutrient sources with foliar nutrition significantly increased yield in n_1s_3 and was on par with n_5s_3, n_4s_3, n_4s_2, n_2s_3 and n_1s_2. Whereas, in combination of treatments with years, $y_2n_1s_3$ registered significantly the highest pooled yield of 35.87 t ha^{-1} which was on par with $y_2n_5s_3$, $y_2n_1s_2$, $y_2n_2s_3$, $y_1n_5s_3$, and $y_1n_1s_3$.

Table 47. Effect of nutrient sources, irrigation and foliar nutrition on pooled yield, t ha^{-1}

Treatments	Pooled yield
Nutrient sources & irrigation	
n_1	32.55
n_2	31.69
n_3	21.50
n_4	31.58
n_5	31.15
n_6	29.81
SEm (±)	0.325
CD (0.05)	1.025
Foliar nutrition	
s_1	27.51
s_2	30.05
s_3	31.59
SEm (±)	0.228
CD (0.05)	0.644
Years	
y_1	29.07
y_2	30.37
SEm (±)	0.186
CD (0.05)	0.526

Table 48. Interaction effect of nutrient sources, irrigation and foliar nutrition on pooled yield, t ha^{-1}

Interaction	Pooled yield
n_1s_1	30.22
n_1s_2	32.62
n_1s_3	34.81
n_2s_1	30.85
n_2s_2	31.18
n_2s_3	33.04
n_3s_1	20.32
n_3s_2	21.66
n_3s_3	22.53
n_4s_1	28.14
n_4s_2	33.26
n_4s_3	33.35
n_5s_1	28.16
n_5s_2	31.23
n_5s_3	34.06
n_6s_1	27.35
n_6s_2	30.34
n_6s_3	31.73
SEm (±)	0.558
CD (0.05)	2.233

Table 49. Interaction effect of years and foliar nutrition on pooled yield, t ha^{-1}

Interaction	Pooled yield
y_1s_1	26.81
y_1s_2	29.54
y_1s_3	30.85
y_2s_1	28.21
y_2s_2	30.55
y_2s_3	32.33
SEm (±)	0.456
CD (0.05)	NS

Table 50. Interaction effect of nutrient sources, irrigation and years on pooled yield, t ha^{-1}

Interaction	Pooled yield
n_1y_1	31.66
n_2y_1	31.49
n_3y_1	21.32
n_4y_1	31.11
n_5y_1	30.48
n_6y_1	28.33
n_1y_2	33.44
n_2y_2	31.89
n_3y_2	21.68
n_4y_2	32.05
n_5y_2	31.82
n_6y_2	31.29
SEm (±)	0.104
CD (0.05)	NS

Table 51. Interaction effect of years, nutrient sources, irrigation and foliar nutrition on pooled yield, t ha^{-1}

Interaction	Pooled yield		
$y_1n_1s_1$	30.00	$y_2n_1s_1$	30.45
$y_1n_1s_2$	31.25	$y_2n_1s_2$	34.00
$y_1n_1s_3$	33.75	$y_2n_1s_3$	35.87
$y_1n_2s_1$	30.93	$y_2n_2s_1$	30.78
$y_1n_2s_2$	31.25	$y_2n_2s_2$	31.12
$y_1n_2s_3$	32.31	$y_2n_2s_3$	33.77
$y_1n_3s_1$	20.13	$y_2n_3s_1$	20.51
$y_1n_3s_2$	21.67	$y_2n_3s_2$	21.65
$y_1n_3s_3$	22.17	$y_2n_3s_3$	22.90
$y_1n_4s_1$	27.11	$y_2n_4s_1$	29.17
$y_1n_4s_2$	33.12	$y_2n_4s_2$	33.40
$y_1n_4s_3$	33.12	$y_2n_4s_3$	33.58
$y_1n_5s_1$	25.83	$y_2n_5s_1$	30.50
$y_1n_5s_2$	31.87	$y_2n_5s_2$	30.60
$y_1n_5s_3$	33.75	$y_2n_5s_3$	34.38
$y_1n_6s_1$	26.87	$y_2n_6s_1$	27.83
$y_1n_6s_2$	28.12	$y_2n_6s_2$	32.57
$y_1n_6s_3$	30.00	$y_2n_6s_3$	33.47
SEm (±)			0.789
CD (0.05)			2.234

4.3.4 Scoring of Pests and Diseases

Uniform score of one for pest and disease incidence (Appendix IX and Appendix X) was adopted since there was no variation between treatments in the incidence of pests and diseases.

4.3.5 Quality Attributes

Data on quality attributes and shelf life of fruits as influenced by nutrient sources, irrigation and foliar nutrition are presented in Tables 52 and 53.

Different nutrient sources and irrigation exerted significant influence on all quality attributes except TSS, non-reducing sugars and ascorbic acid content in banana fruits. Significant increase in acidity of fruits (0.35 per cent) was noticed in drip irrigation alone without any fertilizer (n_3) which was on par with fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) and fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6). The highest total sugar of 21.73 per cent was registered by n_6 which was on par with all treatments except n_3. Though non-reducing sugar was not altered by nutrient sources and irrigation, significant increase in reducing sugar was observed by nutrient sources. Soil application of full dose of nutrients with drip irrigation (n_2) registered the highest value of 19.22 per cent and was on par with n_6, n_5 and n_4. Whereas in sugar : acid ratio, the highest value of 85.25 was recorded by soil application of full dose of nutrients with basin irrigation (n_1) which was on par with n_2. The different nutrient sources significantly increased the pulp : peel ratio except drip irrigation alone without any fertilizer (n_3) and the ratio ranged from 3.42 to 3.64. In shelf life of fruits, n_5 recorded a significantly higher shelf life period of 12.50 days which was on par with n_2 (12.16 days).

Bunch spray of SOP (s_3) significantly increased all quality attributes except ascorbic acid content in banana fruits. In TSS and non-reducing sugars, s_3 was observed to be on par with foliar application of 19-19-19 (s_2). But, acidity of

Table 52. Effect of nutrient sources, irrigation and foliar nutrition on quality attributes (second crop)

Treatments	TSS (%)	Ascorbic acid (mg 100g^{-1})	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Sugar : acid ratio
Nutrient sources & irrigation							
n_1	31.66	14.40	0.25	21.16	18.22	2.93	85.25
n_2	31.33	15.50	0.28	21.42	19.22	2.20	76.89
n_3	31.11	14.58	0.35	19.56	17.20	2.36	57.12
n_4	31.22	13.85	0.30	21.21	18.48	2.72	71.88
n_5	31.88	14.01	0.32	21.47	18.74	2.73	67.33
n_6	31.55	14.95	0.32	21.73	18.84	2.88	66.36
SEm (±)	0.357	0.446	0.012	0.256	0.295	0.219	3.174
CD (0.05)	NS	NS	0.040	0.807	0.932	NS	10.001
Foliar nutrition							
s_1	30.72	14.12	0.32	19.94	17.67	2.27	63.02
s_2	31.38	14.57	0.30	20.98	18.19	2.78	70.56
s_3	32.27	14.95	0.29	22.36	19.49	2.86	78.85
SEm (±)	0.325	0.311	0.008	0.309	0.210	0.135	2.523
CD (0.05)	0.950	NS	0.023	0.903	0.613	0.395	7.366
Interaction							
n_1s_1	31.33	13.30	0.25	20.11	17.50	2.61	79.75
n_1s_2	31.66	14.95	0.25	20.78	17.85	2.93	84.32
n_1s_3	32.00	14.95	0.24	22.59	19.33	3.26	91.69
n_2s_1	31.66	14.95	0.28	20.56	18.33	2.23	73.34
n_2s_2	30.33	14.95	0.28	21.48	19.16	2.31	77.06
n_2s_3	32.00	16.60	0.28	22.23	20.16	2.06	80.27
n_3s_1	30.33	14.95	0.39	17.83	15.73	2.10	47.39
n_3s_2	31.00	13.85	0.34	20.13	17.36	2.76	59.92
n_3s_3	32.00	14.95	0.32	20.73	18.50	2.23	64.07
n_4s_1	30.33	13.30	0.37	20.20	18.10	2.10	54.75
n_4s_2	31.33	14.95	0.30	20.58	17.66	2.91	67.89
n_4s_3	32.00	13.30	0.25	22.85	19.68	3.16	93.01
n_5s_1	30.66	14.95	0.32	20.16	17.76	2.40	61.78
n_5s_2	32.00	13.80	0.32	20.96	18.50	2.46	65.61
n_5s_3	33.00	13.30	0.31	23.30	19.96	3.33	74.61
n_6s_1	30.00	13.30	0.34	20.80	18.60	2.20	61.11
n_6s_2	32.00	14.95	0.32	21.93	18.60	3.33	68.54
n_6s_3	32.66	16.60	0.32	22.46	19.33	3.13	69.44
SEm (±)	0.797	0.761	0.019	0.757	0.514	0.331	6.181
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

Table 53. Effect of nutrient sources, irrigation and foliar nutrition on pulp : peel ratio and shelf life (second crop)

Treatments	Pulp : peel ratio	Shelf life (days)
Nutrient sources & irrigation		
n_1	3.64	11.50
n_2	3.60	12.16
n_3	2.84	11.16
n_4	3.51	10.33
n_5	3.49	12.50
n_6	3.42	11.33
SEm (±)	0.104	0.157
CD (0.05)	0.328	0.495
Foliar nutrition		
s_1	3.22	10.25
s_2	3.37	11.25
s_3	3.65	13.00
SEm (±)	0.055	0.225
CD (0.05)	0.161	0.658
Interaction		
n_1s_1	3.57	11.00
n_1s_2	3.64	10.50
n_1s_3	3.71	13.00
n_2s_1	3.43	10.00
n_2s_2	3.50	13.00
n_2s_3	3.86	13.50
n_3s_1	2.57	9.50
n_3s_2	2.85	10.50
n_3s_3	3.11	13.50
n_4s_1	3.23	10.00
n_4s_2	3.50	10.00
n_4s_3	3.80	11.00
n_5s_1	3.26	11.00
n_5s_2	3.46	13.00
n_5s_3	3.75	13.50
n_6s_1	3.27	10.00
n_6s_2	3.32	10.50
n_6s_3	3.67	13.50
SEm (±)	0.135	0.552
CD (0.05)	NS	1.613

fruits was found to be significantly higher in water spray (s_1) which was on par with s_2. The highest pulp : peel ratio of 3.65 was registered by s_3 which was significantly superior to other treatments. Bunch spray was also effective in enhancing the shelf life period (13.00 days) over foliar application of 19-19-19 (11.25 days).

Quality attributes in banana was not at all influenced by the combination of nutrient sources, irrigation and foliar nutrition. However, the shelf life of fruits was found to be significantly improved by the combination of n_2s_3 which was on par with n_3s_3, n_5s_3, n_6s_3, n_1s_3, n_2s_2 and n_5s_2.

4.3.6 Water Requirement, Water Use Efficiency and Water Productivity

Data on total water requirement, water use efficiency and water productivity as influenced by nutrient sources, irrigation and foliar nutrition are shown in Appendix V and in Table 54.

Total water requirement was 2151.75 mm and 1596.20 mm in basin and drip irrigation respectively in the second year resulting in 26 per cent reduction in water requirement in drip irrigation. Irrigation requirement was also computed as 753.75 mm in basin irrigation and 198.20 mm in drip irrigation.

Soil application of full dose of nutrients with drip irrigation (n_2) recorded significantly higher water productivity of 15.07 kg $ha.mm^{-1}$ and was on par with soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4). The treatment, n_4 registered the highest water use efficiency (20.08 kg $ha.mm^{-1}$) and was on par with n_2, n_5 and n_6.

Significantly higher water productivity (13.57 kg $ha.mm^{-1}$) and water use efficiency (19.28 kg $ha.mm^{-1}$) were observed by bunch spray of SOP (s_3) compared to other treatments.

Table 54. Effect of nutrient sources, irrigation and foliar nutrition on water productivity and water use efficiency (second crop), kg ha.mm^{-1}

Treatments	Water productivity	Water use efficiency
Nutrient sources & irrigation		
n_1	11.51	15.54
n_2	15.07	19.98
n_3	9.58	13.58
n_4	14.40	20.08
n_5	14.02	19.93
n_6	13.41	19.60
SEm (±)	0.239	0.359
CD (0.05)	0.753	1.134
Foliar nutrition		
s_1	12.25	16.85
s_2	13.18	18.22
s_3	13.57	19.28
SEm (±)	0.089	0.165
CD (0.05)	0.262	0.483
Interaction		
n_1s_1	11.21	14.15
n_1s_2	11.60	15.80
n_1s_3	11.71	16.67
n_2s_1	14.66	19.28
n_2s_2	15.19	19.49
n_2s_3	15.36	21.15
n_3s_1	8.83	12.85
n_3s_2	9.74	13.56
n_3s_3	10.15	14.34
n_4s_1	13.65	18.27
n_4s_2	14.72	20.92
n_4s_3	14.83	21.03
n_5s_1	13.02	19.10
n_5s_2	13.95	19.17
n_5s_3	15.09	21.54
n_6s_1	12.10	17.43
n_6s_2	13.87	20.40
n_6s_3	14.25	20.97
SEm (±)	0.220	0.405
CD (0.05)	0.642	1.184

Among the treatment combinations, significantly higher water productivity of 15.36 kg ha.mm^{-1} was recorded by n_2s_3 which was on par with n_2s_2, n_5s_3, n_4s_3 and n_4s_2.

However water use efficiency was significantly improved by n_5s_3 (21.54 kg ha.mm^{-1}) and it was on par with n_2s_3, n_4s_3, n_6s_3, n_4s_2 and n_6s_2.

4.3.7 Nutrient Uptake (kg ha^{-1})

4.3.7.1 N Uptake (kg ha^{-1})

Data presented in Table 55 revealed that different nutrient sources and irrigation showed significant influence on the N uptake by all parts of banana at harvest. It was noticed that the N uptake by fruit and leaf were significantly higher in soil application of full dose of nutrients with basin irrigation (n_1) which was on par with fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) and soil application of full dose of nutrients with drip irrigation (n_2) for fruit N uptake and it was on par with n_2 and n_4 (soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP) for leaf uptake. However, n_2 registered the highest N uptake by pseudostem (64.47 kg ha^{-1}) which was on par with n_1 and n_4. Highest N uptake by rhizome (115.72 kg ha^{-1}) and total N uptake (424.41 kg ha^{-1}) was registered by n_1 which was significantly superior to other nutrient sources.

Fruit, leaf, rhizome and total N uptake were significantly improved with foliar application of 19-19-19 (s_2) and was on par with bunch spray of SOP (s_3) on fruit N uptake. Regarding pseudostem N uptake, s_3 registered the highest value (55.19 kg ha^{-1}) which was on par with s_2.

Interaction between nutrient sources and foliar nutrition also showed significant effect on N uptake by plant parts of banana. Fruit N uptake was highest in n_5s_2 (203.52 kg ha^{-1}) which was on par with n_1s_2, n_2s_3, n_5s_3 and n_1s_3. Whereas, leaf N uptake was significantly improved in n_1s_3 which was on par with n_2s_1, n_2s_2, n_1s_2, n_5s_2 and n_4s_1. Though n_1s_2 registered significantly higher value for

Table 55. Effect of nutrient sources, irrigation and foliar nutrition on N uptake by different parts at harvest (second crop), kg ha^{-1}

Treatments	Leaf	Pseudostem	Fruit	Rhizome	Total
Nutrient sources & irrigation					
n_1	65.18	62.23	181.25	115.72	424.41
n_2	63.26	64.47	176.55	89.15	393.45
n_3	28.67	24.32	80.73	49.66	183.40
n_4	57.54	60.57	148.86	84.52	351.51
n_5	52.94	53.85	177.01	76.22	360.03
n_6	44.81	52.31	146.59	78.12	321.85
SEm (±)	3.583	1.320	5.003	1.928	7.889
CD (0.05)	11.291	4.160	15.765	6.077	24.858
Foliar nutrition					
s_1	47.63	49.15	125.33	71.07	293.20
s_2	57.98	54.53	168.78	91.82	373.13
s_3	50.59	55.19	161.39	83.80	350.99
SEm (±)	1.526	0.811	2.768	1.027	3.430
CD (0.05)	4.455	2.367	8.081	2.998	10.013
Interaction					
n_1s_1	57.34	64.58	154.51	91.46	367.90
n_1s_2	66.44	67.00	201.76	139.08	474.29
n_1s_3	71.76	55.13	187.49	116.64	431.03
n_2s_1	70.65	62.17	150.71	79.07	362.62
n_2s_2	70.11	66.59	183.56	98.78	419.05
n_2s_3	49.03	64.66	195.38	89.60	398.68
n_3s_1	26.22	21.48	72.57	40.24	160.52
n_3s_2	30.63	23.35	83.99	58.19	196.17
n_3s_3	29.17	28.12	85.63	50.56	193.50
n_4s_1	61.33	58.10	128.88	74.05	322.37
n_4s_2	60.10	61.24	163.32	92.60	377.27
n_4s_3	51.18	62.39	154.38	86.91	354.88
n_5s_1	36.93	43.09	135.00	71.96	287.00
n_5s_2	66.40	58.03	203.52	78.45	406.41
n_5s_3	55.48	60.41	192.53	78.24	386.67
n_6s_1	33.30	45.49	110.31	69.66	258.78
n_6s_2	54.20	50.99	176.52	83.83	365.55
n_6s_3	46.93	60.44	152.95	80.87	341.21
SEm (±)	3.738	1.986	6.781	2.516	8.402
CD (0.05)	10.912	5.798	19.796	7.345	24.526

pseudostem N uptake (67.00 kg ha^{-1}), it was on par with n_2s_2, n_2s_3, n_1s_1, n_4s_3, n_2s_1 and n_4s_2. However, rhizome and total N uptake was significantly superior in n_1s_2 (139.08 kg ha^{-1} and 474.29 kg ha^{-1}, respectively) compared to all other treatments.

4.3.7.2 P Uptake (kg ha^{-1})

The P uptake values by different plant parts of banana is presented in Table 56. Soil application of full dose of nutrients with drip irrigation (n_2) resulted in significantly higher leaf, rhizome and total P uptake. However, P uptake by fruits was highest (34.78 kg ha^{-1}) in soil application of full dose of nutrients with basin irrigation (n_1) and that by pseudostem (14.53 kg ha^{-1}) in fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5).

Foliar application of 19-19-19 (s_2) registered significantly highest P uptake by leaf and rhizome (8.39 kg ha^{-1} and 17.08 kg ha^{-1} respectively). P uptake by fruit and pseudostem were significantly improved by bunch spray of SOP (s_3) and it was on par with s_2 on pseudostem P uptake. Total P uptake was significantly higher in s_2 (61.24 kg ha^{-1}) and it was on par with s_3 (59.72 kg ha^{-1}).

Though P uptake by leaf and rhizome were not affected by any of the treatment combinations, fruit, pseudostem and total P uptake were significantly influenced by combined effect of fertigation and foliar nutrition. Fruit P uptake was significantly highest in n_5s_3 which was on par with n_1s_3, n_1s_2 and n_2s_2. Pseudostem P uptake was found to be significantly higher in n_5s_2 and was on par with n_5s_3. Regarding total P uptake, n_2s_2 registered the highest value of 85.81 kg ha^{-1} which was significantly superior to all other combinations.

4.3.7.3 K Uptake (kg ha^{-1})

Data presented in Table 57 indicates that the K uptake by different parts of banana was significantly influenced by different nutrient sources. Soil application of full dose of nutrients with basin irrigation (n_1) registered the highest K uptake values by all parts of banana. However, it was on par with soil application of full

Table 56. Effect of nutrient sources, irrigation and foliar nutrition on P uptake by different parts at harvest (second crop), kg ha^{-1}

Treatments	Leaf	Pseudostem	Fruit	Rhizome	Total
Nutrient sources & irrigation					
n_1	8.38	7.67	34.78	24.59	75.43
n_2	9.48	8.28	32.47	27.11	77.35
n_3	3.26	2.60	9.23	4.84	19.94
n_4	7.07	10.71	24.17	11.71	53.68
n_5	7.30	14.53	30.93	8.98	61.76
n_6	6.76	11.49	20.57	15.43	54.26
SEm (±)	0.199	0.347	0.466	0.275	0.573
CD (0.05)	0.627	1.093	1.471	0.867	1.806
Foliar nutrition					
s_1	6.10	8.19	22.15	13.80	50.25
s_2	8.39	9.56	26.20	17.08	61.24
s_3	6.63	9.89	27.73	15.45	59.72
SEm (±)	0.335	0.256	0.519	0.305	0.864
CD (0.05)	0.978	0.747	1.516	0.891	2.524
Interaction					
n_1s_1	7.37	8.60	31.96	23.28	71.23
n_1s_2	9.84	7.89	35.99	25.84	79.57
n_1s_3	7.92	6.51	36.40	24.65	75.48
n_2s_1	8.86	7.57	32.26	24.23	72.92
n_2s_2	12.03	8.32	35.25	30.20	85.81
n_2s_3	7.55	8.94	29.91	26.90	73.33
n_3s_1	2.64	2.19	8.57	3.81	17.21
n_3s_2	3.65	2.61	10.06	6.08	22.41
n_3s_3	3.48	3.00	9.08	4.63	20.20
n_4s_1	6.58	10.38	21.83	8.68	47.48
n_4s_2	8.48	10.23	23.66	14.43	56.81
n_4s_3	6.14	11.53	27.03	12.03	56.74
n_5s_1	5.68	10.93	21.38	8.70	46.71
n_5s_2	8.24	16.45	32.46	9.14	66.30
n_5s_3	7.99	16.22	38.94	9.10	72.26
n_6s_1	5.46	9.49	16.91	14.09	45.95
n_6s_2	8.11	11.85	19.76	16.81	56.55
n_6s_3	6.73	13.14	25.03	15.38	60.29
SEm (±)	0.821	0.627	1.272	0.748	2.118
CD (0.05)	NS	1.832	3.714	NS	6.183

Table 57. Effect of nutrient sources, irrigation and foliar nutrition on K uptake by different parts at harvest (second crop), kg ha^{-1}

Treatments	Leaf	Pseudostem	Fruit	Rhizome	Total
Nutrient sources & irrigation					
n_1	65.66	258.11	304.87	421.99	1050.65
n_2	61.28	257.39	268.75	390.34	977.78
n_3	28.42	70.76	100.30	131.86	331.37
n_4	60.14	186.23	170.65	284.39	701.43
n_5	55.18	160.68	212.09	296.75	724.72
n_6	45.49	185.58	184.05	259.67	674.80
SEm (±)	3.286	2.965	6.485	8.915	17.351
CD (0.05)	10.356	9.344	20.433	28.090	54.672
Foliar nutrition					
s_1	48.49	157.42	158.43	277.31	641.67
s_2	61.06	214.56	197.38	307.89	780.90
s_3	48.54	187.40	264.55	307.30	807.80
SEm (±)	1.285	2.792	2.917	4.921	5.882
CD (0.05)	3.750	8.150	8.514	14.365	17.169
Interaction					
n_1s_1	68.58	237.29	180.08	379.81	865.77
n_1s_2	64.21	321.20	337.25	441.95	1164.62
n_1s_3	64.20	215.84	397.28	444.21	1121.54
n_2s_1	62.32	184.76	226.28	365.26	838.64
n_2s_2	74.15	339.54	225.42	400.70	1039.82
n_2s_3	47.37	247.87	354.56	405.05	1054.87
n_3s_1	25.00	61.93	89.61	114.94	291.50
n_3s_2	30.78	66.54	102.43	145.32	345.08
n_3s_3	29.49	83.82	108.86	135.33	357.52
n_4s_1	59.06	173.92	142.97	267.45	643.40
n_4s_2	72.10	190.40	164.59	313.05	740.15
n_4s_3	49.26	194.39	204.39	272.68	720.73
n_5s_1	38.06	114.83	157.86	289.42	600.19
n_5s_2	72.92	199.59	160.65	285.58	718.75
n_5s_3	54.55	167.62	317.76	315.26	855.20
n_6s_1	37.90	171.80	153.79	247.00	610.50
n_6s_2	52.21	170.08	193.93	260.73	676.96
n_6s_3	46.37	214.85	204.43	271.28	736.94
SEm (±)	3.147	6.839	7.145	12.055	14.408
CD (0.05)	9.187	19.963	20.856	NS	42.057

dose of nutrients with drip irrigation (n_2) and soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) on leaf K uptake. On pseudostem K uptake, n_1 was on par with n_2. The total K uptake was highest in n_1 (1050.65 kg ha^{-1}) which was significantly superior to all other treatments.

Foliar application of 19-19-19 (s_2) registered significantly highest values for leaf, pseudostem and rhizome K uptake and it was on par with bunch spray of SOP (s_3) in rhizome K uptake. Regarding fruit and total K uptake s_3 was found significantly superior with uptake values of 264.55 and 807.80 kg ha^{-1}, respectively.

Interaction effect also had significant influence on the K uptake by all parts of the plant except rhizome. The highest fruit K uptake of 397.28 kg ha^{-1} was registered by n_1s_3. While, n_2s_2 recorded the highest values of K uptake by leaf and pseudostem. On leaf K uptake, n_2s_2 was on par with n_5s_2, n_4s_2 and n_1s_1 and on pseudostem K uptake, it was on par with n_1s_2. Total K uptake (1164.62 kg ha^{-1}) was highest in n_1s_2 which was significantly superior to other combinations.

4.3.8 Nutrient Use Efficiency

4.3.8.1 Physiological Efficiency of Major Nutrients (kg kg^{-1})

From the data (Table 58) on physiological efficiency of nutrients, it was observed that nutrient sources and irrigation had significant influence on physiological efficiency of N, P and K. Among the nutrient sources and irrigation, soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) recorded significantly higher physiological efficiency values of 46.75, 245.23 and 21.70 kg kg^{-1} for N, P and K, respectively. However, n_4 was on par with fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) and fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) for physiological efficiency of N.

Table 58. Effect of nutrient sources, irrigation and foliar nutrition on physiological efficiency of major nutrients (second crop), kg kg^{-1}

Treatments	N	P	K
Nutrient sources & irrigation			
n_1	41.09	201.20	14.31
n_2	42.99	166.98	14.72
n_4	46.75	245.23	21.70
n_5	44.26	191.98	19.24
n_6	46.67	204.41	18.72
SEm (±)	1.057	5.147	0.346
CD (0.05)	3.446	16.792	1.129
Foliar nutrition			
s_1	50.14	210.43	18.72
s_2	37.74	193.96	17.30
s_3	45.18	201.49	17.19
SEm (±)	1.052	5.397	0.205
CD (0.05)	3.102	NS	0.605
Interaction			
n_1s_1	48.10	195.96	17.30
n_1s_2	34.25	191.46	12.30
n_1s_3	40.92	216.19	13.32
n_2s_1	46.11	166.87	16.98
n_2s_2	39.21	148.41	13.56
n_2s_3	43.66	185.66	13.61
n_4s_1	47.37	256.55	21.88
n_4s_2	43.31	237.23	20.98
n_4s_3	49.56	241.92	22.24
n_5s_1	55.89	221.44	21.17
n_5s_2	32.95	189.42	18.98
n_5s_3	43.94	165.07	17.57
n_6s_1	53.24	211.32	16.26
n_6s_2	38.98	203.30	20.70
n_6s_3	47.80	198.63	19.21
SEm (±)	2.351	12.068	0.459
CD (0.05)	6.936	NS	1.353

Water spray (s_1) exerted significant influence on increasing physiological efficiency of N and K. However foliar nutrition had no influence on P.

The interaction of nutrient sources with foliar nutrition also showed significant influence on physiological efficiency of major nutrients except P. Physiological efficiency of N was significantly higher in n_5s_1 which was on par with n_6s_1 and n_4s_3. Regarding K, n_4s_3 recorded the highest physiological efficiency (22.24 kg kg^{-1}) which was on par with n_4s_1, n_5s_1 and n_4s_2.

4.3.8.2 Apparent Recovery of Major Nutrients (per cent)

Data on apparent recovery of nutrients presented in Table 59 revealed that apparent recovery of nutrients was significantly influenced by nutrient sources, irrigation and foliar nutrition. Significantly higher N and P apparent recovery (44.26 and 25.73 per cent respectively) were recorded by fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5), but it was on par with soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) for N. However, the highest K apparent recovery of 67.38 per cent was registered by soil application of full dose of nutrients with basin irrigation (n_1) and was on par with n_5 and soil application of full dose of nutrients with drip irrigation (n_2).

Foliar application of 19-19-19 (s_2) registered the highest N apparent recovery of 44.79 per cent and was significantly superior to other treatments. However, apparent recovery of P and K were significantly higher (22.08 and 70.72 per cent, respectively) in bunch spray of SOP (s_3) than water spray (s_1) and was on par with s_2 for P.

Interaction effect also showed significant influence on apparent recovery of major nutrients. Significantly higher apparent recovery of 54.44 per cent for N was registered by n_5s_2 which was on par with n_5s_3. It was observed that n_5s_3 recorded the highest values of P and K apparent recovery (31.91 and 83.20 per cent respectively).

Table 59. Effect of nutrient sources, irrigation and foliar nutrition on apparent recovery of major nutrients (second crop), per cent

Treatments	N	P	K
Nutrient sources & irrigation			
n_1	35.15	20.20	67.38
n_2	31.03	20.87	60.91
n_4	42.38	12.65	60.59
n_5	44.26	25.73	64.02
n_6	35.79	21.40	56.65
SEm (±)	1.771	0.299	2.064
CD (0.05)	5.775	0.975	6.732
Foliar nutrition			
s_1	28.10	16.49	48.96
s_2	44.79	21.95	66.06
s_3	40.28	22.08	70.72
SEm (±)	0.782	0.491	0.890
CD (0.05)	2.309	1.450	2.628
Interaction			
n_1s_1	27.65	18.78	51.04
n_1s_2	41.74	21.56	77.49
n_1s_3	36.06	20.26	73.61
n_2s_1	26.94	19.37	48.63
n_2s_2	34.39	23.72	66.41
n_2s_3	31.75	19.51	67.70
n_4s_1	35.96	10.52	52.13
n_4s_2	47.98	13.69	66.30
n_4s_3	43.18	13.74	63.35
n_5s_1	28.10	17.09	45.73
n_5s_2	54.44	28.18	63.14
n_5s_3	50.25	31.91	83.20
n_6s_1	21.83	16.66	47.26
n_6s_2	45.39	22.58	56.96
n_6s_3	40.15	24.97	65.74
SEm (±)	1.750	1.099	1.992
CD (0.05)	5.163	3.244	5.876

4.3.8.3 Nutrient Use Efficiency of Major Nutrients (kg kg^{-1})

From the results on nutrient use efficiency presented in Table 60, it was observed that soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) registered significantly highest nutrient use efficiency of 19.71 kg kg^{-1} and 13.12 kg kg^{-1} respectively for N and K and was on par with fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5). However, the highest P use efficiency of 48.24 kg kg^{-1} was recorded in n_5 which was on par with fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6).

Bunch spray of SOP (s_3) was found to have significant effect on increasing nutrient use efficiency of N, P and K. However, it was on par with foliar application of 19-19-19 (s_2) in enhancing P use efficiency.

Interaction effect also showed significant effect on nutrient use efficiency of major nutrients except P. It was noticed that n_5s_3 registered significantly higher values of N and K use efficiency which was on par with n_4s_3 and n_4s_2.

4.3.8.4 Agronomic Efficiency (kg kg^{-1})

Data on agronomic efficiency of major nutrients are furnished in Table 60.

Different nutrient sources and irrigation had significant influence on agronomic efficiency of nutrients. Significantly higher values of N and K use efficiency (25.59 kg kg^{-1} and 17.05 kg kg^{-1} respectively) were registered by soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) and was on par with fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) for N and n_5 and fertigation of 60 per cent RDN as 13-0-45, SOP and DAP (n_6) for K. The highest P use efficiency was noticed in n_5 and was on par with n_6.

Bunch spray of SOP (s_3) was found to be significantly superior to other treatments in producing higher agronomic efficiency of 25.35, 60.09 and 16.85 kg kg^{-1} for N, P and K respectively.

Table 60. Effect of nutrient sources, irrigation and foliar nutrition on nutrient use efficiency of major nutrients and agronomic efficiency (second crop), kg kg^{-1}

Treatments	Nutrient use efficiency			Agronomic efficiency		
	N	P	K	N	P	K
Nutrient sources & irrigation						
n_1	14.20	40.60	9.46	17.22	44.87	11.47
n_2	13.26	34.55	8.83	15.15	39.50	10.09
n_4	19.71	30.82	13.12	25.59	40.03	17.05
n_5	18.36	48.24	12.23	25.10	65.38	16.72
n_6	16.19	43.70	10.78	23.91	62.25	15.92
SEm (±)	0.832	1.450	0.554	1.267	3.221	0.845
CD (0.05)	2.713	4.730	1.807	4.135	10.5054	2.756
Foliar nutrition						
s_1	13.85	33.90	9.23	16.92	40.13	11.28
s_2	16.92	41.65	11.29	21.91	50.99	14.62
s_3	18.26	43.20	12.13	25.35	60.09	16.85
SEm (±)	0.296	1.482	0.197	0.603	1.324	0.401
CD (0.05)	0.875	4.373	0.582	1.781	3.908	1.185
Interaction						
n_1s_1	13.36	36.87	8.90	13.25	34.57	8.83
n_1s_2	14.46	41.32	9.64	17.93	46.62	11.96
n_1s_3	14.80	43.61	9.84	20.47	53.41	13.62
n_2s_1	12.40	32.34	8.26	13.68	35.71	9.12
n_2s_2	13.50	35.10	9.00	14.11	36.68	9.41
n_2s_3	13.88	36.20	9.23	17.67	46.11	11.75
n_4s_1	17.08	26.74	11.39	19.23	30.11	12.82
n_4s_2	20.78	32.47	13.87	28.52	44.55	19.03
n_4s_3	21.25	33.26	14.11	29.03	45.44	19.28
n_5s_1	14.84	38.72	9.89	22.18	57.87	14.79
n_5s_2	18.06	53.19	12.05	22.32	57.89	14.90
n_5s_3	22.18	52.80	14.73	30.81	80.39	20.46
n_6s_1	11.57	34.81	7.71	16.26	42.42	10.84
n_6s_2	17.80	46.16	11.88	26.69	69.22	17.81
n_6s_3	19.21	50.12	12.76	28.79	75.11	19.12
SEm (±)	0.663	3.315	0.441	1.350	2.962	0.898
CD (0.05)	1.958	NS	1.302	3.983	8.738	2.651

Among the treatment combinations, significantly higher agronomic N, P and K use efficiency were observed in n_5s_3 and was on par with n_4s_3 and n_4s_2 for N and with n_6s_3 for P. For K, n_5s_3 was on par with n_4s_3, n_6s_3, n_4s_2, and n_6s_2.

4.3.9 Soil Nutrient Status after Second Year of Experimentation

Data on available N, P and K status of the soil presented in (Table 61) after the experiment revealed that significantly higher values of available N, P K (334.90, 178.22 and 275.44 kg ha^{-1} respectively) were recorded by soil application of full dose of nutrients with basin irrigation (n_1) which was on par with soil application of full dose of nutrients with drip irrigation (n_2).

Foliar nutrition and the interaction had no significant effect on available N, P and K status of the soil after the experiment.

4.3.10 Soil Microbial Status after Second Year of Experimentation

From the data on microbial status in the soil after the experiment (Table 62), it was noticed that bacteria and actinomycetes count were significantly higher in drip irrigation alone without any fertilizer (n_3) at both the dilutions. However, higher fungi count was noticed by soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) and soil application of full dose of fertilizers with drip irrigation (n_2) at 10^{-3} and 10^{-4} dilution respectively.

Microbial count was not at all influenced by foliar nutrition.

Interaction also showed significant influence on microbial status in the soil after the experiment. At 10^{-6} dilution, bacterial count was highest in n_3s_1, while at 10^{-7} dilution, n_3s_2 gave the highest count which was on par with n_3s_3. Fungi count was significantly increased in n_4s_3 at 10^{-3} dilution.

Table 61. Effect of nutrient sources, irrigation and foliar nutrition on soil nutrient status after the experiment (second crop), kg ha^{-1}

Treatments	Available N	Available P	Available K
Nutrient sources & irrigation			
n_1	334.90	178.22	275.44
n_2	333.45	172.77	272.77
n_3	277.87	107.38	177.38
n_4	282.12	158.66	223.66
n_5	284.33	133.38	235.16
n_6	269.88	129.11	232.00
SEm (±)	5.859	4.708	4.988
CD (0.05)	18.463	14.835	15.719
Foliar nutrition			
s_1	302.52	144.00	236.50
s_2	289.62	150.22	237.38
s_3	299.14	145.55	234.33
SEm (±)	5.845	2.583	2.250
CD (0.05)	NS	NS	NS
Interaction			
n_1s_1	327.13	173.00	273.00
n_1s_2	336.90	187.83	279.50
n_1s_3	340.66	173.83	273.83
n_2s_1	348.36	174.66	274.66
n_2s_2	323.33	166.33	266.33
n_2s_3	328.66	177.33	277.33
n_3s_1	284.00	109.83	179.83
n_3s_2	260.76	115.00	185.00
n_3s_3	288.86	97.33	167.33
n_4s_1	298.63	155.50	220.50
n_4s_2	274.06	162.00	227.00
n_4s_3	273.66	158.50	223.50
n_5s_1	290.00	129.50	239.50
n_5s_2	275.66	136.66	230.00
n_5s_3	287.33	134.00	236.00
n_6s_1	267.00	121.50	231.50
n_6s_2	267.00	133.50	236.50
n_6s_3	275.66	132.33	228.00
SEm (±)	14.318	6.328	5.512
CD (0.05)	NS	NS	NS

Table 62. Effect of nutrient sources, irrigation and foliar nutrition on soil microbial count after the experiment (second crop), cfu g^{-1} soil

Treatments	Bacteria		Fungi		Actinomycetes	
	x 10^6	x 10^7	x 10^3	x 10^4	x 10^2	x 10^3
Nutrient sources & irrigation						
n_1	6.66	1.33	10.22	2.22	45.55	41.55
n_2	7.77	5.67	9.33	3.33	30.44	30.00
n_3	12.55	7.55	12.66	2.33	72.33	71.11
n_4	2.88	1.55	20.44	2.67	39.66	38.11
n_5	3.22	2.66	16.22	2.44	43.44	38.55
n_6	9.11	2.33	9.11	2.33	46.44	20.55
SEm (±)	0.163	0.240	0.255	0.201	1.350	0.681
CD (0.05)	0.515	0.756	0.805	0.635	4.255	2.148
Foliar nutrition						
s_1	7.05	3.33	12.83	2.72	47.50	40.16
s_2	6.72	3.66	13.00	2.55	45.88	39.38
s_3	7.33	3.55	13.16	2.38	45.55	40.38
SEm (±)	0.168	0.153	0.231	0.106	0.672	0.540
CD (0.05)	NS	NS	NS	NS	NS	NS
Interaction						
n_1s_1	7.00	1.33	10.00	2.00	47.66	40.00
n_1s_2	6.33	1.33	10.66	2.33	42.33	42.00
n_1s_3	6.66	1.33	10.00	2.33	46.66	42.66
n_2s_1	6.66	5.00	8.00	3.67	31.33	30.00
n_2s_2	7.33	5.66	9.00	3.33	28.00	30.00
n_2s_3	9.33	6.33	11.00	3.00	32.00	30.00
n_3s_1	13.66	6.33	12.66	2.33	70.66	71.00
n_3s_2	11.66	8.33	11.66	2.33	74.66	71.66
n_3s_3	12.33	8.00	13.66	2.33	71.66	70.66
n_4s_1	3.00	2.00	19.66	3.00	42.00	39.33
n_4s_2	2.33	1.33	20.00	2.33	40.66	35.00
n_4s_3	3.33	1.33	21.66	2.67	36.33	40.00
n_5s_1	3.33	2.33	18.00	2.33	43.66	38.00
n_5s_2	3.00	3.33	16.66	3.00	44.66	38.00
n_5s_3	3.33	2.33	14.00	2.00	42.00	39.66
n_6s_1	8.66	3.00	8.66	3.00	49.66	22.66
n_6s_2	9.66	2.00	10.00	2.00	45.00	19.66
n_6s_3	9.00	2.00	8.66	2.00	44.66	19.33
SEm (±)	0.412	0.376	0.566	0.261	1.646	1.324
CD (0.05)	1.202	1.099	1.653	NS	NS	NS

Table 63. Effect of nutrient sources, irrigation and foliar nutrition on economics of banana cultivation (second crop)

Treatments	Gross income (` ha^{-1})	Net income (` ha^{-1})	B : C ratio	Average net income (` ha^{-1})	Average B : C ratio
Nutrient sources & irrigation					
n_1	1072917	830625	4.42	836958	4.33
n_2	1053472	813600	4.39	830465	4.39
n_3	760416	583423	4.29	543826	4.00
n_4	1063194	856436	5.14	861804	5.07
n_5	1072917	365785	1.51	355209	1.49
n_6	1034028	737814	3.49	709009	3.35
SEm (±)	21002.400	21002.400	0.074	-	-
CD (0.05)	66175.787	66175.787	0.233	-	-
Foliar nutrition					
s_1	957638	646058	3.69	624077	3.55
s_2	1015972	703079	3.86	699801	3.79
s_3	1054861	744705	4.07	744757	3.99
SEm (±)	22800.632	22800.632	0.077	-	-
CD (0.05)	66553.604	66553.604	0.225	-	-
Interaction					
n_1s_1	1043750	801421	4.30	793171	4.16
n_1s_2	1043750	800108	4.28	813733	4.23
n_1s_3	1131250	890346	4.69	903971	4.62
n_2s_1	1014583	774674	4.22	801163	4.27
n_2s_2	1043750	802528	4.32	819903	4.33
n_2s_3	1102083	863599	4.62	870328	4.58
n_3s_1	702083	525052	3.96	493719	3.72
n_3s_2	789583	611240	4.42	563136	4.08
n_3s_3	789583	613977	4.49	574623	4.19
n_4s_1	1043750	836954	5.04	781850	4.70
n_4s_2	1043750	835641	5.01	885829	5.16
n_4s_3	1102083	896712	5.36	917733	5.36
n_5s_1	985416	278248	1.39	229998	1.32
n_5s_2	1102083	393602	1.55	392748	1.54
n_5s_3	1131250	425506	1.60	442881	1.62
n_6s_1	956250	659999	3.22	644562	3.14
n_6s_2	1072917	775353	3.60	723458	3.39
n_6s_3	1072917	778091	3.63	759008	3.53
SEm (±)	55849.914	55849.914	0.189	-	-
CD (0.05)	NS	NS	NS	-	-

4.3.11 Economic Analysis

Data on economic analysis presented in Table 63 revealed that the different nutrient sources and irrigation methods except drip irrigation alone without any fertilizer (n_3) significantly increased gross income. Soil application of 100 per cent P as rock phosphate and fertigation of 60 per cent N and K as urea and MOP (n_4) recorded significantly higher net income of ` 8,56,436 ha^{-1} and was on par with soil application of full dose of nutrients with basin irrigation (n_1) and soil application of full dose of nutrients with drip irrigation (n_2). Significantly higher B : C ratio of 5.14 was registered by n_4 which was found superior to all other nutrient sources.

Foliar nutrition also showed significant influence on all the economic parameters. Bunch spray of SOP (s_3) registered significantly highest gross income (` 10,54,861 $ha^{-1}$), net income (` 7,44,705 ha^{-1}) and B : C ratio (4.07) and was on par with foliar application of 19-19-19 (s_2).

The interaction had no influence on gross income, net income and B : C ratio. The two year mean values of net income (` 8,61,804 $ha^{-1}$) and B : C ratio (5.07) revealed that the highest net income and B : C ratio was registered by $n_4$. Bunch spray with SOP ($s_3$) also enhanced net income (` 744757 ha^{-1}) and B : C ratio (3.99) over foliar application of 19-19-19 (s_2).

DISCUSSION

5. DISCUSSION

An investigation was undertaken to standardize the precision farming practices for banana cv. Nendran. As a preliminary requirement for precision farming, land management practices like deep ploughing to a depth of 50 cm and raised beds of 30 cm height with 3 m width were uniformly followed for all treatments and tissue culture plantlets were used. Irrigation and nutrient management practices adopted included basin and drip irrigation with soil application of full dose of nutrients and drip fertigation using different water soluble fertilizers at 60 per cent of recommended dose. Foliar application of 19-19-19 and bunch spray with SOP also formed part of the treatments. The results obtained from the study are critically discussed in this chapter.

5.1 PART I

STANDARDIZATION OF CONCENTRATIONS OF NUTRIENT SOURCES FOR FERTIGATION

From the preliminary trial conducted to standardize the concentration of different nutrient sources for fertigation, it was observed that the pH values recorded by different sources (urea, MOP, 10-10-10, DAP, SOP and 13-0-45) ranged from 5.76 to 8.28. This range is considered to be safe for plant growth and it is within the ideal pH limit specified for proper growth of banana (Broadley *et al.*, 2004). It was also noticed that the pH values showed an increasing trend with increase in concentration from 0.25 to 1.00 per cent (Fig. 4). Analysis of pH registered by different sources at different concentrations revealed that 10-10-10 and 13-0-45 registered pH in alkaline range (9.09 and 9.01 respectively) at higher concentrations. However, this enhanced pH did not cause any phytotoxicity symptoms like yellowing and browning of plant parts. This indicates that in general, all the water soluble fertilizers (urea, MOP, 10-10-10, DAP, SOP and 13-0-45) at lower concentrations are safe for fertigation. Concentration ranging from 0.20 to 0.70 per cent was used for different water soluble fertilizers in the subsequent field trial. This preliminary trial also gave an indication that the

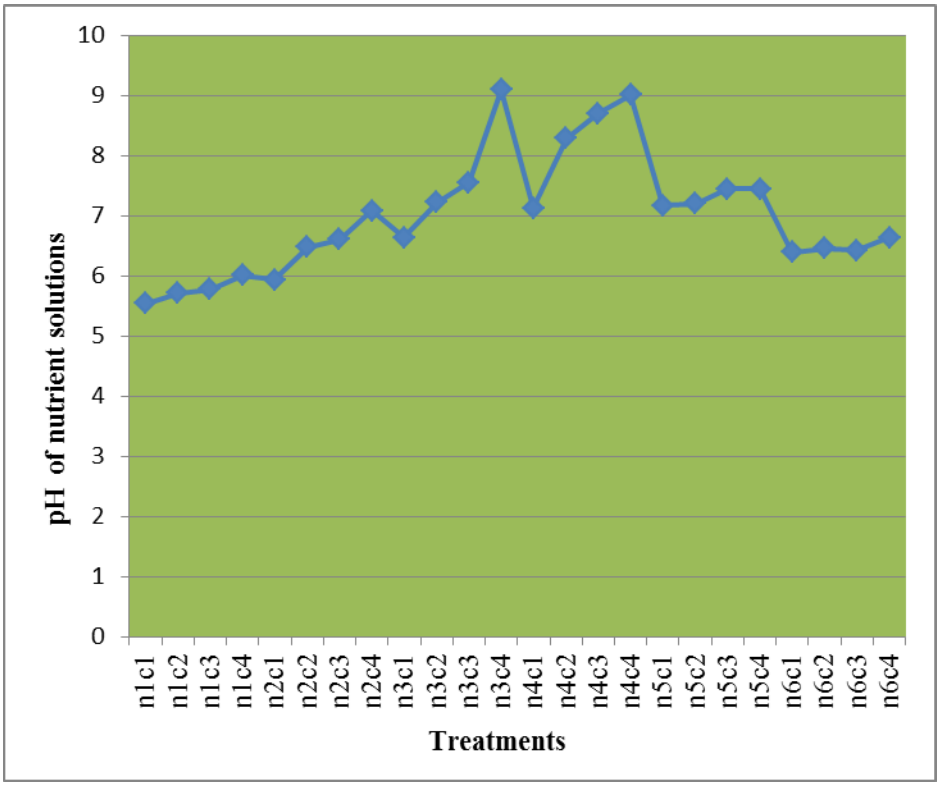


Fig. 4. pH of nutrient solutions as influenced by combined effect of nutrient sources and concentrations

different nutrient sources up to one per cent concentration did not cause any phytotoxicity in banana.

5.2 PART II

NUTRIENT SCHEDULING THROUGH FERTIGATION AND FOLIAR APPLICATION

5.2 Effect of Nutrient Application and Irrigation on Growth, Yield and Quality of Banana

5.2.1 Nutrient Sources and Irrigation

Critical examination of results of the study indicated that bunch weight and productivity of banana were highest in the treatment receiving soil application of full dose of nutrients with basin irrigation (n_1). This was on par with soil application of full dose of nutrients with drip irrigation (n_2), fertigation of 60 per cent N and K as urea and Muriate of Potash (MOP) and soil application of full P as rock phosphate (n_4) and fertigation of 60 per cent RDN as combination of 10-10-10, urea and Sulphate of Potash, SOP (n_5). The superiority of n_1, n_2 and n_4 treatments were further confirmed by the pooled analysis of yield data (Table 47) (Fig. 5). This revealed that with improved land management, both methods of irrigation (basin and drip) behaved similarly with respect to productivity of banana. Varghese (1995) also observed no significant difference in yield of banana plants under drip and basin method of irrigation. The improved land management practices like deep ploughing and taking raised beds might have created favourable rhizosphere environment with better aeration and effective drainage during rainy days for developing efficient root system for better nutrient uptake resulting in higher yield (Vadivel, 2008). The results of the present study is in conformity with this report where n_1 and n_2 were observed to be on par.

Drip fertigation with 60 per cent RDN resulted in an yield which was on par with soil application of 100 per cent of nutrients. Application of lower dose of nutrients in splits is favourable for increasing nutrient uptake by reducing the

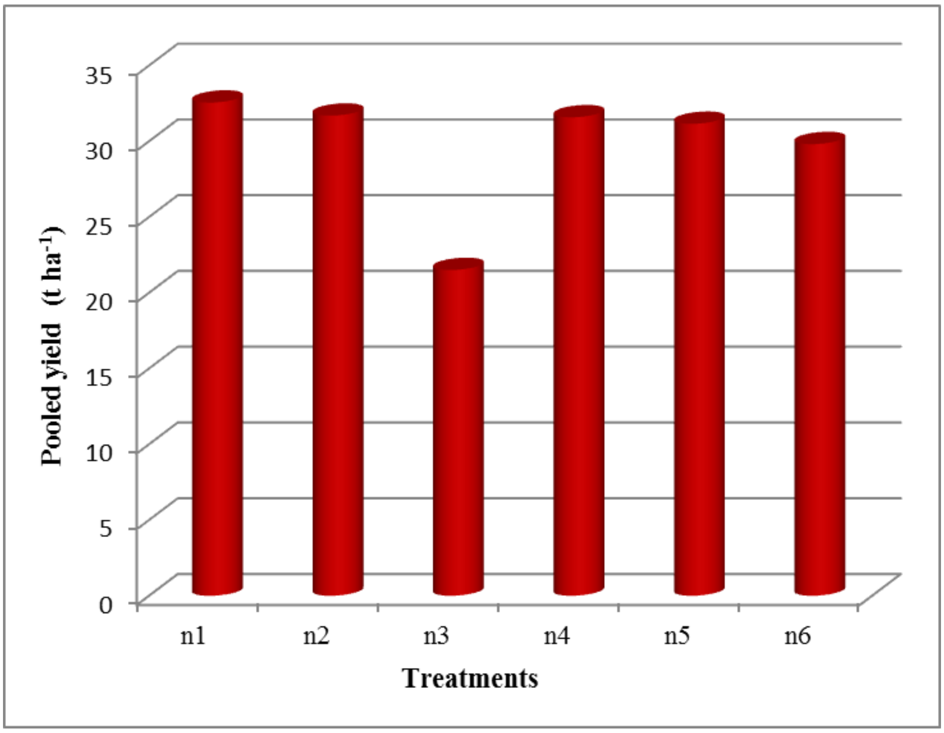


Fig. 5. Pooled yield as influenced by nutrient sources and irrigation

losses. Yield improvement by increasing the number of splits with low concentration rather than increasing the dose in few application was observed by Thomas *et al.* (2001). Bhalerao *et al.* (2009) also reported an yield improvement in banana cv. Grand Naine by soil application of recommended dose of P and fertigation of 75 per cent N and K at weekly intervals in 44 splits which also supports the present observation.

The superiority of n_1, n_2 and n_4 in producing enhanced yield is a reflection of the favourable influence of these treatments on growth and yield attributes. Even with application of 60 per cent RDN through drip fertigation, n_4 was capable of producing better growth and yield comparable to soil application of full dose of nutrients with basin and drip irrigation. This is evident from the plant height, girth, number of functional leaves, functional leaf area and LAI recorded at active growth stages of the crop (4 and 6 MAP). The improvement in functional leaves and LAI at the active growth phase might have enhanced photosynthetic rates of the plant leading to higher crop yield. At harvest stage also, n_4 registered a LAI value comparable to full dose (n_1 and n_2) (Fig. 6 a and Fig. 6 b). Retaining more functional leaf area after bunch emergence will help to prolong the photosynthetic activity over a long period *ie.,* towards the later stage contributing to yield improvement. The growth and development of the banana bunch rely on the physiological activity of functional leaves that were present from the appearance of inflorescence at the apex of the pseudostem and during fruit development (Barrera *et al.,* 2009). Sheela and Nair (2001) opined that the potential for bunch production of tissue culture banana could be determined by the improvement in production of more leaves, greater height and circumference of pseudostem. In addition, irrigating the plants more frequently with a volume of water approaching consumptive use of plants directly to roots also could have resulted in better growth performance (Michael, 1992). The improvement in growth in terms of height, girth, number of leaves and LAI by increasing the frequency of fertigation from monthly to weekly intervals was also reported by Thomas (2001).

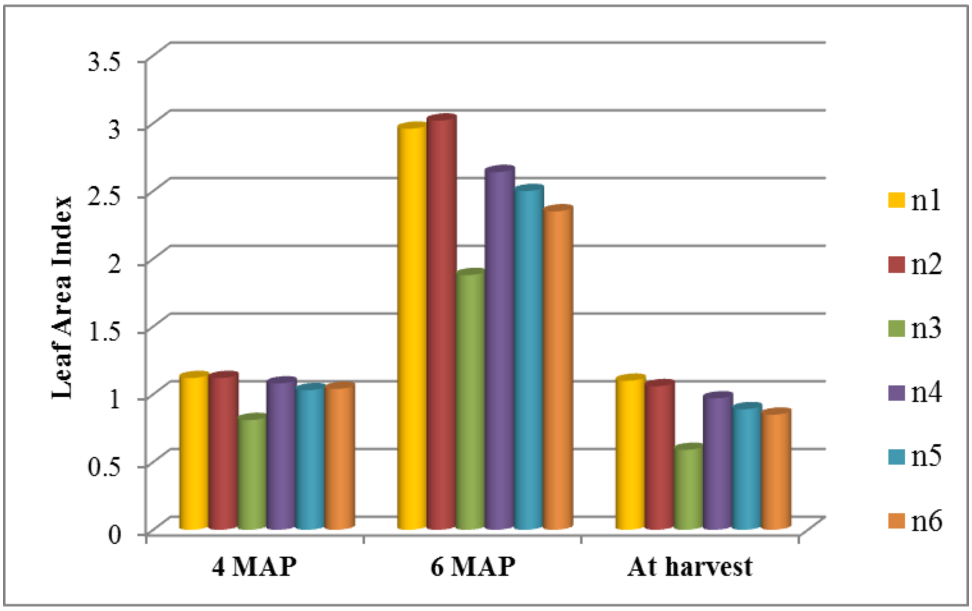


Fig. 6 a. LAI as influenced by nutrient sources and irrigation (I Year)

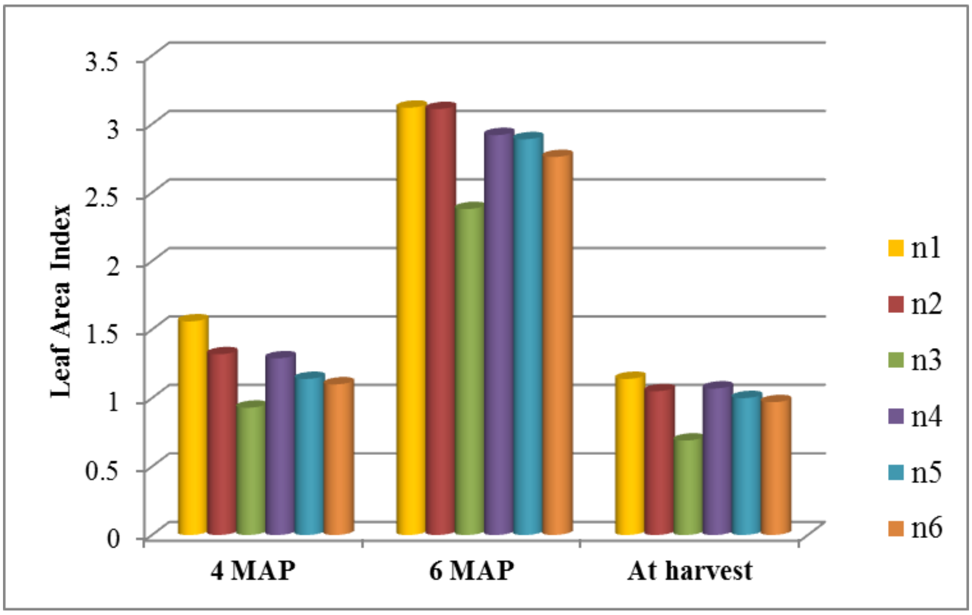


Fig. 6 b. LAI as influenced by nutrient sources and irrigation (II Year)

Total dry matter production of banana (Tables 15 and 40) was significantly higher in soil application of full dose of nutrients with basin and drip irrigation. But in the case of leaf and fruit dry matter production, the fertigation treatments (n_4 and n_5) were observed to be on par with soil application of 100 per cent of nutrients with basin and drip irrigation. This revealed that though the quantity of nutrients supplied by fertigation is less it did not cause any adverse effect on photosynthesis. The photosynthates produced were also efficiently translocated and accumulated in the fruits as evident from the high dry matter production of fruits. From this, it is understood that drip fertigation tends to accumulate photosynthates in the economically important part (fruits) rather than accumulating in the unproductive plant parts like pseudostem and rhizome.

Improvement in growth characters had a positive influence on yield attributes of banana (Fig. 7 a and Fig. 7 b). Fertigation treatments (n_4 and n_5) and soil application (n_1 and n_2) did not register any variation in yield attributes like number of hands bunch^{-1}, number of fingers bunch^{-1}, fingers in D hand, length, breadth and weight of D finger. Application of nutrients in several splits through fertigation might have resulted in steady and continuous supply of nutrients for enhancing yield attributes and yield. The reason stated by Simmonds (1982) that application of major nutrients, N and K at proper growth stages before shooting ensured uninhibited growth resulting in better yield attributes and enhanced yield, is applicable here.

Perusal of the data on nutrient uptake revealed that total N and K uptake were high in soil application with basin and drip irrigation. Better land management practices along with availability of sufficient quantity (100 per cent RDN) of nutrients might have enhanced the nutrient uptake. But P uptake was more in drip irrigation with soil application of full dose of P. Source being rock phosphate, the increased contact with soil might have increased the availability of P and resulted in high P uptake. Fertigation significantly enhanced K uptake in fruits. The enhanced uptake of nutrients was due to the high dry matter accumulation in plant parts. The advantage of drip fertigation in providing

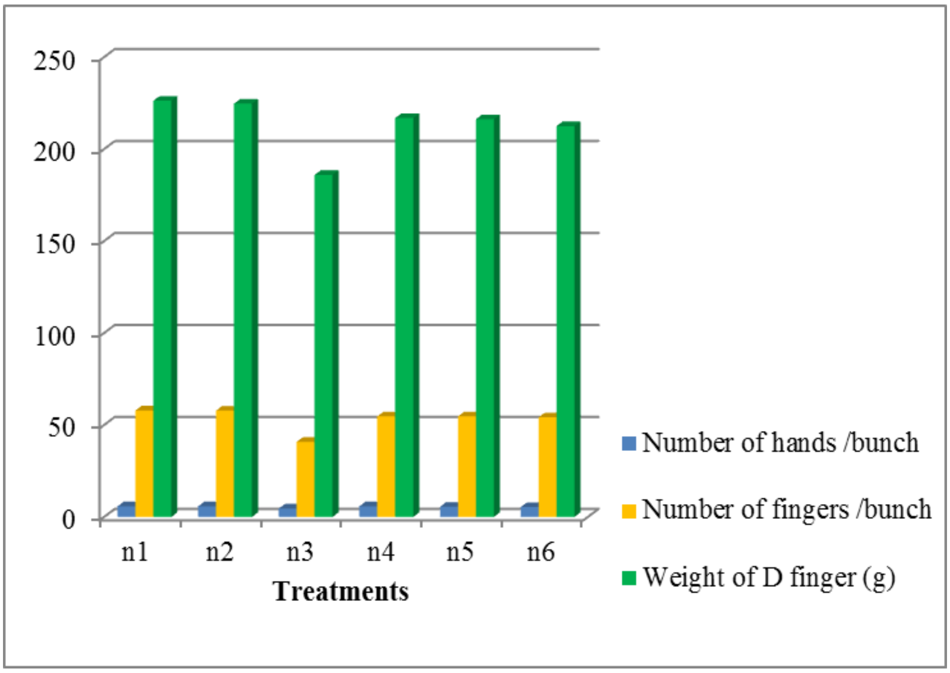


Fig. 7 a. Yield attributes as influenced by nutrient sources and irrigation (I Year)

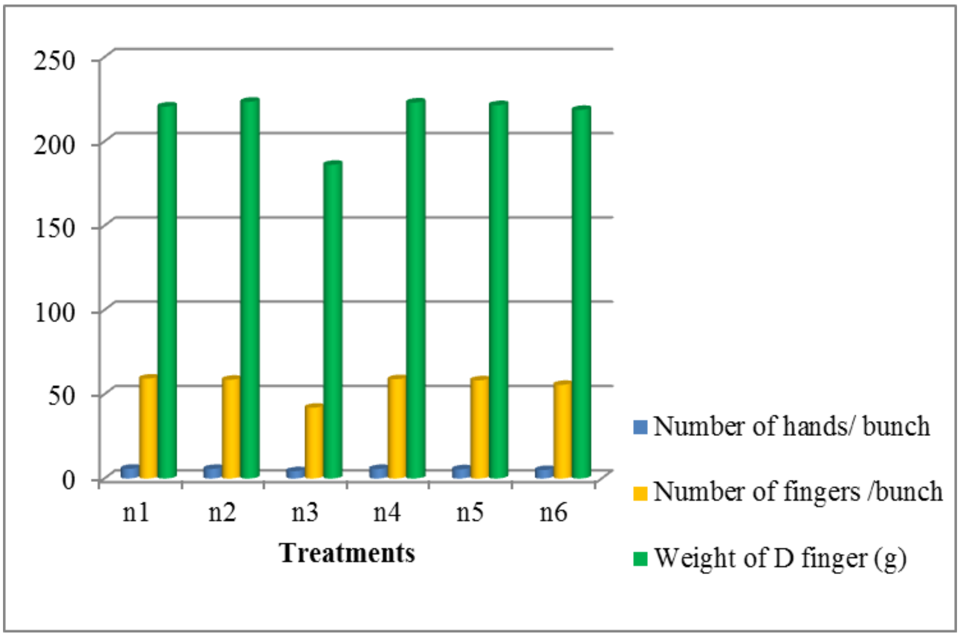


Fig. 7 b. Yield attributes as influenced by nutrient sources and irrigation (II Year) nutrients directly to root zone in available forms and in controlling the nutrient concentration in soil solution (FAI, 1995) might have resulted in enhanced availability of nutrients for absorption and translocation to fruits.

The results (Tables 30 and 60) revealed that the nutrient use efficiency was enhanced by fertigation treatments (Fig. 8 a and Fig. 8 b). Fertigation treatments (n_4 and n_5) significantly improved N and K use efficiency over soil application of nutrients. Feigin *et al.* (1982) opined that enhanced nutrient use efficiency in fertigation was due to reduced leaching loss. Haynes (1985) explained that increased N availability through fertigation was due to reduced NO_3^- leaching as the NO_3^- ion tend to accumulate at the periphery of the wetted soil volume and at the soil surface midway between emitter. Increased K use efficiency was due to the reduced leaching loss as explained by Kafkafi and Yosef (1980) that some of the K ions under fertigation would be exchanged on the clay complex with binding sites in a uniform wetted volume. Results on P use efficiency indicated that though fertigation in general enhanced the P use efficiency, it was highest in fertigation using the liquid fertilizer 10-10-10. Since P in the liquid fertilizer is in a readily available form, its uptake was improved resulting in high P use efficiency. Bacon and Davey (1982) opined that drip fertigation would result in horizontal and vertical movement of native soil P near the outlet and remain near the soil surface and root zone. In other treatments, P was applied as rock phosphate and DAP. Rock phosphate, being an insoluble phosphatic fertilizer and DAP which was sparingly soluble in water might have resulted in low P use efficiency in n_4 and n_6. Moreover, fertigation using DAP was difficult and time consuming as it resulted in clogging of drippers necessitating frequent cleaning of emitters. All the above mentioned reasons might have contributed to enhanced nutrient use efficiency in fertigation. Thomas (2001) also observed better nutrient use efficiency by drip fertigation in banana. Similar improvement in nutrient use efficiency was obtained by Teixeira *et al.* (2011).

Total crop duration was also significantly influenced by nutrient sources and irrigation. Reduction in crop duration by 30 days in fertigation treatments

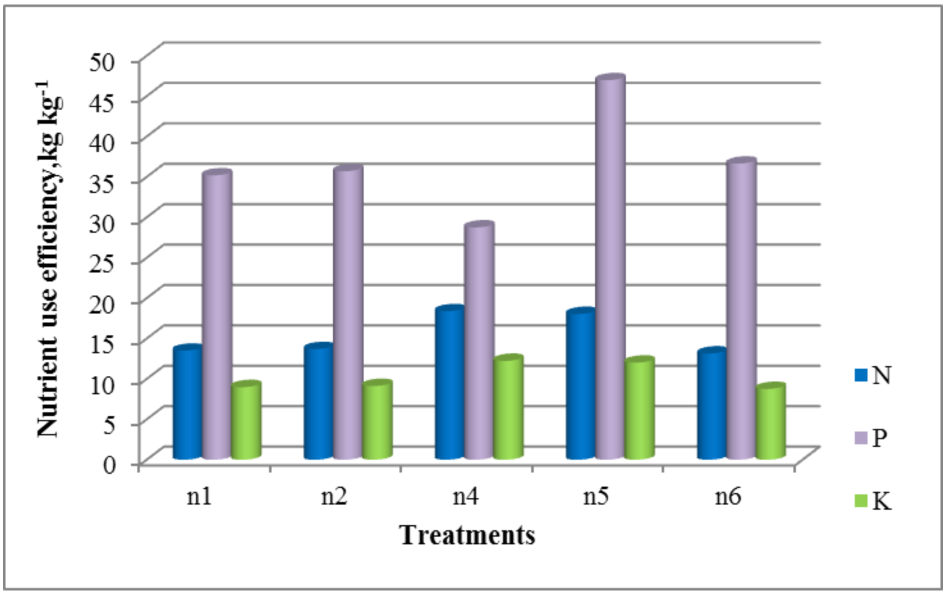


Fig. 8 a. Nutrient use efficiency as influenced by nutrient sources and irrigation (I Year)

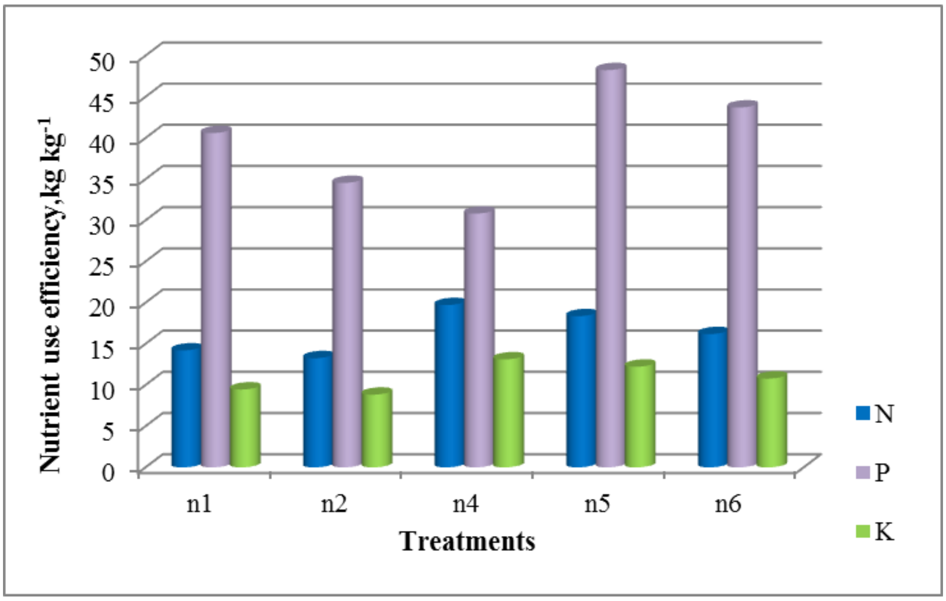


Fig. 8 b. Nutrient use efficiency as influenced by nutrient sources and irrigation (II Year) compared to basin irrigation in the first year was characterized by low rainfall (774.50 mm) during the cropping period. This reduction in crop duration observed in fertigation treatments did not cause any reduction in yield. Compared to first year, 157 per cent increase in rainfall (1996.70 mm) was received during the cropping period in second year. Hence, conspicuous reduction in total crop duration was not observed. During periods of low rainfall, plants under fertigation treatments might have experienced mild stress due to the low quantity of water and nutrients supplied through drip irrigation which in turn resulted in an earliness of bunch emergence and crop duration. Availability of water and nutrients were more in treatments receiving full dose of nutrients with basin irrigation which might have triggered the active growth and extended the crop duration. The early maturity of banana obtained in first year was in conformity with the report of Hedge and Srinivas (1991). Influence of fertigation on early flowering and bunch maturity were also observed by Parikh *et al.* (1994). As per the reports of NCPAH INDIA (2012), fertigation treatments registered 17 days earliness for harvesting fruits compared to conventional cultivation. Similar result was observed by Patel and Tandel (2013).

Review of data on quality attributes (Tables 22 and 52) showed that quality parameters of banana showed varying response to nutrient sources and irrigation. Acidity of fruits was low in basin irrigation with full dose of nutrients as soil application. High acidity of fruits under drip fertigation compared to soil application might be due to low concentration of K in fertigated treatments. This is evident from the report of El-Razek *et al.* (2011) who mentioned that high K fertilization resulted in lower acid concentration in grape fruits. Moreover, Gonzales-Altozano and Castel (1999) opined that water stress would tend to increase organic acid content in ripe fruits through a simple dilution/dehydration effect. Water stress increases the production of organic acids in the leaves and xylem fluid resulting in the accumulation of organic acids in fruits. Hummel *et al.* (2010) explained that under water stress, all plant tissues would accumulate solutes, mainly sugars and organic acids to lower their osmotic potential and prevent a drop in cell turgor pressure. In the case of total sugars, reducing sugars and non-reducing sugars, high values were recorded in drip irrigation treatments (n_6, n_2 and n_5). Gates (1968) reported that under conditions of limited water, the starch hydrolysis was enhanced resulting in higher total sugar. Mahalakshmi (2000) also found that low quantity of irrigation water with optimum level of nutrients was beneficial for increasing the quality in banana. Better fruit quality, especially high sugar content in fertigated crop could be explained by the role K plays in synthesis, breakdown and translocation of carbohydrate (Havlin *et al.*, 2013). Similar increase in total sugar was also obtained by Mahmoud (2013).

5.2.2 Foliar Nutrition

Effect of foliar application of 19-19-19, bunch spray with Sulphate of Potash (SOP) were studied in comparison with water spray. Bunch spray with SOP @ 2 per cent concentration after complete bunch emergence and three weeks after first application (s_3) significantly improved all yield attributes and yield of banana except number of hands in both the years (Fig. 9 a and Fig. 9 b). Foliar application of 19-19-19 at 2, 4 and 6 MAP was found to be equally effective in enhancing all yield attributes including the number of hands in both the years. But in pooled analysis, bunch spray with SOP (2 times) @ 2 per cent was found to be significantly superior to other treatments with a yield of 31.59 t ha^{-1} (Table 47) (Fig. 10). The presence of S in SOP might have favourably influenced the yield attributes and yield. The influence of S in enhancing fruit yield in banana was stressed by Lahav and Turner (1992). Moreover, S is present in the form of SO_4^- in SOP which is water soluble and can be readily absorbed. S helps in energy transformation and activation of enzymes in carbohydrate metabolism resulting in greater partitioning of photosynthates to yield attributes. Influence of S on yield improvement was also stressed by Ahmed *et al.* (1998)

Data on growth attributes (plant height, girth, number of functional leaves, functional leaf area and LAI) revealed that foliar application of 19-19-19 @ 0.50 per cent at 2, 4 and 6 MAP resulted in better growth performance. This

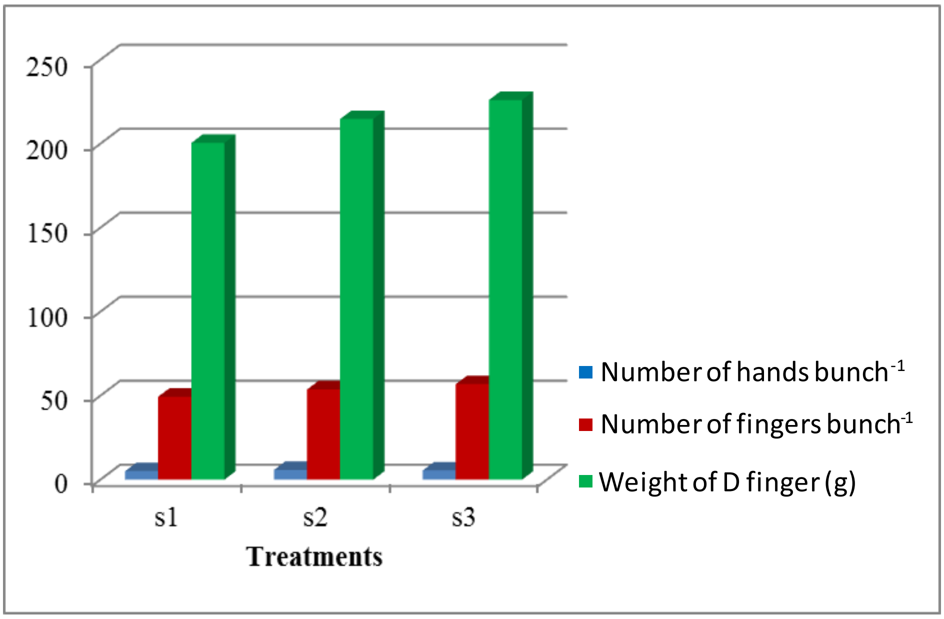


Fig. 9 a. Yield attributes as influenced by foliar nutrition (I Year)

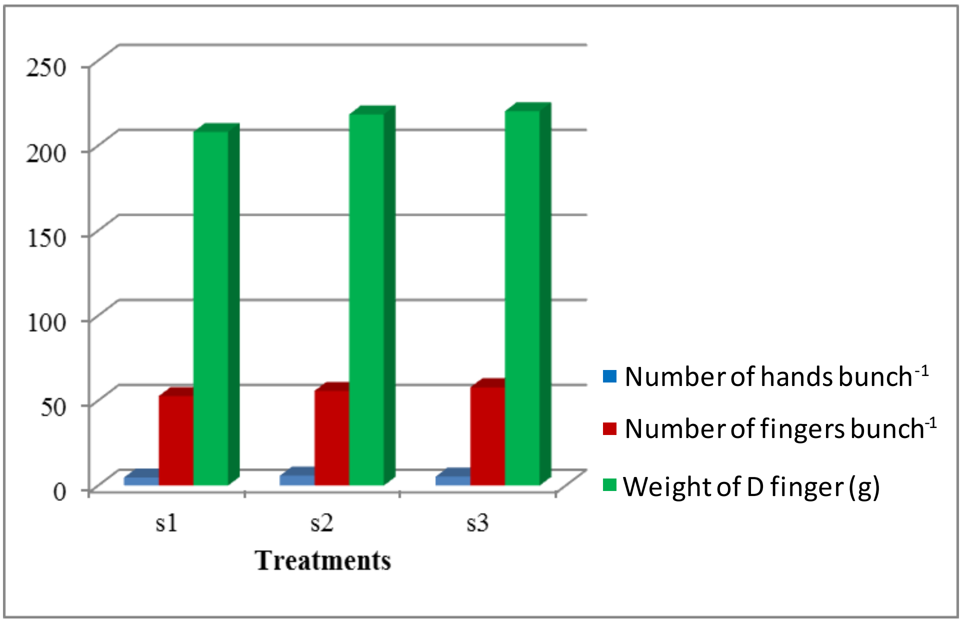


Fig. 9 b. Yield attributes as influenced by foliar nutrition (II Year)

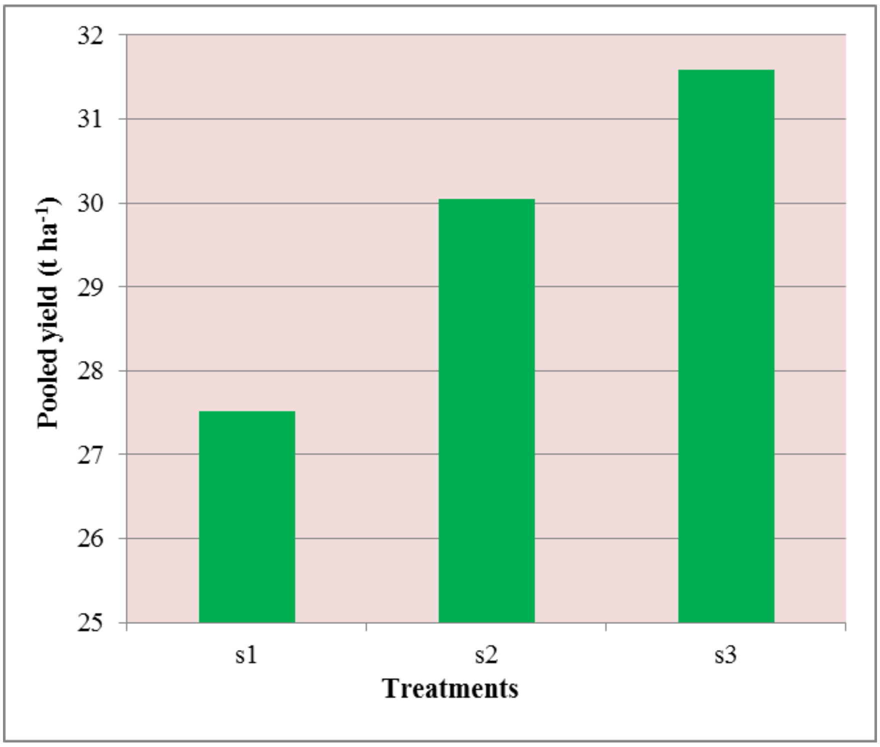


Fig. 10. Pooled yield as influenced by foliar nutrition

a. Bunch spray with SOP @ 2 per cent

b. Foliar spray with 19-19-19 @ 0.50 per cent

c. Water spray

Plate 8. Comparison of finger characteristics- foliar nutrition

improvement in growth might have enhanced the photosynthetic rates leading to increase in number of hands in bunches and improvement in other yield attributes. Similar increase in yield attributes by foliar application of 19-19-19 and bunch spray with SOP were recorded by Chaurasia *et al*. (2005) and Kumar and Kumar (2007) respectively. Though bunch spray with SOP @ 2 per cent registered lower values for number of hands, it had considerable effect on improving the finger characters resulting in higher yield. K applied as bunch spray might have improved translocation of photosynthates to finger resulting in improvement of finger characteristics especially finger weight. Post-shoot application of K probably favoured the growth and development of bunches with better filling of fruit resulting in increased finger weight, length and mid-circumference (Twyford, 1967 and Yadav *et al*. 1988). Kumar and Kumar (2007) also observed increased yield attributes like number of hands, fingers, finger length, finger girth and finger weight in banana (Musa AAA cv. Neypoovan) by bunch spraying with SOP @ 1.50 per cent two times. The results of the present study are in conformity with the findings of Kumar *et al*. (2008).

Improvement in fruit characters by bunch spray is further evident from the high fruit dry matter production (Tables 15 and 40). In both the years, bunch spray with SOP was found to be significantly superior to other treatments in producing more dry matter in fruits. Foliar application of 19-19-19 showed its effect on dry matter accumulation in other plant parts like leaves, pseudostem and rhizome since the application was confined to the vegetative growth stages.

Bunch spray with SOP significantly increased the quality attributes (Tables 22 and 52) in banana. TSS, reducing sugars, non-reducing sugars, total sugars, acidity and sugar-acid ratio were found to be increased by this treatment. Lower values of acidity registered by bunch spray with SOP confirmed its superiority over other treatments in fruit quality. Quality improvement in fruits was attributed to the role of K in phloem loading and unloading of sucrose and amino acids, and storage of starch in developing fruits by activating the enzyme starch synthase (Mengel and Kirkby, 1987). Yadav *et al*. (2014) also registered high TSS and ascorbic acid content in banana fruits by bunch spray with 2 per cent SOP. Similar improvement in quality aspects by bunch spray was also observed by Kumar and Kumar (2007) and Patel *et al.* (2010) in banana.

An overview of data on nutrient uptake revealed that both the sources behaved similarly in nutrient uptake and superior to water spray. Regular supply of nutrients by foliar nutrition with 19-19-19 at bi monthly intervals and bunch spray with SOP @ 2 per cent after bunch emergence might have resulted in increased nutrient absorption and dry matter accumulation resulting in increased nutrient uptake. Similar trend was also observed in nutrient use efficiency of major nutrients (Fig. 11 a and Fig. 11 b). Foliar application and bunch spray favoured quick absorption of nutrients without any loss (Oosterhuis, 2009) resulting in high nutrient use efficiency.

5.2.3 Combined Effect of Nutrient Application, Irrigation and Foliar Application on Productivity of Banana

Perusal of the data on yield in both the years revealed that the fertigation treatments (n_4 and n_5) along with s_3 and s_2 registered a comparable yield to that under soil application of full dose of nutrients with drip and basin irrigation (n_1 and n_2) in combination with s_3 and s_2. Pooled analysis data showed that bunch spray with SOP and foliar application of 19-19-19 resulted in same productivity when 100 per cent RDN was applied to soil along with basin irrigation (Fig. 12). When basin irrigation was changed to drip irrigation with 100 per cent RDN, bunch spray with SOP was significantly superior to foliar application of 19-19-19. In fertigation treatments (n_4 and n_5) also, foliar application with 19-19-19 and bunch spray with SOP were on par. In the treatment where bunch spray with SOP was found better than 19-19-19, the nutrients were applied to soil and crop was irrigated through drip irrigation (n_2s_3). K being a nutrient absorbed by diffusion, drip irrigation might have failed to maintain a continuous film of water to enable the diffusion of K from soil. Moreover, in bunch spray using SOP, higher quantity of K was applied compared to 19-19-19. This might have resulted in

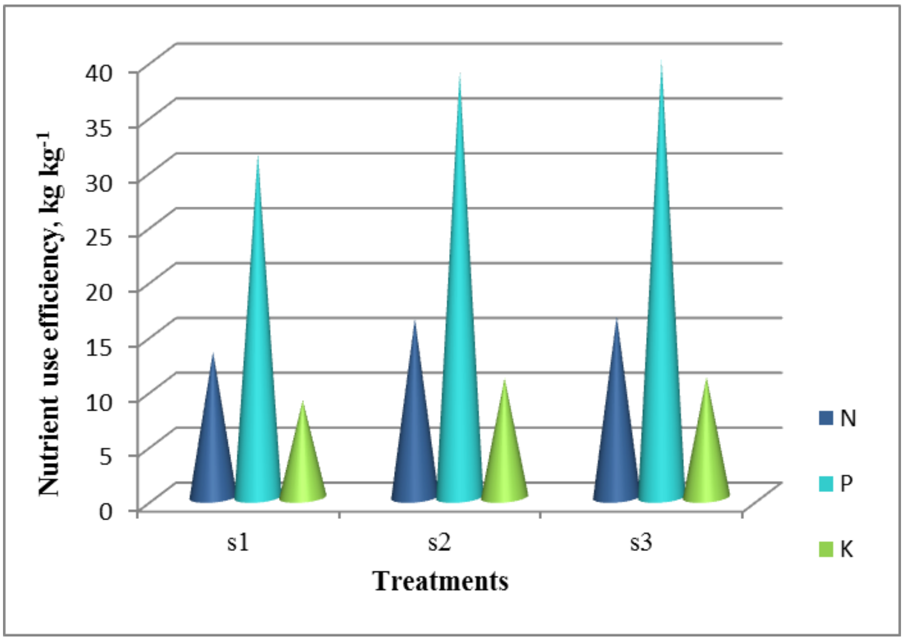


Fig. 11 a. Nutrient use efficiency as influenced by foliar nutrition (I Year)

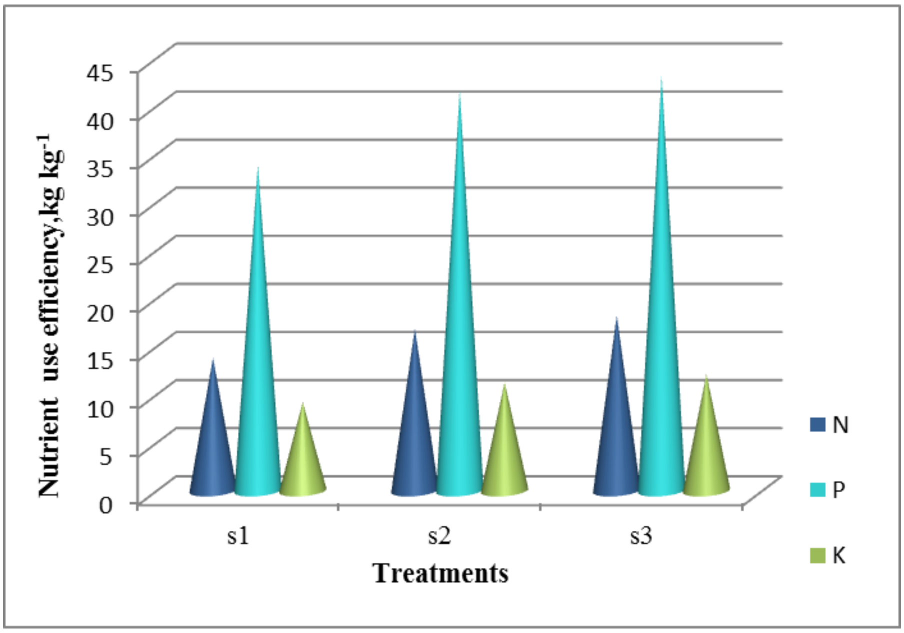


Fig. 11 b. Nutrient use efficiency as influenced by foliar nutrition (II Year)

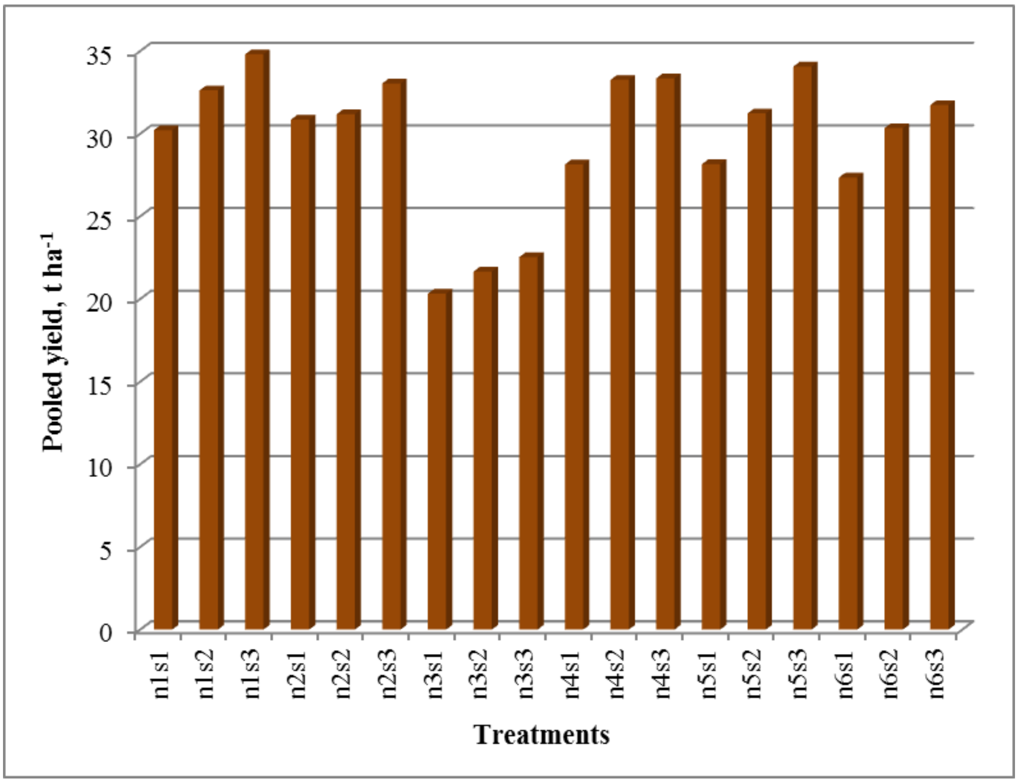


Fig. 12. Pooled yield as influenced by combined effect of nutrient sources, irrigation and foliar nutrition

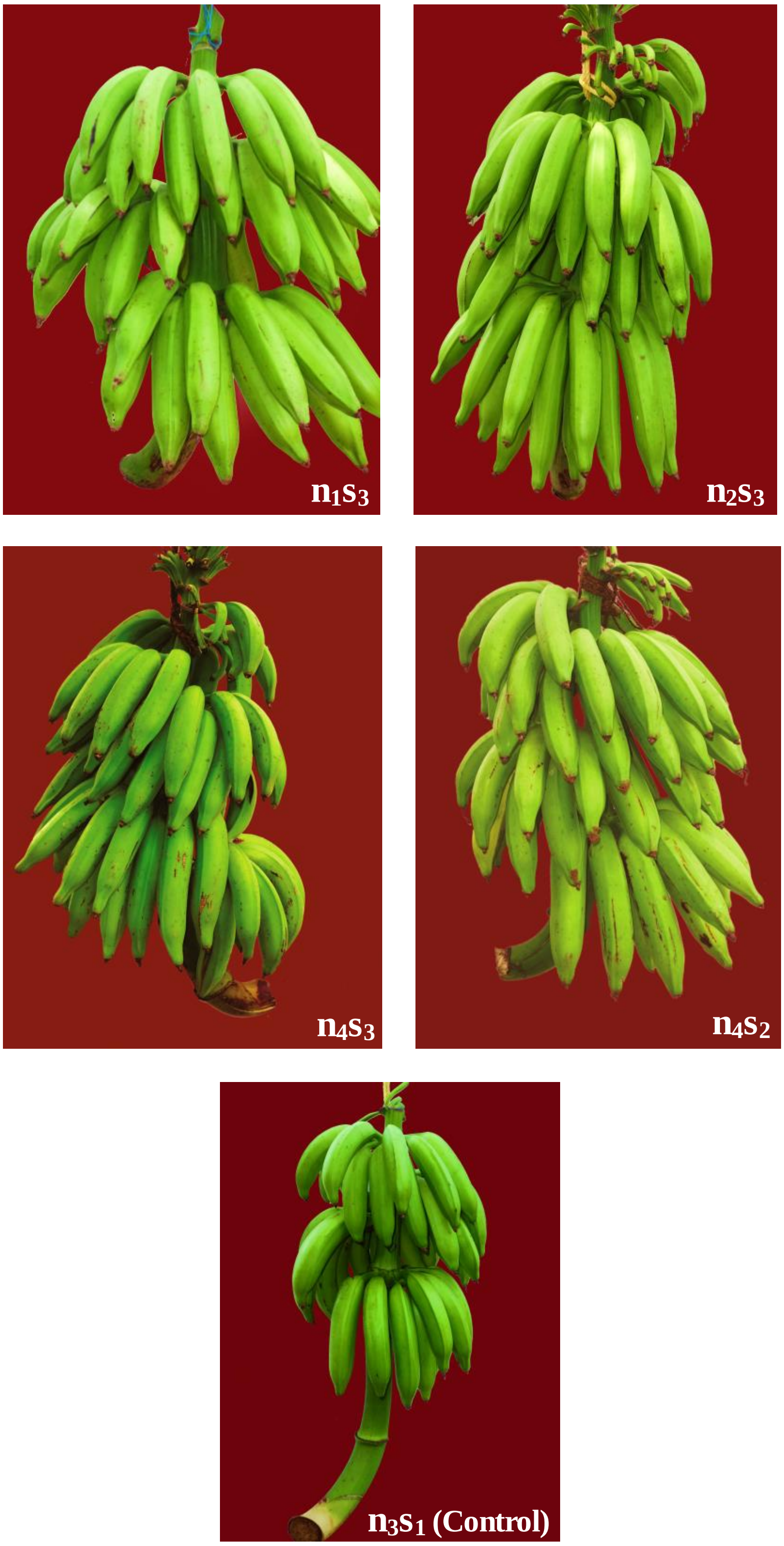


Plate 9. Comparison of bunches (best treatments vs control)

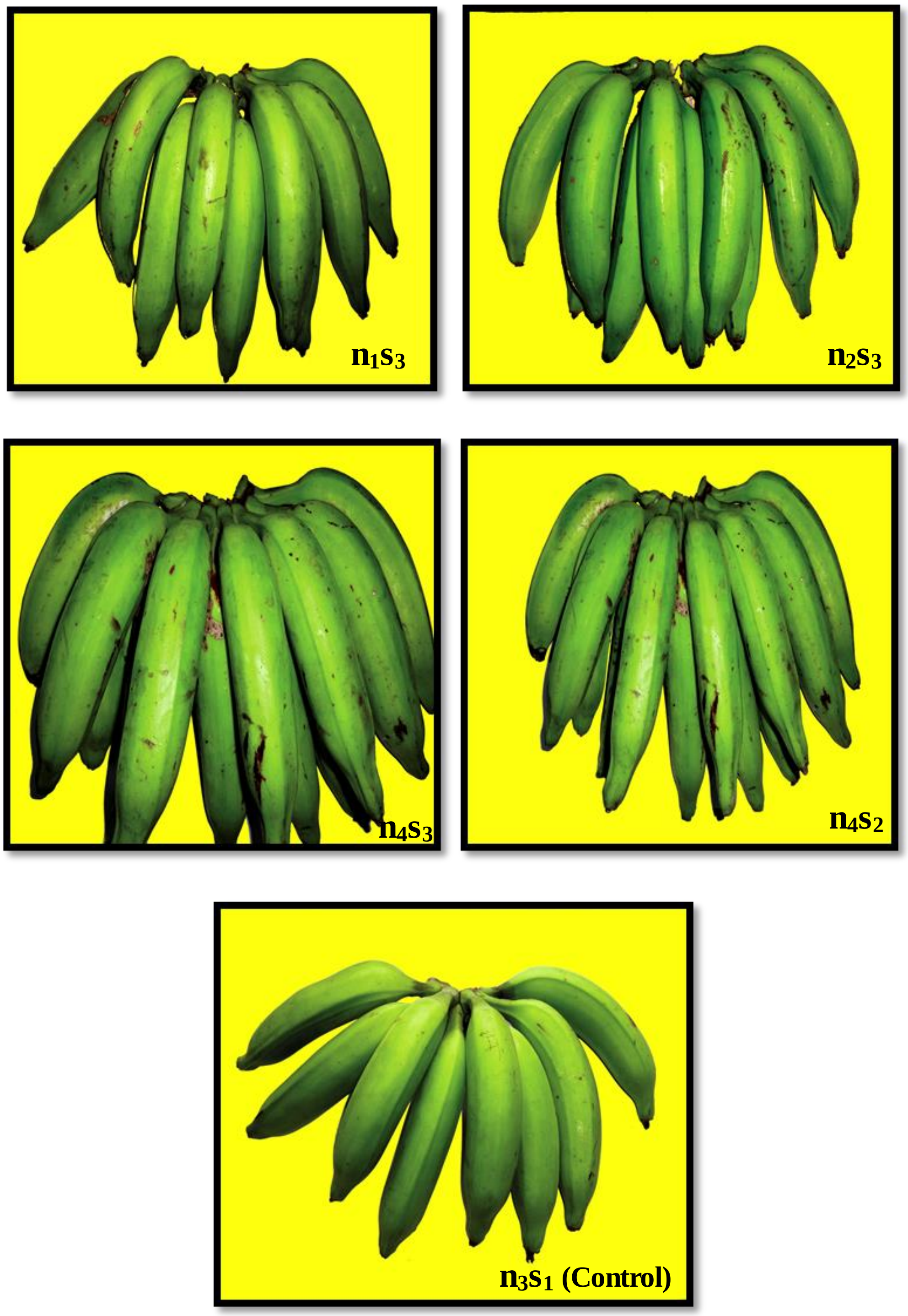


Plate 10. Comparison of hand characteristics

better performance of crop in soil application of nutrients with drip irrigation along with bunch spray of SOP. The improvement in finger characteristics especially weight of D finger brought about by bunch spray of SOP had direct reflection on yield of above combinations. Moreover, the nutrient uptake by fruits and leaves in general were significantly increased by foliar nutrition of 19-19-19 or bunch spray with SOP in combination with n_1, n_2, n_4 and n_5. The enhanced dry matter accumulation by way of fertigation and foliar nutrition (Tables 15 and 40) resulted in higher uptake of nutrients in leaves and fruits. Nutrient use efficiency of N and K were also found to be high in the combinations of n_4 and n_5 with foliar application of 19-19-19 or bunch spray with SOP. All these clearly indicate that with improved land management practices, soil application of full dose of P as rock phosphate with fertigation of 60 per cent recommended dose of N and K as urea and MOP (n_4) or fertigation of 60 per cent RDN as 10-10-10, urea and SOP (n_5) along with foliar application of 19-19-19 or bunch spray of SOP registered same productivity with soil application of full dose of nutrients with foliar nutrition.

5.3 Water Requirement, Water Use Efficiency and Water Productivity as Influenced by Nutrient Application, Irrigation and Foliar Nutrition

Drip irrigation always results in reduced water requirement compared to basin irrigation. The results of this study also indicates considerable saving in irrigation water by drip irrigation (Fig. 13). In the first year of study, water requirement was computed to be 1387 mm in basin irrigation and 782.82 mm in drip irrigation. Whereas in the second year, water requirement was 2151.75 mm and 1596.20 mm respectively *i.e.*, 44 and 26 per cent reduction in water requirement in drip irrigation compared to basin irrigation in both the years respectively. This year wise difference was due to the variation in the total quantity of rainfall and number of rainy days received during the crop period. Though 105 rainy days were obtained during cropping period in first year, it was increased to 132 days in second year. Irrigation requirement was computed to be 845 mm and 753.75 mm in first year and second year, respectively in basin

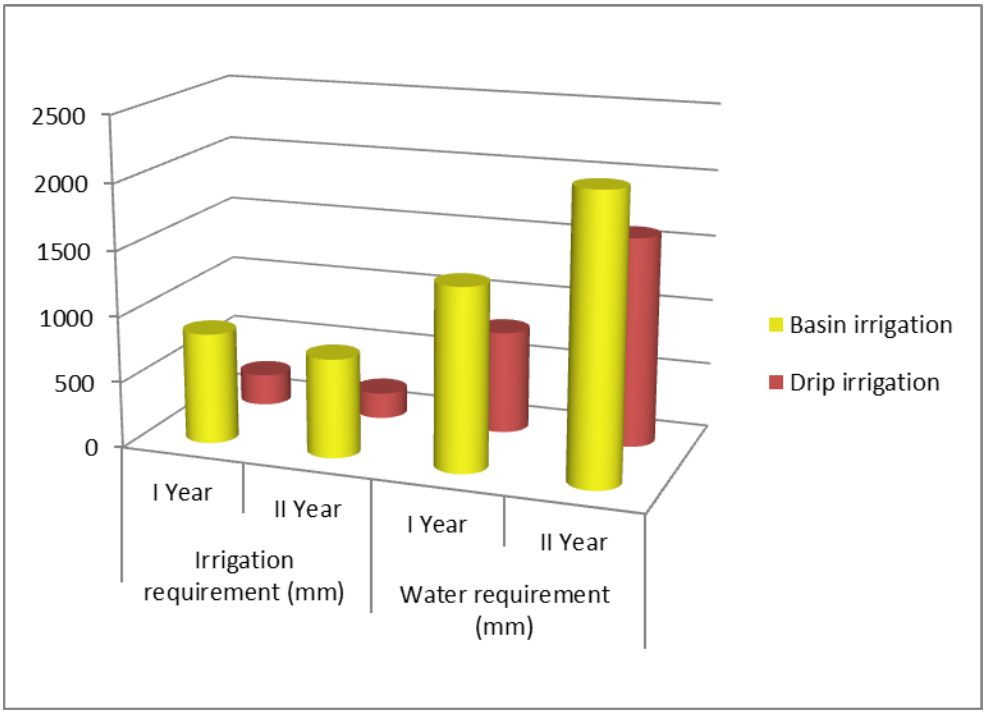


Fig. 13. Irrigation requirement and water requirement as influenced by methods of irrigation

irrigation. Whereas, in drip irrigation treatments, it was 240.82 mm and 198.20 mm in both the years, respectively. It was also noticed that compared to basin irrigation, drip irrigation treatments resulted in a saving of 73 per cent in irrigation water. Sivanappan (2004) and Rekha and Mahavishnan (2008) also observed water saving to the tune of 40 to70 per cent by drip irrigation.

Drip irrigation also had significant influence on water productivity and water use efficiency (Fig. 14 a and Fig. 14 b). Drip irrigation with soil application of full dose of nutrients registered the highest water productivity in both years and was on par with the fertigation treatment, n_4. This comparable high water productivity in drip fertigation was due to the increased biomass production achieved with reduced water as water productivity is an indication of the total dry matter production per unit quantity of water. Water use efficiency was also significantly increased in all drip irrigation treatments except n_3 (drip irrigation alone without any fertilizer). Among the drip irrigation treatments, n_4 registered the highest water use efficiency which was on par with drip irrigation with soil application of full dose of nutrients, n_5 and n_6 in the second year. The results showed 68 and 28 per cent improvement in water use efficiency by drip fertigation treatments with 60 per cent RDN over basin method of irrigation with full dose of nutrients in first year and second year, respectively. The increased water use efficiency under drip fertigation system was mainly due to the better performance of the crop as evident from increased yield. Effective utilization of water and nutrients applied at regular intervals by fertigation throughout the crop period to meet the crop demand enhanced the yield and water use efficiency (Bangar and Chaudhari, 2004). Kumar *et al.* (2009) also noticed an increase in water use efficiency by 25 per cent in drip fertigated plots in comparison to check basin method of irrigation.

Both water productivity and water use efficiency were significantly improved by bunch spray with SOP @ 2 per cent. Significant improvement in dry matter production and economic yield realized by this treatment have resulted in increased water productivity and water use efficiency. Bunch spray of SOP

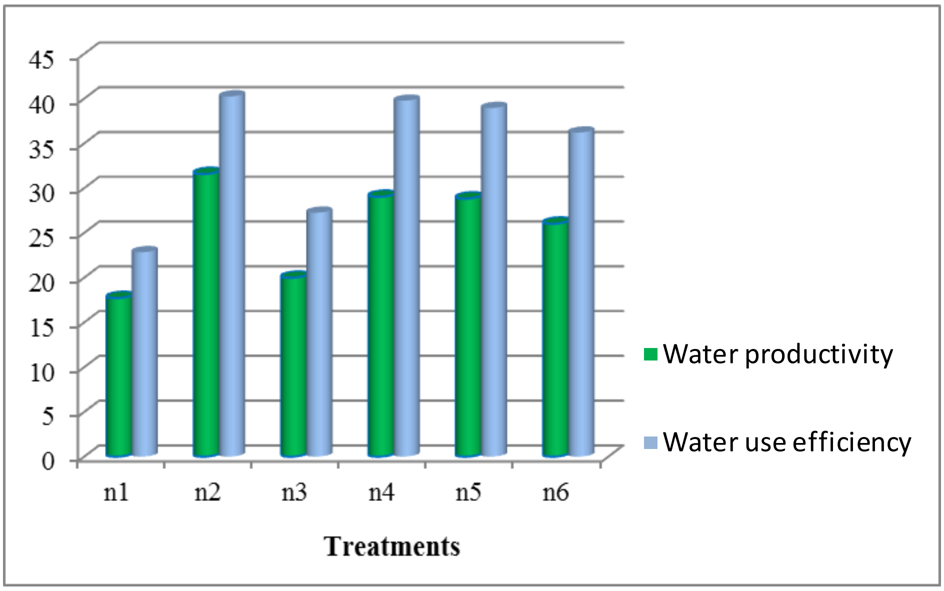


Fig. 14 a. Water productivity and water use efficiency as influenced by nutrient sources and irrigation (I Year)

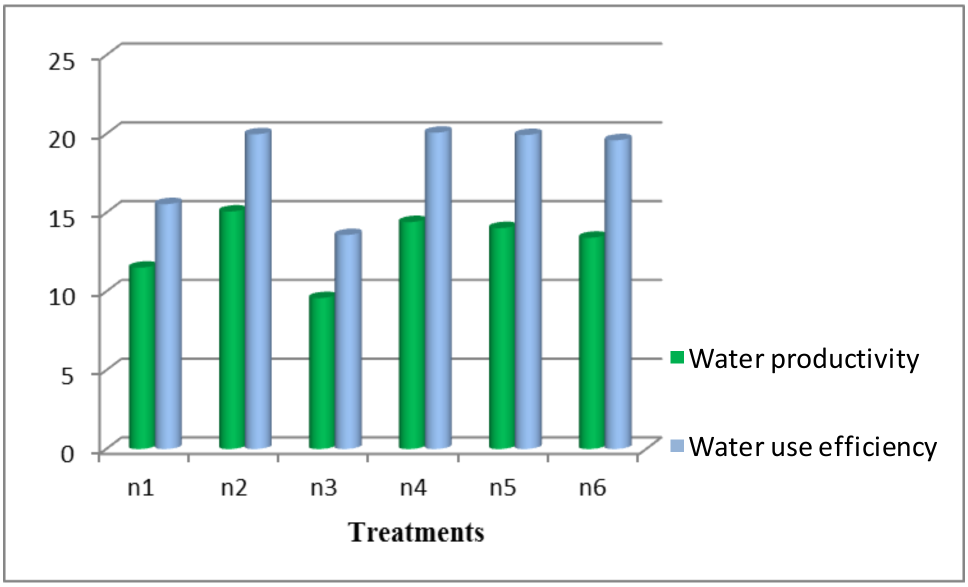


Fig. 14 b. Water productivity and water use efficiency as influenced by nutrient sources and irrigation (II Year) resulted in 10 and 15 per cent improvement in water productivity and water use efficiency over control.

Among the treatment combinations, n_2, n_4 and n_5 along with foliar application of 19-19-19 (s_2) or bunch spray with SOP (s_3) significantly increased water use efficiency in both the years. While in water productivity, significance was observed only in second year and the combinations of n_2, n_4, and n_5 with s_2 and s_3 were found superior. Increased economic yield and total biomass production obtained in these combinations due to the reasons described earlier have resulted in enhanced water use efficiency and water productivity in banana.

5.4 Economics as Influenced by Nutrient Application, Irrigation and Foliar Nutrition

The different nutrient sources and irrigation caused significant variation in gross income, net income and B : C ratio (Fig. 15). Compared to control (n_3- drip alone without fertilizer) all the other treatments except n_6 were on par and registered higher returns. High yield obtained in these treatments have contributed to increased gross income. Though the yield variation between n_4 and n_5 was not significant, n_5 was found inferior to n_4 on net income and B : C ratio. The high cost of liquid fertilizer (38 times more than urea) and SOP (3 times more than MOP) enhanced the cost of cultivation in n_5. The low economic viability of the liquid fertilizers was supported by the finding of Mahmoud (2013). Fertigation of 60 per cent N and K as urea and MOP along with full dose of P as soil application with rock phosphate (n_4) was the most economically viable treatment with a B : C ratio of 5.07. Drip fertigation with considerable saving in fertilizer and labour resulted in high net income. Moreover, the cost of drip installation for drip irrigation treatments was equally distributed over eight years by following amortization. All these factors favourably enhanced the B : C ratio in n_4. Kavino *et al.* (2004) also obtained a higher B : C ratio of 3.32 and 2.65 in banana by fertigation using conventional fertilizers. Asokaraja (2004) registered

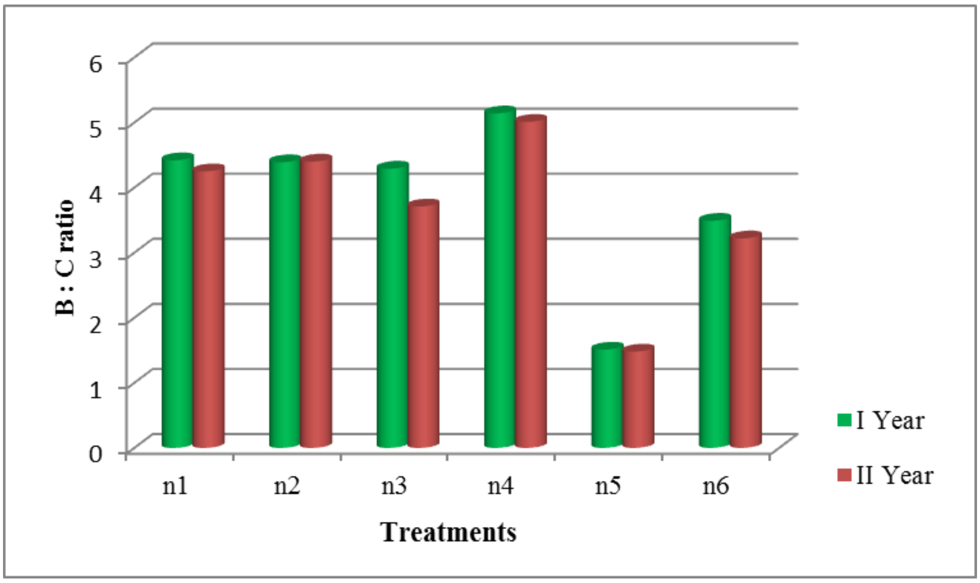


Fig. 15. B : C ratio as influenced by nutrient sources and irrigation

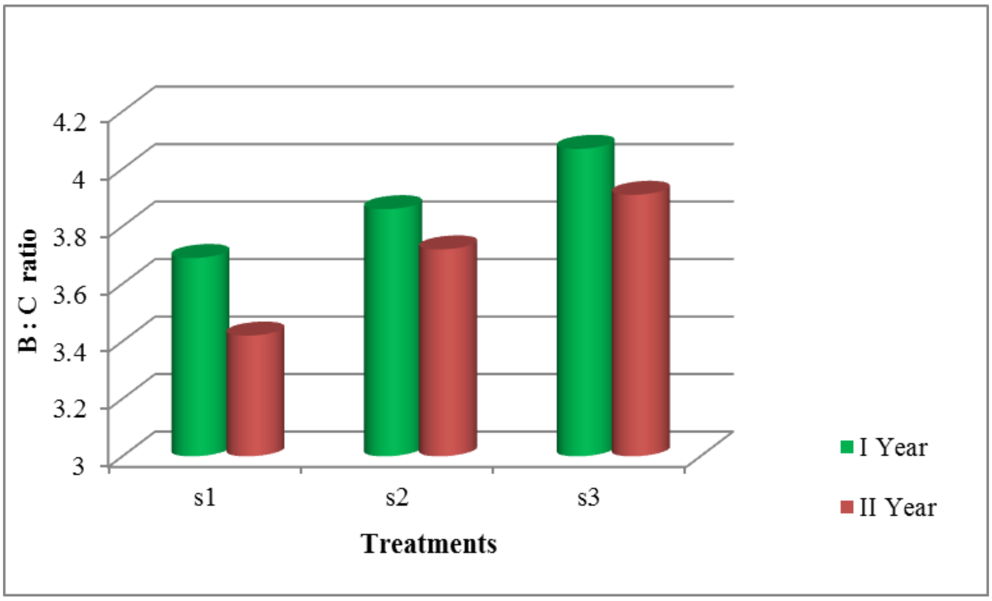


Fig. 16. B : C ratio as influenced by foliar nutrition

high extra income per extra rupee invested (4.67 and 4.75 for first crop and second crop, respectively) with drip fertigation at lower dose of 75 per cent RDN.

Bunch spray with SOP @ 2 per cent significantly increased gross income, net income and B : C ratio during first year. In the second year, foliar application of 19-19-19 @ 0.50 per cent was observed to be on par with bunch spray of SOP on economics (Fig. 16). Improvement in yield attributes and yield from these resulted in increased economic returns. Kumar *et al.* (2008) also obtained a B : C ratio of 4.19 by bunch spray with SOP (1.50 per cent) compared to water spray (3.37) in banana cv. Robusta.

The treatment combinations had significant influence on economics only in the first year (Fig. 17). The combinations of n_1, n_2, n_4 and n_5 with foliar application of 19-19-19 or bunch spray with SOP significantly increased gross income. In net income, combinations of n_1, n_2, n_4 with s_2 and s_3 were found beneficial. However, an average B : C ratio of 5.36 and 5.16 were registered by n_4s_3 and n_4s_2, respectively. High yield coupled with saving in fertilizer and labour resulted in higher B : C ratio in these combinations.

5.5 Sustainability as Influenced by Nutrient Sources and Methods of Application and Irrigation

The effect of nutrient sources and methods of nutrient application along with irrigation on sustainability was assessed by evaluating the nutrient status in index leaf (at 4 MAP) and soil after the experiment. Index leaf analysis of major, secondary and micronutrients in both the years revealed that fertigation resulted in efficient absorption and utilization of nutrients. Among the fertigation treatments, n_4 was found to be on par with soil application of full dose of nutrients with basin and drip irrigation. The result also indicated that fertigation with 60 per cent RDN was sufficient to bring the nutrient content in the index leaf above critical level as observed in soil application of full dose of nutrients. All the treatments except n_3 (drip irrigation alone without any fertilizer) have attained N and K values above the critical level of 2.60 and 3.00 per cent, respectively. Even

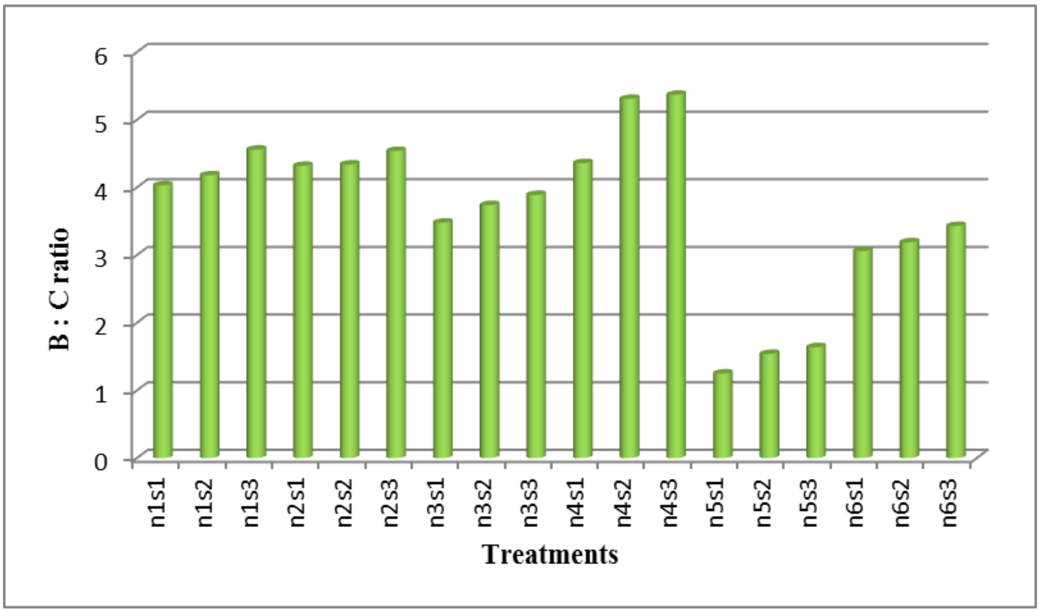


Fig. 17. B : C ratio as influenced by combined effect of nutrient sources, irrigation and foliar nutrition

though there was a slight reduction in P content in index leaf during first year, it was more than the critical level of 0.20 per cent in the second year. Attainment of this optimum nutrient status was due to the increased nutrient use efficiency. Mahalakshmi (2000) also noticed an increased NPK status in leaves of fertigated banana.

Foliar application of 19-19-19 @ 0.50 per cent at 2 and 4 MAP also increased the N and K content in the index leaf, taken at 4 MAP. The N and K status in index leaf were increased above the critical level. Enhanced availability of nutrients supplied by foliar spray of 19-19-19 (2 and 4 MAP) had a direct influence in improving the nutrient content in index leaf.

Soil analysis after two years of experimentation revealed that the treatments showed significant influence on the nutrient status of soil. Treatments receiving 100 per cent RDN registered higher nutrient status compared to fertigation of 60 per cent RDN. However, the final soil nutrient status in all treatments fall under the same category *i.e.,* medium for N and K and high for P. N and K content of soil before and after the experiment were in medium range. While the P content registered an increase from medium to high range after two years. Residual effect of P fertilizers might have contributed to this high P status after experimentation. The medium N and K status after two years of experimentation indicated the sustainability of the nutrient management system. Moreover, since soil P is registering a high level after two crops of banana, there is a possibility of exploring the residual effect of P for succeeding crop. In addition, the nutrient contribution from biomass is also significant. On an average, soil application of 100 per cent RDN had a total dry matter production of 24.53 t ha^{-1} accounting to an N, P, K contribution of 231.27, 40.04 and 704.87 kg ha^{-1} respectively from the uneconomic parts (rhizome, pseudostem and leaves). In the fertigation treatments (60 per cent RDN) also, higher dry matter production of 22.10 t ha^{-1} was observed which was having potential to supply 180.00 kg N, 27.87 kg P, 503.97 kg K ha^{-1} from the uneconomic plant parts. This indicates that there is ample scope for adopting proper recycling methods for enriching the soil.

Balance sheet for major nutrients was worked out for the best treatments *viz.* n_1, n_2 and n_4 and presented in Appendix XI. The results revealed that the actual soil nutrient status after two years of experimentation was lower than the computed value. In plots receiving soil application of full dose of nutrients as per POP with basin and drip irrigation (n_1 and n_2), the difference between the actual and computed values was more. Whereas in the best fertigation treatment (n_4), the difference between computed and actual values was less. This clearly indicates that drip fertigation practice was very effective in reducing the losses of nutrients by way of leaching. Compared to soil application of full dose of nutrients, drip fertigation of 60 per cent of recommended dose was more beneficial in maintaining the fertility status of soil and sustainability of the system.

SUMMARY

6. SUMMARY

An investigation was carried out at the College of Agriculture, Vellayani to study the effect of precision farming practices on the growth and yield of banana cv. Nendran. The experiment was undertaken in two parts. In part I, standardization of nutrient sources for fertigation was carried out in factorial CRD replicated thrice. The treatments included six nutrient sources [urea, Muriate of Potash (MOP), 10-10-10, 13-0-45, SOP (Sulphate of Potash) and Diammonium Phosphate (DAP)] and four concentrations (0.25, 0.50, 0.75 and 1.00 per cent). In part II, nutrient scheduling was standardized in split plot design with six main plots and three sub-plots treatments in three replications. The main plot treatments included irrigation (drip and basin irrigation) and nutrient management practices- soil application (full dose of RDN) and drip fertigation (60 per cent RDN). Sub-plot treatments consisted of foliar application with 19-19-19, bunch spray with Sulphate of Potash (SOP) and water spray. As a preliminary requirement for precision farming, land management practices like deep ploughing to a depth of 50 cm and raised beds of 30 cm height with 3 m width were uniformly followed for all treatments.

The salient results of the study are summarized in this chapter.

The preliminary trial in part I with different nutrient sources (urea, MOP, 10-10-10, DAP, SOP, 13-0-45) at four different concentrations (0.25, 0.50, 0.75 and 1.00 per cent) showed that the pH values registered by the sources ranged from 5.76 to 8.28 which was within the safe pH limit for banana. Though pH increased with increase in concentrations, it did not cause any phytotoxicity in banana up to one per cent concentration.

Growth parameters like plant height, girth, number of functional leaves plant^{-1}, functional leaf area and LAI indicated a varying response under different nutrient sources at different growth stages in both the years. Drip fertigation treatments (n_4, n_5 and n_6) with 60 per cent RDN registered growth parameters comparable to full dose of soil application of nutrients with basin and drip irrigation. The highest values of these parameters were registered by foliar application of 19-19-19 fertilizer (0.50 per cent) (s_2) at different growth stages except at 2 MAP (Months After Planting).

Plants under drip fertigation treatments (n_4, n_5 and n_6) took less number of days for bunch emergence compared to soil application of nutrients with basin and drip irrigation. However, foliar nutrition of 19-19-19 @ 0.50 per cent (s_2) and bunch spray of SOP @ 2 per cent (s_3) increased bunch emergence duration compared to water spray (s_1) during second year. In both the years, crop duration was significantly influenced by the treatments. All drip fertigation treatments resulted in an early harvest compared to soil application of full dose of nutrients with drip and basin irrigation in the first year. Whereas in the second year, drip fertigation and POP treatments showed similar effect on duration. In the case of foliar nutrition, bunch spray with SOP @ 2 per cent slightly delayed the harvest during the second year.

More number of suckers were produced in the treatments receiving full dose of recommended nutrients as per POP (Package of Practices). Foliar nutrition with 19-19-19 @ 0.50 per cent also enhanced sucker number.

Soil application of full dose of nutrients with drip and basin irrigation (n_1 and n_2) resulted in significant increase in dry matter accumulation in different plant parts and these treatments were on par with drip fertigation treatments with 60 per cent RDN (n_4 and n_5) on fruit and leaf dry matter production. Bunch spray of SOP @ 2 per cent (s_3) enhanced dry matter accumulation. Improvement in leaf, pseudostem and total dry matter production were also observed by foliar application with 19-19-19 @ 0.50 per cent.

Nitrogen content in index leaf was increased by soil application of fertilizers with drip and basin irrigation (n_1 and n_2). Whereas, the P and K content were significantly improved by fertigation of 60 per cent RDN as urea and MOP and soil application of full dose of P (n_4) and soil application of full dose of nutrients along with basin irrigation (n_1). Though the Ca, Mg and micronutrient content were not influenced by the treatments, S content was significantly enhanced by drip fertigation (n_5 and n_6). The N and K content in index leaf were significantly increased by foliar application with 19-19-19 @ 0.50 per cent.

In both the seasons, yield attributes and yield were significantly influenced by nutrient sources, irrigation and foliar nutrition. Plants under drip fertigation with 60 per cent RDN (n_4 and n_5) registered comparable yield attributes and yield with full dose of RDN applied to soil with basin and drip irrigation. Number of hands was improved by foliar application of 19-19-19 @ 0.50 per cent alone. All other yield attributes were significantly enhanced by foliar application with 19-19-19 (s_2) and bunch spray with SOP (s_3). Bunch spray with SOP @ 2 per cent was found superior to other treatments in producing higher bunch weight. Pooled analysis revealed the superiority of individual effects of n_4 and s_3. It was also observed that soil application of full dose of nutrients with drip and basin irrigation (n_1 and n_2) and drip fertigation treatments (n_5 and n_4) along with bunch spray of SOP or foliar application of 19-19-19 were equally effective in enhancing the yield.

Pest and disease incidence did not show any variation due to different treatments.

All quality attributes except TSS and ascorbic acid content were significantly influenced by the treatments in both the seasons. Though the treatments showed a varying response in quality attributes, it was evident that fertigation with straight fertilizers (urea and MOP) did not adversely affect the quality compared to new generation water soluble fertilizers. Foliar application of 19-19-19 @ 0.50 per cent and bunch spray with SOP @ 2 per cent increased TSS, ascorbic acid content and non-reducing sugar. Bunch spray with SOP @ 2 per cent significantly increased total sugar, reducing sugar and sugar acid ratio. Acidity of fruits was the lowest in the treatment receiving full dose of nutrients along with basin irrigation. All the treatments except control (drip irrigation alone without fertilizer) showed higher pulp peel ratio in first year. Whereas in the second year, POP treatments (n_1 and n_2) registered the highest values. Bunch spray with SOP @ 2 per cent was found superior in pulp-peel ratio. Different nutrient sources, irrigation and foliar nutrition significantly influenced shelf life in both the years. Fertigation of 60 per cent RDN as urea, 10-10-10, SOP (n_5) and soil application of full dose of nutrients along with drip irrigation (n_2) registered the highest values of shelf life. Bunch spray with SOP @ 2 per cent slightly increased the shelf life of banana fruits.

From this study, water requirement was computed to be 1387 mm in basin irrigation and 782.82 mm in drip irrigation during first year. Whereas in the second year, it was 2151.75 mm and 1596.20 mm, respectively *i.e.*, 44 and 26 per cent reduction in water requirement in drip irrigation compared to basin irrigation in both the years respectively. Irrigation requirement was computed to be 845 mm and 753.75 mm in first year and second year, respectively in basin irrigation. Whereas, for drip irrigation treatments, it was 240.82 mm and 198.20 mm in both the years respectively. Compared to basin irrigation, drip irrigation treatments resulted in a saving of 73 per cent in irrigation water. Water productivity was significantly higher in drip irrigation treatments (n_2 and n_4) compared to basin method of irrigation (n_1). Whereas in water use efficiency, the highest values were recorded by n_2, n_4 and n_5 in first year. In second year, n_4 was found superior to other treatments. Bunch spray with SOP @ 2 per cent also improved these parameters significantly.

Total N, P and K uptake was found to be highest in soil application of full dose of nutrients with drip and basin irrigation. However, N, P and K uptake by fruit and leaf were significantly improved by fertigation treatments (n_4 and n_5). Bunch spray with SOP and foliar application with 19-19-19 were equally effective in enhancing the total uptake of the nutrients.

Drip fertigation treatments (n_4 and n_5) recorded higher N and K use efficiency in both the seasons. Whereas, P use efficiency was found to be high in n_5 during both the years. Agronomic efficiency of nutrients was also significantly higher for drip fertigation treatments (n_4, n_5 and n_6) compared to soil application of nutrients with drip and basin irrigation. N, P and K use efficiency was improved by bunch spray with SOP @ 2 per cent and foliar application of 19-19-19 @ 0.50 per cent. Whereas, agronomic efficiency of all the nutrients were significantly increased by bunch spray with SOP @ 2 per cent alone.

Compared to initial nutrient status, N and K level remained in the 'medium' range after two crops of banana. However, there was a build up of soil P and P level was high after two years.

Microbial population after the experiment was influenced by the treatments. The highest population of bacteria and actinomycetes were observed in the treatment receiving drip irrigation alone without any fertilizer whereas, more fungi count was noticed at n_4 and n_2.

Fertigation with 60 per cent RDN as urea and MOP along with soil application of full dose of P as rock phosphate (n_4) was the most economically viable treatment in terms of net income and B : C ratio. Bunch spray with SOP @ 2 per cent and foliar application of 19-19-19 @ 0.50 per cent (s_2) were equally effective in enhancing the B : C ratio. An average B : C ratio of 5.36 and 5.16 was obtained by n_4s_3 and n_4s_2 respectively after two years of experimentation.

From the results of the study, an economic nutrient schedule for precision farming in banana can be summarized as:-

- basal application of organic manure @ 15 kg plant^{-1},
- soil application of rock phosphate @ 325 g plant^{-1} (1 MAP) and @ 250 g plant^{-1} (3 MAP),
- weekly fertigation using urea @ 16.30 g plant^{-1} from 1 to 7 MAP (except 6 MAP) and MOP @ 16.25 g plant^{-1} from 1 to 5 MAP and @ 31.25 g plant^{-1} (7 MAP)

- bunch spray of 2 per cent SOP (after complete bunch emergence and three weeks after first application) or foliar spray of 0.50 per cent 19-19-19 (2, 4 and 6 MAP).

This schedule is effective when followed along with better land management practices of deep ploughing (50 cm deep) and raised beds (30 cm height).

Future line of work

- The possibility of yield improvement by enhancing the N and K levels through drip fertigation needs to be explored.
- As soil P showed an increasing trend after two years of experimentation, modification in P management for succeeding crop needs investigation.
- Use of enriched organic sprays / fortified sprays for improving bunch characteristics needs to be undertaken.
- The feasibility of mulching or intercropping in precision farming as a means for weed management needs further studies.

REFERENCES

7. REFERENCES

[Anonymous]. 2011. Annual reports of AICRP on water management. Available: http://www.dwm.res.in/pdf/AICRP_WM_2009_10.pdf [12 Aug. 2012].

[Anonymous]. 2012. Young, educated and proud to be farmers. *The Hindu*, 8 May 2012, p.13.

Abdel-Khalik, A., Iman, A., Morsi, M.E., and El-shewy, A.A. 2009. Effect of nitrogen and potassium fertilization on banana cv. Williams on growth and productivity. *Egypt. J. Appl. Sci.* 24 (5): 853-867.

Ahmed, A., Abraham, G., Gandotra, N., Abrol, Y.P., and Abdin, M.Z. 1998. Interactive effect of nitrogen and sulphur on growth and yield of rapeseed–mustard (*Brassica juncea* L. and *Brassica compestris* L.) genotyoes. *J. Agron. Crop Sci.* 181: 193-197.

Amilton, G., Zanini, J.R., Natale, W., and Pavani, L.C. 2004. Frequency of fertigation with nitrogen and potassium applied by microsprinkler system on prata-ana banana plant. *Engenharia Agrícola* 24: 80-88.

Anitha, N. 2000. Bioecology and integrated management of banana pseudostem weevil (*Odoiporus longicollis* Oliv). Ph.D. thesis, Kerala Agricultural University, Thrissur, 178p.

Arscott, T.G. 1970. Nitrogen fertilization of banana through a sprinkler irrigation system. *Trop. Agric.* 7 (1): 17-22.

Asokaraja, N. 2004. Enhanced water use efficiency under drip fertigation in Nendran banana [on-line]. Available: http:// issuu. com /indiawaterweek. in /docs /s1-ashok_raja [13 Dec. 2013].

Asokaraja, N. 2011. Effect of drip irrigation and fertigation levels on the yield and quality of Muscat grapes (*Vitis vinifera*). *Proceedings of the Eighth*

International Micro Irrigation Congress, 15-23 October 2011, Tehran, Iran, pp.305-322.

Bacon, R.E. and Davey, B.G. 1982. Nutrient availability under trickle irrigation: Mineral nitrogen. *Soil Sci. Soc. Am. J.* 46: 987-993.

Bakry, K.A. 2002. Response of Williams banana plants to potassium fertigation: gibberellin spray and bunch sleeving with blue polythene grown in drip irrigated sandy soil. *Ann. Agric. Sci.* 40 (2): 1259-1274.

Bangar, A.R. and Chaudhari, B.C. 2004. Nutrient mobility in soil, uptake, quality and yield of sugarcane as influenced by drip fertigation in medium vertisols. *J. Indian Soc. Soil Sci.* 52 (2): 164-171.

Barrera, J.L., Cayón, G.S., and Robles, J. 2009. Influencia de la exposición de las hojas y el epicarpio de frutos sobre el desarrollo y calidad del racimo de plátano Hartón (Musa AAB Simmonds). *Agronomía Colombiana* 27(1): 73-79. In (French).

Baskar, B.S. 2002. Effect of planting techniques and fertigation on growth, yield and quality of banana. *Indian Agric. J. Agron*. 48: 235-237.

Bhalerao, V.P., Pujari, C.V., Jagdhani, A.D., and Mendhe, A.R. 2009. Performance of banana cv. Grand Naine under nitrogen and potassium fertigation. *An Asian J. Soil Sci*. 4 (2): 220-224.

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

Black, C.A. 1965. *Methods of Soil Analysis.* American Society of Agronomy, Winconsin, USA, 128p.

Broadley, R., Rigden, P., Cheay-Prove, P., and Daniells, J. 2004. *Subtropical Banana Grower's Handbook*. Department of Primary Industries, Queensland, 206p.

Chaurasia, S.N.S., Singh, K.P., and Rai, M. 2005. Effect of foliar application of water soluble fertilizers on growth, yield and quality of tomato (*Lycopersicon esculentum* L.). *Sri Lankan J. Agric. Sci.* 42: 66-70.

Chesnin, L. and Yien, C.H. 1950. Turbidimetric determination of available sulfates. *Soil Sci. Soc. Amer. Proc.* 15: 149-151.

Craswell, E.T. and Godwin, D.C. 1984. The efficiency of nitrogen fertilizer applied to cereals in different climates. *Adv. Plant Nutr.* 1: 1-55.

Dastane, N.G. 1967. *A Practical Manual for Water Use Research*. Navbhar Publications, Poona, 105p.

Dastane, N.G. 1974. *Effective Rainfall in Irrigated Agriculture*. Land and water development division, FAO, Rome, 25p.

Dinesh, K., Pandey, V., and Vishal, N. 2012. Growth, yield and quality of vegetable banana Monthan (Banthal-ABB) in relation to NPK fertigation. *Indian J. Hort.* 69(4): 467- 471.

Dixon, R.C. 2003. Foliar fertilization improves nutrient use efficiency. *Fluid J.*11: 22-23.

El-Razek, A.E., Treutter, D., Saleh, M.M.S., El-Shammaa, M., Fouad, A.A., and Abdel-Hamid, N. 2011. Effect of nitrogen and potassium fertilization on productivity and fruit quality of 'crimson seedless' grape. *Agric. Biol. J. N. Am.* 2 (2): 330-340.

FAI, 1995. Importance of fertigation in Indian agriculture. *Fert. News.* 40: 9-10.

FAO, 1998. Crop evapotranspiration-Guidelines for computing crop water requirements. In: *Irrigation and Drainage,* p.103.

Feigin, A., Letey, L., and Jarrell, W.M. 1982. Nitrogen utilization efficiency by drip irrigated celery receiving pre-plant or water applied N fertilizer. *Agron. J.* 74: 978-983.

FIB (Farm Information Bureau). 2014. *Farm Guide 2014*. Farm Information Bureau, Kerala, 213p.

Gates, C.T. 1968. Water deficits and growth of herbaceous plants. In: Kozlowski, T.T. (ed.), *Water Deficits and Plant Growth*. Academic Press, New York, pp.135-190.

Gonzales-Altozano, P. and Castel, J.R. 1999. Regulated deficit irrigation in 'Clementina De Nules' citrus trees. I. Yield and fruit quality effects. *J. Hort. Sci. Biotechnol.* 74: 706–713.

Goodroad, L.L. and Jellum, M.D. 1988. Effect of nitrogen fertilizer rate and soil pH on nitrogen use efficiency in corn. *Plant and Soil* 106: 85-89.

Goovaerts, P. 2000. Geo statistical approaches for incorporating elevation into the spatial interpolation of rainfall. *J. Hydrol.* 228: 113-129.

Gottriech, M., Bradu, D., and Halevy, Y. 1964. A simple method for determining average banana fruit weight. *Katavani* 14:161-162.

Gupta, R.P. and Dakshinamoorthi, C. 1980. *Procedures of Physical Analysis of Soil and Collection of Agro Meteorological Data*. Indian Agricultural Research Institute, New Delhi, 280p.

Gupta, U.C. 1967. A simplified method for determining hot water soluble boron in podzol soils. *Soil Sci.* 103: 424-428.

Hasan, M., Singh, B., Singh, M.C., Singh, A.K., Kaore, S., Tarunendu, V., Sabir, N., and Tomar, B.S. 2010. *Fertigation Scheduling for Horticultural Crops*. IARI and IIFCO, New Delhi, 44p.

Havlin, J.L., Beaton, J.D., Tisdale, S.L., and Nelson, W.L. 2013. *Soil Fertility and Fertilizers* (8^{th} Ed.). Prentice Hall, Delhi, India, 528p.

Haynes, R.J. 1985. Principles of fertilizer use for trickle irrigation crops. *Fert. Res.* 6: 235-225.

Haynes, R.J. 1988. Comparison of fertigation with broadcast application of urea N on levels of available soil nutrients and yield of trickle irrigated peppers. *Scientia Horticulturae* 35: 189-198.

Hedge, D.M. and Srinivas, K. 1991. Growth, yield nutrient uptake and water use of banana crops under drip and basin irrigation with N and K fertilization. *Trop. Agric.* 86 (4): 331-334.

Hummel, I., Pantin, F., and Sulpice, R. 2010. Arabidopsis plants acclimate to water deficit at low cost through changes of carbon usage: an integrated perspective using growth, metabolite, enzyme, and gene expression analysis. *Plant Physiol.* 154: 357–372.

Jackson, M.L. 1973. *Soil Chemical Analysis* (2^{nd} Ed.). Prentice Hall of India, New Delhi, 498p.

Jifon, J.L. and Lester, G.E. 2011. Effects of foliar potassium fertilization on muskmelon fruit quality and yield. *Better Crops* 95: 26-28.

Kadam, J.R., Dukre, M.V., and Firake, N.N. 1993. Effect of N application through drip irrigation on N saving and yield of okra. *J. Water Manage*. 1: 53-54.

Kafkafi, U. and Yosef, B.B. 1980. Trickle irrigation and fertilization of tomatoes in calcareous soils. *Agron. J.* 72: 893-897.

KAU (Kerala Agricultural University). 1997. *Annual Report 1996-97*. Directorate of Research, Kerala Agricultural University, Thrissur, 42p.

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

Kavino, M., Kumar, N., Soorianathasundaram, K., and Jeyakumar, P. 2004. Effect of fertigation on the growth and development of first ratoon crop of banana cv. Robusta (AAA) under high density planting system. *Indian J. Hort*. 61: 39-41.

Kijne, J.W., Barker, R., and Molden, D.J. 2003. *Water Productivity in Agriculture: Limits and Opportunities for Improvement*. CABI, Wallingford, U.K., 352p.

Kuepper, G. 2003. Foliar fertilization [online]. Available: http://www.attra. org/attra- pub/foliar.html [4 June 2013].

Kumar, A., Kumar, A., Singh, H.K., Kumari, N., and Kumar, P. 2009. Effect of fertigation on banana biometric characteristics and fertilizer use efficiency. *J. Agric. Eng.* 46: 27-31.

Kumar, N. and Jeyakumar, P. 2002. Influence of micronutrients on growth and yield of banana cv. Robusta (AAA). *Dev. Plant Soil Sci.* 92: 354-355.

Kumar, R.A. and Kumar, N. 2007. Sulfate of Potash foliar spray effects on yield, quality and post-harvest life of banana. *Better Crops* 91: 22-24.

Kumar, R.A., Kumar, N., and Jeyakumar, P. 2008. Effect of post-shooting spray of Sulphate of Potash (SOP) on yield and quality of banana cv. Robusta (AAA- cavendish). *Res. J. Agric. Biol. Sci.* 4 (6): 655-659.

Lahav, E. and Turner, D. 1992. Fertilizacion del bananopararendimentos altos. In: Lopez, A. and Espinosa, J. (eds), *Manual on the Nutrition and Fertilization of Banana*. Potash and Phosphate Institute of Canada, p.54.

Lindsay, W.L. and Norwell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.* 42: 421-428.

Lopez, A. and Espinosa, J. 2000. *Manual on the Nutrition and Fertilization of Banana*. Potash and Phosphate Institute of Canada, 54p.

Mahalakshmi, M. 2000. Water and fertigation management studies in banana cv. Robusta (AAA) under normal planting and high density planting systems. Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, 304p.

Mahalakshmi, M., Kumar, N., Jayakumar, P., and Soorianathasundaram, K. 2001. Fertigation studies in banana under high density planting system. *S. Indian Hort*. 49: 86-91.

Mahmoud, H.H. 2013. Effect of different levels of planting distances, irrigation and fertigation on quality characters of main and ratoon banana crop cv. Grand Naine. *Global J. Plant Ecophysiol.* 3(2): 110-114.

Malakouti, A. 2004. The Iranian experiences in fertigation and use of potash fertilizers. *Proceedings of the Regional Workshop on Potassium and Fertigation Development in West Asia and North Africa*, 24-28 November 2004, Morocco, p.11.

Martin, J.D. 1950. Use of acid Rose Bengal and Streptomycin in the plate method for estimating soil fungi. *Soil Sci*. 69: 215-233.

Martins, S. and Novias, A. 2011. Irrigation and potassium fertilization by fertigation in banana 'Willians': production and fruit quality. *Rev. Bras* .33 (1): 743-751.

Mengel, K. and Kirkby, E.A. 1987. *Principles of Plant Nutrition*. International Potash Institute, Bern, pp.436-437.

Michael, A.M. 1992. *Irrigation-Theory and Practice*. Vikas Publishing House, New Delhi, pp.662-681.

Murray, D.B. 1960. Shade and fertilizer relations in banana. *Trop. Agric.* 38: 123-132.

NCPAH INDIA [National Committee on Plasticulture Applications in Horticulture India]. 2012. NCPAH INDIA homepage [online]. Available: http://www.ncpahindia.com [12 August 2012].

NHB [National Horticulture Board]. 2013. NHB homepage [online]. Available: http://www.nhb.gov.in [12 July 2014].

Oosterhuis, D. 2009. Foliar fertilization: mechanisms and magnitude of nutrient uptake. *Proceedings on Fluid Fertilizer Foundation*, 6-9 February 2009, Arizona pp.15-17.

Or, D. and Coelho, F.E. 1996. Soil water dynamics under drip irrigation: transient flow and uptake models. *Trans. ASAE*. 39: 2017-2025.

Pan, N., Shen, H., Wu, D.M., Deng, L.S., Tu, P.R., Gan, H.H., and Liang, Y.C. 2011. Mechanism of improved phosphate uptake efficiency in banana seedlings on acidic soils using fertigation. *Agric. Water Manag*e. 98 (4): 632-638.

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers* (4^{th} Ed.). Indian Council of Agricultural Research, New Delhi, 347p.

Parikh, M.M., Savani, N.G., Shrivastava, P.K., Holer, G.H., Shah, G.B., and Raman, S. 1994. Nitrogen economy in banana through fertigation. *J. Water Manage*. 2: 10-13.

Patel, A.R., Saravaiya, S.N., Patel, A.N., Desai, K.D., Patel, N.M., and Patel, J.B. 2010. Effect of micronutrients on yield and fruit quality of banana (*Musa paradisiaca* L.) cv. Basrai under pair row planting method. *The Asian J. Hort*. 5 (1): 245-248.

Patel, C.B. and Tandel, Y.N. 2013. Nitrogen management in banana cv. Basrai through drip under paired row system. *Global J. Sci. Frontier Res*.13 (8): 38-44.

Pawar, D.D. and Dingre, S.K. 2013. Influence of fertigation scheduling through drip on growth and yield of banana in western Maharashtra. *Indian J. Hort*. 70 (2): 200-205.

Pawar, D.D., Baskar, B.S., Bangar, A.R., Bhoi, P.G., and Shinde, S.H. 2000. Effects of water soluble fertilizers through drip and planting techniques on growth, yield and quality of banana. *Proceedings of the International Conference on Micro and Sprinkler Irrigation Systems*, 8-10 Feb 2000, Jain Irrigation Hills, Jalgaon, Maharashtra, pp.515 -519.

Piper, C.S. 1967. *Soil and Plant Analysis.* Hans Publication, Bombay, 368p.

Prabhu, M.J. 2006. Drip fertigation boosts yield in banana cultivation. *The Hindu,* 26 Oct. 2006, p.15.

Ramachandrappa, B.K., Nanjappa, H.V., Soumya, T.M., and Mudalagiriyappa, D. 2010. Effect of fertigation with sources and levels of fertilizer on yield, quality and use efficiency of water and fertilizer in green chilli (*Capsicum annuum*). *Indian J. Dryland Agric. Res. Dev*. 25 (2): 33-39.

Rane, N.B. 2011. Development, scope and future potential of fertigation in India. *Proceedings of National Seminar on Advances in Micro Irrigation*, 15-16 February 2011, NCPAH, Ministry of Agriculture, GOI, pp.44-54.

Ranganna, S. 1977. *Manual on Analysis of Fruit and Vegetable Products*. Tata McGraw Hills Publishing Company Ltd, New Delhi, pp.7-94.

Reddy, B.M.C., Srinivas, K., Padma, P., and Reghupathi, H.B. 2002. Response of Robusta banana to N and K fertigation. *Indian J. Hort*. 59: 342-348.

Reddy, Y.T. and Reddi, S.G.H. 2011. *Principles of Agronomy*. Kalyani Publishers, New Delhi, 527p.

Rekha, K.B. and Mahavishnan, K. 2008. Drip fertigation in vegetable crops with emphasis on okra (*Abelmoschus esculentus*). *Agric. Rev*. 29 (3): 55-60.

Saji, K.V. 1993. Leaf blight of banana and its control. M.Sc. (Ag.) thesis, Kerala Agriculture University, Thrissur, 100p.

Santhanabosu, S., Rajakrishnamurthy, V., Duraisamy, V.K., and Rajagopal, A. 1995. Studies on the strategy of drip irrigation to banana. *Madras Agric. J.* 82 : 44-45.

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

Shirgure, P.S., Ram, L.R.A., and Yadav, R.P. 1999. Effect of nitrogen fertigation on vegetative growth and leaf nitrogen content of acid lime. *Indian J. Soil Conserv*. 27 (1): 45-49.

Shivashankar, K. 1995. Highlights of the project on fertigation studies with water soluble NPK fertilizers in crop production. *Proceedings of the National Workshop on Micro Irrigation and Fertigation*, 21-22 September 1995, Bangalore, pp. 312-317.

Simmonds, N.W. 1982. *Bananas* (2nd Ed.). Tropical Agricultural Series. Longman, New York, 512p.

Sivanappan, K. 2004. Irrigation and rainwater management for improving water use efficiency and production in cotton crop. *Proceedings of International Symposium on Strategies for Sustainable Cotton Production, A Global Vision,* 23-25 November 2004, UAS, Dharwad, Karnataka, pp. 112-117.

Soumya, T.M., Ramachandrappa, B.K., and Nanjappa, H.V. 2009. Effect of fertigation with different sources and levels of fertilizer on growth and yield of tomato. *Mysore J. Agric. Sci.* 43: 80-84.

Srinivas, K. 1998. Standardization of micro irrigation in fruit crops- An overview. *Proceedings of the Workshop on Micro Irrigation and Sprinkler Irrigation Systems*, 28-30 April 1998, Central Board of Irrigation and Power, New Delhi, pp. 127-133.

Srinivas, K., Reddy, B.M.C., Kumar, C.S.S., Gowda, T.S., Raghupati, H.B., and Padma, P. 2001. Growth, yield and nutrient uptake of Robusta banana in relation to N and K fertigation. *Indian J. Hort*. 58 (4): 287-293.

Stover and Simmonds, N.W. 1987. *Bananas* (3rd Ed.). Tropical Agricultural Series. Longman, New York, 468p.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* 25: 259-260.

Suganthi, L. 2002. Fertigation management studies in banana cv. Red Banana (AAA) under different planting densities. M.Sc. (Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore, 230p.

Swietlik, D. and Faust, M. 1984. Foliar nutrition of fruit crops. *Hort. Rev*. 6: 287-355.

Tabatabai, M.A. 1982. Sulfur. In: Miller, R.H. and Keeney, D.R. (eds), *Methods of Soil Analysis* (2nd Ed.). ASA-SSSA, Madison, USA, pp.501-538.

Teixeira, L.A.J., Junqueira, A., Quaggio, A.J., Antonio, J., and Vicari, M.E. 2011. Enhancing nutrient use efficiency in banana due to irrigation and fertigation. *Rev. Bras.* 33(1): 272-278.

Thomas, D. 2001. Water use efficiency in drip fertigated banana Musa (AAB) 'Nendran'. Ph.D. thesis, Kerala Agricultural University, Thrissur, 315p.

Thomas, D. and John, P.S. 2014. Rooting pattern and water use efficiency in drip fertigated banana Musa (AAB) Nendran. In: Prasad, N.B.N., Harikumar, P.S., Joseph, E.J., Gopinath, G., Resmi, T.R., Surendran, U., and Ambili, G.K. (eds), *Integrated Water Resources Management*. Proceedings of an international symposium, 19-21 February 2014, CWRDM, Kozhikode, Kerala, India, pp.971-975.

Thomas, D., Potty, N.N., and John, P.S. 2001. Regulatory management for high productivity, nutrient use efficiency and sustainability. In: Das, M.R. (ed.), *Proceedings of the Thirteenth Kerala Science Congress*, 29-31 January 2001, Kochi. Kerala State Committee on Science, Technology, and Environment, Government of Kerala, pp.305-307.

Timonin, M.J. 1940. The interaction of higher plants and soil microorganisms- microbial population of rhizosphere of seedlings of certain cultivated plants. *Can. J. Res*. 181: 307-317.

Torres-Guy, A. 2011. Efficacy evaluation of Hyfer plus green as foliar fertilizer for banana. Available: http: //www. mjmultilines. com/wpcontent/uploads /2013/02/Hyfer Banana Research. pdf [9 June 2013].

Twyford, I.T. 1967. Banana nutrition: A review of principles and practices. *J. Sci. Food. Agric*. 18: 177-183.

Vadivel, E. 2008. *Tamil Nadu Precision Farming Project*. Tamil Nadu Agricultural University, Coimbatore, 101p.

Varghese, K. 1995. Relative efficiency evaluation of drip and basin methods of irrigation in banana. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 72p.

Venkatarayappa, T., Narasimhan, B., and Venkatesan, C. 1979. Effect of potassium dihydrogen phosphate applied after shooting on the development and composition of banana fruits. *Mysore J. Agric. Sci*. 13 (4): 428-432.

Venugopal, V. 2004. Crop intensification and resource management in banana based cropping system. Ph.D. thesis, Kerala Agricultural University, Thrissur, 243p.

Xiao-ping, Z. 2013. Effects of Suspension Liquid Fertilizer on banana growth and water and nutrient utilization efficiency under drip fertigation. *J. Anhui Agric. Sci*. 9: 22-29.

Yadav, D., Singh, S.P., and Singh, S. 2014. Effect of foliar application of potassium compounds on yield and quality of ber (*Zizyphus mauritiana)* cv. Banarasi karaka. *Int. J. Res. Appl. Nat. Soc. Sci.* 2 (2): 89-92.

Yadav, I.S., Singh, H.P., and Singh, K.D. 1988. Response of banana to different levels and frequency of potassium application. *S. Indian Hort*. 36 (3): 167-171.

INPUT MANAGEMENT FOR PRECISION FARMING IN BANANA

by

SHIMI G. J.

(2011 - 21 - 101)

Abstract of the thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM – 695 522
KERALA, INDIA

2014

ABSTRACT

The investigation entitled "Input management for precision farming in banana" was carried out for two years (2012-2014) in Instructional Farm, College of Agriculture, Vellayani. The objectives were to study the impact of precision land management, fertigation and foliar nutrition on the growth and yield of tissue culture banana (Musa AAB cv. Nendran), to standardize the nutrient concentration and nutrient sources for fertigation and to work out the economics.

The experiment was undertaken in two parts. In part I, standardization of nutrient sources for fertigation was carried out in factorial CRD with six nutrient sources [urea, Muriate of Potash (MOP), 10-10-10, 13-0-45, SOP (Sulphate of Potash), and Diammonium Phosphate (DAP)] and four concentrations (0.25, 0.50, 0.75 and 1.00 per cent), replicated thrice. In part II, nutrient scheduling was standardized in split plot design with six main plots and three sub plots in three replications. Main plot treatments were n_1-POP (Package of Practices) with basin irrigation, n_2-POP with drip irrigation, n_3-drip irrigation alone without fertilizer, n_4-soil application of rock phosphate and fertigation using urea and MOP, n_5-fertigation using 10-10-10, urea and Sulphate of Potash (SOP) and n_6- fertigation using 13-0-45, 0-0-50 and DAP. The sub-plot treatments were water spray (s_1), foliar application of 19-19-19 @ 0.50 per cent [2, 4 and 6 MAP (Months After Planting)] (s_2) and bunch spray with 2 per cent SOP (after complete bunch emergence and three weeks after first application) (s_3). The general practices such as deep ploughing (50 cm), taking raised beds (30 cm height, 3 m width) and organic manure application (15 kg plant^{-1}) were uniformly followed. Daily water requirement for drip irrigation was calculated using the formula suggested by FAO (1998). Separate sub mains were laid out for irrigating each treatment and fertigation was done using ventury.

The concentrations tested revealed no phytotoxic effect on plants. Nutrient sources had significant influence on growth, yield and quality of banana. Growth parameters showed varying effect due to nutrient sources. During both the years,

n_1, n_2, n_4 and n_5 registered higher yield which were on par and significantly superior to other sources. But in pooled analysis, n_1, n_2 and n_4 recorded significantly higher yield of 32.55, 31.69, 31.58 t ha^{-1}, respectively which were on par. Quality parameters also responded differently to nutrient sources and irrigation. The effect of foliar application on growth, yield and quality was also significant. Bunch spray with 2 per cent SOP significantly improved growth, yield and quality aspects.

Input use efficiency also showed significant variation due to treatments. Among the nutrient sources and irrigation, the highest nutrient use efficiency (NUE) was registered by n_4. Whereas in water productivity (WP), n_2 was found superior and was on par with n_4 in second year. Water use efficiency (WUE) was enhanced in n_2 which was on par with n_4 and n_5 in first year. In second year, n_4 was on par with n_2, n_5 and n_6. NUE, WUE and WP were also significantly enhanced by s_3. Compared to basin irrigation, fertigation resulted in a saving of 73 per cent in irrigation water and 40 per cent in nutrients.

Significantly higher B : C ratio of 5.07 and 3.99 were registered by n_4 and s_3.

The nutrient schedule standardized for precision farming in banana can be summarized as:- basal application of organic manure @ 15 kg $plant^{-1}$, soil application of rock phosphate @ 325 g $plant^{-1}$ (1 MAP) and @ 250 g $plant^{-1}$ (3 MAP), weekly fertigation using urea @ 16.30 g $plant^{-1}$ from 1 to 7 MAP (except 6 MAP) and MOP @ 16.25 g $plant^{-1}$ from 1 to 5 MAP and @ 31.25 g $plant^{-1}$ (7 MAP) along with bunch spray of 2 per cent SOP (after complete bunch emergence and three weeks after first application) or foliar spray of 0.50 per cent 19-19-19 (2, 4 and 6 MAP). This schedule along with improved land management practices of deep ploughing (50 cm deep) and taking raised beds (30 cm height) is beneficial for productivity enhancement in banana.

APPENDICES

APPENDIX – I

Media composition for microbial study

1. Nutrient agar medium

Sl.No.	Reagents	Quantity
1.	Peptone	5.00 g
2.	Sodium chloride	5.00 g
3.	Beef extract	3.00 g
4.	Agar	20.00 g
5.	Distilled water	1000.00 ml
6.	pH	7.00

2. Kenknight's agar medium

Sl.No.	Reagents	Quantity
1.	Dextrose	1.00 g
2.	KH_2PO_4	0. 10 g
3.	$NaNO_3$	0. 10 g
4.	KCl	0. 10 g
5.	$MgSO_4.7\ H_2O$	0. 10 g
6.	Agar	15.00 g
7.	Distilled water	1000.00 ml

3. Martin's Rose Bengal agar medium

Sl.No.	Reagents	Quantity
1.	Glucose	10.00 g
2.	Peptone	5.00 g
3.	KH_2PO_4	1.00 g
4.	$MgSO_4.7\ H_2O$	0.50 g
5.	Streptomycin	30.00 mg
6.	Agar	15.00 g
7.	Rose Bengal	35.00 mg
8.	Distilled water	1000.00 ml

APPENDIX – II

Weather parameters during the cropping period (Feb. 2012 to Nov. 2013)

Month and year	Temperature (°C)		Max. RH (%)	Bright sunshine hours	Rainfall (mm)	Number of rainy days	Evaporation (mm day^{-1})
	Max.	Min.					
Feb-12	31.20	22.48	97.34	9.22	0.00	0	3.36
Mar-12	31.70	23.30	93.66	9.33	22.00	7	3.23
Apr-12	32.10	25.08	90.03	8.90	116.40	12	3.41
May-12	31.22	25.78	90.82	9.60	48.50	5	3.58
Jun-12	30.48	24.56	91.28	9.40	72.00	16	2.95
Jul-12	29.75	24.25	92.68	9.58	114.00	15	3.36
Aug-12	29.78	23.84	92.06	9.20	182.50	14	3.44
Sep-12	30.23	24.10	89.83	9.54	57.50	10	3.48
Oct-12	30.38	23.64	92.23	8.50	110.00	13	3.03
Nov-12	30.26	23.06	97.38	8.62	11.10	9	3.26
Dec-12	30.68	22.75	97.90	8.43	40.50	4	2.63
Jan-13	30.30	22.02	95.90	9.05	262.00	3	3.45
Feb-13	31.25	22.13	92.48	9.28	38.00	5	3.72
Mar-13	32.26	23.72	92.70	9.56	86.00	5	4.50
Apr-13	33.05	25.43	89.40	9.85	42.10	3	4.15
May-13	32.32	25.45	91.72	9.33	61.30	11	3.80
Jun-13	29.32	22.82	93.53	8.18	507.50	24	2.45
Jul-13	28.88	22.95	92.30	8.63	228.80	24	2.50
Aug-13	29.28	23.52	92.48	9.25	109.10	11	2.82
Sep-13	29.13	23.85	96.40	8.75	216.20	19	3.32
Oct-13	30.64	23.24	93.13	9.20	153.00	13	3.82
Nov-13	30.65	23.45	96.64	8.18	292.70	14	2.68

APPENDIX – II (Continued)

Weather parameters during the cropping period (Feb. 2012 to Nov. 2013)

Evaporation (weekly average, mm)			
2012		2013	
February	3.25	January	3.60
	3.00		3.30
	3.37		3.40
	3.83		3.50
March	3.26	February	3.60
	3.00		3.60
	3.30		3.80
	3.38		3.90
April	3.96	March	4.20
	3.30		4.40
	3.55		4.60
	2.85		4.80
May	3.20	April	4.10
	3.00		4.20
	4.50		4.30
	3.60		4.00
June	2.80	May	4.00
	3.10		4.00
	2.50		4.20
	3.40		3.00
July	3.14	June	1.80
	3.46		2.80
	3.40		2.00
	3.42		3.20
August	3.46	July	2.30
	3.51		1.90
	3.29		2.50
	3.51		3.30
September	3.51	August	3.30
	3.49		3.00
	3.40		3.00
	3.51		2.00
October	3.11	September	4.30
	2.60		3.00
	2.80		2.00
	3.60		4.00
November	3.34	October	3.60
	3.11		5.00
	3.77		3.10
	2.80		3.60
December	2.06	November	3.10
	2.23		2.20
	3.20		2.00
	3.03		3.40

APPENDIX – III

Quantity of fertilizers (kg ha^{-1}) and their cost (` kg^{-1}) used in the experiment

Treat-ments	Urea	Rock Phosphate	MOP	10-10-10	SOP	13-0-45	DAP	19-19-19
n_1s_1	1630.40	1437.50	1875.00	0.00	0.00	0.00	0.00	0.00
n_1s_2	1630.40	1437.50	1875.00	0.00	0.00	0.00	0.00	8.75
n_1s_3	1630.40	1437.50	1875.00	0.00	5.00	0.00	0.00	0.00
n_2s_1	1630.40	1437.50	1875.00	0.00	0.00	0.00	0.00	0.00
n_2s_2	1630.40	1437.50	1875.00	0.00	0.00	0.00	0.00	8.75
n_2s_3	1630.40	1437.50	1875.00	0.00	5.00	0.00	0.00	0.00
n_3s_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
n_3s_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.75
n_3s_3	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00
n_4s_1	978.26	1437.50	1125.00	0.00	0.00	0.00	0.00	0.00
n_4s_2	978.26	1437.50	1125.00	0.00	0.00	0.00	0.00	8.75
n_4s_3	978.26	1437.50	1125.00	0.00	5.00	0.00	0.00	0.00
n_5s_1	652.00	0.00	0.00	1950	960.00	0.00	0.00	0.00
n_5s_2	652.00	0.00	0.00	1950	960.00	0.00	0.00	8.75
n_5s_3	652.00	0.00	0.00	1950	965.00	0.00	0.00	0.00
n_6s_1	0.00	0.00	0.00	0.00	390.00	1068.00	375.00	0.00
n_6s_2	0.00	0.00	0.00	0.00	390.00	1068.00	375.00	8.75
n_6s_3	0.00	0.00	0.00	0.00	395.00	1068.00	375.00	0.00
*Cost (` kg^{-1})	6.50	6.50	12.50	250.00	40.00	90.00	20.00	150.00

APPENDIX – IV

Concentration of nutrient sources used for fertigation

Nutrient sources	Concentration range, per cent
Urea	0.20-0.54
MOP	0.39-0.54
10-10-10	2.40-3.25
13-0-45	0.52-0.72
SOP	0.47-0.65
DAP	0.41-0.71

APPENDIX – V

Details of Irrigations given during the first and second years of experimentation

Treatments	Crop duration (days)		Number of irrigations		Irrigation requirement (mm)		Effective rainfall (mm)		Total water requirement (mm)	
	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
n_1s_1	287.50	296.66	108	88	845.00	753.75	542	1398	1387.00	2151.75
n_1s_2	292.66	280.66	108	88	845.00	753.75	542	1398	1387.00	2151.75
n_1n_3	297.66	294.33	108	88	845.00	753.75	542	1398	1387.00	2151.75
n_2s_1	271.50	278.00	165	129	240.82	198.20	542	1398	782.82	1596.20
n_2s_2	273.00	276.00	165	129	240.82	198.20	542	1398	782.82	1596.20
n_2s_3	283.83	295.00	165	129	240.82	198.20	542	1398	782.82	1596.20
n_3s_1	256.00	258.33	165	129	240.82	198.20	542	1398	782.82	1596.20
n_3s_2	256.33	264.00	165	129	240.82	198.20	542	1398	782.82	1596.20
n_3s_3	264.00	270.66	165	129	240.82	198.20	542	1398	782.82	1596.20
n_4s_1	264.00	269.66	165	129	240.82	198.20	542	1398	782.82	1596.20
n_4s_2	263.66	289.00	165	129	240.82	198.20	542	1398	782.82	1596.20
n_4s_3	259.33	278.00	165	129	240.82	198.20	542	1398	782.82	1596.20
n_5s_1	259.00	278.00	165	129	240.82	198.20	542	1398	782.82	1596.20
n_5s_2	261.00	278.00	165	129	240.82	198.20	542	1398	782.82	1596.20
n_5s_3	264.50	281.33	165	129	240.82	198.20	542	1398	782.82	1596.20
n_6s_1	259.00	279.33	165	129	240.82	198.20	542	1398	782.82	1596.20
n_6s_2	257.50	275.66	165	129	240.82	198.20	542	1398	782.82	1596.20
n_6s_3	266.00	281.00	165	129	240.82	198.20	542	1398	782.82	1596.20

APPENDIX – VI

Quantity of nutrients added (kg ha^{-1})

Treatments	N	P	K
n_1s_1	750.00	287.50	1125.00
n_1s_2	751.66	289.16	1126.66
n_1s_3	750.00	287.50	1127.50
n_2s_1	750.00	287.50	1125.00
n_2s_2	751.66	289.16	1126.66
n_2s_3	750.00	287.50	1127.50
n_3s_1	0.00	0.00	0.00
n_3s_2	1.66	1.66	1.66
n_3s_3	0.00	0.00	2.50
n_4s_1	450.00	287.50	675.00
n_4s_2	451.66	289.16	676.66
n_4s_3	450.00	287.50	677.50
n_5s_1	450.00	172.50	675.00
n_5s_2	451.66	174.16	676.66
n_5s_3	450.00	172.50	677.50
n_6s_1	450.00	172.50	675.00
n_6s_2	451.66	174.16	676.66
n_6s_3	450.00	172.50	677.50

APPENDIX – VII

Cost of cultivation of banana with different nutrient sources and foliar nutrition

Treatments	Cost of cultivation (` ha^{-1})		Per plant cost of cultivation (` plant^{-1})	
	I Year	II Year	I Year	II Year
n_1s_1	258828.90	242328.90	103.53	96.93
n_1s_2	260141.40	243641.40	104.05	97.45
n_1s_3	257403.90	240903.90	102.96	96.36
n_2s_1	248909.20	239909.20	99.56	95.96
n_2s_2	250221.70	241221.70	100.08	96.48
n_2s_3	247484.20	238484.20	98.99	95.39
n_3s_1	186030.40	177030.40	74.41	70.81
n_3s_2	187342.90	178342.90	74.93	71.33
n_3s_3	184605.40	175605.40	73.84	70.24
n_4s_1	215795.80	206795.80	86.31	82.71
n_4s_2	217108.30	208108.30	86.84	83.24
n_4s_3	214370.80	205370.80	85.74	82.14
n_5s_1	716168.40	707168.40	286.46	282.86
n_5s_2	717480.90	708480.90	286.99	283.39
n_5s_3	714743.40	705743.40	285.89	282.29
n_6s_1	305250.40	296250.40	122.10	118.50
n_6s_2	306562.90	297562.90	122.62	119.02
n_6s_3	303825.40	294825.40	121.53	117.93

APPENDIX – VIII

Market price of the produce

Produce	Market price (`)
Bunch	35 / bunch
Sucker	10 / sucker

APPENDIX – IX

Score chart for pseudostem weevil

Damage grade index	Symptoms
0	no symptoms
1	1 to 5 bore holes on the pseudostem
2	6 to 10
3	>10 bore holes on the pseudostem
4	pseudostem about to break or already broken

APPENDIX – X

Score chart for leaf spot disease

Grade	Disease Intensity (%)	Description
0	0	No spots
1	5 to 10	2 to 10 spots
2	11 to 25	10 or more spots
3	26 to 50	half of the leaf area infected
4	51 to 75	½ to ¾ of the leaf area infected
5	76 to 100	Almost complete infection of leaf