NUTRIENT AND MOISTURE OPTIMIZATION IN BANANA (*Musa* AAA. GRAND NAIN)

by

BINDHU J. S.

(2013 - 21 - 102)

THESIS

Submitted in partial fulfilment 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

2016

DECLARATION

I, hereby declare that this thesis entitled "**NUTRIENT AND MOISTURE OPTIMIZATION IN BANANA (*Musa* AAA. GRAND NAIN)"** 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, **Bindhu J. S.**
Date: (2013-21-102)

CERTIFICATE

Certified that this thesis entitled "**NUTRIENT AND MOISTURE OPTIMIZATION IN BANANA (*Musa* AAA. GRAND NAIN)"** is a record of research work done independently by **Ms. Bindhu J. S.** 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. L. Girija devi
(Major Advisor, Advisory Committee)
Professor (Agronomy)
College of Agriculture, Vellayani

Vellayani,
Date:

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Bindhu J. S., a candidate for the degree of **Doctor of Philosophy in Agriculture** with major in Agronomy, agree that the thesis entitled "**NUTRIENT AND MOISTURE OPTIMIZATION IN BANANA (*Musa* AAA. GRAND NAIN)**" may be submitted by Ms. Bindhu J. S., in partial fulfilment of the requirement for the degree.

Dr. L. Girija devi
(Chairman, Advisory Committee)
Professor (Agronomy)
Department of Agronomy
College of Agriculture, Vellayani.

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

Dr. O. Kumari Swadija
(Member , Advisory Committee)
Professor (Agronomy)
Department of Agronomy
College of Agriculture, Vellayani.

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

Dr. R. Gladis
(Member, Advisory Committee)
Assistant Professor
Department of Soil Science and Agricultural Chemistry
College of Agriculture, Vellayani.

EXTERNAL EXAMINER

Dr. B. J. Pandian
Director (i/c) and Nodal Officer (TN-IAMWARM), Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore

ACKNOWLEDGEMENTS

I bow before the 'God almighty' for the blessings showered, enabling me to complete this venture successfully and also to my Guru Sri. P Ramachandran who advised me to take up research on banana for his blessings throughout my investigation.

I express my heartfelt gratitude and indebtedness to Dr. L. Girija devi, Professor, Department of Agronomy and Chairperson of my Advisory Committee for her expert guidance, persisting encouragement, unconditional love, affection and above all the kind understanding, whole hearted cooperation and an unstinted help rendered during my entire course of the investigation and preparation of thesis.

I am extremely thankful to Dr. K.R. Sheela, Professor and Head, Department of Agronomy and member of my Advisory Committee for the invaluable help, expert guidance and valuable suggestions in planning and conducting the experiment.

I express my sincere gratitude to Dr. O. Kumari Swadija, Professor, Department of Agronomy and member of my Advisory Committee for her sincere guidance, advice and help rendered during my study.

I owe my sincere gratitude to Dr. Vijayaraghavakumar, Professor and Head, Department of Agricultural Statistics for the sincere guidance and valuable suggestions in designing the experiment and during the statistical analysis of the data and its interpretation successfully.

My heartfelt thanks to Dr. Gladis R., Assistant Professor, Department of Soil Science and Agriculture Chemistry and member of my Advisory Committee for her valuable suggestions and help during the course of my research work.

I have no words to express my sincere thanks to Dr. V.L. Geethakumari, Rtd. Professor (Agronomy) for her expert guidance, constant motivation and cooperation throughout the course of my investigation.

I wish to place on record my sincere gratitude to Dr. P Babu Mathew, Professor and Head, Instructional Farm, College of Agriculture, Vellayani for extending all possible help and support during the course of my investigation. I wish to express my deep sense of gratitude to Dr. Shalini Pillai for her immense help throughout my study period.

I would like to express my deep sense of gratitude to teachers of Agronomy Department, Dr. M. Meerabai (Rtd. Professor and Head), Dr. R. Pushpa Kumari and Dr. Chandini S. (Rtd. Professors), Dr. Lakshmi S., Dr. Lekha Sreekantan, Dr. Elizabeth Cyriac, Dr. Sansamma George, Dr. Anil Kumar, Sri. Jayakrishna Kumar, Dr. Sajitha Rani T., Dr. Rajasree G., Dr. Shahul Hameed (Rtd. Assoc. Professor) Dr. Ameena, M. Dr. Usha C. Thomas and Dr. Sheeba Rabecca Issac for their teaching, wholehearted co-operation and ready help during the period of course work and Research Programme.

I express my cordial thanks to all the teaching staff, Farm officers and other non teaching staff and causal labourers of the Instructional Farm, College of Agriculture, Vellayani.

The cooperation extended by the Lab Assistants Sri. Shibu, Smt. Vimala and Smt. Remani (Rtd.) and Research Assistants, Ms. Deepthi, Smt. Asha is acknowledged with gratitude.

I wish to express my sincere thanks to Sri. Ajith, K., Asst. Professor and Smt. Linitha, Teaching Assistant, Department of Agricultural Meteorology, for their valuable help during my study.

I accord my sincere thanks to Dr. Sosamma Cherian (Rtd. Professor and Head), Dr. Jessy M. Kuriakose, Dr. Shajan, V.R., Sri. Jayakumar and Sri. Gopakumar of ARS, Thiruvalla for their whole hearted support throughout my study period. I owe a special thanks to Dr. Reena Mathew, Professor, RRS, Moncompu for the sincere help during the entire course of my study.

I am extremely thankful to Dr. Thomas Mathew, Professor and Head, ECF unit Thiruvalla for suggesting the cultivar Grand Nain for my Research Programme based on the felt needs of farmers. I also wish to express my thanks to Dr. Jacob D. Asst. Professor, ECF unit for his valuable suggestions.

I also express my sincere gratitude to Dr. Shehana R.S. and Dr. Suman Susan Varghese (Rtd. Professors of Soil Science Department), Dr. C. S. Jayachandran Nair, Dr. Sumam George (Professor and Head, Soil Science Department) and Dr. K. S. Premila, Dr. Jacob John, Dr. Thomas George for their moral support, motivation, suggestions, encouragement rendered throughout the study.

My sincere and heartfelt thanks to my dearest friends, Dr. Sheeja K. Raj, Smt. Sharu S. R., Sri. Athul Jayapal, Smt. Meera, A.V., Sri. Naveen Leno, Smt. Devi V.S., Sri. Renjan B., Smt. Nisha S.K., Dr. Aparna B., Dr. Sarada S., Dr. Beena V.I., Dr. Sailajakumari, Dr. Sreekala G.S., Ms. Nishan, Vipitha, Pintu, Gayathri, Anjali Hari and Anjana Babu for their affection, personal and professional support throughout the period of study. I also extend my sincere thanks to all my junior friends (both Ph.D. and M.Sc.) for their support throughout the period of study.

I am deeply obliged to my parents and brother for their prayers and blessings, sacrifices and constant encouragement which made me realize the dream. I express my heartfelt gratitude to my in laws for their affection and blessings. No words can truly express my feelings to my husband Dr. D. Srikanth and my son Abhiram S. for their unconditional love and support and also bearing so many inconveniences and without which I won't be able to complete this Venture.

I also acknowledge my sincere thanks to Sri. Alexander Mathew for the neat typing and timely completion of my thesis.

I am grateful to Kerala Agricultural University for providing me deputation for three years to undergo Ph.D. Programme.

I also duly acknowledge my sincere thanks to all my well wishers for their unconditional love and support.

Bindhu J. S.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

B : C	Benefit Cost
BSS	Bright Sunshine hours
C	Carbon
CD	Critical Difference
cm	centimetre
cm^2	square centimetre
CPE	Cumulative Pan Evaporation
d	day/days
d^{-1}	per day
h	hours
dS m^{-1}	decisiemens per metre
EC	Electrical Conductivity
E-H	Emergence to Harvest
et al.	co-workers/co-authors
ET	Evapotranspiration
ETc	Evapotranspiration of crop
Fig.	Figure
FYM	Farmyard manure
g	gram
GDD	Growing Degree Days
HTU	Helio Thermal units
h	hours
ha	hectare
i.e.	That is
IW	Irrigation Water
K/K_2O	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
LAD	Leaf Area Duration

LER	Leaf Emergence Rate
m	metre
m^2	square metre
m^{-2}	per square metre
mg	milligram
mm	millimetre
MAP	Months After Planting
Mg	Mega gram
MOP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Not Significant
P/P_2O_5	Phosphorus
pH	Potenz hydrogen
$plant^{-1}$	per plant
PE	Potential Evaporation
POP	Package of Practices
PTU	Photo Thermal units
RBD	Randomized Block Design
RH	Relative Humidity
SEm	Standard Error of mean
spp. / sp.	Species
T	Temperature
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
^oC	degree Celsius
%	per cent
₹	rupee

1. INTRODUCTION

India is the largest producer of banana in the world. In India, banana contributes 32.60 per cent of the total fruit production (NHB, 2013). Among the horticultural crops, banana contributes more to Agricultural Gross Domestic Product (AGDP) (Singh, 2007). Banana has also good export potential. During the last two decades, the area expansion of banana has registered 209 per cent growth while the production has witnessed a four-fold increase (NRCB, 2013). The year round availability, affordability, varietal range, taste, nutritive and medicinal value makes banana the favourite fruit among all classes of people.

The steady demand for banana and wide adaptability to different farming situations makes banana the small farmer's favourite crop. The dwindling farm holdings also make banana a practical alternative to other crops. Since more than 70 per cent of banana cultivation is done on leased lands by resource poor farmers, obtaining maximum income from a unit area under cultivation assumes utmost importance. With a projected population of 1600 million people in 2050 and more than half of the population living in urban areas with high income generation, a change in food basket is anticipated. To meet the demand of the ever growing population and to achieve an annual per capita consumption of minimum 30 kg banana fruit, a projected target of 50 million tonnes of banana in 2050 AD is proposed (NRCB, 2013).

Banana and plantains are grown in over 130 countries across the world in an area of 10.1 million ha producing 121.85 million tonnes (Mustaffa and Kumar, 2012). India's share in the production of banana is 29.73 million tonnes from an area of 0.803 million ha accounting for an average productivity of 37 t ha^{-1} (NHB, 2015). In Kerala, banana and plantain are cultivated in an area of 1,16,773 ha with a production of 8,93,694 tonnes and the average productivity of banana estimated is 8.5 t ha^{-1} (FIB, 2016).

A number of banana cultivars are grown in Kerala and among all the cultivars, Grand Nain is gaining popularity and may soon be the most preferred variety. In many banana growing states of India, there has been a steady increase in area, production and productivity due to the adoption of high yielding varieties like Grand Nain, Robusta and other Cavendish clones, use of virus free quality planting materials and adoption of improved production technologies (Mustaffa and Kumar, 2012).

Water is the most limiting factor in banana production and copious irrigation is required at all stages of growth. Wide variations were observed in the water requirement of banana cultivars. In Grand Nain banana, water requirement was not adequately estimated under Kerala situation. Hence there is a need to optimize the irrigation schedule for Grand Nain banana.

Bananas owing to its high biomass production, gross feeder and rapid growth rate, require relatively large amount of nutrients for high yield and quality fruit. Cultivar wise nutrient requirement estimation is essential for tapping the full yield potential of the crop. Presently nutrient recommendation lacks for Grand Nain banana under Kerala condition.

Knowledge on the phenology of a crop helps to identify the planting time to match with high productivity as well as demand. Detailed knowledge of phenological cycles of the banana plant in a particular area enables the farmers to intensify the level of management, plan the planting date in order to time the harvest during the ideal marketing period and forecast the volume of crop harvested (Robinson and Sauco, 2010).

The Grand Nain banana has become one of the most popular varieties due to its higher yield, good quality bunches, tolerance to abiotic stresses and better shelf life. The moderate height allows easy harvesting and the crop has some resistance to lodging. Grand Nain is a cultivar of well-known Cavendish bananas and one among the most remunerative banana varieties. However, in Kerala the potential of this cultivar is not fully exploited by the farming community. The production strategies specific to Grand Nain especially nutrient and irrigation schedule are lacking under Kerala condition. Hence, the present investigation was carried out for standardizing the production technologies for enhancing the productivity of Grand Nain with the following objectives:

- To standardize the nutrient and irrigation schedule of Grand Nain banana.
- To study the phenology in relation to various agro-meteorological parameters.
- To work out the economics.

2. REVIEW OF LITERATURE

An experiment entitled “Nutrient and moisture optimization in banana (*Musa* AAA. Grand Nain)” was undertaken with the objectives to standardize the nutrient and irrigation schedule of Grand Nain banana, to study its phenology in relation to various agro-meteorological parameters and to work out the economics of cultivation. Studies in response of banana to different levels of irrigation and nutrients were reviewed and presented in this chapter. Influence of different time of planting on phenology of banana was studied by various scientists and the results of those investigations also form a part in this chapter.

The diverse set of cultivar groups are making up banana dietary diversity for millions of rural and urban households throughout the world. Banana is also a major export crop, the most widely consumed fruit, generating income and employment for millions of households (Calberto *et al*., 2015). Cavendish subgroup is an extremely important one in world banana trade and a major genomic group under AAA group. Grand Nain, an important clone of Giant Cavendish type, comes under Cavendish subgroup and is a tall mutant of Dwarf Cavendish.

The Grand Nain banana (also spelled Grande Naine) literally translates from French meaning "Large Dwarf." It is an early maturing variety and normally comes to harvest 11 months after planting. It bears bunches with well-spaced hands and uniform sized long fingers. The study based on the comparison between banana (*Musa*) cultivars Dwarf Cavendish (DC), Grande Nain (GN) and Williams (W), during five cycles of growth at two planting densities under the subtropical conditions of northern Tenerife found that GN was the best for both quantitative and qualitative characteristics (Sauco *et al*., 1995). Grand Nain is a popular variety grown mostly in many place of India for its high productivity and desired fruit quality (Singh and Chundawat, 2002).

2.1 EFFECT OF IRRIGATION LEVELS ON GROWTH, YIELD AND QUALITY ATTRIBUTES OF BANANA

There is a quandary in our knowledge of the link between water requirement and productivity in banana. Anecdotal evidence, based on experience in plantations, supports the view that bananas require 'abundant and constant' supplies of water (Popenoe, 1941). On the other hand, physiological investigations suggest that banana are remarkably tolerant to soil water deficit (Kallarackal *et al.*, 1990) and can transpire less water than other crops (Lu *et al.*, 2002).

Banana is a plant with a rapid growth rate, high consumption of water, shallow and spreading root distribution and roots with weak penetration strength into the soil (Champion, 1968), poor ability to withdraw water from soil which is drying (Hedge, 1988), low resistance to drought and rapid physiological response to soil water deficit (Robinson, 1995). The water holding capacity of the soil, effective rooting depth of banana, and the percentage of depletion of total available water allowed before irrigation determine the amount of water to apply, while crop coefficient together with the evapotranspiration data determine the irrigation interval (Robinson, 1995).

On a global basis, water deficit is a major cause limiting productivity of agricultural systems and food production (Bray *et al*., 2000). Banana (*Musa* spp.) rarely attains their full genetic potential due to limitations imposed by water ultimately limiting the photosynthesis. Being an herbaceous plant, banana is more sensitive to moisture stress than other fruit crops. Banana productivity is greatly affected by environmental stresses such as drought, water and cold. Plants respond and adapt to these stresses at the molecular and cellular levels as well as at the physiological and biochemical levels.

Physiological response to soil water deficit is the feature that is most likely to determine the response of the crop to irrigation. The banana plants are sensitive to soil moisture stress and it is reflected as reduced growth through reduced stomatal conductance and leaf size (Kallarackal *et al*., 1990). Robinson (1996) reported the high sensitivity of banana to soil water deficit and that in practice, the 'little and often' approach to scheduling irrigation is the best strategy, in addition to the large amount of water that is needed for high production and he summarized the features of high transpiration potential due to large, broad leaves and a high LAI, shallow roots in comparison with other fruit crops, poor ability to withdraw water from drying soil and a rapid physiological response to soil water deficit. Turner and Thomas (1998) reported that banana is sensitive to soil water deficits; expanding tissues such as emerging leaves and growing fruit are among the first to be affected. As soil begins to dry, stomata close and leaves remain highly hydrated, probably through root pressure. Productivity is affected due to early closure of stomata and increased leaf senescence (Turner, 1998). Also, Karam *et al*. (2002) revealed that deficit irrigation significantly reduced the rate of cell expansion and decrease in leaf number. Turner *et al.* (2007) opined that soil moisture together with climate factors, such as temperature, wind and relative humidity are significantly correlated to emerging leaves and rate of leaf production.

Water requirement being a function of effective rainfall and irrigation varies widely throughout the world. Calberto *et al*. (2015) found that banana experience limitations in growth below 1500 mm annual rainfall. Total amount of rainfall and length of dry season (three months or fewer with less than 60 mm of monthly rainfall) determine the irrigation requirement of banana. The study also revealed that with fewer than three dry months and greater than 150 mm rainfall month^{-1}, banana grows well year-round without irrigation.

Holder and Gumbs (1982) studied the effect of water supply during floral initiation and differentiation of female flower production in banana cv. ‘Robusta’ and found that a continuous and non-limiting soil water supply from 120 to 180 days after planting significantly increased female flower production and thereby the yield of banana as compared to continuous soil water stress. Daniells and Watson (1984) investigated the effects of moisture stress in

'Williams' banana plants with water shortage at different stages of development and concluded that water stress after 7 to 12 leaf stage affected all the plant characters. Krishnasastry *et al.* (1985) reported that for obtaining the best results in Robusta banana, it was advisable to maintain a soil water of 20 per cent depletion of available soil moisture throughout the growth period and by this practice banana consumed 2150 mm water. Karam *et al.* (2002) reported that water stress due to deficit irrigation significantly reduced the rate of cell expansion and number of leaf.

Scheduling of irrigation to crops is essential for efficient utilization of available water, saving of input and enhancing yield. The quantity of irrigation water to be applied at each irrigation depends upon the amount of available moisture in the soil (at effective root depth). Simmonds (1966) opined that the water requirement of banana ranged from 50 to 550 mm per month depending on soil and climatic conditions. Goenagea and Irizarry (1998) found that the yield and yield components of the plant and ratoon crops were significantly improved with the increase in water applied.

In irrigation scheduling the climatological approach based on IW/CPE ratio has been found most appropriate. This approach integrates all weather parameters that determine water use by the crop and increase the production by at least 15-20 per cent (Dastane, 1972). In tropical banana, water requirement is 900-1800 mm crop^{-1} and this amount to a consumption of 3-6 mm day^{-1} depending on the combination of leaf area index, temperature, humidity, radiation, cloud cover and wind (Stover and Simmonds, 1987). Hedge (1990) reported that scheduling irrigation to banana cv. Robusta at 60 mm cumulative pan evaporation (CPE) resulted in better growth, early flowering and the highest yield compared to irrigation at 80 and 120 mm CPE. The effective depth of rooting in banana was usually taken to be 0-0.4 m (Carr, 2009). A comparative study of researcher managed and farmer managed irrigated banana production in Shire Valley, Malawi was under taken for irrigation optimization in banana. The results on banana production and gross margin analysis showed that average yield and quality increased linearly with increasing irrigation. Significant differences were observed in both situation between amount of water applied and average bunch weight, average hand weight and average finger weight (Fandika *et al.*, 2014).

Selvakumari *et al.* (1992) stated that the quantity of water consumed had a positive and significant influence on banana fruit yield and irrigation water requirement of banana grown as a pure crop was found to be 2252 mm. The ideal IW/CPE ratio to supply the required irrigation water up to a depth of 5 cm in a red sandy loam soil was one. They also found that in banana, irrigation applied at IW/CPE ratios of 0.6, 0.8, 1.0 and 1.2, the water consumption increased with increasing IW/CPE ratio, the maximum mean rate being 2608 mm ha^{-1}. The highest mean yield, 39.1 t ha^{-1}, was obtained with an IW/CPE ratio of 1.2, although this was not significantly higher than the yield obtained with an IW/CPE ratio of 1.0. Bisen *et al.* (2009) studied the month-wise irrigation scheduling with different combinations of IW/CPE ratios in banana cv. Robusta. The IW fixed at 70 mm irrigation along with a combination of IW/CPE ratio, 1.5 for September-January, 1.8 for February-March and 2.1 for April-June was found to be the most suitable for the sub humid climate of Chhattisgarh plain zone.

Banana production was positively correlated with the quantity of water applied (Burham, 1999). Murali (2002) reported that in Robusta banana, irrigation scheduled at an IW/CPE ratio of 1.0 during vegetative and reproductive stages recorded the highest yield followed by ratios of 0.8 and 0.6. e Silva (2004) studied the vegetative behavior of banana cultivars to different levels of irrigation and found that the cv. FHIA showed a significant response to variation in irrigation levels for the observed variables such as the diameter of the pseudostems, diameter of the pseudostems at point of insertion of the bunch, number of leaves, and productive and total cycles of the plants whereas cv. Grande Nain and Prata were not affected by the irrigation levels. Mahmoud (2013) studied the different levels of irrigation on yield characters of Grand Nain banana and concluded that the irrigation level at 40 per cent PE (764.26 mm $year^{-1}$) improved the yield attributes and yield characters in Grand Nain. Ali *et al*. (2015) studied the performance of banana under different water quantities and found that amount of water applied with 1.0 ETc gave higher plant height (137 cm) followed by 0.75 ETc (115 cm) while 0.5 ETc gave the lowest plant height (97.5 cm).

In India, drip irrigation is superior to the conventional basin irrigation in terms of ensuring more vigorous growth, higher yields, minimal weed growth and high water use efficiency (Hegde and Srinivas, 1989). Banana under drip irrigation flowered 15 days earlier in comparison to that under surface irrigation. In addition to economy of water use, drip irrigation activates uptake of nutrients, and recorded higher yields with higher finger, hand and bunch weight as compared to basin irrigation (Hedge and Srinivas, 1991). Thadchayini and Thiruchelvan (2005) obtained the highest yield in the drip system, 31 per cent higher than in surface irrigation. Ahmed *et al*. (2011) reported that in Grand Nain banana, irrigation regimes under drip irrigation had a significant effect on growth parameters at flowering, yield components and yield. El-Khawaga (2013a) reported that adjusting of irrigation in various banana cultivars was essential for improving water use efficiency as well as yield quantitatively and qualitatively. Surface irrigation at IW/CPE 1.0 could also be advocated with almost same efficiency as an alternative method if the initial investment for laying the drip irrigation system is an impediment for farmers (Sanji and Patra, 2015).

Thus, in banana, the bunch yield showed a positive response to the quantity of water upto optimum crop water requirement.

2.2 EFFECT OF MINERAL NUTRITION IN BANANA

Balanced NPK fertilization has received considerable attention in India (Ghosh *et al*., 2004; Hegde and Babu, 2004). Balanced nutrient management is the key to increased plant use efficiency and to achieve the required crop yield in an efficient, economical and sustainable manner. This may indicate that the need for the application of different nutrients at specific times, in a particular order to derive the maximum benefit from the application of a given quantity of nutrients.

According to Fageria *et al.* (2006) mineral nutrition is the process of addition, translocation, and utilization of essential nutrients by plants. The requirement of nutrients must be supplied through fertilizer application in order to obtain optimum yields and fertilizers not only improve soil nutrient status but also increase plant productivity (Guo *et al*., 2009). Daniells and Armour (2010) observed that banana utilized about 50 per cent of the applied fertilizers, while the remaining nutrients were held in the soil. Banana production was limited by both biotic and abiotic constraints. Among the constraints, decline in soil fertility was a major one limiting the productivity of banana (Ahumuza *et al*., 2015).

The banana plant cannot store nitrogen, so if current soil nitrogen is insufficient for growth, deficiency symptoms quickly develop. Ramaswamy and Muthukrishnan (1974) found out that soil application of nitrogen @ 150 g plant^{-1} was proved to be the optimum level for yield maximization in Robusta banana. Flowering was delayed considerably with no nitrogen application (Kohli *et al.*, 1984). The required net assimilation was presumably reached early in the plants receiving higher dose of nitrogen, thus hastening the process of initiation and emergence of inflorescence (Hasan *et al*., 2001). Research carried out by Follett (2001) indicated that excess nitrogen resulted in increased nutrient loss into environment through leaching, denitrification and volatilization and these losses have a potential to pollute the environment.

Phosphorous is one of the three primary nutrients and is absorbed by banana roots mainly in the form of orthophosphate ($H_2PO_4^-$). Requirement of phosphorus under Indian conditions varied from 35 to 225 g plant^{-1} (Shanmugam and Velayutham, 1972). According to Ramaswamy and Muthukrishnan (1974), number of hands bunch^{-1}, bunch weight, fruit size and volume increased up to 60 g of P_2O_5 plant^{-1}. Requirement of phosphorus in banana is much less than nitrogen and potassium (Vadivel, 1976) and deficiency symptoms are rarely seen in the field. Uptake of phosphorus was peak between two to five months after planting and thereafter, the uptake is reduced.

Potassium commonly known as "quality mineral nutrient" and is the most important element in banana nutrition. Its concentration in the plant system is much higher than all other nutrients, or even all the mineral nutrients combined. Results of many experiments showed that adequate supply of potassium fertilizers not only increases growth and yield in banana, but also improves the quality of the fruit, physiology of the plant and offers resistance against biotic and abiotic stresses. Oubahou and Dafri (1987) found positive correlation for potassium with the height and circumference of pseudostem which they termed as the productivity index. Potassium application at early stages recorded maximum plant growth parameters closely associated with yield (Bhargava *et al.*, 1993). Hasan and Chattopadhyay (2000) observed enhanced growth and yield-attributing parameters with application of 300-600 g K plant^{-1}. Banana being a potassium loving crop has a very high demand for this nutrient. In India, the applied dose of K varies from 800 to 1600 kg ha^{-1} (Kumar *et al*., 2008).

2.3 EFFECT OF NUTRIENTS ON GROWTH, YIELD PARAMETERS AND YIELD OF BANANA

A number of research experiments have clearly demonstrated that, for high productivity of banana, application of recommended doses of essential nutrients at the appropriate growth stages are necessary (Pandey *et al.*, 2005; Thangaselvabai *et al.*, 2009). Essential nutrients in appropriate balance are fundamental for various physiological processes in plants (Fageria *et al.*, 2006).

In Grand Nain the response to different levels of K_2O (400, 600, 800, 1000 g plant^{-1}) was studied by Saad and Atawia (1999) and found that application of 800 g K_2O increased the number of hands, fingers and yield of banana. In Grand Nain, application of 165: 62.5: 495 g of NPK plant^{-1} showed increased yield (Nalina, 2002). Application of 300 g nitrogen in both the first and second crop resulted in maximum pseudostem height and circumference at shooting stage and significantly reduced phyllochron in cv. Robusta (Pandey *et al.*, 2005). Suma *et al.* (2007) observed the highest number of hands and fingers bunch^{-1} with 200:

40: 200 g NPK plant^{-1} in cv. Nendran. Application of 100 per cent recommended dose of NPK (200 g N, 40 g P_2O_5 and 200 g K_2O) with 10 kg FYM plant^{-1} along with *Azosprillum* and phosphorus solubilizing bacteria @ 25 g plant^{-1} each were beneficial in terms of banana yield and monetary returns in tissue culture Grand Nain banana (Bhalerao *et al*., 2009). KAU (2011), recommended a fertilizer dose of 200: 200: 400 g N: P_2O_5: K_2O plant^{-1} year^{-1} for varieties other than Nendran.

2.4 TIME OF APPLICATION OF NUTRIENTS ON GROWTH AND YIELD OF BANANA

Productivity of banana is mainly determined by its growth during its early stage and hence minerals must be available to the plant at the establishment phase. The time of application of nutrient vary with cultivars, soil type, irrigation and agro climatic region. When potassium supply is abundant, large amounts of potassium is absorbed during the later half of the vegetative phase (Twyford and Walmsley, 1973). Under limited potassium supply, the highest potassium uptake rate occurs during the first half of the vegetative phase and is redistributed within the plant (Vorm and Diest, 1982) to allow further accumulation of dry matter. Timing of fertilizer application was studied by Obiefuna (1984) and shown that early applications were critical and when the first application was delayed by 3 months, recovery from nutritional stress was inhibited and a delay of 6 months resulted in a reduction in yield by 42 per cent. Potassium have a special effect on the maturation process (Fox, 1989). Ram and Prasad (1989) opined that the banana plants showed a positive response to the combined application of nutrients than when applied separately. Robinson and Sauco (2010) stated that K accumulates in the plant and not leached easily, K is to be given in less frequent application but with larger quantities each time and phosphorus is applied as basal prior to planting.

From isotopic studies conducted by Kotur (2007) it was reported that application of nitrogen in four splits at early vegetative, late vegetative, flower bud initiation and shooting stages ensured maximum utilization of applied fertilizer in banana. More of nitrogen and potassium are required for its growth and production as compared to phosphorus.

2.5 NUTRIENT UPTAKE OF BANANA

The knowledge of nutrient uptake, transport and distribution with in plants is required to improve their uptake and utilization efficiency. In addition, nutrient source and method of application are also important for improving crop yields and nutrient use efficiency. Martin-Prevel (1987) reported that the nutrient uptake of a Grand Nain banana producing 69 t ha^{-1} was 293, 69 and 1325 kg ha^{-1} of N, P and K respectively. The mineral composition of the leaves is a consequence of factors that influence the absorption, long distance transport and distribution within plant parts (Fageria *et al*., 1997; Epstein and Bloom, 2005). The remobilization of nutrients is particularly important during the reproductive phase, when fruits are formed. At this stage, the root activity usually decays as a result of the decrease in supply of carbohydrates by sink competition (Marschner, 1995; Fageria *et al*., 2006). Translocation of nutrients in fruit bearing plants is very important in the various physiological processes, such as growth and development, ripening and senescence (Epstein and Bloom, 2005; Fageria *et al*., 2006).

Moreira and Fageira (2009) studied the yield, uptake and retranslocation of nutrients in banana plants cultivated in upland soil of central Amazonian region and found that the uptake of macronutrients was in the order K > N > Calcium (Ca) > Magnesium (Mg) and P and micronutrients in the order of Manganese (Mn) > iron (Fe) > Boron (B) > Zinc (Zn) > Copper (Cu). They also opined that N, P, K, Mg and Cu have a high translocation rate inside the plant compared to other nutrients. For unit dry matter production, high land banana take up similar amount of N, half the amount of P and five times the amount of K compared to cereals (Nyombi *et al*., 2010). The uptake, translocation and perhaps assimilation of cations and anions by plants depend not only on the concentration and availability of these ions in the nutrient medium but also on the presence of other cations and anions (Ahumuza *et al*., 2015).

In banana, regardless of the cultivars, soil or climate, amount of total nitrogen uptake by the plant is closely related to total dry matter production (Lahav, 1995). Uptake of K depends on soil K concentration and ontogenic stage of the plant and there is a maximum soil level above which no more K is absorbed. This level is determined by climate, growth rate, root vigour, soil water stress, disease and over or under supply of other cations (Robinson and Sauco, 2010). Kuttimani *et al*. (2013) reported that the growth and yield parameters and nutrient uptake of Grand Nain banana were conspicuously higher in integrated nutrient management practice as compared to chemical fertilizers alone. Banana needs 78 kg N, 0.72–1.5 kg P_2O_5 and 17–20 kg K_2O t^{-1} yield (Biswas and Kumar, 2014).

2.6 EFFECT OF NUTRIENTS ON QUALITY OF BANANA

In high value crops like banana, quality standards have become the most important factor influencing monetary yield. The quality attributes of ripe fruit are mainly influenced by the genotype and nutritional status of the soil (Roy and Chakraborty, 1993). Improvement in fruit quality of banana due to nitrogen and potassium nutrition has been observed by Srinivas *et al.* (2001). Application of K_2O at 600 g $plant^{-1}$ yielded better quality with increased sugars, pulp: peel ratio and shelf life in Njalipoovan (*Musa* AB.) and the TSS and total sugars in ripe fruits increased with increasing doses of nitrogen and potassium (Indira, 2003). Kumar *et al.* (2008) reported that nitrogen and potassium nutrition influenced the quality of banana fruits. Application of 300 g each of N and K resulted in maximum TSS and total sugars and minimum acid in Rasthali Pathkapoora (AAB).

2.7 NUTRIENT CONCENTRATION OF INDEX LEAF OF BANANA

Leaf analysis is an ideal approach to diagnose nutritional disorders and to adjust time of application mainly in perennial plants. The critical concentration of different nutrients varied among different parts at different stages of growth. Hewitt (1955) showed that N, P and K contents were the highest in the third leaf from the top at the time of shooting and selected it as the index part for nutrient analysis and for establishing the ranges and critical values for leaf nutrients. Elements absorbed in excessive quantities could reduce plant yield directly through toxicity, or indirectly by reducing the concentration of other nutrients below critical range. Though nutrient concentrations in soils and leaves may be poorly related (Turner *et al*., 1989), using both soil and plant tests may help in assessing the dose as well as time of application of nutrients (Delvaux *et al*., 1987).

Hewitt (1955) reported that 2.6 per cent N in the leaf is adequate for banana, while Murray (1961) showed that <1.5 per cent nitrogen is designated as deficient for banana. Bhangoo *et al.* (1962) obtained highest yield in Giant Cavendish banana grown in Honduras with 2.8 per cent nitrogen. Ramaswamy and Muthukrishna (1974) reported a level of 3.3 per cent N to be optimum in Robusta banana. Maximum NPK contents in leaf were recorded in a treatment receiving 100 per cent recommended dose of fertilizer along with organic booster slurry (Ziauddin, 2009). Mahendran *et al.* (2013) reported that for obtaining higher yield in banana, it was desirable to maintain more than 3.90, 0.38 and 4.50 per cent NPK, respectively in leaf at shooting stage.

Results obtained by Jambulingam *et al*. (1975) suggested that leaf K should be above 4.3 per cent for optimum production. Later work by Arunachalam *et al.* (1976) showed that adequate levels of nutrient in banana leaf ranged from 3.18–3.43, 0.46–0.54, 3.36–3.76, 2.3–2.4 and 0.25– 0.28 per cent for N, P, K, Ca and Mg, respectively. Ram and Prasad (1988) observed an increasing trend in content of nitrogen upto flowering in banana. According to Ray *et al.* (1988), NPK content of 2.8, 0.52 and 3.8 per cent respectively, in leaf at shooting was a good indicator for satisfactory productivity in Robusta banana.

Many workers have proposed different critical levels of nutrients in third leaf of banana which range from 1.80 to 4.0 per cent for N, 0.17 to 0.29 per cent for P (Angeles *et al*., 1993). Weerasinghe *et al*. (2004) showed the need to maintain nitrogen content in the lamina of the third youngest leaf at 3.5 per cent at five months of age (early vegetative stage), and at 3.0 per cent during the rest of the growth cycle, to obtain high yields in 'Kolikuttu' banana. Memon *et al.* (2010) reported a level of 1.66 to 5.40 per cent for K for realizing optimum yield. To aid practical application there is a need to correlate nutritional composition of leaf with fruit yield on the basis of extensive nutritional surveys of orchards and comprehensive field experiments.

2.8 NUTRIENT- MOISTURE INTERACTION IN BANANA

Nutrient-moisture interaction is a key factor that determines the productivity of banana. But the research on the relations between nutrient and moisture is very limited. Soil moisture plays an important role in the uptake of nutrients. Mahouachi (2007) studied the effects of progressive water stress and subsequent rehydration on fruit growth and mineral nutrient content in Grand Nain under field conditions and found that the main effect of drought is reduced potassium levels. However, all the other minerals either increased (calcium, sodium, iron and zinc), or remained stable (nitrogen, phosphorus, magnesium, manganese and copper) under the drought. But after re-hydration, the nutrient content of banana fruit was similar between stressed and non-stressed plants proved the ability of banana to maintain relatively normal nutrient contents and functional fruit tissues, which continued to expand after rehydration, despite the long period of water stress. Banana has low potentiality to take water and nutrients from deep soil layers due to shallow root system particularly, when there were water stress and conditions of high evaporation (Robinson and Villiers, 2007). The percentage of leaf nutrient content (N, P and K) was not significantly affected by moisture treatments (El-Khawaga, 2013a).

Ahmed *et al*. (2011) indicated that in Grand Nain banana, the best nutrient use efficiency was obtained under 120 per cent crop evapotranspiration (ETc) under drip irrigation due to more uniform soil moisture distribution and high uptake of nutrients. Maia and de Morais (2015) estimated the critical levels for soil chemical attributes through the criterion of reduced continuous probability distribution in irrigated banana cultivation and evaluated soil fertility of low-yield areas and it was concluded that the method can be used to obtain critical levels for soil chemical attributes and the critical levels corresponded to 7.2 for pH, 0.91 g kg^{-1} for N, 0.31, 6.34, 2.63, 1.42 and 25.76 mg kg^{-1} for Cu, Fe, Mn, Zn and P, respectively, and 6.43, 1.14, 0.24 and 0.36 cmol kg^{-1} for Ca, Mg, Na and K, respectively. They also noted that in the low-yield areas, the highest deficiencies were of P and Fe and excess of Mg.

Hedge and Srinivas (1989) revealed that irrigation and nitrogen fertility influences plant water relations, biomass, and nutrient accumulation and distribution in banana cv. Robusta. They opined that decreasing frequency of irrigation resulted in decreased evapotranspiration (ET) but increased N concentration in the dry matter and the water use efficiency (WUE). Effects of irrigation frequency on P, K, Ca and Mg concentrations in the dry matter were fairly small and varied with plant part and time of sampling, and there seemed to be no evidence that infrequent irrigation reduced yields *via* a restriction in supply of these nutrients. Increasing N application had no significant effect on plant water relations but resulted in increased biomass accumulation, yield, ET and WUE although the difference between application rates of 200 and 300 g N $plant^{-1}$ was not conspicuous. Several researchers reported that soil water deficit and nitrogen changed the relationship between fruit growth and green life. Nitrogen promoted growth but soil water deficit reduced it, however both promoted ripening (Srikul and Turner, 1995). Costa *et al.* (2012) evaluated the vegetative growth, yield variables and the accumulation of potassium in the aerial part of the banana cultivar Galil 18, under different irrigation and potassium levels in the coastal tablelands of Bahia state of Brazil and revealed that potassium doses did not significantly affect growth and production variables. Irrigation water depth had a significant effect on the height and diameter of the pseudostem, number of fruits per bunch, yield and water use efficiency. They also opined that pseudostem is the largest K repository in banana plants.

Nutrient moisture interaction on duration of the crop was investigated by different scientists. The total crop duration was strongly influenced by nutrient management practices and the shorter crop duration might be due to the higher net assimilation rate on account of better growth leading to the production of endogenous metabolites earlier in optimum level enabling early flower bud initiation and there by early shooting in banana (Hazarika and Ansari, 2010).

2.9 PHENOLOGICAL INFLUENCE ON BANANA

The term phenology refers to the vegetative and reproductive development cycles of a plant as determined by climate particularly temperature (Robinson and Sauco, 2010). Banana is a semi-perennial crop with nearly a year long crop cycle under optimum conditions and even longer with lower temperatures or more erratic water supply. The vulnerability of the crop to climate change is an important consideration, demanding specific tools suited to banana growth habit and crop cycle (Calberto *et al*., 2015).

The season of planting of banana vary with cultivars and agro-climatic conditions. Banana is day neutral for floral induction, but photoperiods of less than 12 hours are associated with a slowing in the rate of bunch initiation. This may contribute to seasonal variations in banana flowering (Turner *et al.*, 2007). Ramteke *et al*. (1996) reported the use of thermal units approach for quantifying the thermal relation of crops and this had been further modified to include photothermal units and heliothermal units (Rao *et al*., 1999). The photothermal unit concept provides a reliable index for the progress of the crop that can be used to predict the yield of any crop. Growing degree days (GDD), photothermal units (PTU) and heliothermal units (HTU) can be used as tool for predicting the phenology of the crop.

The concept of GDD is that plant development occur when temperature exceed a base temperature and cease when a non-lethal maximum temperature is exceeded. GDD assigns a heat value to each day, then the values are added together to give an estimate of the plant seasonal growth. Day neutral plants do not depend on photoperiod for floral induction (Lincoln *et al*., 1982). If photoperiod does not influence bunch initiation then the development of the plant can be described by GDD which can be demonstrated in planting date experiments where, for each planting date the GDD from planting to bunch emergence is expected to be the same, other things being equal. However, Turner and Hunt (1987) pointed out that for banana cv. 'Williams' (AAA, Cavendish subgroup) growing in the subtropics, the GDD was not the same for three different planting dates suggesting some other factor, perhaps photoperiod, was involved in bunch initiation. Singh and Singh (2015) reported that accumulated growing degree day (AGDD), accumulated heliothermal units (AHTU) and accumulated photothermal units (APTU) can be quiet useful in predicting phenology of a crop.

E-H (bunch emergence to harvest) intervals varied from 108 days (December flowering) to 200 days (April/May flowering). Stover (1979) reported that days from flowering to harvest varied from 98 to 117 in Grand Nain banana and the growth rate averaged 1.0 cm day^{-1}, going as high as 1.4 cm in June-September, and as low as 0.4 cm in November-January. Banana leaf emergence rate was greatest (3 leaves $month^{-1}$) in the summer. The interval between flower emergence and harvest varied from 120 days for flowers emerging in November to 180-220 days for autumn emerging flowers.

Ganry and Sioussaram (1978) found that 900 degree days is needed between shooting and harvest (the threshold temperature being 14 ^{0}C). Kuhne, (1980) observed average monthly leaf emergence rate and average number of days from flower emergence to harvest (E-H interval) in each month for Dwarf Cavendish bananas at Burgershall and Levubu. Total leaf number per year was 1.8 more at Levubu, associated with higher temperature during the summer months. E-H intervals varied throughout the year, but were shorter at Levubu, especially for bunches emerging during February, March and April. Influence of different time of planting as well as temperature on phenology and yield of crop plants can be studied under field conditions through the accumulated heat units system (Shanker *et al*., 1996).

The productivity of banana is based on temperature and available water. The effect of weather on leaf emergence rate was studied by several scientists. It was observed that leaf emission rate increase by 10 leaves year^{-1} only in the sites with abundant water year round. In sites with longer dry season, LER was only 4-6 leaves year^{-1}. The increased temperature that is associated with faster leaf emission rate will also be associated with an increased water demand of 10-15 per cent. Robinson (1981) reported that leaf emergence rate month^{-1} was closely correlated with average minimum monthly temperature, varying between 3 in summer and 1 in winter. LER increased from less than 0.5 leaves month^{-1} in July to 4 leaves month^{-1} in February, these changes being related to mean monthly temperature.

Robinson and Nel (1985) studied the comparative morphology, phenology and production potential of banana cultivars 'Dwarf Cavendish' and 'Williams' in the Eastern Transvaal lowveld. The results revealed that significant seasonal differences were recorded in leaf emergence rates (LER) and flower emergence to harvest intervals (E-H) for both cultivars. LER increased from less than 0.5 leaves month^{-1} in July to 4 leaves month^{-1} in February, these changes being related to mean monthly temperature. E-H intervals varied from 108 days (December flowering) to 200 days (April/May flowering). In Williams, flowering in late August induced a bunch mass increase of 47 per cent compared with flowering two months later followed a different pattern which differed with the cultivars similarities noted for LER and E-H intervals.

Flower emergence to harvest duration (E-H) is the main reproductive index of banana development. Stover (1979) reported that the E-H for Grand Nain was 98 days for hot weather fruit development and 117 days for cool weather development. Yadav *et al.* (2011) reported that summer planting of banana gives high yield, good quality and high local market prices from an autumn/winter harvest. Unlike other fruits, the vegetative growth, flowering and fruit growth is not seasonal in banana and are largely influenced by time of planting, type and size of planting material and prevailing temperature.

Baiyeri (2008) studied the phenotypic relationships of *Musa* genotypes and found out that pre flowering plant growth had stronger relationship with bunch weight only in low yielding (LY) genotypes while foliage traits of plants at flowering were more associated with bunch weight in high yielding (HY) genotypes.

Tixier *et al*. (2004) developed a cohort population model for long-term simulation of banana crop harvest in Grand Nain. The model is based on two linear chains of cohorts characterized by both physiological age (heat unit accumulation) and development-stage dispersion in the banana population due to flowering, harvesting and sucker selection. It can accurately predict temporally-varying banana harvesting dynamics (date and number of harvested bunches) and the harvesting peak was predicted with a precision less than 3 weeks for the first 3 cropping cycles.

Rose (1966) reported the harvesting time in banana for fruit emerging in June, July, September, November and December, and found that the time taken to reach maturity was related to the number of heat units received during the maturation period. Morse *et al*. (1996) calculated the heat units above 14 °C in six banana cultivars (*Musa* AAA; Cavendish subgroup) in a warm subtropical climate and found out that heat units required from planting to flowering and from flowering to harvest were 2152 and 1388, respectively. Ganry and Chillet (2008) found out a methodology to forecast the harvest date of banana bunches by drawing a curve of the temperature sum accumulated by the bunches which have to be harvested at exactly 900 degree days physiological age. Sangudom *et al.* (2014) reported that the growing degree days from flower bloom to harvesting in winter, summer and rainy seasons were 918-1008, 676-731 and 613-690 Celsius degree days, respectively in 'Kluai Khai' banana.

Sam (2011) studied the developmental physiology of banana corm (*Musa* AAB Nendran) in relation to phenology and yield and found that June planting gave the highest yield. The study also revealed that April followed by February and August planting had the highest girth while June planting followed by April and October recorded more height. Yadav *et al*. (2011) reported the response of planting season on growth and yield characteristics of banana cultivars under subtropical conditions of Lucknow and found that the optimum planting time were May, June and July and the ideal cultivars were Grand Nain and Dwarf Cavendish, respectively. El-Khawaga (2013b) reported that planting in the middle of February took minimum days to shooting and harvesting for Williams banana under Aswan region conditions while mid-March planted crop recorded maximum productivity.

Shaun and Ferris (1997) stated that in tropics at ambient temperature, banana have an average market life of 1 to 10 days depending on genotype, maturity stage at harvest and storage and handling conditions. Bugaud *et al*. (2007) opined that daily temperature and cumulated rainfall should be taken into account when assessing the quality of banana. The shelf life can be green life and yellow life stages in banana. The Cavendish group has a longer green life and shorter yellow life stage while other groups have the reverse (Narayana, 2015). The fully mature Cavendish banana has a shelf life of 6-9 days depending upon the ambient temperature.

The above literature review envisaged that the studies on agro meteorological aspects of banana are limited and hence more research might be done on these aspects. This will be useful for the prediction of growth, yield and duration of banana under the climate changing scenario.

3. MATERIALS AND METHODS

The present investigation entitled "Nutrient and moisture optimization in banana (*Musa* AAA. Grand Nain)" was undertaken with the objectives to standardize the nutrient and irrigation schedule for Grand Nain banana, to study the phenology of the crop in relation to various agro-meteorological parameters and to work out the economics.

The investigation comprised two separate experiments. The first experiment was on nutrient - moisture interaction study and the second on phenology study of Grand Nain banana. The first experiment was conducted for two years from June 2014 to May 2016 and the second experiment was conducted from January 2014 to December 2015. Both the experiments were conducted in the Instructional Farm attached to College of Agriculture, Vellayani.

The details of materials used and methods adopted for the study are described below.

3.1 MATERIALS

3.1.1 Experimental Site

The experiment was laid out in the D block of 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 and at an altitude of 19 m above mean sea level (Plate 1).

3.1.2 Soil

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

Plate 1. Location of the experimental field

Table 1. Mechanical composition and physical characteristics of the soil

Particulars	Value	Method adopted
A. Mechanical composition		
Coarse sand (%)	16.92	International pipette method (Piper, 1967)
Fine sand (%)	30.52	
Silt (%)	23.85	
Clay (%)	27.81	
Textural class	Sandy clay loam	
B. Soil physical characteristics		
Particulars	**Soil depth (0-30 cm)**	**Method adopted**
Particle density (Mg m^{-3})	2.59	Pycnometer method (Black, 1965)
Bulk density (Mg m^{-3})	1.45	Core method (Gupta and Dakshinamoorthi, 1980)
Porosity (%)	43.00	
Maximum water holding capacity (%)	30.26	
Field capacity (%)	21.90	Pressure plate membrane apparatus (Dastane, 1967)
Permanent wilting point (%)	9.30	

Table 2. Chemical characteristics of soil prior to experiment

Particulars	Value	Rating	Method adopted
Soil reaction (pH)	4.80	Extremely acidic	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (dS m^{-1})	0.08	Safe	Digital conductivity meter (Jackson, 1973)
Organic C (%)	0.45	Low	Walkley and Black rapid titration method (Jackson, 1973)
Available N (kg ha^{-1})	351.23	Medium	Alkaline Permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	213.05	High	Bray's colorimetric method (Jackson, 1973)
Available K (kg ha^{-1})	195.28	Medium	Ammonium acetate method (Jackson, 1973)

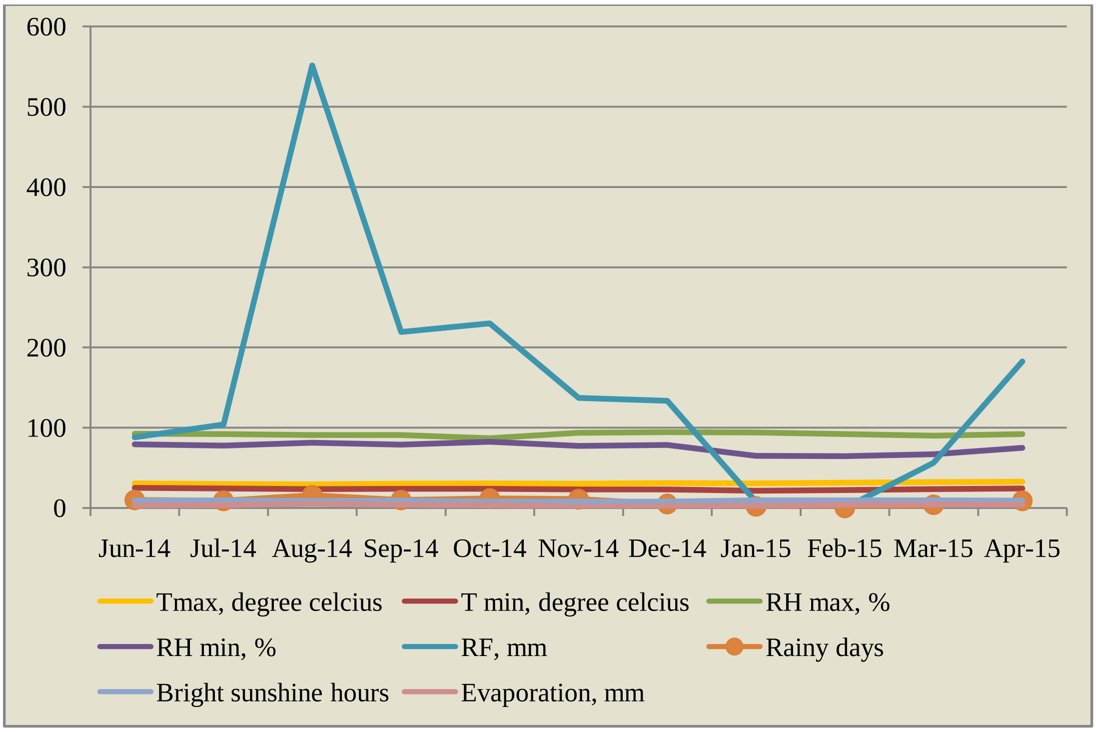

Fig. 1a. Weather parameters during first year (2014-15) - Experiment – I

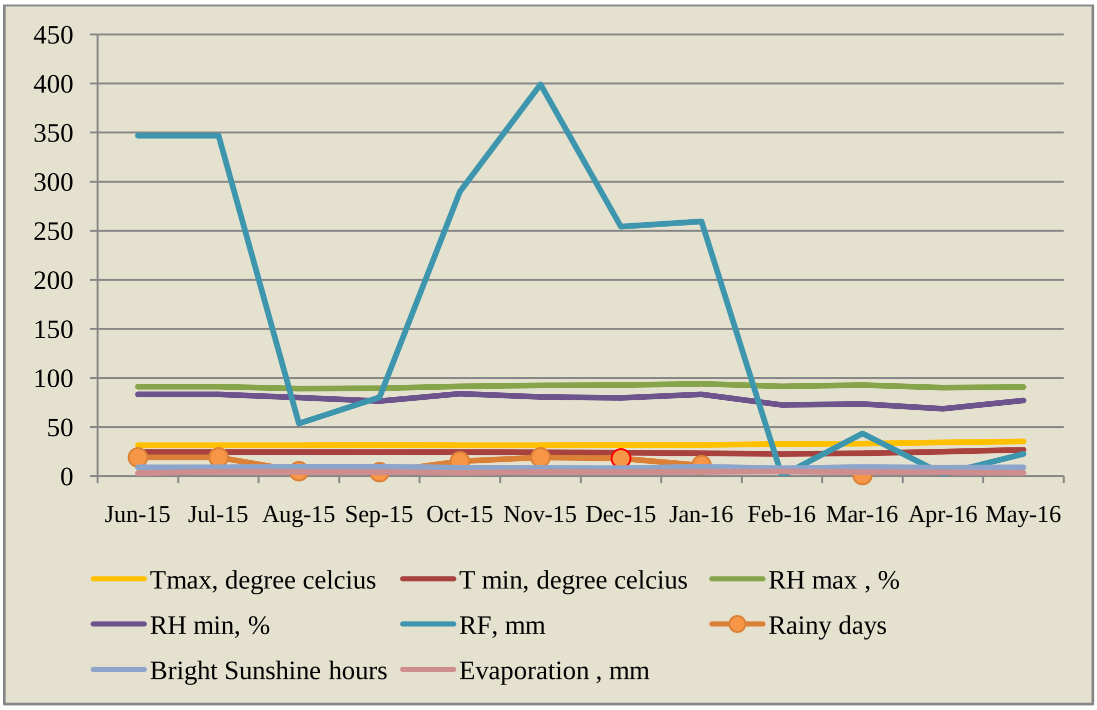

Fig. 1b. Weather parameters during second year (2015-16) - Experiment – I

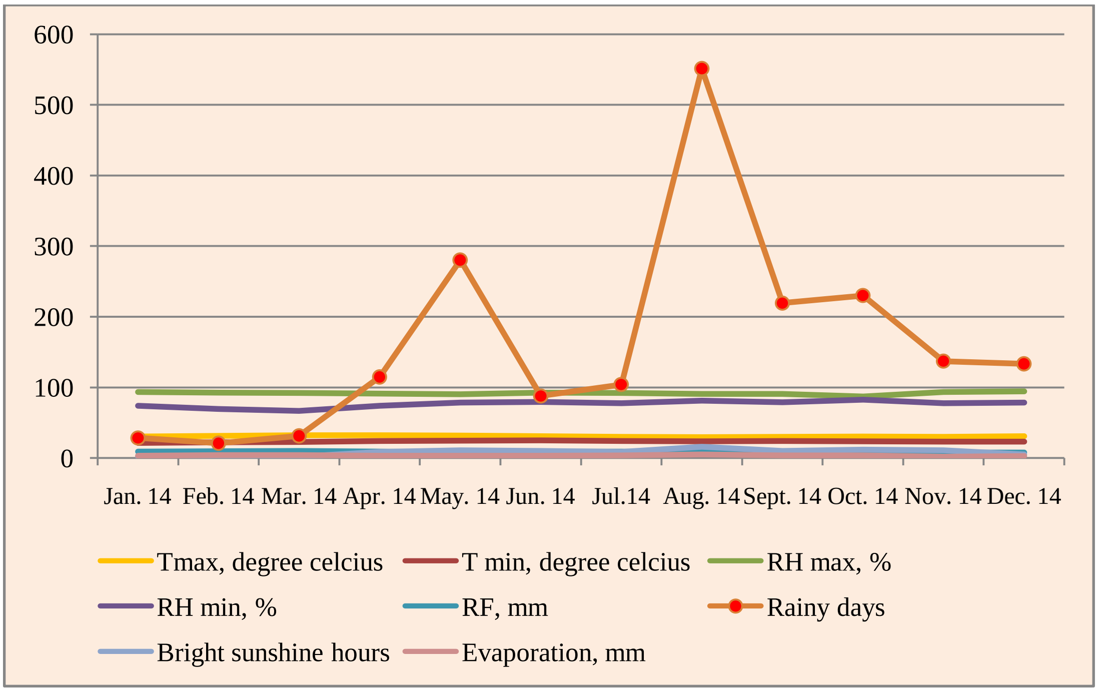

Fig. 2a. Weather parameters during the year 2014- Experiment – II

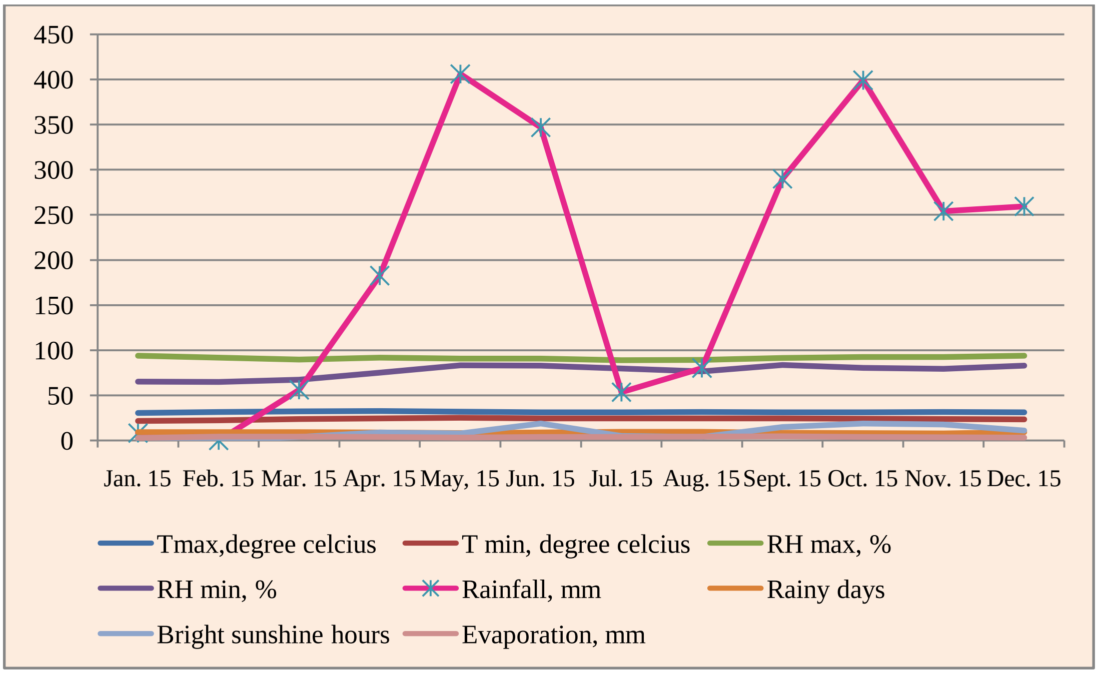

Fig. 2b. Weather parameters during the year 2015- Experiment – II

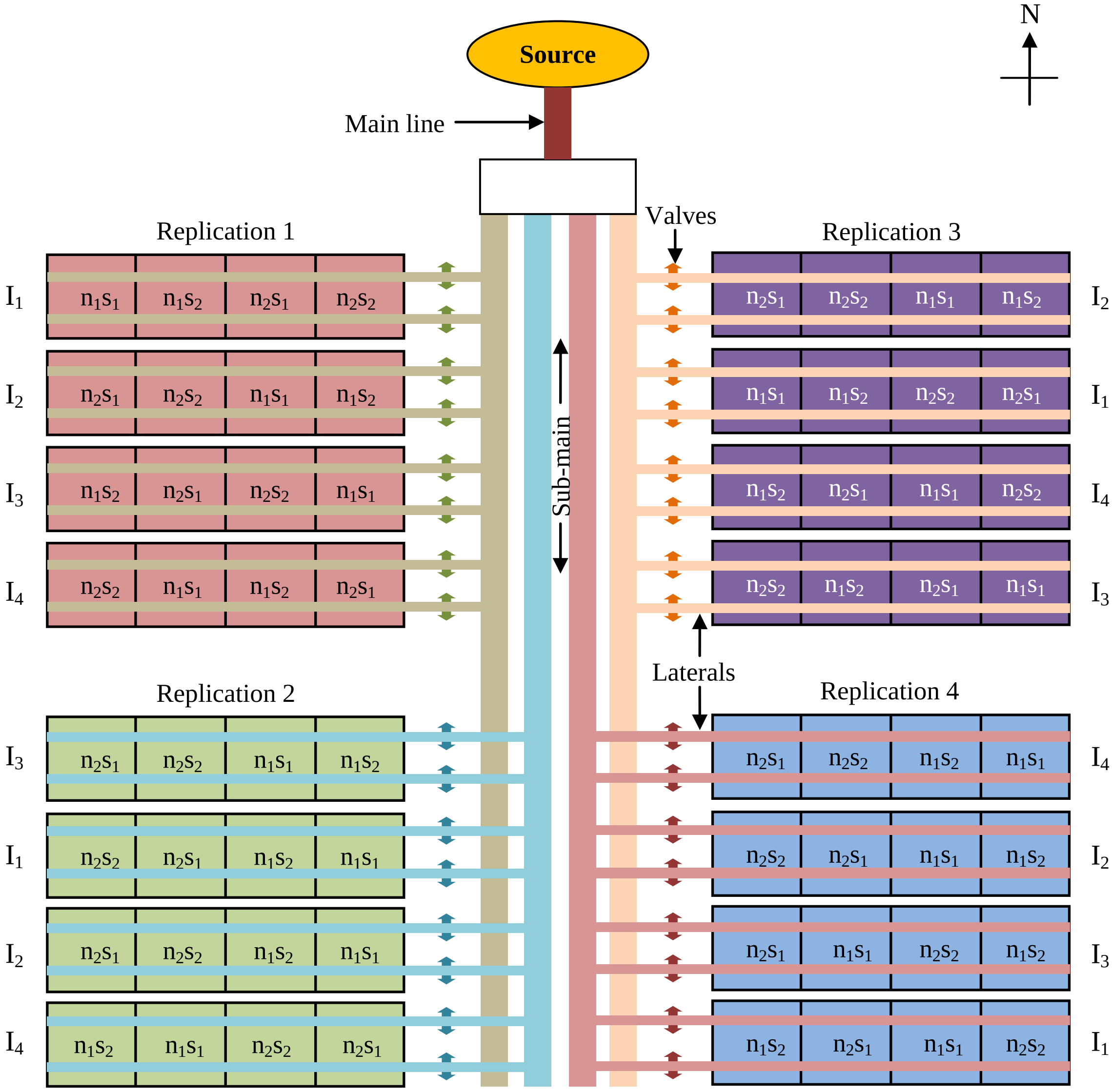

Fig. 3a. Layout plan of Experiment – I

3.1.3 Cropping History

Vegetable cowpea was the previous crop of the experimental field.

3.1.4 Season

The first experiment was conducted from June 2014 to April 2015 and repeated from June 2015 to May 2016. Second experiment was conducted from January 2014 to December 2015.

3.1.5 Weather Conditions

The data on weather parameters (monthly rainfall, number of rainy days $month^{-1}$, maximum temperature, minimum temperature, relative humidity, evaporation and sunshine hours) during the cropping period are presented in Fig. 1a to 2b and Appendix 1 and II.

During the period of first experiment on “Nutrient - moisture interaction study in banana cv. grand nain”, the mean maximum temperature ranged between 35.3 ^{o}C and 29.5 ^{o}C and mean minimum temperature ranged between 26.6 ^{o}C and 21.6 ^{o}C. While the mean maximum relative humidity (RH) ranged from 94 to 87 per cent, the mean minimum RH ranged from 84 to 65 per cent. The average evaporation ranged from 1.3 to 6.8 mm day^{-1}. A total of 1711 and 2098 mm rainfall with 88 and 111, number of rainy days, respectively were recorded during first and second year.

During the period of second experiment on “Studies on phenology of banana cv. Grand Nain”, the mean maximum temperature ranged between 32.7^{o}C and 29.5 ^{o}C and mean minimum temperature ranged between 25.3 ^{o}C and 21.5 ^{o}C. While the mean, maximum relative humidity (RH) ranged from 94 to 87 per cent, the minimum RH ranged from 84 to 67 per cent. The average evaporation ranged from 1.7 to 5.1 mm day^{-1}.

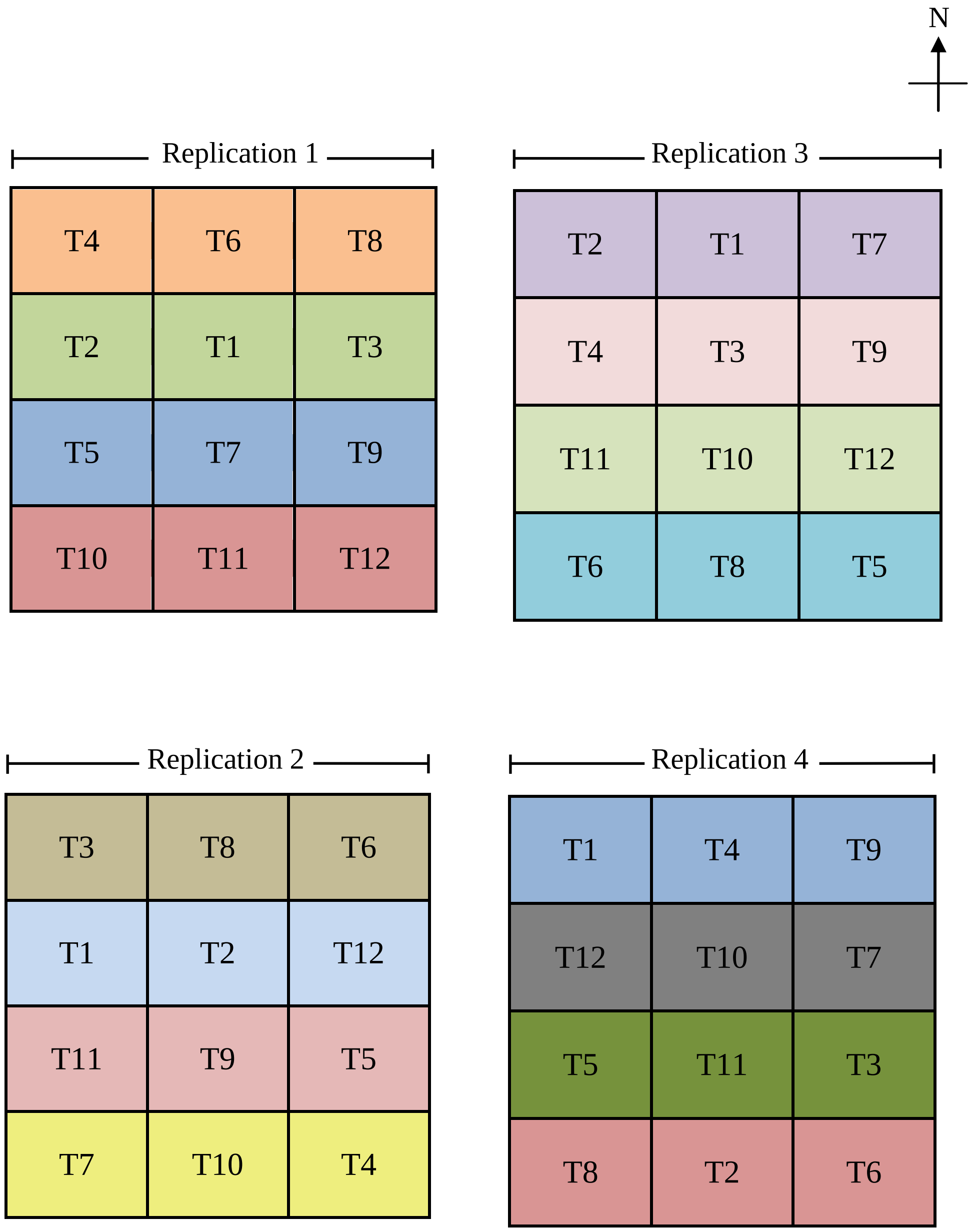

Fig. 3b. Layout plan of Experiment – II

Plate 2. General view – Experiment - I

Plate 3. Field preparation and planting – Experiment - I

Plate 4. Experiment - I: Initial stage

Plate 5. Experiment – I: Active vegetative stage

Plate 6. Experiment – I: Reproductive stage

3.1.6 Planting Material

Tissue culture plants of Grand Nain banana procured from the Biotechnology and Model Floriculture Centre, Kazhakkoottam, Thiruvananthapuram, Kerala were used as the planting material.

3.1.7 Manures and Fertilizers

Farm yard manure (FYM) (0.52 per cent N, 0.20 per cent P_2O_5 and 0.48 per cent K_2O) was used as organic source. Urea (46 per cent N), Rajphos (20 per cent P_2O_5) and Muriate of potash (60 per cent K_2O) were used as the sources of N, P and K respectively.

3.2 METHODS

3.2.1 Experiment 1. Nutrient-moisture Interaction Study in Banana cv. Grand Nain

3.2.1.1 Experimental Design and Layout

Layout plan of the experiment is presented in Fig. 3a. The details of the experiment techniques are described below.

Design	: Split plot
Replication	: 4
Treatments	: 16
Plot size	: 3.6 m x 3.6 m
Spacing	: 1.8 m x 1.8 m
No. of plants per plot	: 4

3.2.1.2 Treatments

3.2.1.2.1 Main Plot Treatments

Irrigation levels (I) - 4

I_1 : Irrigation at IW/CPE ratio of 0.4

I_2 : Irrigation at IW/CPE ratio of 0.6

I_3 : Irrigation at IW/CPE ratio of 0.8

I_4 : Irrigation at IW/CPE ratio of 1.0

3.2.1.2.2 Sub Plot Treatments

Four combinations of two nutrient levels (N) and two time of applications (S)

Nutrient levels (N) - 2

N_1: 212: 50: 332 g N: P_2O_5: K_2O plant^{-1} year^{-1} [KAU, POP recommendation of 200: 200: 400 g N: P_2O_5: K_2O plant^{-1} year^{-1} for varieties other than Nendran was modified based on soil test values (KAU, 2011)]

N_2: 160: 40: 640 g N: P_2O_5: K_2O plant^{-1} year^{-1} (Based on nutrient uptake values of banana cv. Grand Nain)

Time of Application (S) – 2

S_1: N and K in 2 equal splits [2 and 4 months after planting (MAP)]

S_2: N and K in 4 equal splits [2, 3, 4 and 5 MAP]

Treatment combinations - 16 (4x4)

T_1- $i_1n_1s_1$	T_9 - $i_3n_1s_1$
T_2- $i_1n_1s_2$	T_{10}- $i_3n_1s_2$
T_3- $i_1n_2s_1$	T_{11}- $i_3n_2s_1$
T_4- $i_1n_2s_2$	T_{12}- $i_3n_2s_2$
T_5 $i_2n_1s_1$	T_{13}- $i_4n_1s_1$
T_6- $i_2n_1s_2$	T_{14}- $i_4n_1s_2$
T_7- $i_2n_2s_1$	T_{15}- $i_4n_2s_1$
T_8- $i_2n_2s_2$	T_{16}- $i_4n_2s_2$

3.2.2 Experiment II. Studies on Phenology of Banana cv. Grand Nain

Layout plan of the experiment is presented in Fig. 3b. The details of the experiment techniques are described below.

3.2.2.1 Experimental Design and Layout

Design : Randomized Block Design

Replication : 4

Treatments	: 12
Plot size	: 3.6 m x 3.6 m
Spacing	: 1.8 m x 1.8 m
No. of plants per plot	: 4

3.2.2.2 Treatments

Dates of planting : 12
(Planting was done on 28th of every month of the year 2014)

T_1	: January
T_2	: February
T_3	: March
T_4	: April
T_5	: May
T_6	: June
T_7	: July
T_8	: August
T_9	: September
T_{10}	: October
T_{11}	: November
T_{12}	: December

3.3 CULTIVATION PRACTICES OF BANANA

3.3.1 Field Preparation and Planting

The land was ploughed twice with garden tiller and weeds and stubbles were removed from the field. Pits of 50 cm x 50 cm x 50 cm size were dug at a spacing of 1.8 m x 1.8 m and tissue culture plants were planted in the pits. Shade was provided for one month for the proper establishment of tissue culture plants (Plates 2 to 6).

3.3.2 Application of Lime, Manures and Fertilizers

Lime was applied @ 250 g pit^{-1} two weeks before planting. Farm yard manure was applied uniformly to all the pits at the time of planting @ 15 kg

Plate 7. General view – Experiment - II

plant^{1}. Entire phosphorus (P) was given as basal and nitrogen (N) and potash (K) in split doses as per the treatments.

In second experiment, studies on phenology of banana cv. Grand Nain fertilizers were applied to supply 212:50:332 g N: P_2O_5: K_2O plant^{-1} year^{-1}. Phosphorus was given as basal and nitrogen and potash were applied in equal splits at 2 and 4 months after planting.

3.3.3 Irrigation

Uniform irrigation was given to all plants upto one MAP. Afterwards irrigation was scheduled based on IW/ CPE ratios of 0.4, 0.6, 0.8 and 1.0. Drip irrigation was practised for the crop and depth of irrigation adopted was 30 mm. Daily evaporation was added and whenever the cumulative pan evaporation readings reached 75, 50, 37.5, and 30 mm the irrigation was given. These CPE values correspond to 0.4, 0.6, 0.8 and 1.0 IW/CPE ratio. Based on the growth stages and basin area the quantity of water required for each plant per irrigation was calculated and the same was applied at respective IW/CPE ratio. The details are given in Appendix IV and V.

In the second experiment, the crop was raised as rainfed except the initial irrigation given upto 1 MAP for the establishment of the crop (Plate 7). However, in long intervals of dry spell life saving irrigation was provided.

3.3.4 Weeding

Weed free condition was maintained throughout the growth period by periodic intercultivation.

3.3.5 Trashing

The dried and senescent leaves were removed at periodic intervals.

3.3.6 Desuckering

The side suckers were removed till the emergence of bunch.

3.3.7 Plant Protection

Sigatoka leaf spot disease was prevalent in the crop during both seasons. The same was controlled by removing the infected leaves and spraying propiconazole @ 0.1 per cent and carbendazim 50 per cent WP alternatively. Disease incidence (DI) of Sigatoka leaf spot was calculated as percentage of plants affected in a population. Disease Severity Index (DSI) was estimated using Gauhl's formula (2002) modified from Stover (1970) and presented in Appendix III.

$$DSI = \frac{\sum n\, b}{(N-1)T} \times 100$$

where,

n = Number of leaves in each grade

b = Grade

N = Number of grades used in the scale

T = Total number of leaves scored.

Incidence of banana bract mosaic disease was noticed towards the end of the second year. The disease incidence (DI) and per cent disease index (PDI) were recorded and scoring of the disease was done using a 0-4 scale and the PDI was calculated by the method suggested by Mayee and Datar (1986).

$$PDI = \frac{\text{Sum of individual grades}}{\text{Number of plants assessed}} \times \frac{100}{\text{Maximum grade}}$$

No pest was observed during the period of investigation.

3.3.8 Propping

The plants were tied with rope after the emergence of bunch.

3.4 OBSERVATIONS

3.4.1 Experiment I. Nutrient - Moisture Interaction Study in Banana cv. Grand Nain

3.4.1.1 Crop Growth Characters

Crop growth characters were recorded from the observational plants at 4 MAP, 6 MAP and at harvest.

3.4.1.1.1 Height of Pseudostem

The height of pseudostem was measured from the base of the stem at the soil level to the axil of the youngest unopened leaf and expressed in cm.

3.4.1.1.2 Girth of Pseudostem

The girth of pseudostem was measured at 20 cm above the ground level by taking the circumference of the pseudostem and expressed in cm.

3.4.1.1.3 Number of Functional Leaves

The total number of fully opened functional leaves of the plant were counted and recorded.

3.4.1.1.4 Total Functional Leaf Area

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

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

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

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

3.4.1.1.5 Leaf Area Index

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

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

3.4.1.1.6 Leaf Area Duration

Leaf area duration was worked out by the formula (Power *et al.*, 1967), expressed in days.

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

where,

LAI_1 = Leaf area index at the first stage

LAI_2 = Leaf area index at the second stage

$t_2 - t_1$ = Time interval between the first and second stages (days)

3.4.1.1.7 Phyllochron

It was calculated by counting the average number of days between successive leaf emergence and expressed in days.

3.4.1.1.8 Duration for Bunch Emergence

Number of days taken from planting till opening of all bracts was recorded.

3.4.1.1.9 Duration for Bunch Emergence to Harvest

Number of days taken from bunch emergence to harvest was recorded.

3.4.1.1.10 Total Crop Duration

Number of days taken from planting to harvest was recorded.

3.4.1.1.11 Sucker Production after Bunch Emergence

Number of suckers from each plant was counted at harvest.

3.4.1.1.12 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 65 ^oC till attain constant dry weight and expressed in g $plant^{-1}$ and kg ha^{-1}.

3.4.1.2 Yield Attributes and Yield

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

3.4.1.2.1 Bunch Characters

3.4.1.2.1.1 Bunch Weight

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

3.4.1.2.1.2 Yield

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

3.4.1.2.1.3 Length of Bunch

Length of the bunch was measured from the point of attachment of the first hand to that of the last hand and expressed in cm.

3.4.1.2.1.4 Hands Bunch^{-1}

The number of hands in each bunch of the observational plant was counted and recorded.

3.4.1.2.1.5 Fingers Bunch^{-1}

The total number of fingers in each bunch of the observational plant was counted and recorded.

3.4.1.2.1.6 Fingers in the D-hand

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

3.4.1.2.2 Finger Characters

3.4.1.2.2.1 Weight of D-finger

The middle finger in the top row of the second hand 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 g.

3.4.1.2.2.2 Length of D-finger

Length 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.

3.4.1.2.2.3 Girth of D-finger

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

3.4.1.2.2.4 Pulp to Peel Ratio

The weight of pulp and peel of index finger was determined separately and the ratio was worked out.

3.4.1.3 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.

3.4.1.3.1 Total Soluble Solids

The Total Soluble Solids (TSS) was estimated using a hand refractometer and expressed in degree brix (^{0}B).

3.4.1.3.2 Titrable Acidity

Acidity was measured using titration method suggested by Ranganna (1977) and an aliquot from the sample was titrated against 0.1 Normal Sodium Hydroxide and expressed as per cent anhydrous citric acid.

3.4.1.3.3 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.

3.4.1.3.4 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*.4.1.3.5 Non Reducing Sugars*

Non reducing sugar was computed using the following formula (Ranganna, 1977) and expressed in per cent.

Non reducing sugars = Total sugars – Reducing sugars

3.4.1.3.6 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.

3.4.1.3.7 Ascorbic acid

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

3.4.1.4 Shelf Life at Ambient Conditions

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

3.4.1.5 Total Water Requirement, Water Use Efficiency and Water Productivity

Total water requirement in each treatment was calculated directly by adding up the quantity of water required for irrigation, the quantity of effective rainfall and moisture contribution from soil profile. Moisture contribution from soil profile was not considered in the present calculation as the water table is below 2 m depth from soil surface.

Total water requirement = Irrigation requirement + Effective rainfall

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

Water use efficiency (WUE) was worked out using the formula suggested by Viets, 1962 and expressed as kg ha mm^{-1}.

$$\text{WUE} = \frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Total water requirement (mm)}}$$

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

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

3.4.1.6 Soil Analysis

After the harvest of first and second crop of banana, soil samples were collected from individual plots of the experimental area and analysed for organic carbon, N, P and K as per the standard procedures mentioned in Table 2.

3.4.1.7 Plant Chemical Analysis

The plant parts were separately analyzed for nutrient content.

3.4.1.7.1 Nutrient Content (N, P and K) in the Index Leaf at 4 MAP

Leaf lamina of index leaf at 4 MAP 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 65 ^{o}C till constant weight was obtained. The samples were analyzed for N, P and K contents. The procedure adopted for the chemical analysis is given in Table 3.

Table 3. Plant nutrient status estimation

Particulars	**Method used**	**Reference**
N (%)	Modified micro kjeldahl method	(Jackson, 1973)
P (%)	Vanado-molybdo phosphoric yellow colour method using spectrophotometer	(Jackson, 1973)
K (%)	Flame photometry method	(Jackson, 1973)

3.4.1.7.2 Nutrient Content and Uptake of Nutrients (N, P and K) at Harvest

The sample plant was separated into rhizome, pseudostem, leaves and fruits. They were chopped and dried separately in a hot air oven at 65 ^{o}C till constant weights were obtained. The samples were analysed for N, P and K in each plant part as per the method in Table 3. Uptake of nutrients at harvest was calculated from the values of dry matter content and per cent nutrient content of each plant part and expressed as kg ha^{-1}.

3.4.1.8 Economic Analysis

3.4.1.8.1 Cost of Cultivation

Cost of cultivation under different irrigation and nutrient levels were calculated and expressed in ₹ ha^{-1} and is presented in Appendix VI.

3.4.1.8.2 Gross Income

Gross income was calculated on the basis of market price of the produce and expressed in ₹ ha^{-1}.

3.4.1.8.3 Net Income

Net income was calculated by subtracting cost of cultivation from gross income and is expressed in ₹ ha^{-1}.

3.4.1.8.4 Benefit Cost Ratio (BCR)

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

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

3.4.1.9 Statistical Analysis

The data was analyzed statistically by applying the techniques of analysis of variance (Gomez and Gomez, 1984). Wherever the effects were found to be significant, critical differences were given for effecting comparison among the mean. The Correlation of yield with growth and yield parameters were also computed.

3.4.2 Experiment II: Studies on Phenology of Banana cv. Grand Nain

3.4.2.1 Crop Growth Characters

The observations given in 3.4.2.1.1 to 3.4.2.1.7 were recorded for this experiment at 4 MAP, 6 MAP and at harvest using the same procedure mentioned in experiment I of the study.

3.4.2.1.1 Height of Pseudostem

3.4.2.1.2 Girth of Pseudostem

3.4.2.1.3 Number of Functional Leaves Plant^{-1}

3.4.2.1.4 Total Functional Leaf Area Plant^{-1}

3.4.2.1.5 Leaf Area Index

3.4.2.1.6 Leaf Area Duration

3.4.2.1.7 Duration for Bunch Emergence

3.4.2.2 Leaf Emergence Rate Month^{-1}

Leaf Emergence Rate (LER) was obtained by painting the midrib of the youngest fully emerged leaf at the beginning of each month for identification. Monthly LER was the number of fully opened leaves emerging between two painting dates.

3.4.2.3 Date of Onset of Different Phenophases

The duration of vegetative and reproductive phases and total crop duration were recorded in days.

3.4.2.4 Yield and Yield Attributes

Yield and yield attributes were recorded as per 3.4.1.2.

3.4.2.5 Quality Characters of Ripe Fruit

Quality characters were recorded as per 3.4.1.3 and 3.4.1.4.

3.4.2.6 Agro-meteorological Observations

3.4.2.6.1 Meteorological Parameters

a. Maximum and minimum temperature (^{o}C)
b. Rainfall (mm)
c. Relative humidity (per cent)
d. Length of day/ bright sunshine hours
e. Pan evaporation (mm)

Daily reading of each meteorological parameter recorded in the class B Agromet observatory attached to College of Agriculture, Vellayani was used for the computation of the crop-weather parameters and the monthly mean values are presented in Appendix I and II.

3.4.2.6.2 Computed Parameters

The following parameters were computed in this study.

a. Growing degree days (Heat units)
b. Photothermal units (PTU)
c. Heliothermal units (HTU)
d. Heat use efficiency (HUE)

3.4.2.6.2.1 Growing Degree Days (Heat Units)

Growing degree days (GDD)/ heat units was calculated by employing the following formula (Iwata, 1984). The base temperature of banana was taken as 14 ^{o}C (Kurien, 2004).

$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base}$$

where ,

T_{max} = Daily maximum temperature (^{o}C) during a day

T_{min} = Daily minimum temperature (^{o}C) during a day

T_{base} = Minimum base temperature (^{o}C)

Accumulated growing degree day (AGDD) is obtained by GDD added on a daily basis for each phase and expressed in ^{o}C d.

3.4.2.6.2.2 Photothermal Units

Photothermal units (PTU) was calculated by using the equation given by Wilsie (1962) and expressed in ^{o}C d h.

$$PTU = GDD \times L$$

where,

GDD = Growing degree days

L = Maximum possible sunshine hours (Doorenbos and Pruitt, 1975)

Accumulated Photothermal units (APTU) were calculated as the sum of the individual PTU over different phenophases.

3.4.2.6.2.3 Heliothermal Units

The product of growing degree days and corresponding actual sunshine hours for that day was termed as heliothermal units (Rajput, 1980).

$$HTU = GDD \times \text{Actual sunshine hours}$$

Accumulated HTU (AHTU) was calculated as the sum of the individual HTU values for the different phenophases and expressed in ^{o}C d h.

3.4.2.6.2.4 Heat Use Efficiency (HUE)

Heat use efficiency was calculated as growing degree days required to produce dry matter per unit area (Rajput, 1980) and expressed in g m^{-2} $^{o}C^{-1}$ d^{-1}.

$$\text{Heat Use Efficiency} = \frac{\text{Dry matter per unit area (g m}^{-2}\text{)}}{\text{GDD (}^{o}\text{C d)}}$$

3.4.2.7 Statistical Analysis

The data was analysed statistically by applying the techniques of analysis of variance (Gomez and Gomez, 1984). Correlation analysis of yield with growth, yield attributes and weather parameters were also done.

4. RESULTS

The present investigation "Nutrient and moisture optimization in banana (*Musa* AAA. Grand Nain)" was undertaken with the objectives to standardize the nutrient and irrigation schedule of Grand Nain banana, to study its phenology in relation to various agro-meteorological parameters and to work out the economics. The investigation comprised two separate experiments. The first experiment, "Nutrient - moisture interaction study" was conducted for two consecutive years from June 2014 to May 2016. The second experiment, "Phenology study of Grand Nain banana" was conducted from January 2014 to December 2015. The experimental data collected were analysed statistically and the results are presented in this chapter.

4.1 EXPERIMENT – 1. NUTRIENT - MOISTURE INTERACTION STUDY IN BANANA CV. GRAND NAIN

4.1.1 Growth Characters

The data generated on growth characters as influenced by different levels of irrigation and nutrients during the years are presented below. The growth characters were recorded at 4 and 6 months after planting (MAP) and at harvest.

4.1.1.1 Pseudostem Height (cm)

A critical appraisal of data during both the years revealed that the treatments significantly influenced the plant height at all stages of growth. The data are presented in Tables 4a and 4b.

During first year, at 4 MAP, pseudostem height was not influenced by irrigation levels. But at 6 MAP and at harvest, irrigation levels significantly influenced the plant height and the plants were the tallest in irrigation at 1.0 IW/CPE (I_4) and it was on par with irrigation at 0.8 IW/CPE (I_3) at 6 MAP. At harvest stage irrigation at 0.6, 0.8 and 1.0 IW/CPE (I_2, I_3 and I_4) were on a par and the shortest plants were in irrigation at 0.4 IW/CPE (I_1) during all stages of growth.

Table 4a. Effect of irrigation and nutrient schedule on the pseudostem height of Grand Nain banana, cm

Treatments	**4 MAP**		**6 MAP**		**At harvest**	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
Irrigation levels (I)						
I_1	158.44	81.13	242.38	196.13	249.63	202.19
I_2	162.06	89.31	254.38	203.44	262.94	209.94
I_3	164.75	96.44	258.06	215.63	265.00	222.06
I_4	165.75	98.13	266.19	220.81	272.63	226.81
SEm (±)	2.352	2.263	3.274	3.135	3.324	3.074
CD (0.05)	NS	7.240	10.477	10.033	10.637	9.838
Nutrient levels (N)						
N_1	154.22	85.84	248.78	194.56	255.59	201.13
N_2	171.28	96.66	261.72	223.44	269.5	229.38
SEm (±)	1.845	1.385	2.271	1.999	2.660	1.977
CD (0.05)	5.295	3.974	6.520	5.736	7.634	5.673
Time of application (S)						
S_1	160.25	88.53	254.38	205.66	261.69	211.94
S_2	165.25	93.97	256.13	212.34	263.41	218.56
SEm (±)	1.845	1.385	2.271	1.999	2.660	1.977
CD (0.05)	NS	3.974	NS	5.736	NS	5.673
I x N interaction						
i_1n_1	148.75	76.50	236.00	181.88	241.75	187.75
i_1n_2	168.13	85.75	248.75	210.38	257.50	216.63
i_2n_1	153.13	82.50	246.63	187.50	256.13	194.50
i_2n_2	171.00	96.13	262.13	219.38	269.75	225.38
i_3n_1	157.25	92.75	253.88	201.75	259.13	208.88
i_3n_2	172.25	100.13	262.25	229.50	270.88	235.25
i_4n_1	157.75	91.63	258.63	207.13	265.38	213.38
i_4n_2	173.75	104.63	273.75	234.50	279.88	240.25
SEm (±)	3.693	2.772	4.547	4.000	5.324	3.956
CD (0.05)	NS	NS	NS	NS	NS	NS
N x S interaction						
n_1s_1	148.63	81.94	246.00	190.50	252.50	197.00
n_1s_2	159.81	89.75	251.56	198.63	258.69	205.25
n_2s_1	171.88	95.13	262.75	220.81	270.88	226.88
n_2s_2	170.69	98.19	260.69	226.06	268.13	231.88
SEm (±)	2.611	1.960	3.215	2.828	3.764	2.797
CD (0.05)	7.488	NS	NS	NS	NS	NS

NS- not significant

Table 4b. Interaction effect of irrigation and nutrient schedule on the pseudostem height of Grand Nain banana, cm

Treatments	4 MAP		6 MAP		At harvest	
	I year	II year	I year	II year	I year	II year
I x S interaction						
i_1s_1	155.38	78.00	239.63	192.88	248.125	198.88
i_1s_2	161.50	84.25	245.13	199.38	251.125	205.50
i_2s_1	158.88	84.88	252.38	200.38	261.125	206.75
i_2s_2	165.25	93.75	256.38	206.50	264.75	213.13
i_3s_1	163.38	94.13	259.50	211.88	265.25	218.63
i_3s_2	166.13	98.75	256.63	219.38	264.75	225.50
i_4s_1	163.38	97.13	266.00	217.50	272.25	223.50
i_4s_2	168.13	99.13	266.38	224.13	273.00	230.13
SEm (±)	3.693	2.772	4.547	4.000	5.324	3.956
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	142.00	72.00	231.00	178.75	237.5	184.25
$i_1n_1s_2$	155.50	81.00	241.00	185.00	246.00	191.25
$i_1n_2s_1$	168.75	84.00	248.25	207.00	258.75	213.50
$i_1n_2s_2$	167.50	87.50	249.25	213.75	256.25	219.75
$i_2n_1s_1$	148.25	75.00	244.00	184.50	251.00	191.50
$i_2n_1s_2$	158.00	90.00	249.25	190.50	261.25	197.50
$i_2n_2s_1$	169.50	94.75	260.75	216.25	271.25	222.50
$i_2n_2s_2$	172.50	97.50	263.50	222.50	268.25	228.75
$i_3n_1s_1$	153.00	89.75	252.00	196.00	258.25	203.00
$i_3n_1s_2$	161.50	95.75	255.75	207.50	260.00	214.75
$i_3n_2s_1$	173.75	98.50	267.00	227.75	272.25	234.25
$i_3n_2s_2$	170.75	101.75	257.50	231.25	269.50	236.25
$i_4n_1s_1$	151.25	91.00	257.00	202.75	263.25	209.25
$i_4n_1s_2$	164.25	92.25	260.25	211.50	267.50	217.50
$i_4n_2s_1$	175.50	103.25	275	232.25	281.25	237.75
$i_4n_2s_2$	172.00	106	272.5	236.75	278.50	242.75
SEm (±)	5.222	3.919	6.430	5.657	7.529	5.594
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

A perusal of data on second year revealed the superiority of irrigation levels 1.0 IW/CPE (I_4) and 0.8 IW/CPE (I_3) over the other two levels at all stages of growth.

The nutrient levels significantly influenced plant height at all stages of growth during both the years and nutrient application based on uptake of nutrients (N_2) produced the tallest plants and was significantly superior to POP based application (N_1) at all growth stages during both the years. The time of application did not influence the plant height during first year. However during second year, application of fertilizer in 4 splits (S_2) produced the tallest plants and was significantly superior to fertilizer application in 2 splits (S_1).

The interaction of nutrient levels and time of application significantly influenced the plant height at 4 MAP during first year. The nutrient application based on uptake of nutrients in two splits (n_2s_1) and four splits (n_2s_2) recorded the highest plant height (171.88 and 170.69 cm) and were significantly superior to POP based application. However, the N x S interaction was not significant in other stages and also during second year.

The other interactions (I x N, I x S, I x N x S) were not significant during both the years.

4.1.1.2 Girth of Pseudostem (cm)

A critical appraisal of data at both the years revealed that the girth of pseudostem was influenced by the treatments and are summarized in Tables 5a and 5b.

Irrigation levels significantly influenced the pseudostem girth at all stages of growth. At 4 and 6 MAP, irrigation at 0.8 and 1.0 IW/CPE recorded higher girth and were on par and significantly superior to other two levels of irrigation. Irrigation at 1.0 IW/CPE (I_4) recorded the highest girth at harvest during first year, while during the second year it was on a par with the irrigation at 0.8

Table 5a. Effect of irrigation and nutrient schedule on the pseudostem girth of Grand Nain banana, cm

Treatments	4 MAP		6 MAP		At harvest	
	I year	II year	I year	II year	I year	II year
Irrigation levels (I)						
I_1	51.75	30.25	69.69	61.81	73.69	65.56
I_2	51.56	29.00	72.13	63.00	76.13	66.53
I_3	53.56	32.38	74.38	65.00	77.94	68.81
I_4	54.13	35.25	76.06	67.19	80.75	71.19
SEm (±)	0.815	1.245	0.778	0.817	0.822	0.783
CD (0.05)	2.609	3.985	2.490	2.612	2.629	2.505
Nutrient levels (N)						
N_1	50.88	29.84	69.66	61.16	73.78	64.89
N_2	54.63	33.59	76.47	67.34	80.47	71.15
SEm (±)	0.620	0.599	0.665	0.684	0.711	0.701
CD (0.05)	1.780	1.719	1.910	1.962	2.041	2.012
Time of application (S)						
S_1	52.03	31.34	72.00	63.41	76.03	67.14
S_2	53.47	32.09	74.13	65.09	78.22	68.91
SEm (±)	0.620	0.599	0.665	0.684	2.041	0.701
CD (0.05)	NS	NS	1.910	NS	0.711	NS
I x N interaction						
i_1n_1	49.75	29.13	65.63	58.38	69.25	62.13
i_1n_2	53.75	31.38	73.75	65.25	78.13	69.00
i_2n_1	50.00	27.63	68.38	59.50	72.88	63.06
i_2n_2	53.13	30.38	75.88	66.50	79.38	70.00
i_3n_1	52.00	30.38	71.38	63.00	75.13	66.75
i_3n_2	55.13	34.38	77.38	67.00	80.75	70.88
i_4n_1	51.75	32.25	73.25	63.75	77.88	67.63
i_4n_2	56.50	38.25	78.88	70.63	83.63	74.75
SEm (±)	1.242	1.199	1.332	1.368	1.423	1.403
CD (0.05)	NS	NS	NS	NS	NS	NS
N x S interaction						
n_1s_1	48.50	28.44	67.13	59.31	71.13	62.97
n_1s_2	53.25	31.25	72.19	63.00	76.44	66.81
n_2s_1	55.56	34.25	76.88	67.50	80.94	71.31
n_2s_2	53.69	32.94	76.06	67.19	80.00	71.00
SEm (±)	0.878	0.848	0.942	0.967	1.006	0.992
CD (0.05)	2.517	2.431	2.700	2.774	2.886	2.846

NS- not significant

Table 5b. Interaction effect of irrigation and nutrient schedule on pseudostem girth of Grand Nain banana, cm

Treatments	4 MAP		6 MAP		At harvest	
	I year	II year	I year	II year	I year	II year
I x S interaction						
i_1s_1	50.75	30.50	67.50	60.25	71.63	64.00
i_1s_2	52.75	30.00	71.88	63.38	75.75	67.12
i_2s_1	50.38	28.38	70.88	61.50	75.25	65.06
i_2s_2	52.75	29.63	73.38	64.50	77.00	68.00
i_3s_1	52.88	30.63	74.00	64.63	76.75	68.38
i_3s_2	54.25	34.13	74.75	65.38	79.13	69.25
i_4s_1	54.13	35.88	75.63	67.25	80.50	71.13
i_4s_2	54.13	34.63	76.50	67.13	81.00	71.25
SEm (±)	1.242	1.199	1.332	1.368	1.423	1.403
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	47.00	28.25	62.25	56.25	65.75	59.75
$i_1n_1s_2$	52.50	30.00	69.00	60.5	72.75	64.50
$i_1n_2s_1$	54.50	32.75	72.75	64.25	77.50	68.25
$i_1n_2s_2$	53.00	30.00	74.75	66.25	78.75	69.75
$i_2n_1s_1$	47.50	27.25	65.75	57.50	70.00	61.13
$i_2n_1s_2$	52.50	28.00	71.00	61.50	75.75	65.00
$i_2n_2s_1$	53.25	29.50	76.00	65.50	80.50	69.00
$i_2n_2s_2$	53.00	31.25	75.75	67.50	78.25	71.00
$i_3n_1s_1$	49.25	27.25	69.50	61.25	72.50	65.00
$i_3n_1s_2$	54.75	33.50	73.25	64.75	77.75	68.50
$i_3n_2s_1$	56.50	34.00	78.50	68.00	81.00	71.75
$i_3n_2s_2$	53.75	34.75	76.25	66.00	80.50	70.00
$i_4n_1s_1$	50.25	31.00	71.00	62.25	76.25	66.00
$i_4n_1s_2$	53.25	33.50	75.50	65.25	79.50	69.25
$i_4n_2s_1$	58.00	40.75	80.25	72.25	84.75	76.25
$i_4n_2s_2$	55.00	35.75	77.50	69.00	82.50	73.25
SEm (±)	1.756	1.695	1.883	1.935	2.013	1.984
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

IW/CPE (I_3). At all stages, irrigation scheduled at 0.4 and 0.6 IW/CPE were on par and registered lower girth during both the years.

The nutrient levels significantly influenced the pseudostem girth at all stages of growth during both the years and was the highest in application based on uptake of nutrients (N_2) and was significantly superior to POP based application (N_1) at all growth stages during both the years.

The time of application (S) did not influence the pseudostem girth at 4MAP during first year. However the application of fertilizer in four splits (S_2) recorded the highest girth (74.13 and 78.22 cm) and was superior to application in two splits (S_1) at 6 MAP and at harvest. But during second year, the time of application was not significant.

The interaction of nutrient levels and time of application significantly influenced the pseudostem girth and nutrient application based on uptake of nutrients in two splits (n_2s_1) recorded the highest girth and it was on a par with nutrient application based on the uptake of nutrients in four splits (n_2s_2) at all stages of growth during both the years. During first year it was also on par with POP based application in four splits (n_1s_2) at 4 MAP. The pseudostem girth was the lowest in POP based application in 2 splits (n_1s_1) and was significantly inferior to all other combinations.

The other interactions (I x N, I x S, I x N x S) were not significant during both the years.

4.1.1.3 Number of Functional Leaves

The analysed data are presented in Tables 6a and 6b.

Irrigation scheduled at 1.0 IW/CPE (I_4) recorded the highest number of functional leaves during both the years of experimentation and irrigation scheduled at 0.4 IW/CPE recorded the lowest number and inferior to other three levels of irrigation.

Table 6a. Effect of irrigation and nutrient schedule on the number of functional leaves plant^{-1} of Grand Nain banana

Treatments	4 MAP		6 MAP		At harvest	
	I year	II year	I year	II year	I year	II year
Irrigation levels (I)						
I_1	10.31	9.94	9.56	9.88	5.31	5.00
I_2	11.44	10.19	10.38	11.63	6.38	6.06
I_3	11.63	11.88	10.69	11.75	7.00	5.88
I_4	11.94	12.13	11.13	11.94	7.88	6.38
SEm (±)	0.215	0.356	0.144	0.209	0.225	0.287
CD (0.05)	0.687	1.141	0.462	0.667	0.719	0.919
Nutrient levels (N)						
N_1	11.03	10.34	9.69	11.00	6.09	5.44
N_2	11.63	11.72	11.19	11.59	7.19	6.22
SEm (±)	0.136	0.183	0.142	0.163	0.207	0.162
CD (0.05)	0.391	0.525	0.406	0.467	0.595	0.467
Time of application (S)						
S_1	11.22	10.91	10.47	11.28	6.69	5.56
S_2	11.44	11.16	10.41	11.31	6.59	6.09
SEm (±)	0.136	0.183	0.142	0.163	0.207	0.162
CD (0.05)	NS	NS	NS	NS	NS	0.467
I x N interaction						
i_1n_1	10.00	9.25	9.13	9.63	5.00	4.75
i_1n_2	10.63	10.63	10.00	10.13	5.63	5.25
i_2n_1	11.13	9.38	9.63	11.50	5.88	5.75
i_2n_2	11.75	11.00	11.13	11.75	6.88	6.38
i_3n_1	11.25	11.38	9.88	11.38	6.38	5.38
i_3n_2	12.00	12.38	11.50	12.13	7.63	6.38
i_4n_1	11.75	11.38	10.13	11.50	7.13	5.88
i_4n_2	12.13	12.88	12.13	12.38	8.63	6.88
SEm (±)	0.273	0.366	0.283	0.326	0.415	0.326
CD (0.05)	NS	NS	NS	NS	NS	NS
N x S interaction						
n_1s_1	10.69	10.06	9.63	10.81	5.94	5.19
n_1s_2	11.38	10.63	9.75	11.19	6.25	5.69
n_2s_1	11.75	11.75	11.31	11.75	7.44	5.94
n_2s_2	11.50	11.69	11.06	11.44	6.94	6.50
SEm (±)	0.193	0.259	0.200	0.230	0.293	0.230
CD (0.05)	0.553	NS	NS	NS	NS	NS

NS- not significant

Table 6b. Interaction effect of irrigation and nutrient schedule on the on number of functional leaves plant^{-1} of Grand Nain banana

Treatments	4 MAP		6 MAP		At harvest	
	I year	II year	I year	II year	I year	II year
I x S interaction						
i_1s_1	10.13	9.75	9.38	9.88	5.25	4.75
i_1s_2	10.50	10.13	9.75	9.88	5.38	5.25
i_2s_1	11.38	10.25	10.38	11.63	6.38	5.88
i_2s_2	11.50	10.13	10.38	11.63	6.38	6.25
i_3s_1	11.50	11.63	10.88	11.88	7.00	5.50
i_3s_2	11.75	12.13	10.50	11.63	7.00	6.25
i_4s_1	11.88	12.00	11.25	11.75	8.13	6.13
i_4s_2	12.00	12.25	11.00	12.13	7.63	6.63
SEm (±)	0.273	0.366	0.283	0.326	0.415	0.326
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	9.50	9.00	9.00	9.50	4.75	4.50
$i_1n_1s_2$	10.50	9.50	9.25	9.75	5.25	5.00
$i_1n_2s_1$	10.75	10.50	9.75	10.25	5.75	5.00
$i_1n_2s_2$	10.50	10.75	10.25	10.00	5.50	5.50
$i_2n_1s_1$	10.75	9.25	9.50	11.25	5.75	5.50
$i_2n_1s_2$	11.50	9.50	9.75	11.75	6.00	6.00
$i_2n_2s_1$	12.00	11.25	11.25	12.00	7.00	6.25
$i_2n_2s_2$	11.50	10.75	11.00	11.50	6.75	6.50
$i_3n_1s_1$	11.00	11.00	10.00	11.50	6.00	5.00
$i_3n_1s_2$	11.50	11.75	9.75	11.25	6.75	5.75
$i_3n_2s_1$	12.00	12.25	11.75	12.25	8.00	6.00
$i_3n_2s_2$	12.00	12.50	11.25	12.00	7.25	6.75
$i_4n_1s_1$	11.50	11.00	10.00	11.00	7.25	5.75
$i_4n_1s_2$	12.00	11.75	10.25	12.00	7.00	6.00
$i_4n_2s_1$	12.25	13.00	12.50	12.50	9.00	6.50
$i_4n_2s_2$	12.00	12.75	11.75	12.25	8.25	7.25
SEm (±)	0.386	0.518	0.401	0.461	0.587	0.460
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

Applied nutrient levels exerted significant effect on the number of functional leaves at all stages of growth during both the years. Nutrient application based on uptake of nutrients (N_2) recorded the highest number of functional leaves and was significantly superior to the POP based application (N_1) at all growth stages during both the years except at four MAP during second year. The time of application (S) did not influence the number of functional leaves during first year, while during second year, the application of fertilizer in four splits (S_2) recorded more number of leaves than two splits (S_1) application.

The interaction between nutrient levels and time of application significantly influenced the number of functional leaves at 4 MAP during first year. The nutrient application based on the uptake of nutrients in 2 splits (n_2s_1) recorded the highest number of functional leaves (11.75) and was significantly superior to POP based application in two splits (n_1s_1).

The other interactions were not significant during both the years.

4.1.1.4 Total Functional Leaf Area (m^2)

Total functional leaf area at 4 and 6 MAP and at harvest during both the years are presented in Tables 7a and 7b.

The irrigation levels had significant influence on the total functional leaf area. During both the years, at 4 MAP irrigation scheduled at 0.8 and 1.0 IW/CPE (I_3 and I_4) were on a par and significantly superior to the other two levels of irrigation. But at 6 MAP and at harvest, irrigation scheduled at 1.0 IW/CPE (I_4) recorded the highest functional leaf area during both the years and significantly superior to other three levels of irrigation.

The nutrient levels significantly influenced leaf area at all stages of growth. Nutrient application based on uptake of nutrients (N_2) recorded the highest functional leaf area and significantly superior to the POP based application (N_1) at all growth stages during both the years. The time of application (S) had no significant influence except at harvest during second year, where application of

Table 7a. Effect of irrigation and nutrient schedule on the total functional leaf area plant^{-1} of Grand Nain banana, m^2

Treatments	4 MAP		6 MAP		At harvest	
	I year	II year	I year	II year	I year	II year
Irrigation levels (I)						
I_1	5.75	2.11	13.10	11.24	8.33	6.01
I_2	6.68	3.03	14.71	12.66	10.31	8.22
I_3	7.09	4.09	15.65	13.13	11.55	8.73
I_4	7.58	4.49	17.45	14.81	13.22	10.09
SEm (±)	0.269	0.236	0.376	0.460	0.391	0.334
CD (0.05)	0.860	0.756	1.202	1.472	1.250	1.069
Nutrient levels (N)						
N_1	6.11	2.97	13.84	11.98	9.40	7.28
N_2	7.44	3.90	16.62	13.94	12.31	9.24
SEm (±)	0.155	0.142	0.285	0.234	0.354	0.262
CD (0.05)	0.444	0.407	0.819	0.671	1.015	0.753
Time of application (S)						
S_1	6.62	3.40	14.85	12.86	10.92	7.76
S_2	6.93	3.46	15.61	13.06	10.78	8.76
SEm (±)	0.155	0.142	0.285	0.234	0.354	0.262
CD (0.05)	NS	NS	NS	NS	NS	0.753
I x N interaction						
i_1n_1	5.13	1.59	12.45	10.03	7.49	5.14
i_1n_2	6.36	2.62	13.76	12.46	9.17	6.88
i_2n_1	6.07	2.50	13.55	12.08	8.82	7.28
i_2n_2	7.30	3.57	15.88	13.25	11.80	9.15
i_3n_1	6.41	3.78	14.30	12.64	9.98	7.72
i_3n_2	7.76	4.40	17.00	13.62	13.12	9.74
i_4n_1	6.82	4.00	15.05	13.18	11.30	8.99
i_4n_2	8.34	4.99	19.85	16.44	15.14	11.18
SEm (±)	0.310	0.284	0.571	0.468	0.708	0.525
CD (0.05)	NS	NS	1.637	NS	NS	NS
N x S interaction						
n_1s_1	5.60	2.76	13.26	11.48	8.85	6.82
n_1s_2	6.62	3.17	14.41	12.48	9.94	7.75
n_2s_1	7.63	4.04	16.43	14.24	12.99	8.70
n_2s_2	7.25	3.75	16.81	13.65	11.63	9.78
SEm (±)	0.219	0.201	0.404	0.331	0.500	0.371
CD (0.05)	0.628	NS	NS	0.948	1.435	NS

NS- not significant

Table 7b. Interaction effect of irrigation and nutrient schedule on the total functional leaf area plant^{-1} of Grand Nain banana, m^2

Treatments	4 MAP		6 MAP		At harvest	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
I x S interaction						
i_1s_1	5.51	2.05	12.94	11.01	8.18	5.55
i_1s_2	5.98	2.17	13.27	11.47	8.47	6.47
i_2s_1	6.60	3.17	14.08	12.75	10.33	7.81
i_2s_2	6.77	2.90	15.34	12.58	10.29	8.62
i_3s_1	6.91	3.99	15.16	13.17	11.67	8.07
i_3s_2	7.26	4.20	16.14	13.09	11.43	9.39
i_4s_1	7.44	4.41	17.21	14.50	13.50	9.62
i_4s_2	7.72	4.57	17.70	15.12	12.94	10.56
SEm (±)	0.310	0.284	0.571	0.468	0.708	0.525
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	4.58	1.47	12.49	9.29	6.53	4.70
$i_1n_1s_2$	5.69	1.71	12.40	10.76	8.45	5.57
$i_1n_2s_1$	6.45	2.63	13.38	12.73	9.84	6.41
$i_1n_2s_2$	6.27	2.62	14.15	12.18	8.50	7.32
$i_2n_1s_1$	5.57	2.39	12.85	11.95	8.48	6.86
$i_2n_1s_2$	6.57	2.61	14.26	12.20	9.16	7.72
$i_2n_2s_1$	7.63	3.95	15.32	13.54	12.18	8.77
$i_2n_2s_2$	6.97	3.19	16.43	12.95	11.42	9.56
$i_3n_1s_1$	5.93	3.45	13.36	12.39	9.36	7.03
$i_3n_1s_2$	6.90	4.11	15.24	12.88	10.60	8.47
$i_3n_2s_1$	7.89	4.52	16.95	13.95	13.97	9.19
$i_3n_2s_2$	7.63	4.28	17.04	13.29	12.27	10.49
$i_4n_1s_1$	6.32	3.75	14.34	12.29	11.04	8.67
$i_4n_1s_2$	7.32	4.25	15.76	14.06	11.56	9.35
$i_4n_2s_1$	8.57	5.07	20.08	16.71	15.96	10.50
$i_4n_2s_2$	8.12	4.90	19.63	16.17	14.32	11.89
SEm (±)	0.438	0.402	0.808	0.661	1.001	0.742
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

nutrients in four splits (S_2) recorded the highest leaf area (8.76 m^2) and significantly superior to two splits (S_1).

The interaction between nutrient levels and time of application were significant at 4 MAP and at harvest during first year, in second year it was significant at 6 MAP only. Nutrient application based on uptake of nutrients in two splits (n_2s_1) recorded the highest functional leaf area and was significantly superior to POP based application in two splits and four splits (n_1s_1 and n_1s_2) and on a par with nutrient application based on the uptake of nutrients in 4 splits (n_2s_2). During first year, the interaction effects of irrigation and nutrient levels (I x N) were found significant at 6 MAP and the functional leaf area was the highest in i_4n_2 (19.85 m^2) and was found superior to other combinations. The other interactions (I x S and I x N x S) were not significant during both the years.

4.1.1.5 Leaf Area Index (LAI)

The leaf area index (LAI) recorded at 4 and 6 MAP and at harvest during both the years are presented in Tables 8a and 8b.

The LAI varied significantly with irrigation levels at all stages during both the years. At 4 MAP, the LAI recorded at 0.8 and 1.0 IW/CPE (I_3 and I_4) were on par in both the years. But at 6 MAP, the irrigation level of 1.0 IW/CPE (I_4) was significantly superior to the other treatments in first year. However, in second year irrigation levels of 0.8 and 1.0 IW/CPE (I_3 and I_4) were at par. During both years at harvest stage the LAI was the highest (4.08, 3.11) at irrigation level 1.0 IW/CPE (I_4) and was significantly superior to other levels of irrigation.

Nutrient application based on uptake of nutrients (N_2) recorded the highest LAI and was significantly superior to POP based application (N_1) at all growth stages during both the years. However the time of application (S) significantly influenced the LAI at harvest stage during second year of study. The application of nutrients in four splits (S_2) recorded the highest LAI (2.70) and was significantly superior to two splits (S_1).

Table 8a. Effect of irrigation and nutrient schedule on the leaf area index of Grand Nain banana

Treatments	**4 MAP**		**6 MAP**		**At harvest**	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
Irrigation levels (I)						
I_1	1.77	0.65	4.05	3.47	2.57	1.86
I_2	2.06	0.94	4.54	3.91	3.18	2.54
I_3	2.19	1.26	4.83	4.05	3.56	2.69
I_4	2.34	1.39	5.39	4.57	4.08	3.11
SEm (±)	0.083	0.073	0.116	0.142	0.120	0.103
CD (0.05)	0.266	0.232	0.370	0.455	0.385	0.329
Nutrient levels (N)						
N_1	1.89	0.92	4.27	3.70	2.90	2.25
N_2	2.30	1.20	5.13	4.30	3.80	2.85
SEm (±)	0.048	0.044	0.088	0.072	0.109	0.081
CD (0.05)	0.137	0.125	0.253	0.207	0.313	0.232
Time of application (S)						
S_1	2.04	1.05	4.58	3.97	3.37	2.40
S_2	2.14	1.07	4.82	4.03	3.33	2.70
SEm (±)	0.048	0.044	0.088	0.072	0.109	0.081
CD (0.05)	NS	NS	NS	NS	NS	0.232
I x N interaction						
i_1n_1	1.59	0.49	3.84	3.10	2.31	1.59
i_1n_2	1.96	0.81	4.25	3.85	2.83	2.12
i_2n_1	1.87	0.77	4.18	3.73	2.72	2.25
i_2n_2	2.25	1.10	4.9	4.09	3.64	2.82
i_3n_1	1.98	1.17	4.42	3.90	3.08	2.38
i_3n_2	2.40	1.36	5.25	4.20	4.05	3.01
i_4n_1	2.11	1.23	4.65	4.07	3.49	2.78
i_4n_2	2.57	1.53	6.13	5.08	4.67	3.45
SEm (±)	0.096	0.087	0.176	0.144	0.218	0.162
CD (0.05)	NS	NS	0.505	NS	NS	NS
N x S interaction						
n_1s_1	1.73	0.86	4.09	3.54	2.73	2.11
n_1s_2	2.04	0.98	4.45	3.85	3.07	2.39
n_2s_1	2.36	1.25	5.07	4.39	4.01	2.69
n_2s_2	2.24	1.16	5.19	4.21	3.59	3.02
SEm (±)	0.068	0.062	0.125	0.102	0.154	0.115
CD (0.05)	0.194	NS	NS	0.292	0.443	NS

NS- not significant

Table 8b. Interaction effect of irrigation and nutrient schedule on the leaf area index of Grand Nain banana

Treatments	4 MAP		6 MAP		At harvest	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
I x S interaction						
i_1s_1	1.70	0.64	3.99	3.40	2.53	1.71
i_1s_2	1.85	0.67	4.10	3.54	2.62	2.00
i_2s_1	2.04	0.98	4.35	3.93	3.19	2.41
i_2s_2	2.09	0.90	4.74	3.88	3.18	2.66
i_3s_1	2.13	1.23	4.68	4.07	3.60	2.49
i_3s_2	2.24	1.29	4.98	4.04	3.53	2.90
i_4s_1	2.30	1.36	5.31	4.48	4.17	2.97
i_4s_2	2.38	1.41	5.46	4.67	3.99	3.26
SEm (±)	0.096	0.087	0.176	0.144	0.218	0.162
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	1.41	0.46	3.85	2.87	2.02	1.45
$i_1n_1s_2$	1.76	0.53	3.83	3.32	2.61	1.72
$i_1n_2s_1$	1.99	0.81	4.13	3.93	3.04	1.98
$i_1n_2s_2$	1.94	0.81	4.37	3.76	2.62	2.26
$i_2n_1s_1$	1.72	0.74	3.96	3.69	2.62	2.12
$i_2n_1s_2$	2.03	0.81	4.40	3.77	2.83	2.38
$i_2n_2s_1$	2.35	1.22	4.73	4.18	3.76	2.71
$i_2n_2s_2$	2.15	0.98	5.07	4.00	3.53	2.95
$i_3n_1s_1$	1.83	1.06	4.12	3.83	2.89	2.17
$i_3n_1s_2$	2.13	1.27	4.70	3.98	3.27	2.61
$i_3n_2s_1$	2.44	1.40	5.23	4.31	4.31	2.84
$i_3n_2s_2$	2.35	1.32	5.26	4.10	3.79	3.24
$i_4n_1s_1$	1.95	1.16	4.43	3.79	3.41	2.68
$i_4n_1s_2$	2.26	1.31	4.86	4.34	3.57	2.88
$i_4n_2s_1$	2.64	1.56	6.20	5.16	4.93	3.24
$i_4n_2s_2$	2.51	1.51	6.06	4.99	4.42	3.67
SEm (±)	0.135	0.124	0.249	0.214	0.309	0.229
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

During first year, the interaction between nutrient levels and time of application significant at 4 MAP and at harvest. But in second year it was significant only at 6 MAP. The interaction effect of irrigation and nutrient levels (I x N) was significant only at 6 MAP during first year with i_4n_2 recording the highest LAI (6.13) and was superior to all other combinations. The other interactions (Ix S and I x N x S) were not significant.

4.1.1.6 Leaf Area Duration (LAD)

The leaf area duration (LAD) recorded at 4 and 6 MAP and at harvest during both the years is summarized in Tables 9a and 9b.

During both the years, the LAD recorded at 0.8 and 1.0 IW/CPE (I_3 and I_4) were on par at 4 MAP. But at 6 MAP and at harvest the irrigation level of 1.0 IW/CPE (I_4) was significantly superior to the other levels of irrigation.

Nutrient application based on the uptake of nutrients (N_2) recorded the highest LAD and significantly superior to POP based application (N_1) at all growth stages during first year. However the time of application (S) influenced the LAD only at 6 MAP, where the application of fertilizers in four splits (S_2) recorded the highest LAD (208.78 days).

During first year, the interaction between nutrient levels and time of application significantly influenced LAD at all stages of growth and the nutrient application based on uptake of nutrients in two splits (n_2s_1) recorded the highest LAD. The LAD was the lowest in POP based application in two splits (n_1s_1) and significantly inferior to all other combinations. The interaction between irrigation and nutrient levels (I x N) was significant only at 6 MAP during first year with i_4n_2 recording the highest LAD (261 days) and was superior to all other combinations. The other interaction effects (I x S and I x N x S) were not significant.

Table 9a. Effect of irrigation and nutrient schedule on the leaf area duration of Grand Nain banana, days

Treatments	**4 MAP**		**6 MAP**		**At harvest**	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
Irrigation levels (I)						
I_1	65.01	32.98	174.56	171.55	77.12	55.65
I_2	73.76	40.22	198.11	170.79	95.45	76.08
I_3	79.65	51.92	210.53	185.83	106.93	80.83
I_4	86.04	57.41	231.77	202.77	122.40	93.38
SEm (±)	3.223	1.982	4.293	7.871	3.616	3.092
CD (0.05)	10.314	6.342	13.739	25.187	11.571	9.895
Nutrient levels (N)						
N_1	69.99	41.04	184.71	176.24	87.00	67.43
N_2	82.24	50.22	222.78	189.23	113.95	85.54
SEm (±)	1.488	1.434	2.888	2.876	3.273	2.428
CD (0.05)	4.272	4.116	8.288	9.203	9.394	6.968
Time of application (S)						
S_1	74.64	45.38	198.70	183.20	101.11	71.86
S_2	77.59	45.88	208.78	182.27	99.85	81.12
SEm (±)	1.488	1.434	2.888	2.876	3.273	2.428
CD (0.05)	NS	NS	8.288	NS	NS	6.968
I x N interaction						
i_1n_1	59.74	27.41	162.86	155.14	69.36	47.60
i_1n_2	70.28	38.55	186.26	187.96	84.87	63.71
i_2n_1	67.31	34.35	181.61	163.06	81.65	67.43
i_2n_2	80.21	46.09	214.61	178.52	109.26	84.73
i_3n_1	73.80	49.46	191.81	191.88	92.40	71.45
i_3n_2	85.50	54.38	229.24	179.78	121.47	90.21
i_4n_1	79.13	52.95	202.54	194.88	104.61	83.26
i_4n_2	92.96	61.88	261.00	210.66	140.20	103.50
SEm (±)	2.979	2.871	5.780	6.418	6.552	4.859
CD (0.05)	NS	NS	16.576	18.404	NS	NS
N x S interaction						
n_1s_1	64.71	38.72	174.6	169.80	81.96	63.15
n_1s_2	75.28	43.37	194.81	182.68	92.05	71.72
n_2s_1	84.58	52.05	222.81	196.60	120.25	80.56
n_2s_2	79.89	48.39	222.75	181.86	107.64	90.51
SEm (±)	2.106	2.030	4.087	4.538	4.632	3.436
CD (0.05)	6.040	5.821	11.719	13.015	13.284	NS

NS- not significant

Table 9b. Interaction effect of irrigation and nutrient schedule on the leaf area duration of Grand Nain banana, days

Treatments	4 MAP		6 MAP		At harvest	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
I x S interaction						
i_1s_1	62.33	32.06	170.78	168.61	75.78	51.37
i_1s_2	67.69	33.90	178.35	174.48	78.46	59.94
i_2s_1	73.39	41.70	191.48	178.46	95.64	72.34
i_2s_2	74.14	38.74	204.75	163.12	95.27	79.82
i_3s_1	78.08	51.04	204.34	187.29	108.02	74.68
i_3s_2	81.23	52.80	216.71	184.37	105.85	86.97
i_4s_1	84.79	56.74	228.23	198.43	124.99	89.03
i_4s_2	87.3	58.09	235.31	207.10	119.82	97.73
SEm (±)	2.979	2.871	5.780	4.538	6.552	4.859
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	53.78	25.80	158.03	147.09	60.47	43.49
$i_1n_1s_2$	65.70	29.03	167.70	163.19	78.26	51.56
$i_1n_2s_1$	70.88	38.33	183.53	190.14	91.09	59.34
$i_1n_2s_2$	69.68	38.78	189.00	185.78	78.66	67.73
$i_2n_1s_1$	62.18	32.85	170.40	163.55	78.50	63.56
$i_2n_1s_2$	72.45	35.85	192.83	162.57	84.79	71.47
$i_2n_2s_1$	84.6	50.55	212.55	193.36	112.78	81.16
$i_2n_2s_2$	75.83	41.63	216.68	163.67	105.74	88.47
$i_3n_1s_1$	68.25	45.38	178.65	182.98	86.69	65.05
$i_3n_1s_2$	79.35	53.55	204.98	200.78	98.10	78.40
$i_3n_2s_1$	87.90	56.70	230.03	191.60	129.35	85.11
$i_3n_2s_2$	83.10	52.05	228.45	167.95	113.59	97.13
$i_4n_1s_1$	74.63	50.85	191.33	185.57	102.18	80.26
$i_4n_1s_2$	83.63	55.05	213.75	204.18	107.04	86.53
$i_4n_2s_1$	94.95	62.63	265.13	211.29	147.80	97.18
$i_4n_2s_2$	90.98	61.13	256.88	210.03	132.59	110.09
SEm (±)	4.212	4.059	8.173	9.075	9.264	6.871
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

4.1.1.7 Phyllochon (Days)

The data on phyllochon are presented in the Tables 10a and 10b.

Phyllochon is the number of days between successive leaf emergences. The influence of irrigation levels was evident during both the years of experimentation. The irrigation scheduled at 1.0 IW/CPE registered the least time interval of 7.93 and 8.53 days, respectively in first and second year and was on a par with irrigation levels of 0.6 and 0.8 IW/CPE. The irrigation scheduled at 0.4 IW/ CPE recorded the maximum interval.

The nutrient application based on the uptake of nutrients (N_2) recorded the least phyllochon (8.21 and 8.23 days) and significantly superior to POP based application (N_1). The phyllochon was not influenced by the time of application of nutrients (S) and the interactions were not significant.

4.1.1.8 Duration for Bunch Emergence (Days)

The duration in number of days from planting to shooting is presented in Tables 10a and 10b.

During first year, the duration for bunch emergence was the shortest with irrigation levels of 0.8 and 1.0 IW/CPE (I_3 and I_4) and they were also on a par (189.88 and 192 days, respectively). Similar trend was observed during second year also. The days for shooting was maximum (210.25 and 249.06 days, respectively) in 0.4 IW/CPE (I_1) in both the years. The POP based nutrient application (N_1) recorded the lowest duration (192.97 and 234.16 days, respectively) during both the years and significantly superior to nutrient application based on the uptake of nutrients (N_2). The time of application (S) of nutrients and the interaction effects were not significant.

4.1.1.9 Duration from Bunch Emergence to Harvest (E-H) (Days)

The data on duration from bunch emergence to harvest (days) is presented in Tables 10a and 10b.

Table 10a. Effect of irrigation and nutrient schedule on the duration of the crop and Phyllochron of Grand Nain banana, days

Treatments	Duration for bunch emergence		Bunch emergence to harvest duration		Total duration		Phyllochron	
	I year	II year	I year	II year	I year	II year	1 year	II year
Irrigation levels (I)								
I_1	210.25	249.06	88.94	94.44	299.19	343.50	8.86	9.20
I_2	195.44	239.75	96.31	99.00	291.75	338.75	8.34	8.86
I_3	192.00	231.94	101.63	96.00	293.63	327.94	8.34	8.63
I_4	189.88	229.56	105.00	101.06	294.88	330.63	7.93	8.53
SEm (±)	1.355	2.590	2.651	1.227	3.429	3.438	0.191	0.180
CD (0.05)	4.338	8.287	8.482	3.927	NS	11.003	0.613	0.576
Nutrient levels (N)								
N_1	192.97	234.16	96.97	95.25	289.94	329.41	8.52	9.38
N_2	200.81	241.00	98.97	100.00	299.78	341.00	8.21	8.23
SEm (±)	1.176	1.174	0.942	0.780	1.336	1.239	0.099	0.148
CD (0.05)	3.376	3.370	NS	2.239	3.836	3.557	0.286	0.425
Time of application (S)								
S_1	198.00	237.91	94.75	97.44	292.75	335.34	8.49	8.98
S_2	195.78	237.25	101.18	97.81	296.97	335.06	8.24	8.62
SEm (±)	1.176	1.174	0.942	0.780	1.336	1.239	0.099	0.148
CD (0.05)	NS	NS	2.704	NS	3.836	NS	NS	NS
I x N interaction								
i_1n_1	205.50	245.00	85.50	91.88	291.00	336.88	8.93	9.78
i_1n_2	215.00	253.13	92.38	97.00	307.38	350.13	8.79	8.61
i_2n_1	191.13	237.38	97.25	96.00	288.38	333.38	8.42	9.41
i_2n_2	199.75	242.13	95.38	102.00	295.13	344.13	8.26	8.31
i_3n_1	188.50	227.88	94.63	93.25	283.13	321.13	8.50	9.28
i_3n_2	195.50	236.00	108.63	98.75	304.13	334.75	8.18	7.99
i_4n_1	186.75	226.38	110.50	99.88	297.25	326.25	8.24	9.06
i_4n_2	193.00	232.75	99.50	102.25	292.50	335.00	7.62	7.99
SEm (±)	2.354	2.351	1.886	1.562	2.675	2.480	8.93	1.492
CD (0.05)	NS	NS	5.408	NS	7.671	NS	0.199	NS
N x S interaction								
n_1s_1	195.06	233.88	91.31	94.50	286.38	328.38	8.64	9.59
n_1s_2	190.88	234.44	102.63	96.00	293.50	330.44	8.41	9.17
n_2s_1	200.94	241.94	98.19	100.38	299.13	342.31	8.35	8.38
n_2s_2	200.69	240.06	99.75	99.63	300.44	339.69	8.07	8.08
SEm (±)	1.664	1.662	1.333	1.562	1.891	1.754	0.141	1.055
CD (0.05)	NS	NS	3.824	NS	NS	NS	NS	NS

NS- not significant

Table 10b. Interaction effect of irrigation and nutrient schedule on the duration of the crop and Phyllochron of Grand Nain banana, days

Treatments	Duration for bunch emergence		Bunch emergence to harvest duration		Total duration		Phyllochron	
	I year	II year	I year	II year	I year	II year	1 year	II year
I x S interaction								
i_1s_1	213.13	248.25	85.25	95.13	298.38	343.38	8.94	9.35
i_1s_2	207.38	249.88	92.63	93.75	300.00	343.63	8.77	9.04
i_2s_1	194.63	241.50	84.75	98.00	289.38	339.50	8.44	9.02
i_2s_2	196.25	238.00	97.88	100.00	294.13	338.00	8.24	8.70
i_3s_1	192.50	232.88	97.63	96.13	290.13	329.00	8.52	8.81
i_3s_2	191.50	231.00	105.63	95.88	297.13	326.88	8.16	8.46
i_4s_1	191.75	229.00	101.38	100.50	293.13	329.50	8.08	8.76
i_4s_2	188.00	230.13	108.63	101.63	296.63	331.75	7.79	8.29
SEm (±)	2.354	2.351	1.886	1.562	2.675	2.480	0.199	1.492
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
I x N x S interaction								
$i_1n_1s_1$	208.75	243.00	81.00	91.25	289.75	334.25	9.05	10.13
$i_1n_1s_2$	202.25	247.00	90.00	92.50	292.25	339.50	8.81	9.44
$i_1n_2s_1$	217.50	253.50	89.50	99.00	307.00	352.50	8.84	8.58
$i_1n_2s_2$	212.50	252.75	95.25	95.00	307.75	347.75	8.73	8.65
$i_2n_1s_1$	191.75	239.00	90.25	94.50	282.00	333.50	8.48	9.55
$i_2n_1s_2$	190.50	235.75	104.25	97.50	294.75	333.25	8.36	9.27
$i_2n_2s_1$	197.50	244.00	99.25	101.50	296.75	345.50	8.40	8.49
$i_2n_2s_2$	202.00	240.25	91.50	102.50	293.50	342.75	8.13	8.13
$i_3n_1s_1$	189.75	228.25	86.50	92.50	276.25	320.75	8.73	9.39
$i_3n_1s_2$	187.25	227.50	102.75	94.00	290.00	321.50	8.27	9.17
$i_3n_2s_1$	195.25	237.50	108.75	99.75	304.00	337.25	8.30	8.23
$i_3n_2s_2$	195.75	234.50	108.50	97.75	304.25	332.25	8.05	7.75
$i_4n_1s_1$	190.00	225.25	107.50	99.75	297.50	325.00	8.29	9.31
$i_4n_1s_2$	183.50	227.50	113.50	100.00	297.00	327.50	8.19	8.81
$i_4n_2s_1$	193.50	232.75	95.25	101.25	288.75	334.00	7.86	8.21
$i_4n_2s_2$	192.50	232.75	103.75	103.25	296.25	336.00	7.38	7.78
SEm (±)	3.329	3.324	2.667	2.208	3.782	3.507	0.282	2.111
CD (0.05)	NS	NS	7.649	NS	NS	NS	NS	NS

NS- not significant

The E-H duration was significantly influenced by the irrigation levels and the duration was the shortest with irrigation levels of 0.4 and 0.6 IW/CPE (I_1 and I_2) during first year and with 0.4 and 0.8 IW/CPE (I_1 and I_3) during second year. The E-H duration was influenced by the nutrient levels (N) in second year only and POP based nutrient application (N_1) recorded the shortest duration (95.25 days). The E-H duration was influenced by the time of application (S) of nutrients during first year and the duration was the shortest (94.75 days) in two split application (S_2) compared to four splits (101.18 days).

Among the I x N interactions, except the irrigation level of 0.6 IW/CPE (I_2), all other levels with the POP based application (N_1), (i_1n_1, i_3n_1 and i_4n_1) recorded the shortest duration and significantly superior to the combinations of treatments, i_1n_2, i_3n_2 and i_4n_2. At irrigation level of 0.6 IW/CPE (I_2), the nutrient levels were at par. In N x S interactions, the E-H duration was the lowest in POP based application in 2 splits (n_1s_1) (91.31days) and significantly superior to all other combinations. Among, I x N x S interactions, the treatment combination of $i_1n_1s_1$ recorded the lowest E-H duration (81 days). The duration was the longest in $i_4n_1s_2$ (113.5 days) and was on a par with $i_3n_2s_1$, $i_3n_2s_2$ and $i_4n_1s_1$.

4.1.1.10 Total Duration (Days)

The data on total crop duration is presented in Tables 10a and 10b.

The total crop duration was not influenced by the irrigation levels (I) during first year. But during second year, irrigation levels significantly influenced the total duration and the irrigation at 0.4 and 0.6 IW/CPE (I_1 and I_2) were at par and recorded the longest duration. Early harvest was observed in the irrigation level of 0.8 and 1.0 IW/CPE (I_3 and I_4). The nutrient levels (N) significantly influenced the total duration and POP based nutrient application (N_1) recorded the lowest total duration (289.94 and 329.41days, respectively) during both the years and significantly superior to nutrient application based on the uptake of nutrients (N_2).

Among the time of application, the application in two splits (S_1) recorded the lowest duration (292.75 days) during first year while it was not significant during second year.

Among the Ix N all irrigation levels with nutrient interactions (I x N), the irrigation levels except i_4n_1, with POP based application (i_1n_1, i_2n_1 and i_3n_1) recorded the lowest total duration during first year. The other interactions (N x S, I x S and I x N x S) were not significant. None of the interactions were significant during second year.

4.1.2 Yield and Yield Attributes

4.1.2.1 Bunch Characters

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

The data pertaining to bunch weight and yield are presented in the Tables 11a and 11b.

The analysed data revealed that the irrigation levels significantly influenced the bunch weight and yield during both the years. During first year, irrigation at 0.8 IW/CPE (I_3) recorded the highest bunch weight (27.44 kg plant^{-1}) and it was at par with irrigation at1.0 IW/CPE (I_4) and significantly superior to the other two levels of irrigation. The Irrigation scheduled at 0.4 IW/CPE (I_1) recorded the lowest bunch weight (19.47 kg plant^{-1}). The bunch weight and yield were the highest in irrigation at 1.0 IW/CPE (I_4) and significantly superior to the other three levels of irrigation during second year.

The nutrient application based on the uptake of nutrients (N_2) recorded the highest bunch weight and significantly superior to POP based application (N_1) during both the years (26.58 and 22.63 kg plant^{-1}, respectively). The bunch yield also showed the same trend. The time of application of nutrients (S) did not influence the bunch weight and yield during first year. But during second year, application of nutrients in 4 splits (S_2) recorded the highest bunch weight (21.69 kg plant^{-1}) and yield (66.93 t ha^{-1}) and was significantly superior to application of nutrients in 2 splits (S_1).

Table 11a. Effect of irrigation and nutrient schedule on the bunch characters of Grand Nain banana

Treatments	Bunch weight (kg)		Yield (t ha^{-1})		Number of hands per bunch	
	I year	II year	I year	II year	I year	II year
Irrigation levels (I)						
I_1	19.47	16.63	60.08	51.30	10.06	7.44
I_2	22.63	19.25	69.82	59.41	10.13	8.69
I_3	27.44	23.13	84.67	71.36	10.63	10.00
I_4	27.41	25.00	84.58	77.15	11.19	10.19
SEm (±)	0.616	0.513	1.900	1.582	0.263	0.162
CD (0.05)	1.970	1.641	6.081	5.062	0.843	0.517
Nutrient levels (N)						
N_1	21.89	19.38	67.55	59.79	9.97	8.75
N_2	26.58	22.63	82.02	69.82	11.03	9.41
SEm (±)	0.399	0.228	1.231	0.704	0.160	0.105
CD (0.05)	1.145	0.655	3.534	2.020	0.460	0.301
Time of application (S)						
S_1	24.45	20.31	75.46	62.68	10.63	9.00
S_2	24.02	21.69	74.11	66.93	10.38	9.16
SEm (±)	0.399	0.228	1.231	0.704	0.160	0.105
CD (0.05)	NS	0.655	NS	2.020	NS	NS
I x N interaction						
i_1n_1	18.50	15.25	57.09	47.06	9.50	7.13
i_1n_2	20.44	18.00	63.07	55.55	10.63	7.75
i_2n_1	20.75	17.75	64.04	54.78	9.63	8.50
i_2n_2	24.50	20.75	75.61	64.03	10.63	8.88
i_3n_1	24.69	21.75	76.19	67.12	10.113	9.63
i_3n_2	30.19	24.50	93.16	75.61	11.13	10.38
i_4n_1	23.63	22.75	72.91	70.21	10.63	9.75
i_4n_2	31.19	27.25	96.24	84.09	11.75	10.63
SEm (±)	0.799	0.457	2.465	1.409	0.321	0.210
CD (0.05)	2.291	NS	7.69	NS	NS	NS
N x S interaction						
n_1s_1	21.59	18.50	66.64	57.09	10.00	8.63
n_1s_2	22.19	20.25	68.47	62.49	9.93	8.88
n_2s_1	27.31	22.13	84.29	68.28	11.25	9.38
n_2s_2	25.84	23.13	79.75	71.36	10.81	9.44
SEm (±)	0.565	0.323	1.743	0.996	0.227	0.148
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

Table 11b. Interaction effect of irrigation and nutrient schedule on the bunch characters of Grand Nain banana

Treatments	Bunch weight (kg)		Yield (t ha^{-1})		Number of hands per bunch	
	I year	II year	I year	II year	I year	II year
I x S interaction						
i_1s_1	19.13	16.00	59.02	49.38	10.25	7.38
i_1s_2	19.81	17.25	61.14	53.23	9.88	7.50
i_2s_1	22.75	18.50	70.21	57.09	10.25	8.63
i_2s_2	22.50	20.00	69.44	61.72	10.00	8.75
i_3s_1	28.19	22.50	86.99	69.43	10.88	9.88
i_3s_2	26.69	23.75	82.36	73.29	10.38	10.13
i_4s_1	27.75	24.25	85.64	74.84	11.13	10.13
i_4s_2	27.06	25.75	83.51	79.46	11.25	10.25
SEm (±)	0.799	0.457	2.465	1.582	0.321	0.210
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	18.13	14.50	55.93	44.75	9.75	7.00
$i_1n_1s_2$	18.88	16.00	58.25	49.38	9.25	7.25
$i_1n_2s_1$	20.13	17.50	62.11	54.01	10.75	7.75
$i_1n_2s_2$	20.75	18.50	64.03	57.09	10.50	7.75
$i_2n_1s_1$	20.25	16.50	62.49	50.92	9.75	8.25
$i_2n_1s_2$	21.25	19.00	65.58	58.63	9.50	8.75
$i_2n_2s_1$	25.25	20.50	77.92	63.26	10.75	9.00
$i_2n_2s_2$	23.75	21.00	73.29	64.81	10.50	8.75
$i_3n_1s_1$	24.75	21.00	76.38	64.81	10.25	9.50
$i_3n_1s_2$	24.63	22.50	75.99	69.44	10.00	9.75
$i_3n_2s_1$	31.63	24.00	97.59	74.06	11.50	10.25
$i_3n_2s_2$	28.75	25.00	88.72	77.15	10.75	10.50
$i_4n_1s_1$	23.25	22.00	71.75	67.89	10.25	9.75
$i_4n_1s_2$	24.00	23.50	74.06	72.52	11.00	9.75
$i_4n_2s_1$	32.25	26.50	99.52	81.78	12.00	10.50
$i_4n_2s_2$	30.13	28.00	92.97	86.41	11.50	10.75
SEm (±)	1.130	0.645	3.485	1.992	0.454	0.297
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

Among the interactions, the I x N interaction was found significant only during first year. The nutrient application based on uptake of nutrients at irrigation levels 0.6,0.8 and 1.0 IW/CPE (i_2n_2, i_3n_2, i_4n_2) were significantly superior to POP based application (i_2n_1, i_3n_1, i_4n_1) while the interactions $i_1n_1$and i_1n_2 were at par. Other interactions (N x S, I x S, I x N x S) were found not significant during both the years.

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

The results of two year yield data are pooled and the analysed values are presented in Tables 12a and 12b.

The irrigation levels significantly influenced the pooled yield and the irrigation at 1.0 IW/CPE (I_4) recorded the highest bunch weight and yield (26.20 kg plant^{-1}and 80.85 t ha^{-1}, respectively) and it was on a par with irrigation at 0.8 IW/CPE (I_3) and superior to the other two levels of irrigation. The pooled yield was the lowest in irrigation at 0.4 IW/CPE (55.70 t ha^{-1}).

The nutrient application based on the uptake of nutrients (N_2) recorded the highest bunch weight and yield (26.20 kg plant^{-1}and 80.85 t ha^{-1}, respectively) and superior to POP based application of nutrients (N_1). However the time of application (S) had no significant influence on the pooled bunch weight and yield.

The influence of year (Y) of experimentation was also analysed. The yield was significantly the highest in first year (Y_1) of experimentation and was 24.23 kg plant^{-1} and 21.00 t ha^{-1}, respectively. Among the interactions, I x N, N x Y and S x Y interactions were significant. Among, I x N interaction, i_4n_2 recorded the highest pooled yield and was significantly superior to all other combinations. In N x Y and S x Y interactions, the pooled yield was the highest in n_2y_1 and s_2 y_1, respectively.

4.1.2.1.3 Number of Hands Bunch^{-1}

Data pertaining to number of hands bunch^{-1} are presented in Tables 11a and 11b.

Table 12a. Effect of irrigation and nutrient schedule on pooled bunch weight (kg plant^{-1}) and pooled yield (t ha^{-1})

Treatments	Pooled bunch weight (kg plant^{-1})	Pooled yield (t ha^{-1})
Irrigation levels (I)		
I_1	18.05	55.70
I_2	20.94	64.62
I_3	25.28	78.01
I_4	26.20	80.85
SEm (±)	0.457	1.410
CD (0.05)	1.300	4.012
Nutrient levels (N)		
N_1	20.63	63.66
N_2	24.60	75.92
SEm (±)	0.256	0.790
CD (0.05)	0.729	2.250
Time of application (S)		
S_1	22.38	69.06
S_2	22.85	70.52
SEm (±)	0.256	0.790
CD (0.05)	NS	NS
Year (Y)		
Y_1	24.23	74.77
Y_2	21.00	64.81
SEm (±)	0.215	0.663
CD (0.05)	0.610	1.882
I x N interaction		
i_1n_1	16.88	52.09
i_1n_2	19.22	59.31
i_2n_1	19.25	59.41
i_2n_2	22.63	69.84
i_3n_1	23.22	71.66
i_3n_2	27.34	84.37
i_4n_1	23.19	71.56
i_4n_2	29.22	90.17
SEm (±)	0.513	1.583
CD (0.05)	1.457	4.496
N x S interaction		
n_1s_1	20.05	61.87
n_1s_2	21.22	65.48
n_2s_1	24.72	76.29
n_2s_2	24.48	75.55
SEm (±)	0.363	1.120
CD (0.05)	NS	NS

NS- not significant

Table 12b. Interaction effect of irrigation and nutrient schedule on pooled bunch weight (kg plant^{-1}) and pooled yield (t ha^{-1})

Treatments	**Pooled bunch weight (kg plant^{-1})**	**Pooled yield (t ha^{-1})**
I x Y interaction		
i_1y_1	19.47	60.08
i_1y_2	16.63	51.32
i_2y_1	22.63	69.84
$i_2 y_2$	19.25	59.41
$i_3 y_1$	27.44	84.68
i_3y_2	23.13	71.38
i_4y_1	27.41	84.59
i_4y_2	25.00	77.15
SEm (±)	0.430	1.327
CD (0.05)	NS	NS
N x Y interaction		
n_1y_1	21.89	67.55
n_1y_2	19.38	59.81
n_2y_1	26.58	82.03
n_2y_2	22.63	69.84
SEm (±)	0.304	0.938
CD (0.05)	0.863	2.663
S x Y interaction		
s_1y_1	24.45	75.45
s_1y_2	20.31	62.68
s_2y_1	24.02	74.13
s_2y_2	21.69	66.94
SEm (±)	0.304	0.938
CD (0.05)	0.863	2.663

NS- not significant

It is obvious from the data that the number of hands bunch^{-1} varied significantly due to irrigation levels during both the years. During first year, irrigation scheduled at 0.8 and1.0 IW/CPE (I_3 and I_4) resulted in higher number of hands (10.63 and 11.19) and minimum number of hands were recorded at 0.4 and 0.6 IW/CPE(I_1 and I_2). During second year, irrigation scheduled at 0.8 and 1.0 IW/CPE (I_3 and I_4) were on a par and significantly superior to other two levels of irrigation. The number of hands was the lowest in irrigation (7.44) at 0.4 IW/CPE (I_1) and significantly inferior to other three levels of irrigation.

The nutrient levels (N) significantly influenced the number of hands and nutrient application based on the uptake of nutrients (N_2) recorded the highest number of hands per bunch (11.03, 9.41, respectively) during both the years. The time of application of nutrients (S) were found to be not significant during first year and application of nutrients in four splits (S_2) recorded the highest number of hands (9.16) and significantly superior to two split (S_1) application in second year.

The interactions (I x N, N x S, I x S, I x N x S) were found not significant.

4.1.2.1.4 Number of Fingers Bunch^{-1}

The analysed data on the number of fingers bunch^{-1} are presented in the Tables 13a and 13b.

The number of fingers bunch^{-1} varied significantly due to irrigation levels. Irrigation scheduled at 1.0 IW/CPE (I_4) recorded higher number of fingers (166.8 and 166.7, respectively) during both the years and was on a par with 0.8 IW/CPE (I_3) during first year. The nutrient application based on the uptake of nutrients (N_2) recorded the highest number of fingers per bunch (157.9 and 152.0, respectively) during both the years. The time of application (S) of nutrients and the interaction effects were found to be not significant.

4.1.2.1.5 Number of Fingers in the D-hand

The data on the number of fingers in the D-hand is presented in the Tables 13a and 13b.

Table 13a. Effect of irrigation and nutrient schedule on the bunch characters of Grand Nain banana

Treatments	Number of fingers per bunch		Number of fingers in the D-hand		Bunch length (cm)	
	I year	II year	I year	II year	I year	II year
Irrigation levels (I)						
I_1	130.00	125.60	19.38	17.31	80.88	64.31
I_2	142.40	147.80	20.25	20.19	92.94	75.56
I_3	164.00	149.80	20.44	20.00	95.38	73.25
I_4	166.80	161.70	21.50	21.94	106.75	81.19
SEm (±)	2.723	1.597	0.947	0.583	1.816	1.443
CD (0.05)	8.712	5.111	3.030	1.867	5.811	4.617
Nutrient levels (N)						
N_1	143.60	140.38	19.41	18.75	91.06	70.31
N_2	157.90	152.00	21.38	20.97	96.91	76.84
SEm (±)	2.938	1.580	0.480	0.630	1.199	1.056
CD (0.05)	8.432	4.536	1.379	1.807	3.440	3.030
Time of application (S)						
S_1	153.40	144.53	20.81	19.97	93.34	73.50
S_2	148.10	147.84	19.97	19.75	94.63	73.66
SEm (±)	8.938	1.580	0.480	0.630	1.199	1.056
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N interaction						
i_1n_1	127.10	120.00	18.25	16.88	78.63	60.88
i_1n_2	136.60	131.13	20.50	17.75	83.13	67.75
i_2n_1	139.10	139.38	18.50	19.75	90.00	73.00
i_2n_2	145.60	156.13	22.00	20.63	95.88	78.13
i_3n_1	155.40	146.00	20.25	18.88	93.50	69.63
i_3n_2	172.60	153.50	20.63	21.13	97.25	76.88
i_4n_1	152.60	156.13	20.63	19.50	102.13	77.75
i_4n_2	180.90	167.25	22.38	24.38	111.38	84.63
SEm (±)	5.881	3.162	0.962	1.260	2.399	2.113
CD (0.05)	NS	NS	NS	NS	NS	NS
N x S interaction						
n_1s_1	146.30	137.80	19.31	19.06	89.13	69.75
n_1s_2	140.90	142.90	19.50	18.44	93.00	70.88
n_2s_1	160.50	151.30	22.31	20.88	97.56	77.25
n_2s_2	155.40	152.80	20.44	21.06	96.25	76.44
SEm (±)	4.158	2.235	0.680	0.891	1.696	1.494
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

Table 13b. Interaction effect of irrigation and nutrient schedule on the bunch characters of Grand Nain banana

Treatments	Number of fingers per bunch		Number of fingers in the D-hand		Bunch length (cm)	
	I year	II year	I year	II year	I year	II year
I x S interaction						
i_1s_1	133.80	124.13	19.88	16.88	80.25	62.75
i_1s_2	126.00	127.00	18.88	17.75	81.50	65.88
i_2s_1	144.10	144.00	20.00	20.38	90.75	75.75
i_2s_2	140.60	151.50	20.50	20.00	95.13	75.38
i_3s_1	165.20	151.00	21.38	20.25	95.63	72.88
i_3s_2	162.80	148.50	19.50	19.75	95.13	73.63
i_4s_1	170.40	159.00	22.00	22.38	106.75	82.63
i_4s_2	163.10	164.38	21.00	21.50	106.75	79.75
SEm (±)	4.158	3.162	0.962	1.260	2.399	2.113
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	130.80	115.50	18.00	16.75	77.00	58.00
$i_1n_1s_2$	123.50	124.50	18.50	17.00	80.25	63.75
$i_1n_2s_1$	136.80	132.80	21.75	17.00	83.50	67.50
$i_1n_2s_2$	128.50	129.50	19.25	18.50	82.75	68.00
$i_2n_1s_1$	137.50	136.30	17.50	20.50	86.50	72.75
$i_2n_1s_2$	140.80	142.50	19.50	19.00	93.50	73.25
$i_2n_2s_1$	150.80	151.80	22.50	20.25	95.00	78.75
$i_2n_2s_2$	140.50	160.50	21.50	21.00	96.75	77.50
$i_3n_1s_1$	159.30	147.50	21.00	20.00	93.75	69.50
$i_3n_1s_2$	151.50	144.50	19.50	17.75	93.25	69.75
$i_3n_2s_1$	171.30	154.50	21.75	20.50	97.50	76.25
$i_3n_2s_2$	174.00	152.50	19.50	21.75	97.00	77.50
$i_4n_1s_1$	157.50	152.00	20.75	19.00	99.25	78.75
$i_4n_1s_2$	147.80	160.30	20.50	20.00	105.00	76.75
$i_4n_2s_1$	183.30	166.00	23.25	25.75	114.25	86.50
$i_4n_2s_2$	178.50	168.50	21.50	23.00	108.50	82.75
SEm (±)	8.316	2.235	1.360	1.782		2.988
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

The irrigation levels influenced the number of fingers in the D-hand during second year. The fingers in D-hand were at par in 0.6, 0.8 and 1.0 IW/CPE (I_2, I_3 and I_4) and superior to the lowest level of irrigation at 0.4 IW/CPE (I_4). The nutrient application based on the uptake of nutrients (N_2) recorded the highest number of fingers in D-hand (21.38 and 20.97, respectively) during both years. The time of application and interactions were found not significant.

4.1.2.1.6 Bunch Length (cm)

The analysed data is presented in Tables 13a and 13b.

The irrigation levels significantly influenced the bunch length and irrigation at 1.0 IW/CPE (I_4) produced the longest bunch (106.75 and 81.19 cm, respectively) during both the years and was found superior to the other three levels of irrigation.

Among the nutrient levels, N_2 produced the longest bunch (96.91and 76.84 cm, respectively) during both the years. The time of application and interactions were found not significant.

4.1.2.2 Finger Characters

4.1.2.2.1 Length of D-finger (cm)

The data in respect of fruit length is summarized in Tables 14a and 14b.

The data revealed that irrigation scheduled at 1.0 IW/CPE (I_4) was significantly superior to other levels of irrigation and registered a mean fruit length of 19.53 cm during first year. However, during second year, the irrigation levels of 0.6, 0.8 and 1.0 IW/CPE were at par and significantly superior to irrigation at 0.4 IW/CPE.

The influence of nutrient levels on fruit length was significant during both the years of experimentation with N_2 producing the longest fruits (19.83 and 19.04 cm, respectively). However, the time of application did not influence fruit length during both the years of experimentation.

Table 14a. Effect of irrigation and nutrient schedule on finger characters of Grand Nain banana

Treatments	**Length of D-finger (cm)**		**Girth of D-finger (cm)**		**Weight of D-finger (g)**		**Pulp to peel ratio**	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**	**I year**	**II year**
Irrigation levels (I)								
I_1	18.88	16.86	12.05	11.78	161.69	117.75	2.14	1.82
I_2	18.66	18.66	12.08	12.14	160.28	127.41	2.08	1.98
I_3	18.71	18.68	12.06	11.99	172.25	138.91	2.48	2.42
I_4	19.53	18.83	11.99	11.98	182.19	151.88	3.21	2.49
SEm (±)	0.240	0.430	0.116	0.136	3.109	2.011	0.062	0.054
CD (0.05)	0.767	1.375	NS	NS	9.948	6.435	0.199	0.173
Nutrient levels (N)								
N_1	18.06	17.47	11.78	11.70	156.73	127.25	2.17	2.09
N_2	19.83	19.04	12.30	12.24	181.47	140.72	2.78	2.26
SEm (±)	0.276	0.240	0.115	0.115	1.845	1.953	0.030	0.039
CD (0.05)	0.794	0.689	0.331	0.328	5.296	5.606	0.102	0.111
Time of application (S)								
S_1	19.02	18.28	11.98	11.92	167.98	131.66	2.45	2.21
S_2	18.86	18.24	12.11	12.03	170.22	136.31	2.50	2.15
SEm (±)	0.276	0.240	0.115	0.115	1.845	1.953	0.030	0.039
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
I x N interaction								
i_1n_1	18.63	16.44	11.88	11.69	151.50	112.13	1.83	1.82
i_1n_2	19.13	17.29	12.22	11.86	171.88	123.38	2.46	1.82
i_2n_1	17.88	17.88	11.81	11.75	149.31	122.31	1.96	1.97
i_2n_2	19.44	19.44	12.35	12.54	171.25	132.50	2.20	1.99
i_3n_1	18.04	17.98	11.98	11.85	163.63	134.44	2.15	2.15
i_3n_2	19.39	19.39	12.14	12.14	180.88	143.38	2.81	2.69
i_4n_1	17.70	17.60	11.48	11.53	162.50	140.13	2.76	2.43
i_4n_2	21.35	20.06	12.50	12.44	201.88	163.63	3.66	2.55
SEm (±)	0.391	0.481	0.231	0.229	3.694	3.909	0.071	0.077
CD (0.05)	1.122	NS	NS	NS	10.593	11.211	0.200	0.222
N x S interaction								
n_1s_1	17.66	17.38	11.63	11.58	152.03	125.72	2.12	2.18
n_1s_2	18.46	17.57	11.94	11.83	161.44	128.78	2.23	2.01
n_2s_1	20.39	19.18	12.33	12.27	183.94	137.59	2.78	2.24
n_2s_2	19.26	18.91	12.28	12.22	179.00	143.84	2.78	2.29
SEm (±)	0.553	0.340	0.163	0.162	2.611	2.764	0.050	0.055
CD (0.05)	1.587	NS	NS	NS	7.489	NS	NS	NS

NS- not significant

Table 14b. Interaction effect of irrigation and nutrient schedule on finger characters of Grand Nain banana

Treatments	Length of D-finger (cm)		Girth of D-finger (cm)		Weight of D-finger (g)		Pulp to peel ratio	
	I year	II year	I year	II year	I year	II year	I year	II year
I x S interaction								
i_1s_1	18.79	16.79	11.88	11.75	159.38	115.19	2.06	1.72
i_1s_2	18.96	16.94	12.22	11.80	164.00	120.31	2.22	1.92
i_2s_1	18.84	18.84	11.94	11.94	157.56	126.94	2.10	2.11
i_2s_2	18.48	18.48	12..22	12.35	163.00	127.88	2.07	1.85
i_3s_1	19.14	19.14	12.23	12.04	175.63	137.06	2.45	2.28
i_3s_2	18.29	18.23	11.89	11.95	168.88	140.75	2.50	2.55
i_4s_1	19.33	18.35	11.88	11.96	179.38	147.44	3.20	2.72
i_4s_2	19.73	19.31	12.10	12.00	185.00	156.31	3.22	2.26
SEm (±)	0.391	0.481	0.231	0.229	3.694	3.909	0.071	0.077
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	0.222
I x N x S interaction								
$i_1n_1s_1$	17.63	16.50	11.25	11.63	145.00	109.25	1.76	1.71
$i_1n_1s_2$	19.63	16.38	12.50	11.75	158.00	115.00	1.89	1.93
$i_1n_2s_1$	19.95	17.08	12.50	11.88	173.75	121.13	2.36	1.74
$i_1n_2s_2$	18.30	17.50	11.95	11.85	170.00	125.63	2.56	1.91
$i_2n_1s_1$	17.93	17.93	12.00	11.63	147.38	120.88	1.98	2.07
$i_2n_1s_2$	17.83	17.83	11.63	11.88	151.25	123.75	1.95	1.88
$i_2n_2s_1$	19.75	19.75	11.88	12.25	167.74	133.00	2.22	2.15
$i_2n_2s_2$	19.13	19.13	12.83	12.83	174.75	132.00	2.18	1.83
$i_3n_1s_1$	18.38	18.38	12.25	11.88	164.50	134.63	2.02	2.03
$i_3n_1s_2$	17.70	17.58	11.70	11.83	162.75	134.25	2.28	2.31
$i_3n_2s_1$	19.90	19.90	12.20	12.20	186.75	139.50	2.89	3.07
$i_3n_2s_2$	18.88	18.88	12.08	12.08	175.00	147.25	2.73	2.07
$i_4n_1s_1$	16.70	16.70	11.00	11.18	151.25	138.13	2.73	2.68
$i_4n_1s_2$	18.70	18.50	11.95	11.88	173.75	142.13	2.79	2.19
$i_4n_2s_1$	21.95	20.00	12.75	12.75	207.50	156.75	3.67	2.77
$i_4n_2s_2$	20.75	20.13	12.25	12.13	196.25	170.50	3.65	2.33
SEm (±)	0.783	0.680	0.326	0.324	5.223	5.528	0.100	0.109
CD (0.05)	NS	NS	0.935	NS	NS	NS	NS	0.314

NS- not significant

Among the interactions, I x N and N x S interactions significantly influenced the fruit length during first year. In I x N interactions, irrigation at all levels with nutrient application based on the uptake of nutrients (N_2) recorded higher fruit length than with N_1 level. The fruits were the longest in i_4n_2 (21.35 cm) which was on par with i_3n_2 and i_2n_2. In N x S interaction, n_2s_1 produced the longest fruits, which was on a par with n_2s_2 and found significantly superior to n_1s_1 and n_1s_2. The interactions, I x S and I x N x S were found not significant.

4.1.2.2.2 Girth of D-finger (cm)

The data in respect of fruit girth is summarized in Tables 14a and 14b.

The influence of irrigation levels and time of application of nutrients were found not significant during both the years of experimentation. The influence of nutrient levels on fruit girth was significant during both the years of experimentation with the nutrient application based on uptake of nutrients (N_2) recording the highest fruit girth during both the years (12.30 and 12.24 cm, respectively).

All interactions were found not significant, except I x N x S during first year. Among the I x N x S interaction, $i_4n_2s_1$ recorded the highest girth and was on par with all combinations except $i_1n_1s_1$, $i_2n_1s_2$, $i_3n_1s_2$ and $i_4n_1s_1$.

4.1.2.2.3 Weight of D-finger (g)

The analysed data is presented in Tables 14a and 14b.

The results revealed that weight of D-finger was significantly influenced by irrigation and nutrient levels. Irrigation scheduled at 1.0 IW/CPE recorded the highest finger weight during both the years. It was at par with the irrigation level of 0.8 IW/CPE during first year. The weight of D-finger was the lowest in 0.4 and 0.6 IW/CPE during first year and 0.4 IW/CPE during second year.

The influence of nutrient levels on fruit weight was significant during both the years of experimentation. The nutrient application based on the uptake of nutrients (N_2) recorded the highest fruit weight during first and second year (181.47 and 140.72 g, respectively). The time of application was found to be not significant.

Among the interactions, I x N and N x S interactions significantly were influenced the finger weight. In I x N interaction, nutrient application based on the uptake of nutrients (N_2) at all irrigation levels recorded more fruit weight than the corresponding N_1 level during both the years and the fruit weight was the highest in i_4n_2. The N x S interaction influenced the finger weight during first year with $n_2s_1$recording the highest (183. 94 g) and it was at par with n_2s_2.

4.1.2.2.4 Pulp to Peel Ratio

The analysed data is presented in the Tables 14a and 14b.

The data summarized in the table showed that the pulp to peel ratio was significantly influenced by the levels of irrigation and nutrients. The time of application did not affect the ratio. The irrigation scheduled at 1.0 IW/CPE recorded the highest pulp peel ratio and was statistically on a par with the irrigation level of 0.8 IW/CPE during first year. The nutrient application based on the uptake of nutrients (N_2) recorded the highest pulp peel ratio (2.78 and 2.26, respectively) during both the years.

Among the interactions, I x N interaction was significant during both the years of experimentation and in I x N interaction, nutrient application based on the uptake of nutrients (N_2) with all irrigation levels recorded higher pulp to peel ratio than the corresponding N_1 level and it was the highest in i_4n_2. The interaction N x S was found not significant. The I x S and I x N x S interactions were found significant during the second year of study with i_4s_1 and i_4n_2 s_1 recording the highest.

4.1.3 Quality Parameters

4.1.3.1 Total Soluble Solids (TSS) (^{0}B)

Data pertaining to TSS is presented in Tables 15a and 15b.

The TSS was unaffected by the irrigation levels, time of application of nutrients and their interactions. However, the nutrient levels significantly influenced the TSS content of fruits with the nutrient application based on the uptake of nutrients (N_2) recording the highest TSS content (23.69 ^{o}B and 24.06 ^{o}B, respectively) during first and second year.

4.1.3.2 Titrable Acidity (%)

Data pertaining to the titrable acidity is presented in the Tables 15a and 15b.

The irrigation levels significantly influenced the titrable acidity only during second year. Among the irrigation levels, irrigation scheduled at 0.4 IW/CPE recorded the highest titrable acidity value of 0. 36 per cent, but it was at par with the irrigation levels of 0.6 and 0.8 IW/CPE and the lowest in irrigation level 1.0 IW/CPE (0.32%).

The nutrient application based on the uptake of nutrients (N_2) recorded the lowest acidity while the POP based application (N_1) recorded the highest.

None of the interactions were found significant.

4.1.3.3 Total Sugar (%)

Data pertaining to the total sugar is presented in the Tables 16a and 16b.

Analysis of data revealed that the irrigation levels significantly influenced the total sugar content during second year of experimentation. The irrigation scheduled at 1.0 IW/CPE recorded the highest total sugar content (17.31%). It was significantly superior to the other three levels of irrigation.

Table 15a. Effect of irrigation and nutrient schedule on the quality attributes and shelf life of Grand Nain banana

Treatments	TSS (^{o}B)		Titrable acidity (%)		Ascorbic acid (mg 100g^{-1})		Shelf life (days)	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels (I)								
I_1	22.50	23.31	0.37	0.36	14.73	14.13	8.63	8.13
I_2	22.81	23.38	0.34	0.35	14.53	14.96	9.56	9.00
I_3	23.19	23.56	0.38	0.34	15.33	15.56	9.63	8.69
I_4	23.25	23.81	0.32	0.32	15.61	16.40	9.69	9.63
SEm (±)	0.292	0.344	0.015	0.005	0.396	0.521	0.211	0.340
CD (0.05)	NS	NS	NS	0.017	NS	1.667	0.674	1.088
Nutrient levels (N)								
N_1	22.19	22.97	0.38	0.37	14.23	14.82	8.00	8.25
N_2	23.69	24.06	0.33	0.33	15.86	15.71	9.17	9.47
SEm (±)	0.192	0.218	0.007	0.006	0.241	0.178	0.133	0.184
CD (0.05)	0.552	0.626	0.020	0.018	0.693	0.510	0.381	0.528
Time of application (S)								
S_1	22.81	23.38	0.35	0.34	14.79	15.11	8.56	8.88
S_2	23.06	23.67	0.36	0.35	15.31	15.42	8.59	8.84
SEm (±)	0.192	0.218	0.007	0.006	0.241	0.178	0.133	0.184
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
I x N interaction								
i_1n_1	21.75	22.88	0.39	0.38	14.16	13.77	8.13	7.88
i_1n_2	23.25	23.75	0.36	0.35	15.29	14.49	9.13	8.38
i_2n_1	22.25	22.88	0.36	0.38	13.86	14.83	8.25	8.38
i_2n_2	23.38	23.88	0.32	0.33	15.19	15.10	8.63	9.63
i_3n_1	22.38	23.25	0.40	0.37	14.62	14.70	7.75	7.63
i_3n_2	24.00	23.88	0.35	0.31	16.03	16.43	9.25	9.75
i_4n_1	22.38	22.88	0.34	0.34	14.28	15.99	7.88	9.13
i_4n_2	24.13	24.75	0.30	0.31	16.94	16.81	9.63	10.13
SEm (±)	0.385	0.437	0.014	0.012	0.483	0.356	0.266	0.368
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
N x S interaction								
n_1s_1	22.00	22.90	0.37	0.36	13.93	14.54	8.63	8.38
n_1s_2	22.38	23.00	0.38	0.37	14.54	15.10	9.06	8.13
n_2s_1	23.63	23.80	0.32	0.33	15.54	15.67	9.94	9.38
n_2s_2	23.75	24.30	0.34	0.33	16.08	15.74	9.88	9.56
SEm (±)	0.272	0.309	0.010	0.009	0.341	0.252	0.188	0.260
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS- not significant

Table 15b. Interaction effect of irrigation and nutrient schedule on the quality attributes of Grand Nain banana

Treatments	TSS (^oB)		Titrable acidity (%)		Ascorbic acid (mg 100 g^{-1})		Shelf life (days)	
	I year	II year	I year	II year	I year	II year	I year	II year
I x S interaction								
i_1s_1	22.25	23.25	0.36	0.36	14.37	14.19	8.63	8.13
i_1s_2	22.75	23.38	0.39	0.37	15.08	14.07	8.63	8.13
i_2s_1	22.63	23.13	0.34	0.36	14.22	14.89	8.50	9.00
i_2s_2	23.00	23.63	0.35	0.35	14.83	15.03	8.38	9.00
i_3s_1	23.00	23.38	0.37	0.34	15.28	15.29	8.38	8.63
i_3s_2	23.38	23.75	0.38	0.35	15.37	15.83	8.63	8.75
i_4s_1	23.38	23.75	0.32	0.32	15.28	16.05	8.88	9.75
i_4s_2	23.13	23.88	0.32	0.32	15.94	14.19	8.63	9.50
SEm (±)	0.385	0.437	0.014	0.012	0.483	0.356	0.266	0.368
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
I x N x S interaction								
$i_1n_1s_1$	21.50	23.00	0.37	0.36	13.48	13.99	7.50	7.75
$i_1n_1s_2$	22.00	22.75	0.42	0.39	14.84	13.55	8.50	8.00
$i_1n_2s_1$	23.00	23.50	0.35	0.35	15.26	14.39	9.25	8.50
$i_1n_2s_2$	23.50	24.00	0.36	0.36	15.32	14.59	9.25	8.25
$i_2n_1s_1$	22.00	22.75	0.38	0.39	13.87	14.63	8.75	8.50
$i_2n_1s_2$	22.50	23.00	0.35	0.37	13.86	15.03	9.25	8.25
$i_2n_2s_1$	23.25	23.50	0.30	0.34	14.58	15.16	10.00	9.50
$i_2n_2s_2$	23.50	24.25	0.35	0.32	15.80	15.04	10.25	9.75
$i_3n_1s_1$	22.00	23.00	0.40	0.36	14.83	14.31	9.00	7.75
$i_3n_1s_2$	22.75	23.50	0.41	0.38	14.41	15.09	9.25	7.50
$i_3n_2s_1$	24.00	23.75	0.34	0.31	15.73	16.28	10.25	9.50
$i_3n_2s_2$	24.00	24.00	0.36	0.32	16.33	16.58	10.00	10.00
$i_4n_1s_1$	22.50	23.00	0.36	0.34	13.54	15.23	9.25	9.50
$i_4n_1s_2$	22.25	22.75	0.33	0.33	15.03	16.75	9.25	8.75
$i_4n_2s_1$	24.25	24.50	0.29	0.31	17.01	16.88	10.25	10.00
$i_4n_2s_2$	24.00	25.00	0.31	0.32	16.86	16.75	10.00	10.25
SEm (±)	0.544	0.618	0.020	0.018	0.683	0.503	0.376	0.521
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS- not significant

Table 16a. Effect of irrigation and nutrient schedule on the quality attributes of Grand Nain banana

Treatments	Total sugar (%)		Reducing sugars (%)		Non reducing sugars (%)		Sugar acid ratio	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels (I)								
I_1	14.73	15.48	9.57	12.27	5.16	3.54	40.08	42.90
I_2	14.53	16.22	9.23	11.99	5.29	3.93	43.21	46.77
I_3	15.33	16.57	10.39	12.86	4.93	3.71	41.44	49.28
I_4	15.61	17.31	10.76	13.56	4.85	3.75	49.63	53.86
SEm (±)	0.396	0.223	0.288	0.214	0.320	0.077	2.249	1.189
CD (0.05)	NS	0.715	0.922	0.686	NS	0.221	7.198	3.805
Nutrient levels (N)								
N_1	14.23	15.93	9.19	12.35	5.04	3.74	38.42	44.11
N_2	15.86	16.86	10.78	12.99	5.08	3.72	48.76	52.29
SEm (±)	0.241	0.232	0.280	0.178	0.194	0.113	0.899	1.140
CD (0.05)	0.693	0.665	0.805	0.512	NS	NS	2.579	3.273
Time of application (S)								
S_1	14.79	16.37	9.75	12.87	5.04	3.65	43.82	48.29
S_2	15.31	16.43	10.23	12.47	5.08	3.81	43.63	48.12
SEm (±)	0.241	0.232	0.280	0.178	0.194	0.113	0.899	1.140
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
I x N interaction								
i_1n_1	14.16	14.69	9.18	11.45	4.98	3.91	36.50	39.57
i_1n_2	15.29	16.26	9.96	13.09	5.33	3.17	43.66	46.22
i_2n_1	13.86	15.62	8.11	11.71	5.76	3.91	38.70	41.50
i_2n_2	15.19	16.83	10.36	12.27	4.82	3.96	47.72	52.05
i_3n_1	14.62	16.38	9.82	12.70	4.80	3.68	36.44	44.74
i_3n_2	16.03	16.76	10.97	13.02	5.06	3.73	46.44	53.82
i_4n_1	14.28	17.04	9.67	13.56	4.62	3.48	42.05	50.65
i_4n_2	16.94	17.58	11.85	13.56	5.09	4.02	57.22	57.08
SEm (±)	0.483	0.463	0.561	0.357	0.388	0.226	1.796	2.282
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
N x S interaction								
n_1s_1	13.93	15.99	8.99	12.55	4.94	3.77	37.57	44.53
n_1s_2	14.54	15.87	9.40	12.16	5.14	3.72	39.27	43.70
n_2s_1	15.64	16.72	10.51	13.19	5.14	3.53	50.07	52.05
n_2s_2	16.08	16.99	11.06	12.78	5.02	3.91	47.45	52.54
SEm (±)	0.341	0.328	0.397	0.252	0.274	0.160	1.271	1.614
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS- not significant

Table 16b. Interaction effect of irrigation and nutrient schedule on the quality attributes of Grand Nain banana

Treatments	Total sugar (%)		Reducing sugars (%)		Non reducing sugars (%)		Sugar acid ratio	
	I year	II year	I year	II year	I year	II year	I year	II year
I x S interaction								
i_1s_1	14.37	15.35	9.42	12.66	4.95	3.36	40.65	43.38
i_1s_2	15.08	15.60	9.71	11.88	5.37	3.72	39.52	42.41
i_2s_1	14.22	16.13	8.66	12.46	5.57	3.67	43.32	45.47
i_2s_2	14.83	16.32	9.81	11.52	5.02	4.20	43.11	48.08
i_3s_1	15.28	16.34	10.25	12.70	5.03	3.64	42.18	49.48
i_3s_2	15.37	16.80	10.53	13.02	4.84	3.78	40.71	49.08
i_4s_1	15.28	17.61	10.66	13.68	4.62	3.94	49.15	54.82
i_4s_2	15.94	17.01	10.85	13.45	5.09	3.56	50.12	52.90
SEm (±)	0.483	0.463	0.561	0.357	0.388	0.226	1.798	2.282
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
I x N x S interaction								
$i_1n_1s_1$	13.48	14.67	8.81	12.24	4.68	3.77	37.19	40.83
$i_1n_1s_2$	14.85	14.71	9.56	10.66	5.29	4.05	35.81	38.32
$i_1n_2s_1$	15.26	16.03	10.04	13.08	5.22	2.95	44.11	45.94
$i_1n_2s_2$	15.32	16.49	9.87	13.10	5.44	3.40	43.22	46.50
$i_2n_1s_1$	13.87	15.51	8.08	11.71	5.79	3.80	37.41	40.48
$i_2n_1s_2$	13.86	15.73	8.14	11.72	5.73	4.02	40.00	42.51
$i_2n_2s_1$	14.58	16.76	9.23	13.21	5.35	3.55	49.22	50.47
$i_2n_2s_2$	15.80	16.90	11.49	11.32	4.31	4.38	46.21	53.64
$i_3n_1s_1$	14.83	16.21	9.72	12.42	5.11	3.79	37.02	45.52
$i_3n_1s_2$	14.41	16.55	9.91	12.98	4.50	3.58	35.86	43.97
$i_3n_2s_1$	15.73	16.47	10.79	12.98	4.95	3.49	47.34	53.45
$i_3n_2s_2$	16.33	17.05	11.15	13.07	5.18	3.98	45.55	54.19
$i_4n_1s_1$	13.54	17.58	9.35	13.86	4.19	3.73	38.68	51.30
$i_4n_1s_2$	15.03	16.50	9.99	13.27	5.04	3.23	45.42	50.00
$i_4n_2s_1$	17.01	17.64	11.97	13.50	5.04	4.15	59.61	58.35
$i_4n_2s_2$	16.86	17.52	11.72	13.63	5.14	3.89	54.82	55.81
SEm (±)	0.683	0.655	0.794	0.505	0.549	0.319	2.543	3.227
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS- not significant

The nutrient application based on the uptake of nutrients (N_2) recorded the highest total sugar content during both the years (15.86 and 16.86%, respectively). The time of application and the interaction effects were found not significant.

4.1.3.4 Reducing Sugar (%)

The analysed data are presented in the Tables 16a and 16b.

The data presented in the Tables clearly indicated that the reducing sugar content vary with the irrigation levels. Among the irrigation levels, irrigation scheduled at 0.8 and 1.0 IW/CPE were at par and recorded the highest reducing sugar (10.39 and 10.76%, respectively), and significantly superior to the irrigation levels of 0.4 and 0.6 IW/CPE during first year. But during second year the irrigation level, 1.0 IW/CPE recorded the highest reducing sugar content (13.56%) and significantly superior to the other three levels of irrigation.

The reducing sugar content in the fruit was also influenced by the nutrient level. The nutrient application based on the uptake of nutrients (N_2) recorded the highest reducing sugar content during both the years (10.78 and 12.99%, respectively). The time of application and the interaction effects were found not significant.

4.1.3.5 Non Reducing Sugar (%)

The analysed data are presented in the Tables 16a and 16b.

The analysed data revealed that the non reducing sugar content in the fruit pulp was affected by the irrigation schedule only during second year of study. The non reducing sugar was the highest in 0.6 IW/CPE and found on par with 0.8 and 1.0 IW/CPE irrigation levels during second year. The nutrient levels, time of application and the interaction effects failed to produce any significant effect on the non reducing sugar content.

4.1.3.6 Sugar Acid Ratio

The analysed data are presented in the Tables 16a and 16b.

A critical analysis of the data revealed that the sugar acid ratio was the highest at 1.0 IW/CPE during both the years and significantly superior to the other three levels of irrigation. The nutrient application based on the uptake of nutrients (N_2) recorded the highest sugar acid ratio during both the years (48.76 and 52.29, respectively). The time of application of nutrients and the interaction effects were not significant.

4.1.3.7 Ascorbic Acid (mg 100 g^{-1})

Data related to the ascorbic acid content is presented in the Tables 15a and 15b.

Though it was not affected by irrigation levels during first year, the irrigation scheduled at 0.6, 0.8 and 1.0 IW/CPE were at par and was significantly superior to 0.4 IW/CPE during second year.

Among the two nutrient levels, nutrient application based on the uptake of nutrients (N_2) recorded the highest ascorbic acid content during first and second year (15.86 and 15.71 mg 100 g^{-1}, respectively).

The time of application and the interaction effects were found not significant.

4.1.4 Shelf Life (Days)

The data on the shelf life is summarized in the Tables 15a and 15b.

The shelf life of fruits was influenced by irrigation and nutrient levels. The irrigation at 0.4 IW/CPE recorded the shortest shelf life, while 1.0 IW/CPE recorded the longest shelf life. The nutrient application based on the uptake of nutrients (N_2) registered the longest shelf life of 9.47 days and it was significantly superior to the other level. The time of application of nutrients as well as the interaction effects was found not significant.

4.1.5 Plant Analysis

4.1.5.1 Nutrient Content (N, P and K) in the Index Leaf at 4 MAP (%)

The primary nutrient (N, P, K) content in the index leaf at 4 MAP for the two crop years are presented in Tables 17a and 17b and the perusal of data during both the years revealed that the N, P, K content in the index leaf at 4 MAP was significantly influenced by the treatments.

Data pertaining to first year indicated that irrigation scheduled at 0.6 and 0.8 IW/CPE (I_2 and I_3) recorded significantly higher nitrogen content than irrigation at 1.0 and 0.4 IW/CPE (I_4 and I_1). Among the nutrient levels (N), nutrient application based on the uptake of nutrients (N_2) recorded the highest N content (3.73%) and the time of application (S) did not influence the leaf N content.

Among the N x S interaction, the nutrient application based on the uptake of nutrients at 2 and 4 MAP (n_2s_1) recorded the highest N content (4.06%) and significantly superior to other treatments. The other interactions were found to be non significant.

During second year, differential irrigation levels only influenced the leaf N content. Irrigation level at 1.0 IW/CPE (I_4) recorded the highest N content (2.99%) and it was at par with irrigation levels of 0.6 and 0.8 IW/CPE (I_2 and I_3) and also it was significantly superior to 0.4 IW/CPE (I_1). Other factors remain not significant.

The phosphorus content in index leaf at 4 MAP was significantly influenced by the treatments. Analysed data during first year revealed that irrigation scheduled at 0.8 IW/CPE (I_3) ratio recorded significantly higher phosphorus content (0.40%) compared to all other treatments followed by 1.0 IW/CPE (I_4).

Table 17a. Effect of irrigation and nutrient schedule on the nutrient content (N, P and K) in the index leaf at 4 MAP of Grand Nain banana

Treatments	**Leaf N %**		**Leaf P %**		**Leaf K %**	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
Irrigation levels (I)						
I_1	3.30	2.62	0.18	0.15	4.55	2.99
I_2	3.60	2.71	0.12	0.16	4.75	3.16
I_3	3.80	2.82	0.40	0.24	5.03	3.32
I_4	3.37	2.99	0.24	0.18	4.93	3.45
SEm (±)	0.091	0.087	0.019	0.012	0.116	0.103
CD (0.05)	0.290	0.278	0.064	NS	0.372	0.329
Nutrient levels (N)						
N_1	3.31	2.76	0.30	0.15	4.39	2.89
N_2	3.73	2.81	0.17	0.21	5.23	3.56
SEm (±)	0.118	0.060	0.011	0.010	0.056	0.067
CD (0.05)	0.339	0.172	0.031	0.029	0.161	0.191
Time of application (S)						
S_1	3.50	2.71	0.26	0.18	4.63	3.22
S_2	3.53	2.86	0.21	0.18	4.99	3.23
SEm (±)	0.118	0.060	0.011	0.010	0.056	0.067
CD (0.05)	NS	NS	0.031	NS	0.161	NS
I x N interaction						
i_1n_1	2.80	2.53	0.12	0.12	4.17	2.72
i_1n_2	3.79	2.71	0.24	0.17	4.93	3.25
i_2n_1	3.46	2.68	0.16	0.14	4.67	2.87
i_2n_2	3.74	2.75	0.08	0.17	4.82	3.44
i_3n_1	3.56	2.78	0.30	0.21	4.39	2.91
i_3n_2	4.05	2.87	0.50	0.27	5.66	3.73
i_4n_1	3.41	3.05	0.12	0.14	4.33	3.06
i_4n_2	3.33	2.93	0.37	0.23	5.52	3.84
SEm (±)	0.236	0.120	0.022	0.020	0.112	0.133
CD (0.05)	NS	NS	0.063	NS	0.321	NS
N x S interaction						
n_1s_1	2.95	2.70	0.15	0.15	4.33	2.84
n_1s_2	3.67	2.82	0.20	0.16	4.46	2.94
n_2s_1	4.06	2.73	0.37	0.21	4.94	3.60
n_2s_2	3.40	2.90	0.22	0.21	5.53	3.53
SEm (±)	0.167	0.085	0.015	0.014	0.079	0.094
CD (0.05)	0.479	NS	0.044	NS	0.227	NS

MAP- months after planting, NS- not significant

Table 17b. Interaction effect of irrigation and nutrient schedule on the nutrient content (N, P and K) in the index leaf at 4 MAP of Grand Nain banana

Treatments	**Leaf N %**		**Leaf P %**		**Leaf K %**	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
I x S interaction						
i_1s_1	3.50	2.50	0.11	0.14	4.47	3.02
i_1s_2	3.09	2.74	0.26	0.15	4.64	2.96
i_2s_1	3.62	2.65	0.05	0.15	4.45	3.06
i_2s_2	3.58	2.77	0.18	0.16	5.05	3.25
i_3s_1	3.56	2.76	0.50	0.25	4.76	3.30
i_3s_2	4.05	2.89	0.30	0.23	5.30	3.34
i_4s_1	3.33	2.94	0.38	0.18	4.86	3.51
i_4s_2	3.40	3.03	0.10	0.18	4.99	3.39
SEm (±)	0.236	0.120	0.022	0.020	0.112	0.133
CD (0.05)	NS	NS	0.063	NS	0.321	NS
I x N x S interaction						
$i_1n_1s_1$	2.81	2.41	0.04	0.11	3.92	2.65
$i_1n_1s_2$	2.80	2.65	0.20	0.14	4.43	2.79
$i_1n_2s_1$	4.20	2.60	0.17	0.18	5.03	3.38
$i_1n_2s_2$	3.39	2.82	0.31	0.17	4.84	3.13
$i_2n_1s_1$	3.04	2.67	0.06	0.14	4.56	2.78
$i_2n_1s_2$	3.89	2.68	0.25	0.15	4.79	2.96
$i_2n_2s_1$	4.20	2.63	0.04	0.16	4.34	3.34
$i_2n_2s_2$	3.27	2.87	0.11	0.18	5.30	3.55
$i_3n_1s_1$	2.92	2.68	0.41	0.22	4.38	2.84
$i_3n_1s_2$	4.21	2.87	0.20	0.20	4.41	2.99
$i_3n_2s_1$	4.20	2.84	0.59	0.28	5.13	3.76
$i_3n_2s_2$	3.89	2.90	0.41	0.26	6.20	3.70
$i_4n_1s_1$	3.04	3.04	0.08	0.13	4.47	3.10
$i_4n_1s_2$	3.77	3.06	0.16	0.14	4.21	3.02
$i_4n_2s_1$	3.62	2.85	0.69	0.24	5.26	3.92
$i_4n_2s_2$	3.04	3.01	0.05	0.22	5.78	3.75
SEm (±)	0.334	0.169	0.030	0.028	0.159	0.189
CD (0.05)	NS	NS	0.086	NS	0.456	NS

MAP- months after planting, NS- not significant

The nutrient levels (N) and time of application (S) were also significantly influenced the P content and was the highest in POP based application of nutrients (N_2) and application in 2 splits (S_1). The I x N interaction was found to be significant and the treatment combination i_3n_2 recorded the highest P content (0.50%). Among N x S interactions, n_2s_1 (0.37%) was significantly superior to all other treatments. Among, I x S interaction, the P content was the highest in i_3s_1 and in I x N x S interactions, the phosphorus content was the highest in $i_4n_2s_1$.

During second year, nutrient levels had significant effect with N_2 recording the highest P content (0.21%) which was significantly superior to POP based application (N_1).

The potassium content at 4 MAP was influenced by the irrigation levels during first year and it was the highest (5.03%) in the irrigation level of 0.8 IW/CPE (I_3). It was on par with the irrigation level of 0.6 and 1.0 IW/CPE (I_2 and I_4). The nutrient levels (N) and time of application (S) were also significantly influenced the K content. The K content was the highest in nutrient application based on uptake of nutrients (N_2) and in time of application the highest K content was recorded in 4 splits (S_2).

All interactions were found to be significant. Among, I x N and I x S interactions, the combinations i_3n_2 and i_3s_2 recorded the highest K content. The N x S interaction was also significant with n_2s_2 recording the highest K content (5.53 %) followed by n_2s_1. Among, I x N x S interaction, the combination $i_3n_2s_2$ recorded the highest K content (6.20%) and it was on par with $i_4n_2s_2$. These two treatment combinations were significantly superior to all other combinations.

During second year, the K content (3.45 %) was the highest in irrigation at 1.0 IW/CPE (I_4). It was on par with the irrigation level of 0.6 and 0.8 IW/CPE (I_2 and I_3). The nutrient levels (N) also had significant influence on K content with N_2 recorded the highest K content (3.56%). The time of application (S) of nutrients and the interactions were found not significant during second year.

4.1.5.2 Nutrient Content (N, P, K) in Plant Parts at Harvest (%)

The N, P and K content of pseudostem, rhizome, leaf and fruit at harvest are presented in the Tables 18a to 20b.

4.1.5.2.1 Nitrogen Content (%)

Analysed data revealed that irrigation levels had significant influence in N content of plant parts. In first year, irrigation at 0.6 IW/CPE (I_2) and 0.8 IW/CPE (I_3) were at par and recorded higher N content in pseudostem than the other two levels of irrigation. During second year, irrigation at 1.0 IW/CPE (I_4) recorded the highest pseudostem N content (1.28%) and was at par with 0.6 and 0.8 IW/CPE (I_2 and I_3) and significantly superior to 0.4 IW/CPE (I_1). The rhizome N content was also the highest in I_4 during both the years. It was at par with 0.6 and 0.8 IW/CPE (I_2 and I_3) during both the years. Leaf N content at harvest was the highest in I_4 during both the years and was on par with 0.6 and 0.8 IW/CPE (I_2 and I_3). The fruit N content was also the highest with 1.0 IW/CPE (I_4) during both the years and was at par with 0.8 IW/CPE (I_3) during second year.

Nutrient levels also had significant influence on the nutrient content of plant parts. The N content in pseudostem was the highest in POP based application (N_1) during first year and in uptake based application (N_2) during second year. The N content in rhizome (0.97%) was found significant only during second year and N_2 recorded the highest N content. The leaf N content (2.71%) was significant only during first year and N_2 recorded the highest. However, N content in fruit was found to be significant during both the years with N_2 recording the highest.

The N content in pseudostem was influenced by I x N interaction during both the years with i_3n_1 and i_4n_2 recording the highest (2.22 and 1.51%, respectively). The N content in rhizome was influenced by I x N, N x S and I x S interactions during first year and the highest were in i_4n_1, n_1s_2 and i_4s_2 treatment combinations, respectively. The leaf and fruit N content were not influenced by any interactions.

Table 18a. Effect of irrigation and nutrient schedule on the N content in different parts of banana, %

Treatments	Pseudostem N (%)		Rhizome N (%)		Leaf N (%)		Fruit N (%)	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels (I)								
I_1	1.30	1.03	1.65	0.82	2.25	1.83	2.02	0.77
I_2	1.72	1.14	1.95	0.79	2.58	1.97	1.85	0.82
I_3	1.80	1.17	1.83	0.96	2.74	2.00	2.24	0.89
I_4	1.32	1.28	2.10	1.02	2.71	2.19	2.67	0.90
SEm (±)	0.090	0.053	0.073	0.030	0.079	0.033	0.074	0.014
CD (0.05)	0.289	0.170	0.234	0.097	0.252	0.094	0.238	0.043
Nutrient levels (N)								
N_1	1.71	1.05	1.93	0.82	2.43	1.96	2.09	0.81
N_2	1.37	1.26	1.84	0.97	2.71	2.04	2.30	0.88
SEm (±)	0.065	0.024	0.040	0.025	0.039	0.033	0.058	0.019
CD (0.05)	0.187	0.070	0.114	0.072	0.112	NS	0.166	0.055
Time of application (S)								
S_1	1.48	1.15	1.70	0.88	2.54	1.97	2.20	0.84
S_2	1.60	1.16	2.06	0.92	2.59	2.03	2.18	0.85
SEm (±)	0.065	0.024	0.040	0.025	0.112	0.033	0.058	0.019
CD (0.05)	NS	NS	0.114	NS	NS	NS	NS	NS
I x N interaction								
i_1n_1	1.44	0.96	1.61	0.69	2.08	1.78	1.81	0.70
i_1n_2	1.17	1.10	1.70	0.95	2.41	1.88	2.24	0.84
i_2n_1	1.75	1.05	1.91	0.75	2.49	1.97	1.72	0.83
i_2n_2	1.70	1.23	1.98	0.83	2.67	1.97	1.97	0.81
i_3n_1	2.22	1.13	1.89	0.91	2.59	2.03	2.33	0.85
i_3n_2	1.39	1.20	1.76	1.01	2.90	1.97	2.15	0.92
i_4n_1	1.42	1.06	2.30	0.93	2.55	2.05	2.50	0.85
i_4n_2	1.23	1.51	1.90	1.11	2.86	2.32	2.83	0.95
SEm (±)	0.130	0.049	0.080	0.050	0.078	0.065	0.116	0.038
CD (0.05)	0.373	0.140	0.229	NS	NS	NS	NS	NS
N x S interaction								
n_1s_1	1.58	1.03	1.62	0.81	2.36	1.93	2.09	0.81
n_1s_2	1.83	1.07	2.23	0.83	2.50	1.99	2.09	0.81
n_2s_1	1.37	1.26	1.78	0.94	2.73	2.02	2.32	0.86
n_2s_2	1.37	1.26	1.89	1.00	2.69	2.05	2.28	0.89
SEm (±)	0.092	0.035	0.056	0.035	0.055	0.046	0.082	0.027
CD (0.05)	NS	NS	0.162	NS	NS	NS	NS	NS

NS- not significant

Table 18b. Interaction effect of irrigation and nutrient schedule on the N content in different parts of banana, %

Treatments	Pseudostem N (%)		Rhizome N (%)		Leaf N (%)		Fruit N (%)	
	I year	II year	I year	II year	I year	II year	I year	II year
I x S interaction								
i_1s_1	1.27	0.98	1.41	0.80	2.22	1.79	2.03	0.77
i_1s_2	1.34	1.07	1.90	0.83	2.28	1.87	2.02	0.77
i_2s_1	1.78	1.15	1.88	0.75	2.55	1.95	1.82	0.82
i_2s_2	1.67	1.13	2.02	0.82	2.61	1.99	1.88	0.82
i_3s_1	1.58	1.18	1.77	0.94	2.77	1.95	2.30	0.89
i_3s_2	2.03	1.16	1.89	0.98	2.72	2.04	2.18	0.89
i_4s_1	1.28	1.28	1.76	1.00	2.63	2.20	2.67	0.87
i_4s_2	1.37	1.29	2.44	1.04	2.78	2.18	2.66	0.93
SEm (±)	0.130	0.049	0.080	0.050	0.078	0.065	0.116	0.038
CD (0.05)	NS	NS	0.229	NS	NS	NS	NS	NS
I x N x S interaction								
$i_1n_1s_1$	1.35	0.91	1.26	0.68	2.04	1.76	1.80	0.71
$i_1n_1s_2$	1.52	1.01	1.95	0.70	2.13	1.80	1.82	0.69
$i_1n_2s_1$	1.18	1.06	1.56	0.93	2.40	1.82	2.25	0.83
$i_1n_2s_2$	1.15	1.14	1.85	0.97	2.43	1.94	2.23	0.85
$i_2n_1s_1$	1.79	1.02	1.85	0.74	2.31	1.91	1.67	0.86
$i_2n_1s_2$	1.71	1.08	1.98	0.76	2.68	2.03	1.78	0.80
$i_2n_2s_1$	1.77	1.28	1.90	0.77	2.80	1.99	1.96	0.78
$i_2n_2s_2$	1.63	1.18	2.06	0.88	2.55	1.96	1.98	0.84
$i_3n_1s_1$	1.81	1.14	1.75	0.89	2.63	1.95	2.35	0.90
$i_3n_1s_2$	2.63	1.13	2.03	0.94	2.56	2.11	2.30	0.81
$i_3n_2s_1$	1.34	1.21	1.78	1.00	2.92	1.96	2.24	0.88
$i_3n_2s_2$	1.43	1.20	1.75	1.02	2.88	1.98	2.05	0.96
$i_4n_1s_1$	1.38	1.06	1.63	0.94	2.45	2.09	2.52	0.77
$i_4n_1s_2$	1.46	1.07	2.97	0.93	2.66	2.02	2.48	0.92
$i_4n_2s_1$	1.18	1.50	1.89	1.07	2.82	2.31	2.82	0.96
$i_4n_2s_2$	1.28	1.51	1.91	1.14	2.90	2.34	2.85	0.93
SEm (±)	0.184	0.069	0.113	0.071	0.111	0.093	0.164	0.054
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS- not significant

Table 19a. Effect of irrigation and nutrient schedule on the P content in different parts of banana, %

Treatments	Pseudostem P (%)		Rhizome P (%)		Leaf P (%)		Fruit P (%)	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels (I)								
I_1	0.12	0.10	0.12	0.12	0.10	0.08	0.17	0.10
I_2	0.10	0.12	0.13	0.12	0.13	0.08	0.18	0.11
I_3	0.13	0.10	0.28	0.13	0.11	0.10	0.17	0.11
I_4	0.14	0.12	0.30	0.16	0.12	0.10	0.22	0.13
SEm (±)	0.005	0.003	0.011	0.007	0.008	0.004	0.026	0.004
CD (0.05)	0.015	0.010	0.037	0.020	0.026	0.012	0.008	0.012
Nutrient levels (N)								
N_1	0.10	0.10	0.12	0.11	0.11	0.10	0.17	0.10
N_2	0.15	0.12	0.30	0.15	0.12	0.09	0.20	0.12
SEm (±)	0.005	0.004	0.009	0.003	0.006	0.003	0.003	0.003
CD (0.05)	0.014	0.012	0.025	0.010	NS	NS	0.010	0.008
Time of application (S)								
S_1	0.13	0.11	0.24	0.13	0.10	0.09	0.19	0.11
S_2	0.12	0.11	0.19	0.13	0.13	0.09	0.18	0.12
SEm (±)	0.005	0.004	0.009	0.003	0.006	0.003	0.003	0.003
CD (0.05)	NS	NS	0.025	NS	0.0184	NS	0.010	0.008
I x N interaction								
i_1n_1	0.07	0.09	0.10	0.09	0.10	0.08	0.12	0.09
i_1n_2	0.17	0.11	0.15	0.15	0.11	0.09	0.22	0.10
i_2n_1	0.10	0.12	0.10	0.10	0.11	0.08	0.16	0.10
i_2n_2	0.10	0.12	0.16	0.14	0.15	0.08	0.20	0.13
i_3n_1	0.11	0.09	0.14	0.12	0.12	0.09	0.17	0.10
i_3n_2	0.16	0.11	0.42	0.14	0.10	0.11	0.17	0.12
i_4n_1	0.12	0.10	0.15	0.14	0.12	0.10	0.22	0.11
i_4n_2	0.16	0.09	0.45	0.17	0.12	0.11	0.21	0.14
SEm (±)	0.010	0.008	0.052	0.007	0.013	0.007	0.007	0.004
CD (0.05)	*	NS	0.018	NS	NS	NS	*	NS
N x S interaction								
n_1s_1	0.11	0.10	0.11	0.11	0.10	0.08	0.18	0.09
n_1s_2	010	0.10	0.14	0.11	0.12	0.09	0.16	0.11
n_2s_1	0.15	0.12	0.36	0.15	0.11	0.10	0.21	0.12
n_2s_2	0.14	0.12	0.23	0.15	0.13	0.09	0.19	0.13
SEm (±)	0.007	0.006	0.013	0.005	0.009	0.005	0.005	0.005
CD (0.05)	NS	NS	0.036	NS	NS	NS	NS	NS

NS- not significant

Table 19b. Interaction effect of irrigation and nutrient schedule on the P content in different parts of banana, %

Treatments	Pseudostem P (%)		Rhizome P (%)		Leaf P (%)		Fruit P (%)	
	I year	II year	I year	II year	I year	II year	I year	II year
I x S interaction								
i_1s_1	0.13	0.09	0.14	0.11	0.09	0.08	0.18	0.09
i_1s_2	0.12	0.10	0.11	0.13	0.12	0.08	0.16	0.10
i_2s_1	0.11	0.11	0.12	0.13	0.12	0.09	0.18	0.11
i_2s_2	0.09	0.12	0.13	0.12	0.14	0.08	0.18	0.12
i_3s_1	0.14	0.10	0.33	0.13	0.09	0.10	0.18	0.10
i_3s_2	0.13	0.12	0.23	0.13	0.13	0.11	0.15	0.12
i_4s_1	0.15	0.12	0.35	0.15	0.12	0.11	0.23	0.12
i_4s_2	0.14	0.13	0.25	0.16	0.12	0.10	0.21	0.13
SEm (±)	0.010	0.008	0.018	0.007	0.013	0.007	0.007	0.005
CD (0.05)	NS	NS	0.052	NS	NS	NS	NS	NS
I x N x S interaction								
$i_1n_1s_1$	0.07	0.10	0.11	0.09	0.08	0.07	0.12	0.09
$i_1n_1s_2$	0.08	0.09	0.09	0.09	0.12	0.08	0.12	0.09
$i_1n_2s_1$	0.19	0.11	0.17	0.13	0.11	0.09	0.24	0.10
$i_1n_2s_2$	0.16	0.11	0.13	0.16	0.11	0.09	0.21	0.11
$i_2n_1s_1$	0.13	0.12	0.08	0.09	0.11	0.09	0.17	0.10
$i_2n_1s_2$	0.08	0.12	0.11	0.10	0.10	0.08	0.16	0.11
$i_2n_2s_1$	0.09	0.13	0.16	0.16	0.12	0.09	0.20	0.13
$i_2n_2s_2$	0.10	0.12	0.16	0.13	0.18	0.07	0.19	0.13
$i_3n_1s_1$	0.12	0.10	0.12	0.12	0.10	0.08	0.20	0.10
$i_3n_1s_2$	0.10	0.09	0.16	0.11	0.14	0.10	0.14	0.11
$i_3n_2s_1$	0.16	0.10	0.55	0.14	0.09	0.11	0.17	0.11
$i_3n_2s_2$	0.15	0.11	0.30	0.14	0.12	0.12	0.16	0.13
$i_4n_1s_1$	0.11	0.10	0.13	0.13	0.12	0.10	0.23	0.10
$i_4n_1s_2$	0.13	0.11	0.18	0.14	0.13	0.10	0.22	0.12
$i_4n_2s_1$	0.18	0.13	0.58	0.17	0.11	0.11	0.22	0.14
$i_4n_2s_2$	0.15	0.13	0.33	0.18	0.12	0.11	0.20	0.15
SEm (±)	0.014	0.011	0.025	0.010	0.018	0.010	0.010	0.008
CD (0.05)	0.040	NS	0.072	NS	NS	NS	0.029	NS

NS- not significant

Table 20a. Effect of irrigation and nutrient schedule on the K content in different parts of banana, %

Treatments	Pseudostem K (%)		Rhizome K (%)		Leaf K (%)		Fruit K (%)	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels (I)								
I_1	10.73	8.55	4.46	4.37	3.75	2.93	4.98	5.00
I_2	10.84	8.34	4.35	5.20	3.32	2.96	5.61	6.06
I_3	9.91	9.65	5.08	5.53	3.52	2.90	5.88	5.88
I_4	12.40	10.88	4.75	6.20	3.61	3.13	6.48	6.38
SEm (±)	0.322	0.662	0.111	0.357	0.085	0.104	0.177	0.287
CD (0.05)	1.03	2.120	0.356	1.143	0.271	0.332	0.565	0.919
Nutrient levels (N)								
N_1	9.33	8.79	3.67	4.98	3.16	2.79	4.72	5.44
N_2	12.61	9.91	5.65	5.67	3.94	3.17	6.75	6.22
SEm (±)	0.208	0.469	0.158	0.215	0.051	0.083	0.126	0.163
CD (0.05)	0.597	NS	0.454	0.618	0.145	0.238	0.362	0.467
Time of application (S)								
S_1	10.69	9.109	4.603	5.23	3.48	2.97	5.95	5.56
S_2	11.25	9.598	4.716	5.42	3.62	2.99	5.53	6.09
SEm (±)	0.208	0.469	0.158	0.215	0.051	0.083	0.126	0.163
CD (0.05)	NS	NS	NS	NS	NS	NS	0.362	0.467
I x N interaction								
i_1n_1	9.09	8.78	3.30	4.09	3.07	2.68	3.69	4.75
i_1n_2	12.34	8.32	5.63	4.65	4.44	3.19	6.26	5.25
i_2n_1	9.16	7.80	3.97	4.83	2.91	2.91	4.98	5.75
i_2n_2	12.51	8.87	4.73	5.58	3.72	3.01	6.23	6.38
i_3n_1	9.31	9.41	3.95	5.15	3.43	2.78	4.78	5.38
i_3n_2	10.50	9.88	6.21	5.90	3.62	3.03	6.99	6.38
i_4n_1	9.76	9.18	3.45	5.85	3.24	2.82	5.44	5.88
i_4n_2	15.04	12.58	6.04	6.55	3.98	3.45	7.51	6.88
SEm (±)	0.416	0.939	0.317	0.431	0.101	0.166	0.253	0.326
CD (0.05)	1.193	NS	0.908	NS	0.290	NS	NS	NS
N x S interaction								
n_1s_1	8.80	8.42	3.55	4.78	2.90	2.82	4.72	5.19
n_1s_2	9.87	9.16	3.79	5.18	3.42	2.77	4.73	5.69
n_2s_1	12.58	9.79	5.66	5.68	4.06	3.13	7.17	5.94
n_2s_2	12.64	10.03	5.64	5.66	3.81	3.21	6.33	6.50
SEm (±)	0.294	0.664	0.224	0.305	0.072	0.117	0.179	0.230
CD (0.05)	NS	NS	NS	NS	0.205	NS	0.512	NS

NS- not significant

Table 20b. Interaction effect of irrigation and nutrient schedule on the K content in different parts of banana, %

Treatments	Pseudostem K (%)		Rhizome K (%)		Leaf K (%)		Fruit K (%)	
	I year	II year	I year	II year	I year	II year	I year	II year
I x S interaction								
i_1s_1	10.49	8.13	4.67	4.35	3.75	2.88	5.01	4.75
i_1s_2	10.98	8.98	4.25	4.39	3.76	2.99	4.94	5.25
i_2s_1	10.98	8.29	3.95	5.29	3.34	2.95	5.90	5.88
i_2s_2	10.69	8.38	4.75	5.11	3.26	2.97	5.31	6.25
i_3s_1	9.38	9.04	5.08	5.44	3.49	2.91	6.05	5.50
i_3s_2	10.44	10.25	5.08	5.61	3.56	2.90	5.72	6.25
i_4s_1	11.90	10.97	4.71	5.84	3.32	3.17	6.83	6.13
i_4s_2	12.90	10.79	4.78	6.56	3.90	3.10	6.13	6.63
SEm (±)	0.416	0.939	0.317	0.431	0.101	0.166	0.253	0.326
CD (0.05)	NS	NS	NS	NS	0.290	NS	NS	NS
I x N x S interaction								
$i_1n_1s_1$	8.68	8.17	3.69	3.90	2.83	2.65	3.50	4.50
$i_1n_1s_2$	9.51	9.40	2.91	4.28	3.31	2.70	3.88	5.00
$i_1n_2s_1$	12.31	8.10	5.66	4.80	4.68	3.10	6.51	5.00
$i_1n_2s_2$	12.44	8.55	5.60	4.50	4.20	3.28	6.01	5.50
$i_2n_1s_1$	9.00	7.86	3.13	4.68	2.78	3.05	5.49	5.50
$i_2n_1s_2$	9.33	7.74	4.81	4.98	3.05	2.76	4.48	6.00
$i_2n_2s_1$	12.96	8.72	4.78	5.90	3.98	2.84	6.31	6.25
$i_2n_2s_2$	12.06	9.02	4.69	5.25	3.46	3.19	6.15	6.50
$i_3n_1s_1$	8.50	8.32	4.00	5.08	3.40	2.77	4.18	5.00
$i_3n_1s_2$	10.13	10.50	3.90	5.23	3.46	2.78	5.38	5.75
$i_3n_2s_1$	10.25	9.76	6.15	5.80	3.58	3.05	7.92	6.00
$i_3n_2s_2$	10.75	9.99	6.26	6.00	3.65	3.01	6.06	6.75
$i_4n_1s_1$	9.01	9.34	3.38	5.45	2.61	2.80	5.71	5.75
$i_4n_1s_2$	10.50	9.02	3.53	6.25	3.87	2.83	5.18	6.00
$i_4n_2s_1$	14.79	12.59	6.05	6.23	4.03	3.54	7.95	6.50
$i_4n_2s_2$	15.30	12.57	6.03	6.88	3.93	3.36	7.08	7.25
SEm (±)	0.589	1.328	0.448	0.609	0.143	0.235	0.357	0.461
CD (0.05)	NS	NS	NS	NS	0.410	NS	NS	NS

NS- not significant

4.1.5.2.2 Phosphorus Content (P%)

Irrigation levels had significant influence on P content in plant parts at harvest. In first year irrigation at 1.0 IW/CPE (I_4) and 0.8 IW/CPE (I_3) were at par and recorded higher P content in pseudostem than the other two levels of irrigation. During second year, irrigation at 1.0 IW/CPE (I_4) and 0.6 IW/CPE (I_2) were at par and recorded the same pseudostem P content (0.12%) and found superior to the other two levels. The P content in rhizome was significantly higher in 0.6 IW/CPE (I_2) during first year and found at par with 0.8 IW/CPE (I_3) and 1.0 IW/CPE (I_4). Leaf P content at harvest was higher in 0.4 IW/CPE (I_1) and found at par with 0.8 IW/CPE (I_3) and 1.0 IW/CPE (I_4) during first year. During second year, irrigation at 1.0 IW/CPE (I_4) and 0.8 IW/CPE (I_3) were at par and recorded the same pseudostem P content (0.10%). During both the years, irrigation at IW/CPE of 1 (I_4) recorded the highest fruit P content.

The nutrient levels did not influence the leaf P content. In other plant parts, the P content was significantly higher in N_2. The time of application (S) significantly influenced the rhizome and fruit P content recording with the highest first year. However during second year, S_2 recorded the higher fruit P content.

Among I x N interactions, pseudostem, rhizome and fruit P content were significant only during first year. However, N x S, I x S, and I x N x S interactions were significant for rhizome P content.

4.1.5.2.3 Potassium Content (K%)

A critical review of the data revealed that K content was significantly influenced by the irrigation levels. The K content in pseudostem was the highest in irrigation at 1.0 IW/CPE (I_4) during both the years. During second year it was at par with I_3. Rhizome K content at harvest was at par with 0.8 IW/CPE (I_3) and 1.0 IW/CPE (I_4) during first year and was at par with 0.6 IW/CPE (I_2) and 0.8 IW/CPE (I_3) and 1.0 IW/CPE (I_4) during second year. Leaf K content at harvest was significantly higher in 0.4 IW/CPE (I_1) and was found at par with 0.8

IW/CPE (I_3) and 1.0 IW/CPE (I_4) during first year, however, not significant during second year. Fruit K content at harvest was significantly higher in irrigation at 1.0 IW/CPE (I_4) during both the years and was at par with 0.6 IW/CPE (I_2) during second year.

The uptake based application of nutrients (N_2) resulted in higher K content in plant parts during both the years except in pseudostem during second year. The fruit K content was influenced by time of application (S) of nutrients and application in two splits (S_1) recorded higher K content during first year, while application in four splits (S_2) recorded higher K content during second year. The interaction, I x N was found significant during first year and the rhizome K content was at par in i_1n_2, i_3n_2 and i_4n_2 and leaf K content was the highest in i_1n_2. Fruit K content was not affected by I x N interaction. In N x S interactions, during first year, leaf and fruit K content were significantly higher in n_2s_1. In I x S interaction, i_4s_2 recorded the highest value and was on par with i_1s_1 and i_1s_2. In the three way interaction (I x N x S), leaf K content was significantly the highest in $i_1n_2s_1$.

4.1.6 Dry Matter Production (DMP) and Partitioning at Harvest

The dry matter production (DMP) of plant parts and total DMP in first and second year is presented in Tables 21a to 24b.

4.1.6.1 Dry Matter of Pseudostem

Dry matter production was significantly influenced by the treatments and the pseudostem dry matter production was the highest in irrigation at 1.0 IW/CPE (I_4) which was on a par with 0.8 IW/CPE (I_3) and significantly superior to other two levels of irrigation during first year. However, during second year the DMP was the highest in irrigation at 1.0 IW/CPE (I_4) which was significantly superior to other three levels of irrigation. The DMP was the lowest in irrigation at 0.4 IW/CPE. Among the two nutrient levels (N), N_2 recorded the highest DMP (1.29 kg plant^{-1} and 3.98 t ha^{-1} and 1.11 kg plant^{-1} and 3.42 t ha^{-1}, respectively) during

Table 21a. Effect of irrigation and nutrient schedule on the dry matter production and total biological yield of plant parts of banana (first year), kg plant^{-1}

Treatments	**Pseudostem DMP**	**Rhizome DMP**	**Leaf DMP**	**Fruit DMP**	**Total DMP**	**Total biological yield**
Irrigation levels (I)						
I_1	1.04	0.56	1.81	2.73	6.13	61.13
I_2	1.10	0.55	1.74	3.17	6.55	64.50
I_3	1.29	0.65	2.23	3.84	8.01	76.75
I_4	1.36	0.71	2.44	3.84	8.34	81.19
SEm (±)	0.028	0.018	0.102	0.086	0.134	0.826
CD (0.05)	0.091	0.059	0.326	0.276	0.429	2.644
Nutrient levels (N)						
N_1	1.10	0.57	1.85	3.06	6.58	64.45
N_2	1.29	0.66	2.26	3.72	7.93	77.33
SEm (±)	0.016	0.009	0.028	0.056	0.079	0.612
CD (0.05)	0.045	0.024	0.079	0.160	0.226	1.758
Time of application (S)						
S_1	1.206	0.62	2.07	3.42	7.30	71.11
S_2	1.186	0.61	2.04	3.36	7.22	70.67
SEm (±)	0.016	0.009	0.028	0.056	0.079	0.612
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N interaction						
i_1n_1	0.97	0.53	1.63	2.59	5.72	56.50
i_1n_2	1.11	0.58	2.00	2.86	6.55	65.75
i_2n_1	1.02	0.51	1.63	2.91	6.06	59.75
i_2n_2	1.18	0.59	1.85	3.43	7.05	69.25
i_3n_1	1.2	0.60	1.97	3.46	7.22	69.25
i_3n_2	1.38	0.70	2.49	4.23	8.79	84.25
i_4n_1	1.22	0.64	2.18	3.31	7.35	72.31
i_4n_2	1.49	0.78	2.70	4.37	9.33	90.06
SEm (±)	0.031	0.017	0.055	0.112	0.157	1.226
CD (0.05)	NS	NS	0.159	NS	0.451	3.516
N x S interaction						
n_1s_1	1.06	0.56	1.84	3.02	6.49	63.34
n_1s_2	1.14	0.58	1.85	3.11	6.68	65.56
n_2s_1	1.31	0.68	2.29	3.82	8.10	78.88
n_2s_2	1.27	0.65	2.23	3.62	7.76	75.78
SEm (±)	0.022	0.012	0.039	0.079	0.111	0.867
CD (0.05)	0.064	0.035	NS	NS	0.319	2.486

DMP- dry matter production, NS- not significant

Table 21b. Interaction effect of irrigation and nutrient schedule on the dry matter production and total biological yield of plant parts of banana (first year), kg plant^{-1}

Treatments	Pseudostem DMP	Rhizome DMP	Leaf DMP	Fruit DMP	Total DMP	Total biological yield
I x S interaction						
i_1s_1	1.04	0.57	1.82	2.68	6.10	61.00
i_1s_2	1.04	0.55	1.81	2.77	6.16	61.25
i_2s_1	1.09	0.53	1.76	3.19	6.57	64.19
i_2s_2	1.11	0.56	1.73	3.15	6.54	64.81
i_3s_1	1.25	0.64	2.19	3.95	8.03	76.38
i_3s_2	1.34	0.65	2.26	3.74	7.99	77.13
i_4s_1	1.37	0.74	2.50	3.89	8.50	82.88
i_4s_2	1.34	0.69	2.37	3.79	8.19	79.50
SEm (±)	0.031	0.017	0.055	0.112	0.157	1.226
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	0.94	0.54	1.59	2.54	5.61	55.50
$i_1n_1s_2$	0.99	0.53	1.66	2.64	5.82	57.50
$i_1n_2s_1$	1.13	0.59	2.05	2.82	6.58	66.50
$i_1n_2s_2$	1.08	0.58	1.95	2.91	6.51	65.00
$i_2n_1s_1$	1.02	0.47	1.63	2.84	5.95	58.63
$i_2n_1s_2$	1.03	0.54	1.63	2.98	6.17	60.88
$i_2n_2s_1$	1.17	0.60	1.89	3.54	7.19	69.75
$i_2n_2s_2$	1.19	0.58	1.82	3.33	6.91	68.75
$i_3n_1s_1$	1.09	0.58	1.95	3.47	7.08	66.75
$i_3n_1s_2$	1.31	0.61	1.98	3.45	7.35	71.75
$i_3n_2s_1$	1.40	0.70	2.44	4.43	8.97	86.00
$i_3n_2s_2$	1.37	0.69	2.54	4.03	8.62	82.50
$i_4n_1s_1$	1.21	0.65	2.21	3.26	7.32	72.50
$i_4n_1s_2$	1.23	0.64	2.15	3.36	7.38	72.13
$i_4n_2s_1$	1.53	0.82	2.80	4.52	9.66	93.25
$i_4n_2s_2$	1.45	0.74	2.60	4.22	9.01	86.88
SEm (±)	0.044	0.024	0.078	0.158	0.223	1.733
CD (0.05)	NS	NS	NS	NS	NS	NS

DMP- dry matter production, NS- not significant

Table 22a. Effect of irrigation and nutrient schedule on the dry matter production and total biological yield of plant parts of banana (first year), t ha^{-1}

Treatments	Pseudostem DMP	Rhizome DMP	Leaf DMP	Fruit DMP	Total DMP	Total biological yield
Irrigation levels (I)						
I_1	3.21	1.73	5.59	8.42	18.92	188.65
I_2	3.39	1.70	5.37	9.78	20.21	199.05
I_3	3.98	2.01	6.88	11.85	24.72	236.85
I_4	4.20	2.19	7.53	11.85	25.74	250.55
SEm (±)	0.09	0.06	0.31	0.27	0.41	2.55
CD (0.05)	0.28	0.18	1.01	0.85	1.32	8.16
Nutrient levels (N)						
N_1	3.40	1.76	5.71	9.44	20.31	198.89
N_2	3.98	2.04	6.97	11.48	24.47	238.64
SEm (±)	0.05	0.03	0.09	0.17	0.24	1.89
CD (0.05)	0.14	0.07	0.24	0.49	0.70	5.43
Time of application (S)						
S_1	3.72	1.91	6.39	10.55	22.53	219.45
S_2	3.66	1.88	6.30	10.37	22.28	218.09
SEm (±)	0.05	0.03	0.09	0.17	0.24	1.89
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N interaction						
i_1n_1	2.99	1.64	5.03	7.99	17.65	174.36
i_1n_2	3.43	1.79	6.17	8.83	20.21	202.90
i_2n_1	3.15	1.57	5.03	8.98	18.70	184.39
i_2n_2	3.64	1.82	5.71	10.58	21.76	213.71
i_3n_1	3.70	1.85	6.08	10.68	22.28	213.71
i_3n_2	4.26	2.16	7.68	13.05	27.13	260.00
i_4n_1	3.76	1.98	6.73	10.21	22.68	223.15
i_4n_2	4.60	2.41	8.33	13.49	28.79	277.93
SEm (±)	0.10	0.05	0.17	0.35	0.48	3.78
CD (0.05)	NS	NS	0.49	NS	1.39	10.85
N x S interaction						
n_1s_1	3.27	1.73	5.68	9.32	20.03	195.47
n_1s_2	3.52	1.79	5.71	9.60	20.61	202.32
n_2s_1	4.04	2.10	7.07	11.79	25.00	243.42
n_2s_2	3.92	2.01	6.88	11.17	23.95	233.86
SEm (±)	0.07	0.04	0.12	0.24	0.34	2.68
CD (0.05)	0.20	0.11	NS	NS	0.98	7.67

DMP- dry matter production, NS- not significant

Table 22b. Interaction effect of irrigation and nutrient schedule on the dry matter production and total biological yield of plant parts of banana (first year), t ha^{-1}

Treatments	Pseudostem DMP	Rhizome DMP	Leaf DMP	Fruit DMP	Total DMP	Total biological yield
I x S interaction						
i_1s_1	3.21	1.76	5.62	8.27	18.82	188.25
i_1s_2	3.21	1.70	5.59	8.55	19.01	189.02
i_2s_1	3.36	1.64	5.43	9.84	20.28	198.09
i_2s_2	3.43	1.73	5.34	9.72	20.18	200.00
i_3s_1	3.86	1.98	6.76	12.19	24.78	235.71
i_3s_2	4.14	2.01	6.97	11.54	24.66	238.02
i_4s_1	4.23	2.28	7.72	12.00	26.23	255.77
i_4s_2	4.14	2.13	7.31	11.70	25.27	245.34
SEm (±)	0.10	0.05	0.17	0.35	0.48	3.78
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	2.90	1.67	4.91	7.84	17.31	171.27
$i_1n_1s_2$	3.06	1.64	5.12	8.15	17.96	177.45
$i_1n_2s_1$	3.49	1.82	6.33	8.70	20.31	205.22
$i_1n_2s_2$	3.33	1.79	6.02	8.98	20.09	200.59
$i_2n_1s_1$	3.13	1.45	5.03	8.76	18.36	180.93
$i_2n_1s_2$	3.18	1.67	5.03	9.20	19.04	187.88
$i_2n_2s_1$	3.61	1.85	5.83	10.92	22.19	215.25
$i_2n_2s_2$	3.67	1.79	5.62	10.28	21.32	212.16
$i_3n_1s_1$	3.36	1.79	6.02	10.71	21.85	205.99
$i_3n_1s_2$	4.04	1.88	6.11	10.65	22.68	221.42
$i_3n_2s_1$	4.32	2.16	7.53	13.67	27.68	265.40
$i_3n_2s_2$	4.23	2.13	7.84	12.44	26.60	254.60
$i_4n_1s_1$	3.73	2.01	6.82	10.06	22.59	223.74
$i_4n_1s_2$	3.80	1.98	6.63	10.37	22.77	222.59
$i_4n_2s_1$	4.72	2.53	8.64	13.95	29.81	287.77
$i_4n_2s_2$	4.47	2.28	8.02	13.02	27.80	268.11
SEm (±)	0.14	0.07	0.24	0.49	0.69	5.35
CD (0.05)	NS	NS	NS	NS	NS	NS

DMP- dry matter production, NS- not significant

Table 23a. Effect of irrigation and nutrient schedule on the dry matter production and total biological yield of plant parts of banana (second year), kg plant^{-1}

Treatments	**Pseudostem DMP**	**Rhizome DMP**	**Leaf DMP**	**Fruit DMP**	**Total DMP**	**Total biological yield**
Irrigation levels (I)						
I_1	0.90	0.47	1.14	2.33	4.84	50.22
I_2	0.97	0.48	1.25	2.70	5.40	55.25
I_3	1.00	0.60	1.45	3.24	6.28	62.13
I_4	1.25	0.71	1.63	3.50	7.09	72.69
SEm (±)	0.031	0.017	0.070	0.071	0.112	0.967
CD (0.05)	0.098	0.055	0.224	0.229	0.360	3.093
Nutrient levels (N)						
N_1	0.95	0.51	1.29	2.71	5.46	55.39
N_2	1.11	0.62	1.44	3.17	6.34	64.75
SEm (±)	0.013	0.011	0.027	0.032	0.044	0.476
CD (0.05)	0.039	0.031	0.079	0.092	0.126	1.366
Time of application (S)						
S_1	1.01	0.54	1.35	2.84	5.74	58.44
S_2	1.05	0.59	1.38	3.04	6.06	61.70
SEm (±)	0.013	0.011	0.027	0.032	0.044	0.476
CD (0.05)	0.039	0.031	NS	0.092	0.126	1.366
I x N interaction						
i_1n_1	0.86	0.44	1.07	2.14	4.51	47.19
i_1n_2	0.94	0.50	1.20	2.52	5.16	53.25
i_2n_1	0.89	0.45	1.22	2.49	5.04	50.94
i_2n_2	1.06	0.52	1.28	2.91	5.77	59.56
i_3n_1	0.93	0.54	1.32	3.05	5.83	57.75
i_3n_2	1.07	0.65	1.58	3.43	6.72	66.50
i_4n_1	1.14	0.61	1.54	3.19	6.47	65.69
i_4n_2	1.37	0.81	1.71	3.82	7.71	79.69
SEm (±)	0.027	0.022	0.055	0.064	0.088	0.953
CD (0.05)	0.077	0.062	NS	NS	0.252	2.732
N x S interaction						
n_1s_1	0.93	0.48	1.27	2.59	5.27	53.41
n_1s_2	0.98	0.53	1.31	2.84	5.66	57.38
n_2s_1	1.09	0.60	1.43	3.10	6.22	63.47
n_2s_2	1.13	0.64	1.45	3.24	6.46	66.03
SEm (±)	0.019	0.015	0.039	0.045	0.062	0.674
CD (0.05)	NS	NS	NS	NS	NS	NS

DMP- dry matter production, NS- not significant

Table 23b. Interaction effect of irrigation and nutrient schedule on the dry matter production and total biological yield of plant parts of banana (second year), kg plant^{-1}

Treatments	Pseudostem DMP	Rhizome DMP	Leaf DMP	Fruit DMP	Total DMP	Total biological yield
I x S interaction						
i_1s_1	0.89	0.45	1.12	2.24	4.69	48.81
i_1s_2	0.92	0.50	1.15	2.42	4.98	51.63
i_2s_1	0.95	0.46	1.24	2.59	5.23	53.44
i_2s_2	1.00	0.50	1.27	2.80	5.57	57.06
i_3s_1	0.99	0.60	1.45	3.15	6.18	61.31
i_3s_2	1.01	0.60	1.45	3.33	6.37	62.94
i_4s_1	1.21	0.67	1.59	3.40	6.87	70.19
i_4s_2	1.30	0.75	1.66	3.61	7.31	48.81
SEm (±)	0.027	0.022	0.055	0.064	0.088	0.953
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	0.83	0.42	1.07	2.03	4.35	45.38
$i_1n_1s_2$	0.89	0.46	1.07	2.24	4.67	49.00
$i_1n_2s_1$	0.94	0.47	1.17	2.45	5.03	52.25
$i_1n_2s_2$	0.94	0.53	1.24	2.59	5.29	54.25
$i_2n_1s_1$	0.86	0.43	1.20	2.31	4.80	48.75
$i_2n_1s_2$	0.91	0.46	1.24	2.66	5.27	53.13
$i_2n_2s_1$	1.03	0.49	1.27	2.87	5.66	58.13
$i_2n_2s_2$	1.09	0.54	1.30	2.94	5.87	61.00
$i_3n_1s_1$	0.92	0.53	1.30	2.94	5.69	56.63
$i_3n_1s_2$	0.94	0.54	1.33	3.15	5.97	58.88
$i_3n_2s_1$	1.06	0.66	1.59	3.36	6.67	66.00
$i_3n_2s_2$	1.07	0.65	1.56	3.50	6.78	67.00
$i_4n_1s_1$	1.09	0.55	1.50	3.08	6.22	62.88
$i_4n_1s_2$	1.18	0.66	1.59	3.29	6.72	68.50
$i_4n_2s_1$	1.33	0.79	1.69	3.71	7.52	77.50
$i_4n_2s_2$	1.41	0.84	1.72	3.92	7.89	81.88
SEm (±)	0.038	0.031	0.078	0.090	0.124	1.347
CD (0.05)	NS	NS	NS	NS	NS	NS

DMP- dry matter production, NS- not significant

Table 24a. Effect of irrigation and nutrient schedule on the dry matter production and total biological yield of plant parts of banana (second year), t ha^{-1}

Treatments	**Pseudostem DMP**	**Rhizome DMP**	**Leaf DMP**	**Fruit DMP**	**Total DMP**	**Total biological yield**
Irrigation levels (I)						
I_1	2.78	1.45	3.51	7.18	14.92	154.98
I_2	3.00	1.49	3.86	8.32	16.67	170.50
I_3	3.08	1.84	4.46	9.99	19.37	191.72
I_4	3.87	2.19	5.01	10.80	21.87	224.31
SEm (±)	0.095	0.053	0.216	0.222	0.347	2.983
CD (0.05)	0.303	0.168	0.692	0.709	1.110	9.546
Nutrient levels (N)						
N_1	2.94	1.57	3.97	8.37	16.85	170.94
N_2	3.42	1.92	4.45	9.77	19.56	199.82
SEm (±)	0.042	0.033	0.085	0.099	0.136	1.469
CD (0.05)	0.119	0.096	0.243	0.283	0.389	4.216
Time of application (S)						
S_1	3.11	1.68	4.16	8.78	17.72	180.34
S_2	3.25	1.81	4.26	9.37	18.69	190.42
SEm (±)	0.042	0.033	0.085	0.099	0.136	1.469
CD (0.05)	0.119	0.096	NS	0.283	0.389	4.216
I x N interaction						
i_1n_1	2.65	1.37	3.31	6.59	13.92	145.62
i_1n_2	2.90	1.54	3.71	7.78	15.93	164.33
i_2n_1	2.73	1.38	3.76	7.67	15.54	157.19
i_2n_2	3.27	1.60	3.96	8.96	17.79	183.81
i_3n_1	2.87	1.66	4.06	9.40	17.99	178.22
i_3n_2	3.29	2.01	4.86	10.58	20.75	205.22
i_4n_1	3.50	1.87	4.76	9.83	19.96	202.71
i_4n_2	4.23	2.51	5.27	11.77	23.78	245.92
SEm (±)	0.059	0.067	0.170	0.064	0.088	2.940
CD (0.05)	0.169	0.192	NS	NS	NS	8.431
N x S interaction						
n_1s_1	2.85	1.49	3.91	7.99	16.25	164.81
n_1s_2	3.02	1.64	4.04	8.75	17.45	177.06
n_2s_1	3.36	1.86	4.41	9.56	19.19	195.86
n_2s_2	3.48	1.97	4.49	9.99	19.93	203.77
SEm (±)	0.059	0.047	0.119	0.045	0.062	2.078
CD (0.05)	NS	NS	NS	NS	NS	NS

DMP- dry matter production, NS- not significant

Table 24b. Interaction effect of irrigation and nutrient schedule on the dry matter production and total biological yield of plant parts of banana (second year), t ha^{-1}

Treatments	Pseudostem DMP	Rhizome DMP	Leaf DMP	Fruit DMP	Total DMP	Total biological yield
I x S interaction						
i_1s_1	2.73	1.38	3.46	6.91	14.48	150.64
i_1s_2	2.82	1.53	3.56	7.45	15.37	159.31
i_2s_1	2.92	1.42	3.81	7.99	16.14	164.91
i_2s_2	3.09	1.55	3.91	8.64	17.19	176.09
i_3s_1	3.06	1.84	4.46	9.72	19.08	189.21
i_3s_2	3.10	1.84	4.46	10.26	19.66	194.23
i_4s_1	3.73	2.07	4.91	10.48	21.19	216.60
i_4s_2	4.00	2.31	5.12	11.13	22.55	232.03
SEm (±)	0.083	0.067	0.170	0.064	0.088	2.940
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	2.56	1.30	3.31	6.26	13.43	140.03
$i_1n_1s_2$	2.75	1.43	3.31	6.91	14.40	151.21
$i_1n_2s_1$	2.90	1.46	3.61	7.56	15.53	161.24
$i_1n_2s_2$	2.90	1.63	3.81	7.99	16.33	167.42
$i_2n_1s_1$	2.65	1.33	3.71	7.13	14.82	150.44
$i_2n_1s_2$	2.81	1.43	3.81	8.21	16.26	163.94
$i_2n_2s_1$	3.18	1.52	3.91	8.86	17.47	179.37
$i_2n_2s_2$	3.36	1.67	4.01	9.07	18.12	188.25
$i_3n_1s_1$	2.84	1.65	4.01	9.07	17.57	174.74
$i_3n_1s_2$	2.90	1.67	4.11	9.72	18.41	181.69
$i_3n_2s_1$	3.27	2.03	4.91	10.37	20.58	203.68
$i_3n_2s_2$	3.30	2.00	4.81	10.80	20.92	206.76
$i_4n_1s_1$	3.36	1.71	4.61	9.50	19.19	194.03
$i_4n_1s_2$	3.64	2.03	4.91	10.15	20.74	211.39
$i_4n_2s_1$	4.10	2.43	5.22	11.45	23.20	239.17
$i_4n_2s_2$	4.35	2.59	5.32	12.10	24.36	252.67
SEm (±)	0.118	0.094	0.240	0.090	0.124	4.157
CD (0.05)	NS	NS	NS	NS	NS	NS

DMP- dry matter production, NS- not significant

first and second year. The time of application (S) did not influence the DMP during first year, however during second year the pseudostem DMP was found affected and application of nutrients in four splits (S_2) recorded the highest value.

During first year, the N x S interaction was found significant with n_2s_1 producing the highest dry matter which was on a par with n_2s_2. During second year, the I x N was found significant with i_4n_2 producing the highest pseudostem dry matter. The other interactions were found not significant.

4.1.6.2 Dry Matter of Rhizome

The rhizome dry matter production was the highest in irrigation at 1.0 IW/CPE (I_4) (0.71 kg plant^{-1} and 2.19 t ha^{-1}) and at par with 0.8 IW/CPE (I_3) and significantly superior to other two levels of irrigation during first year. However, during second year, the DMP was the highest in irrigation at 1.0 IW/CPE (I_4) which was significantly superior to other three levels of irrigation. The DMP was the lowest in 0.4 IW/CPE. Among the two nutrient levels (N), N_2 recorded the highest DMP during both the years. The time of application (S) significantly influenced the DMP during second year with S_2 recording the highest.

The N x S interaction was found significant during first year with n_2s_1 recording the highest which was on a par with n_2s_2. The other interactions (I x N, I x S, I x N x S) were found not significant. During second year the I x N interaction was found significant with i_4n_2 recording the highest rhizome dry matter. The other interactions were found not significant.

4.1.6.3 Dry Matter of Leaves

The results revealed that the effect of irrigation levels were significant. The irrigation scheduled at 1.0 IW/CPE (I_4) recorded the highest DMP (2.44 kg plant^{-1} and 7.53 t ha^{-1}) and at par with 0.8 IW/CPE (I_3) and significantly superior to other two levels of irrigation during first year. The same trend was observed during second year also. Among the two nutrient levels (N), N_2 recorded the highest DMP but the effect of time of application (S) was not significant.

Significant effect was noticed for the interaction I x N during the first year. Among this, i_4n_2 recorded the maximum and i_1n_1 and i_2n_1, the minimum.

4.1.6.4 Dry Matter of Fruit

Dry matter production was significantly influenced by the treatments. The influence of irrigation levels on fruit DMP was on a par in 0.8 and 1.0 IW/CPE ratio (I_3 and I_4) and was significantly superior to other two levels of irrigation during first year. During second year, irrigation scheduled at 1.0 IW/CPE recorded the highest DMP and was significantly superior to other three levels of irrigation. The nutrient application based on the uptake of nutrients (N_2) recorded the highest DMP whereas the time of application (S) had influence DMP.

None of the interactions (N x S, I x N, I x S, I x N x S) were found significant during both the years.

4.1.6.5 Total Dry Matter Production

The irrigation levels significantly influenced the total dry matter production. The DMP was the highest at the irrigation level of 1.0 IW/CPE (I_4) and was at par with 0.8 IW/CPE (I_3) and significantly superior to other two levels of irrigation. However, during second year irrigation at 1.0 IW/CPE recorded significantly higher DMP. Among the nutrient levels, the DMP was the highest in N_2. The time of application (S) did not influence the DMP during first year, but during second year, application of nutrients in four splits (S_2) recording the highest.

Among the interactions, the N x S interaction was found significant with n_2s_1 producing the highest total DMP (8.10 kg plant^{-1}), which was significantly superior to all other treatments during first year. During second year, the treatment combinations n_1s_1 and n_1s_2 were at par and found inferior to n_2s_1 and n_2s_1. The interaction I x N was also found significant during both the years. The maximum value was obtained for i_4n_2 treatment combination and found superior to other combinations. All other interactions were not significant.

4.1.7 Biological Yield

The analysed data are presented in Tables 21 to 24a.

The results revealed that the biological yield was significantly influenced by the treatments. The biological yield was the highest in irrigation level of 1.0 IW/CPE (I_4) and was significantly superior to other three levels of irrigation during both the years. Similarly among the nutrient levels, the biological yield was the highest in N_2. The time of application (S) did not influence the biological yield during first year while, during second year, significant difference was noticed and four splits (S_2) was found superior to two splits (S_1).

Among the I x N interactions, i_4n_2 recorded the highest biological yield during both the years. The N x S interaction was also significantly influenced the biological yield and the highest was obtained in n_2s_1 which was significantly superior to all other treatments during first year. The other interactions were found not significant during both the years.

4.1.8 Nutrient Uptake at Harvest (g plant^{-1} & kg ha^{-1})

The irrigation and nutrient levels and time of application significantly influenced the uptake of nutrients in Grand Nain banana. Analysed data pertaining to uptake of N, P and K by plant parts (pseudostem, rhizome, leaf and fruit) and total uptake during both the years are presented separately.

4.1.8.1 Nitrogen (N) Uptake

Data pertaining to N uptake is presented in Tables 25a to 28b.

During first year, pseudostem N uptake was the highest in irrigation at 0.8 IW/CPE (I_3) and the total plant N uptake, uptake of N by rhizome, leaf and fruit were the highest in irrigation at 1.0 IW/CPE (I_4). However during second year, irrigation scheduled at 1.0 IW/CPE (I_4) recorded the highest N uptake by plant parts and total uptake. It was significantly superior to the other levels of irrigation. The N uptake was the lowest in irrigation at 0.4 IW/CPE (I_1) during both the years.

Table 25a. Effect of irrigation and nutrient schedule on the N uptake at harvest in different parts of banana (first year), g plant^{-1}

Treatments	**N uptake by Pseudostem**	**N uptake by Rhizome**	**N uptake by Leaf**	**N uptake by Fruit**	**Total N uptake**
Irrigation levels (I)					
I_1	13.38	9.19	41.16	55.80	119.53
I_2	18.71	10.63	45.09	58.59	133.02
I_3	23.06	11.75	61.61	85.98	182.40
I_4	17.78	14.84	66.49	103.21	202.31
SEm (±)	1.116	0.540	3.875	3.781	5.962
CD (0.05)	3.573	1.727	12.399	12.099	19.080
Nutrient levels (N)					
N_1	19.02	11.05	45.33	65.22	140.62
N_2	17.45	12.15	61.84	86.57	178.01
SEm (±)	0.701	0.293	0.998	2.316	2.427
CD (0.05)	NS	0.841	2.865	6.648	6.965
Time of application (S)					
S_1	17.16	10.58	53.52	76.99	158.25
S_2	19.31	12.63	53.65	74.80	160.38
SEm (±)	0.701	0.293	0.998	2.316	2.427
CD (0.05)	NS	0.841	NS	NS	NS
I x N interaction					
i_1n_1	13.89	8.47	34.04	47.58	103.98
i_1n_2	12.88	9.91	48.27	64.02	135.07
i_2n_1	17.86	9.70	40.33	49.87	117.76
i_2n_2	19.56	11.57	49.84	67.31	148.29
i_3n_1	27.02	11.21	51.15	80.54	169.92
i_3n_2	19.10	12.27	72.07	91.43	194.88
i_4n_1	17.31	14.83	55.79	82.89	170.83
i_4n_2	18.24	14.84	77.19	123.52	233.80
SEm (±)	1.403	0.587	1.998	4.636	4.857
CD (0.05)	4.025	NS	5.729	13.296	13.930
N x S interaction					
n_1s_1	16.83	9.03	44.00	64.23	134.09
n_1s_2	21.21	13.08	46.66	66.21	147.15
n_2s_1	17.48	12.13	63.04	89.75	182.41
n_2s_2	17.41	12.17	60.64	83.38	173.61
SEm (±)	0.992	0.415	1.412	3.278	3.434
CD (0.05)	2.845	1.189	NS	NS	9.848

NS- not significant

Table 25b. Interaction effect of irrigation and nutrient schedule on the N uptake at harvest in different parts of banana (first year), g plant^{-1}

Treatments	N uptake by Pseudostem	N uptake by Rhizome	N uptake by Leaf	N uptake by Fruit	Total N uptake
I x S interaction					
i_1s_1	13.00	7.97	40.88	54.56	116.41
i_1s_2	13.76	10.41	41.43	57.04	122.65
i_2s_1	18.98	10.04	44.98	58.09	132.08
i_2s_2	18.44	11.23	45.20	59.10	133.97
i_3s_1	19.28	11.27	61.28	90.84	182.67
i_3s_2	26.84	12.22	61.94	81.12	182.13
i_4s_1	17.36	13.04	66.96	104.49	201.85
i_4s_2	18.19	16.64	66.03	101.92	202.79
SEm (±)	1.403	0.587	1.998	4.636	4.857
CD (0.05)	4.025	NS	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	12.71	6.73	32.76	46.11	98.31
$i_1n_1s_2$	15.05	10.20	35.33	49.05	109.63
$i_1n_2s_1$	13.36	9.20	49.00	63.00	134.56
$i_1n_2s_2$	12.42	10.62	47.54	65.03	135.61
$i_2n_1s_1$	18.14	8.79	37.11	47.00	111.04
$i_2n_1s_2$	17.56	10.61	43.55	52.75	124.47
$i_2n_2s_1$	20.74	11.29	52.85	69.18	154.06
$i_2n_2s_2$	19.34	11.85	46.84	65.45	143.48
$i_3n_1s_1$	19.76	10.08	51.34	81.69	162.87
$i_3n_1s_2$	34.45	12.36	50.96	79.38	177.15
$i_3n_2s_1$	18.80	12.46	71.21	100	202.47
$i_3n_2s_2$	19.49	12.09	72.93	82.86	187.37
$i_4n_1s_1$	16.70	10.51	54.8	82.14	164.15
$i_4n_1s_2$	17.90	19.16	56.78	83.65	177.49
$i_4n_2s_1$	17.98	15.56	79.12	126.84	239.50
$i_4n_2s_2$	18.49	14.12	75.27	120.19	228.07
SEm (±)	1.984	0.829	2.825	6.556	6.868
CD (0.05)	NS	2.370	NS	NS	NS

NS- not significant

Table 26a. Effect of irrigation and nutrient schedule on the N uptake at harvest in different parts of banana (first year), kg ha^{-1}

Treatments	N uptake by Pseudostem	N uptake by Rhizome	N uptake by Leaf	N uptake by Fruit	Total N uptake
Irrigation levels (I)					
I_1	41.29	28.36	127.02	172.20	368.87
I_2	57.74	32.80	139.15	180.81	410.50
I_3	71.16	36.26	190.13	265.33	562.89
I_4	54.87	45.80	205.19	318.51	624.33
SEm (±)	3.440	1.670	11.960	11.670	18.400
CD (0.05)	11.030	5.330	38.260	37.340	58.880
Nutrient levels (N)					
N_1	58.70	34.10	139.89	201.27	433.95
N_2	53.85	37.49	190.84	267.16	549.34
SEm (±)	2.160	0.900	3.080	7.150	7.490
CD (0.05)	NS	2.600	8.840	20.520	21.490
Time of application (S)					
S_1	52.96	32.65	165.16	237.59	488.36
S_2	59.59	38.98	165.56	230.83	494.93
SEm (±)	2.160	0.900	3.080	7.150	7.490
CD (0.05)	NS	2.60	NS	NS	NS
I x N interaction					
i_1n_1	42.86	26.14	105.05	146.83	320.88
i_1n_2	39.75	30.58	148.96	197.57	416.83
i_2n_1	55.12	29.93	124.46	153.90	363.41
i_2n_2	60.36	35.71	153.81	207.72	457.62
i_3n_1	83.38	34.59	157.85	248.55	524.37
i_3n_2	58.94	37.87	222.41	282.15	601.40
i_4n_1	53.42	45.77	172.17	255.80	527.18
i_4n_2	56.29	45.80	238.21	381.18	721.51
SEm (±)	4.330	1.810	6.170	14.310	14.990
CD (0.05)	12.420	NS	17.680	41.030	42.990
N x S interaction					
n_1s_1	51.94	27.87	135.78	198.21	413.80
n_1s_2	65.45	40.36	143.99	204.32	454.10
n_2s_1	53.94	37.43	194.54	276.97	562.92
n_2s_2	53.73	37.56	187.14	257.31	535.76
SEm (±)	3.060	1.280	4.360	10.120	10.600
CD (0.05)	8.780	3.670	NS	NS	30.390

NS- not significant

Table 26b. Interaction effect of irrigation and nutrient schedule on the N uptake at harvest in different parts of banana (first year), kg ha^{-1}

Treatments	N uptake by Pseudostem	N uptake by Rhizome	N uptake by Leaf	N uptake by Fruit	Total N uptake
I x S interaction					
i_1s_1	40.12	24.60	126.16	168.37	359.24
i_1s_2	42.46	32.13	127.85	176.03	378.50
i_2s_1	58.57	30.98	138.81	179.27	407.60
i_2s_2	56.91	34.66	139.49	182.38	413.43
i_3s_1	59.50	34.78	189.11	280.33	563.72
i_3s_2	82.83	37.71	191.15	250.34	562.05
i_4s_1	53.57	40.24	206.64	322.46	622.91
i_4s_2	56.13	51.35	203.77	314.53	625.81
SEm (±)	4.33	1.81	6.17	14.31	14.99
CD (0.05)	12.42	NS	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	39.22	20.77	101.10	142.30	303.38
$i_1n_1s_2$	46.44	31.48	109.03	151.37	338.32
$i_1n_2s_1$	41.23	28.39	151.21	194.42	415.25
$i_1n_2s_2$	38.33	32.77	146.71	200.68	418.49
$i_2n_1s_1$	55.98	27.13	114.52	145.04	342.67
$i_2n_1s_2$	54.19	32.74	134.40	162.79	384.11
$i_2n_2s_1$	64.00	34.84	163.10	213.49	475.43
$i_2n_2s_2$	59.68	36.57	144.55	201.98	442.78
$i_3n_1s_1$	60.98	31.11	158.44	252.10	502.62
$i_3n_1s_2$	106.31	38.14	157.26	244.97	546.68
$i_3n_2s_1$	58.02	38.45	219.75	308.60	624.82
$i_3n_2s_2$	60.15	37.31	225.06	255.71	578.22
$i_4n_1s_1$	51.54	32.43	169.11	253.48	506.57
$i_4n_1s_2$	55.24	59.13	175.22	258.14	547.73
$i_4n_2s_1$	55.49	48.02	244.16	391.43	739.10
$i_4n_2s_2$	57.06	43.57	232.28	370.91	703.82
SEm (±)	6.122	2.558	8.717	20.23	21.19
CD (0.05)	NS	7.31	NS	NS	NS

NS- not significant

Table 27a. Effect of irrigation and nutrient schedule on the N uptake at harvest in different parts of banana (second year), g plant^{-1}

Treatments	**N uptake by Pseudostem**	**N uptake by Rhizome**	**N uptake by Leaf**	**N uptake by Fruit**	**Total N uptake**
Irrigation levels (I)					
I_1	9.29	3.92	20.78	18.07	52.06
I_2	11.11	3.81	24.68	21.98	61.57
I_3	11.71	5.79	28.75	28.73	74.99
I_4	16.31	7.33	35.53	31.52	90.69
SEm (±)	0.543	0.324	1.228	0.652	1.455
CD (0.05)	1.739	0.931	3.929	2.089	4.657
Nutrient levels (N)					
N_1	10.02	4.22	25.29	22.16	61.70
N_2	14.19	6.20	29.58	27.99	77.95
SEm (±)	0.298	0.197	0.611	0.663	0.920
CD (0.05)	0.856	0.566	1.755	1.903	2.641
Time of application (S)					
S_1	11.79	4.92	26.74	24.02	67.46
S_2	12.42	5.51	28.13	26.13	72.20
SEm (±)	0.298	0.197	0.611	0.663	0.920
CD (0.05)	NS	0.566	NS	1.903	2.641
I x N interaction					
i_1n_1	8.26	3.01	18.96	15.00	45.23
i_1n_2	10.32	4.84	22.59	21.14	58.89
i_2n_1	9.22	3.34	24.01	20.58	57.15
i_2n_2	12.99	4.27	25.35	23.38	65.99
i_3n_1	10.56	4.94	26.63	25.99	68.13
i_3n_2	12.86	6.65	30.87	31.49	81.86
i_4n_1	12.04	5.60	31.57	27.10	76.31
i_4n_2	20.58	9.05	39.49	35.94	105.06
SEm (±)	0.597	0.395	1.224	1.327	1.842
CD (0.05)	1.712	1.133	NS	NS	5.282
N x S interaction					
n_1s_1	9.56	3.97	24.44	21.18	59.15
n_1s_2	10.48	4.48	26.14	23.15	64.25
n_2s_1	14.02	5.87	29.03	26.85	75.76
n_2s_2	14.36	6.54	30.12	29.12	80.14
SEm (±)	0.422	0.279	0.865	0.938	1.302
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 27b. Interaction effect of irrigation and nutrient schedule on the N uptake at harvest in different parts of banana (second year), g plant^{-1}

Treatments	N uptake by Pseudostem	N uptake by Rhizome	N uptake by Leaf	N uptake by Fruit	Total N uptake
I x S interaction					
i_1s_1	8.77	3.66	19.93	17.35	49.71
i_1s_2	9.81	4.19	21.62	18.79	54.40
i_2s_1	11.01	3.50	24.07	21.17	59.75
i_2s_2	11.21	4.11	25.29	22.79	63.40
i_3s_1	11.73	5.68	28.18	27.91	73.49
i_3s_2	11.69	5.90	29.33	29.57	76.50
i_4s_1	15.65	6.83	34.77	29.63	86.88
i_4s_2	16.97	7.83	36.30	33.40	94.50
SEm (±)	0.049	0.395	1.224	1.327	1.842
CD (0.05)	NS	NS	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	7.56	2.81	18.69	14.50	43.56
$i_1n_1s_2$	8.96	3.21	19.23	15.50	46.89
$i_1n_2s_1$	9.98	4.51	21.18	20.20	55.86
$i_1n_2s_2$	10.66	5.16	24.01	22.09	61.91
$i_2n_1s_1$	8.72	3.18	22.91	20.00	54.81
$i_2n_1s_2$	9.73	3.51	25.10	21.15	59.48
$i_2n_2s_1$	13.30	3.82	25.23	22.33	64.68
$i_2n_2s_2$	12.69	4.72	25.47	24.44	67.31
$i_3n_1s_1$	10.57	4.73	25.30	26.39	67.00
$i_3n_1s_2$	10.55	5.14	27.98	25.59	69.26
$i_3n_2s_1$	12.89	6.63	31.06	29.42	79.99
$i_3n_2s_2$	12.84	6.66	30.68	33.56	83.74
$i_4n_1s_1$	11.39	5.15	30.88	23.82	71.23
$i_4n_1s_2$	12.69	6.05	32.27	30.38	81.39
$i_4n_2s_1$	19.91	8.50	38.66	35.46	102.52
$i_4n_2s_2$	21.25	9.61	40.33	36.42	107.61
SEm (±)	0.844	0.559	1.730	1.876	2.604
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 28a. Effect of irrigation and nutrient schedule on the N uptake at harvest in different parts of banana (second year), kg ha^{-1}

Treatments	**N uptake by Pseudostem**	**N uptake by Rhizome**	**N uptake by Leaf**	**N uptake by Fruit**	**Total N uptake**
Irrigation levels (I)					
I_1	28.67	12.10	64.13	55.76	160.66
I_2	34.29	11.76	76.16	67.83	190.01
I_3	36.14	17.87	88.72	88.66	231.42
I_4	50.33	22.62	109.65	97.27	279.87
SEm (±)	1.676	1.000	3.790	2.012	4.490
CD (0.05)	5.367	2.873	12.125	6.447	14.372
Nutrient levels (N)					
N_1	30.92	13.02	78.04	68.39	190.41
N_2	43.79	19.13	91.28	86.38	240.55
SEm (±)	0.920	0.608	1.886	2.046	2.839
CD (0.05)	2.642	1.747	5.416	5.873	8.150
Time of application (S)					
S_1	36.38	15.18	82.52	74.11	208.18
S_2	38.33	17.00	86.81	80.65	222.81
SEm (±)	0.920	0.608	1.886	2.046	2.839
CD (0.05)	NS	1.747	NS	5.873	8.150
I x N interaction					
i_1n_1	25.49	9.29	58.51	46.29	139.58
i_1n_2	31.85	14.94	69.71	65.24	181.73
i_2n_1	28.45	10.31	74.09	63.51	176.36
i_2n_2	40.09	13.18	78.23	72.15	203.65
i_3n_1	32.59	15.24	82.18	80.21	210.25
i_3n_2	39.69	20.52	95.26	97.18	252.62
i_4n_1	37.16	17.28	97.43	83.63	235.49
i_4n_2	63.51	27.93	121.87	110.91	324.22
SEm (±)	1.842	1.219	3.777	4.095	5.684
CD (0.05)	5.283	3.496	NS	NS	16.300
N x S interaction					
n_1s_1	29.50	12.25	75.42	65.36	182.54
n_1s_2	32.34	13.83	80.67	71.44	198.28
n_2s_1	43.27	18.11	89.59	82.86	233.80
n_2s_2	44.31	20.18	92.95	89.86	247.31
SEm (±)	1.302	0.861	2.669	2.895	4.018
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 28b. Interaction effect of irrigation and nutrient schedule on the N uptake at harvest in different parts of banana (second year), kg ha^{-1}

Treatments	**N uptake by Pseudostem**	**N uptake by Rhizome**	**N uptake by Leaf**	**N uptake by Fruit**	**Total N uptake**
I x S interaction					
i_1s_1	27.06	11.29	61.50	53.54	153.41
i_1s_2	30.27	12.93	66.72	57.99	167.88
i_2s_1	33.98	10.80	74.28	65.33	184.39
i_2s_2	34.59	12.68	78.04	70.33	195.65
i_3s_1	36.20	17.53	86.96	86.13	226.79
i_3s_2	36.08	18.21	90.51	91.25	236.08
i_4s_1	48.30	21.08	107.30	91.44	268.11
i_4s_2	52.37	24.16	112.02	103.07	291.63
SEm (±)	1.842	1.219	3.777	4.095	5.684
CD (0.05)	NS	NS	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	23.33	8.67	57.68	44.75	134.43
$i_1n_1s_2$	27.65	9.91	59.34	47.83	144.70
$i_1n_2s_1$	30.80	13.92	65.36	62.34	172.38
$i_1n_2s_2$	32.90	15.92	74.09	68.17	191.05
$i_2n_1s_1$	26.91	9.81	70.70	61.72	169.14
$i_2n_1s_2$	30.03	10.83	77.46	65.27	183.56
$i_2n_2s_1$	41.04	11.79	77.86	68.91	199.60
$i_2n_2s_2$	39.16	14.57	78.60	75.42	207.72
$i_3n_1s_1$	32.62	14.60	78.08	81.44	206.76
$i_3n_1s_2$	32.56	15.86	86.35	78.97	213.74
$i_3n_2s_1$	39.78	20.46	95.85	90.79	246.85
$i_3n_2s_2$	39.62	20.55	94.68	103.57	258.42
$i_4n_1s_1$	35.15	15.89	95.30	73.51	219.82
$i_4n_1s_2$	39.16	18.67	99.59	93.75	251.17
$i_4n_2s_1$	61.44	26.23	119.30	109.43	316.38
$i_4n_2s_2$	65.58	29.66	124.46	112.39	332.08
SEm (±)	2.605	1.725	5.339	5.789	8.036
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Among the nutrient levels, the N uptake by plant parts and total N uptake were the highest in N_2 and the total uptake was 178.01 g plant^{-1} and 549.34 kg ha^{-1} and 77.95 g plant^{-1} and 240.55 kg ha^{-1}, respectively during first and second year.

During first year, the time of application of nutrients had a significant effect on the uptake of N by rhizome only. The application of nutrients in 4 splits (S_2) resulted in more N uptake by rhizome (12.63 g plant^{-1} and 38.98 kg ha^{-1}). But during second year, uptake by rhizome, fruit and total uptake were significantly influenced by time of application. Application in four splits (S_2) resulted in more N uptake and superior to two splits (S_1).

Among I x N interactions, the total N uptake was the highest in i_4n_2 during both the years and significantly superior to all other treatment combinations and the lowest was recorded in i_1n_1. The interaction effect of I x N was also significant and influenced the uptake by pseudostem, leaf and fruit during first year and by pseudostem and rhizome during second year. The first year result revealed that uptake by pseudostem was the highest in i_3n_1 and in all other parts the uptake was the highest in i_4n_2. However during second year, i_4n_2 recorded the highest uptake by all the plant parts.

The interaction between nutrient levels and time of application (N x S) had significant influence on total N uptake during first year with n_2s_1 recording the higher total uptake and it was on par with n_2s_2. The N uptake by pseudostem and rhizome were also significantly influenced by the treatments with n_1s_2 recording the highest. In rhizome it was on par n_2s_1 and n_2s_2. The interactions, N x S, I x S and I x N x S were not significant during second year.

The interaction effect of I x S was significant in N uptake by pseudostem during first year i_3s_2 recording the highest uptake. The interaction effect of I x N x S was also significant in the uptake of N by rhizome during first year with $i_4n_1s_2$ recording the highest N uptake.

4.1.8.2 Phosphorus (P) Uptake

Data pertaining to P uptake is presented in Tables 29a to 32b.

Table 29a. Effect of irrigation and nutrient schedule on the P uptake at harvest in different parts of banana (first year), g plant^{-1}

Treatments	P uptake by Pseudostem	P uptake by Rhizome	P uptake by Leaf	P uptake by Fruit	Total P uptake
Irrigation levels (I)					
I_1	1.32	0.69	1.89	4.72	8.62
I_2	1.09	0.70	2.24	5.74	9.77
I_3	1.74	1.90	2.47	6.45	12.56
I_4	1.96	2.28	2.92	8.28	15.43
SEm (±)	0.088	0.101	0.182	0.367	0.512
CD (0.05)	0.283	0.325	0.581	1.175	1.639
Nutrient levels (N)					
N_1	1.141	0.70	2.09	5.28	9.21
N_2	1.915	2.08	2.67	7.32	13.99
SEm (±)	0.062	0.072	0.135	0.172	0.233
CD (0.05)	0.179	0.205	0.388	0.494	0.668
Time of application (S)					
S_1	1.59	1.63	2.18	6.65	12.06
S_2	1.46	1.16	2.56	5.94	11.14
SEm (±)	0.062	0.072	0.135	0.172	0.233
CD (0.05)	NS	0.205	NS	0.494	0.668
I x N interaction					
i_1n_1	0.71	0.52	1.64	3.11	5.98
i_1n_2	1.93	0.87	2.15	6.32	11.27
i_2n_1	1.06	0.48	1.70	4.76	8.00
i_2n_2	1.12	0.92	2.79	6.72	11.54
i_3n_1	1.30	0.84	2.38	5.86	10.38
i_3n_2	2.19	2.97	2.56	7.04	14.75
i_4n_1	1.50	0.97	2.66	7.37	12.49
i_4n_2	2.42	3.59	3.19	9.20	18.38
SEm (±)	0.124	0.143	0.271	0.239	0.466
CD (0.05)	0.357	0.411	NS	0.686	NS
N x S interaction					
n_1s_1	1.15	0.61	1.93	5.45	9.14
n_1s_2	1.14	0.79	2.25	5.10	9.28
n_2s_1	2.04	2.65	2.43	7.86	14.98
n_2s_2	1.79	1.52	2.90	6.78	12.99
SEm (±)	0.088	0.101	0.191	0.169	0.329
CD (0.05)	NS	0.290	NS	0.485	0.944

NS- not significant

Table 29b. Interaction effect of irrigation and nutrient schedule on the P uptake at harvest in different parts of banana (first year), g plant^{-1}

Treatments	P uptake by Pseudostem	P uptake by Rhizome	P uptake by Leaf	P uptake by Fruit	Total P uptake
I x S interaction					
i_1s_1	1.38	0.79	1.71	4.80	8.68
i_1s_2	1.26	0.60	2.07	4.64	8.57
i_2s_1	1.17	0.65	2.04	5.89	9.76
i_2s_2	1.00	0.75	2.45	5.58	9.79
i_3s_1	1.77	2.28	2.02	7.24	13.31
i_3s_2	1.71	1.53	2.92	5.66	11.82
i_4s_1	2.05	2.80	2.96	8.68	16.49
i_4s_2	1.87	1.75	2.88	7.88	14.37
SEm (±)	0.124	0.143	0.271	0.239	0.466
CD (0.05)	NS	0.411	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	0.64	0.56	1.27	2.94	5.41
$i_1n_1s_2$	0.79	0.48	2.00	3.28	6.56
$i_1n_2s_1$	2.13	1.01	2.15	6.66	11.95
$i_1n_2s_2$	1.74	0.72	2.14	5.99	10.59
$i_2n_1s_1$	1.32	0.37	1.82	4.68	8.19
$i_2n_1s_2$	0.79	0.60	1.58	4.84	7.81
$i_2n_2s_1$	1.02	0.94	2.26	7.11	11.33
$i_2n_2s_2$	1.22	0.90	3.32	6.32	11.76
$i_3n_1s_1$	1.26	0.70	1.89	6.84	10.69
$i_3n_1s_2$	1.34	0.98	2.86	4.89	10.07
$i_3n_2s_1$	2.29	3.85	2.14	7.65	15.93
$i_3n_2s_2$	2.08	2.07	2.98	6.43	13.57
$i_4n_1s_1$	1.37	0.81	2.74	7.34	12.27
$i_4n_1s_2$	1.63	1.12	2.57	7.39	12.71
$i_4n_2s_1$	2.73	4.79	3.18	10.02	20.72
$i_4n_2s_2$	2.11	2.39	3.19	8.36	16.04
SEm (±)	0.176	0.202	0.383	0.338	0.658
CD (0.05)	0.505	0.581	NS	NS	NS

NS- not significant

Table 30a. Effect of irrigation and nutrient schedule on the P uptake at harvest in different parts of banana (first year), kg ha^{-1}

Treatments	P uptake by Pseudostem	P uptake by Rhizome	P uptake by Leaf	P uptake by Fruit	Total P uptake
Irrigation levels (I)					
I_1	4.07	2.13	5.83	14.57	26.60
I_2	3.36	2.16	6.91	17.71	30.15
I_3	5.37	5.86	7.62	19.90	38.76
I_4	6.05	7.04	9.01	25.55	47.62
SEm (±)	0.272	0.312	0.562	1.133	1.580
CD (0.05)	0.873	1.003	1.793	3.626	5.058
Nutrient levels (N)					
N_1	3.52	2.16	6.45	16.29	28.42
N_2	5.91	6.42	8.24	22.59	43.17
SEm (±)	0.191	0.222	0.417	0.531	0.719
CD (0.05)	0.552	0.633	1.197	1.524	2.061
Time of application (S)					
S_1	4.91	5.03	6.73	20.52	37.22
S_2	4.51	3.58	7.90	18.33	34.38
SEm (±)	0.191	0.222	0.417	0.531	0.719
CD (0.05)	NS	0.633	NS	1.524	2.061
I x N interaction					
i_1n_1	2.19	1.60	5.06	9.60	18.45
i_1n_2	5.96	2.68	6.63	19.50	34.78
i_2n_1	3.27	1.48	5.25	14.69	24.69
i_2n_2	3.46	2.84	8.61	20.74	35.61
i_3n_1	4.01	2.59	7.34	18.08	32.03
i_3n_2	6.76	9.17	7.90	21.73	45.52
i_4n_1	4.63	2.99	8.21	22.74	38.54
i_4n_2	7.47	11.08	9.84	28.39	56.72
SEm (±)	0.383	0.441	0.836	0.738	1.438
CD (0.05)	1.102	1.268	NS	2.117	NS
N x S interaction					
n_1s_1	3.55	1.88	5.96	16.82	28.21
n_1s_2	3.52	2.44	6.94	15.74	28.64
n_2s_1	6.30	8.18	7.50	24.26	46.23
n_2s_2	5.52	4.69	8.95	20.92	40.09
SEm (±)	0.272	0.312	0.589	0.522	1.015
CD (0.05)	NS	0.895	NS	1.497	2.913

NS- not significant

Table 30b. Interaction effect of irrigation and nutrient schedule on the P uptake at harvest in different parts of banana (first year), kg ha^{-1}

Treatments	P uptake by Pseudostem	P uptake by Rhizome	P uptake by Leaf	P uptake by Fruit	Total P uptake
I x S interaction					
i_1s_1	4.26	2.44	5.28	14.81	26.79
i_1s_2	3.89	1.85	6.39	14.32	26.45
i_2s_1	3.61	2.01	6.30	18.18	30.12
i_2s_2	3.09	2.31	7.56	17.22	30.21
i_3s_1	5.46	7.04	6.23	22.34	41.07
i_3s_2	5.28	4.72	9.01	17.47	36.48
i_4s_1	6.33	8.64	9.13	26.79	50.89
i_4s_2	5.77	5.40	8.89	24.32	44.35
SEm (±)	0.383	0.441	0.836	0.738	1.438
CD (0.05)	NS	1.268	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	1.98	1.73	3.92	9.07	16.70
$i_1n_1s_2$	2.44	1.48	6.17	10.12	20.24
$i_1n_2s_1$	6.57	3.12	6.63	20.55	36.88
$i_1n_2s_2$	5.37	2.22	6.60	18.49	32.68
$i_2n_1s_1$	4.07	1.14	5.62	14.44	25.27
$i_2n_1s_2$	2.44	1.85	4.88	14.94	24.10
$i_2n_2s_1$	3.15	2.90	6.97	21.94	34.96
$i_2n_2s_2$	3.76	2.78	10.25	19.50	36.29
$i_3n_1s_1$	3.89	2.16	5.83	21.11	32.99
$i_3n_1s_2$	4.14	3.02	8.83	15.09	31.08
$i_3n_2s_1$	7.07	11.88	6.60	23.61	49.16
$i_3n_2s_2$	6.42	6.39	9.20	19.84	41.88
$i_4n_1s_1$	4.23	2.50	8.46	22.65	37.87
$i_4n_1s_2$	5.03	3.46	7.93	22.81	39.22
$i_4n_2s_1$	8.42	14.78	9.81	30.92	63.94
$i_4n_2s_2$	6.51	7.38	9.84	25.80	49.50
SEm (±)	0.543	0.623	1.182	1.043	2.031
CD (0.05)	1.558	1.793	NS	NS	NS

NS- not significant

Table 31a. Effect of irrigation and nutrient schedule on the P uptake at harvest in different parts of banana (second year), g plant^{-1}

Treatments	P uptake by Pseudostem	P uptake by Rhizome	P uptake by Leaf	P uptake by Fruit	Total P uptake
Irrigation levels (I)					
I_1	0.93	0.56	0.91	2.25	4.64
I_2	1.17	0.59	1.01	3.06	5.81
I_3	0.99	0.77	1.50	3.54	6.79
I_4	1.45	1.12	1.68	4.44	8.70
SEm (±)	0.040	0.037	0.079	0.136	0.148
CD (0.05)	0.128	0.119	0.254	0.435	0.473
Nutrient levels (N)					
N_1	0.97	0.57	1.13	2.73	5.40
N_2	1.30	0.95	1.42	3.91	7.58
SEm (±)	0.040	0.023	0.061	0.240	0.109
CD (0.05)	0.115	0.067	0.176	0.084	0.314
Time of application (S)					
S_1	1.105	0.72	1.26	3.06	6.14
S_2	1.160	0.79	1.29	3.59	6.83
SEm (±)	0.040	0.023	0.061	0.240	0.109
CD (0.05)	0.115	0.067	NS	0.084	0.314
I x N interaction					
i_1n_1	0.81	0.39	0.78	1.90	3.87
i_1n_2	1.04	0.72	1.05	2.60	5.41
i_2n_1	1.04	0.43	1.02	2.50	4.99
i_2n_2	1.29	0.75	0.99	3.62	6.64
i_3n_1	0.85	0.63	1.20	3.05	5.73
i_3n_2	1.11	0.91	1.80	4.02	7.85
i_4n_1	1.16	0.83	1.52	3.48	7.00
i_4n_2	1.75	1.41	1.85	5.41	10.41
SEm (±)	0.080	0.047	0.123	0.167	0.219
CD (0.05)	NS	0.133	NS	0.480	0.627
N x S interaction					
n_1s_1	0.93	0.53	1.07	2.46	5.00
n_1s_2	1.00	0.61	1.19	3.00	5.79
n_2s_1	1.28	0.92	1.45	3.65	7.29
n_2s_2	1.32	0.98	1.40	4.17	7.87
SEm (±)	0.057	0.033	0.087	0.118	0.155
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 31b. Interaction effect of irrigation and nutrient schedule on the P uptake at harvest in different parts of banana (second year), g plant^{-1}

Treatments	P uptake by Pseudostem	P uptake by Rhizome	P uptake by Leaf	P uptake by Fruit	Total P uptake
I x S interaction					
i_1s_1	0.93	0.48	0.90	2.04	4.35
i_1s_2	0.92	0.64	0.93	2.46	4.94
i_2s_1	1.14	0.59	1.05	2.91	5.69
i_2s_2	1.20	0.58	0.96	3.21	5.94
i_3s_1	0.98	0.80	1.42	3.23	6.42
i_3s_2	0.99	0.75	1.58	3.85	7.16
i_4s_1	1.37	1.03	1.67	4.06	8.13
i_4s_2	1.54	1.21	1.70	4.83	9.28
SEm (±)	0.080	0.047	0.123	0.167	0.219
CD (0.05)	NS	0.133	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	0.79	0.36	0.76	1.73	3.64
$i_1n_1s_2$	0.82	0.41	0.78	2.07	4.10
$i_1n_2s_1$	1.08	0.61	1.02	2.35	5.04
$i_1n_2s_2$	1.01	0.85	1.07	2.86	5.78
$i_2n_1s_1$	0.99	0.40	1.02	2.23	4.64
$i_2n_1s_2$	1.09	0.47	1.02	2.76	5.34
$i_2n_2s_1$	1.28	0.78	1.08	3.58	6.74
$i_2n_2s_2$	1.30	0.69	0.89	3.65	6.53
$i_3n_1s_1$	0.87	0.65	1.05	2.79	5.36
$i_3n_1s_2$	0.83	0.62	1.35	3.31	6.10
$i_3n_2s_1$	1.08	0.94	1.79	3.66	7.48
$i_3n_2s_2$	1.15	0.89	1.81	4.38	8.23
$i_4n_1s_1$	1.09	0.72	1.45	3.10	6.36
$i_4n_1s_2$	1.24	0.93	1.60	3.87	7.63
$i_4n_2s_1$	1.66	1.34	1.88	5.02	9.89
$i_4n_2s_2$	1.83	1.49	1.81	5.80	10.93
SEm (±)	0.113	0.066	0.174	0.237	0.309
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 32a. Effect of irrigation and nutrient schedule on the P uptake at harvest in different parts of banana (second year), kg ha^{-1}

Treatments	P uptake by Pseudostem	P uptake by Rhizome	P uptake by Leaf	P uptake by Fruit	Total P uptake
Irrigation levels (I)					
I_1	2.86	1.72	2.81	6.94	14.32
I_2	3.60	1.81	3.12	9.44	17.94
I_3	3.04	2.38	4.63	10.92	20.96
I_4	4.49	3.45	5.18	13.70	26.85
SEm (±)	0.123	0.114	0.244	0.420	0.456
CD (0.05)	0.395	0.365	0.784	1.342	1.459
Nutrient levels (N)					
N_1	2.98	1.76	2.86	8.42	16.65
N_2	4.01	2.93	3.49	12.07	23.39
SEm (±)	0.123	0.072	0.188	0.741	0.337
CD (0.05)	0.354	0.205	0.543	0.259	0.968
Time of application (S)					
S_1	3.41	2.22	3.89	9.44	18.96
S_2	3.58	2.44	3.98	11.08	21.08
SEm (±)	0.123	0.072	0.188	0.741	0.337
CD (0.05)	NS	0.205	NS	0.259	0.968
I x N interaction					
i_1n_1	2.49	1.20	2.41	5.86	11.94
i_1n_2	3.22	2.22	3.24	8.02	16.71
i_2n_1	3.22	1.33	3.15	7.72	15.40
i_2n_2	3.98	2.31	3.06	11.17	20.48
i_3n_1	2.63	1.94	3.70	9.41	17.69
i_3n_2	3.44	2.81	5.55	12.41	24.23
i_4n_1	3.59	2.56	4.69	10.74	21.59
i_4n_2	5.39	4.35	5.71	16.70	32.12
SEm (±)	0.247	0.143	0.380	0.52	0.675
CD (0.05)	NS	0.411	NS	1.48	1.935
N x S interaction					
n_1s_1	2.88	1.64	3.30	7.59	15.43
n_1s_2	3.08	1.88	3.67	9.26	17.88
n_2s_1	3.94	2.84	4.47	11.26	22.49
n_2s_2	4.08	3.02	4.32	12.87	24.28
SEm (±)	0.175	0.101	0.268	0.364	0.477
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 32b. Interaction effect of irrigation and nutrient schedule on the P uptake at harvest in different parts of banana (second year), kg ha^{-1}

Treatments	**P uptake by Pseudostem**	**P uptake by Rhizome**	**P uptake by Leaf**	**P uptake by Fruit**	**Total P uptake**
I x S interaction					
i_1s_1	2.88	1.48	2.78	6.30	13.40
i_1s_2	2.83	1.98	2.87	7.59	15.24
i_2s_1	3.51	1.82	3.24	8.98	17.55
i_2s_2	3.69	1.79	2.96	9.91	18.33
i_3s_1	3.01	2.47	4.38	9.97	19.81
i_3s_2	3.06	2.31	4.88	11.88	22.11
i_4s_1	4.23	3.18	5.15	12.53	25.07
i_4s_2	4.74	3.73	5.26	14.91	28.64
SEm (±)	0.247	0.143	0.380	0.515	0.675
CD (0.05)	NS	0.411	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	2.44	1.11	2.35	5.34	11.24
$i_1n_1s_2$	2.54	1.30	2.41	6.39	12.64
$i_1n_2s_1$	3.33	1.85	3.15	7.25	15.57
$i_1n_2s_2$	3.12	2.62	3.30	8.83	17.85
$i_2n_1s_1$	3.06	1.20	3.15	6.88	14.31
$i_2n_1s_2$	3.37	1.45	3.15	8.52	16.49
$i_2n_2s_1$	3.97	2.44	3.33	11.05	20.80
$i_2n_2s_2$	4.00	2.16	2.75	11.26	20.16
$i_3n_1s_1$	2.68	2.01	3.24	8.61	16.54
$i_3n_1s_2$	2.58	1.88	4.17	10.21	18.84
$i_3n_2s_1$	3.35	2.90	5.52	11.29	23.08
$i_3n_2s_2$	3.54	2.75	5.59	13.52	25.39
$i_4n_1s_1$	3.35	2.25	4.47	9.57	19.63
$i_4n_1s_2$	3.83	2.87	4.94	11.94	23.54
$i_4n_2s_1$	5.12	4.14	5.80	15.49	30.52
$i_4n_2s_2$	5.66	1.11	5.59	17.90	33.73
SEm (±)	0.349	0.203	0.537	0.731	0.954
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

During both the years, irrigation scheduled at 1.0 IW/CPE (I_4) recorded the highest P uptake by Pseudostem, rhizome, leaf, fruit and total uptake. The P uptake by pseudostem and leaf were at par with irrigation scheduled at 0.8 IW/CPE (I_3) during first year and the P uptake by leaf was at par with 0.8 IW/CPE (I_3) during second year.

The nutrient levels significantly influenced the total uptake of P at harvest and uptake by pseudostem, rhizome, leaf and fruit. Nutrient application based on the uptake of nutrients in two splits (n_2s_1) recorded significantly higher P uptake by rhizome and fruit and total uptake. The P uptake by pseudostem was the highest in n_2s_1 and was on par with the uptake of nutrients in four splits. The leaf P uptake was higher in 4 splits (n_2s_2) and was on par with uptake of nutrients in two splits (n_2s_1).

The interaction effects were also significantly influenced the total P uptake and uptake by pseudostem and rhizome. The highest total P uptake was recorded in treatment combination, $i_4n_2s_1$. The uptake by pseudostem and rhizome also followed the same trend.

4.1.8.3 Potassium (K) Uptake

Data pertaining to K uptake is presented in Tables 33a to 36b.

Irrigation scheduled at 1.0 IW/CPE (I_4) recorded the highest K uptake by pseudostem, rhizome, leaf, fruit and total uptake by plant during both the years. However, during first year the K uptake by rhizome, leaf and fruit were at par with 0.8 IW/CPE (I_3).

The nutrient levels significantly influenced the total K uptake at harvest and uptake by plant parts during both the years N_2 recording the highest. The time of application significantly influenced the K uptake by fruit at harvest during first year. Nutrient application in 2 splits (S_2) recorded the highest uptake.

Among the interactions, I x N interaction significantly influenced the K uptake at both years. In both the years, the highest uptake was recorded in i_4n_2. During first

Table 33a. Effect of irrigation and nutrient schedule on the K uptake at harvest in different parts of banana (first year), g plant^{-1}

Treatments	K uptake by Pseudostem	K uptake by Rhizome	K uptake by Leaf	K uptake by Fruit	Total K uptake
Irrigation levels (I)					
I_1	112.23	25.19	69.40	137.53	344.35
I_2	120.63	24.00	58.38	179.52	382.54
I_3	128.69	33.27	78.91	230.24	471.10
I_4	171.52	34.67	88.95	253.74	548.89
SEm (±)	2.557	1.290	4.155	8.027	7.828
CD (0.05)	8.181	4.129	13.295	25.686	25.048
Nutrient levels (N)					
N_1	103.17	20.94	59.084	145.93	329.13
N_2	161.92	37.62	88.74	254.59	542.87
SEm (±)	3.216	0.921	1.496	4.867	6.734
CD (0.05)	9.229	2.643	4.293	13.969	19.326
Time of application (S)					
S_1	129.39	29.21	73.15	210.85	442.60
S_2	135.70	29.36	74.67	189.67	429.39
SEm (±)	3.216	0.921	1.496	4.867	6.734
CD (0.05)	NS	NS	NS	13.969	NS
I x N interaction					
i_1n_1	87.88	17.82	50.07	96.06	251.84
i_1n_2	136.58	32.55	88.73	179.00	436.86
i_2n_1	93.74	20.30	47.43	144.16	305.63
i_2n_2	147.52	27.70	69.32	214.89	459.44
i_3n_1	111.90	23.45	68.10	164.21	367.66
i_3n_2	139.70	43.08	89.73	296.26	568.77
i_4n_1	119.17	22.20	70.74	179.28	391.38
i_4n_2	223.86	47.15	107.17	328.20	706.39
SEm (±)	6.436	6.295	2.994	9.742	13.478
CD (0.05)	18.458	18.052	8.586	27.939	38.654
N x S interaction					
n_1s_1	93.56	19.95	53.83	142.79	310.13
n_1s_2	112.79	21.93	64.34	149.07	348.13
n_2s_1	165.22	38.47	92.48	278.91	575.08
n_2s_2	161.50	36.78	85.00	230.27	513.54
SEm (±)	4.550	4.450	2.117	6.889	9.529
CD (0.05)	NS	NS	6.070	19.753	27.328

NS- not significant

Table 33b. Interaction effect of irrigation and nutrient schedule on the K uptake at harvest in different parts of banana (first year), g plant^{-1}

Treatments	K uptake by Pseudostem	K uptake by Rhizome	K uptake by Leaf	K uptake by Fruit	Total K uptake
I x S interaction					
i_1s_1	110.30	26.56	70.31	135.79	342.96
i_1s_2	114.17	23.82	68.48	139.27	345.73
i_2s_1	121.54	21.45	60.13	189.96	393.08
i_2s_2	119.72	26.56	56.63	169.09	371.99
i_3s_1	118.08	33.11	77.04	246.43	474.65
i_3s_2	133.53	33.43	80.79	214.04	461.78
i_4s_1	167.64	35.73	85.13	271.21	559.71
i_4s_2	175.39	33.62	92.78	236.28	538.06
SEm (±)	6.436	6.295	2.994	9.742	13.478
CD (0.05)	NS	NS	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	81.70	20.31	45.08	88.11	235.19
$i_1n_1s_2$	94.08	15.33	55.06	104.01	268.48
$i_1n_2s_1$	138.90	32.81	95.55	183.47	450.73
$i_1n_2s_2$	134.25	32.31	81.90	174.53	422.99
$i_2n_1s_1$	91.10	14.79	45.18	155.00	306.06
$i_2n_1s_2$	96.38	25.81	49.69	133.32	305.21
$i_2n_2s_1$	151.99	28.11	75.08	224.93	480.10
$i_2n_2s_2$	143.06	27.30	63.57	204.86	438.79
$i_3n_1s_1$	92.30	23.07	67.08	144.31	326.76
$i_3n_1s_2$	131.50	23.84	69.11	184.12	408.57
$i_3n_2s_1$	143.85	43.15	87.00	348.55	622.55
$i_3n_2s_2$	147.10	43.02	92.46	243.97	526.55
$i_4n_1s_1$	109.14	21.65	57.98	183.73	372.50
$i_4n_1s_2$	129.20	22.74	83.50	174.83	410.27
$i_4n_2s_1$	226.15	49.82	112.29	358.68	746.93
$i_4n_2s_2$	221.58	44.49	102.05	297.73	665.85
SEm (±)	9.101	8.901	4.234	13.775	19.058
CD (0.05)	NS	NS	12.143	39.505	54.658

NS- not significant

Table 34a. Effect of irrigation and nutrient schedule on the K uptake at harvest in different parts of banana (first year), kg ha^{-1}

Treatments	K uptake by Pseudostem	K uptake by Rhizome	K uptake by Leaf	K uptake by Fruit	Total K uptake
Irrigation levels (I)					
I_1	346.34	77.74	214.17	424.42	1062.66
I_2	372.26	74.06	180.16	554.00	1180.52
I_3	397.14	102.67	243.52	710.52	1453.81
I_4	529.31	106.99	274.50	783.04	1693.87
SEm (±)	7.891	3.981	12.822	24.771	24.157
CD (0.05)	25.247	12.742	41.028	79.267	77.298
Nutrient levels (N)					
N_1	318.38	64.62	182.33	450.34	1015.70
N_2	499.69	116.10	273.84	785.66	1675.30
SEm (±)	9.92	2.84	4.62	15.02	20.78
CD (0.05)	28.48	8.16	13.25	43.11	59.64
Time of application (S)					
S_1	399.30	90.14	225.74	650.68	1365.86
S_2	418.77	90.60	230.43	585.32	1325.10
SEm (±)	9.925	2.842	4.617	15.020	20.781
CD (0.05)	NS	NS	NS	43.108	NS
I x N interaction					
i_1n_1	271.20	54.99	154.52	296.44	777.18
i_1n_2	421.49	100.45	273.82	552.39	1348.15
i_2n_1	289.28	62.65	146.37	444.88	943.17
i_2n_2	455.25	85.48	213.92	663.15	1417.83
i_3n_1	345.32	72.37	210.16	506.75	1134.60
i_3n_2	431.11	132.94	276.91	914.26	1755.22
i_4n_1	367.76	68.51	218.30	553.26	1207.80
i_4n_2	690.83	145.50	330.73	1012.83	2179.92
SEm (±)	19.861	19.426	9.239	30.064	41.593
CD (0.05)	56.961	55.708	26.496	86.220	119.286
N x S interaction					
n_1s_1	288.73	61.57	166.12	440.65	957.06
n_1s_2	348.07	67.68	198.55	460.03	1074.33
n_2s_1	509.87	118.72	285.39	860.72	1774.70
n_2s_2	498.39	113.50	262.31	710.61	1584.78
SEm (±)	14.041	13.733	6.533	21.259	29.406
CD (0.05)	NS	NS	18.732	60.958	84.334

NS- not significant

Table 34b. Interaction effect of irrigation and nutrient schedule on the K uptake at harvest in different parts of banana (first year), kg ha^{-1}

Treatments	K uptake by Pseudostem	K uptake by Rhizome	K uptake by Leaf	K uptake by Fruit	Total K uptake
I x S interaction					
i_1s_1	340.39	81.96	216.98	419.05	1058.37
i_1s_2	352.33	73.51	211.33	429.79	1066.92
i_2s_1	375.07	66.19	185.56	586.22	1213.04
i_2s_2	369.46	81.96	174.76	521.81	1147.96
i_3s_1	364.39	102.18	237.75	760.48	1464.77
i_3s_2	412.07	103.16	249.32	660.53	1425.05
i_4s_1	517.34	110.26	262.71	836.95	1727.27
i_4s_2	541.25	103.75	286.32	729.16	1660.45
SEm (±)	19.861	19.426	9.239	30.064	41.593
CD (0.05)	NS	NS	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	252.13	62.68	139.12	271.91	725.80
$i_1n_1s_2$	290.33	47.31	169.92	320.97	828.53
$i_1n_2s_1$	428.65	101.25	294.87	566.19	1390.95
$i_1n_2s_2$	414.30	99.71	252.74	538.60	1305.35
$i_2n_1s_1$	281.13	45.64	139.43	478.33	944.50
$i_2n_1s_2$	297.43	79.65	153.34	411.43	941.88
$i_2n_2s_1$	469.04	86.75	231.70	694.13	1481.59
$i_2n_2s_2$	441.48	84.25	196.18	632.20	1354.11
$i_3n_1s_1$	284.84	71.19	207.01	445.34	1008.38
$i_3n_1s_2$	405.81	73.57	213.27	568.19	1260.85
$i_3n_2s_1$	443.92	133.16	268.48	1075.63	1921.19
$i_3n_2s_2$	453.95	132.76	285.33	752.89	1624.93
$i_4n_1s_1$	336.81	66.81	178.93	566.99	1149.54
$i_4n_1s_2$	398.71	70.18	257.68	539.53	1266.09
$i_4n_2s_1$	697.90	153.74	346.53	1106.89	2305.03
$i_4n_2s_2$	683.80	137.30	314.93	918.79	2054.81
SEm (±)	28.086	27.468	13.066	42.510	58.813
CD (0.05)	NS	NS	37.473	121.912	168.675

NS- not significant

Table 35a. Effect of irrigation and nutrient schedule on the K uptake at harvest in different parts of banana (second year), g plant^{-1}

Treatments	K uptake by Pseudostem	K uptake by Rhizome	K uptake by Leaf	K uptake by Fruit	Total K uptake
Irrigation levels (I)					
I_1	77.26	20.67	33.58	75.97	207.48
I_2	81.93	25.01	36.91	100.60	244.45
I_3	97.15	33.59	41.88	115.50	288.12
I_4	139.00	44.56	51.28	143.86	378.70
SEm (±)	7.635	2.715	2.541	9.948	13.224
CD (0.05)	24.433	8.689	8.130	31.834	42.318
Nutrient levels (N)					
N_1	84.58	25.66	35.94	88.46	234.65
N_2	113.09	36.26	45.88	129.50	324.73
SEm (±)	5.442	1.412	1.325	5.334	8.927
CD (0.05)	15.619	4.051	3.803	15.310	25.620
Time of application (S)					
S_1	94.41	29.19	40.31	103.29	267.21
S_2	103.26	32.73	41.51	114.67	292.21
SEm (±)	5.442	1.412	1.325	5.334	8.927
CD (0.05)	NS	NS	NS	NS	NS
I x N interaction					
i_1n_1	76.34	18.16	28.68	68.29	191.46
i_1n_2	78.19	23.19	38.48	83.65	223.50
i_2n_1	68.75	21.30	35.04	83.94	209.03
i_2n_2	95.11	28.73	38.77	117.25	279.87
i_3n_1	87.97	27.80	36.12	95.36	247.26
i_3n_2	106.33	39.37	47.65	135.64	328.99
i_4n_1	105.26	35.39	43.93	106.26	290.84
i_4n_2	172.73	53.74	58.63	181.47	466.57
SEm (±)	10.893	2.826	2.652	10.677	17.868
CD (0.05)	31.239	NS	NS	30.621	NS
N x S interaction					
n_1s_1	79.26	23.22	35.77	83.98	222.24
n_1s_2	89.90	28.10	36.12	92.94	247.06
n_2s_1	109.57	35.16	44.86	122.60	312.18
n_2s_2	116.61	37.36	46.90	136.40	337.28
SEm (±)	7.701	1.998	1.875	7.549	12.633
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 35b. Interaction effect of irrigation and nutrient schedule on the K uptake at harvest in different parts of banana (second year), g plant^{-1}

Treatments	K uptake by Pseudostem	K uptake by Rhizome	K uptake by Leaf	K uptake by Fruit	Total K uptake
I x S interaction					
i_1s_1	71.18	18.77	32.22	70.30	193.41
i_1s_2	83.35	20.60	34.94	81.64	221.56
i_2s_1	78.59	23.12	36.34	106.52	245.73
i_2s_2	85.28	24.51	37.47	94.68	243.16
i_3s_1	91.16	31.46	41.80	101.55	267.53
i_3s_2	103.14	32.52	41.97	129.45	308.71
i_4s_1	136.73	37.85	50.90	134.81	362.17
i_4s_2	141.26	49.39	51.66	152.92	395.24
SEm (±)	10.893	2.826	2.652	10.677	17.868
CD (0.05)	NS	NS	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	66.64	16.40	28.44	63.62	175.09
$i_1n_1s_2$	86.04	19.92	28.93	72.96	207.84
$i_1n_2s_1$	75.71	23.03	36.01	76.97	211.73
$i_1n_2s_2$	80.65	23.35	40.95	90.32	235.28
$i_2n_1s_1$	67.34	19.72	36.74	74.79	198.59
$i_2n_1s_2$	70.16	22.87	33.34	93.10	219.47
$i_2n_2s_1$	89.84	28.85	35.95	138.25	292.88
$i_2n_2s_2$	100.39	28.61	41.60	96.25	266.86
$i_3n_1s_1$	77.99	26.86	35.33	94.21	234.38
$i_3n_1s_2$	97.96	28.75	36.92	96.51	260.14
$i_3n_2s_1$	104.34	39.20	48.26	108.89	300.69
$i_3n_2s_2$	108.31	39.55	47.03	162.40	357.29
$i_4n_1s_1$	105.08	29.92	42.58	103.31	280.88
$i_4n_1s_2$	105.44	40.86	45.29	109.20	300.79
$i_4n_2s_1$	168.38	49.55	59.22	166.30	443.45
$i_4n_2s_2$	177.09	57.83	58.04	196.63	489.63
SEm (±)	15.403	3.995	3.751	15.098	25.265
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 36a. Effect of irrigation and nutrient schedule on the K uptake at harvest in different parts of banana (second year), kg ha^{-1}

Treatments	**K uptake by Pseudostem**	**K uptake by Rhizome**	**K uptake by Leaf**	**K uptake by Fruit**	**Total K uptake**
Irrigation levels (I)					
I_1	238.42	63.79	103.63	234.44	640.28
I_2	252.84	77.18	113.90	310.45	754.37
I_3	299.80	103.66	129.24	356.43	889.13
I_4	428.95	137.51	158.25	443.95	1168.66
SEm (±)	23.562	8.378	7.842	30.700	40.809
CD (0.05)	75.400	26.814	25.089	98.240	130.593
Nutrient levels (N)					
N_1	261.01	79.19	110.91	272.99	724.10
N_2	349.00	111.90	141.59	399.64	1002.13
SEm (±)	16.794	4.357	4.089	16.461	27.549
CD (0.05)	48.200	12.501	11.736	47.247	79.063
Time of application (S)					
S_1	291.35	90.08	124.40	318.75	824.61
S_2	318.66	101.00	128.10	353.87	901.76
SEm (±)	16.794	4.357	4.089	16.461	27.549
CD (0.05)	NS	NS	NS	NS	NS
I x N interaction					
i_1n_1	235.59	56.04	88.51	210.74	590.85
i_1n_2	241.29	71.56	118.75	258.14	689.72
i_2n_1	212.16	65.73	108.13	259.04	645.07
i_2n_2	293.51	88.66	119.64	361.83	863.68
i_3n_1	271.48	85.79	111.47	294.28	763.04
i_3n_2	328.13	121.50	147.05	418.59	1015.26
i_4n_1	324.83	109.21	135.57	327.92	897.53
i_4n_2	533.04	165.84	180.93	560.02	1439.84
SEm (±)	33.616	8.721	8.184	32.949	55.141
CD (0.05)	96.404	NS	NS	94.496	NS
N x S interaction					
n_1s_1	244.60	71.66	110.39	259.16	685.83
n_1s_2	277.43	86.72	111.47	286.81	762.43
n_2s_1	338.13	108.50	138.44	378.34	963.39
n_2s_2	359.86	115.29	144.73	420.93	1040.85
SEm (±)	23.765	6.166	5.786	23.296	38.985
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

Table 36b. Interaction effect of irrigation and nutrient schedule on the K uptake at harvest in different parts of banana (second year), kg ha^{-1}

Treatments	K uptake by Pseudostem	K uptake by Rhizome	K uptake by Leaf	K uptake by Fruit	Total K uptake
I x S interaction					
i_1s_1	219.66	60.83	99.43	216.95	596.86
i_1s_2	257.22	66.75	107.82	251.94	683.73
i_2s_1	242.53	74.93	112.15	328.72	758.32
i_2s_2	263.17	79.43	115.63	292.18	750.39
i_3s_1	281.32	101.93	128.99	313.38	825.60
i_3s_2	318.29	105.39	129.52	399.48	952.68
i_4s_1	421.95	122.64	157.08	416.02	1117.66
i_4s_2	435.93	152.42	159.42	471.91	1219.71
SEm (±)	33.616	8.721	8.184	32.949	55.141
CD (0.05)	NS	NS	NS	NS	NS
I x N x S interaction					
$i_1n_1s_1$	205.65	50.61	87.77	196.33	540.33
$i_1n_1s_2$	265.52	61.47	89.28	225.15	641.39
$i_1n_2s_1$	233.64	71.07	111.13	237.53	653.40
$i_1n_2s_2$	248.89	72.06	126.37	278.73	726.07
$i_2n_1s_1$	207.81	60.86	113.38	230.80	612.85
$i_2n_1s_2$	216.51	70.58	102.89	287.31	677.28
$i_2n_2s_1$	277.25	89.03	110.94	426.64	903.83
$i_2n_2s_2$	309.80	88.29	128.38	297.03	823.53
$i_3n_1s_1$	240.68	82.89	109.03	290.73	723.30
$i_3n_1s_2$	302.30	88.72	113.94	297.83	802.79
$i_3n_2s_1$	321.99	120.97	148.93	336.03	927.93
$i_3n_2s_2$	334.24	122.05	145.13	501.17	1102.60
$i_4n_1s_1$	324.28	92.33	131.40	318.81	866.80
$i_4n_1s_2$	325.39	126.09	139.76	336.99	928.24
$i_4n_2s_1$	519.62	152.91	182.75	513.20	1368.49
$i_4n_2s_2$	546.50	178.77	179.11	606.80	1511.18
SEm (±)	47.534	12.329	11.576	46.592	77.968
CD (0.05)	NS	NS	NS	NS	NS

NS- not significant

year, uptake by all plant parts and total uptake were significant. The uptake by rhizome in the treatment combination, i_4n_2 was at par with i_3n_2 and i_1n_2. During second year, I x N interaction was significant only in pseudostem and fruit uptake.

In N x S interactions, during first year n_2s_1 recorded significantly higher leaf, fruit and total K uptake. The uptake by pseudostem and rhizome in n_2s_1 was on a par with uptake of nutrients in four splits (n_2s_2). During second year, N x S interaction was not significant. The interaction I x S was not significant during both the years.

The three way interaction (I x N x S) was significant only during first year. The uptake by leaf and fruit and total uptake were found to be significant and the highest value was recorded in $i_4n_2s_1$. The K uptake by leaf was at par with $i_4n_2s_2$.

4.1.9 Soil Nutrient Status after the Experiment

4.1.9.1 Organic Carbon (%)

The mean values of the organic carbon of the soil after the experiment are presented in Tables 37a and 37b.

The irrigation scheduled at 1.0 IW/CPE (I_4) recorded the highest organic carbon content in the soil and was at par with 0.8 IW/CPE (I_3) during first year and at par with 0.6 and 0.8 IW/CPE (I_2 and I_3) during second year. The irrigation scheduled at 0.4 IW/CPE (I_1) recorded the lowest organic carbon. The two nutrient levels (N) were not significant during first year and application based on uptake of nutrients (N_2) recorded the highest content (0.82%) during second year. The time of application of nutrients (S) influenced the organic carbon content during second year with application in four splits recording the highest value (0.77%).

None of the interactions were found significant.

4.1.9.2 Available Nitrogen (kg ha^{-1})

The mean values of available soil nitrogen are presented in Tables 37a and 37b.

Table 37a. Effect of irrigation and nutrient schedule on soil nutrient status after the experiment

Treatments	Organic carbon (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels (I)								
I_1	0.71	0.61	225.23	149.35	220.41	161.12	286.00	304.79
I_2	0.74	0.73	229.14	157.58	216.61	155.55	294.44	322.82
I_3	0.86	0.76	208.70	163.47	222.90	159.33	345.69	340.67
I_4	0.89	0.80	220.40	186.90	198.57	164.81	359.56	345.22
SEm (±)	0.025	0.033	4.567	4.108	3.120	4.474	6.181	10.858
CD (0.05)	0.079	0.107	14.613	13.144	9.983	14.317	19.778	34.744
Nutrient levels (N)								
N_1	0.77	0.64	228.99	166.25	210.24	160.36	240.41	279.34
N_2	0.82	0.82	212.75	162.41	219.01	164.80	402.44	377.42
SEm (±)	0.018	0.025	3.947	3.270	2.477	2.914	5.810	4.622
CD (0.05)	0.059	0.071	11.329	NS	7.108	8.362	16.662	13.265
Time of application (S)								
S_1	0.80	0.68	224.59	160.00	210.61	163.44	312.13	319.18
S_2	0.80	0.77	217.15	168.66	218.63	161.72	330.71	337.57
SEm (±)	0.018	0.025	3.947	3.270	2.477	2.914	5.810	4.622
CD (0.05)	NS	0.071	11.329	NS	7.108	NS	16.662	13.265
I x N interaction								
i_1n_1	0.69	0.57	234.89	149.74	237.87	158.61	233.05	250.50
i_1n_2	0.73	0.67	215.57	148.96	202.95	163.63	338.95	359.08
i_2n_1	0.73	0.60	242.88	158.37	209.89	154.02	228.33	279.14
i_2n_2	0.75	0.86	215.41	156.80	223.33	157.07	360.55	366.51
i_3n_1	0.83	0.68	226.12	165.44	201.49	159.50	245.13	295.08
i_3n_2	0.89	0.84	191.29	161.50	244.32	159.16	446.26	386.27
i_4n_1	0.84	0.70	212.06	191.43	191.71	169.30	255.13	292.62
i_4n_2	0.93	0.91	228.73	182.36	205.42	179.35	464.00	397.83
SEm (±)	0.041	0.050	7.901	6.544	4.957	5.832	4.052	9.251
CD (0.05)	NS	NS	22.658	NS	14.216	16.725	11.620	NS
N x S interaction								
n_1s_1	0.76	0.60	242.76	163.19	209.59	159.46	225.58	272.66
n_1s_2	0.78	0.68	215.21	169.30	210.89	151.01	255.23	286.01
n_2s_1	0.83	0.77	206.41	156.80	211.63	168.15	398.69	365.70
n_2s_2	0.82	0.87	219.09	168.01	226.38	162.19	406.19	389.13
SEm (±)	0.029	0.035	5.586	4.627	3.505	4.123	8.216	6.541
CD (0.05)	NS	NS	16.019	NS	10.051	NS	NS	NS

NS- not significant

Table 37b. Interaction effect of irrigation and nutrient schedule on soil nutrient status after the experiment

Treatments	Organic carbon (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	I year	II year	I year	II year	I year	II year	I year	II year
I x S interaction								
i_1s_1	0.71	0.57	233.76	145.04	219.80	161.72	267.91	298.68
i_1s_2	0.71	0.66	216.70	153.66	221.01	160.53	304.08	310.90
i_2s_1	0.74	0.70	230.42	153.66	219.77	160.53	291.24	313.86
i_2s_2	0.74	0.77	227.87	161.50	213.44	150.56	297.64	331.79
i_3s_1	0.85	0.75	202.04	158.37	213.30	156.20	341.25	329.45
i_3s_2	0.86	0.78	215.37	168.57	232.51	162.45	350.13	351.89
i_4s_1	0.88	0.72	232.13	182.91	189.56	175.29	348.13	334.73
i_4s_2	0.89	0.88	208.66	190.88	207.57	173.36	371.00	355.72
SEm (±)	0.041	0.050	7.901	6.544	4.957	5.832	11.620	9.251
CD (0.05)	NS	NS	NS	NS	14.216	NS	NS	NS
I x N x S interaction								
$i_1n_1s_1$	0.68	0.56	252.76	148.96	248.62	155.30	213.66	244.50
$i_1n_1s_2$	0.70	0.58	217.02	150.53	227.11	161.93	252.43	256.50
$i_1n_2s_1$	0.75	0.57	214.75	141.12	190.99	168.14	322.17	352.86
$i_1n_2s_2$	0.72	0.74	216.38	156.80	214.92	159.13	355.73	365.29
$i_2n_1s_1$	0.73	0.56	261.37	156.80	220.15	155.93	208.15	267.78
$i_2n_1s_2$	0.72	0.65	224.40	159.94	199.63	152.12	248.50	290.50
$i_2n_2s_1$	0.74	0.84	199.48	150.53	219.39	165.14	374.33	359.94
$i_2n_2s_2$	0.76	0.89	231.34	163.07	227.26	149.01	346.78	373.08
$i_3n_1s_1$	0.81	0.67	230.39	159.94	180.10	159.04	241.25	287.95
$i_3n_1s_2$	0.84	0.70	221.85	170.94	222.88	159.95	249.00	302.21
$i_3n_2s_1$	0.90	0.83	173.69	156.80	246.51	153.36	441.24	370.96
$i_3n_2s_2$	0.88	0.86	208.89	166.21	242.14	164.95	451.26	401.58
$i_4n_1s_1$	0.82	0.61	226.54	187.07	189.47	167.57	239.25	290.39
$i_4n_1s_2$	0.86	0.79	197.58	195.80	193.96	171.03	271.00	294.85
$i_4n_2s_1$	0.94	0.84	237.72	178.75	189.65	183.01	457.00	379.07
$i_4n_2s_2$	0.92	0.98	219.75	185.97	221.19	175.69	471.00	416.59
SEm (±)	0.058	0.070	11.17	9.254	7.010	8.246	16.431	13.081
CD (0.05)	NS	NS	NS	NS	20.105	NS	NS	NS

NS- not significant

The irrigation scheduled at 0.4, 0.6 and 1.0 IW/CPE (I_1, I_2 and I_4) were on a par and superior to 0.8 IW/CPE (I_3) in soil available nitrogen during first year. However, during second year irrigation at 1.0 IW/CPE (I_4) recorded the highest (186.90 kg ha^{-1}) and was significantly superior to other levels of irrigation.

Among nutrient levels, N_1 recorded more soil available nitrogen during first year, whereas the nutrient levels were not significant during second year. The time of application (S) was not significant during both the years.

The interaction effect of I x N was found significant only during first year of experimentation. All irrigation levels with N_1 (i_1n_1, i_2n_1 and i_3n_1) except at 1.0 IW/CPE, recorded more soil available nitrogen than N_2 level. Irrigation at 1.0 IW/CPE, the treatments (i_4n_1 and i_4n_2) were on a par. Among N x S interaction, n_1s_1 was significantly superior to other combinations during first year. However during second year, N x S interaction was not significant. All other interactions were not significant during both the years.

4.1.9.3 Available Phosphorus (kg ha^{-1})

The analysed data is presented in Tables 37a and 37b.

The irrigation scheduled at 0.4, 0.6 and 0.8 IW/CPE (I_1, I_2 and I_3) were on a par and superior to irrigation at 1.0 IW/CPE (I_4) during first year. Among the two nutrient levels (N), nutrient application based on the uptake of nutrients (N_2) recorded the highest available soil phosphorus (219.01 kg ha^{-1}). During second year the effects of irrigation and nutrient levels were not significant. The available soil phosphorus was influenced by the time of application (S) during first year and application of nutrients in four splits (S_2) was found superior to two split (S_1) application.

The interaction effect of I x N was significant during both the years. The available soil phosphorus was the highest in i_3n_2 and i_4n_2 during first and second year, respectively. Among the N x S interaction, phosphorus content was the highest in n_2s_2 during first year and non significant during second year. The interactions, I x S and I x N x S were significant during first year and not significant during second year. During first year, among the interactions of I x S, i_3s_2 recorded the highest (232.51 kg ha^{-1}) and i_4s_1 recorded the lowest (189.56 kg ha^{-1}). Among I x N x S interaction $i_1n_1s_1$ recorded the highest and $i_3n_1s_1$, the lowest.

4.1.9.4 Available Potassium (kg ha^{-1})

The analysed data is presented in Tables 37a and 37b.

The results revealed that irrigation at 0.8 and 1.0 IW/CPE ($I_3$and I_4) recorded higher soil available potassium and significantly superior to the other two levels of irrigation during first year. During second year, irrigation at 0.6, 0.8 and 1.0 IW/CPE (I_2, I_3 and I_4) were at par and significantly superior to irrigation at 0.4 IW/CPE (I_1). Among the two nutrient levels (N), nutrient application based on the uptake of nutrients (N_2) recorded the highest potassium (402.44 and 377.42 kg ha^{-1}, respectively) during first and second year and was superior to POP based application (N_1). The application of nutrients in four splits (S_2) recorded higher potassium than two splits (S_1).

Among the interactions, only I x N interaction was significant during first year of experimentation. With all irrigation levels (I_1, I_2, I_3 and I_4), uptake based nutrient application (N_2) recorded the highest potassium content in the soil (i_1n_2, i_2n_2, i_3n_2 and i_4n_2).

4.1.10 Incidence of Major Pests and Diseases

The incidence of diseases during the crop growth period is presented in Appendix III. Uniform scoring was given for sigatoka leaf spot disease during first and second year, respectively. There was no variation between treatments in the incidence of diseases. The incidence of banana bract mosaic virus was noticed towards the end of the second year. There was no incidence of any pest during the crop period.

4.1.11 Total Water Requirement (mm), Water Use Efficiency and Water Productivity (kg ha mm^{-1})

Data on total water requirement, water use efficiency and water productivity are presented in Appendix IV and V, and in Tables 38a and 38b.

The number of irrigations, irrigation requirement and total water requirement varied with irrigation levels. The number of irrigations under 0.4, 0.6, 0.8 and 1.0 IW/CPE (I_1, I_2, I_3 and I_4) was 19, 26, 31 and 36, respectively during first year and 22, 31, 36 and 43, respectively during second year. The irrigation requirement with 0.4, 0.6, 0.8 and 1.0 IW/CPE (I_1, I_2, I_3 and I_4) were 570, 780, 930 and 1080 mm, respectively during first year and 660, 930, 1080 and 1290 mm, respectively during second year. The total water requirement which includes irrigation requirement and effective rainfall in irrigation at 0.4, 0.6, 0.8 and 1.0 IW/CPE (I_1, I_2, I_3 and I_4) were 1661, 1871, 2021 and 2171 mm, respectively during first year and 1929, 2199, 2349 and 2559 mm, respectively during second year.

Water use efficiency (WUE) was the highest (40.11 and 30.38 kg ha mm^{-1}) at 0.8 IW/CPE (I_3) during both the years. It was found at par with 0.6 IW/CPE (I_2) and 1.0 IW/CPE (I_4) during first year and with 1.0 IW/CPE (I_4) during second year.

Water productivity was the highest (12.22 and 8.55 kg ha^{-1} mm^{-1}) at 0.8 IW/CPE (I_3) and 1.0 IW/CPE (I_4) during first and second year, respectively. It was at par with 1.0 IW/CPE (I_4) and 0.8 IW/CPE (I_3) during first and second year of study.

WUE and water productivity were the highest in nutrient application based on the uptake of nutrients (N_2) during both the years of experimentation. WUE and water productivity were influenced by the time of application (S) during second year only. The application of nutrients in 4 splits (S_2) recorded the highest WUE and water productivity (29.48 and 8.24 kg ha mm^{-1}).

Table 38a. Effect of irrigation and nutrient schedule on water use efficiency and water productivity, kg ha mm^{-1}

Treatments	Water use efficiency		Water productivity		Water productivity (kg m^{-3})	
	I year	II year	I year	II year	I year	II year
Irrigation levels (I)						
I_1	36.17	26.60	11.39	7.74	1.14	0.77
I_2	37.32	27.01	10.81	7.58	1.08	0.76
I_3	40.11	30.38	12.22	8.25	1.22	0.83
I_4	38.43	30.15	11.86	8.55	1.19	8.55
SEm (±)	1.022	0.694	0.215	0.152	0.022	0.015
CD (0.05)	3.269	2.222	0.687	0.487	0.069	0.049
Nutrient levels (N)						
N_1	34.45	26.33	10.52	7.44	1.05	0.74
N_2	41.56	30.74	12.62	8.62	1.26	0.86
SEm (±)	0.640	0.322	0.128	0.059	0.013	0.006
CD (0.05)	1.838	0.924	0.367	0.171	0.037	0.017
Time of application (S)						
S_1	38.29	27.59	11.62	7.81	1.16	0.78
S_2	37.72	29.48	11.52	8.24	1.15	0.82
SEm (±)	0.640	0.322	0.128	0.059	0.013	0.006
CD (0.05)	NS	0.924	NS	0.171	NS	0.017
I x N interaction						
i_1n_1	34.37	24.40	10.62	7.22	1.07	0.72
i_1n_2	37.97	28.80	12.17	8.26	1.22	0.83
i_2n_1	34.23	24.91	9.99	7.07	0.10	0.71
i_2n_2	40.41	29.12	11.63	8.09	1.16	0.81
i_3n_1	36.09	28.58	11.02	7.66	1.10	0.77
i_3n_2	44.13	32.19	13.43	8.84	1.34	0.88
i_4n_1	33.13	27.44	10.45	7.80	1.05	0.78
i_4n_2	43.73	32.86	13.27	7.22	1.33	0.72
SEm (±)	1.282	0.645	0.256	0.119	0.026	0.012
CD (0.05)	NS	NS	0.733	NS	0.073	NS
N x S interaction						
n_1s_1	33.96	25.12	10.36	7.17	1.04	0.72
n_1s_2	34.94	27.54	10.67	7.70	1.07	0.77
n_2s_1	42.62	30.06	12.88	8.46	1.29	0.85
n_2s_2	40.50	31.42	12.37	8.78	1.24	0.88
SEm (±)	0.906	0.456	0.181	0.084	0.018	0.008
CD (0.05)	NS	NS	0.519	NS	0.052	NS

NS- not significant

Table 38b. Interaction effect of irrigation and nutrient schedule on water use efficiency and water productivity, kg ha mm^{-1}

Treatments	Water use efficiency		Water productivity		Water productivity (kg m^{-3})	
	I year	II Year	I year	II Year	I year	I year
I x S interaction						
i_1s_1	35.53	25.60	11.33	7.51	1.13	0.75
i_1s_2	36.81	27.60	11.45	7.97	1.15	0.80
i_2s_1	37.53	25.96	10.83	7.34	1.08	0.73
i_2s_2	37.11	28.07	10.79	7.82	1.08	0.78
$_3s_1$	41.21	29.56	12.26	8.12	1.23	0.81
i_3s_2	39.01	31.20	12.19	8.37	1.22	0.84
i_4s_1	38.91	29.25	12.07	8.28	1.21	0.83
i_4s_2	37.95	31.05	11.64	7.51	1.16	0.75
SEm (±)	1.282	0.645	0.256	0.119	0.026	0.012
CD (0.05)	NS	NS	NS	NS	NS	NS
I x N x S interaction						
$i_1n_1s_1$	33.67	23.20	10.43	6.96	1.04	0.70
$i_1n_1s_2$	35.07	25.60	10.80	7.47	1.08	0.75
$i_1n_2s_1$	37.39	28.00	12.23	8.05	1.22	0.81
$i_1n_2s_2$	38.55	29.60	12.10	8.47	1.21	0.85
$i_2n_1s_1$	33.40	23.16	9.81	6.74	0.98	0.67
$i_2n_1s_2$	35.05	26.66	10.17	7.40	1.02	0.74
$i_2n_2s_1$	41.65	28.77	11.85	7.94	1.19	0.79
$i_2n_2s_2$	39.17	29.47	11.40	8.24	1.14	0.82
$i_3n_1s_1$	36.18	27.59	10.81	7.48	1.08	0.75
$i_3n_1s_2$	36.00	29.56	11.23	7.84	1.12	0.78
$i_3n_2s_1$	46.23	31.53	13.69	8.76	1.37	0.88
$i_3n_2s_2$	42.03	32.84	13.16	8.90	1.32	0.89
$i_4n_1s_1$	32.60	26.53	10.41	7.50	1.04	0.75
$i_4n_1s_2$	33.65	28.34	10.48	8.10	1.05	0.81
$i_4n_2s_1$	45.22	31.96	13.73	9.07	1.37	0.91
$i_4n_2s_2$	42.24	33.77	12.80	9.52	1.28	0.95
SEm (±)	1.812	0.911	0.362	0.168	0.036	0.017
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- not significant

WUE was not affected by the interactions. Water productivity was influenced by I x N and N x S interactions only during first year of study. Among I x N interactions, water productivity in i_3n_2 and i_4n_2 were at par and recorded the highest value. Among N x S interactions, n_2s_1 and n_2s_2 were at par and significantly superior to n_1s_1 and n_2s_2. Other interactions were found not significant.

4.1.12 Number of Suckers at Harvest

The mean number of suckers at harvest is presented in Tables 39a and 39b. The irrigation levels, time of application of nutrients and interactions were not significant in sucker production of Grand Nain banana. The numbers of suckers at harvest were the highest in N_2 during both the years of experimentation.

4.1.13 Economic Analysis

The cost of cultivation is presented in Appendix VI and gross returns, net returns and Benefit: Cost ratio are presented in Tables 40a and 40b. The cost of cultivation varied with the nutrient levels and time of application of nutrients. The total cost of cultivation under the different sub plot combinations n_1s_1, n_1s_2, $n_2s_1$and n_2s_2 were 3,83,004, 3,94,204, 4,13,627 and 4,24,827 ₹ ha^{-1}, respectively during first year and 4,14,197, 4,26,597, 4,48,343 and 4,60,743 ₹ ha^{-1}, respectively during second year.

During first year, irrigation schedule at 0.8 IW/CPE recorded the highest gross returns and net returns (14,99,217 and 10,95,302 ₹ ha^{-1}, respectively). However, during second year, 1.0 IW/CPE (I_4) recorded the highest gross and net returns (1,38,407 and 9,39,663 ₹ ha^{-1}). Irrigation scheduled at 0.4 IW/CPE recorded the lowest gross and net returns during both the years. Among the two nutrient levels (N), N_2 recorded the highest gross returns, net returns and BCR during both the years. The application of nutrients in two splits (S_1) recorded the highest returns and BCR during first year, but during second year, application of nutrients in four splits (S_2) recording the highest. Among the I x N interaction, i_4n_2 recorded the highest returns and BCR during both the years. Among the N x S and I x S interactions, $n_2s_1$and $i_3s_1$recorded the highest BCR during first year and n_2s_2 and i_4s_2 during second year, respectively. Among the I x N x S interactions, $i_4n_2s_1$ recorded the highest returns and BCR during first year and $i_4n_2s_2$ during second year.

Table 39a. Effect of irrigation and nutrient schedule on number of suckers at harvest

Treatments	Suckers	
	I year	**II year**
Irrigation levels (I)		
I_1	5.9	4.6
I_2	6.6	6.2
I_3	6.2	6.0
I_4	5.8	6.1
SEm (±)	0.356	0.553
CD (0.05)	NS	NS
Nutrient levels (N)		
N_1	5.7	5.5
N_2	6.6	5.9
SEm (±)	0.202	0.193
CD (0.05)	0.580	NS
Time of application (S)		
S_1	6.3	5.8
S_2	6.0	5.7
SEm (±)	0.202	0.193
CD (0.05)	NS	NS
I x N interaction		
i_1n_1	5.4	4.1
i_1n_2	6.4	5.0
i_2n_1	6.0	6.1
i_2n_2	7.3	6.3
i_3n_1	5.8	6.1
i_3n_2	6.6	5.9
i_4n_1	5.5	5.6
i_4n_2	6.1	6.6
SEm (±)	0.405	0.386
CD (0.05)	NS	NS
N x S interaction		
n_1s_1	5.9	5.6
n_1s_2	5.4	5.4
n_2s_1	6.6	5.9
n_2s_2	6.6	5.9
SEm (±)	0.286	0.273
CD (0.05)	NS	NS

NS- not significant

Table 39b. Interaction effect of irrigation and nutrient schedule on number of suckers at harvest

Treatments	**Suckers**	
	I year	**I year**
I x S interaction		
i_1s_1	6.0	4.5
i_1s_2	5.8	4.6
i_2s_1	6.4	6.1
i_2s_2	6.9	6.3
i_3s_1	6.4	6.1
i_3s_2	6.0	5.9
i_4s_1	6.3	6.3
i_4s_2	5.4	6.0
SEm (±)	0.405	0.386
CD (0.05)	NS	NS
I x N x S interaction		
$i_1n_1s_1$	5.8	4.0
$i_1n_1s_2$	5.0	4.3
$i_1n_2s_1$	6.3	5.0
$i_1n_2s_2$	6.5	5.0
$i_2n_1s_1$	5.3	6.0
$i_2n_1s_2$	6.8	6.3
$i_2n_2s_1$	7.5	6.3
$i_2n_2s_2$	7.0	6.3
$i_3n_1s_1$	6.3	6.3
$i_3n_1s_2$	5.3	6.0
$i_3n_2s_1$	6.5	6.0
$i_3n_2s_2$	6.8	5.8
$i_4n_1s_1$	6.3	6.0
$i_4n_1s_2$	4.8	5.3
$i_4n_2s_1$	6.3	6.5
$i_4n_2s_2$	6.0	6.8
SEm (±)	0.572	0.546
CD (0.05)	NS	NS

NS- not significant

Table 40a. Effect of irrigation and nutrient schedule on economics

Treatments	Gross income (₹ ha^{-1})		Net income (₹ ha^{-1})		Benefit cost ratio	
	I year	II year	I year	II year	I year	II year
Irrigation levels (I)						
I_1	1118771	938524	714856	505402	2.77	2.14
I_2	1292648	1120211	888733	708200	3.20	2.56
I_3	1499217	1292639	1095302	878019	3.71	2.95
I_4	1483884	1384071	1079968	939663	3.66	3.16
Nutrient levels (N)						
N_1	1222779	1100540	834175	694034	3.15	2.62
N_2	1474481	1267182	1055254	821608	3.52	2.79
Time of application (S)						
S_1	1363385	1153200	965070	733649	3.41	2.67
S_2	1333875	1214523	924360	781993	3.25	2.73
I x N interaction						
i_1n_1	1055412	858676	666808	445811	2.72	2.04
i_1n_2	1182131	1018373	762904	564992	2.82	2.24
i_2n_1	1182710	1048465	794106	667996	3.04	2.49
i_2n_2	1402587	1191956	983360	748404	3.35	2.62
i_3n_1	1355718	1233621	967114	835785	3.49	2.93
i_3n_2	1642716	1351657	1223489	920252	3.92	2.97
i_4n_1	1297277	1261399	908673	826543	3.34	3.00
i_4n_2	1670490	1506743	1251263	1052784	3.99	3.32
N x S interaction						
n_1s_1	1217138	1062359	834134	665530	3.18	2.56
n_1s_2	1228421	1138721	834217	766292	3.12	2.67
n_2s_1	1509633	1244040	1096006	801768	3.65	2.77
n_2s_2	1439330	1290324	1014503	841449	3.39	2.80

Table 40b. Interaction effect of irrigation and nutrient schedule on economics

Treatments	**Gross income (₹ ha^{-1})**		**Net income (₹ ha^{-1})**		**Benefit cost ratio**	
	I year	**II year**	**I year**	**II year**	**I year**	**II year**
I x S interaction						
i_1s_1	1107488	907288	709173	484135	2.78	2.10
i_1s_2	1130055	969761	720539	526669	2.76	2.18
i_2s_1	1289177	1083190	890861	668115	3.23	2.51
i_2s_2	1296120	1157231	886605	748285	3.16	2.61
i_3s_1	1540878	1268327	1142563	868295	3.86	2.94
i_3s_2	1457556	1316951	1048041	887742	3.55	2.97
i_4s_1	1515998	1353994	1117682	914051	3.79	3.13
i_4s_2	1107488	1414148	1042255	965275	3.53	3.18
I x N x S interaction						
$i_1n_1s_1$	1051940	819341	668936	420205	2.75	1.98
$i_1n_1s_2$	1058884	898011	664680	471418	2.69	2.11
$i_1n_2s_1$	1163036	995235	749409	548064	2.81	2.22
$i_1n_2s_2$	1201226	1041510	776399	581921	2.83	2.26
$i_2n_1s_1$	1131791	985992	748787	607674	2.96	2.38
$i_2n_1s_2$	1233629	1110938	839425	728318	3.13	2.60
$i_2n_2s_1$	1446563	1180388	1032936	728556	3.50	2.63
$i_2n_2s_2$	1358612	1203525	933785	768253	3.20	2.61
$i_3n_1s_1$	1377128	1203525	994124	821727	3.60	2.91
$i_3n_1s_2$	1334309	1263717	940105	849842	3.38	2.96
$i_3n_2s_1$	1704629	1333130	1291002	914862	4.12	2.97
$i_3n_2s_2$	1580804	1370184	1155977	925643	3.72	2.97
$i_4n_1s_1$	1307693	1240580	924689	812513	3.41	3.00
$i_4n_1s_2$	1286862	1282218	892658	840573	3.26	3.01
$i_4n_2s_1$	1724303	1467408	1310676	1015590	4.17	3.27
$i_4n_2s_2$	1616678	1546079	1191851	1089978	3.81	3.36

The benefit cost ratio (BCR) was the highest (3.71 and 3.66) at 0.8 IW/CPE (I_3) and 1.0 IW/CPE (I_4) during first year and irrigation at 1.0 IW/CPE (I_4) recorded the highest (3.16) BCR in second year and significantly superior to the other levels of irrigation.

4.1.14 Correlation Analysis

The mean values of simple correlation coefficient in Grand Nain banana are given in Table 41.

All the growth attributes at 4 MAP, 6 MAP and at harvest were positively correlated with the yield. However, phyllochon and crop duration were negatively correlated with the yield. The yield attributes, *viz*., number of hands, total number of fingers, number of fingers in D-hand, bunch length, length and weight of D-finger except the girth of D-finger were positively correlated with the yield. The highest correlation of yield was found with leaf parameters at harvest and total number of fingers.

4.2 EXPERIMENT II. STUDIES ON PHENOLOGY OF BANANA CV. GRAND NAIN

4.2.1 Crop **Growth Characters**

The plant growth characters were recorded at 4 and 6 months after planting (MAP) and also at harvest. The data indicated that the growth characters, *viz*., plant height, girth of pseudostem, number of functional leaves, functional leaf area, leaf area index, leaf area duration and leaf emergence rate were significantly different under different planting dates.

4.2.1.1 Height and Girth of Pseudostem (cm)

The data on height and girth of pseudostem are presented in Table 42.

At 4 MAP, height and girth of pseudostem were significantly influenced by planting dates. July (T_7) and February (T_2) planting recorded plants with

Table 41. Correlation of growth and yield parameters with yield in nutrient-moisture interaction study

Variables correlated	Correlation coefficient
Yield vs. Pseudostem height at 4 MAP	0.699**
Yield vs. Pseudostem girth at 4 MAP	0.697**
Yield vs. Number of functional leaves at 4 MAP	0.830**
Yield vs. Functional leaf area, LAI at 4 MAP	0.889**
Yield vs. LAD at 4 MAP	0.898**
Yield vs. Pseudostem height at 6 MAP	0.896**
Yield vs. Pseudostem girth at 6 MAP	0.809**
Yield vs. Number of functional leaves at 6 MAP	0.921**
Yield vs. Functional leaf area, LAI at 6 MAP	0.903**
Yield vs. LAD at 6 MAP	0.912**
Yield vs. N % in the index leaf at 4 MAP	0.348
Yield vs. P % in the index leaf at 4 MAP	0.612*
Yield vs. Phyllochron	-0.777**
Yield vs. K % in the index leaf at 4 MAP	0.615*
Yield vs. Pseudostem height at harvest	0.880**
Yield vs. Pseudostem girth at harvest	0.785**
Yield vs. Number of functional leaves at harvest	0.937**
Yield vs. Functional leaf area at harvest, LAI, LAD	0.938**
Yield vs. Number of hands	0.839**
Yield vs. Number of fingers in D-hand	0.674**
Yield vs. Total number of fingers	0.949**
Yield vs. Bunch length	0.835**
Yield vs. D-Finger weight	0.827**
Yield vs. Length of D-finger	0.601*
Yield vs. Girth of D-finger	0.330
Yield vs. Crop duration	-0.194

** Significant at 1 % level (0.623)
* Significant at 5 % level (0.426)

Table 42. Effect of planting dates on growth characters of Grand Nain banana, cm

Treatments (Dates of planting)	4 MAP		6 MAP		At harvest	
	Height of pseudostem (cm)	Girth of pseudostem (cm)	Height of pseudostem (cm)	Girth of pseudostem (cm)	Height of pseudostem (cm)	Girth of pseudostem (cm)
January (T_1)	75.00	24.00	171.25	64.75	300.00	70.75
February (T_2)	157.50	42.25	196.75	68.25	229.50	72.75
March (T_3)	121.00	28.25	204.50	65.25	223.75	66.75
April (T_4)	141.00	48.75	213.25	65.75	226.25	67.50
May (T_5)	121.00	38.50	202.75	64.00	230.25	68.50
June (T_6)	102.25	48.50	246.75	67.75	264.00	81.00
July (T_7)	163.00	52.25	218.25	69.75	262.25	78.25
August (T_8)	69.50	24.00	176.25	52.50	223.50	68.00
September (T_9)	126.25	44.25	206.25	63.75	264.00	71.50
October (T_{10})	129.00	41.50	211.75	66.00	241.25	69.75
November (T_{11})	92.500	34.00	173.75	52.00	206.25	60.75
December (T_{12})	97.50	35.75	170.0	54.50	196.75	64.50
SEm (±)	3.052	1.380	5.94	2.362	6.147	2.468
CD (0.05)	8.785	3.974	17.089	6.796	17.758	7.131

MAP- months after planting

maximum height (163 cm and 157.5 cm, respectively) than other months. The plant height was the lowest in August planting (T_8) and was on a par with January planting (T_1). The pseudostem girth was the highest (52.25 cm) in July planting (T_7) which was on a par with April (T_4) and June (T_6) planting. These treatments were followed by September (T_9), February (T_2) and October (T_{10}) planting and were statistically similar. The girth of pseudostem was the lowest (24 cm) in January (T_1) and August (T_8) planting.

The analysed data of 6 MAP revealed that June (T_6) planted crop was the tallest (246.75 cm) and December planted crop (T_{12}), the shortest (170 cm) and it was on par with January (T_1), November (T_{11}) and August (T_8) planted crops. The pseudostem girth (69.75 cm) was the highest in July planted crop (T_7) which was on par with all other treatments except August (T_8), November (T_{11}) and December (T_{12}) planted crops.

The data analysed at harvest revealed that the maximum plant height was in January (T_1) planted (300 cm) which was followed by September (T_9), June (T_6) and July (T_7) planting which were on a par and the lowest height was in December (T_{12}) planting (196.75 cm) which was statistically on a par with November planting (T_{11}). The June (T_6) planted crop recorded the highest girth (81 cm) and was comparable with July planting (T_7). The girth was the lowest in November (T_{11}) planted crop (60.75 cm) which was statistically comparable with December (T_{12}), March (T_3)**,** May (T_5) and April (T_4) plantings.

4.2.1.2 Number of Functional Leaves and Functional Leaf Area (m^2)

The data on number of functional leaves and functional leaf area are presented in Table 43.

A critical review of the data on number of functional leaves and functional leaf area plant^{-1} showed that planting dates had significant influence at all growth stages. At 4 MAP, April (T_4) planted crop recorded more number of leaves (13.75) which was on par with February (T_2) planted crop and August (T_8)

Table 43. Effect of planting dates on growth characters of Grand Nain banana

Treatments (Dates of planting)	4 MAP		6 MAP		At harvest	
	Number of functional leaves plant^{-1}	**Total functional leaf area plant^{-1} (m^2)**	**Number of functional leaves plant^{-1}**	**Total functional leaf area plant^{-1} (m^2)**	**Number of functional leaves plant^{-1}**	**Total functional leaf area plant^{-1} (m^2)**
January (T_1)	10.00	3.52	14.00	10.01	6.00	11.67
February (T_2)	13.00	7.77	15.25	18.92	10.00	16.43
March (T_3)	12.25	7.24	10.25	8.81	6.00	7.94
April (T_4)	13.75	10.71	14.75	20.77	7.50	11.01
May (T_5)	9.50	4.67	15.00	16.77	6.50	8.94
June (T_6)	10.50	6.42	14.25	19.16	7.00	10.48
July (T_7)	10.75	7.16	14.50	21.13	8.00	13.10
August (T_8)	8.75	5.43	13.75	11.85	6.00	7.78
September (T_9)	10.75	4.25	10.50	12.95	7.00	11.40
October (T_{10})	12.25	7.10	14.75	18.43	5.75	8.46
November (T_{11})	12.00	4.92	8.75	7.74	5.75	6.23
December (T_{12})	9.75	3.58	8.75	6.79	5.25	5.37
SEm (±)	0.309	0.321	0.327	1.124	0.414	0.831
CD (0.05)	0.892	0.926	0.946	3.247	1.197	2.40

MAP- months after planting

planted crop recorded less leaves (8.75) which was at par with May (T_5) planted ones. The functional leaf area plant^{-1} was the highest in April (T_4) planted crop (10.71 m^2) followed by February (T_2) planted crop which was on par with March (T_3), July (T_7) and October (T_{10}) planted crops. However, January (T_1) planted crop recorded the lowest functional leaf area plant^{-1} which was on a par with December (T_{12}) and September (T_9) planted crops.

At 6 MAP, February (T_2) planted crop produced more number of number of functional leaves (15.25) which was on a par with May (T_5), April (T_4), October (T_{10}) and July (T_7) planted crops. The functional leaf area plant^{-1} was the highest in July (T_7) planted crop (21.13 m^2) and was at par with April (T_4), June (T_6), February (T_2), and October (T_{10}) planted crops. The number of leaves and functional leaf area were the lowest in December (T_{12}) and November (T_{11}) planted crops.

At harvest stage number of functional leaves were the highest in February (T_2) planted crop (10) which was significantly superior to all other plantings. This was followed by July (T_7) planting which was on par with April (T_4), September (T_9) and June (T_6) planting. The number of functional leaves was the lowest in December (T_{12}) planted crop (5.25) which was statistically comparable with October (T_{10}) and November (T_{11}) planted crops. The functional leaf area was the highest in February (T_2) planted crop (16.43 m^2). The next best result was obtained in July (T_7) planted crop which was at par with January (T_1), September (T_9) and April (T_4) planted crops. The functional leaf area plant^{-1} was the lowest in December (T_{12}) planted crop (5.37 m^2) and it was on par with November (T_{11}) planted crop.

4.2.1.3 Leaf Area Index (LAI) and Leaf Area Duration (LAD) (Days)

The data on mean Leaf area index (LAI) and Leaf area duration (LAD) (days) are presented in Table 44.

Table 44. Effect of planting dates on growth characters of Grand Nain banana

Treatments (Dates of planting)	4 MAP		6 MAP		At harvest		Leaf emergence rate (month^{-1})
	Leaf area index (LAI)	**Leaf area duration (LAD) (days)**	**Leaf area index (LAI)**	**Leaf area duration (LAD) (days)**	**Leaf area index (LAI)**	**Leaf area duration (LAD) (days)**	
January (T_1)	1.08	49.91	3.09	125.40	3.61	108.15	3.62
February (T_2)	2.40	111.94	5.84	247.20	5.07	152.10	4.75
March (T_3)	2.24	100.58	2.72	148.50	2.45	73.43	4.53
April (T_4)	3.31	148.73	6.41	291.60	3.40	101.93	4.32
May (T_5)	1.44	64.91	5.18	198.60	2.76	82.80	4.14
June (T_6)	1.98	89.33	5.91	236.70	3.24	97.05	3.93
July (T_7)	2.21	99.34	6.52	261.90	4.04	121.28	4.17
August (T_8)	1.68	75.60	3.66	160.20	2.40	72.08	3.91
September (T_9)	1.31	58.84	4.00	159.30	3.52	105.60	3.89
October (T_{10})	2.19	98.66	5.69	236.40	2.61	78.30	3.66
November (T_{11})	1.52	68.40	2.39	117.30	1.92	57.68	3.25
December (T_{12})	1.11	50.48	2.10	96.00	1.67	50.03	3.49
SEm (±)	0.099	4.474	0.348	11.450	0.256	7.679	0.130
CD (0.05)	0.286	12.926	1.002	33.078	0.740	22.186	0.375

MAP- months after planting

The planting season had a significant influence on Leaf area index (LAI) during the growth period. At 4 MAP, April (T_4) planted crop recorded the highest LAI (3.31) and was significantly superior to all other treatments. This was followed by February (T_2) planting which was on par with March (T_3), July (T_7) and October (T_{10}) plantings. The lowest LAI was recorded in January (T_1) and December (T_{12}) planted crops which were on par with September (T_9) planted crop. The mean LAI value ranged from 1.09 to 3.31.

At 6 MAP, July (T_7) planted crop recorded the highest LAI (6.52). But it was on par with April (T_4), February (T_2), June (T_6) and October (T_{10}) planted crops. The LAI was the lowest in December (T_{12}) planted crop which was found on par with November (T_{11}), March (T_3) and January (T_1) planting. The mean value of LAI ranged from to 2.10 to 6.52.

At harvest stage, the mean value of LAI ranged from 1.67 to 5.07 and the highest LAI was recorded in February (T_2) planted crop which was on par with July (T_7), September (T_9) and January (T_1) planted crops and the lowest value was recorded in December (T_{12}) planted crop.

The Leaf area duration (LAD) was significantly influenced by the planting seasons.

At 4 MAP, the LAD was the longest in April planting (T_4) (148.73 days) and the shortest in January (T_1) planting (49.91 days) which was at par with December (T_{12}) and September (T_9) plantings.

At 6 MAP also, the LAD was the longest in April (T_4) planted crop (291.45 days) and was on par with July (T_7) planted crop (261.98 days). This was followed by February (T_2) planting which was on par with June (T_6) and October (T_{10}) planting. The LAD was the shortest in December (T_{12}) planting (101.48 days) which was on par with November (T_{11}) and January (T_1) planting.

At harvest, February (T_2) planting recorded the longest LAD (152.1 days) followed by July (T_7) planting and the LAD was the shortest in December (T_{12}) planting and was statistically on par with November (T_{11}) and August (T_8) planting.

4.2.1.4 Leaf Emergence Rate (LER) Month^{-1}

The data on LER is presented in Table 44.

The monthly leaf emergence was influenced by planting season. February (T_2) planting recorded the highest LER (4.75) and was on par with March (T_3) planting. But the March (T_3), planted crop was found at par with April (T_4) and July (T_7) planted crops. The LER was the lowest in November (T_{11}) planted crop and found on par with December (T_{12}) and January (T_1) planted crops.

4.2.2 Effect of Phenology on Yield Attributes, Yield and Quality Parameters

The planting dates significantly influenced the yield, yield attributes and quality parameters of Grand Nain banana.

4.2.2.1 Bunch Characters

Data pertaining to bunch characters are presented in Table 45.

The number of hands bunch^{-1}, number of fingers bunch^{-1}, number of fingers in the D-hand, weight of D-hand and bunch length were significantly influenced by the treatments. The number of hands was the highest in June (T_6) planted crop (11 hands) and was on par with February (T_2), October (T_{10}) and April (T_4) planted crops. The number of hands was the lowest in January (T_1) planted crop. The total number of fingers were the highest in June (T_6) planting (198.75) and was on par with February (T_2) planting and the lowest in January (T_1) planting (104.75) which was statistically on par with November (T_{11}) planting.

The number of fingers in D-hand was significantly influenced by the treatments and was the highest in March (T_3) planting (27) which was on par with February (T_2) and June (T_6) plantings and the lowest in November (T_{11}) planting.

Table 45. Effect of planting dates on yield and bunch characters of Grand Nain banana

Treatments (Dates of planting)	**Bunch weight (kg plant $^{-1}$)**	**Yield (t ha^{-1})**	**Number of hands (bunch^{-1})**	**Number of fingers (bunch^{-1})**	**Number of fingers in D-hand**	**Weight of D-hand (kg)**	**Bunch length (cm)**
January (T_1)	19.00	58.63	7.00	104.75	17.50	2.63	62.50
February (T_2)	29.50	91.04	10.5	186.25	26.75	4.00	101.25
March (T_3)	22.50	69.44	9.25	174.00	27.00	3.25	87.50
April (T_4)	22.88	70.59	10.25	161.25	21.50	3.25	90.00
May (T_5)	23.75	73.29	8.75	152.50	17.00	2.51	67.50
June (T_6)	24.88	76.76	11.00	198.75	26.75	3.61	92.50
July (T_7)	28.63	88.34	9.75	163.50	21.75	4.28	97.25
August (T_8)	20.50	63.26	8.25	152.00	17.50	2.65	73.75
September (T_9)	20.00	61.72	9.50	172.25	18.00	2.32	72.50
October (T_{10})	19.50	60.18	10.50	165.50	18.50	2.12	85.50
November (T_{11})	14.75	45.52	8.00	113.50	14.50	1.28	95.00
December (T_{12})	16.00	49.38	8.25	121.75	15.50	1.53	96.25
SEm (±)	1.07	3.301	0.318	4.881	1.645	0.253	4.359
CD (0.05)	3.091	9.538	0.915	14.102	4.751	0.731	12.593

The weight of D-hand was found significantly higher in July (T_7) planted crop (4.28 kg) and was found on par with February (T_2) and June (T_6) planted crops. The length of bunch was the highest in February (T_2) planting (101.25 cm) and was on par with July (T_7), December (T_{12}), November (T_{11}), June (T_6) and April (T_4) plantings. The bunch length was the lowest in January (T_1) planted crop which was on par with May (T_5), September (T_9) and August (T_8) planted crops.

4.2.2.2 Finger Characters

The finger characters at harvest are presented in Table 46.

The finger characters, *viz*., length of D-finger, weight of D-finger and pulp peel ratio were significantly influenced by the treatments while, the girth of D-finger was not influenced by the treatments. The D-finger was the longest in February (T_2) planting (22 cm) and was on par with April (T_4) planting and the shortest in November (T_{11}) planting. The November planted crop was at par with January (T_1), June (T_6), October (T_{10}), May (T_5) and December (T_{12}) planted crops. Similarly the weight of D finger, was found the highest in July (T_7) planting followed by February (T_2) planting and the lowest in November (T_{11}) planting which was on par with December (T_{12}), October (T_{10}), January(T_1) and March (T_3) planting. The pulp: peel ratio was the highest in February (T_2) planted crop (2.80) and was found on par with July (T_7) planted crop. The lowest pulp: peel ratio was in November (T_{11}) planted crop and it was statistically on par with December (T_{12}), October (T_{10}), September (T_9)and May (T_5) planted crops.

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

The data pertaining to the influence of planting season on the bunch weight (kg plant^{-1}) and yield (t ha^{-1}) are presented in Table 45.

Planting dates affected the bunch weight and bunch weight was the highest in February (T_2) planting (29.5 kg plant^{-1}) which was on par with July (T_7) planting and was significantly superior to all other planting dates. The bunch weight of June (T_6), May (T_5), April (T_4) and March (T_3) planted crops

Table 46. Effect of planting dates on finger characters of Grand Nain banana

Treatments (Dates of planting)	Length of D-finger (cm)	Girth of D-finger (cm)	D-finger weight (g)	Pulp to peel ratio	Shelf life (days)
January (T_1)	16.50	11.00	130.25	2.35	9.50
February (T_2)	22.00	12.38	165.00	2.80	11.00
March (T_3)	19.75	12.00	130.38	2.21	9.75
April (T_4)	21.75	12.13	147.63	2.45	9.50
May (T_5)	16.95	12.00	150.00	1.95	10.75
June (T_6)	16.63	12.00	134.93	2.21	9.50
July (T_7)	19.80	12.38	183.75	2.69	11.75
August (T_8)	17.50	12.31	138.00	2.01	9.25
September (T_9)	19.63	12.44	144.75	1.90	9.00
October (T_{10})	16.80	11.50	117.00	1.88	9.25
November (T_{11})	15.75	11.00	115.50	1.82	9.50
December (T_{12})	17.20	11.95	116.75	1.85	10.00
SEm (±)	0.550	0.353	5.549	0.084	0.338
CD (0.05)	1.589	NS	16.032	0.243	0.976

were statistically on par and the lowest in November (T_{11}) planted crop (14.75 kg) which was found to be on a par with December (T_{12}) planted crop.

The highest yield was recorded in February (T_2) planted crop (91.04 t ha^{-1}) which was at par with July (T_7) planted crop. These two planting dates were followed by June planted crop (T_6) which was statistically on par with May (T_5), April (T_4), and March (T_3) planted crops. The lowest yield (45.52 t ha^{-1}) was recorded in November (T_{11}) planted crop which was on par with December (T_{12}) planted crop. The yield range varied from 45.52 t ha^{-1} to 91.04 t ha^{-1} due to different planting dates.

4.2.2.4 Quality Parameters

The quality parameters at harvest are presented in Table 47.

The fruit quality parameters like total sugar, reducing sugar, titrable acidity and sugar acid ratio were influenced by the planting dates, while TSS, ascorbic acid and non reducing sugar were not influenced by the planting dates. The TSS content was the highest in February (T_2) planting, and the lowest in December (T_{12}) planting. The titrable acidity was the lowest in August (T_8) planted crop (0.26 %) which was on par with February (T_2), September (T_9), October (T_{10}) and July (T_7) planted crops and the highest in November (T_{11}) planted crop which was on par with December (T_{12}), April (T_4), June (T_6) and January (T_1) planted crops. The total sugar was the highest in February (T_2) planted crop which was on par with July (T_7) and June (T_6) planted crops. The February (T_2) planted crop recorded the highest reducing sugar content which was at par with June (T_6), July (T_7) and March (T_3) planted crops. The total sugar content was the lowest in November (T_{11}) planted crop which was statistically on par with December (T_{12}), August (T_8), October (T_{10}) and September (T_9) planted crops. The December (T_{12}) planted crop recorded the lowest reducing sugar which was on par with November (T_{11}), September (T_9), August (T_8), April (T_4), October (T_{10}) and January (T_1) planted crops. The sugar acid ratio (64.73) was the highest in February (T_2) planted crop which was on par with July (T_7) planted crop and the

Table 47. Effect of planting dates on quality parameters of Grand Nain banana

Treatments (Dates of planting)	TSS (%)	Titrable acidity (%)	Total sugar (%)	Reducing sugars (%)	Non reducing sugars (%)	Sugar acid ratio	Ascorbic acid (mg 100 g^{-1})
January (T_1)	20.75	0.33	14.50	9.77	4.73	44.75	14.54
February (T_2)	24.50	0.27	17.10	11.49	5.62	64.73	14.82
March (T_3)	23.50	0.31	14.87	10.17	4.71	48.49	15.04
April (T_4)	22.00	0.34	15.23	9.62	5.61	45.34	15.21
May (T_5)	23.75	0.31	15.46	9.94	5.52	49.47	14.75
June (T_6)	23.00	0.33	15.93	10.68	5.25	49.11	14.95
July (T_7)	21.75	0.30	16.28	10.57	5.71	55.00	14.86
August (T_8)	22.25	0.26	13.55	9.31	4.24	52.50	15.97
September (T_9)	22.00	0.27	13.62	8.71	4.91	51.09	13.63
October (T_{10})	21.25	0.28	13.55	9.68	3.87	48.85	15.50
November (T_{11})	21.00	0.37	12.82	8.63	4.19	33.30	14.13
December (T_{12})	20.50	0.35	13.48	8.60	4.87	38.37	14.30
SEm (±)	1.034	0.017	0.510	0.463	0.660	3.477	0.715
CD (0.05)	NS	0.048	1.474	1.339	NS	10.045	NS

NS- not significant

lowest sugar acid ratio was in November (T_{11}) and December (T_{12}) planted crops and were statistically inferior to all other treatments. The non reducing sugar was the highest in February (T_2) planted crop and it was statistically insignificant. The ascorbic acid content was not influenced by the planting dates.

4.2.3 Effect of Phenology on the Onset of Different Phenophases (Days)

The onset of different phenophases is significantly influenced by the planting dates and is presented in Table 48.

The shooting was earlier in February (T_2) planting (203.25 days) which was on par with March (T_3) and April (T_4) plantings and late in December (T_{12}) planting and was found on par with November (T_{11}) and January (T_1) planting. Similarly from shooting to harvest (E-H), February (T_2) planting took the shortest time period and was significantly superior to all other dates of planting except April (T_4) and January (T_1) planting. The emergence to harvest (E-H) was the longest in June (T_6) planted crop (100.75 days) which was on par with November (T_{11}), October (T_{10}) and March (T_3) planted crops. The crop duration was the shortest in February (T_2) planted crop (277days) while the crop duration was the longest in November (T_{11}) planted crop (377 days). February (T_2) planting was at par with April (T_4) planting and November (T_{11}) planting was on par with December (T_{12}) and October (T_{10}) planting.

4.2.4 Shelf Life at Ambient Conditions

The data on shelf life of different treatments are presented in Table 46.

The shelf life or the keeping quality of fruits was influenced by the planting season. The shelf life of fruits was the longest in July (T_7) planting (11.75 days) and was statistically on a par with February (T_2) planting. It was followed by May (T_5) and December (T_{12}) planting. All other treatments were on par and inferior to these treatments.

Table 48. Effect of planting dates on the dates of onset of different phenophases of Grand Nain banana

Treatments (Dates of planting)	Duration to shooting (days)	Bunch emergence to harvest duration (days)	Total duration (days)
January (T_1)	274.25	81.25	355.5
February (T_2)	203.25	73.75	277.0
March (T_3)	212.25	93.75	306.0
April (T_4)	219.25	76.75	296.0
May (T_5)	228.75	82.25	311.0
June (T_6)	239.0	100.75	339.75
July (T_7)	232.0	84.25	316.25
August (T_8)	246.25	88.75	335.0
September (T_9)	251.75	83.25	335.0
October (T_{10})	260.50	97.25	357.75
November (T_{11})	281.25	97.75	379.0
December (T_{12})	283.50	82.25	365.75
SEm (±)	6.759	2.700	7.950
CD (0.05)	19.528	7.8	22.967

4.2.5 Agro-meteorological Studies

The data presented in this part are not statistically analysed.

The monthly maximum, minimum and mean values of various meteorological parameters recorded during the growth period of banana under different dates of planting are presented in Appendix I. The following growth parameters were computed in this study.

4.2.5.1 Growing Degree Days (GDD)

The GDD are a simple means of relating plant growth, development and maturity to air temperature. The Growing degree days (GDD)/ heat units required to attain the different phenophases under different dates of planting is presented in Table 49.

The vegetative and reproductive period and total duration of Grand Nain banana under different dates of planting showed vide variation. The GDD/ heat units of vegetative phenophase (from planting to shooting) varied between 2765 ^{o}C d and 3921 ^{o}C d. The GDD or heat units required for vegetative stage was the lowest in February (T_2) planting followed by March (T_3), April (T_4), May (T_5), July (T_7) and June (T_6) planting, while the GDD required was the longest in December (T_{12}) (3921 ^{o}C d) and November (T_{11}) planting (3848 ^{o}C d). The results showed that on an average of 1170 ^{o}C d heat units or degree days above 14 ^{o}C was required for reproductive stage in Grand Nain banana from bunch emergence to harvest stage (range 968-1446) under different planting dates. Here also the GDD/ heat units required was the lowest for bunch maturity in February (T_2) planting (968 ^{o}C d) while it was the highest for June (T_6) planting (1446 ^{o}C d). GDD/ heat unit ranges from 3734 to 5176 ^{o}C d for different planting dates with an average of 4438 degree days from planting to harvest. The total GDD/ heat units required was the lowest in February (T_2) planting and the highest in November (T_{11}) planting.

4.2.5.2 Heliothermal Units (HTU)

The heliothermal unit obtained by multiplying GDD with bright sunshine hours, was computed for Grand Nain banana during the year 2014-2015 and is presented in the Table 49.

The average HTU for Grand Nain banana was 28,724 ^{o}C d h, 10,012 ^{o}C d h and 38,736 ^{o}C d h, respectively during the vegetative, reproductive and whole growth period. The data indicated that the dates of planting from February (T_2) to July (T_7) required less heliothemal units (25,030 to 26,402 ^{o}C d h) while January (T_1), November (T_{11}) and December (T_{12}) planting required more heliothermal units (33,186 to 35,291) in the vegetative phase. The January (T_1) to May (T_5) and December (T_{12}) planting required less than 10,000 ^{o}C d h HTU during the reproductive phase while other dates of planting required more than 10,000 ^{o}C d h heliothermal units. The HTU requirement was the lowest in February (T_2) planting (7625 ^{0}C d h) and the highest in June (T_6) planting (12,796 ^{o}C d h). The February (T_2) planting required the lowest total HTU (32,750 ^{o}C d h) followed by April (T_4) planting (33,436 ^{o}C d h) while November (T_{11}) planting the highest (45,169 ^{o}C d h) followed by December (T_{12}) planting (44,156 ^{o}C d h).

4.2.5.3 Photothermal Units (PTU)

The photothermal unit was worked out by multiplying the GDD with maximum possible sunshine hours and is presented in Table 49.

The results showed that planting dates play a major role in the accumulation of PTU from planting to harvest stage of crop. The average accumulated PTU were 39,628 ^{o}C d h and 14,045 ^{o}C d h, respectively during the vegetative and reproductive phases of the crop. The PTU requirement was the lowest in February (T_2) planting, both in vegetative (34,296 ^{o}C d h) and reproductive (11,244 ^{o}C d h) phases. The PTU required by the December (T_{12}) planted crop was the highest during vegetative

Table 49. Effect of planting dates on crop weather parameters of Grand Nain banana

Treatments (Dates of planting)		**Accumulated GDD (^{0}C d)**			**Accumulated HTU (^{o}C d h)**			**Accumulated PTU (^{o}C d h)**			**HUE (g m^{-2} ^{o}C^{-1}d^{-1})**
		Vegetative phase	**Reproductive phase**	**Total crop period**	**Vegetative phase**	**Reproductive phase**	**Total crop period**	**Vegetative phase**	**Reproductive phase**	**Total crop period**	**At harvest**
January	(T_1)	3692.5	1008.3	4700.8	33185.60	8160.60	41346.20	45275.0	11664.2	56939.1	0.40
February	(T_2)	2765.4	968.4	3733.8	25125.64	7624.93	32750.57	34296.0	11244.3	45540.3	0.73
March	(T_3)	2875.2	1169.6	4044.8	25424.51	9598.59	35023.10	35566.8	13701.3	49268.1	0.48
April	(T_4)	2918.1	971.1	3889.2	25030.70	8406.13	33436.83	35783.2	11268.7	47051.9	0.51
May	(T_5)	2994.2	1081.0	4075.2	25607.55	9969.87	35577.42	36214.1	12806.9	49021.0	0.50
June	(T_6)	3071.4	1446.4	4517.8	26401.57	12796.39	39197.96	36690.0	17751.3	54441.3	0.45
July	(T_7)	2984.1	1222.6	4206.7	25646.38	10691.09	36337.47	35381.1	14978.3	50359.4	0.51
August	(T_8)	3245.3	1252.4	4497.7	28226.09	11099.10	39325.19	38480.3	15822.1	54302.4	0.44
September	(T_9)	3377.3	1149.2	4526.5	29145.76	10668.91	39814.67	40340.0	14436.5	54776.5	0.42
October	(T_{10})	3534.9	1329.5	4864.4	31016.37	11686.08	42702.45	42663.7	16248.0	58911.7	0.39
November	(T_{11})	3848.4	1327.4	5175.8	34586.46	10582.50	45168.96	46885.6	15833.8	62719.4	0.35
December	(T_{12})	3921.2	1099.8	5021	35291.05	8865.43	44156.48	47961.3	12786.9	60748.2	0.35

GDD-Growing degree days
HTU- Heliothermal units
PTU- Photothermal units
HUE- Heat use efficiency

phase (47,961 ^{o}C d h), while June (T_6) planted crop required the highest PTU during the reproductive phase (17,751 ^{o}C d h). Like GDD and HTU the total PTU requirement was also the lowest in February (T_2) planting (45,540 ^{o}C d h) and the highest in November (T_{11}) planting.

4.2.5.3 Heat Use Efficiency (HUE)

The heat use efficiency (g m^{-2} $^{o}C^{-1}$ d^{-1}) at harvest as influenced by dates of planting is presented in Table 49. Heat use efficiency was calculated as growing degree days required to produce the dry matter per unit area.

The heat use efficiency was the highest (0.73 g m^{-2} $^{o}C^{-1}$ d^{-1}) in February (T_2) planting and the lowest (0.35 g m^{-2} $^{o}C^{-1}$ d^{-1}) in November (T_{11}) and December (T_{12}) plantings. The average heat use efficiency recorded in different dates of planting was 0.45 g m^{-2} $^{o}C^{-1}$ d^{-1}.

4.2.6 Correlation Analysis

The mean values of correlation coefficient in phenological studies of Grand Nain banana are presented in Table 50.

The pseudostem height at 4 MAP was correlated with the yield. The girth of pseudostem and leaf parameters at 4 MAP was not correlated with the yield. All the growth attributes at 6 MAP and at harvest were positively correlated with the yield except the pseudostem height at harvest. The duration for shooting and total duration was significant and negatively correlated with the yield. Among the growth attributes, the highest correlations were found with leaf emergence rate and number of leaves at harvest. The yield attributes, *viz*., number of hands, total number of fingers, number of fingers in D-hand, weight of D-hand, length, girth and weight of D-finger except bunch length were positively correlated with the yield. The highest correlation of yield was obtained with weight of D-hand.

Correlation of yield with important weather parameter was worked out (Table 51). The results revealed that the phenophases varied with weather parameters. Yield was positively correlated with maximum temperature (T_{max}) during vegetative phenophase and the total crop growth period. At reproductive stage, there was significant negative correlation of yield with T_{max} was obtained. The yield was negatively correlated with minimum temperature (T_{min}) at different phenophases. Yield was positively correlated with minimum relative humidity (RH_{min}) only at shooting stage. Rainy days and total rainfall were found negatively correlated with yield. The highest negative correlation was found between yield and the total number of rainy days during the crop growth period (-0.708). Bright sunshine hours (BSS) during total growth period was positively correlated with yield.

Table 50. Correlation of growth and yield parameters with yield in phenological studies in Grand Nain

Variables correlated	**Correlation coefficient**
Yield vs. Pseudostem height at 4 MAP	0.703**
Yield vs. Pseudostem girth at 4 MAP	0.523
Yield vs. Pseudostem height at 6 MAP	0.611*
Yield vs. Pseudostem girth at 6 MAP	0.765**
Yield vs. Pseudostem height at harvest	0.278
Yield vs. Pseudostem girth at harvest	0.725**
Yield vs. No. of leaves at 4 MAP	0.218
Yield vs. Functional leaf area at 4 MAP	0.544
Yield vs. No. of leaves at 6 MAP	0.693*
Yield vs. Functional leaf area at 6 MAP	0.771**
Yield vs. No. of leaves at harvest	0.848**
Yield vs. Functional leaf area at Harvest	0.801**
Yield vs. LAI at 4 MAP	0.543
Yield vs. LAD at 4 MAP	0.558
Yield vs. LAI at 6 MAP	0.770**
Yield vs. LAD at 6 MAP	0.758**
Yield vs. LAI at harvest	0.799**
Yield vs. LAD at harvest	0.800**
Yield vs. LER	0.841**
Yield vs. Shooting duration	-0.847**
Yield vs. E-H duration	-0.337
Yield vs. Total duration	-0.836**
Yield vs. Number of hands	0.620*
Yield vs. Total number of fingers	0.718**
Yield vs. Number of fingers in D-hand	0.752**
Yield vs. Weight of D-hand	0.944**
Yield vs. Bunch length	0.264
Yield vs. Length of D-finger	0.636*
Yield vs. Girth of D-finger	0.634*
Yield vs. D-finger weight	0.869**

** Significant at 1 % level (0.703)
* Significant at 5 % level (0.576)

Table 51. Correlation of yield with weather parameters during different phenophases

Variables correlated	**Correlation coefficient**
Yield vs. Tmax at shooting	0.455
Yield vs. Tmax EH duration	*-0.644
Yield vs. Tmax total duration	0.234
Yield vs. Tmin shooting	-0.064
Yield vs. Tmin EH	-0.116
Yield vs. Tmin total duration	-0.112
Yield vs. Tmean shooting	0.329
Yield vs. Tmean EH	*-0.681
Yield vs. Tmean total duration	0.178
Yield vs. RHmax shooting	-0.078
Yield vs. RHmax EH	-0.359
Yield vs. RHmax total duration	-0.521
Yield vs. RHmin shooting	0.183
Yield vs. RHmin EH	-0.234
Yield vs. RHmin total duration	-0.140
Yield vs. Total rainfall shooting	-0.055
Yield vs. Total rainfall EH	-0.431
Yield vs. Total rainfall total duration	-0.561
Yield vs. Rainy days shooting	-0.044
Yield vs. Rainy days EH	-0.561
Yield vs. Rainy days total duration	**-0.708
Yield vs. BSS shooting	-0.302
Yield vs. BSS EH	0.141
Yield vs. BSS total duration	0.383

** Significant at 1 % level (0.703)
* Significant at 5 % level (0.576)

5. DISCUSSION

An investigation entitled "Nutrient and moisture optimization in banana (*Musa* AAA. Grand Nain)" was undertaken with the objectives to standardize the nutrient and irrigation schedule of Grand Nain banana, to study its phenology in relation to various agro-meteorological parameters and to work out the economics. The results of the investigation are discussed below.

5.1 EXPERIMENT I. NUTRIENT - MOISTURE INTERACTION STUDY IN BANANA CV. GRAND NAIN

5.1.1 Effect of Irrigation Levels on Growth, Productivity and Quality of Grand Nain Banana

The successful growth and productivity of any crop depends on the amount of water available during its growth period. The amount and distribution of rainfall and the level of irrigation determines the availability of water. In the present study, irrigation level at 1.0 IW/CPE resulted in better growth and yield parameters of Grand Nain banana. The irrigation at 1.0 IW/CPE was on a par with 0.8 IW/CPE and resulted in more pseudostem height and girth during all growth stages and found superior to other two levels of irrigation. Plants with thicker pseudostem had a positive impact on bunch weight. Goenaga and Irizarry (1995) stated that increasing the amount of irrigation resulted in an increased stem diameter in banana. The significant effect of irrigation water depth on height and diameter of the pseudo-stem, number of fruits bunch^{-1} and yield was also reported (Costa *et al*., 2012). Growth attributes in banana responded positively to differential water application was reported by Ali *et al.* (2015).

The role of leaf parameters such as number of leaves, functional leaf area, leaf area index, leaf area duration and phyllochron are crucial in determining the yield potential. In the present study, increased number of leaves at 1.0 IW/CPE might have increased the photosynthetic activity resulting in higher accumulation of carbohydrates. Relatively higher carbohydrates could have promoted the

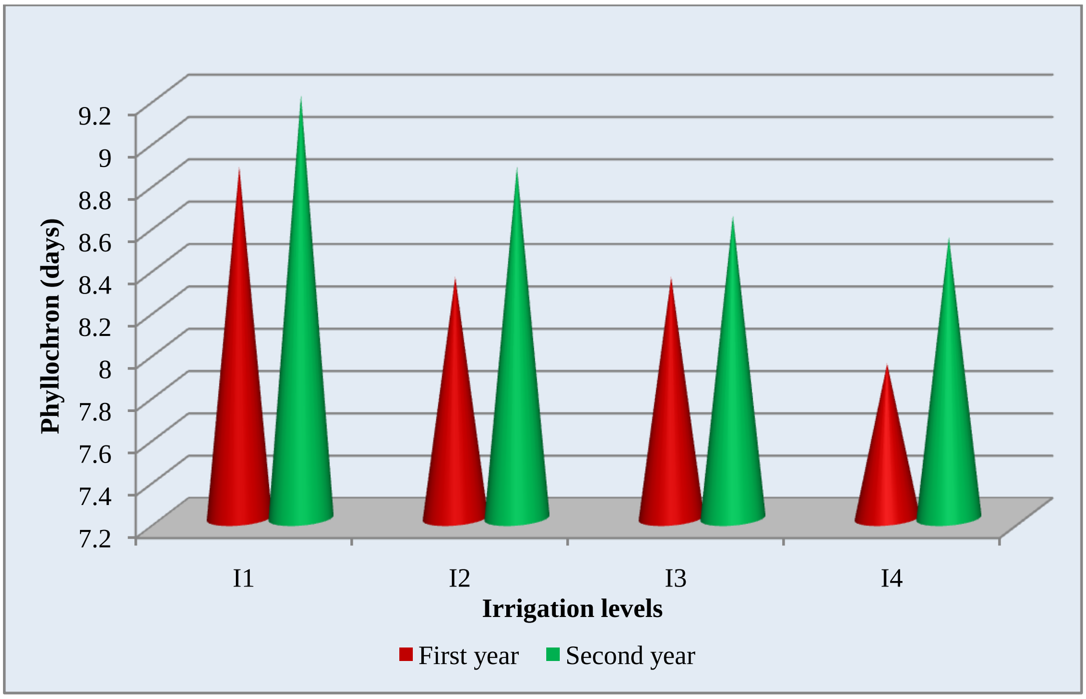

Fig. 4a. Phyllochron as influenced by irrigation levels

growth rate which in turn increased bunch weight. This was in accordance with the results of Turner (1980) and Chezhiyen *et al.* (1999) in banana. The growth and development of the banana bunch relied on the physiological activity of functional leaves that were present from shooting to fruit development (Barrera *et al*., 2009). In this experiment irrigation scheduled at 1.0 IW/CPE recorded more number of functional leaves, functional leaf area, LAI, LAD and less phyllochron at harvest during both the years. Irrigation at 0.4 IW/CPE resulted in the lowest leaf parameters during both the years. Karam *et al.* (2002) reported that water stress caused by the deficit irrigation significantly reduced the rate of cell expansion and a decrease in the number of leaf. Turner *et al.* (2007) reported that the optimum LAI for banana is 2 to 5 and at a LAI of 4.5, about 90 per cent of the ground will be shaded and about 90 per cent of incoming radiation was intercepted by the leaf canopy. The phyllochron was the least at 1.0 IW/CPE due to enhanced soil moisture status and the interval of leaf emergence was the highest at 0.4 IW/CPE (Fig. 4a). Turner *et al.* (2007) reported that soil moisture together with climatic factors, such as temperature, wind and relative humidity are significantly correlated to the expanding tissues such as emerging leaves and rate of leaf production.

In the present study long irrigation interval of 16 days in 0.4 IW/CPE resulted in soil moisture stress during vegetative stage of banana and this prolonged the leaf emergent rate leading to extended crop duration. Wider irrigation intervals at 0.4 IW/CPE registered poor bunch formation as evident from lesser number of fingers and small sized fingers and bunch weight. The moisture stress during vegetative stage caused reduction in number of hands and fingers. Continuous stress at reproductive stage resulted in poor filling of fingers and unmarketable bunches. The results are in agreement with the findings of Goenaga and Irizarry (2000) and Carr (2009).

The effect of irrigation at 1.0 IW/CPE improved growth attributes and had a positive influence on yield attributes also. The number of hands and total fingers bunch^{-1}, number of fingers in D-hand, bunch length, girth, length and weight of

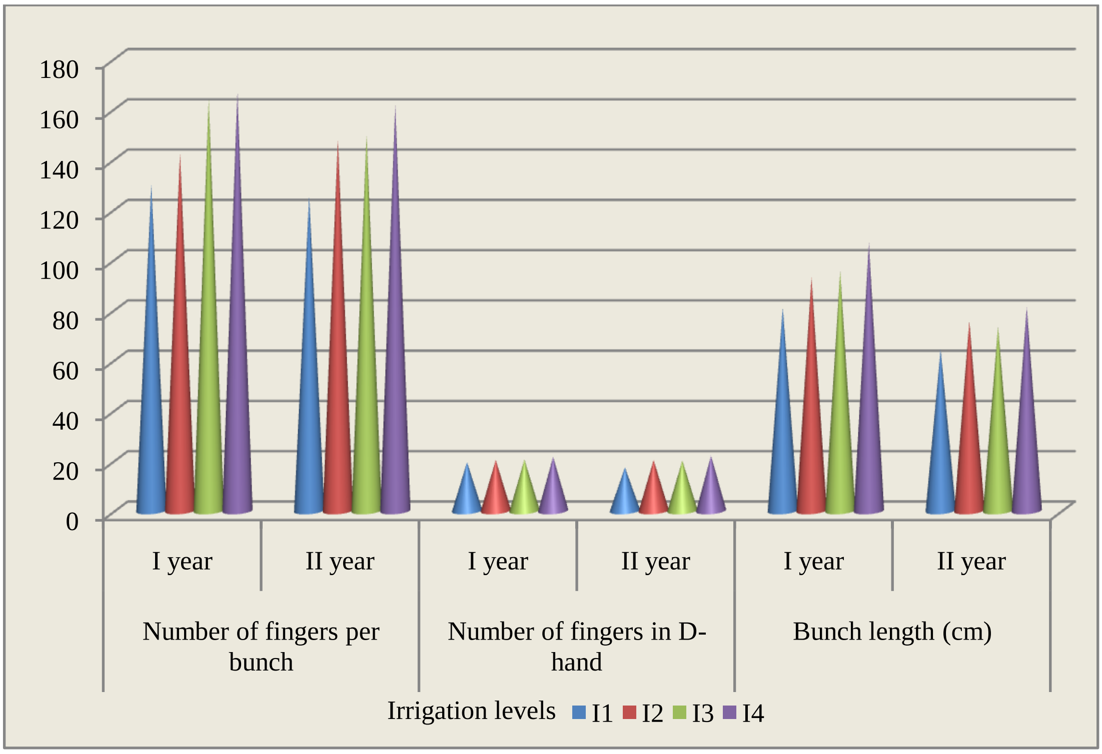

Fig. 5a. Yield attributes as influenced by irrigation levels

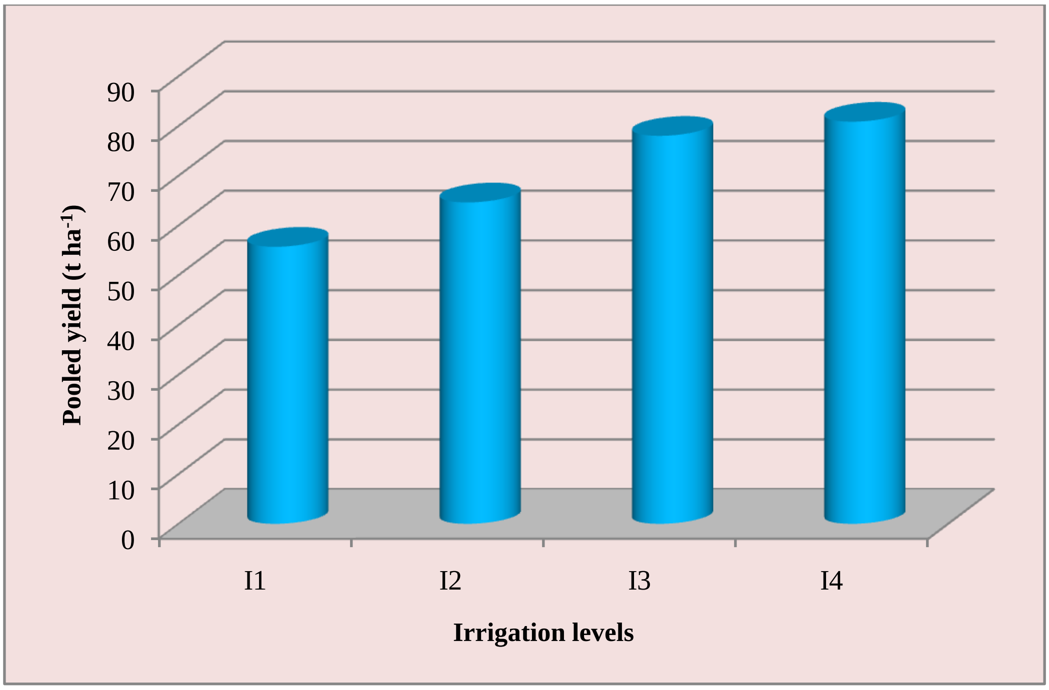

Fig. 5b. Pooled yield as influenced by irrigation levels

D-finger, pulp to peel ratio were found superior at 1.0 IW/CPE (Fig. 5a). Pooled analysis of data also revealed the superiority of irrigation at 1.0 IW/CPE on bunch weight and yield and was on a par with 0.8 IW/CPE (Fig. 5b). The increased fruit yield might be due to the higher soil moisture availability throughout the growth stages because of frequent irrigation leading to better water availability and nutrient uptake compared to irrigation at 0.4 IW/CPE ratio.

Among the quality attributes, TSS was not affected by the irrigation levels. Total sugar, reducing sugar and sugar acid ratio were higher in irrigation at 1.0 IW/CPE ratio. Significant variation in titrable acidity, non reducing sugar and ascorbic acid was observed only in second year. Titrable acidity was less with 1.0 IW/CPE due to increased moisture availability. The ascorbic acid and non reducing sugar were on a par with all irrigation levels except 0.4 IW/CPE. The shelf life was the lowest at 0.4 IW/CPE ratio and was on a par with all other three levels of irrigation and it ranged from 9.00 to 9.69 days.

The irrigation at 0.8 and 1.0 IW/CPE took least days for shooting while 0.4 IW/CPE took longer days for shooting. This early shooting at 0.8 and 1.0 IW/CPE could be attributed to the better source sink relations in these irrigation levels. The E-H duration was the highest at 1.0 IW/CPE. The total duration was influenced in second year only where all irrigation levels were on a par except irrigation at 0.4 IW/CPE. The total duration was more in irrigation at 0.4 IW/CPE due to the moisture stress experienced during the growth period.

5.1.2 Effect of Nutrient Schedule on Growth, Productivity and Quality of Grand Nain Banana

An analysis of the plant growth in quantitative terms is essential to interpret crop yields in banana. In the present study, uptake based application of nutrients @ 160: 40: 640 g N: P_2O_5: K_2O plant^{-1} significantly enhanced the growth parameters at all stages of growth compared to modified POP based application of nutrients @ 212: 50: 332 g N: P_2O_5: K_2O plant^{-1}. The increase in the height and girth of pseudostem with increase in dose of potassium was also reported by

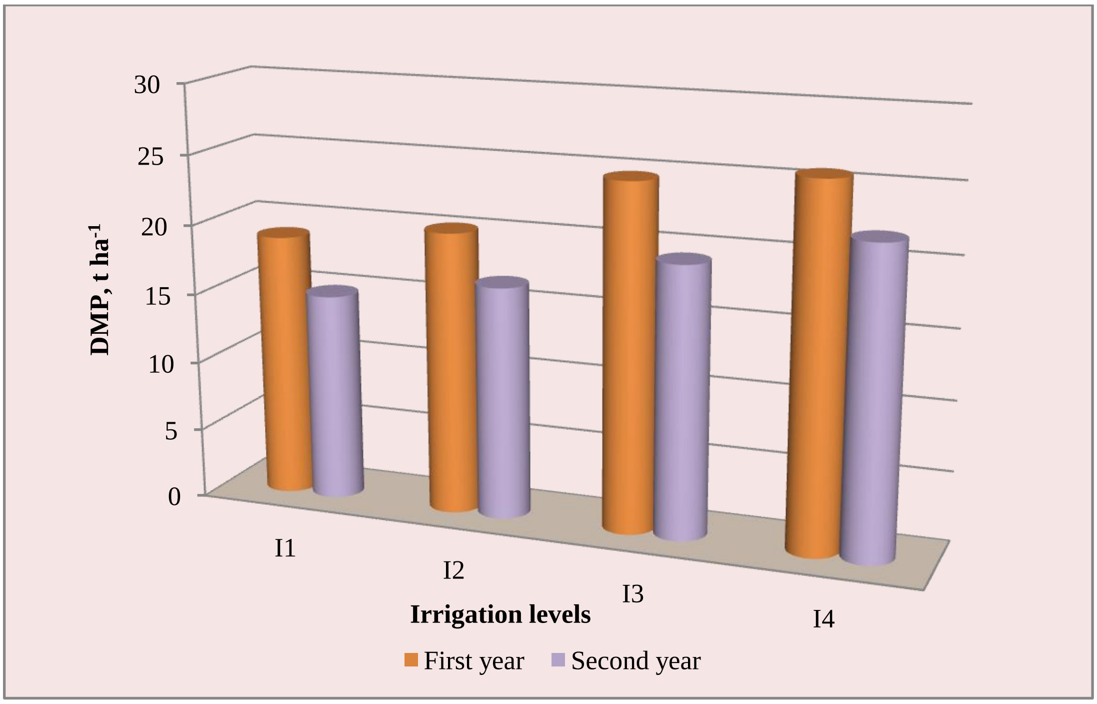

Fig. 6a. Dry matter production (DMP) as influenced by the irrigation levels

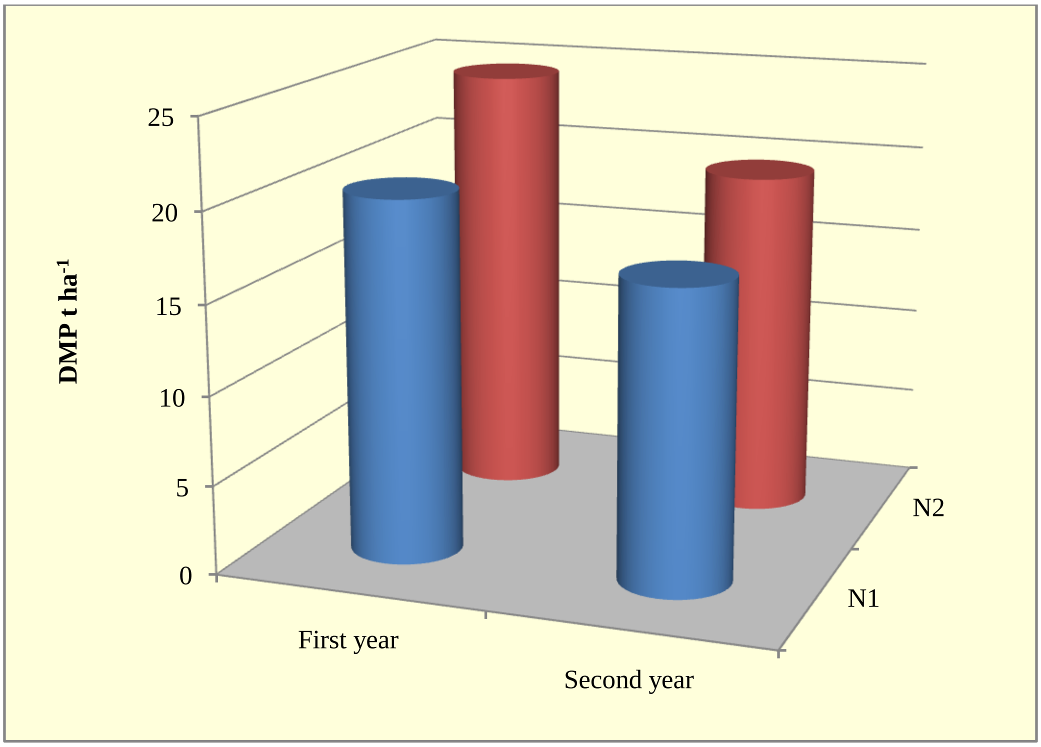

Fig. 6b. Dry matter production (DMP) as influenced by the nutrient levels

Sheela (1995) and Sindhu (1997). The role of leaf parameters such as number of leaves produced and number of functional leaves retained at shooting is crucial in determining the yield potential in banana. The functional leaf area is very critical in banana as it has strong relation with photosynthetic efficiency reflecting on biomass production. Leaf area index (LAI) is an important source of photoassimilates for determining dry matter accumulation and crop yield. An increase in LAI results in better utilization of solar energy leading to higher dry matter accumulation (Fig. 6a and 6b). Insufficient potassium supply reduces the total dry matter production of banana plants and the distribution of dry matter within the plant especially bunch dry matter production. This shows the importance of potassium for banana crop. Turner and Barkus (1980) found that while low potassium supply halved the total dry matter produced, the bunch dry matter was reduced by 80 per cent and the roots were unaffected.

The critical LAI necessary for maximum utilization of photosynthetically active radiation in banana ranges from 4 to 4.5. It is evident from the present study that the leaf area, LAI and LAD were higher when plants were supplied with nutrients @ 160: 40: 640 g N: P_2O_5: K_2O plant^{-1} depicting better utilization of land area and solar energy. More than the number of leaves, the rate of its production (phyllochron) is an important factor in banana and it should be at closer interval so that vegetative crop cycle is not extended unduly. In the present study, phyllochron at closer interval was observed in uptake based application of nutrients (160: 40: 640 g N: P_2O_5: K_2O plant^{-1}) indicating that the application of NPK was at optimum level promoting faster rate of leaf production (Fig. 4b).

Baruah and Mohan (1991) indicated that reduced longevity of banana leaves could be due to high mobility of K from older leaves to other plant parts, and as a result, leaf duration can be severely hampered by low K content. Thus, an overall assessment of fertilizer treatments on vegetative characters brought to lime light that application of 160: 40: 640 g N: P_2O_5: K_2O plant^{-1} favoured all the morphological characters. A plausible reason is that timely application of

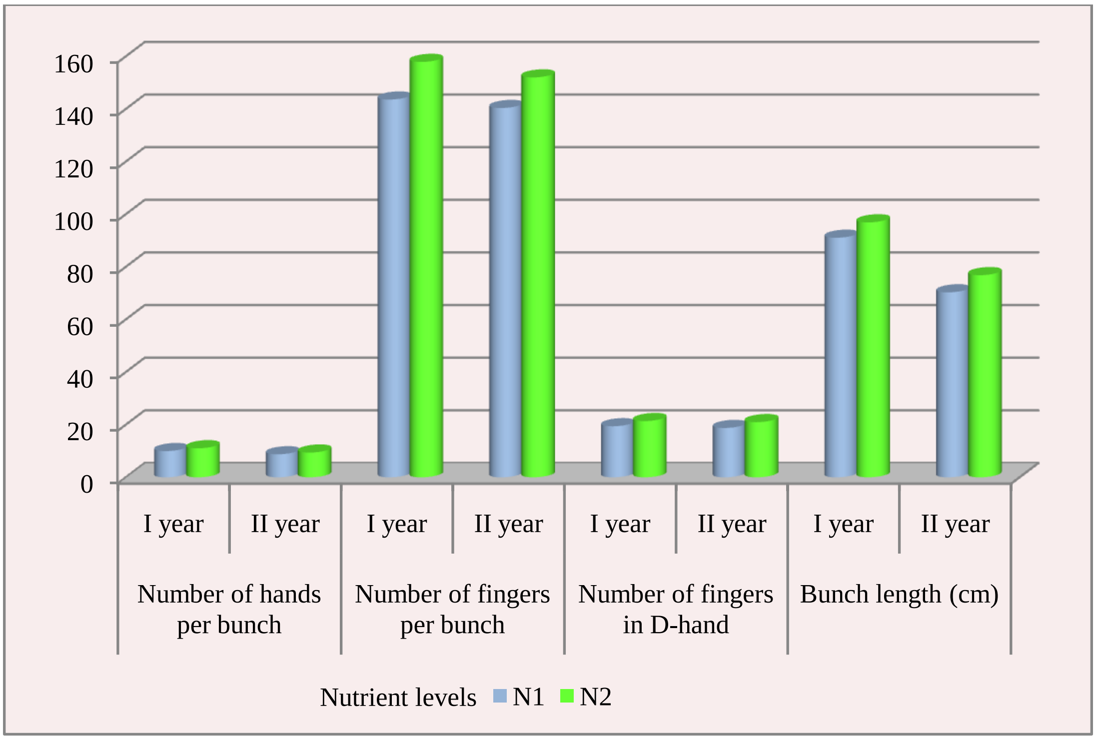

Fig. 7a. Yield attributes as influenced by nutrient levels

optimum dose of nutrients would have resulted in greater nutrients use efficiency. The total dry matter production and partitioning to different plant parts was also influenced by K status.

The application of nutrients @ 212:50:332 g N: P_2O_5: K_2O plant^{-1} reduced crop duration due to higher N application when compared to nutrient application based on uptake of nutrients. Praburam and Sathiyamoorthy (1993) also found that application of 200 g nitrogen plant^{-1} recorded the earliest flowering and the shortest total crop duration in cv. Rasthali. Similar observation on delay in shooting due to reduction in supply of inorganic N in cv. Nendran was also reported by Soorianathasundaram *et al.* (2000). The required net assimilation was presumably reached early in the plants receiving higher dose of nitrogen, thus hastening the process of initiation and emergence of inflorescence (Hasan *et al.,* 2001) resulting in shorter duration of crop.

Yield and yield components were the most important economic traits, highly influenced by the nutrient levels. The number of hands and fingers bunch^{-1}, number of fingers in D-hand and bunch length were more in uptake based nutrient application (Fig. 7a). The finger characters *viz*., length and girth of D-finger and finger weight were the highest with the application of nutrients @160: 40: 640 g N: P_2O_5: K_2O plant^{-1}. Any factor that stimulates higher finger production and favours better finger development leads to better bunch weight. The increase in finger weight might be due to the increase in production of growth promoting endogenous substances and enhancement of nutrient uptake by banana plants (Nijjar, 1985). In the present study, all yield attributes were significantly correlated with yield except the girth of D-finger. The pooled yield was also the highest with the uptake based nutrient application. Pooled analysis revealed that nutrient and year (N x Y) and time of application and year (S x Y) interactions were significant and the combination n_2y_1 recorded the highest yield in first year. The increase was 27 per cent over n_1y_2, treatment which gave the lowest yield. The $s_1y_1$and s_2y_1 were on a par in first year whereas s_2y_2 was superior during second year. The superiority of four split application (S_2) might be due to higher

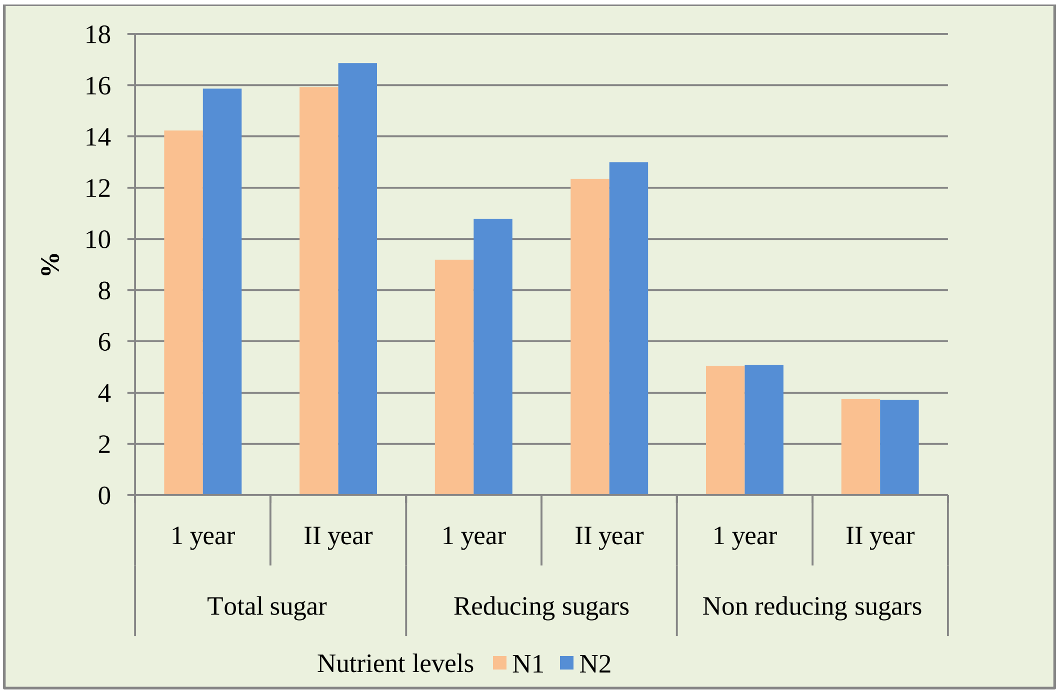

Fig. 7b. Quality attributes as influenced by nutrient levels

nutrient use efficiency as a result of reduced loss of nutrients during second year characterized by heavy rainfall compared to first year. According to Prameela (2010), early vegetative stage and bunch development stage were the critical stages of banana at which yield was affected. The growth and yield parameters were the highest during first year which resulted in the better yield.

A marked effect on fruit quality was observed with the application of 160: 40: 640 g N: P_2O_5: K_2O plant^{-1}. Higher levels of TSS, ascorbic acid, reducing and total sugars, high sugar acid ratio, pulp to peel ratio and lower acidity were recorded in N_2, uptake based application of nutrients @160: 40: 640 g N : P_2O_5: K_2O plant^{-1} (Fig. 7b). Higher fruit quality at N_2 is due to the better availability of potassium which is involved in carbohydrate synthesis, breakdown and translocation of starch, synthesis of protein and neutralization of physiologically important organic acids. The fruit quality parameters were not influenced by the time of application of fertilizers. The shelf life in the same treatment was also high which revealed the role of higher level of K in extending shelf life. This was confirmed by the reports of Ganeshamurthy *et al*. (2011).

5.1.3 Nutrient - Moisture Interaction on Growth, Productivity and Quality of Grand Nain Banana

Irrigation and nutrition are interrelated growth factors and hence the research on relation between them is essential for enhancing the productivity. Soil moisture plays a significant role in the behaviour of nutrients in the soil. Irrigation water in general functions as a carrier of nutrients. Moreover, irrigation was provided by drip irrigation which might have optimized soil water for better nutrient uptake. Timing and amount of rainfall after the fertilizer application are crucial in determining the availability and losses of nutrients. Irrigation in non rainy period thus has a very important role in nutrient uptake and crop yield. In this investigation, in the second year heavy rainfall was received during the active growth stages resulting in heavy leaching losses and lower uptake of nutrients leading to reduction in growth and yield. During second year, application of N

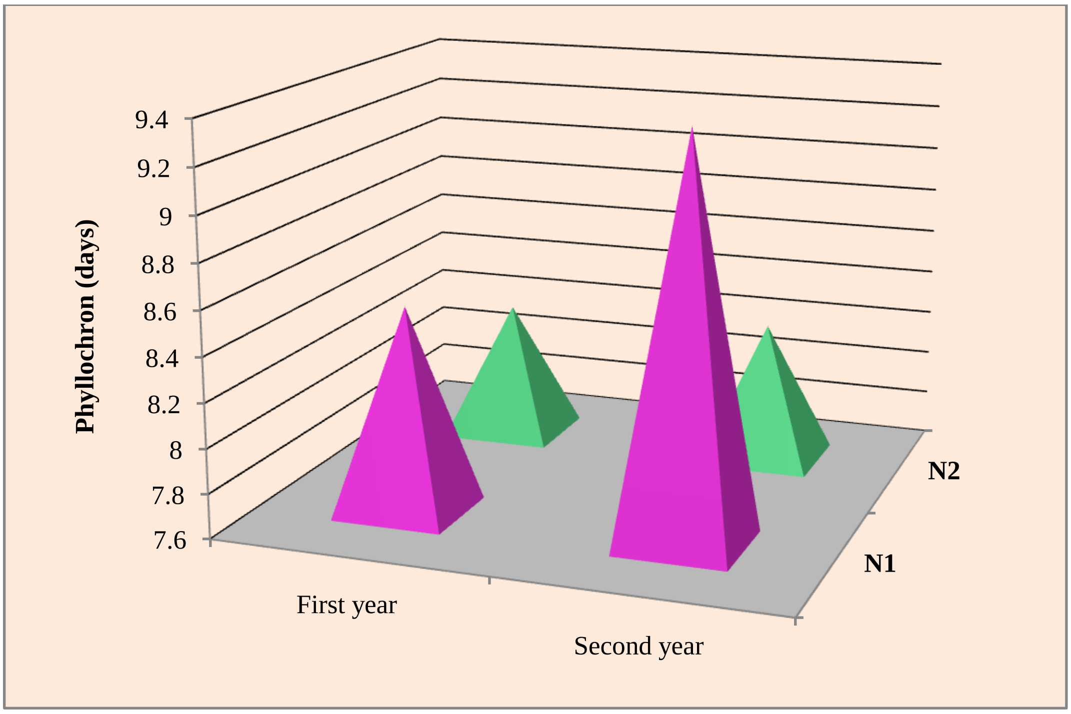

Fig. 4b. Phyllochron as influenced by nutrient levels

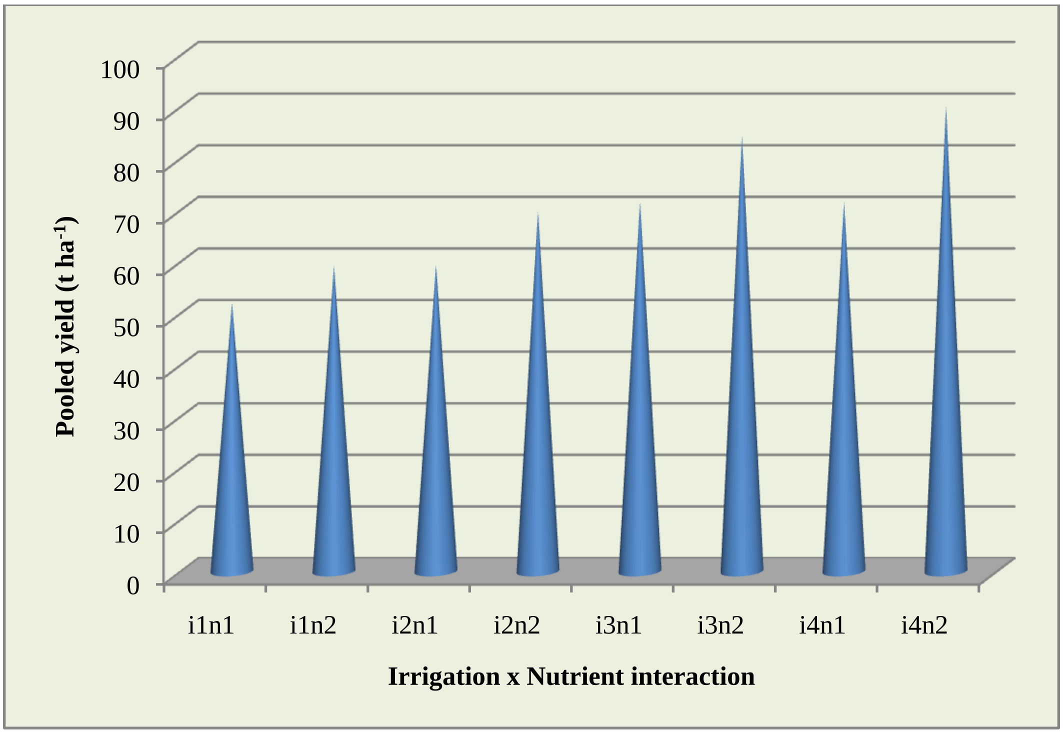

Fig. 8. Pooled yield (t ha^{-1}) as influenced by nutrient - moisture interaction

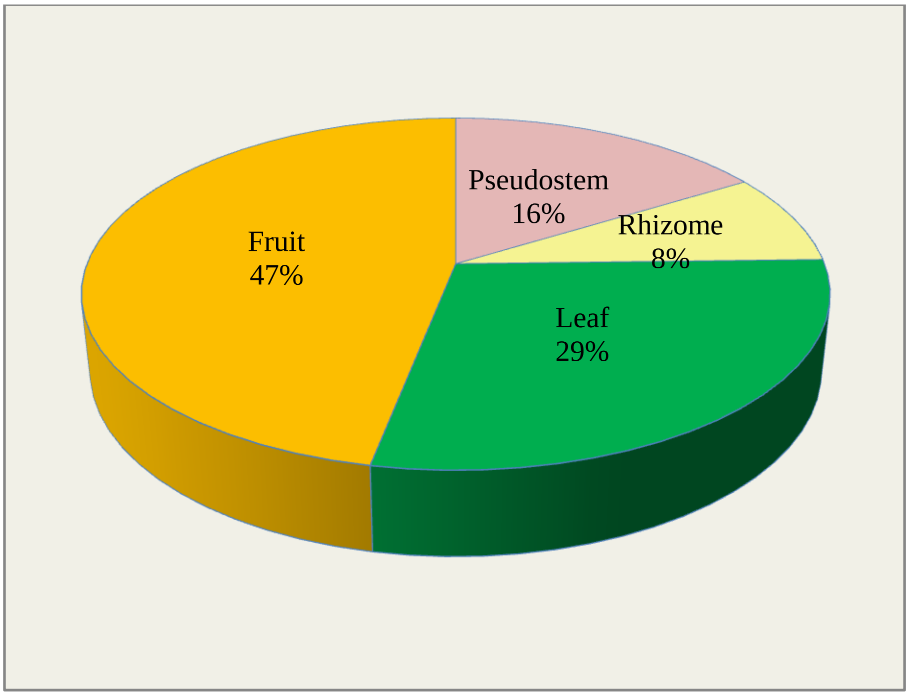

Fig. 9a. Dry matter partitioning as influenced by the uptake based nutrient levels during first year

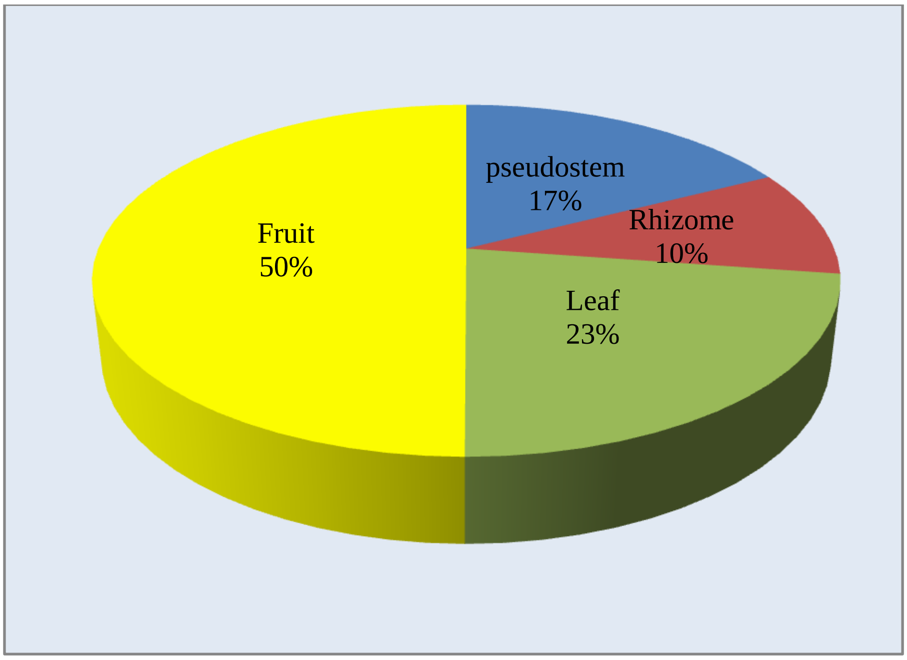

Fig. 9b. Dry matter partitioning as influenced by the uptake based nutrient levels during second year

Plate 8. Experiment – I: The best treatment ($i_4n_2s_1$)

and K in four splits (S_2) resulted in higher yield due to increased availability of nutrients than two splits (S_1) application. Between the years, performance was the best in first year compared to second year (13 per cent increase over second year) due to the favourable climatic conditions. If high rainfall coincides with a period of rapid plant growth, nutrient concentrations may be reduced in such a way to restrict growth, even in the standard plants and allowing for buffering of previously absorbed nutrients (Turner and Barkus, 1980). In the present study also, the nutrient concentration in the index leaf was less when compared to first year due to more rainfall in the second year.

The pooled analysis revealed that the nutrient moisture (I x N) interaction was significant on the productivity of Grand Nain (Fig. 8). Among the interaction, irrigation at 1.0 IW/CPE and application of nutrients @ 160: 40: 640 g N: P_2O_5: K_2O plant^{-1} (i_4n_2) recorded the highest yield due to better growth and yield attributes in this combination. The pooled yield was 42 per cent more in i_4n_2 over i_1n_1 due to enhanced growth and yield attributes. The moisture stress due to the longest irrigation interval at 0.4 IW/CPE resulted in lesser uptake values leading to the lowest yield in i_1n_1. Nutrient movement might be seriously limited in soils with a low moisture content due to reduced hydraulic conductivity and thereby mass flow and also the path ways for nutrient diffusion (Ballard and Cole, 1974).

5.1.4 Effect of Irrigation Levels and Nutrient Schedule on Index Leaf Nutrient Concentration and Nutrient Uptake of Grand Nain Banana

According to Lahav (1995) banana removes more K than any other nutrients from the soil and this amount is nearly thrice of nitrogen. Different workers have proposed different critical levels of nutrients in third leaf of banana which range from 1.80 to 4.0 per cent for N, 0.17 to 0.29 per cent for P (Angeles, *et al*., 1993) and 1.66 to 5.40 per cent for K (Memon *et al*., 2010). Index leaf analysis at 4 MAP showed that the NPK ratio was found optimum with uptake based nutrient application during both the years. During first year NPK ratio was the highest (3.73: 0.17: 5.23) when compared to second year (2.81: 0.21: 3.56) which resulted in enhanced growth and yield attributes in first year. The four split application resulted in more leaf K content in first year mainly due to reduction in leaching loss of K. Earlier reports on split application of nutrients in increasing the leaf nutrient status, uptake and distribution of nutrients ultimately resulting in better growth and yield were made by Thangaselvabai *et al*. (2007). The NPK content of the leaf were the highest in all the treatments at 4 MAP and thereafter the values declined at harvest. This might be due to the heavy loading of NPK in leaves during vegetative and shooting stage followed by a decrease in the concentration due to rapid increase in dry matter caused by faster growth of banana crop (Mahendran *et al*., 2013).

In the pure *acuminata* triploid Grand Nain, fruits had the largest contribution to dry matter accumulation. Out of the total dry matter, 47 and 50 per cent were partitioned to fruit during first and second year, respectively which ultimately reflected in higher fruit yield of the crop under uptake based nutrient application (Fig. 9a and 9b). The total dry matter is the balance between gross photosynthesis and respiration. Respiration was lower in potassium deficient plants (nutrient level of 212: 50: 332) and therefore the main effect of low potassium supply on dry matter production would be through reduction of photosynthesis. Naturally, the reduced photosynthesis was much aggravated by the reduced total leaf area of the plant as evident from Table 7a. This is proved to have a direct impact on bunch weight. Uptake of macronutrients at harvest was in the order of K > N > P. In banana, regardless of the cultivars, soil or climate, amount of total nitrogen uptake by the plant is closely related to total dry matter production (Lahav, 1995). In the present study, among N, P and K uptake by plant parts at harvest, N uptake was the highest in leaf while P and K uptake were the highest in fruit. The differential irrigation had a significant influence on nutrient uptake. Irrigation at 0.4 IW/CPE recorded the lowest uptake of nutrients. Banana has low potentiality for uptake of nutrients and water from deep soil layers due to shallow root system particularly, when there is water stress and

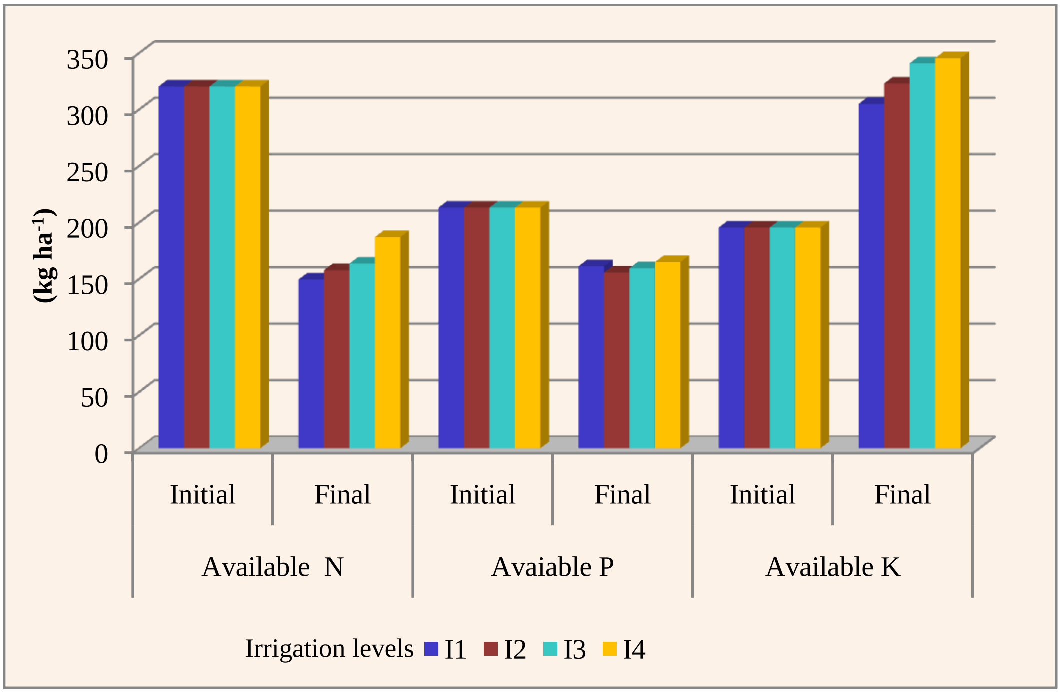

Fig. 10a. Soil nutrient status as influenced by irrigation levels

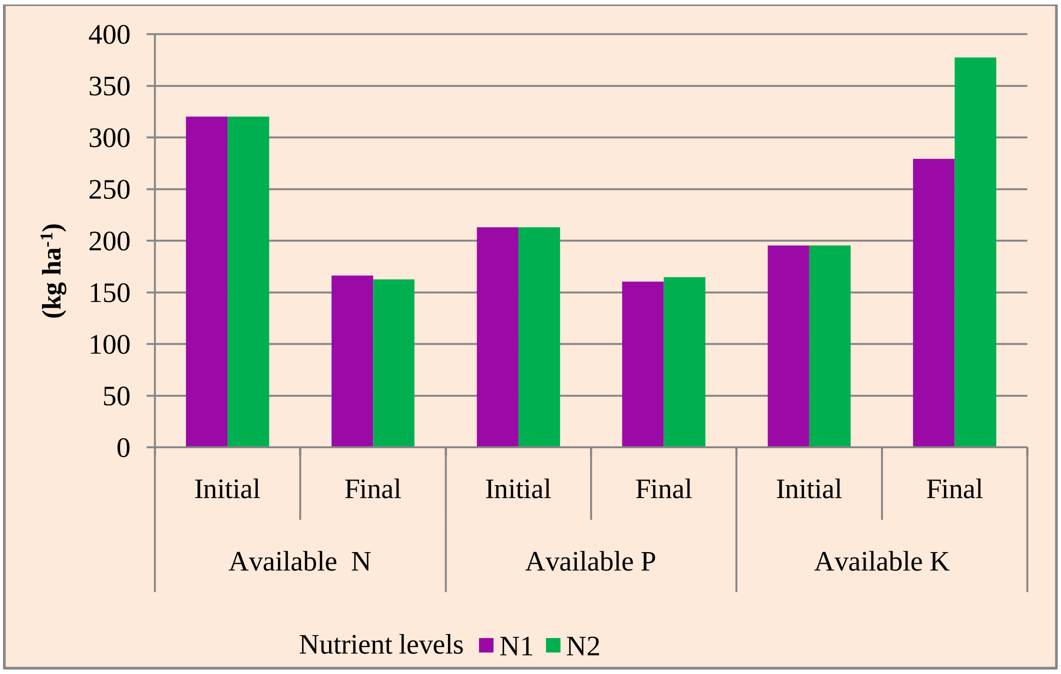

Fig. 10b. Soil nutrient status as influenced by nutrient levels

conditions of high evaporation (Robinson and Villiers, 2007). This might be the reason for the low uptake at 0.4 IW/CPE. Irrigation at 1.0 IW/CPE recorded the highest uptake of nutrients due to favourable soil moisture regime. The uptake based recommendation (160: 40: 640 g N: P_2O_5: K_2O plant^{-1}) recorded the highest NPK uptake at harvest resulting in high bunch weight.

5.1.5 Effect of Irrigation and Nutrient Schedule on Soil Nutrient Status

In general, it is observed that banana requires moderate quantity of nitrogen, relatively lower dose of phosphorus and larger quantity of potassium for growth and yield. Follett (2001) indicated that excess nitrogen application increased nutrient loss through leaching, denitrification and volatilization and these losses have a potential to pollute the environment. The availability of nutrients in the soil depends on several factors, *viz.,* climate, soil and plant. Soil available nitrogen, phosphorous and potassium contents at harvest were significantly influenced by levels of irrigation and nutrient schedule.

Daniells and Armour (2010) observed that banana utilized about 50 per cent of the applied nutrients, while the remaining nutrients were held in the soil. The nutrient use efficiency of N ranged from 20 to 40, P from 5 to 20 and K from 50 to 100 per cent, depending on the variety, growth rate and production potential in fruit crops (Ganeshamurthy, *et al.*, 2011). In general, a large quantity of nutrients applied to soil is lost through run-off, leaching and fixation in the soil. Nutrients were available to the plants from three sources *viz.*, inorganic sources (treatment application), organic sources and from amounts initially present in the soil. The nutrient status is illustrated graphically in Fig. 10. The inorganic sources were the main source of NPK. In the present study, organic carbon status showed a positive build up in all treatments. This might be due to the mineralization of FYM and decomposition of plant residues. Soil N status changed from medium to low while the status of P remained unchanged. The low N status was mainly due to leaching loss of N due to heavy rainfall. The K status changed from medium to high after the experiment. This may due to the major role of exchangeable K

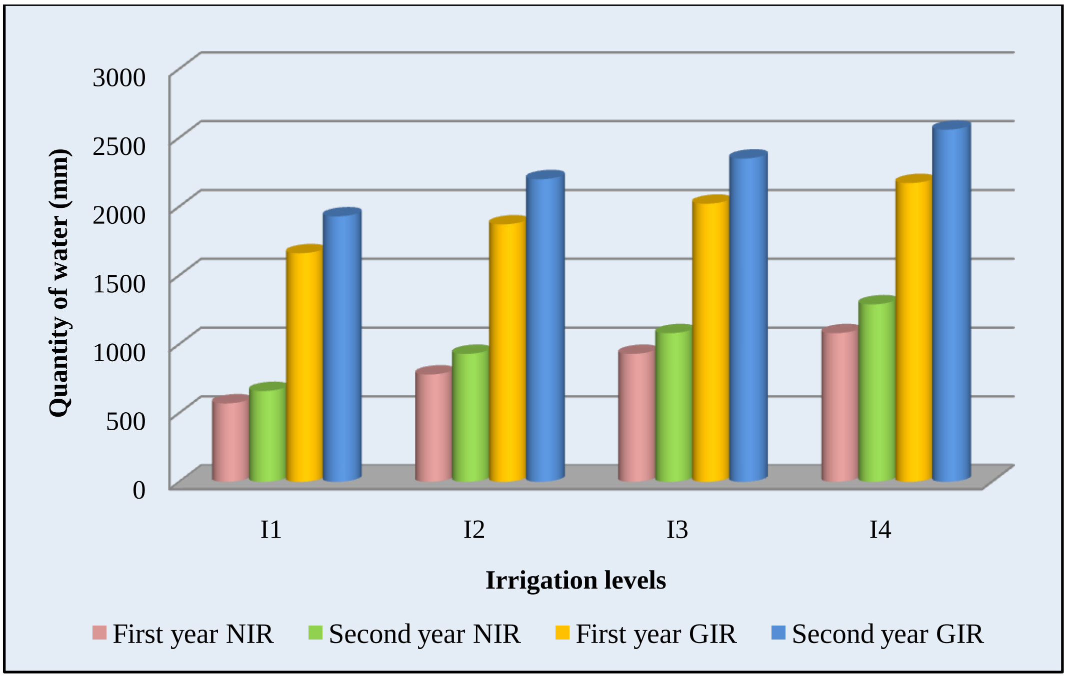

Fig. 11a. Net irrigation requirement (NIR) and gross irrigation requirement (GIR) as influenced by the irrigation levels

in replenishing soil solution K removed by cropping and could be one reason of positive build up of K in the present study. So in the subsequent ratoon, possibility of reducing K could be exploited. The exchangeable and solution K^+ is a good measure of availability of K to banana crop. In general, soil has the ability to maintain the relation between exchangeable and soil solution K^+ against the depletion by plant uptake and leaching by the release of labile K pool. Weerasinghe and Premalal (2002) also reported higher soil potassium pool in soil at the end of the experiment of Embul banana and attributed it to the replenishment of K from the K pool in soil.

5.1.6 Effect of Irrigation and Nutrient Schedule on Water Requirement, Water Use Efficiency and Water Productivity

The details of irrigation during the experimentation are given in Appendix IV and V and illustrated graphically (Fig. 11a). Water requirement of banana was met from effective rainfall and irrigation. The effective rainfall during the study period was 1091mm and 1269 mm, respectively in first and second year, respectively. The number of irrigations given under different irrigation levels ranged from 19 to 36 during first year and 22 to 43 during second year. The irrigation intervals varied with different IW/CPE ratios and the shortest interval of 8 days was with irrigation at 1.0 IW/CPE ratio and the longest (16 days) with 0.4 IW/CPE. The crop duration was extended by more than a month in second year leading to more irrigation and water requirement in second year. Moreover the effective rainfall was also high during second year.

The drip irrigation given for the experiment led to more economic use of water. In banana, drip irrigation has the most significant role for achieving not only higher productivity and water use efficiency, but also to attain sustainability with economic use and productivity (Mustaffa and Kumar, 2012). Banana under drip irrigation performed better in growth, and flowered earlier in comparison to surface irrigation. In the present study irrigation scheduled at 1.0 IW/CPE, with an irrigation interval of 8 days recorded water requirement of 2171 mm and

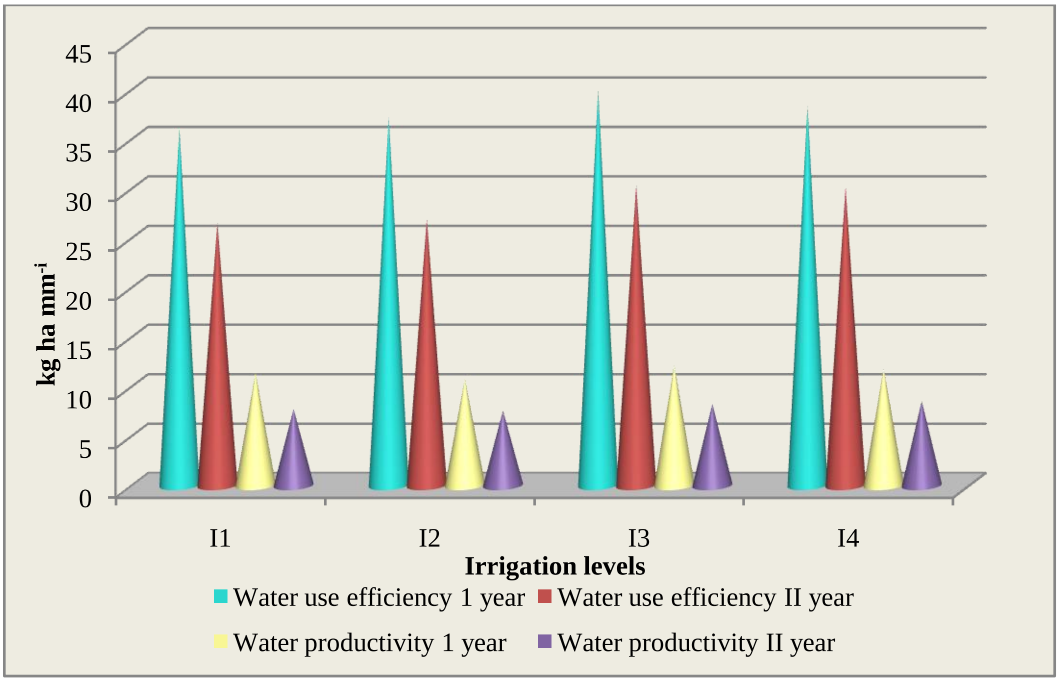

Fig. 11b. Water use efficiency and water productivity as influenced by the irrigation levels

2559 mm, respectively during first and second year. Fathia (1999) opined that the highest growth and yield of banana crop was obtained with water quantity of 2100 mm per season at intervals of 5-7 days.

Water use efficiency is associated with quantity of water applied and crop yield. These different quantities directly affect the WUE through their effect on productivity. High water use efficiency of 40.31 and 30.38 kg ha^{-1} mm^{-1} were recorded by irrigation at 0.8 and 1.0 IW/CPE, respectively during first year while irrigation at 0.4 IW/CPE ranked the last (Fig. 11b). Water use efficiency (WUE) was the highest in irrigation at 0.8 IW/CPE during both the years and was on a par with irrigation at 1.0 IW/CPE. Goenaga and Irizarry (1995) reported that to attain high yields, irrigation must replace the water lost through evapotranspiration, as calculated from pan evaporation measurements. Evapotranspiration rates for banana ranged from 1200 to 2690 mm $year^{-1}$ depending on the climatic conditions and irrigation intervals (Robinson, 1996). Seasonal irrigation with 1200 to 1300 mm of water proved sufficient for maximum productivity in banana (Metochis, 1999). The results illustrated by Katerji and Mastrorilli (2009) also revealed that, water use efficiency of crops is affected greatly by irrigation management. Haijun *et al*. (2015) reported that the banana evapotranspiration rates can range from 1200 to 3000 mm $year^{-1}$.

Water productivity was the highest in irrigation at 0.8 IW/CPE during first year and in irrigation at 1.0 IW/CPE during second year. However, irrigations at 1.0 IW/CPE and 0.8 IW/CPE were on a par during both the years. WUE and water productivity were influenced by the time of application of nutrients in second year. This was due to the higher yield obtained in four split application of nutrients. Water productivity was also influenced by the interactions I x N and N x S. Among the I x N interaction, treatments i_3n_2 and i_4n_2 were significantly superior and were on a par with each other. This is due to the higher yield obtained at I_3, I_4 and N_2 levels. Among the nutrient level higher productivity was recorded at N_2 and this resulted in better WUE at n_2s_1 and n_2s_2.

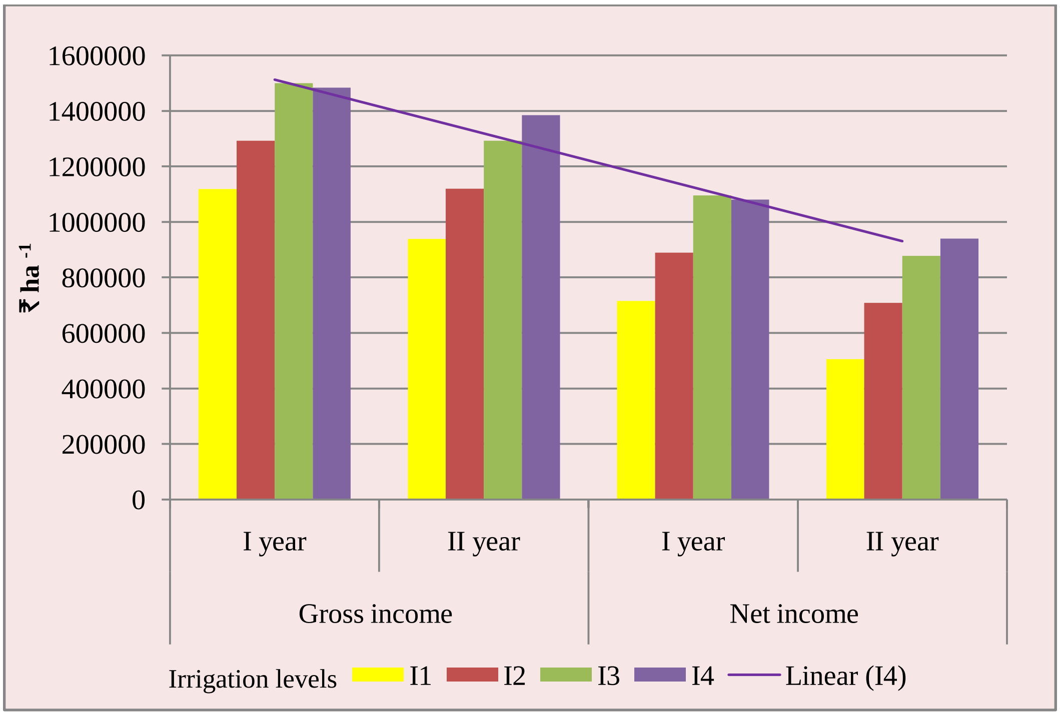

Fig.12a. Economics as influenced by irrigation levels

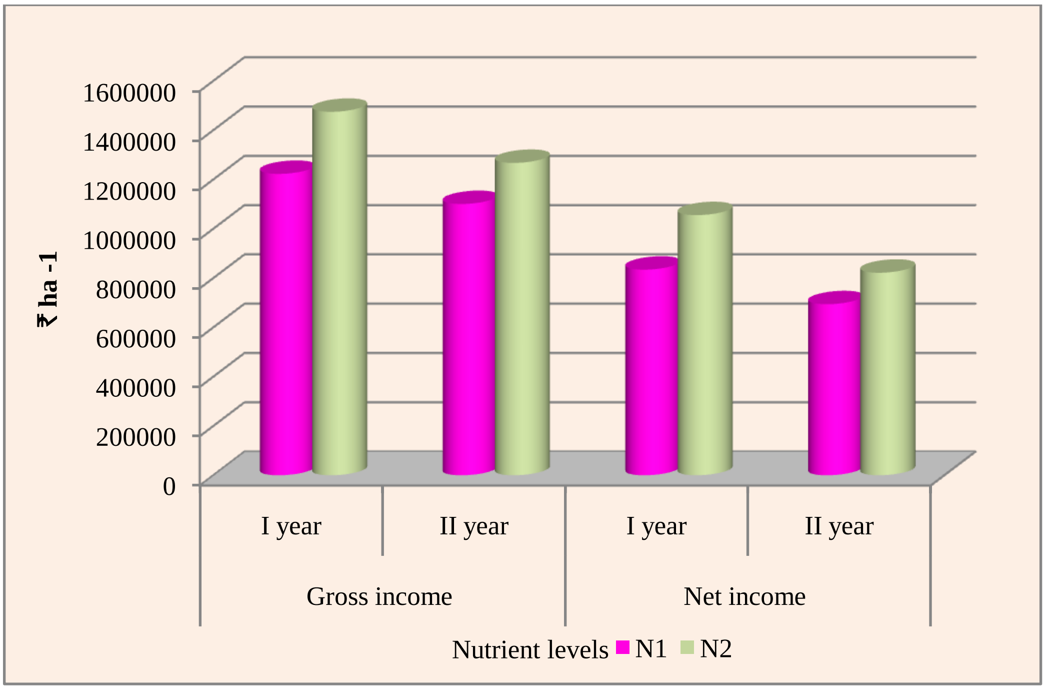

Fig.12b. Economics as influenced by nutrient levels

Plate 9. Experiment – II: Field view (February planting)

5.1.7 Effect of Irrigation and Nutrient Schedule on Economics of Grand Nain Banana

The economics of the present study are illustrated graphically (Fig. 12a and 12b). The bunch and sucker production had contributed to the income from banana. Economic analysis also showed the same trend as that of yield. The results revealed that the economics of banana production was influenced by the irrigation levels and nutrient schedule. The highest gross income and net income and B: C ratio were realized from the irrigation level at 0.8 IW/CPE and 1.0 IW/CPE, respectively during first and second year. The superiority of irrigation at 1.0 IW/CPE is due to better productivity, 45 per cent higher than the productivity realized at 0.4 IW/CPE.

The uptake based application of nutrients @ 160: 40: 640 g N: P_2O_5: K_2O plant^{-1} recorded the highest gross income and net income and B: C ratio during both the years. This was due to higher yield and better sucker production at N_2. N_2 recorded 16 per cent more yield than N_1.

Time of application influenced the economics only during second year. Four split application resulted in more income due to the higher yield obtained with four splits. B: C ratio was influenced by the time of application during first year only and two split application resulted in more B: C ratio (3.41) than 4 splits due to reduced cost of cultivation and increased yield.

Nutrient moisture interaction (I x N) was significant for net income and B: C ratio. The treatment combination i_4n_2 recorded the highest net income and B: C ratio during both years and it was on a par with i_3n_2 during first year. Though I x N x S interactions were not significant, the highest B: C ratio was obtained with the treatment combinations, $i_4n_2s_1$ (4.17) in first year and $i_4n_2s_2$ (3.36) in second year, respectively.

5.2 EXPERIMENT II. STUDIES ON PHENOLOGY OF BANANA CV. GRAND NAIN

5.2.1 Effect of Dates of Planting on Growth, Yield and Quality of Grand Nain Banana

Phenological studies helps to plan the planting date in order to forecast the time of harvest and to study the vegetative and reproductive developmental cycle of plant as determined by the climatic parameters. Based on yield grouping was done as high yielders (24.75-29.75 kg plant^{-1}), medium yielders (19.75-24.74 kg plant^{-1}) and low yielders (14.75-19.74 kg plant^{-1}) (Fig. 13). The high yielders in the present study were February, July and June planted crops and the low yielders were November, December January and October planted ones and the rest comes under medium yielders. The high yield obtained was due to increased growth and yield attributes. The plant height was the highest in early stages with February and July plantings and at 6 MAP, June planting recorded more height. Yadav *et al*. (2011) reported that characteristics of the banana plant could be influenced by the season and observed that suckers planted during June gave the maximum vegetative growth. The results of the study revealed that July planting recorded the highest girth at all stages of growth. The growth parameters like pseudostem height and girth were the lowest in November, December, January and October plantings. However at harvest stage, January planting showed on increased height due to the long duration of vegetative phase.

The weight of bunch increased with increase in number of leaves retained in plants at reproductive stage. Plants with the lowest number of leaves recorded a marked reduction in bunch weight. Baiyeri (2008) reported that the number of standing leaves at harvest was the most reliable predictor of bunch weight. In this study also, the maximum number of leaves was recorded in February planted crop followed by July planted crop. This might be the reason for the highest bunch weight in February and July planted crops.

The functional leaf area, LAI and LAD at harvest were the highest in February planting. This might be the reason for the highest bunch weight in

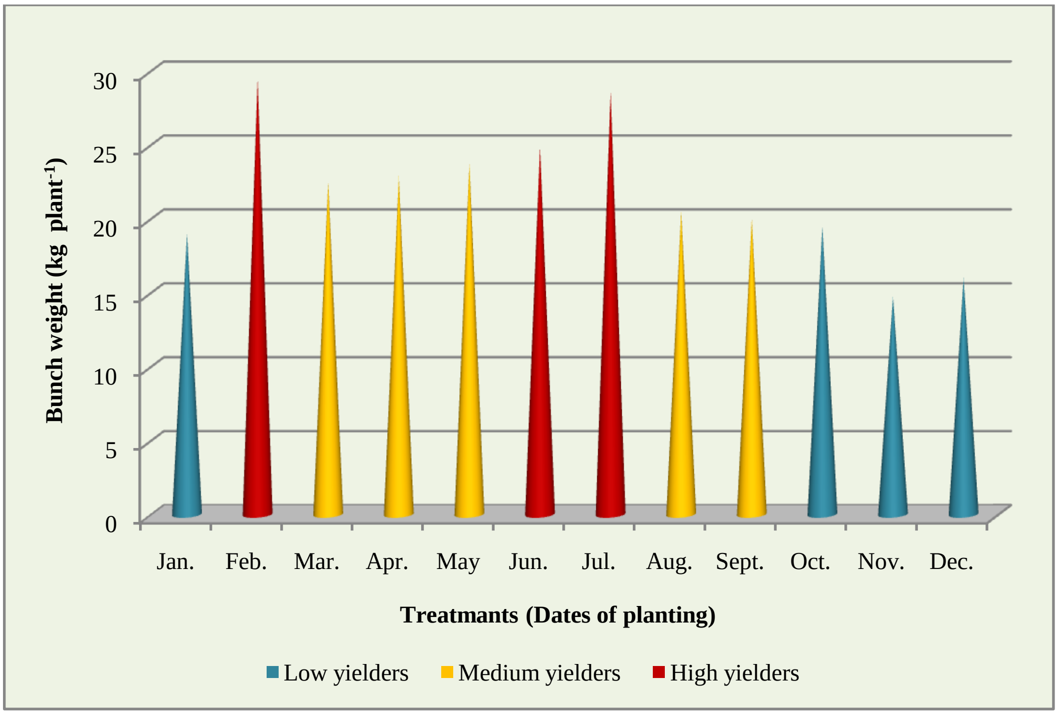

Fig. 13. Bunch weight as influenced by dates of planting

February planting. Also the production cycle from planting to harvest was shorter due to accelerated leaf emergence rate (LER) and LER was found maximum with February planting. The monthly LER depends on the monthly mean minimum temperature during the crop period and February planting recorded the highest mean minimum temperature (Fig. 14).

In banana, the bunch and finger characters like number of hands bunch^{-1}, number of fingers bunch^{-1}, and weight of D-hand, number of fingers in D-hand, length and weight of D-finger are the major yield determinants. The bunch weight plant^{-1} was found maximum in February planting (29.50 kg) which was on a par with July planting and was significantly superior to all other dates of planting due to enhanced yield attributes (Plate 9). The bunch weight was the lowest in November, December, January and October plantings. Yadav *et al*. (2011) reported minimum bunch weight in November planting.

The planting dates significantly influenced the yield attributes of Grand Nain banana (Fig. 15). The number of hands and total fingers were higher in June and February plantings and was the lowest in January planting. The maximum number of fingers in D-hand in February, June and July planting resulted in higher yield. The weight of D-finger is another yield contributor and in this study the weight of D-finger was found higher in July and February planted crops and the lowest in October planted crop. The length of D-finger was maximum in February (T_2) planting and the minimum in January planting. The bunch length was the highest in February and July plantings. In correlation analysis, the highest positive correlation was obtained with weight of D-hand and yield. The D-hand weight was the highest in July, February and June planted crops which resulted in more yield.

Bauri *et al.* (2014) reported that fruit size and quality were of great importance in banana though consumer acceptance varied from place to place. Generally the quality of banana was assessed with sugar content and acidity of the pulp. Low acidity was observed in February and July planted crops and the

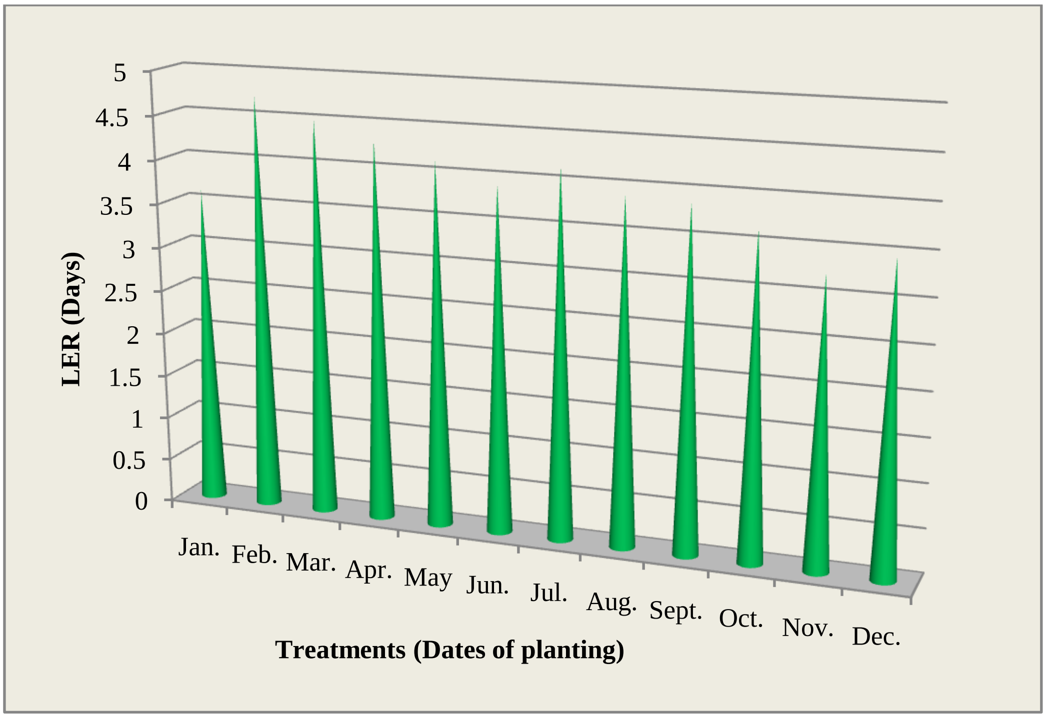

Fig. 14. Leaf emergence rate (LER) as influenced by dates of planting

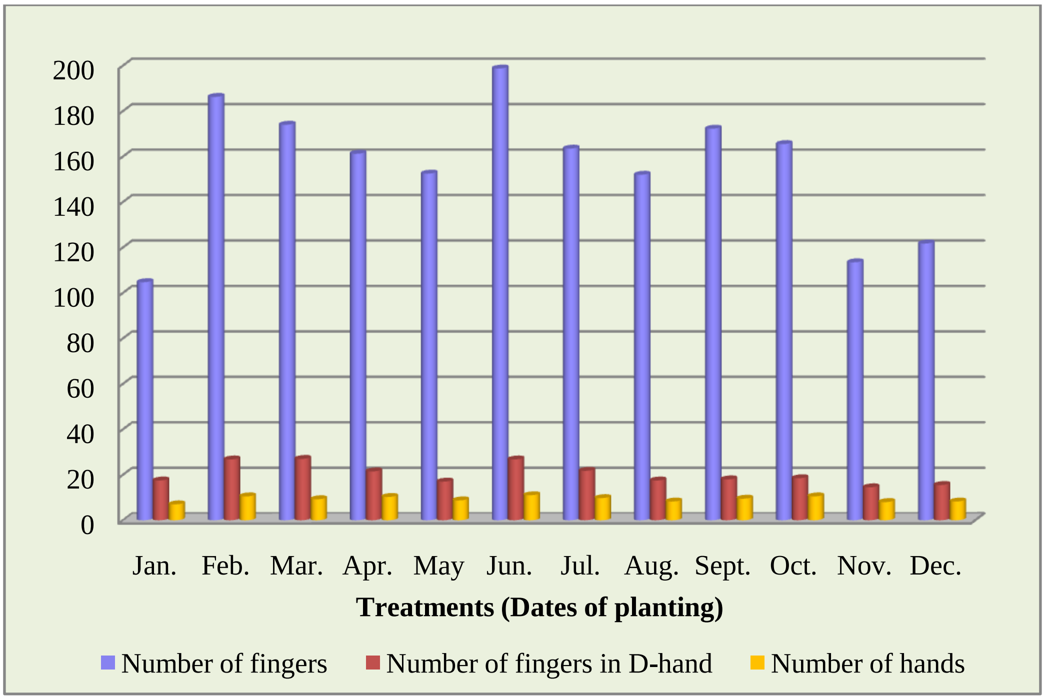

Fig. 15. Yield attributes as influenced by dates of planting

highest in November, December, April, June and January planted crops. The total sugar and reducing sugar content were the highest in February, July and June planted crops and the lowest in low yielders. The sugar acid ratio was the highest in February and July planted crops and the lowest in November and December planted crops. The shelf life or the keeping quality of fruits was influenced by the planting dates and the longest shelf life was in July and February planted crops.

The results revealed that February planting resulted in early harvest of crop due to shorter period for shooting, bunch emergence to harvest (E-H) and physiological maturity. The maximum and minimum temperature during the crop period were the highest (30.8 ^{o}C and 24.1 ^{o}C) in February planting which resulted in less crop duration. The duration of each phenological stage was influenced by temperature which had a direct impact on yield. February planting recorded maximum bunch weight and to the extent of 100 per cent higher over November and 84.4 per cent over December planting indicating optimum thermal regime. Bunch emergence to harvest duration (E-H) is the main reproductive index of banana development. In this study, the February planting took least number of days for flower emergence to harvest (73.75 days). The duration from E-H was extended by 27 days for June planted crop when compared to February planted crop. Stover (1979) reported that the E-H for Grand Nain banana are 98 days for hot weather fruit development and 117 days for cool weather development and the duration recorded in this study is in agreement with the findings of Stover (1979). The total duration of the crop was also significantly influenced by dates of planting and the results revealed that though April planted crop was on par with February planted crop in total duration, the bunch yield of April planted crop was significantly inferior to February planted ones. The total duration of the crop was reduced by planting in February (277 days) whereas the duration was extended for November planting by 102 days when compared to February planting (Fig. 16). February planting took the least duration and similar

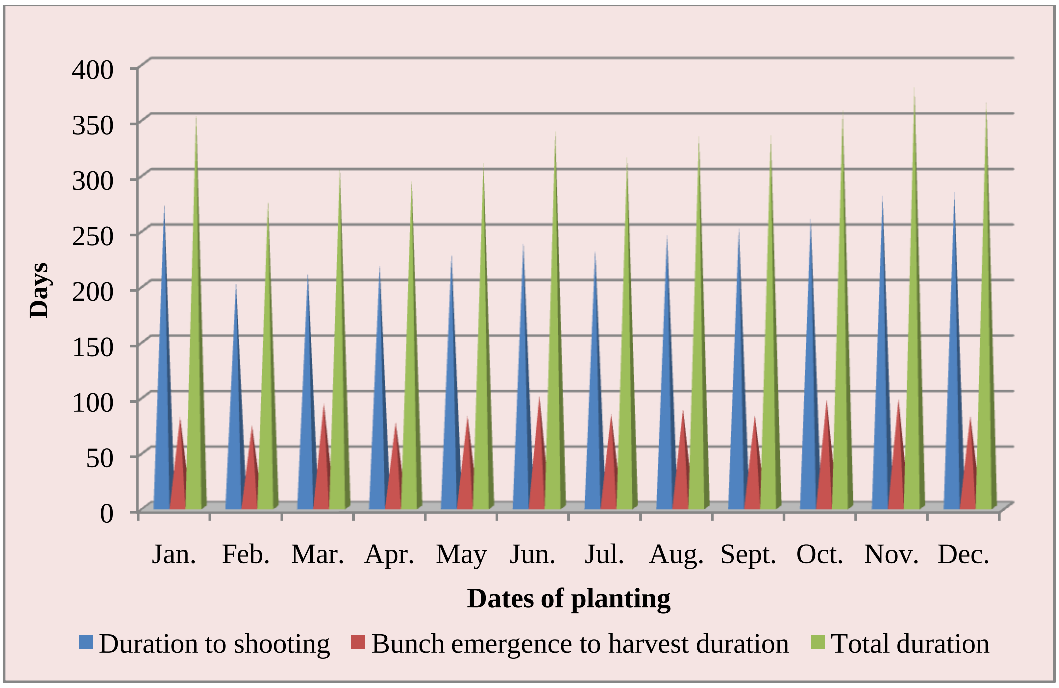

Fig.16. Duration of crop as influenced by dates of planting

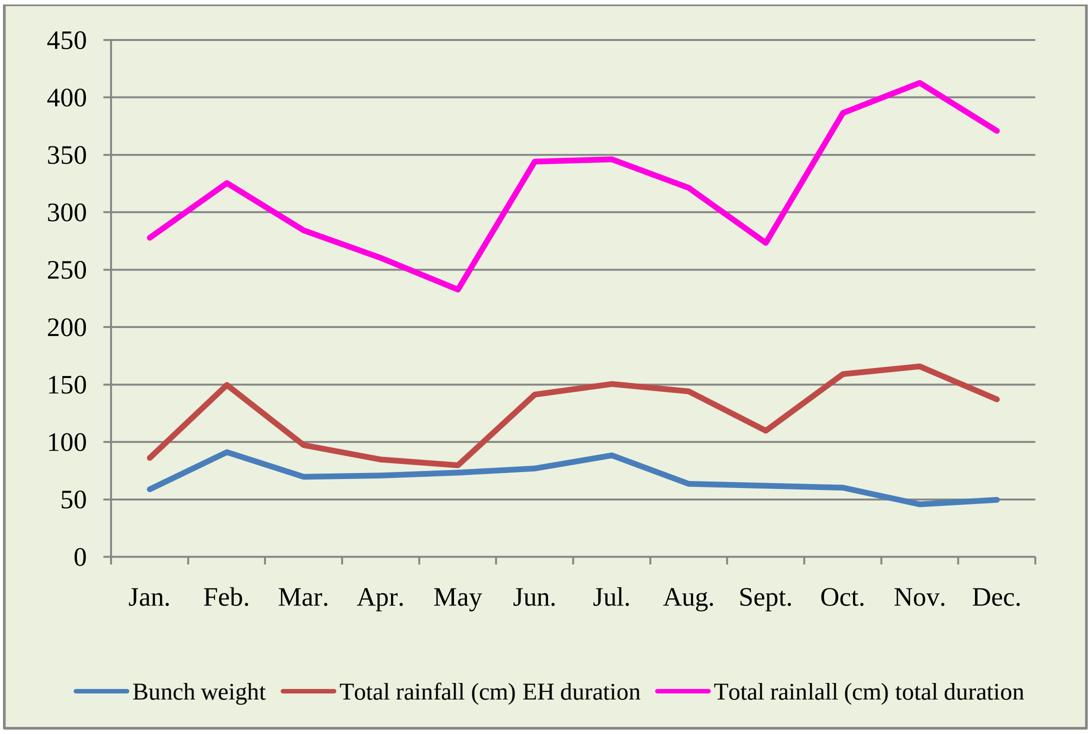

Fig. 18b. Relationship of bunch weight with total rainfall under different phenophases

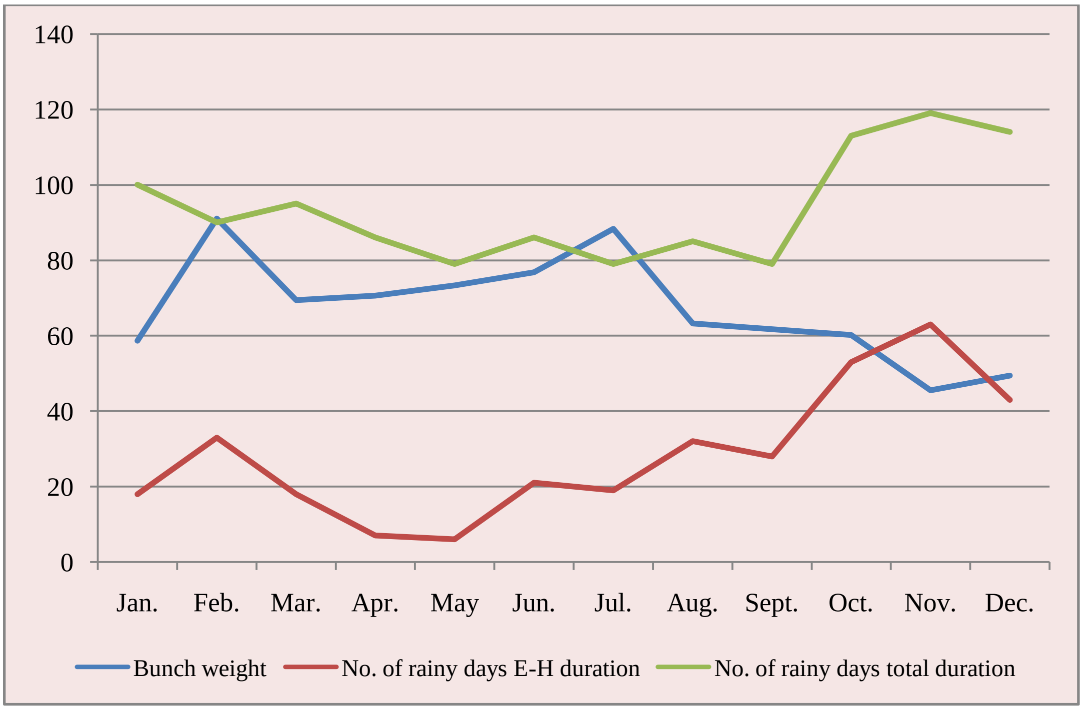

Fig.18c. Relationship of bunch weight and number of rainy days

results were also reported by Ghose and Hossain (1992), Bauri *et al*. (2002) and Ara *et al*. (2011).

5.2.2 Agro-meteorological Studies in Grand Nain banana

Crop physiological processes are depended on integrated atmospheric parameters (Ko *et al*., 2010), in which temperature is an important weather parameter that affects plant growth, development and yield. Temperature in banana growing areas has a significant role in fruit maturation (Fig. 18a). The heat units accumulated over the growing season for a particular crop is defined as Growing degree days. The maturity can be assessed based on heat units accumulated. Dass and Rai (2013) reported that measuring the heat accumulated over time provides a more accurate physiological estimate than counting calendar days. The heat units/growing degree days (GDD) requirement for vegetative and reproductive phases were the lowest in February planting due to the high mean minimum temperature and hence the total crop duration. In nutshell, summer planting (February, March, April and May) required less heat units/GDD for maturity when compared to other dates of planting. November and December planting required more heat units/GDD to complete the vegetative and reproductive phases due to the less mean minimum temperature during this period. The GDD requirement of February planting was 1442 degree days less when compared to November planting.

Similarly the HTU and PTU requirements which are functions of GDD, actual and maximum possible sunshine hours were also the highest in November planting (62,719 and 45,169 ^{o}C d h, respectively). The mean bright sunshine hours (BSS) was the highest (9.6) in February planting which resulted in less heliothermal units for crop maturation (Fig. 18d). The HTU and PTU requirements were the lowest in February planting to complete the growth period, indicating that temperature conditions and day length hours during this period is favourable for Grand Nain banana in southern agro climatic conditions of Kerala. The HUE, which is a function of dry matter production and GDD, was the

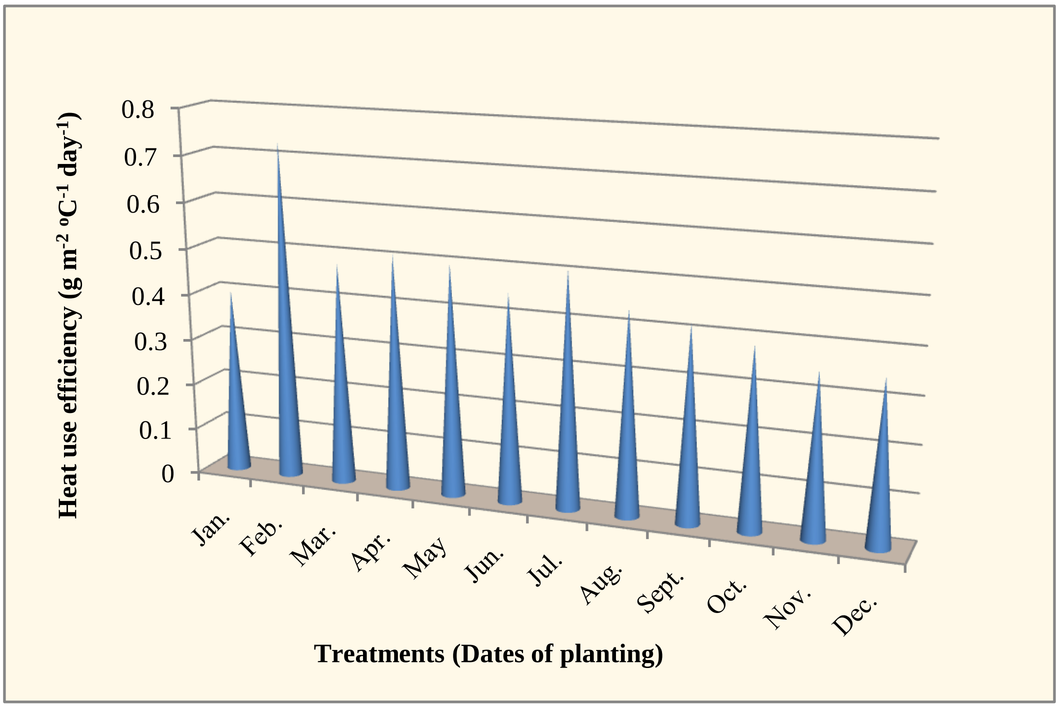

Fig. 17. Heat use efficiency as influenced by dates of planting

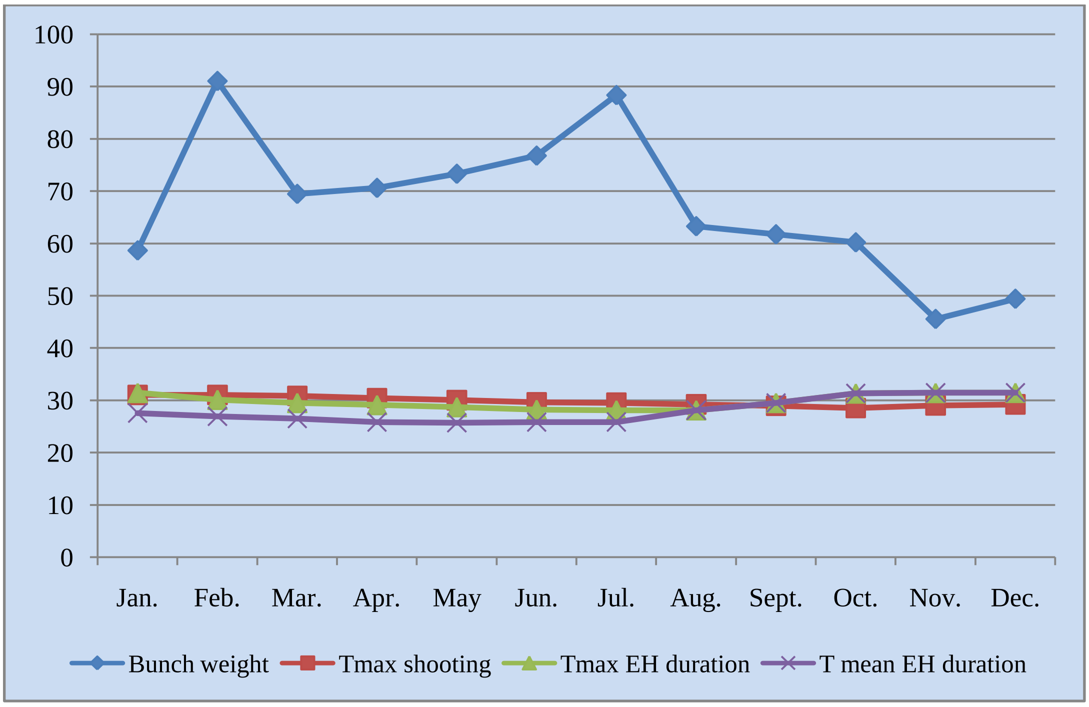

Fig. 18a. Relationship of bunch weight and temperature at different phenophases

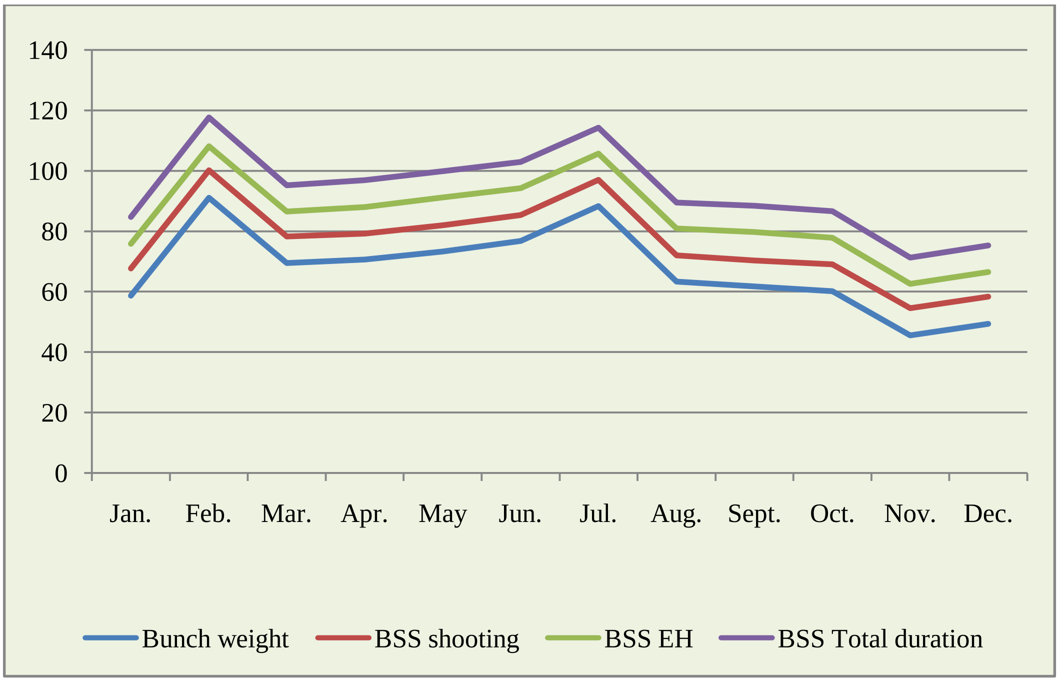

Fig. 18d. Relationship of bunch weight and bright sunshine hours

highest in February planting which implied the efficiency of February planted crop to effectively utilize the radiation for dry matter production and that also resulted in the shortest duration of the crop (Fig. 17). The HUE was the lowest in November and December planted crops indicating the less efficient utilization of radiation parameters by those crops to produce unit dry matter resulting in extension of duration. November and December planted crops required more cumulative heat units for unit production of dry matter and hence resulted in extension of vegetative and reproductive phenophases. Another reason for this higher duration might be due to the receipt of more rainfall during the growth period resulting in extension of phenophases (Fig. 18b and 18c). November and December planted crops took on an average 372 days for harvest whereas for February planted crops, the duration was 277 days.

6. SUMMARY

An investigation entitled “Nutrient and moisture optimization in banana (*Musa* AAA. Grand Nain)” was undertaken with the objectives to standardize the nutrient and irrigation schedule of Grand Nain banana, to study its phenology in relation to various agro-meteorological parameters and to work out the economics. The investigation comprised two separate experiments. The first experiment on ‘Nutrient - moisture interaction study’ was conducted for two years from June 2014 to May 2016 and the second experiment on ‘Phenology study of Grand Nain banana’ from January 2014 to December 2015. Both the experiments were conducted at the Instructional Farm, College of Agriculture, Vellayani.

The first experiment was laid out in split plot design with sixteen treatments and four replications. The main plot treatments were four irrigation levels, *viz*., I_1, I_2, I_3 and I_4 based on IW/CPE (Irrigation water/ Cumulative pan evaporation) ratios of 0.4, 0.6, 0.8 and 1.0 and subplot treatments were four combinations of two nutrient levels (N) and two times of application (S). The two nutrient levels were N_1: 212: 50: 332 g N: P_2O_5: K_2O plant^{-1} year^{-1} [KAU, POP recommendation of 200: 200: 400 g N: P_2O_5: K_2O plant^{-1} year^{-1} for varieties other than Nendran was modified based on soil test values (KAU, 2011)] and N_2: 160: 40: 640 g N: P_2O_5: K_2O plant^{-1} year^{-1} (Based on nutrient uptake values of banana cv. Grand Nain). The two times of applications (S) were S_1 [N and K in 2 equal splits at 2 and 4 months after planting (MAP)] and S_2 (N and K in 4 equal splits at 2, 3, 4 and 5 MAP). The second experiment was laid out in RBD with twelve treatments (twelve dates of planting) and four replications. Planting was done on last week of every month from January onwards. Tissue culture plants were planted at a spacing of 1.8 m x 1.8 m. Entire dose of FYM (15 kg plant^{-1}) and P were applied as basal in both the experiments.

The results of the two experiments are summarized below.

In Nutrient - moisture interaction study, the growth characters were recorded at 4 and 6 MAP and at harvest. In the study, irrigation level at 1.0 IW/CPE resulted in better growth and yield parameters of Grand Nain banana. The irrigation at 1.0 IW/CPE was on a par with 0.8 IW/CPE and resulted in increased height and girth of pseudostem during all growth stages and found superior to other two levels of irrigation. The plants were the shortest in irrigation at 0.4 IW/CPE during all stages of growth. The nutrient schedule significantly influenced the pseudostem height and girth at all stages of growth during both the years and were the highest in N_2, nutrient application based on uptake of nutrients. The time of application did not influence plant height during first year. During second year, application of fertilizer in four splits (S_2) produced the tallest plants and was significantly superior to fertilizer application in two splits (S_1) **w**hile the girth of the plant was the highest in S_2 and superior to S_1 at 6 MAP and at harvest during first year. The interaction effect of nutrient levels and time of application was significant with n_2s_1 recording the highest pseudostem height and girth.

Irrigation scheduled at 1.0 IW/CPE (I_4) and nutrient application based on uptake of nutrients (N_2) recorded the highest number of functional leaves, functional leaf area, LAI and LAD. During second year, the application of fertilizer in four splits (S_2) recorded more number of leaves than two splits (S_1). The interaction between nutrient levels and time of application significantly influenced the number of functional leaves at 4 MAP during first year.

Duration for bunch emergence and total duration were the shortest with irrigation levels of 0.8 and 1.0 IW/CPE (I_3 and I_4) and the longest in irrigation at 0.4 IW/CPE (I_1). The emergence to harvest (E-H) duration was the shortest in irrigation at 0.4 and 0.6 IW/CPE (I_1 and I_2) during first year and in 0.4 and 0.8 IW/CPE (I_1 and I_3) during second year. The duration for shooting, E-H and total duration was the lowest in N_1. The duration for bunch emergence was not influenced by the time of application (S) and the nutrient moisture interactions. The time of application (S) influenced the E-H duration during first year but not influenced during second year.

The number of hands, number of fingers and fingers in D-hand, finger weight, pulp to peel ratio and fruit length were the highest in irrigation at 1.0 IW/CPE (I_4) during both the years. The number of hands, fingers per bunch, number of fingers in D-hand and bunch length were the highest in N_2 during both the years. The application of nutrients in four splits (S_2) recorded the highest number of hands (9.16) and significantly superior to two splits (S_1) application in second year while the total fingers were not influenced by the time of application (S).

The length, girth, weight and pulp to peel ratio of D-finger were the highest in N_2 during both the years. However the time of application did not influence the fruit characters during both the years of experimentation. Among the interactions, I x N and N x S interactions significantly influenced the fruit length, finger weight and pulp to peel ratio. Among I x N interaction, the nutrient level N_2 at all levels of irrigation recorded higher pulp to peel ratio than N_1 level and it was the highest in i_4n_2.

The TSS was unaffected by the irrigation levels, while the nutrient level N_2 recorded the highest content of TSS. The irrigation levels significantly influenced the titrable acidity during second year with I_4 recording the lowest. Among the nutrient levels N_2 recorded the lowest acidity. Total sugar, reducing sugar, sugar acid ratio and ascorbic acid were the highest in irrigation at 1.0 IW/CPE (I_4) and in nutrient level N_2. The time of application and the interaction effects were found not significant on quality attributes.

The shelf life of fruits was influenced by the irrigation and nutrient levels. The irrigation at 1.0 IW/ CPE (I_4) and the nutrient level N_2 recorded the longest shelf life. The time of application of nutrients as well as the interaction effects were found to be not significant.

The analysed data revealed that the irrigation levels significantly influenced the bunch weight and yield during both the years. During first year, irrigation at 0.8 IW/CPE (I_3) recorded the highest bunch weight (27.44 kg plant^{-1}) and it was on a par with irrigation at1.0 IW/CPE (I_4) (27.41 kg plant^{-1}) and significantly superior to the other two levels of irrigation. The Irrigation scheduled at 0.4 IW/CPE (I_1) recorded the lowest bunch weight (19.47 kg plant^{-1}). The highest bunch weight and yield were the highest in irrigation at 1.0 IW/CPE (I_4) and significantly superior to the other three levels of irrigation during second year.

The nutrient application based on the uptake of nutrients (N_2) recorded the highest bunch weight and significantly superior to POP based application (N_1) during first and second year, respectively (26.58 and 22.63 kg plant^{-1}). The time of application of nutrients (S) did not influence the bunch weight and yield during first year. But during second year, application of nutrients in four splits (S_2) recorded the highest bunch weight (21.69 kg plant^{-1}) and yield (66.93 t ha^{-1}) and was significantly superior to application of nutrients in two splits (S_1).

Pooled analysis also revealed that the bunch weight and yield were the highest in I_4 (26.20 kg plant^{-1}and 80.85 t ha^{-1}), but on a par with I_3. Among the nutrient levels, N_2 recorded the highest bunch weight and pooled yield (24.60 kg plant^{-1}and 75.92 t ha^{-1}). The pooled analysis revealed that the nutrient moisture (I x N) interaction was significant on the productivity of Grand Nain. Sigatoka leaf spot disease was the major disease observed during the study. No pest was observed during the crop growth period.

The results on the primary nutrient (N, P and K) content in the index leaf at 4 MAP revealed that the N, P and K content in the index leaf was significantly influenced by the irrigation and nutrient levels.

The irrigation levels significantly influenced the total dry matter production (DMP) and nutrient uptake. The NPK uptake and DMP at harvest were the highest in irrigation at 1.0 IW/CPE (I_4) during both the years. Among the nutrient levels, the DMP was the highest in N_2. The nutrient levels significantly influenced the total N, P and K uptake at harvest and uptake by plant parts during both the years with N_2 recording the highest uptake. The application of nutrients in four splits (S_2) recorded the highest DMP during second year and was found to be superior to two splits (S_1) application. Among the interactions, N x S and I x N interactions were found significant.

In the present study, organic carbon status showed a positive build up in all treatments. Soil N status changed from medium to low, the status of P remained unchanged while the K status changed from medium to high after the experiment.

The drip irrigation given during the experiment led to more economic use of water. Irrigation scheduled at 1.0 IW/CPE, in the present study recorded water requirement of 2171 mm and 2559 mm, respectively during first and second year. Water use efficiency (WUE) was the highest in irrigation at 0.8 IW/CPE during both the years and was on a par with irrigation at 1.0 IW/CPE. Water productivity was the highest in irrigation at 0.8 IW/CPE during first year and in irrigation at 1.0 IW/CPE during second year. However, it was on a par with 1.0 IW/CPE and 0.8 IW/CPE during first and second year, respectively.

WUE and water productivity were significantly the highest in N_2 during both the years of experimentation and were influenced by the time of application (S) during second year only. The application of nutrients in 4 splits (S_2) recorded the highest WUE and water productivity (29.48 and 8.24 kg ha mm^{-1}). Water productivity was also influenced by the interactions I x N and N x S.

The gross income and net income and BCR were the highest in irrigation level at 0.8 IW/CPE and 1.0 IW/CPE, respectively during first and second year. The uptake based application of nutrients @ 160: 40: 640 g N: P_2O_5: K_2O $plant^{-1}$ recorded the highest gross income and net income and B: C ratio during both the years. The two split application resulted in more BCR during first year while during second year; the four split application recorded the highest.

The results of the study on Phenology of banana cv. Grand Nain are summarized below.

The data indicated that the growth characters, *viz.*, plant height, girth of pseudostem, number of functional leaves, functional leaf area, leaf area index, leaf area duration and leaf emergence rate were significantly different under different planting dates. The high yielders (24.75-29.75 kg plant^{-1}) in the present study were February, July and June planted crops and the low yielders (14.75-19.74 kg plant^{-1}) were November, December January and October planted ones. The bunch weight plant^{-1} was found maximum in February planting (29.50 kg) which was on a par with July planting and was significantly superior to all other dates of planting due to increased growth and yield attributes. The plant height was the highest in early stages with February and July plantings and at 6 MAP, June planting recorded more height. The functional leaf area, LAI and LAD at harvest were the highest in February planting.

The planting dates significantly influenced the yield attributes of Grand Nain banana. The number of hands and total fingers were higher in June and February plantings and was the lowest in January planting. The maximum number of fingers in D-hand was in February, June and July planting. The weight of D finger was found higher in July and February planted crops and the lowest in October planted crop. The length of D-finger was maximum in February (T_2) planting and the minimum in January planting. The bunch length was the highest in February and July plantings.

The total sugar and reducing sugar content were the highest in February, July and June planted crops and the lowest in low yielders. The sugar: acid ratio was the highest in February and July planted crops and the lowest in November and December planted crops. Low acidity was observed in February and July planted crops and the highest in November, December, April, June and January planted crops. The shelf life or the keeping quality of fruits was influenced by the planting dates and the longest shelf life was in July and February planted crops.

The results revealed that February planting resulted in early harvest of crop due to shorter period for shooting, bunch emergence to harvest (E-H) and physiological maturity. February planting resulted in the shortest crop duration (277 days) while the longest duration was observed in November planting.

The agro-meteorological parameters such as growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU) and heat use efficiency (HUE) were also computed. The GDD for vegetative phenophase varied between 2765 ^{o}C d to 3921 ^{o}C d and for reproductive stage it was 968 ^{o}C d to 1446 ^{o}C d. The total GDD or heat units required was the lowest in February (T_2) planting and the highest in November (T_{11}) planting. The February (T_2) planting required the lowest total HTU (32,750 ^{o}C d h) followed by April (T_4) planting (33,436 ^{o}C d h) while November (T_{11}) planting the highest (45,169 ^{o}C d h) followed by December (T_{12}) planting (44,156 ^{o}C d h). The total PTU requirement was also the lowest in February (T_2) planting (45,540 ^{o}C d h) and the highest in November (T_{11}) planting. The heat use efficiency was the highest (0.73 g m^{-2} $^{o}C^{-1}$ d^{-1}) in February (T_2) planting and the lowest (g m^{-2} $^{o}C^{-1}$ d^{-1}) in November (T_{11}) and December (T_{12}) plantings.

It is summarized from the present study that application of nutrients @ 160: 40: 640 g N: P_2O_5: K_2O $plant^{-1}$ (N_2) with full P as basal and N and K in two equal splits at 2 and 4 MAP (S_1) with irrigation at 1.0 IW/CPE (I_4) can be recommended for Grand Nain banana for high yield, economics and quality produce. Last week of February is the ideal planting time for getting high yield and quality produce in Grand Nain banana with shorter phenophases in the southern agro climatic conditions of Kerala.

Future Line of Work

- Nutrient management in ratoon crop of Grand Nain
- Management of P in high P soil
- Precision farming in Grand Nain

7. REFERENCES

Ahmed, A. B., Ali, M. A., and Ihsan, M. I. 2011. Effect of drip irrigation on performance of banana under different irrigation regimes in Gezira. *Afr. Crop Sci. Conf. Proc.* 10: 425–431.

Ahumuza, B., Basamba, T. A., Van Asten, P., and Tushemereirwe, W. K. 2015. Physiological nutrient use efficiency of banana hybrids across agro ecological regions in Uganda. *Afr. J. Plant Sci*. 9: 97-105.

Ali, A. B. M., Elshaikh, N. A., Shuang-En, Y., Basheer, A. K., Alnail, M., Alhadi M., and Altayeb, O. A. 2015. Correlation between water deficiency, yield components and crop productivity of banana. *J. Environ. Agric. Sci.* 4: 11-20.

Angeles, D. E., Summer, M. E., and Lahav, E. 1993. Preliminary DRIS norms for banana. *J. Plant Nutr.*16: 1059-1070.

Ara, N., Basher, M. K., and Hossain, M. F. 2011. Growth, yield and quality of banana (*Musa sapientum*) influenced by different banana varieties/lines and planting time. *Trop. Agric. Res. Ext.*14: 46-51.

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

Baiyeri, K. P. 2008. Phenotypic relationships among growth, yield, and black leaf streak disease responses of *Musa* genotypes. *J. Crop Improv*. 21: 41-54.

Ballard, T. M. and Cole, D. W. 1974. Transport of nutrients to tree root systems. *Can. J. For. Res*. 4: 563-565.

Barrera, J. L., Cayón, G., and Robles, Y. J. 2009. Influencia de la exposición de las hojas y el epicarpio de frutossobre el desarrollo y calidaddelracimo de plátano Hartón (*Musa* AAB Simmonds). *Agron. Colombiana* 27: 73-79.

Baruah, P. J. and Mohan, N. K. 1991. Effect of potassium on leaf area index, phyllochron and number of leaves of banana cv. Jahaji. *Banana Newsl.* 14: 21-22.

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

Bauri, F. K., Misra, D. K., and Sarkar, S. K. 2002. Effect of planting time on Post-harvest Performance of banana cv. Martamar. *Indian J. Hortic*. 59(2): 127-129.

Bhalerao, N. M., Patil, N. M., Badgujar, C. D., and Patil, D. R. 2009. Studies on integrated nutrient management for tissue cultured Grand Nain banana. *Indian J. Agric. Res.* 43: 107-112.

Bhangoo, M. S., Altmana, F. G., and Karon, M. L. 1962. Investigations on the Giant Cavendish banana. *Int. Trop. Agric*. 39: 189 -201.

Bhargava, B. S., Singh, H. P., and Chadha, K. L. 1993. Role of potassium in development of fruit quality. In: Chadha, K.L. and Pareek, O. P. (eds), *Advances in Hortic.V.2. Fruit crops: Part 2.* Malhotra Publishing House, New Delhi, pp. 947-960.

Bisen, R. K., Pandey, D., and Chaure, N. K. 2009. Scheduling of irrigation and application of macro-nutrients on growth and yield of banana. *Environ. Ecol*. 27: 121-126.

Biswas, B. C. and Kumar, L. 2014. High density planting: Success stories of banana farmers. *Ferti. Mark. News* 41: 3-10.

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

Bray, E. A., Bailey-Serres, J., and Weretilnyk, E. 2000. Responses to abiotic stresses. In: Buchanan, B. B., Gruisem, W., and Jones, R.L. (eds), *Biochemistry and Molecular Biology of Plants*. Am. Soc. of Plant Physiologists, Rockville, M. D, pp. 1158–1203.

Bugaud, C., Daribo, M. O., and Dubois, C. 2007. Climatic conditions affect the texture and colour of Cavendish bananas (Grande Naine cultivar). *Sci Hortic.* 113(3): 238–243.

Burham, F. O. 1999. Effect of irrigation interval and amount of water on growth and yield of banana. M.Sc. (Ag) thesis, University of Khartoum, Sudan.

Calberto, G., Staver, C., and Siles, P. 2015. An assessment of global banana production and suitability under climate change scenarios, In: Aziz Elbehri (ed.), *Climate Change and Food Systems: Global Assessments and Implications for Food Security and Trade*. Food Agriculture Organization of the United Nations (FAO), Rome, pp. 266-291.

Carr, M. K. V. 2009. The water relations and irrigation requirements of banana (*Musa* spp.). *Expl. Agric*. 45: 333-371.

Champion, J.E. 1968. *Banana*. Barcelona Blume, 247p.

Chezhiyen, N., Balasubramani, P., Harris, C. V., and Anandthan, M. 1999. Effect of inorganic and bio fertilizers on growth and yield of inorganic banana var. Virupakshi. *S. Indian Hortic.* 47: 1-6.

Costa, F. da S., Coelho, E. F., Borges, A. L., Pamponet, A. J. M., Silva, A. dos A. S. M. da., and Azevedo, N. F. de. 2012. Growth, yield and potassium accumulation in 'Galil 18' banana under irrigation and potassium fertilization. *Pesq. Agropec.* 47: 409-416.

Dadzie, B. K. and Orchard, J. E. 1997. *Routine Post Harvest Screening of Banana/Plantain Hybrids: Criteria and Methods*. Technical Guidelines 2, International Plant Genetic Resources Institute, Rome, Italy, 61p.

Daniells, J. W. and Armour, J. 2010. *Managing Crop Nutrition in Banana Production*. QDPI Bull. No. 2:1-8.

Daniells, J. W. and Watson, B. J. 1984. Effects of water stress on bananas. *Banana Newsl.* 7:3.

Dass, B. and Rai, A. K. 2013. Growing degree days (GDD) measurement system to predict plant stages. *JNKVV. Res. J.* 47(3): 346-349.

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

Dastane, N. G. 1972. *A Practical Manual for Water Use Research in Agriculture* (2nd Ed.). Navbharath Prakashan, Poona, India, 120p.

Dastane, N. G. 1974. *Effective Rainfall in Irrigated Agriculture*. Land and Water Development Division, FAO, Rome, 25p.

Delvaux, B., Lassoudiere, A., Perrier, X., and Marchal, J. 1987. A methodology for the study of soil-plant cultivation technique relations - Results for banana-growing in Cameroon. In: Galindo, J. J. (ed.), *ACORBAT 85*. Memorias VII Reunion, pp. 351-357.

Doorenbos, J. and Pruitt, W. O. 1975. Guidelines for predicting crop water requirements. *Irrigation and Drainage paper 24*, FAO, Rome, 179p.

e Silva, L. B., do Nascimento, J. L., Naves, R. V., and Ferreira, P. H. 2004. Vegetative behavior of banana cultivars at different irrigation levels. *Pesqu. Agropec. Trop.* 34: 93-98.

El-Khawaga, A. S. 2013a. Response of Grand Naine Banana plants grown under different soil moisture levels to anti transpirants application. *Asian J. Crop Sci*. 5: 238-250.

El-Khawaga, A. S. 2013b. Adjusting the best time of planting suckers and plant density for Williams Banana grown under Aswan region conditions. *Asian J. Crop Sci.* 5: 251- 263.

Epstein, E., and Bloom, A. J. 2005. *Mineral Nutrition of Plants: Principles and Perspectives,* (2nd Ed.). Sinauer Associates, Sunderland, 380p.

Fageria, N. K., Baligar, V. C., and Clark, R. B. 2006. *Physiology of Crop Production*. The Haworth Press, New York, 356p.

Fageria, N. K., Baligar, V. C., and Jones, C. A. 1997. *Growth and Mineral Nutrition of Field Crop* (2nd Ed.). Marcel Dekker, New York.

Fandika, I. R., Dadyampakeni, D., Mwenebanda, B. M. L. and Magombo, T. M. 2014. Banana irrigation management and optimization: A comparative study of researcher-managed and farmer-managed irrigated banana production in Shire Valley, *Malawi Afr. J. Agric. Res.* 9: 2687-2693.

Fathia, O. B. 1999. Effect of irrigation interval and amount of water on growth and yield of banana. M.Sc. (Ag. Eng.) thesis, University of Khartoum.

FIB [Farm Information Bureau]. 2016. *Farm Guide 2016*. Farm Information Bureau, Thiruvananthapuram, 213p.

Follett, H. F. 2001. Innovative N microplot research techniques to study nitrogen use efficiency under different ecosystems. *Commun. Soil Sci. Plant Anal.* 32:951-979.

Fox, R. L. 1989. *Detecting Mineral Deficiencies in Tropical and Temperate Crops.* Westview Tropical Series 7.

Ganeshamurthy, A. N., Satisha, G. C. and Patil, P. 2011. Potassium nutrition on yield and quality of fruit crops with special emphasis on banana and grapes. *Karnataka J. Agric. Sci.* 24: 29-38.

Ganry, J. and Chillet, M. 2008. Methodology to forecast the harvest date of banana bunches. *Fruits* 63: 371-373.

Ganry, J. and Sioussaram, D. 1978. Research on a method of estimating the harvesting date for bananas, based on climatic data under conditions pertaining to the French West Indies. *Fruits* 33: 669-680.

Gauhl, F. 2002. Are spore traps a useful tool to predict Sigatoka disease development in commercial banana plantations. In: *Abstracts, Int. Workshop Mycosphaerella Leaf Spot Dis. Bananas, 2nd Programme,* P. 22.

Ghose, G. and Hossain, A. K. M. 1992. Effect of time of planting on growth and yield of two commercial banana varieties. In: Subhadrbandu, S. (ed.), *Proceedings of the Frontiers in Tropical Fruit Research*, Wagenigen, Netherland, pp. 463-471.

Ghosh, P. K., Bandopadhyay, K. K., Misra, A. K., and Rao, A. S. 2004. Balanced fertilization for maintaining soil health and sustainable agriculture. *Fert. News* 49: 13–35.

Goenaga, R. and Irizarry, H. 1995. Yield performance of banana irrigated with fractions of class A pan evaporation in a semiarid environment. *Agron. J.* 87: 172-176.

Goenaga, R. and Irizarry, H. 1998. Yield of banana grown with supplemental drip irrigation on an ultisol. *Exp. Agric*. 34: 439-448.

Goenaga, R. and Irizarry, H. 2000. Yield and quality of banana irrigated with fractions of class A pan evaporation on an oxisol. *Agron. J*. 92: 1008-1012.

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research, John Wiley and Sons, New York, 680p.

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

Guo, H. C., Ding, T., Mahmood, Q. C., Zhang, N. D., and Wang, G. 2009. Responses of soil microbial community to phosphate rock and annual ryegrass (*Lolium multiflorum*). *Pak. J. Bot. 41*: 3149-3157.

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.

Haijun, L., Cohen, S., Lemcoff, J. H., Israeli, Y., and Tanny, J. 2015. Sap flow, canopy conductance and microclimate in a banana screen house. *Agric. For. Meteorol.* 201: 165-175.

Hasan, M. A. and Chattopadhyay, P. K. 2000. Influence of potassium fertilization on growth, yield and quality characters of Cavendish banana. In: Singh H. P and Chadha, K. L. (eds), *Banana Improvement, Production and Utilization*, AIPUB, Trichy, pp. 325-330.

Hasan, M. A., Singh, B., Das, B. C., and Suresh, C. P. 2001. Banana production as influenced by nitrogen and potassium nutrition. *Orissa J. Hortic.* 29: 69-73.

Hazarika, B. N. and Ansari, S. 2010. Effect of integrated nutrient management on growth and yield of banana cv. Jahaji. *Indian J. Hortic.* 67: 270-273.

Hedge, D. M. 1988. Growth and yield analysis of "Robusta" banana in relation to soil water potential and nitrogen fertilization. *Sci. Hortic.* 37: 145-155.

Hedge, D. M. 1990. Growth, yield and water use of banana in relation to irrigation. *J. Maharashtra Agric. Univ.* 15: 41-43.

Hedge, D. M. and Srinivas, K. 1989. Irrigation and nitrogen fertility influences on plant water relations, biomass, and nutrient accumulation and distribution in banana cv. Robusta. *J. Hortic. Sci*. 64: 91-98.

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*. 68: 331-334.

Hegde, D. M. and Babu, S. N. S. 2004. Balanced fertilization for nutritional quality in oilseeds. *Fert. News* 49: 52– 93.

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

Holder, G. D and Gumbs, F. A. 1982. Effects of water supply during floral initiation and differentiation on female flower production by robusta bananas. *Exp. Agric*. 18: 183-193.

Indira, M. 2003. Nutrient management for banana Musa (AB Group) Njalipoovan in Onattukara soils. Ph.D. thesis, Kerala Agricultural University, Thrissur, 249p.

Iwata, F. Heat unit concept of crop maturity.1984. In: Gupta, V. S. (ed.), *Physiological Aspects of Dry Land Agriculture*. Oxford and IBH publishing Co., New Delhi, 328p.

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

Jambulingam, A. R., Ramaswamy, N., and Muthukrishnan, C. R. 1975. Studies on the effect of K on Robusta banana. *Potash Rev*. 27: 4-6.

Kallarackal, J., Milburn, J. A., and Baker, D. A. 1990. Water relations of the banana. III. Effects of controlled water stress on water potential, transpiration, photosynthesis and leaf growth. *Aust. J. Plant Physiol.* 17: 79-90.

Karam, F., Mounzer O., Sarkis F., and Lahoud, R. 2002. Yield and nitrogen recovery of lettuce under different irrigation regimes. *J. Appl. Hortic.* 4: 70-76.

Katerji, N. and Mastrorilli, M. 2009. The effect of soil texture on the water use efficiency of irrigated crops: results of a multi-year experiment carried out in the Mediterranean region. *Eur. J. Agron*. 30: 95-100.

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

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

Ko, J., Ahuja, L., Kimball, B., Anapalli, S., Ma, L., Green, T. R., and Ruane, A. C., Wall, G. W., Pinter, P., and Bader, D. A. 2010. Simulation of free air CO_2 enriched wheat growth and interactions with water, nitrogen, and temperature. *Agric. For. Meteorol.* 150: 1331-1346.

Kohli, R. R., Iyengar, B. R. V., and Reddy, Y. T. N. 1984. Growth, dry matter production and yield in banana as influenced by different levels of nitrogen. *Indian J. Hortic.* 41:194-198.

Kotur, S. C. 2007. Boosting banana yield by increasing fertilizer use efficiency. *Indian Hortic*. 1: 4-7.

Krishnasastry, K. S., Udyakumar, M., Ramarao, S., and Prasad, T. G. 1985. Strengthening of in banana as influenced by different levels of nitrogen. *Indian J. Hortic*.41: 194-198.

Kuhne, F. A. 1980. *Banana Phenology*. Information Bulletin, Citrus and Subtropical Fruit Research Institute, 91: 18-19.

Kumar, D., Pandey, V., and Anjaneyulu, K. 2008. Effect of planting density and nutrient management on growth, yield and quality of micro-propagated banana Rasthali Pathkapoora (AAB). *Indian J. Hortic.* 65: 272-276.

Kurien, S. 2004. *Yield Prediction Models in Banana*. Annual report of the DST project. Department of Science and Technology, Govt. of India, 88p.

Kuttimani, R., Velayudham, K., and Somasundaram, E. 2013. Growth and yield parameters and nutrient uptake of banana as influenced by integrated nutrient management practices. *Int. J. Recent Sci. Res*. 4: 680-686.

Lahav, E. 1995. Banana nutrition. In: Gowen, S. (ed.), *Banana and Plantains.* Chapman and Hall, London, pp. 259–297.

Lincoln, R. J., Boxshall, G. A., and Clark, P. F. 1982. A Dictionary of Ecology, Evolution and Systematics. Cambridge University Press, Cambridge.

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

Lu, P., Woo, K. C., and Liu, Z. T. 2002. Estimation of whole-plant transpiration of bananas using sap flow measurements. *J. Exp. Bot.* 53: 1771-1779.

Mahendran, P. P., Yuvaraj, M., Parameswari, C., Gurusamy, A., and Krishnasamy, S. 2013. Enhancing growth, yield and quality of banana through subsurface drip fertigation. *Int. J. Chem. Environ. Biol. Sci.* 1: 391-394.

Mahmoud, H. H. 2013. Effect of different levels of planting distances, irrigation and fertigation on yield characters of main banana crop cv. Grand Naine. *Glob. J. Plant Ecophysiol*. 3: 115-121.

Mahouachi, J. 2007. Growth and mineral nutrient content of developing fruit on banana plants (*Musa acuminata* AAA, 'Grand Nain') subjected to water stress and recovery. *J. Hortic. Sci. Biotechnol*. 82: 839-844.

Maia, C. E., and de Morais, E. R. C. 2015. Critical levels for soil attributes in irrigated banana plantations in semiarid region. *Rev. Bras. Eng. Agríc. Ambient.* 19(10): 926-930.

Marschner, H. 1995. *Mineral Nutrition of Higher Plants*, (2nd Ed.) Academic Press, London.

Martin-Prevel, P. 1987. Banana. In: Martin-Prevel, P. Gagnard, J. and Gautier, P. (eds), *Plant Analysis as a Guide to the Nutrient Requirements of Temperate and Tropical Crops.* Lavoisier, Paris, pp. 637-670.

Mayee, C. D. and Datar, V. V. 1986. *Phytopathometry*. Technical bulletin-1, Marathwala Agricultural University, Parbhani, pp.146.

Memon, N., Kazi, S. M., Anwar, R., Ahmad, S. and Nafees, M. 2010. Status and response to improved N P K fertilization practices in banana. *Pak. J. Bot.* 42: 2369 - 2381.

Metochis, C. 1999. *Water Requirement and Yield of Banana*. Agricultural Research Institute, Ministry of Agriculture, Natural Resources and the Environment, Technical bulletin 203, Agricultural Research Institute, Nicosia, Cyprus.

Moreira, A. and Fageria, N. K. 2009. Yield, uptake, and retranslocation of nutrients in banana plants cultivated in upland soil of central Amazonian. *J. Plant Nutr*. 32: 443-457.

Morse, R. L., Robinson, J. C., and Ferreira, D. I. 1996. A physiological study of six banana cultivars (*Musa* AAA; Cavendish subgroup) in a warm subtropical climate, using *in vitro* derived planting material. *J. South. Afr. Soc. Hortic. Sci.* 6: 45-48.

Murali, K. 2002. Effect of differential irrigation, soil moisture stress and mulch on growth, yield and water use in banana (M*usa paradisiaca L.*). Ph.D. thesis, University of Agricultural Sciences, Bangalore, 340p.

Murray, D. B. 1960. The effect of deficiencies of the major nutrients on growth and leaf analysis of the banana. *Trop. Agric.* 37: 97-106.

Murray, D. B. 1961. Shade and fertilizer relations in banana. *Trop. Agric.* 38: 123-132.

Mustaffa, M. M. and Kumar, V. 2012. Banana production and productivity enhancement through spatial, water and nutrient management. *J. Hortic. Sci*. 7: 1-28.

Nalina, L. 2002. Standardization of fertilizer requirement for tissue cultured banana Robusta (AAA). Ph.D.(Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore, 237p.

Narayana, C. K. 2015. Bananas and Plantains Postharvest Management, Storage, Ripening and Processing. New India publishing agency, New Delhi, 185p.

NHB [National Horticulture Board]. 2013. NHB homepage [on-line]. Available: http://www.nhb.gov.in [17 Sept. 2014].

NHB [National Horticulture Board]. 2015. *Indian Horticulture Database – 2014.* Ministry of Agriculture, Government of India, 286p.

Nijjar, G. S. 1985. Banana- role of nitrogen on yield. In: Usha, R. (ed.), *Nutrition of Fruit Trees*. Kalyani Publishers, New Delhi, India, pp. 306-308.

NRCB [National Research Centre for Banana]. 2013. *Vision 2050* [on-line]. Available: http://www.nrcb.res.in/document/vision%202050.pdf [12 Sept. 2014].

Nyombi, K., Van Asten, P. J. A., Corbeels, M., Taulya, G. Leffelaar, P. A., and Giller, K. E. 2010. Mineral fertilizer response and nutrient use efficiencies of East African highland banana (*Musa* spp., AAA-EAHB, cv. Kisansa). *Field Crops Res.* 117: 38-50.

Obiefuna, J. C. 1984. Effect of delayed fertilizer application on the growth and yield of plantains in South Western Nigeria. *Fertil. Res*. 5: 309-313.

Oubahou, A. A., and Dafiri, M. 1987. Banana N and K nutrition. *Hortic*. *Abstr*. 57: 630.

Pandey, V., Kumar, D., and George, S. 2005. Response of micropropagated 'Robusta' banana to varying combinations of N, P, K nutrition in lateritic soils of coastal Orissa. *Indian J. Hortic.* 62:122-126.

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

Popenoe, W. 1941.Banana culture around the Caribbean. *Trop. Agric.*18:8-38.

Power, J. F., Willis, W. O., Gunes, D. L., and Peichman, G. A. 1967. Effect of soil temperature, phosphorus and plant age on growth analysis of barley. *Agron*. *J*. 59: 231-234.

Praburam, R. and Sathiyamoorthy, S. 1993. Effect of organic manure on duration of cropping in banana. *S. Indian Hortic.* 41**:** 370-371.

Prameela, P. 2010. Identification of critical stages of Weed Competition and effect of Weed Competition in banana variety Palayankodan. *J. Crop Weed* 6: 59-62.

Rajput, R. P. 1980. Response of soyabean crop to climate and soil environment. Ph.D. thesis, IARI, New Delhi, 222p.

Ram, R. A. and Prasad, J. 1988. Effect of nitrogen, Phosphorus and potassium on fruit quality of banana cv. Campierganji local. *South Indian Hortic.* 36:290-292.

Ram, R. A. and Prasad, J. 1989. Studies on nutritional requirement of banana cv. Compierganj local. *Narendra Deva J. Agric. Res.* 4:196-200.

Ramaswamy, N. and Muthukrishnan, C. R. 1974. Correlation studies in nutrition of Robusta banana. *Indian J. Hortic*. 30:145-147.

Ramteke, S. D., Chetti, M. B., and Salimath, P. M. 1996. Heat unit requirement of chickpea genotypes for various phenological stages during *kharif* and *rabi* seasons. *An. Plant Physiol*. 10: 176-181.

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

Rao, V. U. M., Singh, D., and Singh, R. 1999. Heat use efficiency of winter crops in Haryana. *J. Agrometeorol*. 1: 143-148.

Ray, D. P., Farida, G. N., and Chatterjee, R. K. 1988. Nutritional concentration in leaf tissue with different nutritional levels in Robusta banana. *Indian Agric*. 32: 249-256.

Robinson, J. C. 1981. Studies on the phenology and production potential of Williams banana in a sub-tropical climate. *Inf. Bull. Citrus and Subtropical Fruit Research Institute* 107: 12-16.

Robinson, J. C. 1995. *Systems of cultivation and management*. In: Gowen, S (ed.), Bananas and Plantains, Chapman and Hall, London, pp. 15-65.

Robinson, J. C. 1996. *Bananas and Plantains*. CAB International, Wallingford.

Robinson, J. C. and Nel, D. J. 1985. Comparative morphology, phenology and production potential of banana cultivars 'Dwarf Cavendish' and 'Williams' in the Eastern Transvaal lowveld. *Sci. Hortic.* 25: 149-161.

Robinson, J. C. and Sauco, V. G. 2010. *Banana and Plantains* (2nd Ed.). CAB International, UK, pp.90 - 91.

Robinson, J. C. and Villiers, J. E. A. 2007. *The banana Cultivation*. ARC, Institute for Tropical and Subtropical Crops, South Africa, 117p.

Rose, R. J. 1966. Harvesting time for bananas. *Agric. Gaz. N.S.W.* 77: 179-180.

Roy, S. K. and Chakroborty, A. K. 1993. Vegetables of tropical climate commercial and dietary importance, In: MacRae, R.M., Robinson, R.K., and Sandler, M. J. (eds), *Encyclopaedia of Food Sci.*, *J. Food Technol. Nutr*., Academic Press, London. 715p.

Saad, M. M. and Atawia, A. A. R. 1999. Effect of potash application on growth,yield and fruit quality of Grand Nain banana in sandy soil under drip irrigation system. *Alexandria J. Agric. Res*. 44: 171-180.

Sam, B. J. 2011. Deveopmental physiology of banana corm (*Musa* AAB. Nendran) in relation to phenology, yield and quality. Ph.D. thesis, Kerala Agricultural University, Thrissur, 126p.

Sangudom, T., Wasusri, T., Wongs-Aree, C., Srilaong, V. and Kanlayanarat, S. 2014. Maturity index and quality of 'KluaiKhai' fruit as related to growing season. In: Chomchalow, N., Chantrasmi, V. and Sukhvibul, N. (eds), *International Symposium on Tropical and Subtropical Fruits*, Chiang Mai, Thailand, pp. 399-405.

Sanji, P. and Patra, S. K. 2015. Effect of drip vis-a-vis surface irrigation on fruit yield, nutrient uptake, water use efficiency and quality of banana in Gangetic plain of West Bengal. *Indian J. Hortic.* 72: 7-13.

Saúco, V. G., Cabrera, J. C. and Delgado, P. M. H. 1995. A comparison of banana cultivars Dwarf Cavendish, Grande Nain and Williams, for the Canary Islands. *Fruits* 50: 255-266.

Selvakumari, G., Muthuvel, P., Subramaniyan, K. S., Subramaniyan, P. and Shanmugasundaram. V. S. 1992. Irrigation water requirement of banana under intercrop management. *S. Indian Hortic*. 40: 5-8.

Shanker, U., Agrawal, K. K. and Gupta, V. K. 1996. Heat unit requirements of rainfed soybean, *Ind. J. Agr. Sci*. 66: 401-404.

Shanmugam, K. S. and Velayutham, K. S. 1972. Better manure your bananas. *Agric. Digest* 3:17-29.

Shaun, R. and Ferris, B. 1997. Improving storage life of plantain banana. *IITA Research guide No*.62.

Sheela, V. L. 1995. Growth pattern, flowering and yield potential of tissue cultured plants of banana (*Musa* (AAB group) 'Nendran') and standardization of fertilizer schedule. Ph.D. thesis, Kerala Agricultural University, Thrissur, 241p.

Simmonds, N. W. 1966. Bananas (2nd Ed.), London, Longman.

Sindhu, J. 1997. Prediction of potassium fertilizer requirement of banana, *Musa* (AAB) 'Nendran'. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 181p.

Singh, H. P. 2007. Banana: Technological advancements. In**:** Singh, H. P. and Uma, S (eds.), *National and International Scenario of Banana and Plantain*, AIPUB, pp.1-19.

Singh, H. P. and Chundawat, B. S. 2002. *Improved Technology of Banana*. Ministry of Agriculture, Government of India, pp 1-46.

Singh, H. and Singh, G. 2015. Growth, phenology and thermal indices of mung bean as influenced by sowing time, varieties and planting geometry. *Indian J. Agric. Res*. 49: 472-475.

Soorianathasundaram, K., Kumar, R. K., and Shanthi, H. 2000. Influence of organic nutrition on the productivity of banana cv. Nendran. *South Indian Hortic*. 45: 109-114.

Srikul, S. and Turner, D. W. 1995. High nitrogen supply and soil water deficits change the rate of fruit growth of bananas (cv. “Williams”) and promote tendency to ripen. *Sci. Hortic.* 62: 165-174.

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

Stover, R. H. 1970. Leaf spot of bananas caused by *Mycosphaerella musicola*: role of conidia in epidemiology. *Phytopathol.* 60: 856-860.

Stover, R. H. 1979. *Pseudostem growth, Leaf Production and Flower Initiation in the Grand Nain Banana*, SIATSA Bulletin No.8, La Lima, Honduras, pp. 3-37.

Stover, R. H. and Simmonds, N. W. 1987. *Bananas* (3^{rd} Ed.). Longman, Harlow, pp.468.

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

Suma, A., Menon, R., Cheriyan, A. and Shakuntala. 2007. Bio-regulators for yield improvement in banana var. Nendran. In: *National Symposium on Banana,* 25-29^{th} October, 2007, National Research Centre for Banana, Trichy, pp.120.

Thadchayini, T. and Thiruchelvam, S. 2005. An Economic Evaluation of a Drip Irrigation Project for Banana Cultivation in Jaffna. In:Proceedings of Water Professionals Day Symposium, 1 October, 2005, Sri Lanka.

Thangaselvabai, T., Joshua, P. J., Justin, C. G., and Jayasekhar, M. 2007. The uptake and distribution of nutrients by banana in response to application of nitrogen and Azospirillum. *Plant Archives* 7: 137- 140.

Thangaselvabai, T., Suresh, S., Joshua, P. J., and Sudha, K. R. 2009. Banana nutrition- A review. *Agric. Rev.* 30: 24-31.

Tixier, P., Malezieux, E., and Dorel, M. 2004. A cohort population model for long-term simulation of banana crop harvest. *Ecol. Modelling* 180: 407-417.

Turner, D. W. 1980. Some factors related to yield components in relation to sampling to assess nutrient status. *Fruits* 35:19-23.

Turner, D. W. 1998. The impact of environmental factors on the development and productivity of bananas and plantains. In: Arizanga, L. (ed.), *Proceedings of the 13th ACORBAT meeting*, Guayaquil, Ecuador, Conaban.

Turner, D. W. and Barkus, B. 1980. Plant growth and dry-matter production of the 'williams' banana in relation to supply of potassium, magnesium and manganese in sand culture. *Sci. Hortic.* 12: 27-45.

Turner, D. W., Fortescue, J. A., and Thomas, D. S. 2007. Environmental physiology of the bananas (*Musa* spp.). *Brazilian J. Plant. Physiol*. 19: 463-484.

Turner, D. W. and Hunt, N. 1987. Planting date and defoliation influence the time of harvest of bananas. *Sci. Hortic.* 32: 233-248.

Turner, D. W., Korawis, C., and Robson, A. D. 1989. Soil analysis and its relationship with leaf analysis and banana yield with special reference to a study of Carnarvan, Western Australia, *Fruits* 44: 193-203.

Turner, D. W. and Thomas, D. S. 1998. Measurements of plant and soil water status and their association with leaf gas exchange in banana (*Musa* spp.): a laticiferous plant. *Sci. Hortic.* 77: 177-193.

Twyford, I. T. and Walmsley, D. 1973. The mineral composition of the Robusta banana plant, methods and plant growth studies. *Plant Soil* 39: 227-243.

Vadivel, E. 1976. Studies on the growth and development of Robusta banana in relation to K nutrition. M.Sc. (Ag) thesis, Tamil Nadu Agricultural University, Coimbatore.

Viets, F. G. Jr. 1962. Fertilizers and the efficient use of water. *Adv. Agron*. 14: 223-264.

Vorm, V. P. D. J. V. and Diest, V. A. 1982. Redistribution of nutritive elements in a Gross Michel banana plant. *Neth. J. Agric. Sci*. 30: 286-296.

Watson, D. J. 1947. Comparative physiological studies on the growth of field crops: I. Variation in net assimilation rate and leaf area between species and varieties and within and between years. *Ann. Bot.* 11: 41-76.

Weerasinghe, P. and Premalal, N. H. R. 2002. Influence on potassium fertilization on growth and yield of Embul banana (*Musa* spp. AAB group) grown in Rhodudalfs under irrigated conditions. *Ann. Sri Lanka Dep. Agric.* 4: 109-117.

Weerasinghe, P., Premalal, N. H. R., and Seranasinghe, S. N. K. 2004. Influence of nitrogen on crop performances and leaf nitrogen status of dense planted banana. *Ann. Sri Lanka Dep. Agric.* 6: 217-226.

Wilsie, C. P. 1962. Crop Adaptation and Distribution. Freeman, W. H. and Co., London, pp. 52-59.

Yadav, A., Ram, R. B., Kumar, R., Sonkar, P., Meena, M. L., and Latha, R. 2011. Response of planting dates on growth and yield characteristics of banana (*Musa* sp.) cultivars. *Ann. Hortic.* 4**:** 95-100.

Ziauddin, S. 2009. Integrated nutrient management studies in banana (cv. Ardhapuri). *Asian J. Hortic.* 4: 126-130.

Appendix – I

Weather parameters during the cropping period (January 2014 to December 2014)

Month and year	Temperature (°C)		RH (%)		Bright sunshine hours	Rainfall (mm)	Number of rainy days	Evaporation (mm day^{-1})
	Max.	Min.	Max.	Min.				
January, 2014	30.61	21.53	93.41	73.64	8.8	28.5	2	3.2
February, 2014	31.33	22.32	92.35	69.46	9.3	21.0	3	4.0
March, 2014	32.43	22.88	91.90	66.54	9.9	31.5	2	4.3
April, 2014	32.40	24.47	91.20	73.60	9.0	115	9	3.0
May, 2014	31.88	24.73	90.03	78.45	8.7	280.4	11	3.4
June, 2014	30.76	25.21	92.46	79.16	9.0	88.0	10	3.3
July, 2014	29.99	24.30	91.90	77.50	9.2	104.2	9	3.6
August, 2014	29.50	23.74	90.70	81.20	8.6	551.5	16	5.1
September, 2014	30.20	24.19	90.80	78.96	8.8	219.4	10	3.8
October, 2014	30.52	23.82	86.93	82.40	7.9	230.2	12	3.7
November, 2014	30.18	23.38	93.46	77.23	7.7	137.3	11	1.7
December, 2014	31.2	23.25	94.30	78.30	7.9	133.5	5	2.5

Appendix – I (*Continued*)

Weather parameters during the cropping period (January 2015 to December 2015)

Month and year	Temperature (°C)		RH (%)		Bright sunshine hours	Rainfall (mm)	Number of rainy days	Evaporation (mm day^{-1})
	Max.	Min.	Max.	Min.				
January, 2015	30.61	21.56	93.87	65.0	9.16	8.0	2	3.0
February, 2015	31.53	22.34	91.78	64.71	9.35	0	0	4.1
March, 2015	32.42	23.65	89.93	67.12	9.26	56.1	4	4.2
April, 2015	32.74	24.48	92.0	75.00	8.82	182.6	9	4.0
May, 2015	32.14	25.31	90.71	83.29	8.21	406.0	8	3.4
June, 2015	31.43	24.47	90.97	82.97	8.80	346.9	19	3.9
July, 2015	31.31	24.6	89.10	79.87	9.61	53.5	5	4.0
August, 2015	31.68	24.57	89.52	76.42	9.55	80.2	4	4.2
September, 2015	31.41	24.40	91.40	83.77	8.59	289.8	15	4.5
October, 2015	31.29	24.03	92.45	80.54	8.04	399.1	19	3.8
November, 2015	31.54	23.79	92.70	79.57	7.75	254.1	18	3.6
December, 2015	31.48	23.38	93.94	83.16	9.16	259.3	11	3.4

Appendix – I (*Continued*)

Weather parameters during the cropping period (January 2016 to May 2016)

January, 2016	32.52	22.64	91.40	72.50	7.87	0.4	0	4.2
February, 2016	32.91	23.17	92.50	73.30	9.14	43.6	1	4.5
March, 2016	34.40	24.64	90.20	68.50	8.67	1.9	0	3.8
April, 2016	35.29	26.62	90.83	77.03	8.82	22.6	0	3.6
May, 2016	33.81	25.42	89.00	77.00	7.34	463.3	13	3.4

Appendix – II

Weekly evaporation during the cropping period, mm (June 2014 to July 2015)

Evaporation (weekly average)			
2014		2015	
June (I year)	1.9	January	3.0
	3.2		2.9
	3.8		3.0
	4.4		3.1
July	3.4	February	4.0
	3.5		4.0
	3.5		3.8
	3.9		4.4
August	6.8	March	4.4
	6.1		4.9
	3.4		3.1
	4.0		4.0
September	3.5	April	4.1
	3.4		3.6
	3.1		4.4
	4.4		3.8
October	4.0	May	4.4
	3.8		4.0
	3.5		2.5
	1.4		3.2
November	3.0	June (II year)	3.5
	3.2		5.0
	1.7		3.8
	1.3		5.0
December	2.0	July	4.0
	3.2		4.3
	2.6		3.5
	2.0		4.0

Appendix – II (*Continued*)

Weekly evaporation during the cropping period, mm (Sept. 2015 to May 2016)

Evaporation (weekly average)			
2015		2016	
August	4.1	January	3.0
	5.0		3.5
	3.4		3.4
	4.4		3.9
September	5.1	February	4.0
	4.1		3.7
	4.4		4.8
	3.9		4.3
October	3.0	March	4.3
	5.6		5.0
	2.7		5.3
	3.1		5.0
November	3.8	April	5.0
	3.7		4.8
	3.8		4.6
	3.3		5.0
December	2.7	May	5.7
	4.6		4.4
	2.7		3.0
	3.7		3.8

Appendix – III

Incidence of diseases during the crop growth period

Disease	Stage of crop	Disease incidence (%)	Disease index (%)	Score method
Sigatoka leaf spot	Vegetative stage- 1 year (5 MAP)	20	15	(Gauhl's, 2002)
Sigatoka leaf spot	Vegetative stage- 1I year (3 and 6 MAP)	33	45	(Gauhl's, 2002)
Banana bract mosaic virus	Towards harvest (II year)	6.06	1	(Mayee and Datar,1986)

Appendix – IV

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
$i_1n_1s_1$	299	344	19	22	570	660	1091	1269	1661	1929
$i_1n_1s_2$	299	344	19	22	570	660	1091	1269	1661	1929
$i_1n_2 s_1$	299	344	19	22	570	660	1091	1269	1661	1929
$i_1n_2s_2$	299	344	19	22	570	660	1091	1269	1661	1929
$i_2n_1s_1$	292	339	26	31	780	930	1091	1269	1871	2199
$i_2n_1s_2$	292	339	26	31	780	930	1091	1269	1871	2199
$i_2n_2 s_1$	292	339	26	31	780	930	1091	1269	1871	2199
$i_2n_2s_2$	292	339	26	31	780	930	1091	1269	1871	2199
$i_3n_1s_1$	294	328	31	36	930	1080	1091	1269	2021	2349
$i_3n_1s_2$	294	328	31	36	930	1080	1091	1269	2021	2349
$i_3n_2s_1$	294	328	31	36	930	1080	1091	1269	2021	2349
$i_3n_2s_2$	294	328	31	36	930	1080	1091	1269	2021	2349
$i_4n_1s_1$	295	331	36	43	1080	1290	1091	1269	2171	2559
$i_4n_1s_2$	295	331	36	43	1080	1290	1091	1269	2171	2559
$i_4n_2s_1$	295	331	36	43	1080	1290	1091	1269	2171	2559
$i_4n_2s_2$	295	331	36	43	1080	1290	1091	1269	2171	2559

Appendix – V

Details of irrigations given during the first and second years of experimentation

Crop growth stages	Quantity of water requirement plant $^{-1}$ (L)
Up to 1 MAP	4.0 (Uniform)
2-3 MAP	6.0
4-5 MAP	8.5
6-7 MAP	11.5
From 8 MAP to harvest	15.0

Appendix – VI

Economics of experiment - I

Market price of the produce

Produce	Market price (₹)
Banana fruit	15 kg^{-1}
Sucker	12 $sucker^{-1}$

Appendix – VI (*Continued*)

Unit cost of inputs (₹)

Inputs	First year	Second year
Tissue culture plants ($plant^{-1}$)	15	15
FYM (t^{-1})	400	400
Lime (kg^{-1})	13	13
Urea (kg^{-1})	6	7
Raj phos (kg^{-1})	10	10
MOP (kg^{-1})	17	19
Labour (day^{-1})	560	620
Plastic rope (bundle)	200	200
Drip system (Amortized for 4 years)	13285	13285

Appendix – VI (*Continued*)

Cost of cultivation of banana with different nutrient schedule

Treatments	Cost of cultivation (₹ ha^{-1})		Cost of cultivation (₹ $plant^{-1}$)	
	I year	II year	I year	II year
n_1s_1	383004	414197	124	134
n_1s_2	394204	426597	128	138
n_2s_1	413627	448343	134	145
n_2s_2	424827	460743	138	149

NUTRIENT AND MOISTURE OPTIMIZATION IN BANANA (*MUSA* AAA. GRAND NAIN)

by

BINDHU J. S.

(2013 - 21 - 102)

ABSTRACT

of the thesis submitted in partial fulfilment 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

2016

ABSTRACT

An investigation entitled "Nutrient and moisture optimization in banana (*Musa* AAA. Grand Nain)" was undertaken with the objectives to standardize the nutrient and irrigation schedule of Grand Nain banana, to study its phenology in relation to various agro-meteorological parameters and to work out the economics. The investigation comprised two separate experiments. The first experiment on 'Nutrient - moisture interaction study' was conducted for two years from June 2014 to May 2016. The second experiment on 'Phenology study of Grand Nain banana' from January 2014 to December 2015. Both the experiments were conducted at the Instructional Farm, College of Agriculture, Vellayani.

The first experiment was laid out in split plot design with sixteen treatments and four replications. The main plot treatments were four irrigation levels, *viz*., I_1, I_2, I_3 and I_4 based on IW/CPE (Irrigation water/ Cumulative pan evaporation) ratios of 0.4, 0.6, 0.8 and 1.0 and subplot treatments were four combinations of two nutrient levels (N) and two times of application (S). The two nutrient levels were N_1**:** 200: 200: 400 g N: P_2O_5: K_2O plant^{-1} year^{-1} (KAU, POP for varieties other than Nendran and modified as per soil test values of the experimental site) and N_2**:** 160: 40**:** 640 g N: P_2O_5**:** K_2O plant^{-1} year^{-1} (Based on nutrient uptake values of banana cv. Grand Nain). The treatment N_1 was modified as 212: 50: 332 g N: P_2O_5: K_2O plant^{-1} year^{-1} based on soil test values. The two time of applications (S) were S_1 (N and K in 2 equal splits at 2 and 4 months after planting (MAP)) and S_2 (N and K in 4 equal splits at 2, 3, 4 and 5 MAP). Drip irrigation was given based on cumulative pan evaporation. The second experiment was laid out in RBD with twelve treatments **(**twelve dates of planting**)** and four replications. Planting was done on 28th day of every month from January onwards. Except the initial establishment stage, the crop was raised as rainfed. Tissue culture plants were planted at a spacing of 1.8 m x 1.8 m. Entire FYM @15 kg plant^{-1} and P were applied as basal in both the experiments.

Analysis of the crop growth characters at different growth stages (4 and 6 MAP and at harvest), yield attributes, quality parameters and shelf life revealed the superiority of the irrigation level I_4 and nutrient level N_2. The time of application and N x S and I x N interactions were also significant. The treatments I_3 and I_4 recorded the highest bunch weight in first and second year respectively. I_3 was on a par with I_4 during first year. The bunch weight was the highest in N_2 during both the years. Application of nutrients in 4 splits (S_2) recorded the highest bunch weight and significantly superior to S_1 in second year.

Pooled analysis also revealed that the bunch weight and yield were the highest in I_4 (26.20 kg plant^{-1}and 80.85 t ha^{-1}), but on a par with I_3. Among the nutrient levels, N_2 recorded the highest bunch weight and pooled yield (24.60 kg plant^{-1}and 75.92 t ha^{-1}).

Irrigation and nutrient levels also had significant influence on the plant nutrient uptake and nutrient status of soil after the experiment. The total water requirement (WR) was the highest in I_4. Water use efficiency (WUE) was the highest in I_3 during both the years and was on a par with I_4, while water productivity was the highest in I_3 during first year and in I_4 during second year. Gross income, net income and B: C ratio were the highest in I_3 and I_4 during first and second year, respectively. Sigatoka leaf spot disease was the major disease observed during the study. No pest was observed during the crop period.

The study on phenology revealed that planting dates have significant influence on growth characters, yield attributes, shelf life and yield. The bunch weight plant^{-1} was the highest (29.50 kg) in February (T_2) planting which was on a par with July (T_7) planting. All the quality parameters except total soluble solids (TSS), ascorbic acid and non reducing sugars varied significantly with planting dates. Fruit quality was superior with February (T_2) and July (T_7) plantings. The Agro meteorological parameters such as growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU) and heat use efficiency (HUE) were computed. The GDD for vegetative phenophase varied between 2765 ^{0}C d and 3921 ^{0}C d and for reproductive stage it was 968 ^{0}C d and 1446 ^{0}C d. The HTU and PTU requirements were the lowest and the HUE was the highest in February (T_2) planting. February (T_2) planting recorded the shortest crop duration (277days) with the shortest period for shooting and emergence to harvest (E-H) while November (T_{11}) planting the longest.

It is concluded that application of nutrients @ 160: 40: 640 g N: P_2O_5: K_2O plant^{-1} (N_2) with full P as basal and N and K in two equal splits at 2 and 4 MAP (S_1) with irrigation at 1.0 IW/CPE (I_4) can be recommended for Grand Nain banana for high yield, economics and quality produce. Last week of February is the ideal planting time for getting high yield and quality produce in Grand Nain banana with shorter phenophases in the southern agro climatic conditions of Kerala.